ANNUAL RESEARCH REPORT
2021-2022

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Year of Publication

October 2022

Word Processing

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Printed by

Shahida Enterprise
19, South City Corporation Market
Nilkhet, Dhaka-1205
Cell: 01710415200

Research Report
2021-2022

Content

Physical Aspects of Soil Management
Project Leader: Dr. ATMAI Mondol

Chemical Aspects of Soil Management
Project Leader: Dr. MM Masud

Micronutrient Aspects of Soil Management
Project Leader: Dr. Habib Mohammad Naser

Microbiological Aspects of Soil Management
Project Leader: Dr. Mohammad Eyakub Ali

Executive summary

Soil physics section manages the physical aspects of the soil to increase agricultural productivity. The main areas of focus for soil physics research are crop residue management, crop water requirements, irrigation scheduling, soil moisture conservation, and tillage management that emphasizes root growth. This section includes reports on nutrient management affecting plant quality, suitability of different compost ages to plant needs and cultivation techniques. There are also several reports on nutrient requirements, minimal tillage, crop residue retention, and conservation agriculture systems.

The soil chemistry section addresses on soil fertility and plant malnutrition. The section is currently working on soil fertility and organic matter enrichment through its IPNS and INM systems of crop cultivation. Organic composting through waste management to improve soil health and crop production; updating national fertilizer recommendation guides through extensive field testing. In addition to the above topics, the chapter presented reports on the following issues. Long-term integrated nutrition management, crop residue and its biochar, compost, vermicompost, nutrition management with trichocompost, urea fertilizer in various forms and amounts against nitrous oxide emission, organic fertilizers on carbon sequestration, the impact of climate modeling on changes in agriculture, intensification of cultivation to improve system productivity, soil health, and farm income are presented.

The soil micronutrients section contains updates to micronutrient fertilizer recommendations for responsive plants. In this section, laboratory studies demonstrate micronutrient deficiencies in soil, evaluation of heavy metal contamination in soil-plant-water systems in industrially contaminated vegetable intensive production areas, and arsenic dynamics in soil-plant-water systems, and assess the development of mitigation measures. Neno technology was introduced as the subject of the fourth industrial revolution (4iR), food crops were fortified with zinc for nutritious and safe food. This section also contains several reports on the amount of micronutrients that should be used for different crops.

The soil microbiology section deals with microbiological aspects of soil management. The section is currently involved in preparing *Rhizobium* biofertilizers for all types of legumes and oilseed legumes, including salt-tolerant *Rhizobium* biofertilizers for soybeans and peanuts for coastal areas of Bangladesh. This section presented their reports on collection, isolation and screening of indigenous *Rhizobial* strains, Azotobacter, Validation of biofertilizer, arbuscular mycorrhizal fungi, biochar and vermicompost, phosphate solubilizing bacteria (psb) and their efficacy.

Apart from that, research reports of various projects conducted in this division have been included in this report.

DETERMINATION OF CROP COEFFICIENT VALUES OF SWEET PEPPER AND ESTIMATION OF LEACHING LOSS OF NUTRIENTS THROUGH LYSIMETERIC STUDY

A.T.M.A.I. MONDOL, M.J. ALAM and H.M. NASER

Abstract

A study on sweet pepper (cv. BARI Misti morich-1) was conducted in the drainage Lysimeter located in the Central Research Farm, BARI, Gazipur during rabi 2020-2021 and 2021-2022. The objective of the study was to find out the location specific crop coefficient (Kc) values for sweet pepper and to estimate leaching loss of nutrients. Four regimes of irrigation water were applied on the basis of depletion over field capacity (FC) at predetermined intervals such as T_1: Irrigation up to FC at 5 days interval, T_2: Irrigation up to FC at 10 days interval, T_3: Irrigation up to FC at 15 days interval and T_4: Irrigation up to FC at 20 days interval. As such, 11, 8, 6 and 4 irrigations were needed for T_1, T_2, T_3 and T_4, respectively. The experiment was conducted in completely randomized design with 3 replications. The highest sweet pepper yield (26.1 t ha^{-1}) was obtained from T_2, which was significantly higher to other treatments. Therefore, Kc values were calculated from the best performed treatment, T_2. The estimated average Kc values for sweet pepper during rabi season found to be 0.43, 0.82, 94.0 and 0.86 for initial, crop development, mid-season and late season stages, respectively. Thus the values determined from this study may be recommended for Bangladesh and similar climate elsewhere to estimate crop water requirement for sweet pepper. Significant amount of plant nutrients (K, Ca, Mg, S, Zn and B) was lost through leaching. The loss of Ca, Mg and S found to be a great concern. This should be taken into account for ensuring crop nutrition and minimizing ground water pollution.

Introduction

Sweet pepper (*Capsicum annum* L.) is one of the most important laxuriusannualspices cum vegetables under the family Solanaceae (Kurian, 1995). Sweet pepper was originated from central Asia; particularly Mediterranean region (Thompson and Kelly, 1957).Sweet pepper has been recognized all over the world as a valuable vegetable for cooking different dishes. Sweet pepper has been considered as rich source of carbohydrate, protein and phosphorus. In Bangladesh, it is cultivated all over the country but extensively cultivated in the Faridpur, Dhaka, Rajshahi, Comilla, Jassore, Rangpur, and Pabna. The main edible portion of garlic is the fruit which is constituted by the fleshy sheath. The leaves are also consumed as salads, soups or eaten with rice (Lovelook, 1973).Sweet pepper is a minor vegetable in Bangladesh and its production statistics are not available (Hasanuzzaman, 1999).It has got a good demand to some big hotels in the capital city to feed the foreigners residing in Bangladesh (Rashid, 1999).

Non-judicious irrigation not only reduces the efficiency of fertilizers and water but also reduces the yield of spices crops (Rahman*et al*., 1988). On the other hand, improper irrigation management wastes available water resources along with nutrient losses through leaching, run off (Hanson *et al*., 1999). Kruger *et al.* (1999) reported that the optimum use of irrigation can avoid the leaching of nutrients into deeper soil layers.

However, due to high rates of evaporation and low levels of precipitation, the significance of irrigation is vital for attaining and sustaining optimum productivity. Because of our limited knowledge of crop water use, flood irrigation without scheduling is still the main irrigation practice, which is not only a inefficient use of water resources but also has the possibility for increasing the risk of groundwater contamination because a large number of solutes could be leached below the root zone using this irrigation practice (Zeng*et al*., 2014).

The irrigation scheduling was done on the basis of critical growth stages where water requirement was not properly estimated as a result much of applied water may be lost through percolation, runoff and evapotranspiration. Thus, estimation of water requirement of crop is an inevitable task. The crop coefficient value is the better tool for the optimization of crop water requirement throughout the growing period, which would ensure better water use efficiency. Thus, Kc appears as the most important factor in context of intensive and precision agriculture.

Lysimeter is an important tool in soil-plant-atmosphere research because it can directly measure evapotranspiration and facilitate water, fertilizer and solute balance studies. Reliable measurements of drainage quantity and loss of nutrients through leaching are difficult to measure in field conditions but easier using lysimetric study. For instance, water percolation through the root zone may be collected and analyzed. Water requirement of sweet pepper depending on soil and climatic condition. Improvement of water use efficiency is an important task under the present contexts of resource conservation agriculture. Crop coefficient (Kc) values of sweet pepper are not available in the literature under Bangladesh situation. Therefore, it is necessary to determine growth phase wise Kc values in order to find out water requirement of crop. Again, leaching loss of nutrients need to assess for the minimization of ground water pollution. The calculation of crop water requirements by means of lysimeter method is relatively simple. The basic formula for the calculation reads as follows:

ETcrop = Kc x ET_0; Where: ET crop = the water requirement of a given crop in mm per unit of time e.g. mm day^{-1}, mm $month^{-1}$ or mm $season^{-1}$.

Kc = the "crop factor";
ET_0 = the "reference crop evapotranspiration" in mm per unit of time e.g. mm/day, mm/month or mm/season.

Cropwaterrequirement: ET crop=Kc x ET_0
Values of $K_c$are available in literature (Doorenbos and Pruitt, 1977), but none is recommended for a specific location. It is better to determine the factor locally. Physiological characteristics of crop varieties differ under different soil and climatic conditions, thus, showing varying physiological demands including crop water requirements (crop ET). The determination of crop co-efficient lies in the determination of stage-wise crop ET and estimation of reference crop evapotranspiration. The most reliable method for determining the crop co-efficient values is the lysimetric study. Many scientists have studied crop ET using lysimeters (Khan *et al*., 1992). Climatological approaches of estimating ET are available in literature (Ben-Asher *et al.*, 1983 and Michael, 1978). These approaches are based on the empirical data and require local calibration which is impossible without lysimeter.

Materials and Methods

The experiment was conducted at the Soil Science research field of Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh during 2020-2021 and 2021-2022. The experimental field situated at 24° 05' N latitude and 90° 25' E longitudes having an elevation of 8.2 m from sea level.

The micro-lysimeter were constructed recently by Soil Science Division, Bangladesh Agricultural Research Institute (BARI) and established at Soil Science research field, Gazipur. It has 12 tanks spaced at equal distance (4 m). The tanks were installed in 3 lines taking 4 in each line for the 3 replicate measurements. The lysimeter tank has 1meter square area with effective soil depth of 100 cm followed by a perforated Stainless Steel (SS) sheet. Below the SS sheet, 2 meshes of no. 20 and 40 are placed. Below the mesh, a 15 cm thick coarse gravel packs are sandwiched. Then a water receiving reservoir was provisioned where the excess water from the upper parts are discharged. Then the discharged water goes through the drainage piping to the reservoir.

Each lysimeter tank is provided with a stainless steel pipe of 1.75 cm diameter which serves as an air vent. The vent is inserted up to the gravel layer and is provided with a cap at the top end. Below the lysimeter tank, a 7.5 cm thick concrete layer is provided followed by a 7.5 m thick stone soling. A 13 cm thick brick wall was constructed around the lysimeter tank leaving 5 cm sand pack between the tank and the wall. The brick wall is constructed at a depth of 30 cm from the soil surface. For more details, please refer to Khan *et al*. (1992).

Sweet pepper (cv.*BARI Misti morich-1*) seedlings were transplanted in lysimeter tanks, each having 1 m^2 area on 27 November 2021. Also, to maintain a similar environment, the same crop was grown in the lands surrounding the tanks. The soil was clay loam with field capacity and bulk density, 28.5 % and 1.48 g cc^{-1}, respectively. There were four treatments as follows:

T_1 = Irrigation up to FC at 5 days interval
T_2 = Irrigation up to FC at 10 days interval

T_3 = Irrigation up to FC at 15 days interval
T_4 = Irrigation up to FC at 20 days interval

As lysimeter has 12 tanks in operation, therefore the experiment was set up in a completely randomized design with 3 replications. Soil was fertilized with N-P-K-S-Zn-B-Cowdung at the rate of 147-46-190-19-4-1.5-15,000 kg ha^{-1}, respectively. Entire amount of cow dung, TSP, gypsum, boric acid and $^{2}/_{3}$rd of MoPwere applied during the final land preparation. Urea as a source of nitrogen was applied in 4 equal splits at 10, 30, 45 and 60 days after sowing (DAT). The rest of MoP was applied with third dose of urea at 45 DAT. The rooting depth of the crop was considered at each irrigation time.The crop was irrigated up to field capacity for crop stage wise rooting zone as per treatment schedule. Measured quantity of water depending on the FC value was applied. Soil moisture was measured before irrigation. As per treatment, 11, 8, 6and 4 irrigations were required for T_1, T_2, T_3 and T_4, respectively. Percolate was collected whenever it deposited in the buckets placed underneath of the drainage outlets coming from each lysimeter tank. In this way 3 collections after 2nd, 3rd and 4th irrigation were possible during the growing period of garlic. The collected water samples were sent to analyse for P, K, Ca, Mg, S, Zn and B content. The crop showed luxuriant growth especially for the treatment $T_2$and T_1. Harvesting of sweet pepper was done on 13March, 2022. Climatic data, such as maximum and minimum temperatures, air humidity, sunshine hour/day, rainfall and evapotranspiration were collected from the nearest meteorological station (Table 1). The location information like elevation, latitude, and longitude were also collected. All these data were then used to estimate the potential evapotranspiration (ET_0).

Table 1. Monthly average weather data during the crop growing period of 2021-2022

Month	Temperature (°C)	Evaporation (mm)	RH (%)	Sunshine hour	Rainfall (mm)	ET_0 mm/day
*November	22.8	11.8	84	7.1	0.0	2.0
December	21.0	9.5	84	6.1	23.5	2.0
January	19.4	11.3	81	5.1	0.3	2.0
February	20.5	14.4	78	7.7	1.0	2.9
*March	26.8	24.6	70	8.4	0.8	4.0

*In December and March only the crop growing days were considered to calculate average monthly weather components.

Crop data like number of fruits per plant, fruit length, fruit diameter, individual fruit weight and sweet pepper yield were recorded and statistically analyzed. The part of rainfall collected as drainage and the change in stored soil moisture during the period under consideration were subtracted from the applied water to obtain crop evapotranspiration (ET_c). The crop evapotranspiration for the specified period was estimated using the following equation:

$$ET_{ct} = W_a - (D_w \pm \Delta S_s)$$

Where,
ET_{ct}= crop evapotranspiration in mm for time, t
W_a= applied water, mm + rainfall, mm for time, t
D_w= drainage water, mm for time, t
ΔS_S= stored soil moisture, mm for time, t

Then from the potential evapotranspiration (ET_0) estimated for the specified period, the value of $K_c$for the period was determined from the ratio, ET_c/ ET_0.

Results and Discussion

Result presented in Table 2 showed that the crop performed well for T_2 treatment where 9 irrigations up to FC at every 10 days interval were applied. The highest sweet pepper yield (26.1 t ha^{-1}) was obtained from T_2, which was significantly higher over T_1 and T_3 and T_4 treatments. For fruit length and individual fruit weight T_2significantly performed the best result than T_1 and T_3 and T_4 treatments wherasT_4 gave the lowest result. The highest diameter of fruit (7.19 cm) was recorded from T_2 which was significantly higher to other treatments whereas the lowest fruit diameter (5.90. cm) was recordec from T_4 (Table 2). In case of number of fruits plant^{-1}T_1significantly gave the highest result than other treatments followed by T_1, T_2 and T_4. As crop performance was the best for T_2 so irrigation interval set for this treatment provided relatively better environment for plants to produce the highest yield. Therefore, this treatment (T_2) was selected for the determination of Kc value. The optimum crop co-efficient at different growth stages are recommended to calculate from the best growing plants producing the highest yields (Doorenbos and Pruitt, 1977). Therefore, all calculations for the determination of crop water requirementwere based on the performance of treatment, T_2 and are presented in (Tables 4, 5 and 6).

Table 2. Yield attributes of sweet pepper grown in lysimeter tank during rabi season 2021-2022

Treat-ment	Irrigation scheduling	Fruit length (cm)	Fruit diameter (cm)	Fruit plant^{-1}	Individual fruit weight (g)
T_1	Irrigation at every 5 days interval	10.4 b	6.04 b	12.7 b	83.9 b
T_2	Irrigation at every 10 days interval	11.5 a	7.19 a	14.2 a	95.3 a
T_3	Irrigation at every 15 days interval	10.3 b	5.90 b	11.7 bc	82.2 b
T_4	Irrigation at every 20 days interval	9.3 c	5.32 b	11.1 c	70.5 c
F-test		*	*	*	*
CV (%)		5.32	6.8	6.2	6.69

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Table 3.Yield of sweet pepper grown in lysimeter tank during rabi season

Treatment	Yield (2020-2021)	Yield (2021-2022)	Average yield
	(t ha^{-1})		
T_1: Irrigation 5 days interval	14.8 b	32.1 b	23.5
T_2: Irrigation 10 days interval	16.5 a	35.6 a	26.1
T_3: Irrigation 15 days interval	13.7 b	29.9 bc	21.8
T_4: Irrigation 20 days interval	11.6c	26.9.c	19.3
Sig. levels	*	*	-
CV (%)	6.50	5.50	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Irrigation water was applied depending on the moisture content for a certain growing period to raise it up to FC level (28.5%). From Table 4, it was observed that the applied irrigation water for initial, development, midseason stages was 48, 75, 165 and 62 mm, respectively for initial, development, mid-season and late season stage. After first and second irrigation 29.2 mm percolate was collected while for the third and fourth irrigation the collected leachate was 3.75 mm. Due to addition of optimum water on the basis of FC there was a positive balance of moisture storage except at midseason stage. For the midseason stage, the crop might have absorbed water from the stored soil moisture as deficit caused by higher evapotranspiration at later growth stage. Ultimately, storage soil moisture fell down to -1.15 mm, which signified that irrigation interval (15 days) set for this treatment may not suit well for February and March. For this reason, plants for T_3 and T_4 treatments suffered from moisture stress at later growth stage. The average crop ET for T_2 found to be 22.7, 71.7, 180.7 and 76.0 mm for initial, development, midseason and late season stage, respectively (Table 6). However, there was a second order polynomial relationship (R^2= 0.9959**) between cumulative crop ET and crop growth stages (days after transplanting) (Fig. 1). Using local climatic condition, the reference crop evapotranspiration (ET_0) was calculated as 52.3.3, 87.1, 192 and 89.9 mm for initial, development, mid-season and late season stage, respectively. Thus the averageKc value for sweet pepper found to be 0.43, 0.82, 0.94 and 0.86 for initial, development, mid-season and late season stage, respectively (Table 6). These results are in agreement with Fifah*et al*. (2015). Indeed, locally determined Kc values are preferable to generalized standard values to estimate location specific crop evapotranspiration. However, growth stage wise Kc values of garlic are depicted in Fig. 2.

Table 4. Determination of crop evapotranspiration of sweet pepper during rabi season 2021-2022

Treat-ment	Stage	Duration (days)	Applied water	Effective rainfall	Percolation	Change in soil moisture storage	Crop ET
			(mm)				
T_2	Initial	1-25	48	23.5	29.2	18.5	23.8
	Development	26-65	75	0.30	3.75	-1.15	72.7
	Midseason	66-110	165	0.00	0	-16.7	181.7
	Late season	110-132$^+$	62	0.00	0	-14.9	76.9

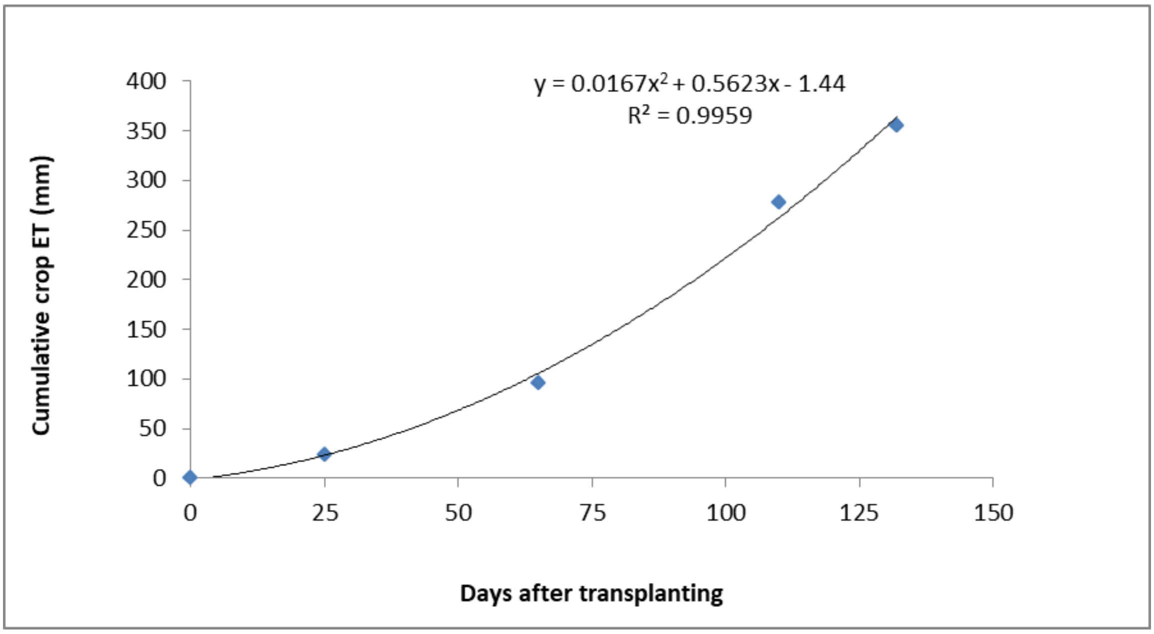

Fig. 1. Functional relationship between cumulative crop ET and growing period of sweet peppper during rabi season 2021-2022

Table 5. Calculations of crop co-efficient for sweet pepper (2021-2022)

Treatment	Development Stage	Estimated Crop ETc	ET_0	Crop Co-efficient (Kc)
		(mm)		
T_2	Initial	23.8	52.3	0.45
	Development	72.7	87.1	0.83
	Mid-season	181.7	192	0.95
	Late season	76.9	89.9	0.86

Table 6.Average value of ETc and Kc during 2020-2021 and 2021-2022 for sweet pepper

Treatment	Development Stage	ETc (2020-2021)	ETc (2021-2022)	Average ETc	Kc (2020-2021)	Kc (2020-2021)	Average Kc
		(mm)					
T_2	Initial	21.6	23.8	22.7	0.41	0.45	0.43
	Development	70.7	72.7	71.7	0.81	0.83	0.82
	Mid-season	179.2	181.7	180.5	0.94	0.95	0.94
	Late season	75.1	76.9	76.0	0.86	0.86	0.86

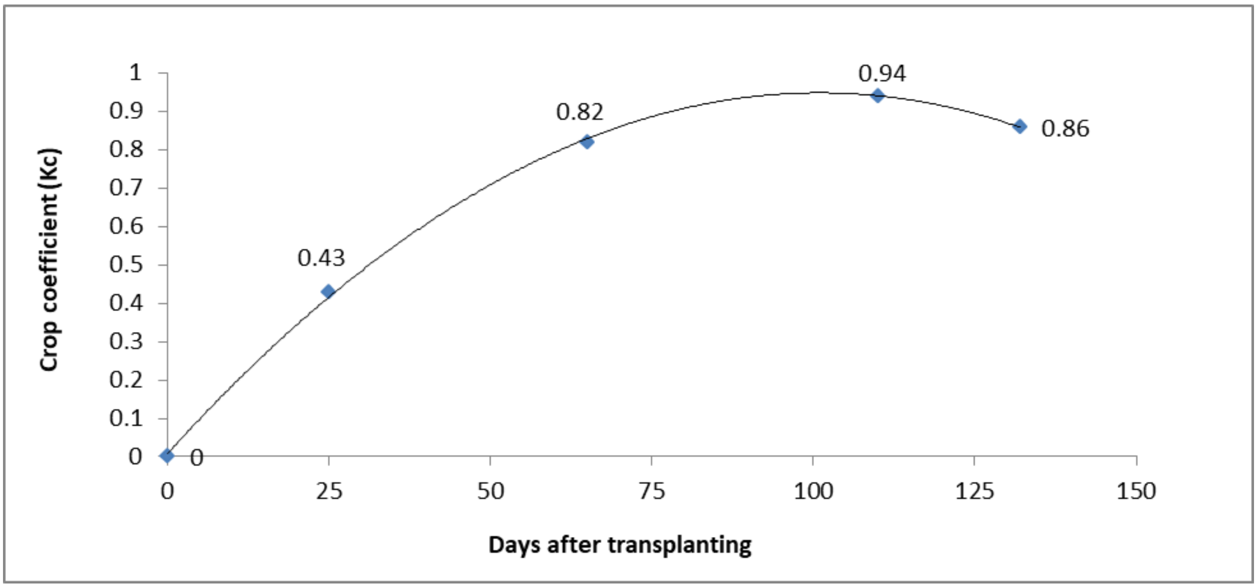

Fig. 2. Growth stage-wise average crop co-efficient values of sweet pepper at Gazipur

Leaching loss nutrients

Leaching loss of nutrients found to be quite high as depicted (Figure3-8). For the first measurement of leachate, which collected after second irrigation, the loss of nutrients was relatively higher than the second collection after third irrigation except S might be due slow dissolution of gypsum to the soil solution. The loss K found to be almost same (4.9-4.1 mg L^{-1})for both the collections (Fig. 3). The loss of Cawas remarkable as high as 37 mg L^{-1} for the first leachate which reduced slightly to 34 mg L^{-1} for the second collection (Fig. 4). The content of Mg was 11 mg L-1 for the first leachate and remained static for second sampling (Fig. 5). This huge amount of basic cation loss might responsible for the rise in acidity.Sulphur loss was also tremendous 35 mg L^{-1} and again jumped to 50.1 mg L^{-1} at second sampling (Fig. 6). Industrial pollution might have accentuated SO_4-S to the environment. The loss of Zn and B as micronutrients appeared to be a rising concern (Fig. 7 and 8). For instance, the loss of B through irrigation water percolate found to be high (0.06-0.0.08 mg L^{-1}).

Fig. 3. Leaching loss of Potassium

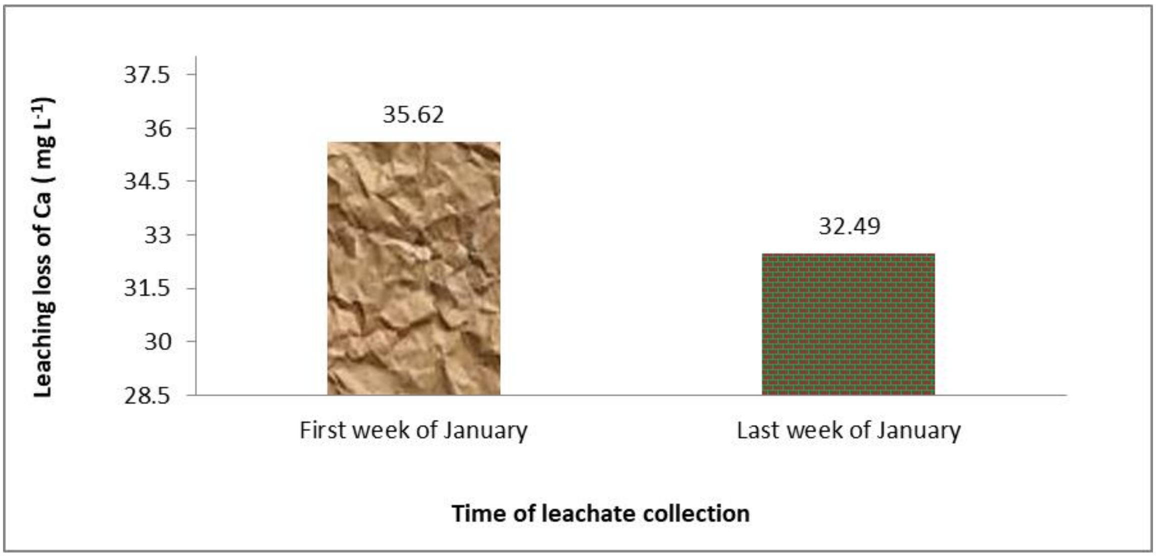

Fig. 4.Leaching loss of Calcium

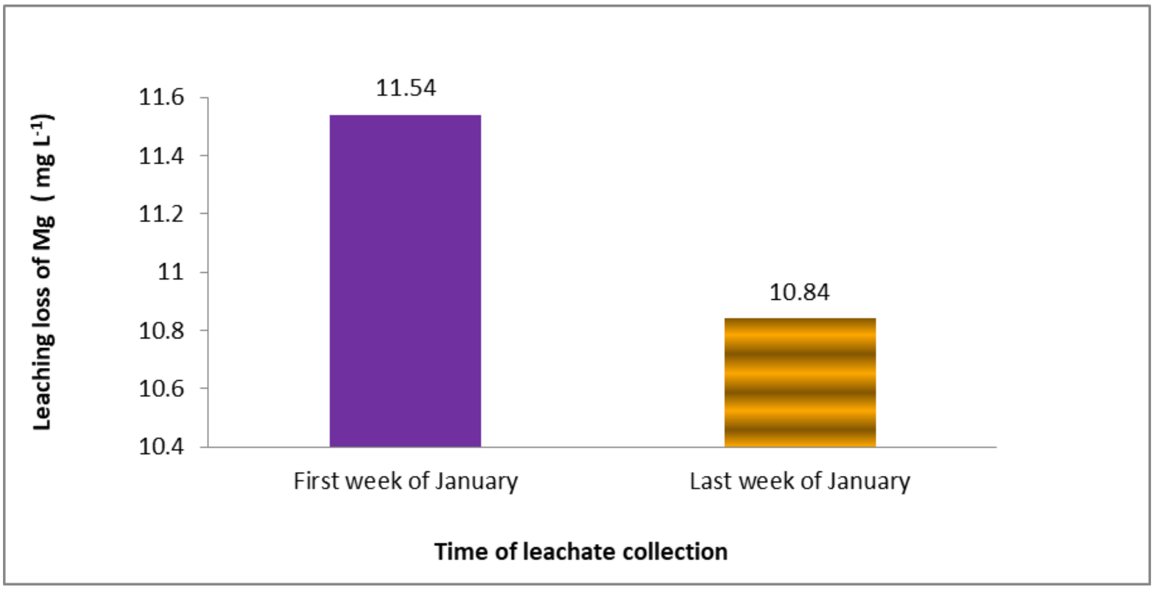

Fig. 5.Leaching loss of Magnesium

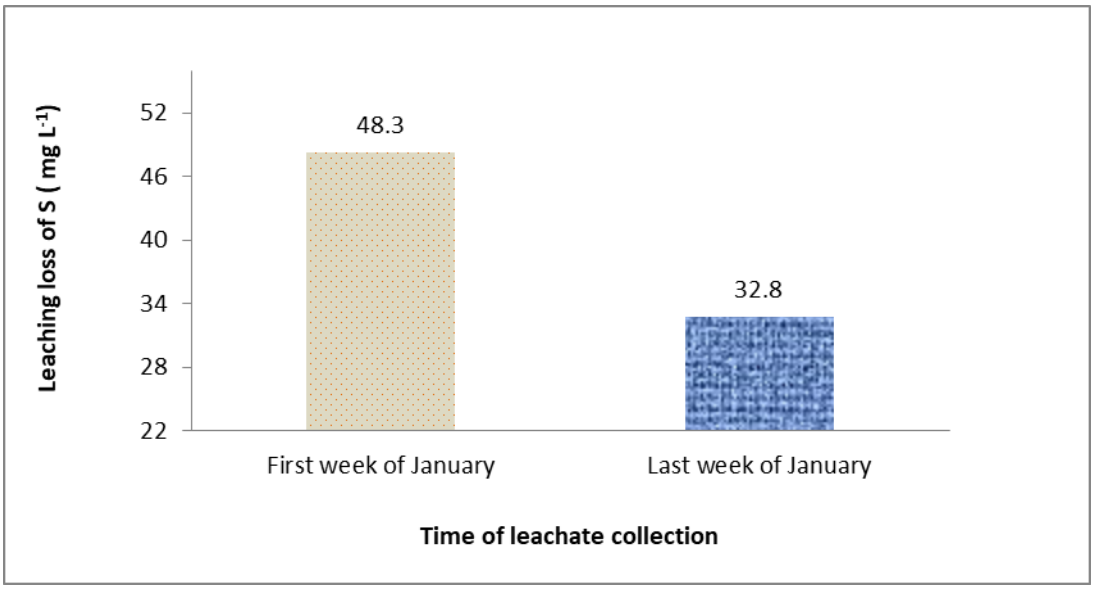

Fig. 6. Leaching loss of Sulphur

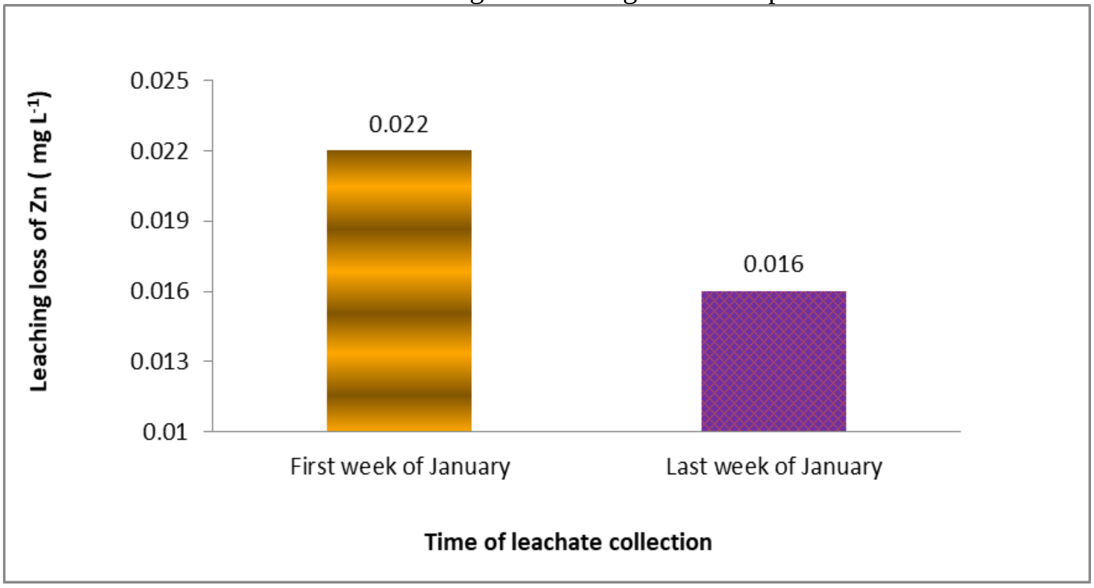

Fig. 7. Leaching loss of Zinc

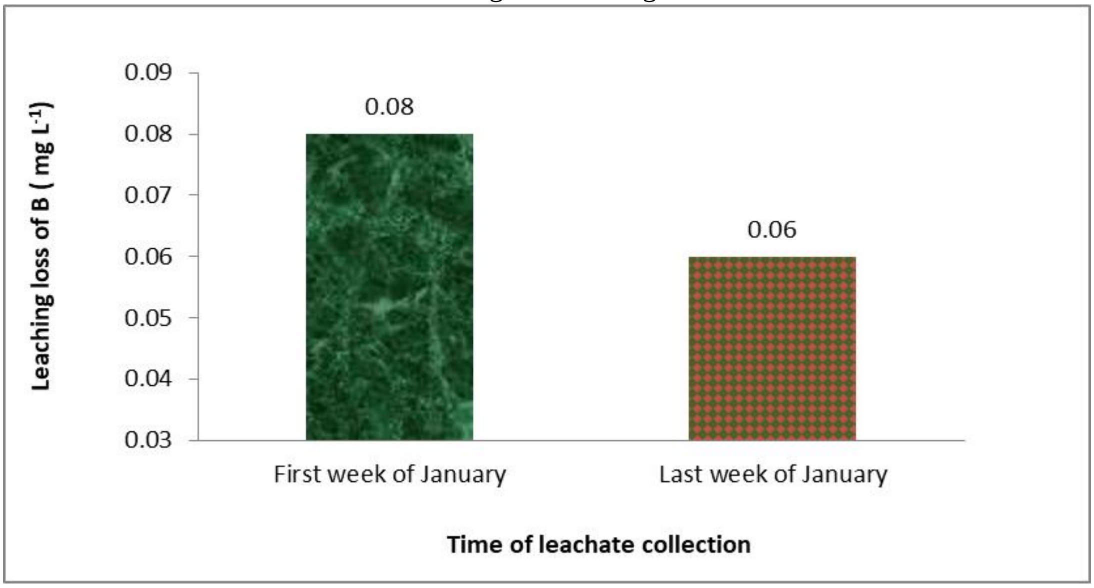

Fig. 8. Leaching loss of Boron

Conclusion

The crop coefficient (Kc) values for sweet pepper during rabi season (late November to March, 2020-2021 and 2021-2022) found to be 0.43, 0.82, 0.94 and 0.86 for initial, development, mid-season and late season stage, respectively. Thus the values determined from this study may be recommended for for Bangladesh and similar climatic elsewhere to estimate crop water requirement for sweet pepper.Significant amount of plant nutrients (K, Ca, Mg, S, Zn and B) was lost through leaching. The loss of Ca, Mg and S found to be a great concern. This should be taken into account for ensuring crop nutrition and minimizing ground water pollution.

Acknowledgement

The authors would like to give thank Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Bangladesh authority for its budgetary support and useful direction in this study under physicals Aspects of Soil Management.

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SYNCHRONIZATION OF DIFFERENT AGED COMPOST TO CROP DEMAND, NUTRIENT RELEASE AND THEIR CONTRIBUTION TO THE PRODUCTION OF RED AMARANTH

A.T.M.A.I. MONDOL, M.J. ALAM and H.M. NASER

Abstract

This study was conducted at the research field of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Gazipurunder AEZ-28during rabi season of 2021-2022 to understand the release of nutrients fo rcrops and their contribution to growth and yield. Red amaranth cv. BARI Lalshak-1 was used for this experiment. Four different organic amendments of different ages were studied in comparison with only chemical fertilizer application. The amendment treatments were T_1: 30 days aged compost, T_2: 45 days aged compost,T_3: 60 days aged compost, T_4: 75 days aged compost and T_5: only chemical fertilizers. The experiment is laid out in a Randomized Complete Block Design (RCBD), where each treatment was replicated thrice. Data on growth and yield attributes of red amaranthus were collected during the crop growing season and after harvesting. Necessary sample were also collected periodically to determine the microbial-respiration of soil during the experimental period.Yield and its component of red amaranthus were significantly affected by the different aged compost. The organic amended performed in the sequence: 75 DOC>60 DOC>45 DOC>30 DOC. The increases of yield in 75 DOC, 60 DOC, 45 DOC and 30 DOC were 98.6, 79.7, 60.8 and 54.0%, respectively higher than yield obtained with only chemical fertilizer. A significant increase in yield, individual plant weight, plant height and number of leaves plant^{-1}of red amaranth was obtained with organic amended treatments relative to only chemical fertilizer application. The hetero-tropic respiration (CO_2 emission) was found higher in soils under75 DOC at 21 days after seed sowing which might be due to synchronization with crop nutrient demand.However no discreet decision can be drawn unless the experiment continues for more years.

Introduction

Red amaranth is one of the most important popular and widely grown vegetables in Bangladesh and abroad. The crop is very well known for its nutritive value. Intensive cultivation of vegetables needs additional supply of plant nutrients for increased production of vegetables as well as their seeds. This is mainly done by addition of both organic manures and inorganic fertilizers.The use of organic manure can restore soil health and helps in raising the production in a sustainable manner. Organic fertilizers play important role in regard to growth and yield of red amaranthus.

Soil fertility is a decisive factor in determining the productivity of all farming systems (Badgley*et al*., 2007). Crop and vegetable production is usually coupled with the use of nitrogen-rich fertilizers that result in high N release to soil (up to 150 kg N ha^{-1}) (Chaves *et al*. 2005). When organic matter decomposes, N usually experiences two different stages of mineralization and immobilization. A high C/N ratio in compost will promote N immobilization. If the plant material has a C/N ratio greater than 25, the microbial population will use available soil N to decompose the residue. If the C/N ratio of the fresh plant material is less than 25, the microbial population will release additional available nitrogen (mineralization). Nutrient release pattern from decomposing organic manures involves three major phases (Swift *et al*. 1979; Berg and McClaugherty 2008): (1) an initial phase where leaching and nutrient release dominate; (2) a net immobilization phase where nutrients increase due to the presence of microbes; and (3) a net release phase where the nutrient mass decreases. The immobilization phase could be absent, particularly in litter with high N concentrations (Berg and Laskowski, 2006). Moreover, N and P dynamics can also be characterized by an early immobilizationfollowed by net release (Vitousek and Sanford 1986). But most importantly, the amount and timing of mineralization determines N availability (Watsonet *et al*., 2002). Synchrony of N release and crop uptake is another important thing to consider for organic matter addition to soils. Hence, addition of plant residues/organic materials has become a pivotal strategy for soil fertility improvement and sustainability of land use. In order to optimize the benefits of plant residue/organic manures on soil quality improvement, it is critical to synchronize the release of nutrients from residue decomposition with patterns of plant nutrient uptake, which may minimize the loss of available nutrients via leaching, runoff and erosion. The amount of N taken up by the crop has a major impact on overall crop growth rate. Maximizing N recovery by the growing crop is of paramount importance in organic systems. This requires synchrony of N release from incorporated plant material with crop N demand (Wagger, 1989). Since N is not stable in soil and becomes less available for crop uptake over time, application timing and age of compost is important. Much of the N uptake occurs in a relatively short time period. If nitrogen is insufficient during this period, yield loss will occur. Applying nitrogen immediately before or during this period will result in higher uptake by the crop and less nitrate lost to leaching or transformations to unavailable forms and ultimately in greater yields. In practice, the pathways by which plant-available forms of N are released from organic residues and taken up by the growing crops is complex. Research conducted in this regard is very sporadic and the results found in this regard are very minimal to come to a conclusion. So, a methodical research should be conducted to find out a corrected age of organic manure to apply for the growing crops so that it synchronizes with the maximal demand of crops. Therefore, this study was undertaken to fulfill the following objectives:

i. To determine the nutrient releasing trend of compost of different ages
ii. To synchronize the optimum age of compost for maximum benefit of the crop at its peak demand
iii. To observe the changes in soil physical, chemical and biological properties

Materials and Methods

A field experiment was conducted at Central Research Farm, BARI,Gazipur under AEZ- 28 during 2021-2022.There were fivetreatmentsi.e.T_1: 30 days aged compost, T_2: 45 days aged compost, T_3: 60 days aged compost, T_4: 75 days aged compost and T_5: control (only chemical fertilizer). The experiment was laid out in randomized complete block design (RCBD) with 3 replications of each treatment. The unit plot size was 3m x 2m and variety used in the experiment was BARI Lalshak-1. The spacing was 25 cm × continuouse line. The STB nutrient dose estimated as N-P-K-S of 81-10-30-7 kg ha^{-1} (FRG, 2018). Conventional compost (rice straw, water hyacinth and cowdung) @ 15 tons ha^{-1} will be applied during final land preparation the rest of the nutrient demand were supplied from chemical fertilizer following IPNS approach. All PS K were incorporated into soil before sowing. Urea was top dressed in two equal splits at 13 and 25 days after sowing.

The weather data during the experimental season was given in Table 1. The experimental soil was clay loam, slightly acidic in nature (pH 6.0) with very low organic matter content (0.60%). Seeds were sownon 17 December, 2021. Soil samples were collected from 0-15 cm soil depth from each plot and analyzed in the laboratory following standard methods (Tables 2a and 2b).Soil samples for moisture content determination were collected from each plot, from sowing to harvesting of spinach according to treatments. All intercultural operations were done as and when necessary to raise a healthy crop. Irrigations were applied during fertilizer application along with an extra irrigation. Harvesting was done when the plant attained proper size. The harvesting of red amaranthus was started on 03February, 2022. After collection of data, it was tabulated in proper form and subjected to statistical analysis with the help of computer package tested with statistics (Statistics-10). Soil physical and chemical properties of initial soils and analytical values of compost arepresentedin table 2 (a & b) and table 3, respectively.

Table 1. Monthly weather data during the crop growing period of 2021-2022

Month	Temperature (°C)	Evaporation (mm)	RH (%)	Sunshine hour	Rainfall (mm)	ET_0 mm/day
*December	19.6	9.5	83	6.5	12.6	2.0
January	19.4	11.3	78	5.1	0.3	2.0
February	19.1	10.2	84	6.6	2.2	2.9

*In Decemberonly the crop growing days were considered to calculate average monthly weather components

Table 2. Physical and chemical properties of the experimental site during December, 2021

a. Initial soil physical properties of the surface soil

Soil depth	Bulk density	Soilmoisture content	Field capacity	Textural class
	(g cm^{-3})			
0-15 cm	1.35	17.61	32.42	Clay loam

b. Chemical properties of the surface soil

Soil depth (0-15cm)	pH	OM	Total N	K	Ca	Mg	P	S	Fe	Mn	Cu	Zn	B
		(%)		meq 100 g^{-1}			µg g^{-1}						
Initial	5.7	1.85	0.10	0.16	7.6	1.7	20	12	58	2.6	0.41	1.2	0.35
Critical level	-	-	-	0.12	2.0	0.5	10	10	4.0	1.0	0.2	0.60	0.20
Interpretation	Low	V. low	V.Low	High.	Medi	Medi	Low	V. high	High	High	Medium	Low	

Table 3. Nutrient content of compost

Item	N	P	K	S	C	Zn	B	Fe
	%					µg g^{-1}		
Compost	1.6	0.9	1.5	0.22	32	132	142	690

Microbial respiration

Microbial respiration was assessed by measuring CO_2 evolution from soil in spinach field during rabi season by trapping emitted CO_2 in NaOH (Anderson, 1982). All assays were performed in triplicate. The trapped CO_2 was measured by adding 15 mL of 10% w/v $BaCl_2$ to the NaOH to precipitate $BaCO_3$. The remaining NaOH was then back titrated against 1M HCI to the phenolphthalein to neutralize NaOH. Finally, more HCI was added to the methyl orange to dissolve $BaCO_3$.

The collected soil samples were dried at room temperature mixed thoroughly, grinded, sieved with a 2 mm sieve and preserved in plastic containers for subsequent laboratory analysis. Soil samples were then analyzed for SOM, total N and available P. The SOM was determined by wet oxidation (Jackson 1973), total N by a modified Kjeldahl method (page et al. 1989) and total P by colourimetric method (Murphy and Riley, 1962).pH was determined through glass electrode pH meter method (Jackson 1962),K and S were determined through NH_4OAC method (Hanlon and Johnson,1984)and turbidimetric method (Sperber, 1984), respectively. Micronutrients were analyzed using atomic absorption spectrophotometer.Particle size distribution of the initial soil was analysed by the hydrometer method (Black, 1965) and the textural class was determined using the USDA texture triangle. The Bulk density of the soil samples were determined by core sampler and pycnometer method (Karim et al., 1988). Moisture content was determined by gravimetric method (Black, 1965). Field capacity was done though pressure plate method.

All the relevant data were statistically analyzed by using excel spreadsheet and Statistix10^{TM} package.

Results and Discussion

Vegetative growth

The data presented in (Table 4) revealed that the vegetative parameters of red amaranth were significantly influenced by the different aged compost**.** There was significant difference in plant height and number of leaves among the treatments.The highest plant height (17.7 cm) and number of leaves plant^{-1}(8.80) were observed in treatment T_4 which were significantly higher over all other treatments whereas the lowest result was obtained from T_5.

Yield attributes and yield

Yield and its component of red amaranth were significantly affected by the different aged compost (Table 4 and 5). Application of 75 days aged compost (T_4) produced higher individual weight (3.63 g) which is significantly higher to other treatments. The highest yield (14.7 t ha^{-1}) of red amaranth was achieved from 75 DOC aged compost which is significantly higher than others aged compost. The increases of yield in 75 DOC, 60 DOC, 45 DOC and 30 DOC were 98.6, 79.7, 60.8, and 54 % higher than yield obtained with only chemical fertilizer.

Adding compost enhanced the soil structure conditions, creates conducive conditions for good root development (Arisha*et al*., 2003).Mineralization by microorganisms was also found synchronized with organic amendments and particularly with 75 DOC treatments compare to control (Figure 1). Hence, plants are able toget nutrients for higher yield (Radwan*et al*., 1993).

Table 4. Synchronization of different aged compost on vegetative growth of red amaranth (2021-2022)

Treatment	Plant height (cm)	No. of leaves plant^{-1}	Individual weight (g)
T_1: 30 days aged compost	14.1 c	6.60 c	2.85 b
T_2: 45 days aged compost	15.6 b	6.91 c	3.00 b
T_3: 60 days aged compost	16.2 b	7.85 b	3.17 b
T_4: 75 days aged compost	17.7 a	8.80 a	3.63 a
T_5: Control	12.5 d	5.40 d	2.18 c
Sig. levels	*	*	*
CV (%)	5.60	6.1	7.50

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Table 5. Synchronization of different aged compost on yield and yield components of red amaranth (2021-2022)

Treatment	Yield (t ha^{-1})	Yield increase over control (%)
T_1: 30 days aged compost	11.4 c	54.0
T_2: 45 days aged compost	11.9 c	60.8
T_3: 60 days aged compost	13.3 b	79.7
T_4: 75 days aged compost	14.7 a	98.6
T_5: Control	7.4 d	-
Sig. levels	*	-
CV (%)	6.50	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Respiration

The application of organic amendment of different ages to soils under red amaranth influenced emission of CO_2 synthesized by respiration. The application of 75 DOC and 60 DOC reached peak of CO_2 emission earlier which then decreased gradually with some fluctuations. The control also had its peak immediately after sowingbut the CO_2 evolution was significantly lower than the organic amendments soils. The CO_2emission was then continued decreasing with some fluctuations. The compost of 75 days old reached peak after 21 days of application. The CO_2 evolution was then reduced with time until the harvest. The 75 DOC amendments to red amaranth had the most varied CO_2 emissions at different DAS. Initially the emissions increased and the peak was recorded at 21 DAS of application, later than other amendments. The fertilizer application and irrigation timing also coincides peaks and lows of CO_2 emissions. The amendment of 75 DOC had the highest emissions during the peak of plant growing period (Figure 1). The higher emissions with the amendments relative to control can be attributed to availability of C sources for microorganisms to decompose it further and hence the evolution of the gas. Again, the increased amount of organic addition to soil would have increased decomposition and increased CO_2 emissions (Mondol, 2014).

The higher CO_2emission recorded with the 75 DOC amended treatment might be due to the amendment having full composted conditionand higher watersoluble C which upon addition became the most interest of soil microorganisms and the hence the increased CO_2 emissions (Wang *et al*., 2016).

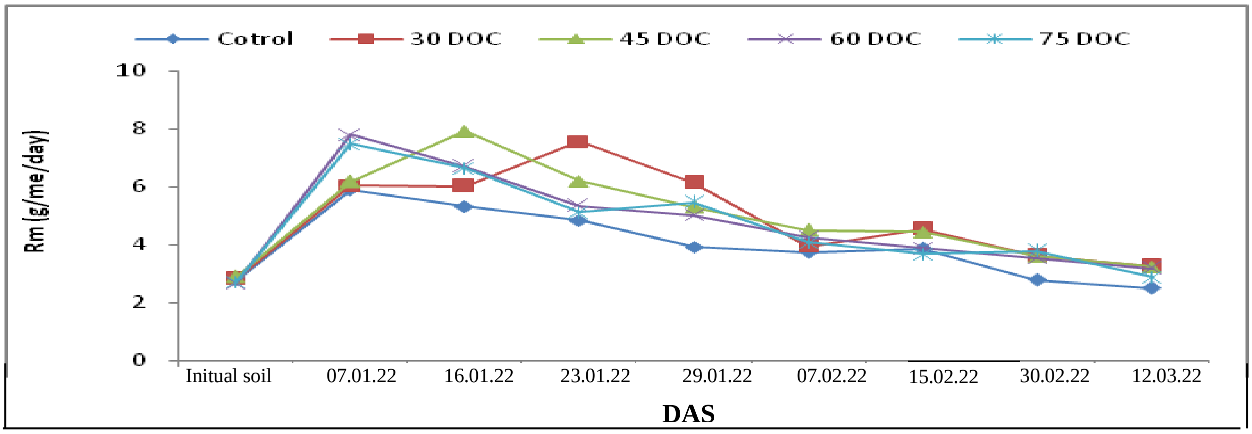

Fig 1.Effect of organic amendments of different ages on CO_2 emission as respiration output in soils under red amaranth cultivation

Conclusion

The growth and yield of red amaranth fertilized with different aged compost were as good as those receiving chemical fertilizers, indicating that they can be an alternative to chemical fertilization. 75 days aged compost could be recommended for red amaranth production under protected structure without affecting plant growth and yield. The nutritional status of the plants demonstrated that the nutrients were adequate and met the requirements for plant growth and yield of compost on plant growth and yield might vary depending on degree of mineralizationof the organic matter. This is the first year experiment; further studies need to be required for final recommendation.

Acknowledgement

The authors would like to give thank Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Bangladesh authority for its budgetary support and useful direction in this study under physicals Aspects of Soil Management.

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EFFECT OF CONSERVATION TILLAGE AND PHOSPHORUS ON THE PRODUCTIVITY OF GARDENPEA-MAIZE-T.AMAN RICE CROPPING PATTERN AND SOIL PHYSICO-CHEMICAL PROPERTIES

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Abstract

A field experiments on Garden pea- Maize-T.aman rice cropping pattern were conducted in Grey Terrace soil of Joydebpur under AEZ-28 during rabi 2018-2019, 2019-2020 and 2020-2021to observe the effect of tillage practices and phosphorus on soil properties and to increase the productivity of cropping system. There were 2 types of tillage such as Strip tillage (ST) and conventional tillage (CT). In addition, 3 forms application of phosphorussuch as granular dose(basal) (P_1), powder doses (basal) (P_2) and granular doses (split) (P_3) in a split plot RCB design with 6 treatments and 3 replications. Strip tillage (ST) gave more grain yield than conventional tillage (CT) for maize ($p \leq 0.05$)andvice-versa for T. aman rice($p \geq 0.05$) due to residual nutrient uptake factor for subsequent crop.Powder dose (basal) significantly performed the best than other phosphorus doses for both maize and T. aman($p \geq 0.05$). Strip tillage with phosphorus combinations comparatively gave more moisture and field capacity than conventional tillage with phosphorus combinations and vice-versa for bulk density. OM, N, P, K, S and Zn increased but pH remained more or less sameand B content decreased compare to initial soil. The 10th crop garden pea damaged at flowering condtion due to heavy rain for cyclone Jaoyad.The11th crop maize washarvested during report writing.

Introduction

Nutrition-safe food security for huge number of population which drives crop expansion continually has led to a growing demand for phosphate fertilizers as well as other major elements. The level of total phosphorus (P) in Bangladesh soils is high but available phosphorus is poor. Farmers apply phosphate fertilizers but it does not turn into available form due to low temperature in winter season and immobile nature of the nutrient when mustard is grown in Bangladesh. In acidic soil, P fixation becomes a serious problem due to farmer's regular phosphate fertilizer application. Adnan (2003) reported that P is deficient in most acidic soils because soluble inorganic P is fixed by Al and Fe. Organic matter through minimum tillage is another option for fixing Al and Fe instead of P and increases available P, soil pH and reduced exchangeable acidity, exchangeable Al, and exchangeable Fe and finally can ensure sustainable crop production as minimum tillage is conducive for reducing organic C loss from soils which maintains high levels of organic matter content. Strip tillage maintained more soil carbon than conventional practices (Faaborget al., 2005). Phosphorus fertilizer placement can have significant agronomic and environmental implications in long-term no-till (NT) system (Fernando et al., 2017). Research on this aspect is very limited. A methodical research needs to be conducted for successful and economic crop production through increasing availability of P in the problem soil.Under the above concern, the present study was taken to settle the following objectives: To find out effect of tillage practices and phosphorus on soil properties and to increase the productivity of cropping system.

Materials and Methods

A field experiments on garden pea-Maize-T.aman rice cropping pattern were conducted in Grey Terrace soil of Joydebpur under AEZ-28. The experiment was started at BARI central research farm during rabi season in 2018-2019.The physical and chemical properties of experimental soil are presented in Table 1.

Table 1. Physical, chemical and microbial properties of initial soil during 2018-2019

a) Physical properties

Soil depth (cm)	Moisture content	Field capacity	Bulk density (g cm^{-3})	Penetration resistance (N cm^{-2})	Particle size (%)			Textural class
	(%)				Sand	Clay	Silt	
0-10	20.9	30.23	1.59	219.7	42.03	27.69	30.28	Clay loam

b) Chemical properties

Soil depth (cm)	pH	OM	Total N	P ($\mu g\ g^{-1}$)	K (meq 100 g^{-1})	S	Zn	B
		%				$\mu g\ g^{-1}$		
0-10	5.75	1.49	0.065	13.5	0.11	16.5	0.65	0.23
Critical level	-	-	-	7.0	0.12	10	0.60	0.20

The tillage operations such as strip tillage with VMP (versatile multi-crop Planter) and conventional tillage with power tiller were employed in combination with three split application of phosphorus Viz. P_1 (All basal dose as granular form), P_2 (All basal dose as powder form) and P_3 (80% basal and 20% at 20 DAS/DAT as granular form).Thus 6 treatment combinations were arranged in split plot design with three replications. The plot size was 4.8 M× 2.4 M.

The tested varieties were BARI Hybrid Vutta-9 and BRRI dhan57 for maize and T.aman, respectively. The crops were fertilized with soil test based (STB) fertilizer dose as per FRG-2018 (BARC, 2018). The fertilizer doses of were N_{202} P_{31} K_{81} $S_{31}Zn_{2.5}B_{0.7}$ kg $ha^{-1}$and N_{102} P_5 K_{54} $S_{10}Zn_{2.0}$ kg ha^{-1} for maize and T. aman, respectively. Maize was sown on 14March, 2021 and crop harvested on 03 July, 2021. T.aman seedling were transplanted on 02 August, 2021 and crop harvested on 26 October, 2021.

For maize, gypsum, zinc sulphate and boric acid were applied during final land preparation. Urea was applied in three equal splits at 15 DAS, 35 DAS and 55 DAS. For MoP half was applied during final land preparation and half was applied 25 DAS. 100 %TSP was applied as granular form (P_1) and as powder form (P_2) and 80% as granular form (P_3) during final land preparation. Rest 20 % TSP for P_3 as granular form was applied 20 DAS. All intercultural operations were done as per requirement of the crop. Irrigations were applied during fertilizer application with an extra irrigation. For T.aman all MoP, gypsum, zinc sulphate were applied during final land preparation. Urea was applied in three equal splits at 7 DAT, 25 DAT and 40 DAT. 100 %TSP was applied as granular form (P_1) and as powder form (P_2) and 80% as granular form (P_3) during final land preparation. Rest 20 % TSP for P_3 as granular form was applied 20 DAT). For T.aman, two irrigations were apllied at dry condition.

Table 2.Monthly average weather data during the crop growing period of 2021

Month	Temperature (°C)	Evaporation (mm)	RH (%)	Sunshine hour	Rainfall (mm)
*March	28.7	23.1	70	7.9	0.0
April	29.6	25.9	72	7.5	1.2
May	29.9	22.8	79	6.3	3.5
June	29.2	15.8	86	3.9	18.1
*July	27.5	9.8	93	0.70	55
*August	30.4	12.7	89	3.3	15.8
September	30.7	18.0	87	5.6	2.1
*October	29.8	15.2	87	6.4	3.6

*In March, July, August October only the crop growing days were considered to calculate average monthly weather components

The collected soil samples were dried at room temperature mixed thoroughly, grinded, sieved with a 2 mm sieve and preserved in plastic containers for subsequent laboratory analysis. Soil samples were then analyzed for SOM, total N and available P. The SOM was determined by wet oxidation (Jackson 1973), total N by a modified Kjeldahl method (page et al. 1989) and total P by using Colorimetric method (Murphy and Riley, 1962).pH was determined through glass electrode pH meter method (Jackson 1962),K and S were determined through NH_4OAC method (Hanlon and Johnson, 1984)and turbidimetric method (Sperber, 1984), respectively. Micronutrients were analyzed using atomic absorption spectrophotometer.Particle size distribution of the initial soil was analysed by the hydrometer method (Black, 1965) and the textural class was determined using the USDA texture triangle. The Bulk densityand particle density of the soil samples were determined by core sampler and pycnometer method (Karim et al., 1988). Moisture content was determined by gravimetric method (Black, 1965). Field capacity was done though pressure plate method.

All relevant data were collected and were analyzed statistically following Statistics 10 program.

Results and Discussion

Maize

Effect of tillage

It observed that plant height, cob length, cob circumference and grain yield showedsignificant($p \leq 0.05$)variationdue to tillage practiceswheras air height, seed cob^{-1} and 500 seed weight showed insignificant variation ($p \geq 0.05$)(table 3). In all cases, Strip tillage performed better than conventional tillage due to more carbon acumulation, available nutrient and soil moisture and temperature.

Table 3. Effect of tillage on yield and yield attributes of maize (2021)

Treatment	Plant height (m)	Ear height (cm)	Cob length (cm)	Cob circumference (cm)	Seed cob^{-1}	500 seed weight (g)	Grain yield (t ha^{-1})
Strip tillage	2.08 a	89.73	19.36 a	13.55 a	524.6	123.4	6.84 a
Conventional tillage	2.00 b	88.11	17.71 b	12.48 b	496.2	108.4	6.11 b
CV (%)	3.76	6.22	4.78	3.08	5.43	12.44	9.11
LSD (0.05)	0.07*	-	0.85*	0.22*	-	-	0.71*

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Effect of phosphorus

It was found that insignificant ($p \geq 0.05$) result was obtained for all cases among phosphorus application (table 4). In case of plant height, ear height, seed pod^{-1}, 500 seed weight and grain yield powderdosegave the highest result than other doses. Forcob length and cob circumference granular dose performed the best than other doses.

Table 4. Effect of phosphorus on yield and yield attributes of maize (2021)

Treatment	Plant height (m)	Ear height (cm)	Cob length (cm)	Cob circumference (cm)	Seed cob^{-1}	500 seed weight (g)	Grain yield (t ha^{-1})
Granular dose	2.01	88.64	18.98	13.21	504.9	115.1	6.53
Powder dose	2.08	91.73	18.35	13.09	525.7	125.2	6.65
Granular Split	2.05	86.38	18.26	12.83	502.1	107.2	6.24
CV (%)	3.76	6.22	4.78	3.08	5.43	12.44	9.11
LSD (0.05)	-	-	-	-	-	-	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

T. aman

Effect of tillage

It is observed that all parameters varied insignificantly ($p \geq 0.05$) due to tillage practices (Table 5). In case of plant height, tillers $hill^{-1}$, grain yield and straw yield non-puddle system performed the better result than strip tillage. In case of panicle length, filled grain panicle^{-1} and 1000 grain weightnon-puddle system performed the better than conventional tillage.

Table 5. Effect of tillage on yield and yield attributes of T.aman (2021)

Treatment	Plant height (cm)	Tillers hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	1000 grain weight (g)	Grain yield	Straw yield
						(t ha^{-1})	
Non-puddle	85.24	17.12	25.97	97.17	18.83	3.68	7.57
Conventional tillage	86.10	18.90	25.61	90.80	18.78	3.77	7.68
CV (%)	2.40	4.34	3.12	10.37	2.27	9.01	9.93
LSD (0.05)	-	-	-	-	-	-	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Effect of phosphorus

All characters varied insignificantly among phosphorus doses (Table 6). In case of plant height and tiller hill^{-1} basaldose (granular) gave the highest result than other doses. In case of panicle length, filled grain panicle^{-1} and grain yield powder dose gave the highest result than other doses. In case of 1000 grain weight and straw yield split dose (granular) performed the highest result than other doses.

Table 6. Effect of phosphorus on yield and yield attributes of T.aman (2021)

Treatment	Plant height (cm)	Tillers hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	1000 grain weight (g)	Grain yield	Straw yield
						(t ha^{-1})	
Granular dose (Basal)	86.57	18.13	25.66	92.75	18.82	3.78	7.61
Powder dose (Basal)	85.87	17.89	25.87	99.03	18.56	4.01	7.56
Granular dose (Split)	84.58	17.94	25.86	90.17	19.01	3.75	7.73
CV (%)	2.40	4.34	3.12	10.37	2.27	9.01	9.93
LSD (0.05)	-	-	-	-	-	-	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Physical properties of post-harvest soils (0-10 cm depth)

Soil moisture content

Tillage with phosphorus doses varied insignificantly ($p \geq 0.05$) on soil moisture content and field capacity (Table 7). Strip tillage with phosphorus combination gave comparatively more moisture and field capacity than conventional tillage with phosphorus treatments. Strip tillage with granular (basal) dose gave the most soil moisture content than other treatment combinations wheras conventional tillage with granular (basal) dose comparatively gave the most field capacity than other combinations.

Bulk density

Tillage with phosphorus doses varied insignificantly ($p \geq 0.05$) for bulk density (Table 7). Bulk density of the soils decreased compare to initial soil. Strip tillage with phosphorus combination gave comparatively less bulk density compare to conventional tillage with phosphorus combinations.

Table 7.Physical properties of post harvest soil (after two years)

Treatment	Moisture content	Field capacity	Bulk density (g cm^{-3})
	(%)		
Initial	20.90	30.23	1.59
ST Granular	23.35	31.09	1.51
ST Powder	22.85	31.78	1.49
ST Split	22.30	31.72	1.46
CT Granular	23.11	32.12	1.53
CT Powder	22.89	31.05	1.51
CT Split	20.91	29.94	1.48

Chemical properties of post-harvest soil (0-10 cm depth)

Tillage with phosphorus doses varied insignificantly ($p \geq 0.05$) on chemical properties of post -harvest soil (Table 8). OM along with N, P, K, S, Zn and B increased but pH remain more or less same and B content decrease compare to initial soil. In case of all nutrient content strip tillage with phosphorus combinatons gave comparatively more nutrient content than conventional tillage with phosphorus combinations.

Table 8.Chemical content of post-harvest soil after second cycle (0-10 cm depth)

Treatment	pH	OM	N	P	K	S	Zn	B
		%		(µg g^{-1})	(meq 100 g^{-1})	µg g^{-1}		
Initial	5.75	1.49	0.065	13.50	0.11	16.50	0.65	0.23
STP_1	5.76	1.88	0.095	15.33	0.14	21.00	2.40	0.18
STP_2	5.77	1.92	0.096	15.67	0.15	21.33	2.47	0.21
STP_3	5.72	1.86	0.091	15.30	0.16	22.11	2.24	0.19
CTP_1	5.67	1.68	0.088	14.67	0.14	20.67	2.32	0.18
CTP_2	5.71	1.85	0.097	15.23	0.14	21.27	2.39	0.19
CTP_3	5.66	1.82	0.087	14.57	0.12	20.33	1.99	0.17
Critical level	-	-	-	7.0	0.12	10.0	0.60	0.20

Note: ST-strip tillage, CT-conventional tillage, P_1-Granular (basal), P_2-Powder (basal), P_3-Split (granular)

Conclusion

Strip tillage give more grain yield than conventional tillage for maize but conventional tillage gave better yield than non-puddle system for T. aman due to residual nutrient factor for subsequent crop. Powder dose gave the best yield than other doses for both crops. Strip tillage with phosphorus combinations comparatively gave more moisture and field capacity than conventional tillage with phosphorus combinations and vice-versa for bulk density. OM along with N, P, K, S and Zn increased but pH remain more or less same and Bdecreased compare to initial soil.The 10th crop garden was damaged at flowering stage due to heavy rainfall for cyclone Jaoyad. The12th crop T. aman is on field at tillering stage.

Acknowledgement

The authors would like to acknowledge Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Bangladesh, for its budgetary support and direction and Farm division for tillage and irrigation support in this study under Physical Aspects of Soil Management.

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EFFECT OF CROP ESTABLISHMENT PRACTICES AND IPNS BASED NUTRIENT MANAGEMENT ON CABBAGE-INDIAN SPINACH-T. AMANCROPPING SYSTEM AND SOIL PHYSICO-CHEMICAL PROPERTIES

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Abstract

A field experiments on Cabbage-Indian spinach-T.aman rice cropping pattern were conducted in Grey Terrace soil of Joydebpur under AEZ-28 during rabi 2019-2020, 2020-2021 and 2021-2022 to investigate the performance of crops in vegetable based triple crops cropping system under the crop establishment and organic fertilizer application practicesand to study the soil physic-chemical properties under crop establishment and organic dominant IPNS in the cropping system.There were 2 types of tillage such as Strip tillage (ST) and conventional tillage (CT). In addition, 3 nutrient management practicessuch as 100% organic ferilizer, IPNS and 100% chemical fertilizersin a split plot design with 6 treatments and 3 replications.Strip tillage gave better yield for cabbage and for T.aman but vice-versa for Indian spinach. IPNS package gave the maximum yield for Indian spinach, and cabbage where 100% Organic fertilizer gave the maximum yield for T.aman under Cabbage- Indian spinach-T. aman cropping pattern. CO_2 emission was more in conventional tillage than strip tillage during cabbage growing period. 100% organic fertilizer treatment emitted more CO_2 than IPNS and 100% chemical fertilizer and IPNS emitted less CO_2. Strip tillage gave more field capacity, soil moisture and less bulk density than conventional tillage. Organic based nutrient package gave more moisture, field capacity and less bulk density than chemical fertilizer. Organic based nutrient package increased OM, N and Zn than chemical fertilizer treatment. In case of Organic based treatment pH, P, K and S increased but more or less remain same for chemical based fertilizer compare to initial soil. B decreased compare to initial soil. The 8th crop Indin spinach is on field and harvesting going on during report writing.

Introduction

Judicious and timely crop establishment practices and appropriate nutrient management are very important for successful production of crops in vegetablebased cropping systems under changing climatic conditions. Conservation agriculture practice like strip planting performs well in establishing crops along with yield, economics, soil health and environment. But sometimes increased residue retention can't be affordable due to different use of residues in rural households. On the other hand, soil, soil organic matter and soil health are the foundation of agriculture and human civilization on the earth because without improving soil health, no breeding or biotechnological approach of sustainable crop production would work.Organic matter management through minimum tillage and fertilizer management practices is subsidiary for increasing soil temperature, moisture, root activation, cation exchange capacity, nutrient use efficiency, resulting increase uptake of nutrient, optimize yield and economic benefits for sustainable crop production. Compared to no-till, strip-till (ST) can allow the soil to warm up and dry faster as the tillage operation removes crop residue from the soil surface and increases soil aeration (Perez-Bidegain et al., 2007).Strip tillage maintained more soil carbon than conventional practices (Faaborget al., 2005).In order to improving soil health and ensuring sustainable crop production, alternative approach of soil health improvement shouldtherefore be explored. Under the above concern, the present study was taken to settle the following objectives to investigate the performance of crops in vegetable based triple crops cropping system under the crop establishment and organic fertilizer application practices and to study the soil health under crop establishment and organic dominant IPNS in the cropping system.

Materials and Methods

A field experiments on Cabbage-Indian spinach-T.aman rice cropping pattern were conducted in Grey Terrace soil of Joydebpur under AEZ-28. The experiment was started at BARI central research farm during rabi season in 2019-2020.The physical and chemical properties of experimental soil are presented in Table 1.

Table1. Physical, chemical andproperties of initial soil and nutrient content of cowdung during 2019-2020

a) Physical properties

Soil depth (cm)	Moisture content	Field capacity	Bulk density (g cm^{-3})	Penetration resistance (N cm^{-2})	Particle size (%)			Textural class
	(%)				Sand	Clay	Silt	
0-10	18.21	29.10	1.54	215.3	44.00	17.28	38.72	Loam

b) Chemical properties

Soil depth (cm)	pH	OM	Total N	P (µg g^{-1})	K (meq 100 g^{-1})	S	Zn	B
		%				µg g^{-1}		
0-10	5.67	1.48	0.071	15.0	0.12	16.0	1.32	0.27
Critical level	-	-	-	7.0	0.12	10.0	0.60	0.20

c) Nutient content of cowdung (Decomposed)

Item	OM	N	P	K	S	Zn	B
	(%)						
Cowdung	9.8	1.0	0.97	0.27	0.30	0.02	0.02

The tillage operations such as strip tillage with VMP (versatile multi-crop Planter) and conventional tillage with power tiller (10-12 cm depth) were employed in combination with three nutrient management practices viz. 100% organic fertilizer, IPNS (60% chemical fertilizer and 40% chemical fertilizers) and 100 chemical fertilizers). Thus 6 treatment combinations were arranged in split plot design with three replications. The plot size was 4.8 M× 3.15M.

For cabbage, variety was Atlas-70 and spacing was 60 cm × 45 cm. The crops were fertilized with soil test based (STB) fertilizer dose as per FRG-2018 (BARC, 2018). The fertilizer doses were 38t $ha^{-1}$for 100% Organic fertilizer treatment, $N_{116}P_{12}K_{31}S_9$ $Zn_{0.7}B_{0.3}$ kg ha^{-1} and 15t $ha^{-1}$for IPNS treatment and N_{193} P_{20} K_{51} $S_{15}Zn_{01.2}$ $B_{0.5}$kg ha^{-1} for 100% chemical fertilizer treatment.Cabbage seedlings were transplanted on 01 December 2021 and crop was harvested on 01 March, 2022.

All decomposed cowdung, phosphorus, gypsum zinc sulphate and boric acid were applied during final land preparation. Urea was applied in three equal splits at 10 DAT, 25 DAT 45 DAT. MoP was applied in three equal splits at final land preparation, 20 DAT and 40 DAT. Every split application of fertilizers was followed by irrigation. Another supplemental irrigation was applied at 55 DAS, while other intercultural operations were done as and when necessary.

For Indian spinach the tested varieties were BARI Puishak-1 and spacing 60 cm × 50 cm. The crops were fertilized with soil test based (STB) fertilizer dose as per FRG-2018 (BARC, 2018). The fertilizer doses were 22 t ha^{-1} decomposed cowdung for 100% Organic fertilizer treatment, $N_{67}P_6K_{31}S_{5.4}$kg ha^{-1} and 9 t ha^{-1}decomposedcowdungfor IPNS treatment and$N_{112}P_{10}K_{51}S_9$ kg ha^{-1} for 100% chemical fertilizer treatment.Indian spinach seeds sown on 03 April, 2021 and crop harvesting was started from on 30 may, 2021.

For Indian spinach all TSP, gypsum, zinc sulphate were applied during final land preparation. Urea was applied in three equal splits at 20 DAS, 35 DAS and 50 DAS. MoP was applied half as basal and rest was applied 25 DAS. Single irrigation was applied at dry condition.

For T. aman the tested varieties were BRRI dhan57 and spacing 20 cm × 20 cm. The crops were fertilized with soil test based (STB) fertilizer dose as per FRG-2018 (BARC, 2018). The fertilizer doses were 15 t ha^{-1} decomposed cowdung for 100% organic fertilizer treatment, $N_{46}P_{2.5}K_{28}S_4Zn_{0.3}$ kg ha^{-1} and 6 t ha^{-1} decomposed cowdung for IPNS treatment and N_{77} P_4 $K_{46}S_7Zn_{0.5}$ kg ha^{-1} for 100% chemical fertilizer treatment.T.aman seedling were transplanted on 25 July, 2021 and crop harvested on 13 October, 2021.

For T.aman all TSP, gypsum, zinc sulphate were applied during final land preparation. Urea was applied in three equal splits at 7 DAT, 25 DAT and 40 DAT. MoP was applied half as basal and rest was applied 25 DAT. Two irrigations were applied at dry condition.

Microbial respiration from the soil in different treatments was also assessed periodically by trapping emitted CO_2 in NaOH (Anderson 1982). All assays were performed in triplicate. The trapped CO_2 was measured by adding 15 mL of 10% w/v $BaCl_2$ to the NaOH to precipitate $BaCO_3$. The remaining NaOH was then back titrated against 1M HCl to the phenolphthalein to neutralize NaOH. Finally, more HCl was added to the methyl orange to dissolve $BaCO_3$.

Table 2.Monthly average weather data during the crop growing period of 2021-2022

Month	Temperature (°C)	Evaporation (mm)	RH (%)	Sunshine hour	Rainfall (mm)
*April	29.5	25.8	73	7.4	1.3
May	29.9	22.8	79	6.3	3.5
June	29.2	15.8	86	3.9	18.1
*July	29.5	15.2	87	3.3	12.9
August	30.4	12.7	89	3.3	15.8
September	30.7	18.0	87	5.6	2.1
*October	30.3	15.9	86	6.4	2.8
December	21.0	9.5	84	6.1	23.5
January	19.4	11.3	81	5.1	0.3
February	20.5	14.4	78	7.7	1.0
*March	24.0	21.6	67	9.7	0.0

*InApril, July and March, only the crop growing days were considered to calculate average monthly weather components.

The collected soil samples were dried at room temperature mixed thoroughly, grinded, sieved with a 2 mm sieve and preserved in plastic containers for subsequent laboratory analysis. Soil samples were then analyzed for SOM, total N and available P. The SOM was determined by wet oxidation (Jackson 1973), total N by a modified Kjeldahl method (page et al. 1989) and total P bycolourimetric method(Murphy and Riley, 1962).pH was determined through glass electrode pH meter method (Jackson 1962),K and S were determined through NH_4OAC method (Hanlon and Johnson,1984)and turbidimetric method (Sperber, 1984), respectively. Micronutrients were analyzed using atomic absorption spectrophotometer. Particle size distribution of the initial soil was analysed by the hydrometer method (Black, 1965) and the textural class was determined using the USDA texture triangle. Bulk density and particle density of the soil samples were determined by core sampler and pycnometer method (Karim et al., 1988). Moisture content was determined by gravimetric method (Black, 1965). Field capacity was done though pressure plate method.

All relevant data were collected and were analyzed statistically following Statistics 10 program.

Results and Discussion

Cabbage

Effect of tillage

From result it observed that all parameters varied significantly ($p \leq 0.05$) except diameter of curd due to tillage practices (Table 3). In all cases strip tillage gave higher result than conventional tillage. Strip tillage gave better marketable yield (95.36 t ha^{-1}) than cnventional tillage (80.32 t ha^{-1}) due to more carbon acumulation, available nutrient and soil moisture and temperature.

Table 3.Effect of tillage on yield and yield attributes of cabbage (2021-2022)

Treatments	Diameter of curd (cm)	Circumference of curd (cm)	Individual weight (kg)	Marketable yield (t ha^{-1})
Strip tillage	23.43	73.99 a	2.58 a	95.14 a
Conventional tillage	21.15	66.21 b	2.16 b	80.32 b
CV (%)	6.07	5.33	9.74	9.97
LSD (0.05)	-	5.24*	0.24*	9.89*

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Effect of nutrient management

All parameters varied significantly ($p \leq 0.05$) except circumference of curd among nutrient management practices (table 4). For all characters IPNS performed the best compared to other nutrient management options. IPNS gave the best marketable yield (98.89 t ha^{-1}) whereas 100% organic fertilizer gave the lowest result (74.67 t ha^{-1})

Table 4. Effect of nutrient management on yield and yield attributes of cabbage (2021-2022)

Treatment	Diameter of curd (cm)	Circumference of curd (cm)	Individual weight (g)	Marketable yield (t ha-^{1})
100% Organic fertilzer	20.89b	65.38	2.02 b	74.67 b
IPNS (60% chemical and 40% organic fertilizer)	24.25 a	74.91	2.67 a	98.89 a
100 % Chemical Fertilizer	20.89 b	65.39	2.42 a	89.62a
CV (%)	6.07	5.33	9.74	9.97
LSD (0.05)	1.80*	-	0.31*	11.65*

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Effect of tillage on soil respiration

Tillage had varied ($p \leq 0.05$) emission of CO_2 synthesized by soil respiration under cultivation of cabbage (Figure 1). In both tillages emission was more or less same up to 27 dats after transplanting and after that, more emission was occured in conventional tillage than strip tillage. The intensity of emission was increased when fertigation and irrigation supplied.

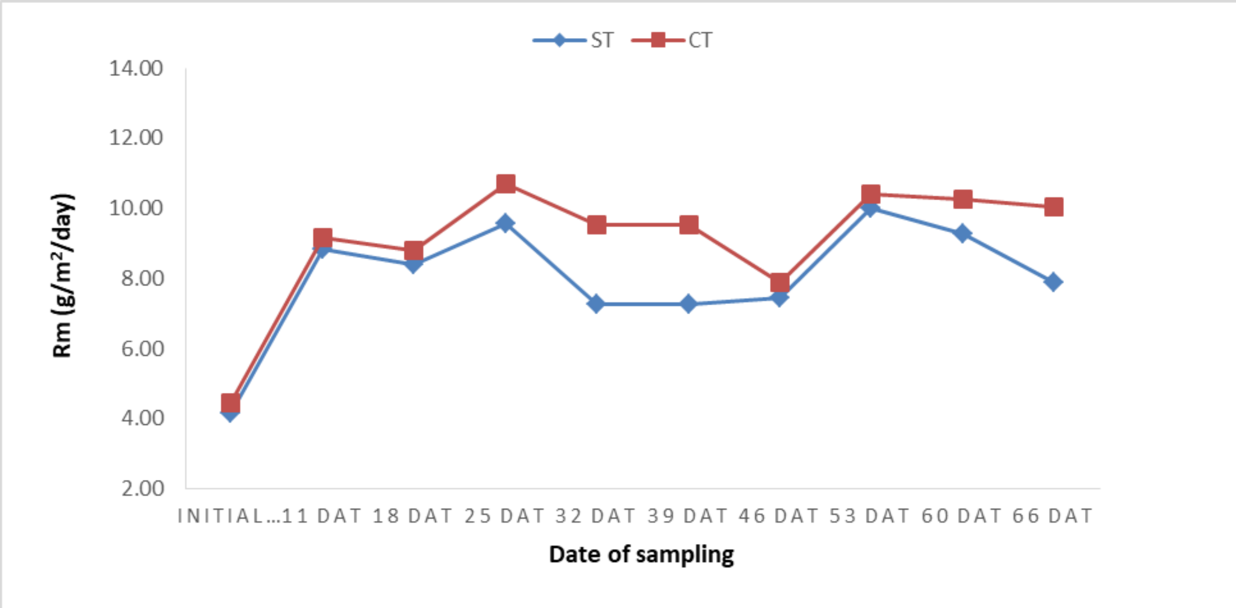

Figure 1.Effect of tillage on soil respiration

Effect of nutrient management on soil respiration

Nutrient management had varied ($p \leq 0.05$) emission of CO_2 synthesized by soil respiration under cultivation of cabbage (Figure 2). 100% organic matter treatment emitted more CO_2 than IPNS and 100% chemical fertilizer treatment due to more carbon and more microbial activity in that plot. Maximum emission was occurred up to 25 dats after transplanting and the intensity of emission was increased when fertigation and irrigation supplied.

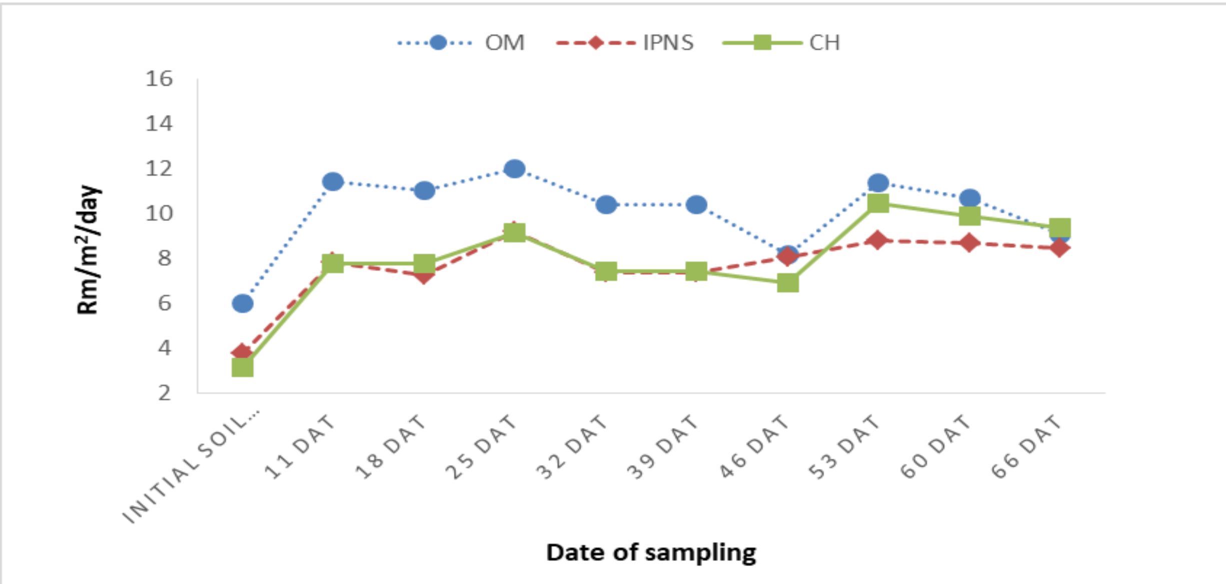

Figure 2.Effect of nutrient management on soil respiration

Indian spinach

Effect of tillage

It is observed that marketable yield varied insignificantly ($p \geq 0.05$) due to tillage practices (Table 5). Conventional tillage gave more marketable yield than strip tillage.

Table 5.Effect of tillage on yield and yield attributes of Indian spinach (2021)

Treatment	Marketable yield ($t\ ha^{-1}$)
Strip tillage	30.57
Conventional tillage	32.46
CV (%)	13.61
LSD (0.05)	NS

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Effect of nutrient management

Marketable yield varied insignificantly ($p \geq 0.05$) among phosphorus doses (Table 6). IPNS package performed the best than other treatments whereas 100% organic fertilizer gave the lowest yield.

Table 6. Effect of nutrient managment on yield and yield attributes of Indian spinach (2021)

Treatment	Marketable yield ($t\ ha^{-1}$)
100% Organic fertilizer	30.75
IPNS (60% chemical and 40% organic fertilizer)	32.05
100 % Chemical Fertilizer	31.75
CV (%)	13.61
LSD (0.05)	NS

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

T. aman

Effect of tillage

It is observed that all parameters varied insignificantly ($p \geq 0.05$) except straw yield ($p \leq 0.05$)due to tillage practices (Table 7). In case of plant height, panicle length, filled grain panicle^{-1}, grain yield and straw yield non-puddle sytemperformed the better than conventional tillage. For tillers hill^{-1} and 1000 grain weight conventional tillage gave the higher yield than non-puddle system.

Table 7. Effect of tillage on yield and yield attributes of T.aman (2021)

Treatment	Plant height (cm)	Tillers hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	1000 grain weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
Non-puddle	84.69	15.68	25.93	121.4	19.49	5.45	7.52 a
Conventional tillage	84.13	16.06	25.91	118.3	20.01	5.42	6.86b
CV (%)	3.78	5.66	3.47	14.06	5.06	12.58	11.81
LSD (0.05)	-	-	-	-	-	-	0.34*

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Effect of nutrient management

All characters varied insignificantly (p≥0.05) for nutrient management practices (Table 8). In case of plant height and tillers hill^{-1}100% chemical fertilizer gave the highest result than other nutrient management options. IPNS management performed the best for panicle length, filled grain panicle^{-1} and straw yield than other treatments. 100% organic fertilizer performed the best for 1000 grain and grain yield than other management options.

Table 8. Effect of nutrient managment on yield and yield attributes of T.aman (2021)

Treatment	Plant height (cm)	Tillers hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	1000 grain weight (g)	Grain yield	Straw yield
						(t ha^{-1})	
100% Organic fertilizer	82.68	15.55	25.87	117.6	20.17	5.90	7.06
IPNS (60% chemical and 40% organic fertilizer)	83.77	15.63	26.10	122.2	19.83	5.36	7.31
100 % Chemical Fertilizer	86.78	16.42	25.81	120.9	19.27	5.09	7.21
CV (%)	3.78	5.66	3.47	14.06	5.06	12.58	11.81
LSD (0.05)	-	-	-	-	-	-	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Physical properties of post-harvest soil after two cycles (0-10 cm depth)

Soil moisture content

Tillage with nutrient management varied insignificantly (p≥0.05) on soil moisture content (Table 9). Strip tillage gave more field capacity, soil moisture and less bulk density than conventional tillage and organic based nutrient management practices gave more soil moisture content, field capacity and less soil bulk density than chemical based nutrient management options.

Bulk density

Tillage with nutrient management varied insignificantly (p≥0.05) on bulk density (Table 10). For all treatment combinations positive change was occurred than initial soil bulk density and strip tillage with nutrient combinations comparatively gave lessbulk density than conventional tillage with nutrient management combinations.

Table 9. Physical properties of post harvest soil (after two years)

Treatment	Moisture content	Field capacity	Bulk density (g cm^{-3})
	(%)		
Initial	18.21	29.10	1.54
ST 100% OM	20.39	32.62	1.46
STIPNS	18.61	32.25	1.50
ST 100% Chemical	17.65	31.05	1.51
CT 100% OM	18.73	32.36	1.47
CTIPNS	18.35	31.15	1.49
CT 100% Chemical	17.56	28.58	1.52

Chemical properties of post-harvest soil (0-10 cm depth)

Tillage with nutrients varied insignificantly ($p \geq 0.05$) on chemical properties of post -harvest soil (Table 10). pH along with OM, N, P, K and S increased for tillage with 100% OM and IPNS package but remain more less same for tillage with 100% chemical fertilizer compare to initial soil. Zn increased but B decreased compared to initial soil.

Table 10. Chemical content of post-harvest soil after two cycle (0-10 cm depth)

Treatment	pH	OM	N	P	K	S	Zn	B
		%		(µg g^{-1})	(meq 100 g^{-1})	µg g^{-1}		
Initial	5.67	1.48	0.071	15.0	0.12	16.00	1.32	0.27
STOM	6.10	3.03	0.17	28.21	0.15	24.6	2.4	0.22
STIPNS	5.90	2.55	0.15	26.52	0.14	20.72	1.85	0.19
STCH	5.60	1.92	0.10	16.36	0.13	16.10	2.34	0.14
CTOM	5.80	2.49	0.12	21.33	0.14	19.14	2.38	0.19
CTIPNS	5.55	1.97	0.11	15.67	0.13	17.32	2.71	0.15
CTCH	5.50	1.89	0.095	15.33	0.13	16.14	2.72	0.10
Critical level	-	-	-	7.0	0.12	10.0	0.60	0.20

Note: OM-organic matter, CH-chemical

Conclusion

Strip tillage gave better yield for cabbage and for T.aman but vice-versa for Indian spinach due to residual nurient of subsequent crop. IPNS package gave the maximum yield for Indian spinach, and cabbage where 100% organic fertilizer gave the maximum yield for T.amanunder Cabbage- Indian spinach-T. aman cropping pattern. CO_2 emission was more in conventional tillage than strip tillage during cabbage growing period. 100% organic mater treatment emitted more CO_2 than IPNS and 100% chemical fertilizer and IPNS emitted less CO_2. Strip tillage gave more field capacity, soil moisture and less bulk density than conventional tillage. Organic based nutrient package gave more moisture, field capacity and less bulk density than chemical fertilizer.Organic based nutrient package increased OM, N and Zn than chemical fertilizer treatment. In case of Organic based treatment pH, P, K and S increased but more or less remain same for chemical based fertilizer compare to initial soil. B decreased compare to initial soil.The 9th crop T. aman is on field at tillering stage.

Acknowledgement

The authors would like to give thank Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Bangladesh, for its budgetary help and useful direction and Farm division for tillage and irrigation support in this study under physicals Aspects of Soil Management.

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REQUIREMENT OF NITROGEN FORMUSTARD-OKRA- T. AMAN CROPPING SYSTEM BASED ON CONSERVATION AGRICULTURAL PRACTICES

M.J. ALAM, A.T.M.A.I. MONDOL and H.M. NASER

Abstract

A field experiments on Mustard-Okra-T.aman rice cropping pattern was conducted in Grey Terrace soil of Joydebpur under AEZ-28 during rabi2021-2022 to investigate the rate of nitrogen fertilizer for the intensive mustard-okra- T. aman cropping system under CA practices, to evaluate the effet of nitrogen and tillage on soil physico-chemical properties and to asses the system productivity. There were 3 types of tillage such as strip tillage (ST), zero tillage (ZT) and conventional tillage (CT). In addition, nitrogen management practicessuch as 100% nitrogen (N_1), 125% nitrogen (N_2), 75% nitrogen (N_3) and 50% nitrogen (N_4) in a split plot design with 12 treatments and 3 replications. Mustard was the first crop and 125% nitrogrn doses gave the maximum result than other doses. The second crop okra harvesting going on during report writting.

Introduction

Well-managed soil under minimum till condition with crop residue retention can support sustainable crop production through improved soil quality with higher soil organic carbon, available nutrients and addition of crop residue have essential roles in improving the enzymatic activity of soil that are important for nutrient cycling, as well as increasing crop productivity (Rajkumara et al. 2014; Wei et al. 2015). Conservation agriculture (CA) is characterized by three linked principles, namely, minimal soil disturbance, permanent organic soil cover and crop rotations (Kassam, 2010; FAO, 2010). CA is already occurring and gathering momentum worldwide as a new paradigm shift for the 21st century to ensure sustainable food production and maintain environmental integrity.

Tillage, residue management and crop rotation have a significant impact on nutrient distribution in soils (Galantini et al. 2000; Etana et al. 1999). Distribution of nutrients in a soil under minimum tillage is different to that in tilled soil. Increased stratification of nutrients is generally observed, with enhanced conservation and availability of nutrients near the soil surface under minimum tillage as compared to conventional tillage (Duiker and Beegle 2006; Franzluebbers and Hons 1996).

The adoption of CA in rice-based cropping systems with traditional nutrient management may have discouraging results. In addition, the fertilizer recommendation guide is also developed only for conventional farming systems (BARC 2018). The fertiliser recommendation guide is therefore should be improved with fertiliser recommendations for CA based cropping systems. The budget and dynamics of nutrients should also be studied in soils under CA based cropping systems. However, the information on effect of crop residue, minimal soil disturbance and nutrient management in mustard-maize-T. Aman cropping system is lacking. Hence, the present study is undertaken to evaluate the effect of nitrogen and tillage on soil-physico-chemical properties and to asses the system productivity.

Materials and Methods

A field experiments on Mustard-Okra-T.aman rice cropping pattern were conducted in Grey Terrace soil of Joydebpur under AEZ-28. The experiment was started at BARI central research farm during rabi season in 2021-2022.The physical and chemical properties of experimental soil are presented in Table 1.

Table1. Physical, chemical andproperties of initial soil during 2021-2022

b) Physical properties

Soil depth (cm)	Moisture content	Field capacity	Bulk density (g cm^{-3})	Penetration resistance (N cm^{-2})	Particle size (%)			Textural class
	(%)				Sand	Clay	Silt	
0-10	20.2	32.11	1.49	200.3	41.28	23.39	35.33	Loam

b) Chemical properties

Soil depth (cm)	pH	OM	Total N	P ($\mu g\ g^{-1}$)	K (meq 100 g^{-1})	S	Zn	B
		%				$\mu g\ g^{-1}$		
0-10	5.32	1.65	0.077	15.0	0.13	18.0	0.23	0.29
Critical level	-	-	-	7.0	0.12	10.0	0.60	0.20

The tillage operations such as strip tillage with VMP (versatile multi-crop Planter), zero tillage with tyne (called nangla) and conventional tillage with power tiller (6-8 cm depth) were employed in combination with four nitrogen management practices such as 100% nitrogen (N_1), 125% nitrogen (N_2), 75% nitrogen (N_3) and 50% nitrogen (N_4).Thus 12 treatment combinations were arranged in split plot design with three replications. The plot size was 4.2 M× 3.0M.

The experiment was started on last rabi season, therefore, only single crop viz mustard has reported here. Before going to start this experiment the soil of the experimental plots was tilled with chisel and mixed thoroughly as there was a pattern experiment for four years. The tested variety was BARI Sharisha-14 and spacing 30 cm with contibuouse line. The crops were fertilized with soil test based (STB) fertilizer dose as per FRG-2018 (BARC, 2018), N_1= $N_{94}P_{11}K_{51}S_8Zn_{1.5}B_{0.5}$kgha^{-1}, N_2= $N_{118}P_{11}K_{51}S_8Zn_{1.5}B_{0.5}$ kg ha^{-1}, N_3=$N_{75}P_{11}K_{51}S_8Zn_{1.5}B_{0.5}$ kg ha^{-1}, N_4= $N_{47}P_{11}K_{51}S_8Zn_{1.5}B_{0.5}$kg ha^{-1}.

All, phosphorus, gypsum zinc sulphate and boric acid and half MoPwere applied during final land preparation. Urea was applied in three equal splits at 7 DAG, 20 DAG35 DAG. Half MoP was applied in at 20 DAG. Every split application of fertilizers was followed by irrigation. Another supplemental irrigation was applied at 55 DAS, while other intercultural operations were done as and when necessary. Mustard seeds were sown on 17November, 2021 and crop was harvested on 22 February, 2022.

Table 2.Monthly weather data during the crop growing period of 2021-2022

Month	Temperature (°C)	Evaporation (mm)	RH (%)	Sunshine hour	Rainfall (mm)
*November	23.0	12.6	84	7.3	0.0
December	21.0	9.5	84	6.1	23.5
January	19.4	11.3	81	5.1	0.3
*February	19.6	13.9	79	7.5	1.3

*InNovember and February, only the crop growing days were considered to calculate average monthly weather components.

The collected initial soil samples were dried at room temperature mixed thoroughly, grinded, sieved with a 2 mm sieve and preserved in plastic containers for subsequent laboratory analysis. Soil samples were then analyzed for SOM, total N and available P. The SOM was determined by wet oxidation (Jackson 1973), total N by a modified Kjeldahl method (page et al. 1989) and total P by using colourimetric method (Murphy and Riley, 1962).pH was determined through glass electrode pH meter method (Jackson 1962),K and S were determined through NH_4OAC method (Hanlon and Johnson,1984)and turbidimetric method (Sperber, 1984), respectively. Micronutrients were analyzed using atomic absorption spectrophotometer.Particle size distribution of the initial soil was analysed by the hydrometer method (Black, 1965) and the textural class was determined using the USDA texture triangle. The BD of the soil samples were determined by core sampler and pycnometer method (Karim et al., 1988). Moisture content was determined by gravimetric method (Black, 1965). Field capacity was done though pressure plate method.

All relevant data were collected and were analyzed statistically following Statistics 10 program.

Results and Discussion

Mustard

Effect of nitrogen fertilizers

All characters ($p \geq 0.05$) except grain yield($p \leq 0.05$) varied insignificantly among nitrogen doses (Table 3). In case of plant height, siliqua plant^{-1}, seed siliqua^{-1} and grain yield 125% nitrogen dose performed the best than other doses 50% nitrogen gave the lowest result. Incase of 1000 grain weight 100% gave the highest result than other doses where 50% nitrogen gave the lowest result.

Table 3. Effect of nitrogen managment on yield and yield attributes of mustard (2021-2022)

Treatment	Plant height (cm)	Siliqua plant^{-1}	Seedsiliqua^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})
100% Nitrogen	64.37	52.79	27.42	3.28	1.01 b
125% Ntrogen	68.16	59.27	29.76	3.23	1.12 a
80% Nitrogen	66.66	55.11	29.17	3.24	0.99 b
50% Nitrogen	64.37	50.01	26.71	3.09	0.77 c
CV (%)	11.87	16.02	12.07	6.81	13.84
LSD (0.05)	NS	NS	NS	NS	0.13*

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Conclusion

125% nitrogen dose performed the best than other doses.Second crop okra is on field and near to finish of harvesting during report writing.This is the first year study; need to be continued for 3-4 more years to see the real picture of CA practices on yield and on soil physic-chemical practices.

Acknowledgement

The authors would like to give thank Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Bangladesh, for its budgetary help and useful direction and Farm division for tillage and irrigation support in this study under physicals Aspects of Soil Management.

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EFFECT OF MINIMUM TILLAGE AND CROP RESIDUE RETENTION ON SOIL PHYSICO-CHEMICAL PROPERTIES AND CROP YIELDS UNDER A RICE-BASED CROPPING SYSTEM

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Abstract

An experiment was conducted at Regional Agricultural Research Station (RARS), Jashore during 2016-2017 to 2021-2022 cropping years to observe the effects of tillage and residue retention on soil physico-chemical properties and crop yields along with to assess the system productivity in rice-based cropping system. Two tillage practices such as, T_1: conventional tillage (CT) and T_2: minimum tillage (MT) were assigned in main plot and two levels of residue retention such as R^+: 30 cm crop residue retention/incorporation of wheat and rice and full straw retention of mungbean, and R^-: removal of crop residue. Tillage practices had significant effect on the grain yield of T. Aman rice in the 2021 cropping year and higher grain yield was obtained from conventional puddling system than that of minimum tillage system.The MT and CT gave statistically similar mungbean and wheat yield as well as rice equivalent yield. After 15th crop harvest, conservation agriculture showed soil properties improvement over conventional agriculture system.

Introduction

Tillage practices influence physical, chemical, and biological properties of soil and have a major impact on soil productivity and sustainability. Tillage management can alter SOM to a new equilibrium level (Dao, 1998). Nutrients concentrations in soil along with their availability to plants could be affected by tillage practices (Lavado*et al.*, 1999). Intensive conventional tillage practices may adversely affect long-term soil productivity due to erosion and loss of organic matter in soils. On the other hand, minimum or reduced or minimum till or no-till practices are suitable tools in conventional farming to prevent soil degradation, to increase water retention capacity (Aziz et al. 2013), and decrease production costs (Derpsch*et al.*, 2010). In addition, the tillage effects are environmentally dependent and different results have been reported under different types of soil and climate (Schomberg*et al.*, 1994). Management and utilization of crop residues is essential for the improvement of soil quality and crop productivity under intensive wheat-based cropping systems. Long-term crop residue application will build soil organic matter level and N reserves, and also increase the availability of macro- and micro-nutrients (Yadvinder-Singh *et al.*, 2005). Residues retention improves soil physical, chemical and biological qualities (Bijay-Singh *et al.*, 2008).

Unfortunately, conventional system of excessive tillage and residue removal is further aggravating the situation by degrading soil quality via accelerated the decomposition of soil organic carbon. Therefore, decline in SOC poses serious agricultural and environmental drawbacks by reduced nutrient concentrations (Ashagrie*et al.*, 2007). In this situation, minimum/reduced tillage, crop residue retention plus suitable crop rotations could be a good option for Bangladesh. This practice is poorly developed for intensive wheat based cropping practice which is common in Bangladesh and has not been adequately assessed in Bangladesh condition. The present study has therefore, been undertaken in context of following objectives:

I. to observe the effects of tillage and residue retention on soil physico-chemical properties and crop yields in the rice–based cropping system,
II. to find out the better combination of tillage system and residue retention for higher crop yield and soil health improvement, and
III. to assess the system productivity in rice-based cropping system.

Materials and Methods

Description of experimental site

The experiment was conducted at RARS, Jashore during rabi season since 2016-2017 to 2021-2022.The study area was under the agro-ecological zone “High Ganges River Floodplain” (AEZ-11). Initial soil properties of the experimental field were determined and information of soil texture, bulk density, soil pH, organic matter, total N, exchangeable K, available P, S, Zn, and B contents at 0-15 cm soil depths are presented in Tables 1& 2.

Table 1. Particle size distribution, textural class and bulk density of initial soil of the experimental field, RARS, Jashore

Soil depth (cm)	Particle size distribution			Textural class	Bulk density ($g\ cm^{-3}$)
	Sand%	Silt%	Clay%		
0-15	53.00	24.28	22.72	Sandy clay loam	1.42

Table 2. Initial soil pH, SOM, total N, available P, K, S, Zn and B contents of the experimental field, RARS, Jashore

Soil depth (cm)	pH	SOM	Total N	Available other nutrients				
		(%)		K	P	S	Zn	B
				meq 100 g $soil^{-1}$	mg kg^{-1}			
0-15	7.6	1.27	0.065	0.18	13.0	14	0.56	0.16
Composite	Slightly alkaline	Low	Very Low	Low	Low	Low	Low	Low

Treatments and design

The unit experimental plot area was 7.2 m × 5.0 m and the design of the experiment was split-plot with four replications. Two tillage practices, such as, T_1: conventional tillage (CT) and T_2: minimum tillage (MT) were assigned in main plot and two levels of crop residue retention was maintained as R^+: 30 cm residue retention of rice and wheat and whole amount of mungbean biomass and R^-: removal of crop residue (farmers' practice) were allotted in sub-plot.

Land preparation, fertilizer application, sowing/transplanting and intercultural operations

At the initiation of the experiment, the plots were separated from each other according to the layout. The minimum tillage (MT) was accomplished by PTOS using rotating blades maintaining 20 cm spacing from row to row for wheat and rice whereas 40 cm for mungbean. In case of conventional tillage (CT), puddling was done with three passes with the high-speed rotary tiller followed by laddering twice for rice cultivation whereas CT was done for wheat and mungbean sowing by high-speed rotary tiller with three passes followed by two times laddering.

The rates of chemical fertilizers were $N_{131}P_{16}K_{60}S_{11}Zn_2B_1$ kg ha^{-1} for wheat, $N_{20}P_{14}K_{24}S_{13}Zn_2B_1$ for mungbean whereas $N_{66}P_7K_{33}S_8Zn_1$ for T. Aman rice, according to STB followed by FRG-2018.

For T. Aman rice, all fertilizers except urea were applied as basal dose and urea was applied at 3 equal splits at 5 DAT, 29 DAT and 45 DAT. For mungbean, whole amount of fertilizers was applied as basal dose. In case of wheat, whole amount of the fertilizers except urea was applied as basal dose whereas urea was applied in three equal splits at 7, 20 and 48 days after sowing (DAS).

Varieties of the tested crops used in the experiments were BARI Mung-6 of mugbean, BRRI dhan57 of T. Aman and BARI Gom-33 of wheat. Mungbean seeds were sown on 10 April 2021; T. Aman seedlings were transplanted on 19 July 2021 whereas wheat seeds were sown on 22 November of 2021.

After that hand weeding (just uprooting the weeds by hand, therefore, no soil pulverization occurred in MT practice) was done once only at 20^{th} DAS. Three irrigations were applied at crown root initiation stage (20 DAS), tillering stage (35 and 48 DAS). Other intercultural operations and plant protection measures were taken as and when required.

Crop harvesting and data collection

Mungbean was harvested on 20 and 27 June 2021, T. Aman rice was harvested on 12 October 2021 and wheat was harvested on 16 March of 2022. Two square meter area from each plot was selected for data collection. Ten plants of each plot were selected for yield contributing data. Thousand grain weights was measured plot wise. The whole plant was cut at ground level from R^- plots whereas 30 cm of wheat straw was retained in the R^+ plots. The grain and straw was separated, sun-dried and weighed from 1.0 m^2 area of each plot. The amount of residue retained in the R^+ plots was found from 1.0 m^2 area. Finally, the grain and straw were converted into t ha^{-1}.

Statistical analysis

All the crop data and soil properties at selected depths were statistically analyzed using a split-plot design. Treatment effects on measured variables were tested by analysis of variance (ANOVA), and comparisons among treatment means were made using the least significant difference (LSD) multiple range test calculated at 5% level of probability ($P \leq 0.05$). Statistical procedures were carried out with the software program "*Statistix for Windows (1998)*".

Results and Discussion

Mungbean

Effects of tillage practices and residue retention on yield attributes and grain and green biomass yields of mungbean (BARI Mung-6) during 2021

Tillage practices and residue retention had no significant effect on the yield attributes along with seed and green biomass yields of mungbean during 2021 (Table 3).

Table 3. Effects of tillage practices and residue retention on the yield attributes of mungbeanat RARS, Jashoreduring 2021

Treatments	Plant height (cm)	No. of pod plant^{-1}	No. of filled grains pod^{-1}	No. of unfilled grains pod^{-1}	1000 seed weight (g)	Seed yield (t ha^{-1})	Biomass yield (t ha^{-1})	Biomass retention (t ha^{-1})
Tillage practices								
Conventional tillage	73	18.5	13.4	2.4	46.6	1.50	13.3	6.45
Minimum tillage	68	21.4	11.9	2.6	46.3	1.45	12.1	6.00
$LSD_{0.05}$ value	8^{ns}	3.2^{ns}	2.2^{ns}	0.2^{ns}	3.4^{ns}	0.59^{ns}	3.3^{ns}	1.4^{ns}
CV (%)	6.85	10.18	11.17	7.13	6.62	15.18	6.45	12.55
Residue retention levels								
Residue retention	71	20.1	12.9	2.6	46.9	1.48	12.9	12.40 a
Residue removal	70	19.9	12.4	2.4	46.0	1.47	12.4	0.00 b
$LSD_{0.05}$ value	4^{ns}	2.1^{ns}	1.0^{ns}	0.3^{ns}	2.9^{ns}	0.35^{ns}	0.6^{ns}	1.1**
CV (%)	4.75	8.73	6.30	6.51	5.12	9.54	4.55	11.56

Effects of tillage practices and residue retention on yield attributes of T. Aman rice (BRRI dhan57) during 2021

Tillage practices showed the significant effects on number of effective tillers hill^{-1}, panicle length, filled grains panicle^{-1} of T. Aman rice during 2021. Longer panicle (27.4 cm), higher number of effective tillers (15.3 tillers hill^{-1}) and filled grains (174 grains panicle^{-1}) were recorded in conventional tillage system compared with minimum tillage system (12.9 cm of panicle, 12.9 nos. of tillers and 133 nos. of grains), shown in Table 4.Residue retention levels had no significant variations in yield attributes of T. Aman rice (Table 4).

Table 4. Effects of tillage practices and residue retention on yield attributes of T. Amanat RARS, Jashore

Treatments	Plant height (cm)	Effective tillers hill^{-1}	Panicle length (cm)	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	1000-grain wt. (gm)
Tillage practices						
Conventional tillage	105	15.3 a	27.4 a	174 a	26.8	20.8
Minimum tillage	100	12.9 b	25.2 b	133 b	27.7	20.1
$LSD_{0.05}$ value	4.9^{ns}	2.1*	1.9^{ns}	36*	8.7^{ns}	3.8^{ns}
CV (%)	3.0	9.59	4.43	14.66	19.99	11.65
Residue retention levels						
Residue retention	103	14.2	26.6	155	25.8	20.7
Residue removal	102	14.0	26.0	152	28.7	20.2
$LSD_{0.05}$ value	3.4^{ns}	0.44^{ns}	0.9^{ns}	14^{ns}	5.7^{ns}	2.2^{ns}
CV (%)	2.71	7.56	3.80	11.68	16.98	8.72

Effect of tillage practices and residue retention on grain- straw yield, harvest index and amount of residue retained of T. Aman rice

Tillage practices showed significant variations on the yields of T. Aman grain and straw with harvest index. Significantly higher grain (5.75 t ha^{-1}), straw (6.02 t ha^{-1}) and harvest index (48.8%) were obtained from conventional tillage system than those of minimum tillage system (4.82 t grain, 5.32 t straw ha^{-1} and 47.5% HI), as presented in Table 5.

Residue retention levels had no significant variations in yield attributes of T. Aman rice (Table 4). On the other hand under the residue retention treatment, 3.19 t ha^{-1} residue of T. Aman was retained on the soil over removal (Table 5).

Table 5. Effects of tillage practices and residue retention on grain and straw yields with harvest index and amount of retained residue of T. Aman

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Residue retained (t ha^{-1})
Tillage practices				
Conventional tillage	5.75 a	6.02 a	48.8 a	1.70 a
Minimum tillage	4.82 b	5.32 b	47.5 b	1.49 b
$LSD_{0.05}$ value	0.49**	0.53*	0.35*	0.20*
CV (%)	5.82	5.86	4.45	7.92
Residue retention levels				
Residue retention	5.41	5.77 a	48.4	3.19 a
Residue removal	5.15	5.58 b	47.9	0.00 b
$LSD_{0.05}$ value	0.27^{ns}	0.22*	1.02^{ns}	0.1*
CV (%)	4.15	4.94	3.73	7.72

Effect of tillage practices and residue retention on weed biomass in wheat field

Tillage practices and crop residue retention had significant effects on weed infestation in the wheat field. Higher weed biomass was observed in minimum tilled plots (34 g m^{-2}) over conventional tilled plots (20 g m^{-2}), shown in Table 6. Ozpinar (2006) and Nakamoto*et al*. (2006) found a maximum weed population under the reduced tillage system.

It was also observed that previous crop residue retention suppressed the weed infestation in subsequent crops. Higher amount of weed biomass was obtained under the residue retained plots (32 g m^{-2}) over residue removed plots (22 g m^{-2}), as shown in Table 6. Similarly, Chhokar *et al*. (2012) and found that leaving of crop residues on the soil surface suppressed weeds.

Table 6. Effects of tillage practices and residue retention on weed biomass of wheat at RARS, Jashore in 2021-2022

Treatments	Weed biomass (g m^{-2})
Tillage practices	
Conventional tillage	20 b
Minimum tillage	34 a
$LSD_{0.05}$ value	11*
CV (%)	11.35
Residue retention levels	
Residue retention	22 b
Residue removal	32 a
$LSD_{0.05}$ value	4**
CV (%)	7.96

Effect of tillage practices and residue retention on yield contributing characters yield of wheat (BARI Gom-33) during 2021-2022

Tillage practices and residue retention had no significant effect on the yield contributing characters yield of wheat (BARI Gom-33) during 2021-2022, as presented in Table 7.

Table 7. Effects of tillage practices and residue retention on yield attributes of wheatat RARS, Jashore

Treatments	Plant populations m^{-2}	Plant height (cm)	Spike length (cm)	No. of spikelet $spike^{-1}$	No. of filled grains $spike^{-1}$	1000-grain weight (g)
Tillage practices						
Conventional tillage	264	92	11.6	18.0	53	43.6
Minimum tillage	266	92	11.8	18.6	57	44.3
$LSD_{0.05}$ value	123^{ns}	5^{ns}	0.5^{ns}	1.3^{ns}	5^{ns}	0.8^{ns}
CV (%)	29.25	3.05	5.58	4.34	10.83	1.18
Residue retention levels						
Residue retention (R^+)	273	93	11.8	18.3	56	44.2
Residue removal (R^-)	258	91	11.6	18.3	54	43.7
$LSD_{0.05}$ value	68^{ns}	2^{ns}	0.3^{ns}	1.2^{ns}	3^{ns}	0.7^{ns}
CV (%)	20.84	1.94	4.88	5.33	9.74	1.31

Effect of tillage practices and residue retention on grain-straw yield and harvest index of wheat

The grain and straw yield of wheat was not significantly influenced by tillage practices and residue retention levels and harvest index of wheat (Table 8).

In addition, the amount of wheat residue retained by weight significantly varied due to variation of residue retention levels. Higher amount of residue was retained in R^+ treatment where 30 cm of residue was kept on the soil (2.92 t ha^{-1}), as presented in Table 8.

Table 8. Effects of tillage practices and residue retention on wheat yield at RARS, Jashore in 2021-2022

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Residue retained (t ha^{-1})
Tillage practices				
Conventional tillage (CT)	3.44	5.75	37.5	1.45
Minimum tillage (MT)	3.70	5.31	41.2	1.48
$LSD_{0.05}$ value	0.86^{ns}	1.07^{ns}	7.4^{ns}	0.2^{ns}
CV (%)	15.02	12.16	3.89	8.66
Residue retention levels				
Residue retention (R^+)	3.57	5.57	39.3	2.92 a
Residue removal (R^-)	3.56	5.49	39.4	0.00 b
$LSD_{0.05}$ value	0.59^{ns}	0.71^{ns}	3.8^{ns}	0.27**
CV (%)	13.44	10.54	7.86	14.87

Effects of tillage practices and residue retention on rice equivalent yield

To compare between the treatments, wheat and mungbean were converted into rice equivalent yield (REY) on the basis of prevailing market price of individual crop. Tillage practices and residue retention levels showed insignificant variations in REY, shown in Table 9.

Table 9. Component crop's yield, rice equivalent yield and total rice (system) yield of Wheat-Mungbean-T. aman

Treatment	Component crop's yield in the pattern (t ha^{-1})			Rice equivalent yield of crops in the pattern (t ha^{-1} $year^{-1}$)		Rice equivalent yield, t ha^{-1} $year^{-1}$)
	Wheat	Mungbean	T. aman	Wheat	Mungbean	
Tillage practices						
Conventional tillage	3.44	1.50	5.75 a	2.91	4.28	12.9
Minimum tillage	3.70	1.45	4.82 b	2.70	4.14	11.7
$LSD_{0.05}$ value	0.86^{ns}	0.59^{ns}	0.49**	0.67^{ns}	1.69^{ns}	2.0^{ns}
CV (%)	15.02	15.18	5.82	15.02	15.18	10.12
Residue retention levels						
Residue retention (R^+)	3.57	1.48	5.41	2.81	4.23	12.4
Residue removal (R^-)	3.56	1.47	5.15	2.80	4.19	12.2
$LSD_{0.05}$ value	0.59^{ns}	0.35^{ns}	0.27^{ns}	0.46^{ns}	1.0^{ns}	1.3^{ns}
CV (%)	13.44	9.54	4.15	13.44	9.54	8.92

Note: Market price of rice was Tk. 28.00 kg^{-1}, wheat was Tk. 22.00 $kg^{-1}$and mungbean was Tk. 80.00

Total residue retained in the plots under different tillage and residue retention treatment
A considerable amount of crop residues were retained in CT, ST practice and increased residue retention treatment over the years which may contribute the improvement of soil nutrient contents (Table 10).

Table 10. Retention of residues by the component crops in the cropping system over the years

Treatments	Crops' name	Amount of residues retained (t ha^{-1})					
		5th year	4th year	3rd year	2nd year	1st year	Yearly average
Tillage practices							
Conventional tillage (CT)	T. Aman	1.70	1.22	1.51	1.15	1.29	8.85
	Wheat	1.45	1.36	1.44	1.49	1.39	
	Mungbean biomass	6.45	6.45	5.13	6.73	5.50	
	Total	9.60	9.03	8.08	9.37	8.18	
Minimum tillage (ST)	T. Aman	1.49	1.18	1.49	1.19	1.25	8.79
	Wheat	1.48	1.41	1.60	1.49	1.12	
	Mungbean biomass	6.00	6.10	5.48	6.38	6.30	
	Total	8.97	8.69	8.57	9.06	8.67	
Residue retention (R^+)	T. Aman	3.19	2.41	3.00	2.34	2.54	17.64
	Wheat	2.92	2.78	3.04	2.98	2.51	
	Mungbean biomass	12.40	12.6	10.6	13.1	11.8	
	Total	18.51	17.79	16.64	18.42	16.85	
Residue removal (R^-)	0	0	0	0	0	0	0

Effect of tillage practices and residue retention levels on post-harvest soil

After 15th crop harvest, most of the chemical properties of post-harvest soil significantly varied due to tillage practices and crop residue retention. Higher amount of OM, TN, available P, K and Zn were obtained from MT than those of CT practice. Similarly, crop residue retention gave higher values of SOM, TN, available P, K, Zn and B contents over residue removal treatment, presented in Table 11. The present study found soil properties improving which can be attributed to combined use of minimum tillage with residue retention (Alam, 2018).

Verma and Pandey (2013) found that crop residue retention significantly influenced the SOM content in a rice-wheat sequence. Higher available nitrogen and potassium content with application of rice residues could be attributed to addition of crop residue by forming organo-mineral complexes (Das *et al.*, 2003). Some studies also found improvement in soil nutrients with the addition of crop residues as compared to crop residue removal (Singh and Sidhu, 2014). In a study, Sardana*et al*. (2005) indicated that minimum tillage with residue retention substantially enhanced SOM.

Table 11. Effects of tillage practices and residue retention levels on SOM, total N, available P, K, S, Zn and B contents after 15th crop harvest

Treatments	OM	TN	Available other nutrients				
			K	P	S	Zn	B
	(%)		(meq 100 g $soil^{-1}$)	(µg ml^{-1})			
Tillage practices							
Conventional tillage	1.22 b	0.059 b	0.16 b	12.8 b	14.2	0.57 b	0.20
Minimum tillage	1.43 a	0.077 a	0.31 a	15.7 a	15.9	0.77 a	0.25
$LSD_{0.05}$ value	0.09*	0.012*	0.08*	0.38**	1.7^{ns}	0.09**	0.06^{ns}
CV (%)	5.12	6.67	9.81	6.68	10.23	11.32	9.13
Residue retention levels							
Residue retention	1.44 a	0.080 a	0.32 a	15.9 a	16.3	0.78 a	0.26 a
Residue removal	1.20 b	0.056 b	0.15 b	12.6 b	13.8	0.56 b	0.19 b
$LSD_{0.05}$ value	0.07**	0.009**	0.05**	1.6**	2.8^{ns}	0.09**	0.03**
CV (%)	4.45	7.84	8.36	7.16	9.55	9.96	8.44
Initial	1.27	0.065	0.18	13.0	14.0	0.56	0.16

Conclusion

Tillage practices had significant effect on the grain yield of T. Aman rice in the 2021 cropping year. Significantly higher grain yield of T.Aman rice was obtained from conventional puddling system than that of minimum tillage system. Tillage practices and residue retention levels showed insignificant variations in mungbean and wheat yield as well as system productivity. After 15th crop harvest, conservation agriculture practice (MT and residue retention) showed higher amount of OM, TN, available P, K and Zn were obtained from MT and crop residue retention than those of CT practice and residue removal treatment.

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REQUIREMENT OF K FERTILIZER UNDER CONSERVATION AGRICULTURE PRACTICE IN THE INTENSIVE WHEAT-MUNGBEAN-T. AMAN CROPPING SYSTEM

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Abstract

An experiment was conducted at Regional Agricultural Research Station (RARS), Jashore during 2019-2020 and 2020-2021 to determine the optimum rate of potassium fertilizer under conservation agriculture (CA) practice and to evaluate the effects of K fertilizer on soil properties and cropping system productivity. Two crop establishment methods, such as, T_1: conventional method (excessive tillage + residue removal) and T_2: conservation agriculture (minimum tillage + residue retention) were assigned in main plots whereas four K fertilizer rates were applied as K_1: 75% of recommended rate of K (RDK), K_2: 100% of RDK, K_3: 125% of RDK and K_4: 150% of RDK were allotted in sub-plots. Potassium fertilizer rates showed significant performance in the yield and yield attributes of wheat regardless of crop establishment methods. The longest spike, highest number of spikelets and filled grains spike^{-1} of wheat was obtained from plots receiving 150% and 125% of RDK. Consequently, significantly the highest grain yield (4.47 t ha^{-1}) of wheat obtained from the plots receiving 150% and 125% of RDK) and differed from 100 and 75% of RDK. In case of T. Aman, crop establishment methodsshowed significant variations on the panicle length and number of filled grains spike^{-1} whereas effective tillers hill^{-1}, panicle length, number of filled grains spike^{-1} and 1000-grain wt. of T. Aman increased with increasing K rates. As a result, higher grain yield (4.79 t ha^{-1}) was obtained from the conventionally crop establishment method compared to conservation agriculture practice (4.42 t ha^{-1}). Highest grain yield (5.11 t ha^{-1}) of T. Amanwas obtained from plots receiving 150% of RDK which were different from other K rates. There was no variation in mungbean performance due to crop establishment methods and K fertilizer rate. In addition higher K doses (150% and 125% of RDK) gave the higher REY than those of lower RDK. Soil organic matter and available K content significantly improved due to CA practice.

Introduction

Conservation agriculture (CA) is characterized by three linked principles, namely,minimal soil disturbance, permanent organic soil cover and crop rotations (Kassam et al., 2010). CA is already occurring and gathering momentum worldwide as a new paradigm for the 21st century to ensure sustainable food production and maintain environmental integrity.

Tillage, residue management and crop rotation have a significant impact on nutrient distribution in soils (Galantini et al., 2000; Etana et al., 1999). Distribution of nutrients in a soil under minimum tillage is different to that in tilled soil. Increased stratification of nutrients is generally observed, with enhanced conservation and availability of nutrients near the soil surface under minimum tillage as compared to conventional tillage (Duiker and Beegle, 2006). Minimum tillage conserves and increases availability of nutrients, such as K, near the soil surface where crop roots proliferate (Franzluebbers and Hons 1996). Tony and Janovick (2001) reported that long-term minimum tillage fields required higher amount of K application to maintain K supplying capacity in subsurface layer, because of its immobile nature which causes stratification in the surface layer. Other studies have found higher extractable K levels at the soil surface as tillage intensity decreases (Ismail et al., 1994). Du Preez et al. (2001) observed increased levels of K in zero tillage compared to conventional tillage, but this effect declined with depth.

Potassium is among the macro nutrients which are taken up by plants in large amount. It plays significant roles in transportation of water, nutrients, nitrogen utilization, and stimulation of early growth and in insect and disease resistance (Lakudzala, 2013). Potassium is also important in the transportation of prepared food from the leaves to the rest of the plant parts, quality of seeds and fruits, strengthens the roots, stem and branches of plants and reduce lodging. Potassium fertilization had shown yield improvement of crops in various areas of the world (Imran and Gurmani, 2011). Research findings in India, Bangladesh and Iran indicated that Potassium fertilizer increased grain and straw yield of wheat at various rates (Saha et al., 2010; Tabatabaei et al., 2012; Malek-Mohammadi et al., 2013).

Soil potassium (K) is an essential and limiting element for plant growth, which is significantly affected by different approaches to soil management. Apart from two major components nitrogen and phosphorous, potassium is the 3rd essential macronutrient required for the growth and metabolism of plant, and its deficiency in plants causes poorly developed roots, slow growth, low resistance to disease, delayed maturity, small seed production and lower yields. Potassium content in the plant tissue is crucial to the proper functioning of several important biochemical and physiological processes that directly determine crop productivity. There is immense scope of increasing productivity through adequate application of K (Bhattacharyya et al., 2006). Better growth and yield of wheat crop has been observed with the addition of' K (Singh et al., 2000).

On the other hand, crop residues are important and a renewable natural resource for the stability of agricultural ecosystems (Singh, 2003). Rice-wheat is the major production system covering an area of 13.5 million hectares across the Indo-Gangetic Plains (IGP) of south Asia (Ladha et al., 2003) and feeds about 1/5th of world population (Saharawat et al., 2010). In cereal-based cropping systems, huge volume of crop residues is produced and about 75% of K-uptake by cereal crops can be retained in crop residues, making them valuable nutrient sources (Singh, 2003). Traditionally, in rice-wheat or other systems of South Asia, straw is fed to cattle, burnt for fuel, or used as building material leaving little for soil incorporation. As a result, soil organic matter levels are declining in these cropping systems which can have serious implications for soil health. Standley et al. (1990) observed higher exchangeable K in the topsoil (0-2 cm) when sorghum stubble was retained than when the stubble was removed.

However, the information on effect of potassium fertilizer under conservation agriculture practices in the intensive wheat-mungbean-T. Aman cropping system is lacking. Hence, the present study has therefore, been undertaken in context of following objectives:

i. to determine the optimum rate of potassium (K) fertilizer for the intensive wheat-mungbean-T. Aman cropping system under CA practice,
ii. to evaluate the effects of K fertilizer on soil properties under CA practice and,
iii. to assess the system productivity in the aforesaid cropping system.

Materials and Methods

Description of experimental site

The experiment was conducted at RARS, Jashore during rabi season in 2019-2020 and 2020-2021.The study area was under the agro-ecological zone "High Ganges River Floodplain" (AEZ-11). Before starting the experiment, initial composite soil samples (0-15 cm depth) were collected from the experimental plots and were analyzed. The analytical result indicated that soil was sandy clay loam (Table 1) with low organic matter content (1.22%) and slightly alkaline in nature. Nitrogen content of the soil was very low whereas P, K, S, Zn and B content of the soil were low (Table 2).

Table 1. Particle size distribution, textural class and bulk density of initial soil of the experimental field, RARS, Jashore

Soil depth (cm)	Particle size distribution			Textural class	Bulk density (g cm^{-3})
	Sand%	Silt%	Clay%		
0-15	52.00	25.28	22.72	Sandy clay loam	1.40

Table 2. Initial soil nutrients status of the experimental field, RARS, Jashore

Soil depth (cm)	pH	SOM	Total N	Available other nutrients				
		(%)		K	P	S	Zn	B
				meq 100 g $soil^{-1}$	mg kg^{-1}			
0-15	7.6	1.22	0.061	0.17	16.0	17	0.54	0.17
Interpretation	Slightly alkaline	Low	Very Low	Low	Low	Low	Low	Low

Treatments and design

The unit experimental plot area was 7.2 m × 3.5 m and the design of the experiment was split-plot with three replications. Treatment consisted of two crop establishment methods, such as, T_1: conventional method (excessive tillage + residue removal) and T_2: conservation agriculture (minimum tillage + residue retention) were assigned in main plots whereas different levels of K, four K fertilizer rates were applied as K_1: 75% of recommended rate of K (RDK), K_2: 100% of RDK, K_3: 125% of RDK and K_4: 150% of RDK were allotted in sub-plots.

Land preparation, fertilizer application, sowing/transplanting and intercultural operations
At the initiation of the experiment, the plots were separated from each other according to the layout. The minimum tillage (MT) was accomplished by one pass with PTOS using rotating blades maintaining 20 cm spacing from row to row for wheat and rice whereas 40 cm for mungbean.In case of conventional tillage (CT), puddling was done with three passes with the high-speed rotary tiller followed by laddering twice for rice cultivation whereas CT was done for wheat and mungbean sowing by high-speed rotary tiller with three passes followed by two times laddering.

A blanket rate (132-20-13-2-1 kg N-P-S-Zn-B ha^{-1}) was applied for high yield goal of wheat whereas 62.0 kg MoP ha^{-1} as 100% recommended rate of potassium (RDK), 46.5 kg MoP ha^{-1} as 75% RDK, 77.5 kg MoP ha^{-1} as 125% RDK and 93.0 kg MoP ha^{-1} as 150% RDK according to STB followed by FRG-2018. The full amount of P, S, Zn, B and half of N were applied at the time of final land preparation in the forms of triple superphosphate, muriate of potash, gypsum, zinc oxide and boric acid. Remaining half urea for N was applied as top dress at 20 days after sowing (at crown root initiation stage). Potassium fertilizer was applied as per treatment specification as basal dose. For mungbean, a blanket rate (20-14-13-2-1 kg N-P-S-Zn-B ha^{-1}) was applied as basal dose. In case of T. Aman, a blanket rate (66-10-35-8-1 kg N-P-S-Zn-B ha^{-1}) was applied. All fertilizers except urea will be applied as basal dose. Urea will be applied at 3 equal splits at 7, 28 and 48 DAT. Potassium fertilizer was applied as per treatment specification as basal dose.

Varieties of the tested crops used in the experiments were BARI Mung-6 of mugbean, BRRI dhan57 of T. Aman and BARI Gom-33 of wheat. Mungbean seeds were sown on 12 April 2020; T. Aman seedlings were transplanted on 31 July 2020 whereas wheat seeds were sown on 30 November of 2020.

After that hand weeding (just uprooting the weeds by hand, therefore, no soil pulverization occurred in MT practice) was done once only at 18^{th} DAS. Three irrigations were applied at crown root initiation stage (20 DAS), tillering stage (35 and 48 DAS). Other intercultural operations and plant protection measures were taken as and when required.

Crop harvesting and data collection
Mungbean was harvested on 23 and 30 June 2020, T. Aman rice was harvested on 23 November 2020 and wheat was harvested on 25 March of 2021. Two square meter area from each plot was selected for data collection. Ten plants of each plot were selected for yield contributing data. Thousand grain weights was measured plot wise. The whole plant was cut at ground level from R^- plots whereas 30 cm of wheat straw was retained in the R^+ plots. The grain and straw was separated, sun-dried and weighed from 1.0 m^2 area of each plot. The amount of residue retained in the R^+ plots was found from 1.0 m^2 area. Finally, the grain and straw were converted into t ha^{-1}.

Statistical analysis
All the crop data and soil properties at selected depths were statistically analyzed using a split-plot design. Treatment effects on measured variables were tested by analysis of variance (ANOVA), and comparisons among treatment means were made using the least significant difference (LSD) multiple range test calculated at 5% level of probability ($P \leq 0.05$). Statistical procedures were carried out with the software program "*Statistix for Windows (1998)*".

Results and Discussion

Effects of crop establishment methodsandK fertilizer rates on yield attributes and grain and green biomass yields of mungbean (BARI Mung-6) during 2020

Crop establishment methodsandK fertilizer rates had no significant effect on the yield attributes along with seed and green biomass yields of mungbean during 2020 (Table 3).

Table 3. Effects of crop establishment methodsandK fertilizer rates on the yield attributes of mungbean during 2020

Treatments	Plant height (cm)	No. of pod plant^{-1}	No. of filled grains pod^{-1}	1000 seed weight (g)	Grain yield (t ha^{-1})	Green biomass yield (t ha^{-1})	Biomass retention (t ha^{-1})
Crop establishment methods							
Conventional method	67	17.0	10.2	44.1	1.22	10.3	0.00 b
Conservation agriculture	65	17.2	9.8	43.8	1.16	10.2	10.2 a
$LSD_{0.05}$ value	19^{ns}	8.7^{ns}	1.7^{ns}	3.4^{ns}	0.27^{ns}	1.9^{ns}	1.6**
CV (%)	9.08	8.96	9.86	4.39	12.67	10.70	7.69
K fertilizer rates							
75% of RDK	65	16.5	9.8	43.5	1.10	9.5	4.78
100% of RDK	67	17.4	10.0	43.7	1.19	10.2	5.05
125% of RDK	64	17.0	10.1	44.0	1.24	10.5	5.06
150% of RDK	68	17.5	10.2	44.6	1.24	10.8	5.52
$LSD_{0.05}$ value	7^{ns}	3.6^{ns}	0.9^{ns}	2.5^{ns}	0.2^{ns}	1.9^{ns}	0.52^{ns}
CV (%)	8.01	6.61	6.77	4.43	13.42	14.86	7.65

Effects of crop establishment methodsandK fertilizer rates on yield attributes of T. Aman rice (BRRI dhan57) during 2020

Crop establishment methods showed significant variations in panicle length and filled grains panicle^{-1} of T. Aman rice (Table 4). The longest panicle (25.2 cm) and higher number of filled grains spike^{-1} (93.7 nos.) was obtained from the conventionally crop establishment method compared to conservation agriculture practice (25.2 cm of panicle and 89.0 nos. of filled grains spike^{-1}).

On the other hand, it was found that effective tillers hill^{-1}, panicle length, number of filled grains spike^{-1} and 1000-grain wt. of T.Aman increased with increasing K rates. The longest panicle, highest number of effective tillers hill^{-1}, filled grains spike^{-1} and 1000-grain wt. of T.Aman was obtained from plots receiving 150% and 125% of RDK which were different from 75% and 100% of RDK (Table 4) .

Table 4. Effects of crop establishment methodsandK fertilizer rates on yield attributes of T. Aman

Treatments	Plant height (cm)	Effective tillers hill^{-1}	Panicle length (cm)	No. of filled grains panicle^{-1}	1000-grain wt. (gm)
Crop establishment methods					
Conventional method	101	15.0	25.2 a	93.7 a	19.5
Conservation agriculture	97	14.1	23.5 b	89.0 b	19.3
$LSD_{0.05}$ value	16^{ns}	3.1^{ns}	1.6*	3.5*	0.3^{ns}
CV (%)	9.41	11.95	3.65	6.18	3.92
K fertilizer rates					
75% of RDK	98	12.9 c	22.9 c	86.3 c	18.6 c
100% of RDK	99	14.5 b	24. b	88.8 b	19.1 b

125% of RDK	99	15.1 ab	24.9 a	94.0 a	19.8 a
150% of RDK	99	15.6 a	25.6 a	96.2 a	20.1 a
$LSD_{0.05}$ value	5^{ns}	0.94**	0.7**	2.4**	0.4**
CV (%)	8.33	5.13	4.39	7.43	4.75

Effect of crop establishment methodsand K fertilizer rates on grain- straw yield, harvest index and amount of residue retained of T. Aman rice

Crop establishment methodsandK fertilizer rates showed significant variations on the grain and straw yield of T. Aman during 2020 (Table 5). Higher grain (4.79 t ha^{-1}) and straw yield (5.47 t ha^{-1}) was obtained from the conventionally crop establishment method compared to conservation agriculture practice (4.42 t ha^{-1} of grain and straw).

On the other hand, it was found that the K fertilizer rate showed that grain and straw yield of T. Amanincreased with increasing K rates. The highest grain and straw of T. Aman was obtained from plots receiving 150% of RDK which were different from all other K doses (Table 5).

Under the conservation agriculture practice, 2.24 t ha^{-1} residue of T. Aman was retained on the soil over conventional practice (Table 5).

Table 5. Effects of crop establishment methodsand K fertilizer rates on grain and straw yields with harvest index and amount of retained residue of T. Aman

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Residue retained (t ha^{-1})
Crop establishment methods				
Conventional method	4.79 a	5.47 a	46.7	0.00 b
Conservation agriculture	4.42 b	4.42 b	49.9	2.24 a
$LSD_{0.05}$ value	0.10**	0.97*	3.9^{ns}	0.31**
CV (%)	8.20	11.14	4.56	15.76
K fertilizer rates				
75% of RDK	4.00 c	4.44 d	47.3	0.99
100% of RDK	4.56 b	4.72 c	49.2	1.00
125% of RDK	4.74 b	5.15 b	48.2	1.19
150% of RDK	5.11 a	5.56 a	48.5	1.28
$LSD_{0.05}$ value	0.37**	0.29**	2.1^{ns}	0.27^{ns}
CV (%)	6.40	3.91	3.46	8.88

Effect of crop establishment methods and K fertilizer rates on weed biomass in wheat field

Total weed biomass was significantly higher under minimum tillage compared to conventional tillage at the beginning of the cropping season in the wheat field. Higher weed biomass was observed in strip tilled plots (54 g m^{-2}) over conventional tilled plots (36 g m^{-2}), shown in Table 6. Ozpinar (2006) and Nakamoto*et al*. (2006) found a maximum weed population under the reduced tillage system. In contrast, different potassium rates had not any remarkable effect on weed infestation.

Table 6. Effect of crop establishment methods and K fertilizer rates on weed biomass of wheat

Treatments	Weed biomass (g m^{-2})
Crop establishment methods	
Conventional method	36 b
Conservation agriculture	54 a
$LSD_{0.05}$ value	14*
CV (%)	17.31
K fertilizer rates	
75% of RDK	44
100% of RDK	46

125% of RDK	44
150% of RDK	46
$LSD_{0.05}$ value	9^{ns}
CV (%)	15.55

Plant height, spike length, number of spikes m^{-2}, spikelets $spike^{-1}$, filled grains $spike^{-1}$ and 1000-grain weight (g) of wheat during 2020-2021

Data presented in Table 7 exhibited that the K fertilizer rate showed that spike length, number of spikelets $spike^{-1}$ and number of filled grains $spike^{-1}$ of wheat increased with increasing K rates. The longest spike, highest number of spikelets and filled grains $spike^{-1}$ was obtained from plots receiving 150% and 125% of RDK. In agreement with this result, highest K rate had significantly longest spike, highest number of spikelets and filled grains $spike^{-1}$ as compared to less K dose (Maurya et al., 2014).

However, all the yield attributes of wheat gave insignificant variation due to crop establishment methods (Table 7).

Table 7. Effect of crop establishment methods and K fertilizer rates on yield attributes of wheat

Treatments	Plant height (cm)	No. of spikes m^{-2}	Spike length (cm)	No. of spikelets $spike^{-1}$	No. of filled grains $spike^{-1}$	1000-grain weight (g)
Crop establishment methods						
Conventional method	100	428	13.5	16.1	48.9	43.6
Conservation agriculture	99	422	12.7	15.9	47.0	43.4
$LSD_{0.05}$ value	6^{ns}	39^{ns}	1.5^{ns}	0.5^{ns}	3.8^{ns}	3.0^{ns}
CV (%)	9.31	5.28	6.36	4.68	4.52	3.96
K fertilizer rates						
75% of RDK	99	426	12.0 c	15.1 c	45.9 c	42.6
100% of RDK	99	419	12.8 b	15.9 b	46.7 bc	43.3
125% of RDK	100	420	13.5 ab	16.5 a	48.5 b	43.9
150% of RDK	100	437	14.1 a	16.7 a	50.8 a	44.0
$LSD_{0.05}$ value	3^{ns}	29^{ns}	0.8**	0.5**	2.3**	1.2^{ns}
CV (%)	8.69	5.50	5.00	5.54	3.78	2.12

Root weight, grain yield, straw yield and harvest index of wheat

Root weight of wheat was significantly influenced by different K rates but not by tillage practices. Root weight of wheat was increased with the increased of K rates and 150% of RDK produced the highest root (3.53 g $plant^{-1}$) followed by 125% of RDK (3.45 g $plant^{-1}$), 100% of RDK (3.38 g $plant^{-1}$) and the lowest root produced by 75% of RDK (3.32 g $plant^{-1}$), as shown in Table 8.

The grain and straw yield of wheat was significantly influenced by various potassium rates (Table 8). Grain and straw yields of wheat increased with the increasing of Kfertilizer rates in the study site.Significantly the highest grain yield (4.57 t ha^{-1}) of wheat gained from plots receiving 150% of RDK which was statistical identical with 125% of RDK ((4.42 t ha^{-1}) and differed from 100% of RDK (4.10 t ha^{-1}) and 75% of RDK (3.75 t ha^{-1}). The significant grain yield obtained in this experiment with K application rate agrees with the research findings (Alam et al., 2009; Tabatabaei et al., 2012; Tahir et al., 2008; Wassie et al., 2013). Similarly, the 150, 125 and 100% of RDK gave the superior straw yield to 75% of RDK.

On the other hand, harvest index was the non-significant. This result agreed with the research findings that potassium effect on harvest index was not significant indicating approximately equal positive effects of potassium on grain and biological yield (Zare et al., 2013).

The amount of wheat residue retained by weight significantly varied due to crop establishment methods. In conservation agriculture method, 2.92 t ha^{-1} of residue was retained on the soil, as presented in Table 8.

Table 8. Effect of crop establishment methods and K fertilizer rates on grain and straw yields with harvest index of wheat

Treatments	Dry root weight (g plant^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Residue retained (t ha^{-1})
Crop establishment methods					
Conventional method	3.41	4.14	4.71	46.9	0.00 b
Conservation agriculture	3.43	4.07	4.54	47.1	2.92 a
$LSD_{0.05}$ value	0.09^{ns}	1.0^{ns}	0.30^{ns}	5.3^{ns}	0.56**
CV (%)	4.43	10.41	8.70	6.16	21.73
K fertilizer rates					
75% of RDK	3.32 c	3.65 c	4.12 b	46.9	1.37
100% of RDK	3.38 bc	3.99 b	4.68 a	46.0	1.52
125% of RDK	3.45 b	4.32 a	4.78 a	47.5	1.48
150% of RDK	3.53 a	4.47 a	4.92 a	47.7	1.47
$LSD_{0.05}$ value	0.08^{**}	0.23**	0.28*	1.6^{ns}	0.28^{ns}
CV (%)	3.85	8.50	8.81	5.66	15.14

Effect of crop establishment methods and K fertilizer rates on soil water content during the wheat growing season

Soil water was measured at the wheat sowing, at 20, 50,80 and at the harvesting time. Initially available soil water content was 24.5%. Available soil water content was varied due to crop establishment methods but not by different K fertilizer rates (Table 9). Higher available soil water content was recorded in MT (24.4, 19.5 & 18.2%) than CT practice (22.2, 17.8 & 16.5%) at 20, 50 and 80 DAS, respectively.

Table 9. Effects of tillage and K fertilizer rates on soil water content (%) in wheat field during 2020-2021

Treatment	At 20 DAS (20 Dec. 2020)	At 50 DAS (19 Jan. 2021)	At 80 DAS (18 Feb. 2021)	At harvest (24 March 2021)
Crop establishment methods				
Conventional method	22.2 b	17.8 b	16.5 b	16.1
Conservation agriculture	24.4 a	19.5 a	18.2 a	16.5
$LSD_{0.05}$ value	0.96*	1.4**	1.4**	0.12^{ns}
CV (%)	5.33	4.34	4.67	4.43
K fertilizer rates				
75% of RDK	22.7	17.8	16.5	16.2
100% of RDK	23.3	18.4	17.1	16.3
125% of RDK	23.4	19.4	17.7	16.3
150% of RDK	23.8	19.0	18.1	16.4
$LSD_{0.05}$ value	1.4^{ns}	1.6^{ns}	1.6^{ns}	0.7^{ns}
CV (%)	4.72	6.79	7.30	3.51
Initial soil water	25.0%			

Effects of crop establishment methods and K doses on rice equivalent yield

To compare between the treatments, wheat and mungbean were converted into rice equivalent yield (REY) on the basis of prevailing market price of individual crop. Crop establishment methods showed insignificant variations in REY. Higher K doses gave the higher REY than those of lower RDK, shown in Table 10.

Table 10. Effect of crop establishment methods and K fertilizer rates on rice equivalent yield

Treatments	REY (t ha^{-1} $year^{-1}$)
Crop establishment methods	
Conventional method	12.7
Conservation agriculture	12.1
$LSD_{0.05}$ value	0.7^{ns}
CV (%)	3.22
K fertilizer rates	
75% of RDK	11.0 c
100% of RDK	12.4 b
125% of RDK	12.8 ab
150% of RDK	13.4 a
$LSD_{0.05}$ value	0.8**
CV (%)	5.04

Note: Market price of rice was Tk. 28.00 kg^{-1}, wheat was Tk. 30.00 kg^{-1}&mungbean was Tk. 80.00

Effects of crop establishment methodsand K fertilizer rates on soil properties

After 4^{th} crop harvest, soil organic matter and available K content significantly varied due to crop establishment methods. Higher amount of OM and K were obtained from CA practice than those of conventional practice. Similarly, available K in soil increased with the increasing of K fertilizer application, presented in Table 11. The present study found SOM and available K content improving which can be attributed to combined use of minimum tillage with residue retention (Alam, 2018).
Verma and Pandey (2013) found that crop residue retention significantly influenced the SOM content in a rice-wheat sequence. Higher available nitrogen and potassium content with application of rice residues could be attributed to addition of crop residue. Sardana*et al.* (2005) also stated that minimum tillage with residue retention substantially enhanced SOM.

Table 11. Effects of crop establishment methodsandK fertilizer rates on soil properties after 4^{th} crop harvest

Treatments	OM	TN	Available other nutrients				
	%		K	P	S	Zn	B
			(meq 100 g $soil^{-1}$)	(µg ml^{-1})			
Crop establishment methods							
Conventional method	1.20 b	0.064	0.17 b	16.3	16.6	0.51	0.19
Conservation agriculture	1.27 a	0.066	0.22 a	17.3	17.4	0.60	0.20
$LSD_{0.05}$ value	0.08*	0.006^{ns}	0.02*	5.2^{ns}	1.3^{ns}	0.15^{ns}	0.08^{ns}
CV (%)	3.03	5.18	6.27	7.65	4.30	5.30	12.20
K fertilizer rates							
75% of RDK	1.20	0.063	0.18 c	15.8	16.6	0.53	0.18
100% of RDK	1.22	0.064	0.19 c	16.7	16.9	0.55	0.19
125% of RDK	1.24	0.067	0.20 b	16.9	17.2	0.57	0.20
150% of RDK	1.29	0.067	0.21 a	17.8	17.4	0.58	0.21
$LSD_{0.05}$ value	1.0^{ns}	0.006^{ns}	0.009**	1.6^{ns}	0.9^{ns}	0.05^{ns}	0.04^{ns}
CV (%)	5.34	7.15	3.62	7.39	5.94	7.19	6.02

Conclusions

A field experiment was done to determine the optimum rate of potassium under conservation agriculture practice. Results from the experiment showed that longest spike, highest number of spikelets and filled grains spike^{-1} of wheat significantly increased with the increased rates of K fertilizer. Consequently, significantly the highest grain yield of wheat gained from plots receiving 150% and 125% of RDK which was differed from 100% and 75% of RDK. On the other hand, higher grain yield (4.79 t ha^{-1}) of T. Aman was obtained from the conventionally puddlingplots compared to CA practice (4.42 t ha^{-1}). Similarly, the highest grain yield (5.11 t ha^{-1}) of T. Amanwas obtained from plots receiving 150% of RDK which were different from other K rates. There was no variation in mungbean performance due to crop establishment methods and K fertilizer rate. In addition, higher K doses (150% and 125% of RDK) gave the higher REY than those of lower RDK. Soil organic matter and available K content significantly improved due to CA practice. However, the present study should be continued up to five years (medium term level) to explore real benefits of tillage practices and residue management together with K fertilizer application for maximizing the yield of the pattern and sustaining the soil health.

Acknowledgement

The authors would like to give thank RARS, Jessore, Bangladesh Agricultural Research Institute (BARI), Bangladesh authority for its budgetary help and respected scientists and staffs for direction and logistic supoortand soil science division for sample analysis in this study.

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NUTRIENT MANAGEMENT FOR SUSTAINING SOIL FERTILITY AND YIELD OF WHEAT-MUNGBEAN-T.AMAN CROPPING PATTERN

M M MASUD, NU MAHMUD, N SALAHIN, R SEN AND HM NASER

Abstract

A long term field experiment on Wheat-Mungbean-T.aman cropping pattern has been carried out in High Ganges Floodplain Soils (AEZ-11) of RARS, Jashore from 2000-2021. The objectives were to find out sustainable fertilizer recommendations, monitor soil health, estimate uptake of different nutrient for the cropping pattern and to make a balance sheet for each of the nutrient. There were six treatments viz. 125% recommended dose (RD), 100% RD, 75% RD, 50% RD, farmers' practice and native nutrient. The design was RCB with three replications. Results showed consistently highest yield from each of the crops of the pattern obtained with 125% RD treatment and which were statistically similar to 100% RD treatment. Highest total rice (system) yield of 13.21 t $ha^{-1}yr^{-1}$ was obtained from T_1 treatment (125% RD). Lowest total rice (system) yield of 7.00 t $ha^{-1}yr^{-1}$ was obtained from control i.e. native fertility treatment (T_6). Highest gross margin of 123309 Tk. ha^{-1} yr^{-1} was also obtained from T_1 treatment (125% RD). The highest benefit cost ratio of 1.88 was found in T_1 (125% RD) treatment.

Introduction

Fertile soil is the most important natural resource of a country. But it is being exhausted with the increase of cropping intensity, introducing high yielding varieties along with modern technologies. As a result, soil resources are going to be depleted many essential elements day by day. Mono crop based fertilizer recommendations are proving to be costly to the poor farmers. On the other hand, rich farmers are using high dose of chemical fertilizer especially urea for some crops which creates imbalance in soil nutrients.

The nutrients added to the soil in the form of fertilizers are not being removed or utilized by the crops in one season. Some amounts are left over in the field. So, proper fertilizer management is very important considering the residual effect of the nutrients. Moreover, inclusion of a pulse crop in the cropping pattern would reduce the requirement of chemical fertilizers in the next crop maintaining a good health of soils through biological nitrogen fixing and addition of organic matter to soil.

For this reason, a fertilizer management experiment was designed to be carried out at RARS, Jashore on long term basis under the cropping pattern: Wheat-Mungbean-T.aman.The main objectives of this experiment are: i) to find out sustainable fertilizers recommendations for wheat-mungbean-T.aman cropping pattern, ii) to monitor soil health after each cropping pattern and iii) to estimate uptake of different nutrients and to make a balance sheet for each nutrient.

Materials and Methods

This field trial has been conducted in High Ganges Floodplain Soils (AEZ-11) of RARS, Jashore from the period of 2000-2021. A description of nutrient status of initial soils prior to fertilization is presented in Table 1.

Table 1. Analytical data of the experimental soils (Initial soil) during 2000 at RARS, Jashore

Location	pH	OM	Ca	Mg	K	Total	P	S	B	Cu	Fe	Mn	Zn
		(%)	meq $100g^{-1}$			N (%)	µg g^{-1}						
RARS, Jashore	7.4	1.5	13	2.3	0.22	0.08	16	16	0.3	1.9	29	7	1.8
Critical level	-	-	2	0.8	0.20	-	14	14	0.2	1.0	10	5	2.0

The experiment was laid out in a RCB design with six treatments replicated three times. The unit plot size was 5m × 6m. The treatment combinations were T_1=125% of recommended dose (RD) (RD =120-35-75-20-5 kg of N P K S Zn ha^{-1}), T_2=100% of RD, T_3=75% of RD, T_4=50% of RD, T_5=Farmers' practice and T_6=Native nutrient. The farmers' practice treatment was 60-40-30 kg ha^{-1} of

NPK respectively. The tested wheat variety was BARI Gom-33. All PKSZn and $^{2}/_{3}$rd of N were applied at the time of final land preparation and the remaining $^{1}/_{3}$rd of N was applied after first irrigation (17-21 DAS). The seeds were sown in 4th week of November and were harvested in 2nd week of March. Only nitrogen was applied @ 20 kg N ha^{-1} in all the plots except the native nutrient treatment for the second crop mungbean (Var. BARI Mung-6). The seeds were sown in the 2nd week of March and first picking was on the2nd week of May and continued up to 1st week of June. Then the total biomass was incorporated in the soil.

The same sequence was maintained in T.aman (BRRIdhan33) for fertilizer treatments. The seedlings were transplanted in the 1st week of August and harvested in the 1st week of November. Records on some yield parameters were taken at certain growth stages of all the crops of the pattern. Data were analyzed by ANOVA (using Statistics 10) to evaluate differences between treatments, and the means were separated using least significant difference (LSD) at the 5% level of significance ($p<0.05$).

Results and Discussion

The data of grain and straw yield of wheat, mungbean and T.Aman as influenced by different treatments have been presented in Fig. 1 to 6.

Wheat

In all the years, statistically identical grain yields were obtained by the 100% RD and 125% RD treatments. The combined effect of 125% RD produced 3.66 t ha^{-1} (average of 16 years) as compared to 3.44 t ha^{-1} (average of 16 years) in the 100% RD treatment. Higher grain and straw yields of 3.66 and 5.03 t ha^{-1} (average of 16 years) were obtained in 125% RD treatment as compared to 1.14 and 1.89 t ha^{-1}, respectively, in the native nutrient treatment (Fig. 1 and Fig. 2).

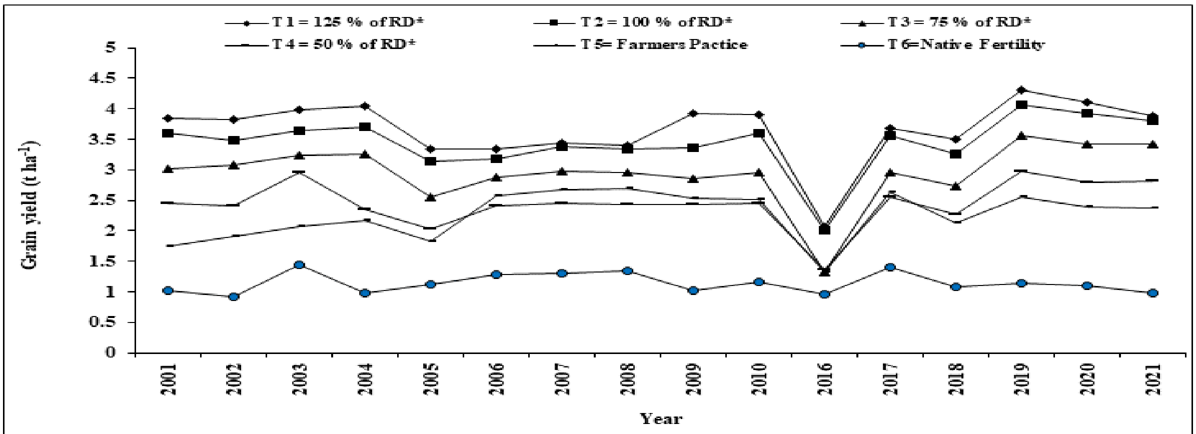

Fig. 1. Grain yield of wehat as influenced by different treatments

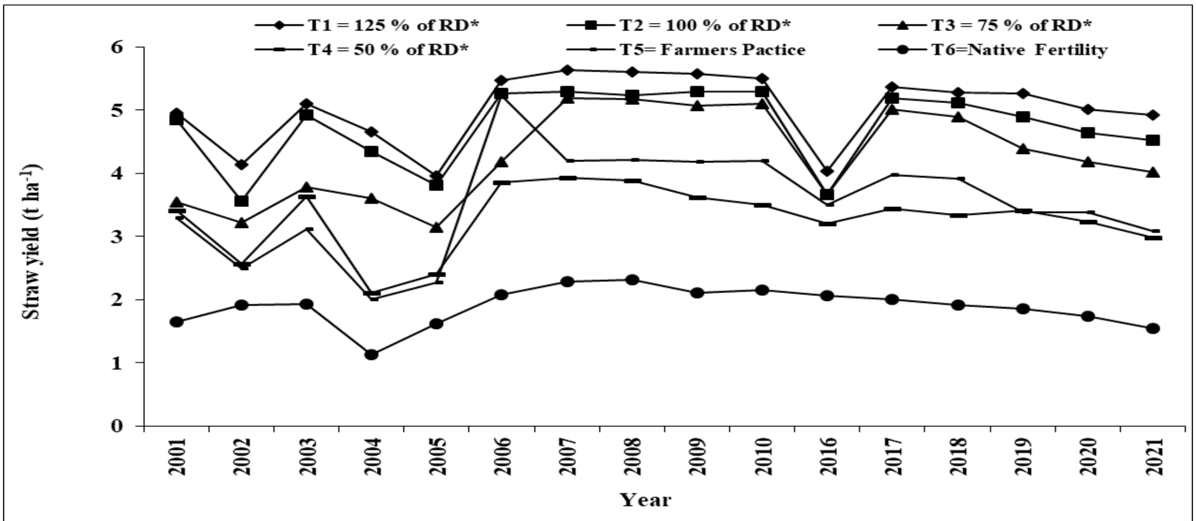

Fig. 2. Straw yield of wehat as influenced by different treatments

Mungbean

In each year, highest grain and biomass yield were obtained from 125%RD treatment followed by 100% RD, 75% RD and 50% RD. The lowest grain and biomass yield were obtained from T_6 native nutrient treatment. The highest grain yield and green biomass of 1.02 and 7.42 t ha^{-1} (average of 16 years) were obtained in 125% RD treatment as compared to 0.75 and 5.99 t ha^{-1}, respectively, in the native nutrient treatment (Fig. 3 and Fig. 4).

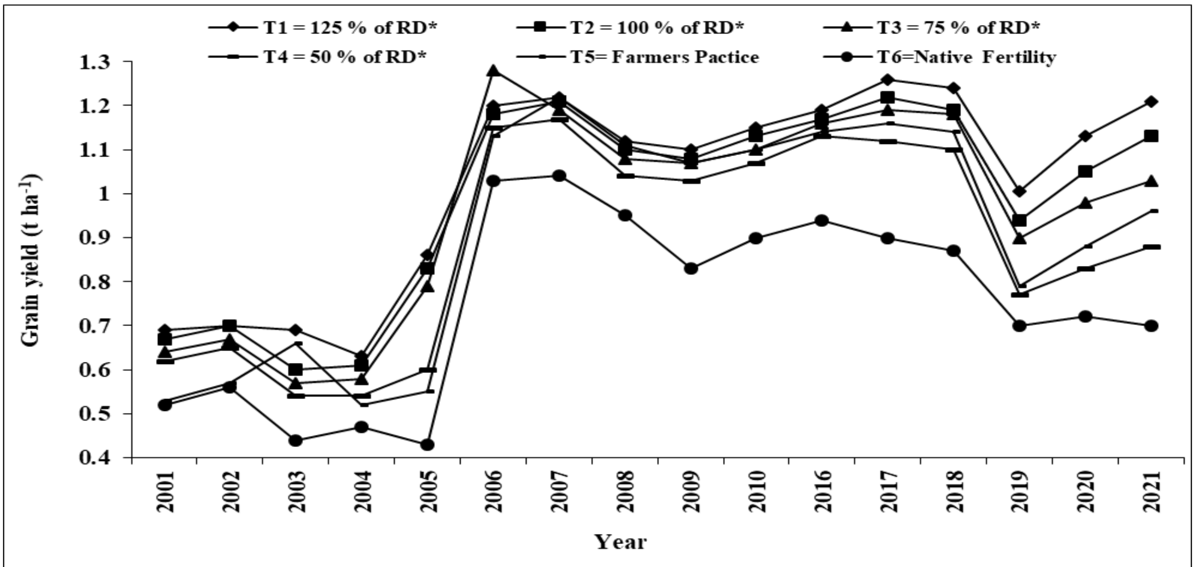

Fig. 3. Grain yield of mungbean as influenced by different treatments

* 20 kg N ha^{-1} was applied in all treatments except native fertility treatment (T_6)

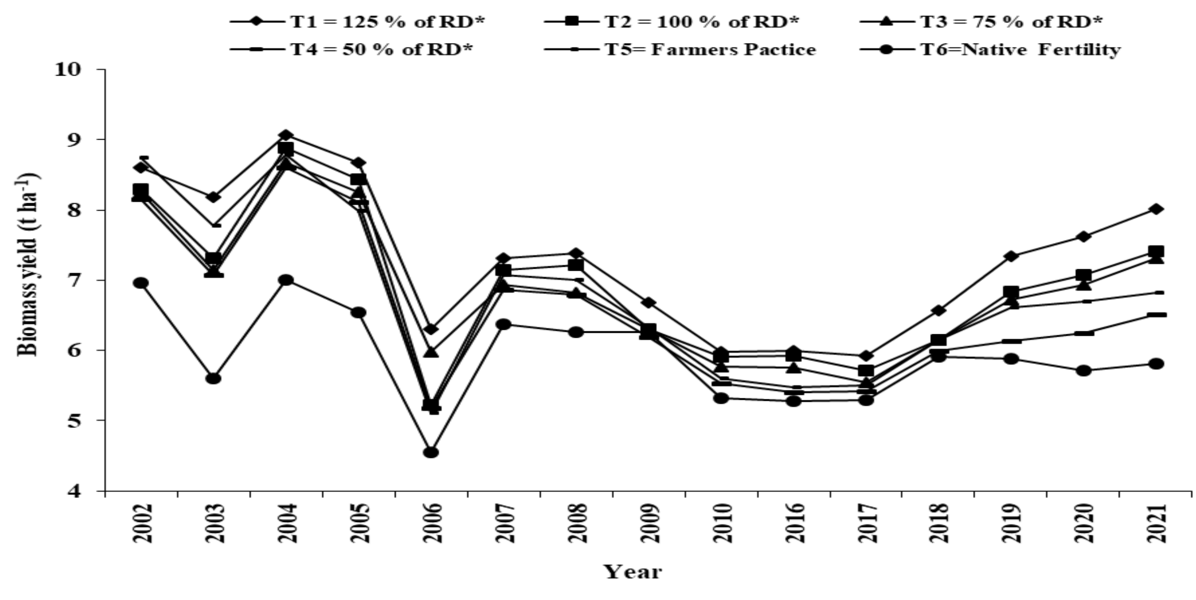

Fig. 4. Biomass of mungbean as influenced by different treatments

***** 20 kg N ha^{-1} was applied in all treatments except native fertility treatment (T_6)

T.Aman

In all the years, statistically identical grain yields were obtained by the T_1 (125% RD) and T_2 (100% RD) treatments. Grain and straw yield of the native nutrient treatment were always lower than any other treatment in each year (Fig. 5 and 6). The highest grain and straw yields of 4.53 and 5.24 t ha^{-1} (average of 16 years) were obtained in 125% RD treatment as compared to 2.58 and 3.63 t ha^{-1}, respectively, in the native nutrient treatment.

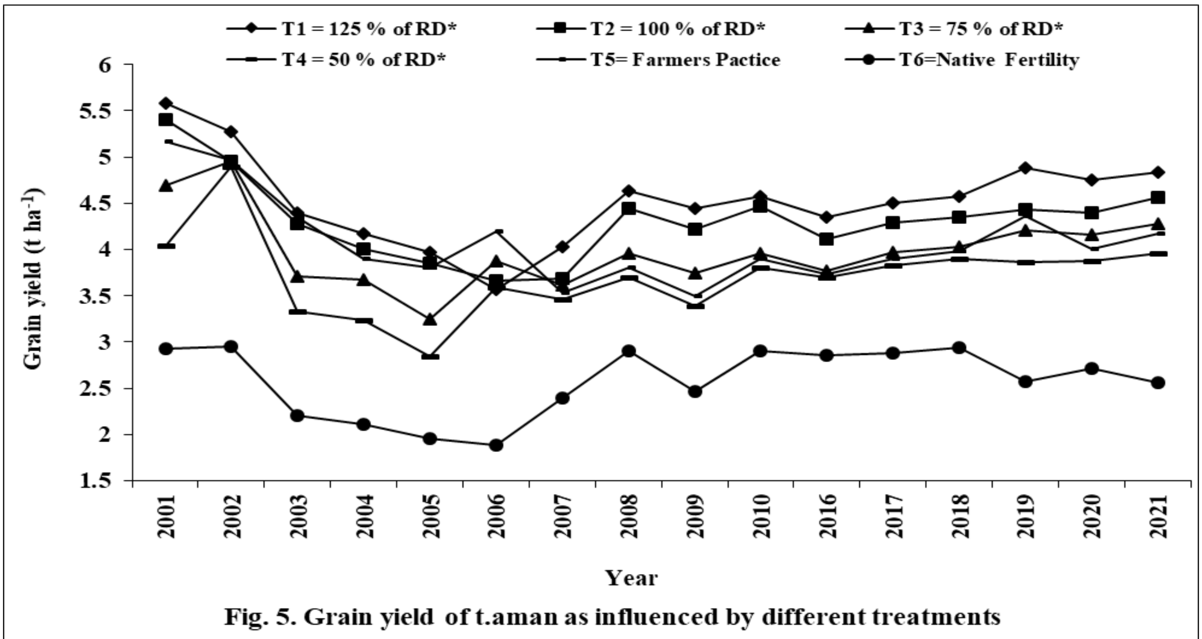

Fig. 5. Grain yield of t.aman as influenced by different treatments

*RD = 100-40-60 kg of N P K ha^{-1}, FP = 60-40-30 kg of N P K ha^{-1}

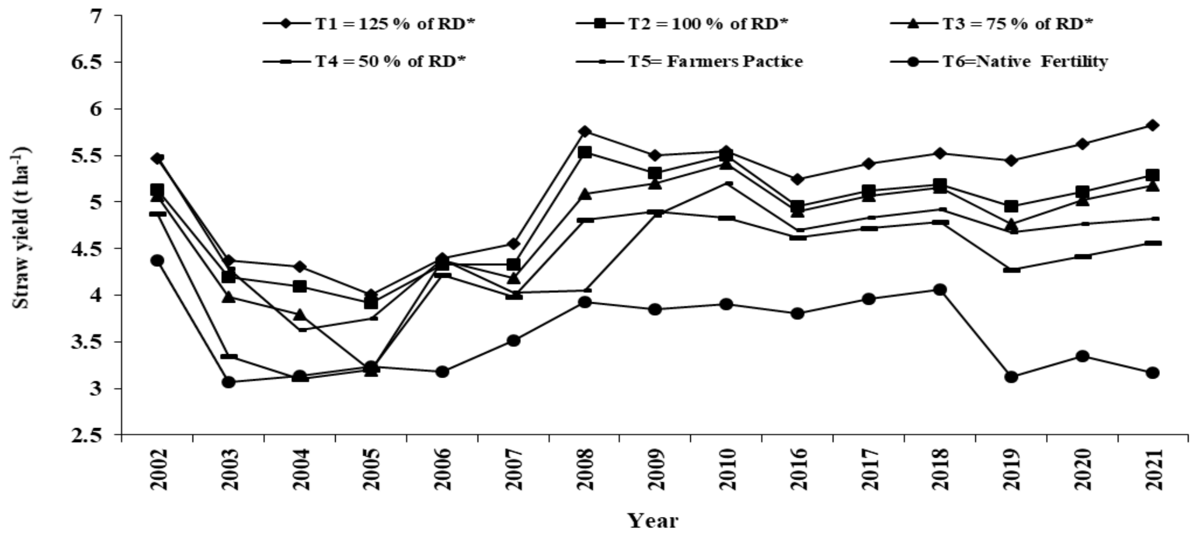

Fig. 6. Straw yield of T.aman as influenced by different treatments

*RD = 100-40-60 kg of N P K ha^{-1}, FP = 60-40-30 kg of N P K ha^{-1}

Total rice (system) yield

Total rice (system) yield as influenced by different treatments has been presented in Table 2. The highest total rice (system) yield of 13.21 t ha^{-1}yr^{-1} was obtained from T_1 treatment (125% RD). The lowest total rice (system) yield of 7.00 t ha^{-1}yr^{-1} was obtained from control i.e. native fertility treatment (T_6).

Table 2. Average yield, rice equivalent yield and total rice (system) yield (t ha^{-1}yr^{-1}) of wheat-mungbean-T.Amancropping pattern at RARS, Jashore in 2021-2021

Treatment	Average yield of crops in the pattern			Rice equivalent yield of crops in the pattern		Total rice (system) yield
	Wheat	Mungbean	T. Aman	Wheat	Mungbean	
T_1 (125% RD)	3.66	1.02	4.53	4.57	4.10	13.21
T_2 (100% RD)	3.44	0.99	4.32	4.30	3.95	12.57
T_3 (75% RD)	2.95	0.96	3.99	3.68	3.85	11.53
T_4 (50% RD)	2.44	0.89	3.71	3.05	3.56	10.33
T_5 (Farmers Practice)	2.26	0.91	4.08	2.82	3.63	10.54
T_6(Native Fertility)	1.14	0.75	2.58	1.42	3.00	7.00

Price: 1 kg wheat = Tk. 25, 1 kgmungbean = Tk. 80, 1 kg rice = Tk. 20

Cost and return analysis

The benefit cost analysis of wheat-mungbean-T.Aman cropping pattern has been given in Table 3. Highest gross return of 2,64,152Tk. ha^{-1}yr^{-1} was obtained from T_1 treatment (125% RD) with a total variable cost 1,40,843 Tk^{-1}ha^{-1}yr^{-1}. Highest gross margin of 1,23,309Tk. ha^{-1}yr^{-1} was also obtained from T_1 treatment (125% RD). The highest benefit cost ratio of 1.88 was found in T_1 (125% RD).

Table 3. Gross return, total variable cost, gross margin and BCR of Wheat-Mungbean-T.Aman cropping pattern at Jashore (Average of 16 years)

Treatment	Total rice (system) yield	Gross return	Total variable cost	Gross margin	BCR
		(Tk. ha^{-1}yr^{-1})			
T_1	13.21	264152	140843	123309	1.88
T_2	12.57	251377	134814	116563	1.86
T_3	11.53	230531	138784	91747	1.66
T_4	10.33	206556	122755	83801	1.68
T_5	10.54	210734	126270	84464	1.67
T_6	7.00	139978	110000	29978	1.27

Soil fertility status

Perceptible changes in soil chemical properties occurred through the use of chemical fertilizer and incorporation of mungbean biomass between two cereal crops (Table 4). The pH of the soil reached near neutrality ranging from 7.2 to 7.5 after fiftteen years. The organic matter content of the soil increased due to biomass addition of the leguminous crop. Phosphorus and Zn balance was found positive and this was observed in the soil test value. The balance between K application and K uptake as well as S application and S uptake were negative and the changes in the soil test values showed also less than that of initial values.

Table 4. Soil fertility status after sixteencropping cycles of wheat-mungbean-T.amanat RARS, Jashore in 2020-2021

Soil status	Treat ment	Soil texture	pH	OM	Total N	P	K	S	Zn
				%		$\mu g\ g^{-1}$	meq 100 g^{-1}	$\mu g\ g^{-1}$	
Initial	All	Silty loam	7.5	1.60	0.084	17	0.23	16	1.7
Final	T_1	Silty loam	7.2	1.80	0.094	24	0.19	14	2.0
	T_2	Silty loam	7.2	1.77	0.092	24	0.16	13	1.9
	T_3	Silty loam	7.3	1.73	0.090	23	0.15	13	1.9
	T_4	Silty loam	7.3	1.69	0.087	21	0.12	13	1.8
	T_5	Silty loam	7.2	1.69	0.089	23	0.15	12	1.5
	T_6	Silty loam	7.5	1.44	0.075	13	0.13	12	1.5

Conclusion

125% and 100% recommended dose of chemical fertilizer produced identical yield and BCR of Wheat-Mungbean-T.Aman cropping patternin High Ganges Floodplain Soils (AEZ-11). This fertilizer combination sustained the total rice (system) productivity over the years. The average soil fertility status was mostly unchanged, somewhere it was increased. Potassium and sulphur showed negative balance;therefore, more potassium and sulphur are to be added (to improve soil status). So, through this practice the soil nutritional status may be sustained.

NUTRIENT MANAGEMENT FOR SUSTAINING SOIL FERTILITY AND YIELD OF MUSTARD-MUNGBEAN-T.AMAN CROPPINGPATTERN

M M MASUD, NU MAHMUD, N SALAHIN, R SEN AND HM NASER

Abstract

A long term field trial on Mustard-Mungbean-T.Aman cropping pattern has been conducted from 2000-2021 in High Ganges Floodplain Soils (AEZ-11) of Jashore. The objectives were to find out sustainable fertilizer doses for the pattern, monitor soil health, estimate uptake of different nutrients and make a balance sheet for each of the nutrient. There were three levels each of N (80, 120 and 160 kg ha^{-1}), P (18, 36 and 54 kg ha^{-1}) and K (35, 70 and 105 kg ha^{-1}) in the treatment combinations. The design was RCB with three replications. The combined effect of 120-54-70-40-3-1 kg ha^{-1} of NPKSZnB (T_5) produced the highest seed yield (1.53 t ha^{-1}) of mustard. The residual effect of 120-54-70-40-3-1 kg ha^{-1} of NPKSZnB (T_5) gave the highest yield of both grain and straw yield of mungbean and T.aman rice. Highest total rice (system) yield of 14.85 t $ha^{-1}yr^{-1}$ was obtained from T_5 treatment. The lowest total rice (system) yield of 8.58 t $ha^{-1}yr^{-1}$ was obtained from control i.e. native fertility treatment (T_8). The highest gross margin of 1,36,37Tk$ha^{-1}yr^{-1}$ and BCR of 1.85 obtained from T_5 treatment.It was observed that a total amount of 1346, 285, 1242, 211 and 11 kg ha^{-1} of NPKS and Zn were removed from the soil by sixteen cropping cycles while 1300, 540, 700, 250, and 15 kg ha^{-1} of NPKS and Zn were added in the soil as nutrients. N and K removal were found to be higher than the amount added. About 129, 71 and 7 kg ha^{-1} of P, S and Zn were added in soil system when about 90 t ha^{-1} of green biomass of mungbean from sixteen cropping cycles were ploughed down after grain harvest.

Introduction

There are a number of cropping patterns in Bangladesh. The patterns are mainly rice based and vary on agro-ecological conditions and availability of irrigation facility. The mustard-mungbean-T.Aman is one of the dominant cropping pattern in High Ganges Floodplain Soil (AEZ-11) of Bangladesh. Soil fertility is a major determinant for the success and failure of a crop production system. Long term soil fertility monitoring under a specific cropping system would be of great help in determining a better soil fertility management program for sustained productivity at high level.

On the other hand, the management practices in a crop of a cropping pattern greatly influence the other crop of the same pattern. Puddling of rice soil creates a plough pan and results in poor soil structure. This in turn, causes water logging, poor root growth and poor availability of nutrients for the next upland crop like mustard. So, this suggests that in a cropping system, sustainability of soil fertility may decline in the long run.

In an intensive fertilizer use program, due consideration must be paid to the residual and cumulative effects of the plant nutrients applied to the preceding crops. Yield should not be limited by a nutrient deficiency or imbalance. Soil nutrient levels should be built to an optimum level and maintained. This study was designed to determine optimum fertilizer doses and nutrient balance using nutrient management approach.

Materials and Methods

This field trial was conducted in High Ganges Floodplain Soils (AEZ-11) of Jashore during the period of 2000-2021 to estimate the contribution and efficiency of individual nutrients and to find out mustard-mungbean-T.Aman cropping pattern based fertilizer recommendation. A description of nutrient status of initial soil prior to fertilization is presented in Table 1.

Table 1. Analytical data of the experimental soils

Soil depth (cm)	pH	OM	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
		(%)	meq $100g^{-1}$			(%)	μg g^{-1}						
0-15	7.6	1.45	13	2.2	0.2	0.07	16	14	0.25	1.9	27	9	1.6
Critical level	-	-	2	0.8	0.2	-	14	14	0.2	1.0	10	5	2.0

The experiment was laid out in RCB design with eight treatments replicated three times. The unit plot size was 5m × 4m. There were three levels each of N (80, 120 and 160 kg ha^{-1}), P (18, 36 and

54 kg ha^{-1}) and K (35, 70 and 105 kg ha^{-1}) in the treatment combinations. BARI Sarisha-14 was used for the study and 40 kg S, 3 kg Zn and 1 kg B ha^{-1} were applied as a blanket dose in all the treatment except the absolute control treatment. All PKSZnB and half of N were applied at the time of final land preparation and the remaining N was applied before flowering stage. The seeds were sown in the 3rd week of November. Only nitrogen was applied at the rate of 20 kg N ha^{-1} in all the plots except the control treatment for the second crop mungbean (Var. BARI Mung-6). The seeds were sown in the 1st week of March and picking was started in the 2nd week of May and continued up to the 1st week of June. After the harvest, the total biomass was ploughed down in the soil.

The fertilizer was applied in T.Aman (BRRI dhan33) according to the schedule.The seedlings were transplanted on 1st week of August and harvested in the last week of October. Records on some yield parameters were taken at certain growth stages of all the crops of the pattern. Data were analyzed by ANOVA (using Statistics 10) to evaluate differences between treatments, and the means were separated using least significant difference (LSD) at the 5% level of significance ($p<0.05$). The treatment combinations for mustard and T. aman were as follows:

Treatment	Treatment for mustard						Treatment for T.Aman			
	N	P	K	S	Zn	B	N	P	K	S
	kg ha^{-1}						kg ha^{-1}			
T_1	80	36	70	40	3	1	80	36	70	10
T_2	120	36	70	40	3	1	120	36	70	10
T_3	160	36	70	40	3	1	160	36	70	10
T_4	120	18	70	40	3	1	120	18	70	10
T_5	120	54	70	40	3	1	120	54	70	10
T_6	120	36	35	40	3	1	120	36	35	10
T_7	120	36	105	40	3	1	120	36	105	10
T_8	0	0	0	0	0	0	0	0	0	0

Results and Discussion

Mustard

Yield increase of mustard seed and straw due to different treatment combinations over the native nutrient treatment in different years have been shown in Fig. 1 and Fig. 2. With the increasing rate of nitrogen application up to 120 kg N ha^{-1}, there was a significant effect in increasing seed yield. Beyond this, higher application rate had some detrimental effect. The seed yield also increased progressively and significantly with the increased rate of P application. The calcareous soil being deficient in available phosphorus showed positive effect in increasing seed yield due to higher rate of P application. Application of 35 kg K ha^{-1} was enough to produce significant seed yield. Higher K addition had beneficial effect. The available K in the soil was above the critical level. So a maintenance dose of potassium was sufficient for higher yield. The combined effect of $N_{120}P_{54}K_{70}S_{40}Zn_3B_1$kg ha^{-1} ($T_5$) produced the highest (average of 16 years) seed and straw yield of 1.53 and 3.71 t ha^{-1} as compared to 0.51 and 1.48 t ha^{-1}, respectively, in the native nutrient treatment (T_8).

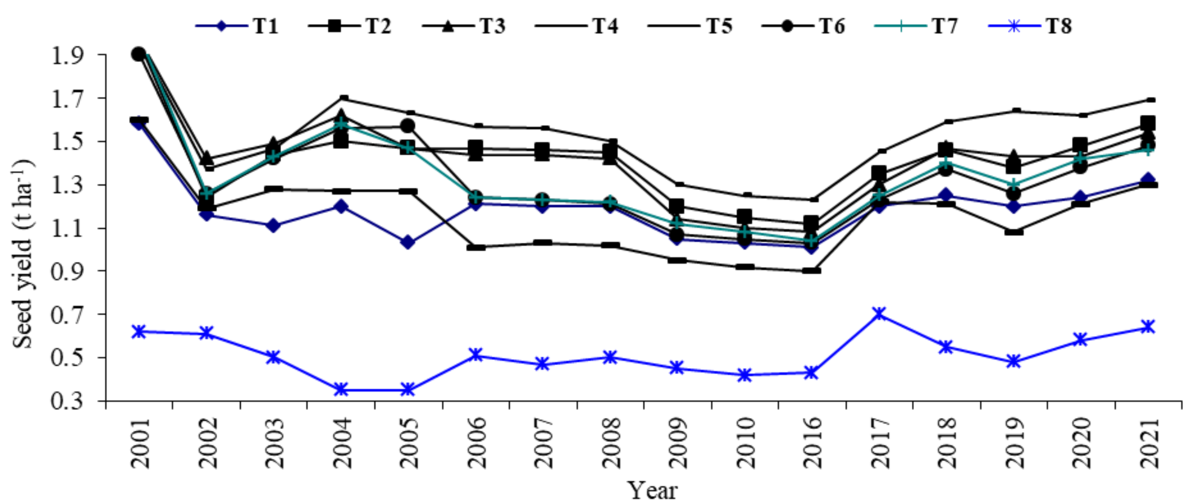

Fig. 1. Seed yield of mustard as influenced by different treatments

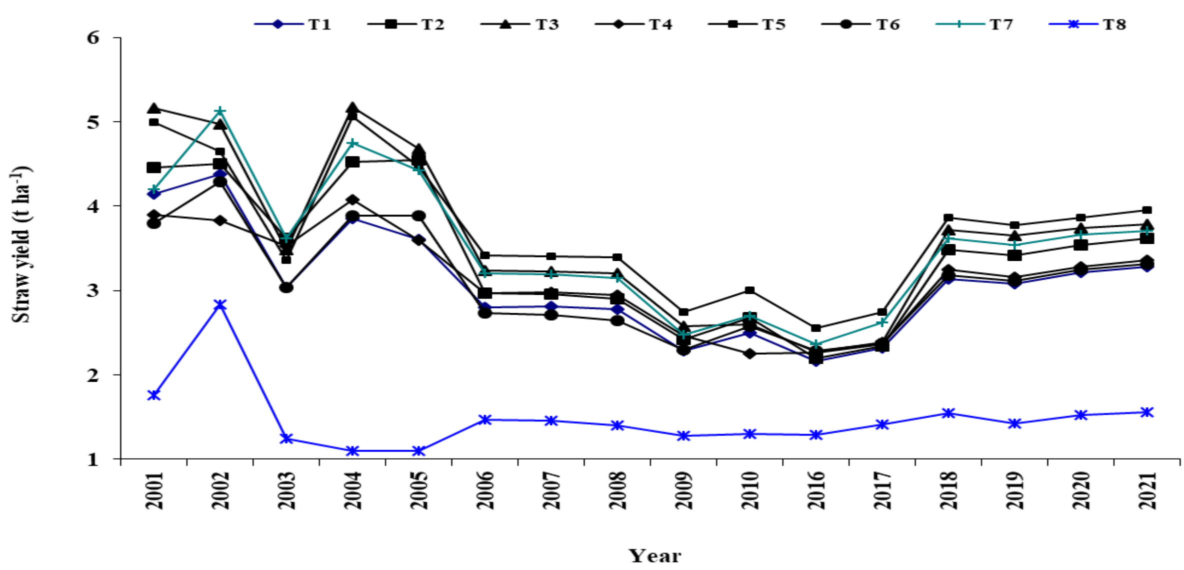

Fig. 2. Straw yield of mustard as influenced by different treatments

Mungbean

No significant difference was observed in seed yield due to fertilizer treatments in the year 2000-2001, 2005-2006, 2006-2007, 2007-2008, 2008-2009, 2009-2010 and 2015-2016, whereas significant difference in 2006-2007 and 2015-2016 on green biomass production. The reason might be due to the variation of vegetative growth among the treatments. But in the following year 2001-2002, 2002-2003, 2003-2004 and 2004-2005 significant differences of both grain and biomass yield were observed over native nutrient treatment. The highest yield (average of 16 years) of 1.51 and 8.71 t ha^{-1} of grain and green biomass were obtained in T_5 ($N_{120}P_{54}K_{70}S_{40}Zn_3B_1$kg ha^{-1}) treatment due to the residual effect of phosphorus (54 kg ha^{-1}) compared to 1.09 and 6.56 t ha^{-1} over native nutrient (T_8) treatment (Fig. 3 and Fig. 4).

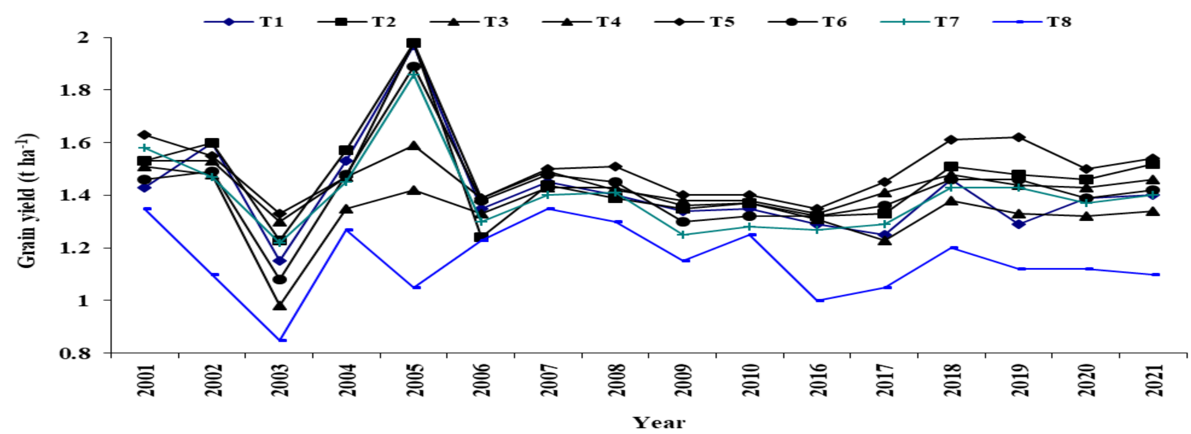

Fig. 3. Grain yield of mungbean as influenced by different treatments

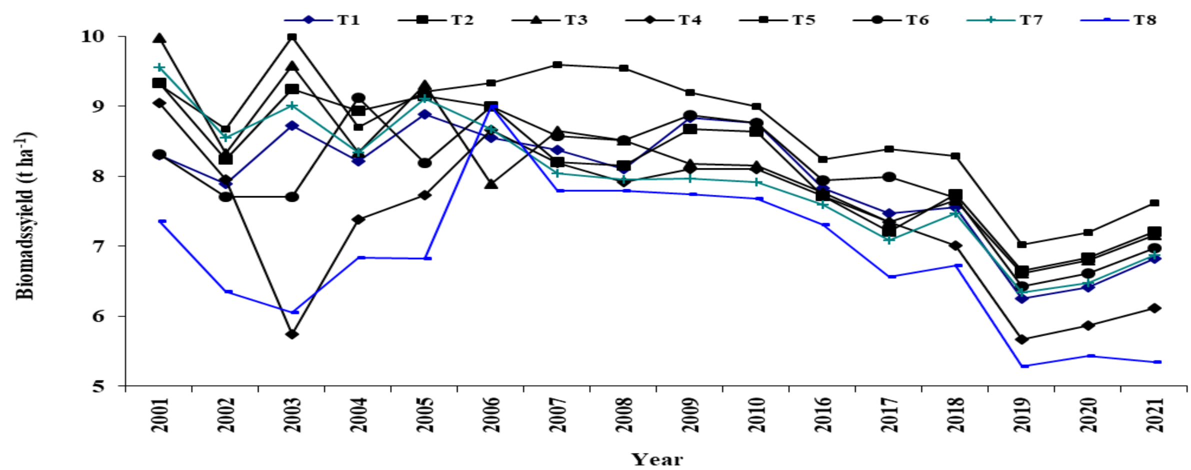

Fig. 4. Biomass yield of mungbean as influenced by different treatments

T.Aman

Incorporation of green biomass of mungbean and residual effect of previous fertilizer and applied fertilizer influenced the grain and straw yield of T. aman significantly (Fig. 5 and Fig. 6). The highest grain yield (average of 16 years) of 4.96 t ha^{-1} was obtained in T_5 treatment as compared to 2.68 t ha^{-1} in the native nutrient treatment (T_8). The grain yield of T. aman showed gradual declining trend during the trial period of 2000 to 2016. The negative nutrient balance of some nutrients, declining soil fertility status of post harvest soils as well as repetition of same cropping pattern for a long time may have contributed to this decrease in grain yield.

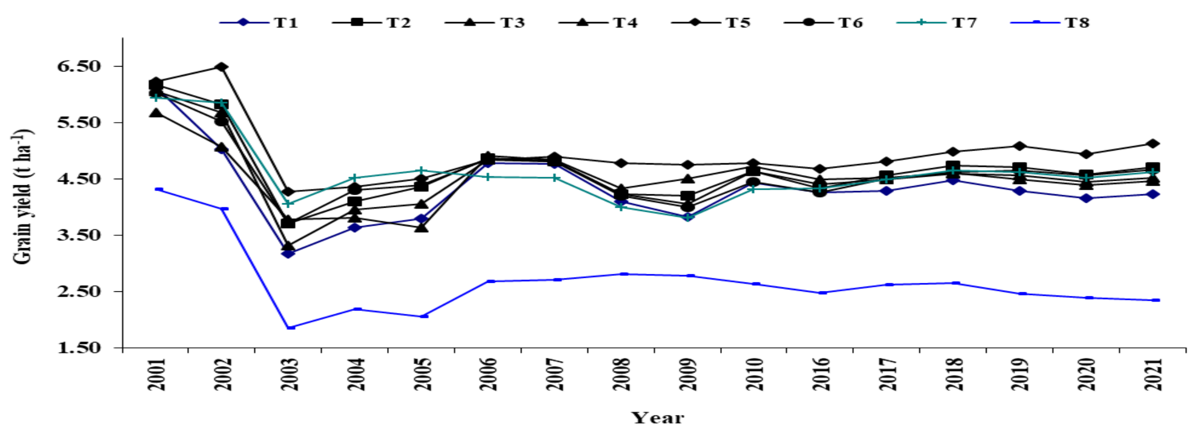

Fig. 5. Grain yield of T.aman as influenced by different treatments

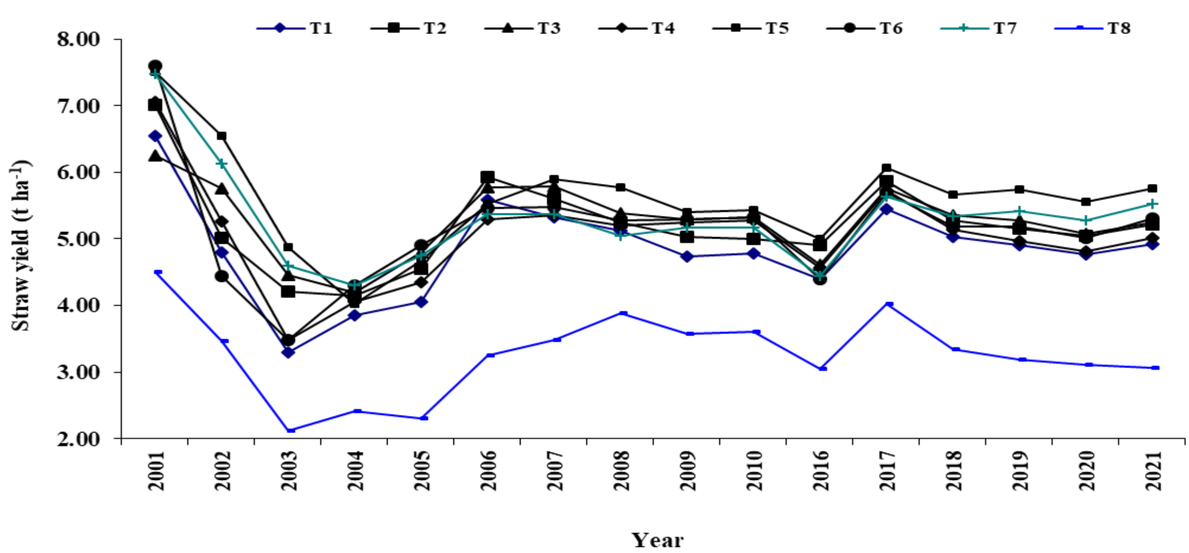

Fig. 6. Straw yield of T.aman as influenced by different treatments

Total rice (system) yield

Total rice (system) yield as influenced by different treatments has been presented in Table 2. The highest total rice (system) yield of 14.854 t $ha^{-1}yr^{-1}$ was obtained from T_5 treatment. The lowest total rice (system) yield of 8.58 t $ha^{-1}yr^{-1}$ was obtained from control i.e. native fertility treatment (T_8).

Table 2. Average yield, rice equivalent yield and total rice (system) yield (t $ha^{-1}yr^{-1}$) of mustard-mungbean-T.Aman

Treatment	Average yield of crops in the pattern			Rice equivalent yield of crops in the pattern		Total rice (system) yield
	Mustard	Mungbean	T. Aman	Mustard	Mungbean	
T_1	1.19	1.42	4.33	2.97	5.66	12.96
T_2	1.42	1.46	4.66	3.55	5.83	14.03
T_3	1.42	1.44	4.51	3.56	5.76	13.82
T_4	1.15	1.35	4.54	2.88	5.39	12.81
T_5	1.53	1.51	4.96	3.83	6.06	14.85
T_6	1.33	1.42	4.59	3.32	5.69	13.60
T_7	1.34	1.40	4.58	3.36	5.60	13.54
T_8	0.51	1.16	2.68	1.28	4.62	8.58

Price : 1 kgmustard = Tk. 50, 1 kg mungbean = Tk. 80, 1 kg rice = Tk. 20

Cost and return analysis

The benefit cost analysis of mustard-mungbean-T.Aman cropping pattern has been given in Table 3. Highest gross return of 2,97,063 Tk. ha^{-1} yr^{-1} was obtained from T_5 treatment with a total variable cost 1,60,690 Tk^{-1} ha^{-1} yr^{-1}.The highest gross margin of 1,36,373 Tk. ha^{-1} yr^{-1} was also obtained from T_5 treatment. The highest benefit cost ratio of 1.85 was found in T_5 treatment.

Table 3. Gross return, total variable cost, gross margin and BCR of Mustard-Mungbean-T.Aman at RARS, Jashore (average of 16 years)

Treatment	Total rice (system) yield	Gross return	Total variable cost	Gross margin	BCR
		(Tk ha^{-1} yr^{-1})			
T_1	12.96	259181	153588	105593	1.69
T_2	14.03	280675	156370	124305	1.79
T_3	13.82	276475	159153	117322	1.74
T_4	12.81	256250	152050	104200	1.69
T_5	14.85	297063	160690	136373	1.85
T_6	13.60	271975	154270	117705	1.76
T_7	13.54	270863	158470	112393	1.71
T_8	8.58	171538	130000	41538	1.32

Nutrient uptake

Nutrient uptake by grain and straw of all the crops of the cropping pattern were influenced by different fertilizer treatment. Total nutrient added and harvested by fourteen cropping cycles (2000-2021) of mustard-mungbean-T.Aman cropping pattern have been shown in Table 4. Effect of T_5 ($N_{120}P_{54}K_{70}S_{40}Zn_3B_1$kg ha^{-1}) treatment on the uptake of N, P, K, S and Zn grain and straw was very prominent and distinct as compared to native nutrient treatment.

It was observed that a total amount of 1346, 285, 1242, 211 and 11 kg ha^{-1} of N, P, K, S and Zn were removed form the soil by sixteen cropping cycles, with the best yielding of T_5 treatment. N and K removal were found to be higher than the amount added. Corresponding data for the lowest yielding treatment (T_8) were 712, 168, 667, 93 and 5 kg ha^{-1} and these amounts of nutrients were supposed to be supplied from the soil. About 129, 71 and 7kgofP, S and Zn ha^{-1} were added in soil system when 90 t ha^{-1} of green biomassofmungbean from sixteen cropping cycles were ploughed down after total grain harvest.

Table 4. Total nutrient added and harvested by mustard-mungbean-T.Aman cropping pattern at RARS, Jashore after sixteen cropping pattern in 2020-2021

Treatment	Nutrient added (kg ha^{-1})					Nutrient harvested (kg ha^{-1})				
	N	P	K	S	Zn	N	P	K	S	Zn
T_1	900	360	700	250	15	1155	231	1073	179	8
T_2	1300	360	700	250	15	1297	254	1207	201	10
T_3	1700	360	700	250	15	1295	248	1251	200	9
T_4	1300	180	700	250	15	1156	227	1102	179	8
T_5	1300	540	700	250	15	1346	285	1242	211	11
T_6	1300	360	350	250	15	1292	258	1190	203	10
T_7	1300	360	1050	250	15	1300	252	1325	200	11
T_8	0	0	0	0	0	712	168	667	93	5

Soil fertility status

The status of soil pH, organic matter, total N and available P, K,S and Zn in initial soil as well as in soil after completion of sixteen cycles of mustard-mungbean-T.Aman cropping pattern have been shown in Table 5. Initially the pH of the soil was 7.6. But after sixteen cropping cycles, there was no appreciable change in pH. The highest amount of organic matter was found in T_5 treatment while high amount of green biomass 12.55 t ha^{-1} (average of 16 years) was added. Higher amount of available P was obtained in T_5 and T_7 treatments where maximum phosphorus fertilizer was added.

Table 5. Soil test values after sixteen cropping cycle

Soil status	Treatment	Soil texture	pH	OM	Total N	P	K	S	Zn
				(%)		μg g^{-1}	meq 100 g^{-1}	μg g^{-1}	
Initial	All	Silty loam	7.6	1.49	0.075	17	0.21	13	1.5
Final	T_1	Silty loam	7.5	1.53	0.076	21	0.15	15	1.6
	T_2	Silty loam	7.5	1.57	0.081	21	0.15	15	1.6
	T_3	Silty loam	7.5	1.58	0.082	21	0.15	16	1.6
	T_4	Silty loam	7.5	1.54	0.081	20	0.15	15	1.5
	T_5	Silty loam	7.5	1.59	0.083	22	0.16	18	1.7
	T_6	Silty loam	7.5	1.56	0.081	21	0.14	15	1.5
	T_7	Silty loam	7.5	1.58	0.083	23	0.17	16	1.6
	T_8	Silty loam	7.6	1.43	0.074	16	0.13	11	1.1

Conclusion

The T_5 treatment ($N_{120}P_{54}K_{70}S_{40}Zn_3B_1$ kg ha^{-1} for the mustard, 20 kg N for mungbean and $N_{120}P_{54}K_{70}S_{10}$ kg ha^{-1} for T.Aman cropping pattern) is suitable in respect of sustainable yield and BCR for High Ganges Floodplain Soils (AEZ-11) of Jashore.The highest system productivity was attributed from T_5 treatment and the lowest from T_1i.e. control treatment.The average soil fertility status was mostly unchanged, somewhere it was changed positively although potassium showed negative balance and more potassium is to be added to improve soil fertility. So, through this practice the soil nutritional status may be sustained in the study area of AEZ-11.

LONGTERM INTEGRATED NUTRIENT MANAGEMENT FOR SUSTAINING SOIL FERTILITY AND YIELD OF MAIZE-MUNGBEAN-T. AMAN CROPPING PATTERN

M. R. KHATUN, M. M. MASUD, M. M. SULTANA, I. S. M. FARHAD, A. BARMAN.AND H. M. NASER

Abstract

A long-term field experiment on Maize-Mungbean-T.Aman cropping pattern was conducted in the Grey Terrace Soil (AEZ-28) of Gazipur during the year of 2008-2022 with the objectives of finding out suitable fertilizer combination for sustainable yield of the pattern, monitoring soil health as affected by chemical fertilizers and organic manures and to make a balanced sheet of each nutrient. There were six treatments viz. T_1: Native fertility, T_2: 75% of Soil Test Based (STB) chemical fertilizer+ 5 t ha^{-1} CD, T_3: 100% of STB chemical fertilizer, T_4: 100% of STB chemical fertilizer + 5 t ha^{-1} CD, T_5: 100% of STB chemical fertilizer + 3 t ha^{-1} PM and T_6: 75% of STB chemical fertilizer. The experiment was laid out in RCB design with four replications. Data revealed that the T_5 treatment produced the highest yield of maize grain consistently in fourteen cropping cycle. The legume component (mungbean) produced over 1 t ha^{-1} grain and added over 13 t ha^{-1} green biomass. The third crop (T.Aman rice) also produced the highest grain yield in the T_5 treatment. The yields of maize and rice were statistically similar to all other fertilizer treatments.The native fertility treatment produced the lowest yield. This trend of influence was consistent for almost all the yield contributing characters of maize and T. Aman rice. N, K and S balances were found negative whereas P balance was found positive except T_1 treatment (native fertility).

Introduction

In the recent years, intensive crop cultivation using high yielding varieties of crop with imbalanced fertilization has led to mining out the inherent plant nutrients from the soils and thereby fertility status of the soils severely declined in Bangladesh.

Mono crop based fertilizer recommendations are proving to be costly to the poor farmers. On the other hand rich farmers are using high dose of chemical fertilizer especially urea for some crops which creates imbalance in soil nutrients. The nutrients added to the soil in the form of fertilizers are not being removed or utilized by the crops in one season. Some amounts are left over in the field. So, proper fertilizer management is very important considering the residual effect of the nutrients. Moreover, inclusion of a pulse crops in the cropping pattern would reduce the requirement of chemical fertilizers in the next crop maintaining a good health of soils through biological nitrogen fixing and addition of organic matter to soil.

There are a several number of cropping patterns in Bangladesh. The patterns are mainly rice based and vary on agro-ecological conditions and availability of irrigation facility. Maize-Fallow-T.aman is one of the dominant cropping patterns in the Grey Terrace Soil (AEZ-28) of Bangladesh. Soil fertility is a major determinant for the success and failure of a crop production system. Long term soil fertility monitoring under a specific cropping system would be of great help in determining a better soil fertility management program for sustained productivity at high level. On the other hand the management practices in a crop of a cropping pattern greatly influence the other crop of the same pattern.

The present study was undertaken with the long-term objectives: a) to find out judicious fertilizer recommendation for Maize-Mungbean-T.aman cropping pattern for sustainable yield, b) to monitor soil health after each cropping cycle and c) to estimate uptake of different plant nutrients and make a balance sheet for each of the nutrients.

Materials and Methods

The field experiment was initiated in the Chhiata series (*Aeric Albaquepts*) at Joydebpur (AEZ-28) during 2007-08 and continues thereafter. The initial soil samples, collected from depth of 0-15 cm were analyzed in the laboratory following standard methods. Initial values of some important soil physical and chemical parameters of the experimental soil are presented in Table 1. The different nutrient status of the cowdung (CD) and poultry manure (PM) used in the experiment are shown in Table 2.

The experiment was laid out in a randomized complete block design with four replications. Six different treatments viz. T_1: Native fertility, T_2: 75% of Soil Test Based (STB) chemical fertilizer + 5 t ha^{-1} CD, T_3: 100% of STB chemical fertilizer, T_4: 100% of STB chemical fertilizer + 5 t ha^{-1} CD, T_5: 100% of STB chemical fertilizer + 3 t ha^{-1} PM and T_6: 75% of STB chemical fertilizer were selected for different plots randomly. The unit plot size was 5m × 6m. The first crop in the pattern was maize and variety was BARI Hybrid Maize-9. Maize seeds were sown in line with 60 cm row to row and 20 cm seed to seed spacing in November, each year. Two seeds were placed in each hole and thinned out to one when the seedlings were established properly. Seeds were treated with vitavex prior to seeding.

Fertilizer N-P-K-S-Mg and B were supplied from urea, TSP, MoP, gypsum, magnesium sulphate and boric acid, respectively (Table 3a). All PKSMgB and $^1/_3$ of N were applied at the time of final land preparation. The remaining two third of N were applied as top dress at 30 and 60 days after sowing. Irrigations and other intercultural operations were done as and when required. Maize was harvested at the end of April, each year.

After maize, the mungbean variety BARI Mug-6 was sown in the plots and except the native fertility all plots received 20 kg N ha^{-1} (Table 3b). After two or three picking of the grains the green biomass was ploughed down into the soil and left for decomposition until the T. aman was transplanted.

For the third crop in the pattern T.Aman rice, the variety BRRI dhan57 was used in the experiment. Transplanting was done during the middle of July with a row to row spacing of 20 cm and plant to plant spacing of 15 cm. The treatment combinations for rice showing fertilizer rates are outlined in the Table 3c. All fertilizers including $1/3^{rd}$ of N were applied before transplanting. Rest of N was applied in two installments at 15 and 45 days after transplanting. T.Aman rice was harvested in the third week of October.

Table 1. Chemical properties of experimental soil (initial) at the Central Research Farm (BARI), Gazipur during 2007

pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
		meq 100 g^{-1} soil				µg g^{-1}						
5.57	1.36	3.5	0.8	0.11	0.076	9	10	0.21	1.42	84	10	0.6
Critical level		2.0	0.5	0.12	0.12	7	10	0.20	0.20	4	1	0.6

Table 2. Nutrient status of poultry manure and cowdung used in the experimental field

Name of the manure	pH	OM	Ca	Mg	K	Total N	P	S	B	Zn	Pb	Cd	As
		%									µg g^{-1}		
Cow dung	6.8	21.9	1.35	0.44	0.53	1.05	0.58	0.33	0.011	0.015	3.10	1.84	1.26
Poultry manure	7.8	23.8	4.29	1.81	0.87	1.27	0.74	0.44	0.013	0.018	5.89	2.11	1.72

Moisture content of CD = 25%& PM = 20%

Table 3. Treatment combinations for Maize-Mungbean-T.aman cropping pattern

a. First Crop: Maize

Treatment	Treatment combinations							
	Chemical fertilizer (kg ha^{-1})						Organic manure	
	N	P	K	S	Mg	B	Poultry manure (PM)	Cowdung (CD)
							(t ha^{-1})	
T_1	Native fertility						-	-
T_2	200	30	75	20	12	-	0	5
T_3	240	40	80	25	15	1.2	-	-
T_4	240	40	80	25	15	1.2	0	5
T_5	240	40	80	25	15	1.2	3	0
T_6	200	30	75	20	12	-	-	-

b. Second crop : Mungbean received 20 kg N ha^{-1} (except T_1)

c. Third Crop: Rice

Treatment	Treatment combinations							
	Chemical fertilizer (kg ha^{-1})						Organic manure	
	N	P	K	S	Zn	B	Poultry manure (PM)	Cowdung (CD)
							(t ha^{-1})	
T_1	Native Fertility						-	-
T_2	110	20	40	12	3	-	0	5
T_3	120	25	45	15	4	-	-	-
T_4	120	25	45	15	4	-	0	5
T_5	120	25	45	15	4	-	3	0
T_6	110	20	40	12	3	-	-	-

Data on yield and yield contributing characters of maize, mungbean and T.Aman were recorded and statistically analyzed. Duncan's Multiple Range Test (DMRT) was used to determine the significant differences between treatments (Steel and Torrie, 1960). Plant samples and post harvest soil samples were collected from each plot for chemical analysis at three years interval.

Results and Discussion

Maize

The information regarding grain yield and stover yield of maize as influenced by different treatments are summarized in Figure 1 and 2. The fertilizer and manure treatments influenced grain yield and stover yield of maize. Highest grain yield was obtained from T_5(100% STB chemical fertilizer + 3 t ha^{-1} PM) treatmentwhich was almost simitar to T_4 treatment (100% STB chemical fertilizer + 5 t ha^{-1} CD).

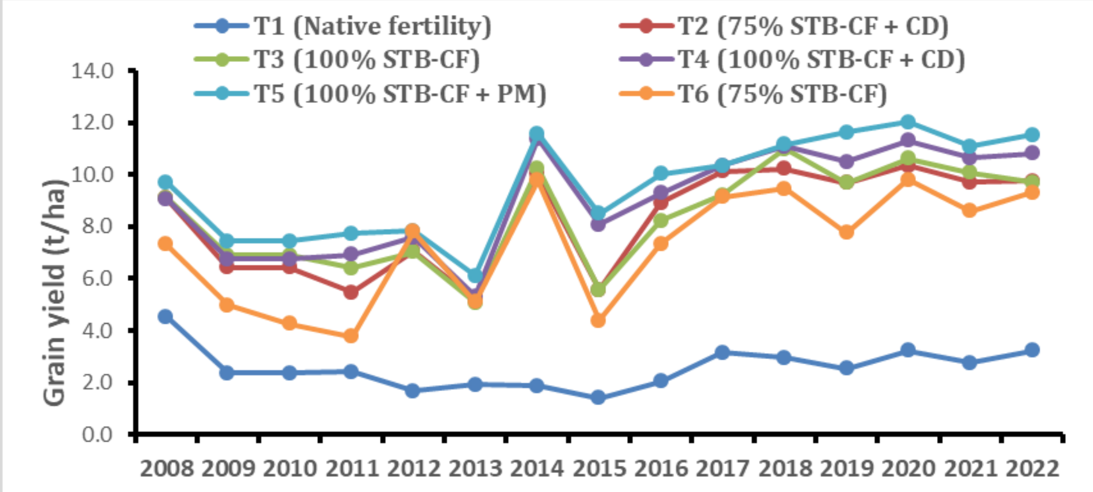

Fig. 1. Grain yield of maize as influenced by different treatments

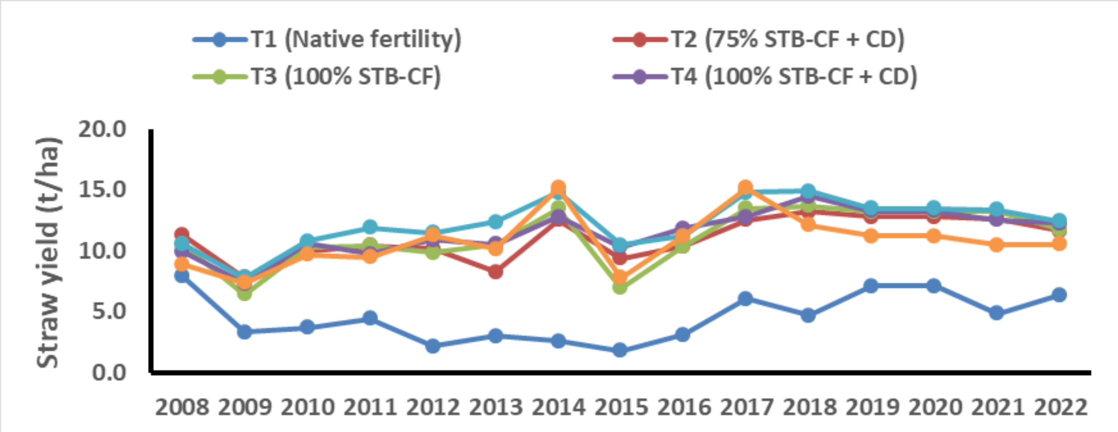

Fig. 2. Straw yield of maize as influenced by different treatments

Mungbean

The legume crop mungbean was cultivated after maize harvest. Mungbean received only 20 kg N ha^{-1} from urea. After 2-3 picking the green biomass was ploughed down into the soil. The fertilizer and manure treatments influenced seed yield and stover yield of mungbean (Fig. 3 and 4). Highest seed yield was obtained from T_5(100% STB chemical fertilizer + 3 t ha^{-1} PM) treatment. Mungbean crop could not established since the year 2015 due to untimely rainfall.

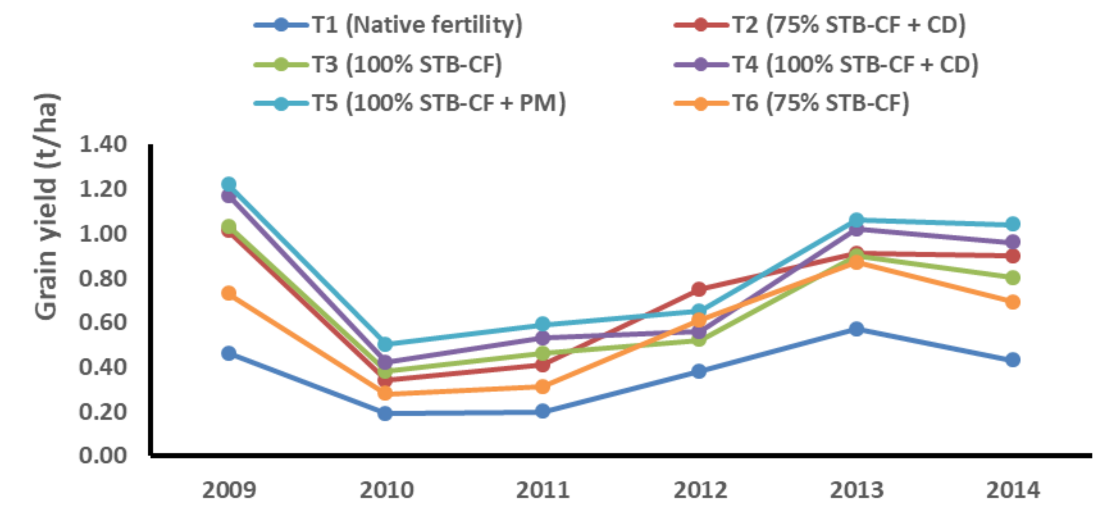

Fig. 3. Grain yield of mungbean as influenced by different treatments

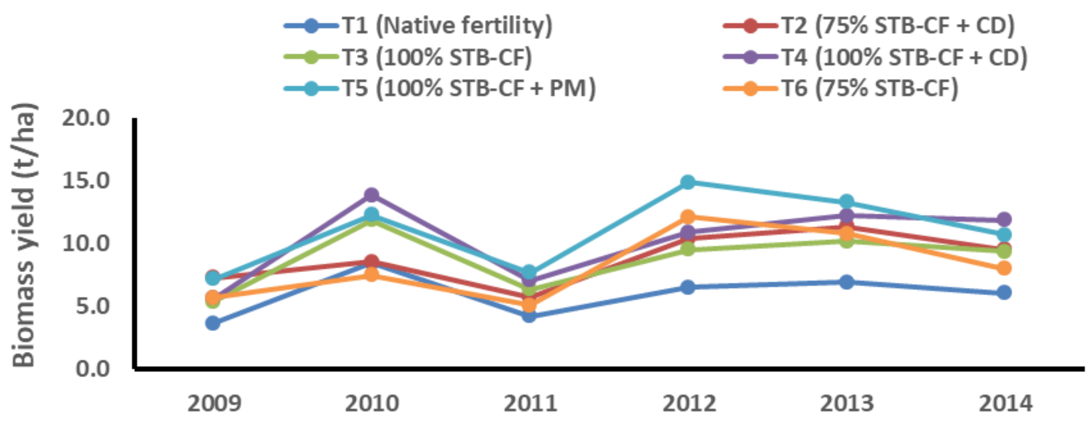

Fig.4. Biomass yield of mungbean as influenced by different treatments

T.Aman Rice

Grain yield and straw yield of T.Aman rice as influenced by different treatments are summarized in Figure 5 and 6. T.Aman rice crop cultivated in 2008 to 2020, it is showed similar response to the fertilizer packages. These responses were somewhat similar to that showed by earlier maize crops. Highest grain yield was obtained from T_5(100% of STB chemical fertilizer + 3 t ha^{-1} PM) treatment.

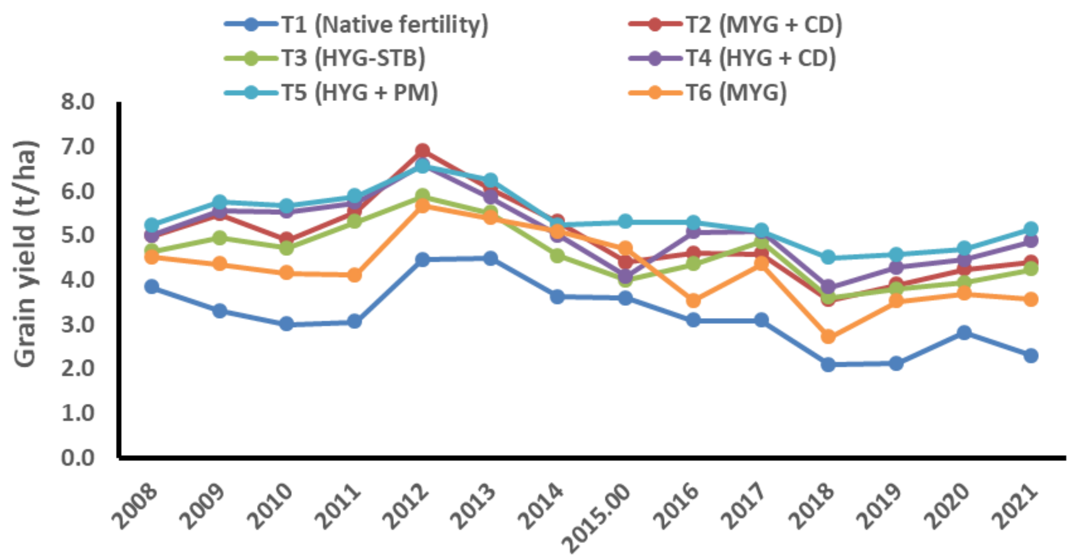

Fig. 5. Grain yield of T. Aman as influenced by different treatments

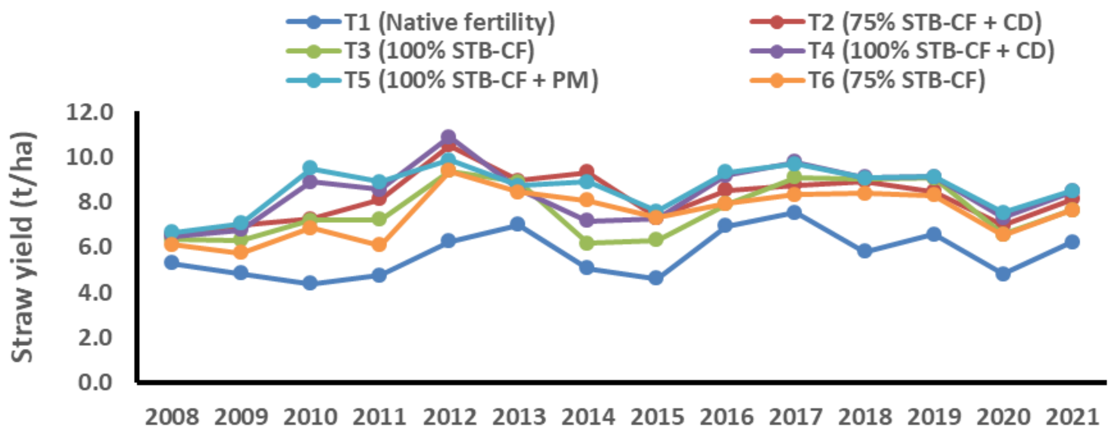

Fig. 6. Straw yield of T. Aman as influenced by different treatments

Total rice (system) yield

Total rice (system) yield as influenced by different treatments has been presented in Table 4. Highest total rice (system) yield of 17.16 t $ha^{-1}yr^{-1}$ was obtained from T_5(100% of STB chemical fertilizer + 3 t ha^{-1} PM) treatment. Lowest total rice (system) yield of 6.85 t $ha^{-1}yr^{-1}$ was obtained from control i.e. native fertility treatment (T_1).

Table 4. Average yield, rice equivalent yield and total rice (system) yield (t $ha^{-1}yr^{-1}$) of Maize-Mungbean-T.aman cropping pattern upto 2021-22

Treatment	Average yield of crops in the pattern			Rice equivalent yield of crops in the pattern		Total rice (system) yield
	Maize	Munbean	T.Aman	Maize	Munbean	
T_1	2.56	0.46	3.20	2.07	1.61	6.85
T_2	8.27	0.85	4.81	6.90	2.99	14.41
T_3	8.38	0.74	4.59	6.92	2.59	13.88
T_4	9.06	0.85	5.06	7.52	2.96	15.27
T_5	10.61	0.92	5.46	7.94	3.21	17.16
T_6	6.25	0.72	4.28	5.80	2.53	11.82

Price : 1 kg maize = Tk. 16, 1 kg mung bean = Tk. 70, 1 kg rice = Tk. 20

Nutrient uptake and nutrient balance by the Maize-Mungbean-T.Aman cropping pattern

Nitrogen uptake by maize crop in the year 2022 ranged between 44.5 kg ha^{-1} in the control treatment to 191kg ha^{-1} in the T_5 treatment where PM was added with the 100% STB chemical fertilizers (Table 5). The highest P, K, S, Zn and B uptake by maize were noticed from the T_5 treatment.

Nitrogen uptake by T. Aman rice crop in the year 2021 ranged between 54.7 kg ha^{-1} in the control treatment to 92.2kg ha^{-1} in the T_5 treatment where PM was added with the 100% STB chemical fertilizers (Table 6). The highest P, K, S, Zn and B uptake by T.Aman rice were noticed from the T_5 treatment. Because of the higher yield was found from this treatment.

The nitrogen removal by mungbean grain ranged from 48.8 kg ha^{-1} to 97.5kg ha^{-1} (Table 7a). The range of P removal was 9.66-19.3, K ranged from 27.1 to 54.3 and S ranged from 9.63 to 19.3 kg ha^{-1}. The nutrient recycled by mungbean green biomass was estimated as nitrogen 16.1 to 60.3, P 12.5 to 43.7, K 16.1 to 60.3 and S 5.08 to 13.2 kg ha^{-1} (Table 7b).

Table 5. Nutrient uptake by maize crop in 2022

Treatments	Nutrient uptake by maize (kg ha^{-1})					
	N	P	K	S	Zn	B
T_1 (Native fertility)	44.5	8.44	28.4	7.67	0.09	0.12
T_2 (75% STB-CF + CD)	168	32.8	126	27.6	0.87	0.67
T_3 (100% STB-CF)	161	28.4	123	28.8	0.96	0.70
T_4(100% STB-CF + CD)	181	36.5	137	32.7	1.01	0.91
T_5 (100% STB-CF + PM)	191	40.2	146	38.3	1.09	0.98
T_6 (75% STB-CF)	149	26.3	112	25.0	0.47	0.42

Table 6. Nutrient uptake by T.Aman rice crop in 2021

Treatments	Nutrient uptake by rice crop (kg ha^{-1})					
	N	P	K	S	Zn	B
T_1 (Native fertility)	54.7	8.93	44.2	4.67	3.30	0.23
T_2 (75% STB-CF + CD)	79.0	16.2	75.1	7.89	7.73	0.59
T_3 (100% STB-CF)	75.3	14.1	70.2	7.52	8.04	0.63
T_4(100% STB-CF + CD)	84.5	15.9	77.5	7.98	8.55	0.76
T_5 (100% STB-CF + PM)	92.2	17.3	83.3	8.60	9.08	0.78
T_6 (75% STB-CF)	68.1	11.3	67.0	6.30	6.11	0.44

Table 7a.Nutrient removal by Mungbean grain (kg ha^{-1})

Treatments	N	P	K	S	Zn	B
T_1 (Native fertility)	48.8	9.66	27.1	9.63	0.024	0.020
T_2 (75% STB-CF + CD)	90.1	17.9	50.2	17.8	0.038	0.035
T_3 (100% STB-CF)	78.4	15.5	43.7	15.5	0.046	0.041
T_4(100% STB-CF + CD)	90.1	18.0	50.2	17.8	0.035	0.032
T_5 (100% STB-CF + PM)	97.5	19.3	54.3	19.3	0.044	0.040
T_6 (75% STB-CF)	76.3	15.1	42.5	15.1	0.028	0.027

Table 7b. Nutrient recycled by Mungbean green biomass (kg ha^{-1})

Treatments	N	P	K	S	Zn	B
T_1 (Native fertility)	16.1	12.5	16.1	5.08	0.044	0.089
T_2 (75% STB-CF + CD)	41.3	33.9	41.3	12.2	0.124	0.152
T_3 (100% STB-CF)	39.9	37.7	39.9	11.7	0.117	0.205
T_4(100% STB-CF + CD)	51.8	39.1	51.8	13.2	0.124	0.230
T_5 (100% STB-CF + PM)	60.3	43.7	60.3	18.7	0.143	0.322
T_6 (75% STB-CF)	24.6	21.1	24.6	8.71	0.075	0.112

Table 8. Effect of different treatments on apparent nutrient balance in soil under Maize-Mungbean T.Aman rice cropping pattern

Treatments	Nutrient balance (kg ha^{-1}yr^{-1})			
	N	P	K	S
T_1 (Native fertility)	-130.2	-14.4	-95.7	-18.8
T_2 (75% STB-CF + CD)	-106.1	36.9	-58.9	-13.2
T_3 (100% STB-CF)	-118.4	45.2	-70.4	-0.5
T_4(100% STB-CF + CD)	-94.2	55.6	-33.0	-5.7
T_5 (100% STB-CF + PM)	-122.6	62.5	-66.6	-3.6
T_6 (75% STB-CF)	-116.7	16.0	-87.2	-8.9

Apparent nutrient balance of major nutrients calculated after twelve cropping cycles, indicated that the balance for some nutrients are negative. Varying levels of negative balance was observed with N, K and S in soil. Only positive balance of P was noticed from all treatments except T_1 (Native fertility) treatment (Table 8).

Changes in soil properties

After completion of fourteen cropping cycle, the contents of organic matter, total N, exchangeable K and Mg, available P, available S and available B in post-harvest soils were increased due to combined application of inorganic fertilizers and organic manure compared to that of initial soil (Table 9). Treatment T_5 (100% STB-CF + 3 t ha^{-1}PM) showed better performance in case of all nutrient content in post havest soil during 2021-2022. The contents of organic matter and total N were almost similar to that of year 2017-2018 in post harvest soil.Again in the year of 2018-2019, content of K, P, Zn & B in soil were increased compared to initial soil content. After completion of fourteen cropping cycle the pH ranged from 5.73 to 6.25 while the initial pH value was 5.7. This might be due to release of organic acid from additional organic manure.

Table 9. Chemical properties of post harvest soil after completion of twelve cropping cycle of the cropping pattern during 2021-22

Treatments	Soil pH	OM	Total N	K	Mg	P	S	B	Zn
				meq 100g^{-1}		µg g^{-1}			
		(%)							
Initial soil	5.57	1.36	0.076	0.12	0.8	9	10	0.21	0.6
T_1 (Native fertility)	5.73ab	1.06e	0.080	0.09d	0.64c	8.22c	13.0d	0.16e	0.38e
T_2 (75% STB-CF + CD)	5.62b	1.55cd	0.094	0.11bc	1.0b	13.7ab	23.5b	0.26cd	0.67c
T_3 (100% STB-CF)	5.55b	1.62bc	0.087	0.13ab	1.0b	14.5ab	22.4bc	0.27bc	0.77b
T_4 (100% STB-CF + CD)	5.72ab	1.74ab	0.095	0.13ab	1.0b	15.0a	24.1b	0.31b	0.90a
T_5 (100% STB-CF + PM)	6.25a	1.79a	0.095	0.15a	1.1a	17.8a	26.8a	0.40a	0.92a
T_6 (75%-STB-CF)	6.20a	1.48d	0.088	0.10cd	1.0b	10.7bc	20.7c	0.21de	0.51d
CV (%)	5.31	5.25	8.03	8.24	1.38	10.33	4.13	4.15	3.11
Critical level	-	-	-	0.12	0.5	7.0	10	0.20	0.6

Cost and return analysis

The estimated gross return, total variable cost, gross margin, marginal value product (MVP) and marginl benefit cost ratio (MBCR) are presented in Table 10. Gross margin was calculated by subtracting the variable cost from the gross return. MBCR was calculated from the marginal value product divided by total variable cost. Gross return was calculated as the market value of rice. The cost and return analysis of the cropping pattern demonstrated that, the highest gross return (3,43,242/-Tkha^{-1}) was obtained in T_5 (100% STB-CF + PM) treatment which was followed by 3,05,400/-Tkha^{-1}and 2,88,266/-Tkha^{-1} obtained inT_4(100% STB-CF + 5 t ha^{-1}CD) and T_2 (75% STB-CF+ 5 t ha^{-1}CD) treatments, respectively. The highest gross margin (2,54,523/-Tkha^{-1}) was obtained in T_5 (100% STB-CF + 3 t ha^{-1}PM) which was followed by 2,22,547/-Tk ha^{-1} obtained in T_2 (75% STB-CF+ 5 t ha^{-1}CD). The highest marginal value product (2,,06,209/- Tkha^{-1}) was obtained in T_5 (100% STB-CF + 3 t ha^{-1}PM) which was followed by 1,68,371/-Tkha^{-1} obtained in T_4(100% STB-CF+ 5 t ha^{-1}CD) treatments. The highest MBCR (2.32) was found in T_5 treatment. The farmers will preferably choose tothis treatmentbecauseit can give a higher gross margin and it could besustained soil fertility.

Table 10. Cost and return analysis of long-term integrated nutrient management for sustaining soil fertility and yield of Maize-Mungbean-T.aman cropping pattern

Treatments	Total rice system yield (t ha^{-1})	Gross return	Total variable cost	Gross margin	Marginal Value product (MVP)	MBCR
		(Tk.)				
T_1 (Native fertility)	6.85	137032	0	137032	-	-
T_2 (75% STB-CF + CD)	14.41	288266	65719	222547	151234	2.30
T_3 (100% STB-CF)	13.88	277623	64719	212904	140591	2.17
T_4 (100% STB-CF + CD)	15.27	305404	89719	215685	168371	1.88
T_5 (100% STB-CF + PM)	17.16	343242	88719	254523	206209	2.32
T_6 (75%-STB-CF	11.82	236362	50719	185643	99329	1.96

Legend: Urea = 16 Tk kg^{-1}, TSP = 25 Tk kg^{-1}, MoP= 15 Tk kg^{-1}, Gypsum= 12 Tk kg^{-1}, Rice = Tk. 20 kg^{-1}
Zinc sulphate = 200 Tk kg^{-1}, Boric acid = 250 Tk kg^{-1}, PM =8 Tk kg^{-1}, CD = 3 Tk kg^{-1}

Conclusion

Nutrient application of $N_{240}P_{40}K_{80}S_{25}Mg_{15}B_{1.2}$ kg ha^{-1} plus 3 t PM ha^{-1} for maize, only 20 kg N ha^{-1} for mungbean and $N_{120}P_{25}K_{45}S_{15}Zn_4$ kg ha^{-1} plus 3 t PM ha^{-1} for T.Aman i.e. T_5 treatment was found best combination for the pattern. Highest average yield, rice equivalent yield and total rice system yield (t ha^{-1} $year^{-1}$) of maize, mungbean and T.Aman was noted by T_5 treatment. Nutrient status in post harvest soil was also improved by PM and CD incorporation with 100% soil test basis chemical fertilizers.

EFFECT OF CROP RESIDUE AND THEIR BIOCHARS ON MAIZE YIELD

M.M. MASUD, R. SEN, A. BARMAN, R. KHATUN, I.S.M. FARHAD AND H. M. NASER

Abstract

Three years field study was conducted on the effects of crop straw and its derived biochars on maize (BARI Khoibhutta) yieldat Central research field, BARI, Gazipur under Grey Terrace Soil (AEZ 28) from 2018-2021. Three crop straws (i.e. groundnut straw, chickpea straw and mustard straw) and their derived biochars were used where cowdung used as comparison.The experiment consisted of eight treatments laid out in randomized complete block design with three replications. The changes of soil properties like pH, organic matter content and soil health effect on yield and yield components of maize were investigated. Results indicated biochar, especially those were high in pH, enhanced soil pH (>0.2 units, $p < 0.05$), whereas reduction and or unaffected soil pH was observed among treatments with crop straws. The organic matter content increased with the application of crop straws and biochars as well as cowdung. After three years study, result showed that biochar treated soil increased and last in soil ranges from (0.21 to 0.27 unit) but crop straw increased only 0.04 unit. Initially, carbon stock increased average 28% by using crop straw and crop straw derivate biochar increased average 75% from initial soil organic carbon where chickpea straw biochar increased greater (77%). The carbon content decreased almost full from CD and crop straw treated soil but biochar amended plot decreased a little form first year to third year. Greater nutrient uptake by maize were observed with the treatment receiving biochar compared to crop straw as well as cowdung and no amendment plot, respectively. The lowest uptake of nutrient element was recorded in treatment receiving amendment plot (100% RDCF). The incorporation of biochar not only neutralizes soil acidity, but can also improve soil fertility and carbon stock into the soil. Three years average results on the yield parameters of the BARI Khoibhutta showed that crop straw increased the grain yield from 4.55 t ha^{-1} to 4.67 t ha^{-1} where crop straw biochar increased 5.12 t ha^{-1} to 5.60 t ha^{-1}, where 4.53 t ha^{-1}yield obtained from RDCF with cowdung 5 t ha^{-1}, that is 20% higher yield produced from RDCF treatment.Crop straw biochar enhanced the yield up to 45% from RDCF and 25% from crop straw but statistically higher yield in chickpea straw biochar (CSB) treated plot. The overall result indicated that RDCF with 10 t ha^{-1} CSB out of three crop straw biochars showed more effective for Khoibutta yield and improve soil fertility.

Introduction

Bangladesh being an agriculture-dominant country produced huge amount of crop residues annually. The residues of rice, wheat, maize, millet, sugarcane, jute, chickpea, mustard and groundnut are typically burnt on-farm across different regions of the Bangladesh. A large portion of unused crop residues are burnt in the fields primarily to clear the left-over straw and stubbles after the harvest. These residues can be used directly as organic fertilizers. Alternatively, this residue could undergo a process of pyrolysis under controlled conditions of temperature and oxygen to produce a material called biochar (Mukherjee and Lal, 2016). The problem is more severe in the crop production, particularly in the mechanism of long term, poorly crop management has decreased the soil organic carbon (SOC) content resulting low productivity. Traditional composts and manures are rich sources of plant macronutrients and have been used extensively as fertilizers, either as partial or full substitutes for mineral fertilizers (Chen *et al*., 2018). Usually, manures as source of SOC but it has ability to increase the pH and exchangeable cations(Olowoboko *et al*., 2018). Besides this, leftover crop stubble and straw is usually incorporated into the soil to improve the fertility and crop yield and to maintain the SOC (Hanafi *et al*., 2012). Application of crop straw increases the SOC as a function of application amounts and duration. For instance, rice straw added into paddy soils increased seasonal soil carbon sequestration (Cseq) by 0.10 t C ha^{-1} and 0.36 t C ha^{-1} at an application rate of 2.63 t ha^{-1} and 4.5 t ha^{-1}, respectively, in a long term field experiment (Xionghui *et al*., 2012).

However, conventional organic materials specially cowdung and crop straws are also sources of GHG emissions (Peterson, 2018), while biochar is a stable, carbon rich material which can be reduce GHG and enhance soil C sequestration (Lehmann *et al*., 2011). Biochar produced from crop residues can improves the physiochemical characteristics of soil because biochar is rich in organic carbon content, which makes the soil more fertile and acts as a carbon sequestration agent over the long term (Panwar, 2019). Previous study reported that BC can remain in soil for hundreds to thousands of years (Sohi *et al.,* 2009; Sparkes and Stoutjesdijk, 2011), providing an alternative for sequestering C in soil (Shen *et al*., 2014).

Soil acidity is one of the major constraints affecting soil productivity. Many soil fertility researchers are still of the opinion that, low soil pH is responsible for poor plant growth yields due to the deficiencies and toxicities associated with a number of elements (Blamey and Chapman, 1982; Ok *et al.*, 2007). Low pH decreases microbial activities and decomposition of organic matter. Importantly, nitrification appears to be more sensitive to low pH than ammonification and other processes (Robson and Abbott, 1989). Soil pH does also greatly affect association/dissociation of organic compounds, reactions between soil particles and plant residues. Acidity amelioration is very important in these soils for adequate crop growth.

There have been recent observations that some plant materials including crop straws can directly neutralize soil acidity (Yuan *et al*., 2011), but the liming potential of these plant materials on acid soils depends on the properties of both plant materials and soils. Organic anions associated with base cations Ca, Mg, K and Na in plant materials are the main source for ash alkalinity of the materials (Yuan *et al*., 2011). Biochar contained a remarkable amount of cation that can improve soil fertility and reduce soil acidity (Steiner *et al.*, 2007; Chan *et al.*, 2008). The amelioration effects with the direct incorporation of plant materials into soils cannot last for long time due to the decomposition of the plant materials by soil microorganisms (Tang *et al.*, 1999; Xu *et al.*, 2006). While, research indicates that biochar is recalcitrant and it may persist for hundreds of years in soils (Rebecca, 2007; Steiner *et al.*, 2007). Natural coal and coal extracts have been shown to ameliorate acid soils and improve root growth (Yazawa *et al.*, 2000). Therefore, straws of mustard, chickpea and groundnut were chosen to prepare biochar samples at <700°C, and the amelioration effects and carbon stock enrichment on an acid soil and their feedstock where cowdung as comparison.

Materials and Methods

Field experimental site, climatic condition, soil, biochar and straw amendment

The experiment was conducted from November toMarch in 2018-2019, 2019-2020and 2020-2021at Soil Science Division, BARI experimental field (23º59´21.584´´ N, 90°24´34.999´´E) under Grey Terrace Soil(AEZ 28)classified as Inceptisols. The chemical characteristics of the top soil (0-15 cm) are shown in Table 1. The cowdung was collected from village near experimental field. The straws of mustard, chickpea and groundnut were collected from BARI experimental plot. These straws were air-dried at room temperature and pyrolysis in a conventional kiln at 500°C to 700°C for 1 h. It was then ground and passed through a 2 mm sieve. There were three replicates for each crop straw during the biochar-generating process. Mustard, chickpea and groundnut were chopped into 5-10 cm lengths before use. The physicochemical characteristics of the cowdung, biochars and straws are shown in Table 2.

Table 1.Chemical properties of the initial experimental soil of the experimental field.

Location	pH	OC	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
		(%)	meq 100 g^{-1}			(%)	µg g^{-1}						
Gazipur	5.41	0.87	4.52	1.54	0.16	0.08	14	15	0.12	2.2	73	11	2.2
Critical level		-	2.00	0.50	0.12	-	7	10	0.20	0.2	4	1	0.6

Preparation and analysisof biochar

Mustard, chickpea and groundnut were collected and air-dried at room temperature. Then they were chopped into small pieces. After that they are placed into biochar making device (made in Soil Science Division, BARI) and pyrolyzed under oxygen-limited conditions. The pyrolysis temperature was raised into 700°C at a rate of approximately 20°C per minute and held constant for 2 h. Then the biochar was allowed to cool at room temperature and ground to pass a 0.2 mm sieve. All biochar samples were analysed for chemical properties(Table 2). After being thoroughly mixed with deionized water at a ratio of 1:20and equilibrated for 1 h, the pH of the biochars was measured by Metler Toledo S220 with a combine electrode. The exchangeable base cations were extracted with 1.0 M ammonium acetate (pH 7.0) (Pansu and Gautheyrou, 2006). Ca^{2+} and Mg^{2+} were measured with AAS, and K^+ and Na^+ with flame photometer. The phosphorus was determined colorimetrically after digesting the biochars with sulphuric acid and hydrogen peroxide.

Treatments, maize cultivation and field management

Each plot size was 3m × 2 m with the adjacent plots sharing a soil boundary of 30 cm in width and 20 cm in height. Eight treatments were arranged in a randomized complete block design with three replications. The treatments were: i.Recommendation dose of chemical fertilizer (RDCF) alone, ii.RDCFwith cowdung (CD) 5 t ha^{-1}, iii.RDCFwith groundnut straw (GS) 10 t ha^{-1}, iv.RDCFwith chickpea straw (CS) 10 t ha^{-1}, v.RDCFwith mustard straw (MS) 10 t ha^{-1}, vi.RDCFwith groundnut straw biochar (GSB) 10 t ha^{-1}, vii.RDCFwith chickpea straw biochar (CSB) 10 t ha^{-1} and viii.RDCFwith mustard straw biochar (MSB) 10 t ha^{-1}. All plots received RDCF ($N_{255}P_{50}K_{120}S_{40}Zn_5B_2$ kg ha^{-1}) as a basal fertilizer. Before commencing the experimental set up, the cowdung, crop straw and biochar were incorporated into the soil corresponding to 15 days before sowing. Top dressing of urea as mentioned above was done at 22 and 46 days after sowing (DAS), include in the control. For yield and yield contributing character samples were collected inside a quadrant area of 1.0 m^2 per plot.

Khoibhutta yield and yield Components

Plant height was measured on five random plants per plot. Thousand grain weight was determined by counting a hundred maize grains and weighing. Grain yield (t ha^{-1}) was corrected to 12% moisture level. Grains yield was recorded after shelling of ears of two central rows from each plot and then dried and weight was converted into kg ha^{-1}.

Soil and plant analysis

Soil samples were analyzed before and after termination of the experiment at a depth of 0–15 cm. Soil samples were air dried and partially ground and pass through 0.3mm sieve. Soil pH was determined using Metler Toledo S220 with a combine electrode in a soil water ratio of 1:2.5 (w/w)as described by Mehmood *et al*. (2018). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934) Total N was determined by modified Kjeldhal method. The base cations (Ca^{2+}, Mg^{2+} and K^+) were extracted with 1 M ammonium acetate (pH 7.0) (Pansu and Gautheyrou, 2006). Cu, Fe, Mn, Zn were determined by DTPA extraction followed by atomic absorption spectrophotometer (AAS).

Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method while S by turbidimetric method with $BaCl_2$. The clean plant samples were air-dried and placed in an electric oven, dried at 105ºC for 24 h, weighted for dry biomass. Again, place it in the oven at 105ºC for 2h. Cool it in a desiccator and weight it again. Repeat drying, cooling and weighing until the weight become onstant. The dried plant samples were homogenized by grinding using willey mill and used for nutrient analysis. Then, the grains were ground and N, P, K, Ca, Mg, S, B and Zn contents were determined according to the method described by Jones and Case (2018). Atomic absorption spectrophotometer (Thermo Scientific-SOLAAR S Series AA spectrometer) was used for metal ion and spectrophotometer (Agiland Technologies, cary 60 UV-Vis) for anion analysis.The accumulation of nutrients in the grains was estimated by multiplying nutrient content by dry grain weight.

Statistical analysis

SPSS 15.0 (SPSS, Inc., Chicago, IL, USA) was used for the statistical analysis of data. A one-way analysis of variance was undertaken for each time interval of the incubations to determine significant differences between treatments. The significant effects for various treatments were detected using a t-test.

Results and Discussion

Chemical compositions and properties of crop straws and their biochars

The chemical compositions of crop straws and their biochar are presented in Table 2. All biochars had a higher pH than their corresponding crop straws, indicating the higher alkalinity of biochar compared to the straws and suggesting the concentrating of alkaline substances in crop straws during pyrolysis. It was found that the total elemental concentration of feedstock had a significant influence on the chemical composition of biochar (Table 2). Gaskin *et al*. (2008) observed a similar relationship between elemental concentration of the feedstock and the chemical composition of the biochar. The legume straws of chickpea and groundnut had higher contents of total base cations and total N than the non-legume straws (Table 2), and thus the biochars produced from the legumes had higher contents of total base cations and total N than non-legume straws (Table 2).

Table 2. Chemical composition at the crop straws and their biochars

Amendment	Cowdung	← Straw →			← Biochar →		
		Groundnut	Chickpea	Mustard	Groundnut	Chickpea	Mustard
pH	5.6	5.31	5.99	6.46	8.19	8.36	9.14
OC (%)	20.0	35.85	39.5	39.35	39.45	48.9	45.5
OM (%)	34.4	61.66	67.94	67.68	68.25	84.60	78.72
Total N (%)	0.90	1.045	1.06	1.31	2.6	2.73	1.54
Ca(%)	0.30	2.81	2.62	2.71	3.02	3.56	3.07
Mg (%)	0.10	1.89	1.12	0.9	1.955	1.81	1.98
K (%)	0.08	1.04	1.58	0.195	1.84	3.16	1.06
S (%)	0.02	0.116	0.198	0.09	0.34	0.29	0.64
P (%)	0.13	0.172	0.196	0.173	0.54	0.65	0.47
Cu (%)	0.002	0.002	0.002	0.023	0.014	0.011	0.001
Fe (%)	1.20	0.152	0.124	0.275	0.188	0.062	0.131
Mn (%)	0.02	0.085	0.069	0.166	0.082	0.037	0.073
Zn (%)	0.005	0.004	0.005	0.032	0.017	0.072	0.019

The highest P content was found in the biochar from the chickpea straw compared with the other straws, and was attributed to the much higher P content in chickpea straw (Table 2). Therefore, the higher contents of base cations, N and P in feedstock resulted in the greater concentrations for these elements in biochar. The contents of base cations and total P in biochar were higher than in the feedstock-also evident for total N in biochars from straws of rice, wheat, maize and mustard. These results suggest that the chemical components were concentrated in the biochar during pyrolysis, leading to higher contents of these chemical components in biochar compared to the feedstock. All biochars had abundant soluble base cations and exchangeable base cations. These base cations can be released into acid soils easily, thus incorporation of biochar can improve soil fertility.

Amelioration effect of cowdung, crop straws and crop straw biochar on the acid soil

Soil pH increased by the incorporation of cowdung, crop straws and crop straw biochar (*$p<0.05$*). At the end of the field experiment, soil pH was 0.6 to 0.12 units higher for the treatments with crop straws incorporated than that of controls,respectively.Compared with control, cowdung applied with fertilizer slightly increased soil pH.Nitrification of NH_4^+ in controls is the main reason for the decreased soil pH due to (NO_3^-+NO_2^-)-as consistent with the change of soil pH in the corresponding treatments.These results suggest that the inhibition of nitrification is the main mechanism for the ameliorating effect of the straws and CD on soil acidity. The changing of the soil pH were similar to those for a study in which acid soils were treated with lupin shoots (Xu and Coventry, 2003). A similar phenomenon was also reported by Wang *et al*. (2011) when an acidic ultisol was incubated with 1% straws of pea and soybean, and 1% Chinese milk vetch shoots. The maximum value of soil pH increased with the increased addition level of the three straws.

Table 3. Soil pH and the difference of soil pH (ΔpH) at the end of four years field experiment

Treatment with straw	Soil pH	ΔpH	Treatment with biochar	Soil pH	ΔpH
Control	5.40	-	Cowdung	5.42	0.02
Groundnut Straw	5.46	0.06	Groundnut Biochar	5.61	0.21
Chickpea Straw	5.44	0.04	Chickpea Biochar	5.67	0.27
Mustard Straw	5.44	0.04	Mustard Biochar	5.64	0.24

The transformation of N was responsible for the soil pH fluctuation for the treatments with legume straws added due to their relatively higher N contents (Table 3). The input of ash alkalinity and the mineralization of organic N are two main factors increasing the soil pH while subsequent nitrification of NH_4^+–N would have contributed to declines in soil pH. This is due to the release of protons from the reaction, and the dependence of the final soil pH on the balance of these reactions (Xu and Coventry, 2003; Wang *et al*., 2011). Therefore, the nitrification of NH_4^+ counteracted the amelioration effects of legume straws on the acid soil. The incorporation of crop straw biochars increased soil pH ($p<0.05$). These biochars increased soil pH from 0.21 to 0.37 units at the addition of 10 t ha^{-1}, respectively (Table 3). Compared with biochars materials and crop straw were incorporated into acid soils, their higher pH and greater alkalinityled to a greater increase in soil pH.

The pyrolysis of legume straws made the organic N in biochar unavailable to soil microorganisms. The N in the biochar exists mostly as organic N, with inorganic N representing no more than 0.1% of total N. Therefore, although the C/N ratio of the biochars from legume straws was close to that of their feedstock, the organic N is difficult for microorganisms to utilize, and so mineralization of organic N and subsequent nitrification of NH_4^+ from biochar is weak in soil. The NH_4^+ in the nitrification reaction mainly came from the original soil NH_4^+, not from biochar.

Ameliorating mechanism of the biochar from crop straws

Organic anions associated with base cations Ca^{2+},Mg^{2+}, K^+ and Na^+ in plant materials are the main source of alkalinity in plant materials (Yan *et al*., 1996; Wong *et al*., 2000; Li *et al*., 2008). When plant materials are returned to and decomposed in soils, the decarboxylation of organic anions in the materials consumes protons and thus neutralizes soil acidity (Yan *et al*., 1996). Generally, legume materials have higher alkalinity than non-legume materials due to more uptake of cations than anions during the growth of legumes, and thus more organic anions accumulate in legume materials. The data of the present and previous reports (Chan *et al*., 2007; Novak *et al*., 2009) indicate that biochar is commonly alkaline, and so can be used as soil amendments to neutralize soil acidity and increase soil pH. However, the forms of the alkalis in biochar are not still understood.

Effect of amendments on maize growth and yield

Maize yield increased with application of organic amendments whereas crop straw showed least performance compared with its derivate biochar treatments (Table 4). Maize plant height showed highest in the chickpea straw biochar treatment and statistically similar with mustard and groundnut straw biochar where same amount of NPK fertilizer was applied in all treatments. Application of biochar showed increased parameters because of biochar reduces exchangeable acidity, increased soil pH of acidic soils, and inherently contains significant amounts of plant nutrients such as potassium, calcium and magnesium, it is reported that these are the main reasons for enhanced plant growth (Chan and Xu, 2009).

The grain yields at mature stage have been presented in Table 4. The data showed that biochar addition could enhance the crop yields. The average yield of the BARI Khoibhutta on the RDCF soils without biochar weighed 3.52t ha^{-1}. Obviously, crop straw increased the grain yield from 4.29 t ha^{-1} to 4.69t ha^{-1} where crop straw biochar increased 4.89 t ha^{-1} to 5.03 t ha^{-1}. In addition of cowdung 5 t ha^{-1}, average yield produced 3.87 t ha^{-1}but decreasing trained from first year to 4th year. In comparison to the average yield by crop straw and crop straw biochar, crop straw biochar enhanced the yield up to 43% from control and 26% from crop straw, except for the yield that was increased by over 100% than that reported by Yamato *et al.*(2006).

Table 4. Effect of cowding, straw and biochar on maize growth 2021-2022

Treatment	Plant height (cm)	Dry weight/m^2 (kg)	Cob no. m^{-2}	Cob length (cm)	Cob diameter (cm)	100 grain weight (gm)	Yield (t ha^{-1})
T_1 = RDCF	182b	1.04ef	13.2b	17.27c	3.43	16.93de	3.52d
T_2 = RDCF + CD 5 t ha^{-1}	181b	0.99f	13.5b	17.23c	3.54	16.66e	3.87d
T_3 = RDCF + GS 10 t ha^{-1}	180b	1.17de	12.9b	17.8bc	3.43	17.4cde	4.29c
T_4 = RDCF + CS 10 t ha^{-1}	190ab	1.23cd	13.8b	18.4abc	3.51	17.93cd	4.56bc
T_5 = RDCF + MS 10 t ha^{-1}	192ab	1.35bc	14.4ab	18.4abc	3.52	18.46bc	4.69abc
T_6= RDCF + GSB10 t ha^{-1}	202a	1.36bc	15.6ab	19.13ab	3.64	19.13ab	4.89ab
T_7= RDCF +CSB 10 t ha^{-1}	205a	1.42ab	16.8a	19.53a	3.63	19.86a	5.03a
T_8= RDCF +MSB10 t ha^{-1}	204a	1.55a	16.8a	20.07a	3.66	20.13a	4.95ab
CV (%)	5.04	7.59	10.88	5.03	7.09	3.39	5.12

These observations were similar with previous reports. Application of biochars increased the biomass yields in acid soils significantly (Atkinson *et al*., 2010; Waters *et al*., 2011, Masud *et al*., 2014). According to the soil taxonomy map from U.S. Dept. of Agriculture, the soil in the study of

Manuel (Olmo *et al.*, 2014) was similar to the soil in our study and the results were similar that biochar increased the yield by about 20%.

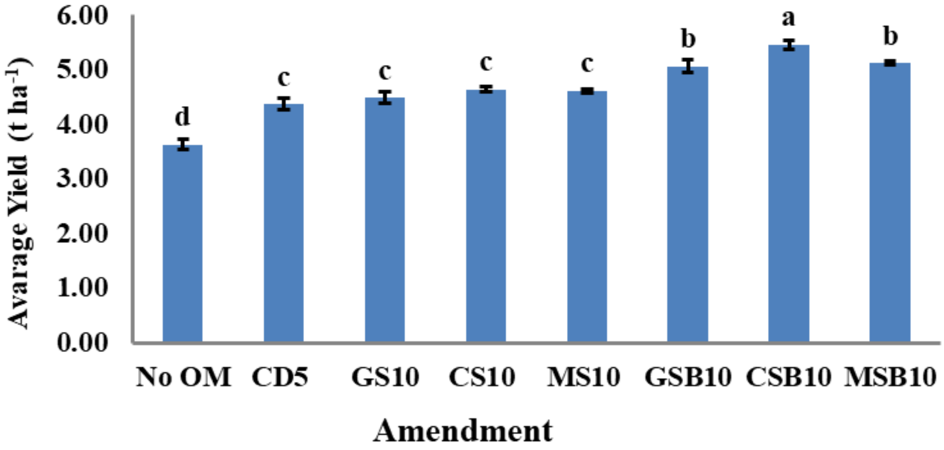

Fig. 1. After four year soil organic matter status using different organic amendment

Effect of amendments on soil pH

After four harvest of maize, soil pH in field experiment was increased by using crop straw biochar, where reduction and or unaffected of soil pH was observed among treatments with crop straws. The ameliorating effects were greater for the biochars derived from crop straw, which was consistent with the observations in the previous incubation study. Response of the effect of organic manures on soil acidity has not been consistent. Decomposition of organic matter has been known to lead to introduction of organic and inorganic acids with concomitant increases in soil acidity (Agbede, 2009). The study of Agbede (1984) with application of residues showed that the significant pH improvement obtained with lighter soils was not observed in heavier ones.

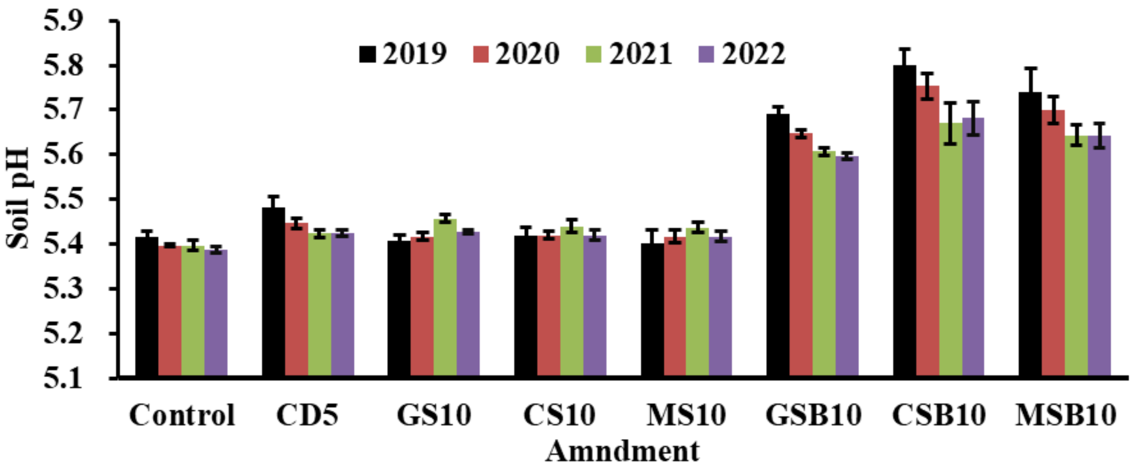

Fig. 2. Changes of soil pH after maize crop harvest using cowdung, crop straw and their biochar with RDCF under field condition

Nutrient uptake is usually governed by nutrient concentration in plant tissue and dry matter yield. The absorption of nutrients depends on availability of their ionic forms in the rhizosphere, which is influenced by soil acidity and concentration of nutrients in the soil. Biochar amendments resulted in the increase in N uptake by maize, and more uptakes in chickpea straw biochar where P, K, S, Ca and Mg uptake higher in the same treatment. N uptake by plants grown in biochar amended soils was reported before (Sarfraz *et al*., 2017; Van Zwieten *et al*., 2010), which was similar with our observation in this study. The increase in P uptake may be mainly due to the increase in soil pH which increased P availability to plant.

Table 5. The nutrient uptake by maize after harvest from field (2021)

Treatment	Nutrients uptake by maize (kgha^{-1})							
	N	P	K	Ca	Mg	S	Zn	B
T_1 = RDCF	80f	21.1d	84.4d	25.8e	12.1d	21.9e	0.41e	0.46c
T_2 = RDCF+ CD 5 t ha^{-1}	97e	28.7c	82.8d	28.8e	13.9cd	24.2e	0.45e	0.46c
T_3 = RDCF+ GS 10 t ha^{-1}	115d	32.6bc	96.3cd	35.6cd	17.2bc	30.1d	0.52d	0.50c
T_4 = RDCF+ CS 10 t ha^{-1}	121cd	36.9ab	101bc	33.9d	17.1bc	33.1cd	0.56cd	0.52bc
T_5 = RDCF+ MS 10 t ha^{-1}	135ab	39.8a	114ab	41.1b	19.2b	36.3bc	0.61bc	0.53bc
T_6 = RDCF+ GSB 10 t ha^{-1}	130bc	38.3ab	109abc	38.6bc	24.9a	37.4bc	0.61bc	0.50c
T_7 = RDCF+ CSB 10 t ha^{-1}	140ab	40.4a	119a	36.7bcd	25.0a	38.9ab	0.65ab	0.60ab
T_8 = RDCF+ MSB 10 t ha^{-1}	141a	40.1a	122a	46.6a	25.8a	43.2a	0.71a	0.64a
CV (%)	4.78	10.72	8.42	6.99	10.53	7.71	6.69	9.57

The results on total uptake of N, P, K, Ca, Mg, S, B and Zn by maize varied significantly. Significantly higher nutrient uptake by maize was observed in biochar amended soil, which was consistent with the contents of these base cations (Table 2) in the amendments and the increase in soil exchangeable Ca and Mg induced by the amendments. The lowest uptake of nutrient element was recorded in treatment receiving 100% RDCF only. Therefore, the application of chickpea straw biochar was the best choice for amelioration of acid soil, because this option achieved a greater amelioration effect on soil acidity and increased soil nutrients of Ca, Mg and K and thus enhanced the uptake of Ca, Mg, K and P by plants simultaneously.

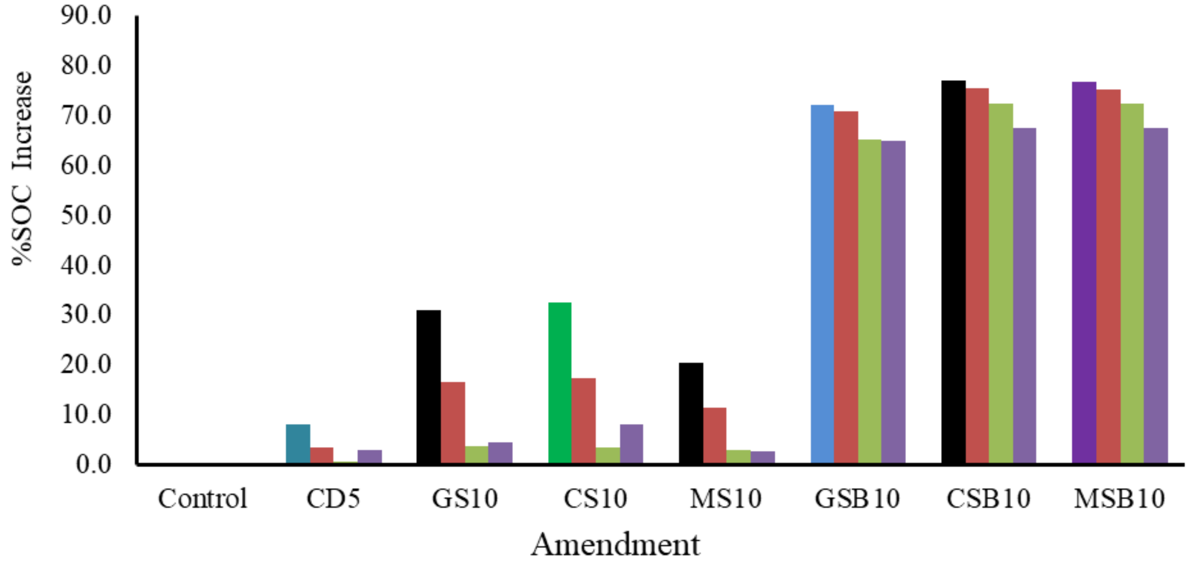

Fig. 3. Percent SOC increase from control after four harvest using cowdung, crop straw and their biochar with RDCF under field condition

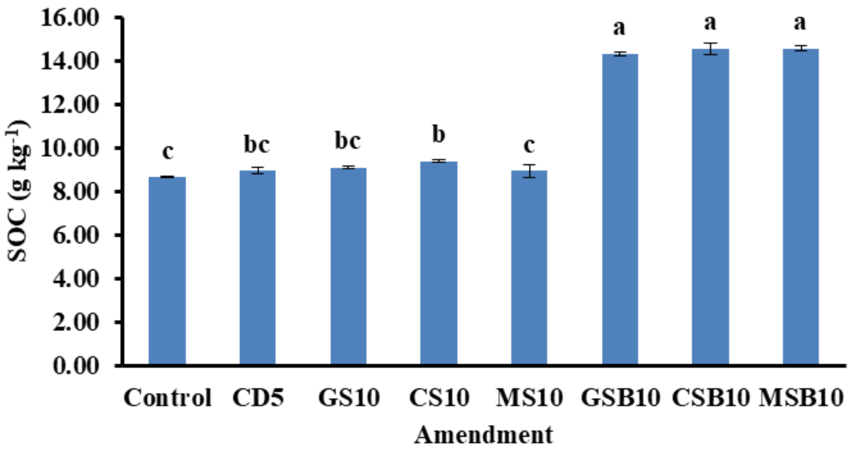

Fig 4. Soil organic carbon status after end of the experiment

Carbon status

SOC status evaluated after one year and found that crop straw and their biochars increased the soil carbon status. Incensement of carbon stock in soil ranges from 0.18 to 0.28 unit by using crop straw and biochar from same sources increases two fold and increases soil organic carbon (around 0.60 unit). The carbon content decreased from CD and crop straws rapidly but biochar carbon slightly decreased up to end of the experiment. Straw return has been widely recommended as an environmentally friendly practice to manage carbon (C) sequestration in agricultural ecosystems but the high amount of recalcitrant C molecules in biochar (BC) decreases in the C loss and increases in C sequestration. In contrast, crop straw had high amounts of labile components that enhanced the C emission and reduced C sequestration.

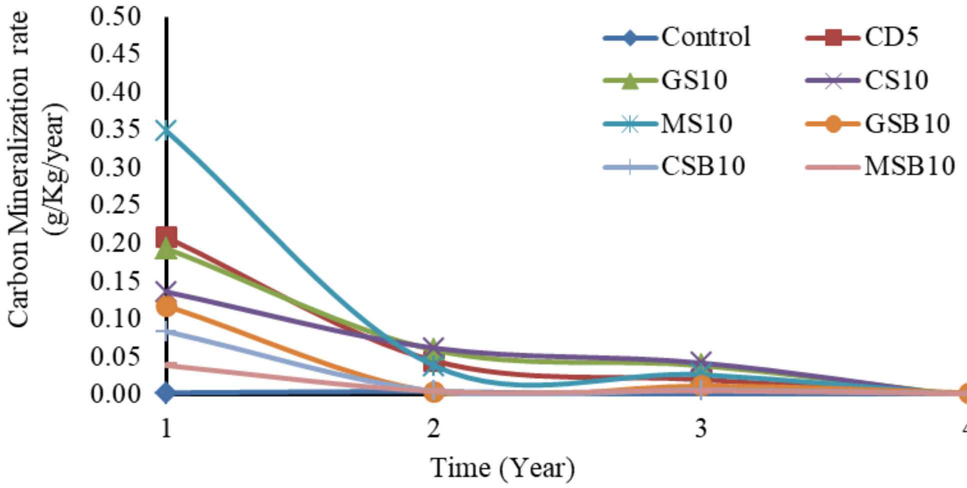

Fig 5. Mineralization rate of different amendment with RDCF under field condition

The result indicates that organic application initially increased soil organic carbon content of organic amended soils (Figure 4). Organic carbon content was found from 8.97 to 14.57 in organic treated soils. Organic carbon content decreased significantly ($p < 0.05$) in control (0.1 g kg^{-1}) i.e. 1.15% decreased at the end of experiment. However, application of cow dung into soil increases SOC but last short period of time (Figure 4). Comparatively higher content of organic carbon was found under biochar treated soil (14.33 to 14.57 g kg^{-1}) and at the end of the experiment 9-17% decrease. The organic matter application has positive effect on the input of total organic carbon in the soil.We fitted the results with the model and estimated the maximum of unstable carbon pool as given in Fig 4. Application of biochar obviously decreased the minimum of unstable carbon and raw organic compound decreased maximum unstable carbon in the field experiment period.

Conclusion

Based on four years trial, the incorporation of crop residue and their biochar showed significant effect on yield and yield components of maize. The grain yields in all the treatments are more or less near about, but these are significantly different from each other. Biochar, especially those were high in pH, enhanced soil pH, whereas reduction and or unaffected of soil pH was observed among treatments with crop straws. The organic matter content increased with the application of cowdung, crop straws and biochars but biochar treated soil preserve the carbon long time. This result suggests that part of the main mechanisms behind the reported positive effects of chickpea straw biochar (CSB) application to soils on plant productivity may be a combined effect of soil nutrient release following biochar application and liming property of biochar. The technology of using biochar as soil conditioner and fertilizer in the soil is therefore a promising future alternative to the production of crops such as maize.

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NUTRIENT MANAGEMENT FOR A ROOFTOP GARDEN

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Abstract

The study has been conducted in Gazipur (rooftop of Soil Science Division) during the year of 2020-2021 and 2021-2022. Two types of research work have been conducted in this study. One is organic and inorganic fertilizer combination based research which have 8 treatments viz. T_1 = 100% STB, T_2 = T_1 + 1 kg kitchen waste (decomposed) 6 kg^{-1} soil, T_3 = 80% of T_1 + 2 kg kitchen waste (decomposed) 6 kg^{-1} soil, T_4 = T_1 + 1 kg cowdung 6 kg^{-1} soil, T_5 = 80% of T_1 + 2 kg cowdung 6 kg^{-1} soil, T_6 = T_1 + 1 kg vermicompost 6 kg^{-1} soil, T_7 =80% of T_1 + 2 kg vermicompost 6 kg^{-1} soil & T_8 = absolute control; and another is towards soil to organic materials ratio based research for safe food production in the rooftop garden consisting of 6 treatments viz.T_1 = 1 kg kitchen waste for 1 kg soil, T_2 = 1 kg kitchen waste for 2 kg soil, T_3 = 1 kg cowdung for 1 kg soil, T_4 = 1 kg cowdung for 2 kg soil, T_5 = 1 kg vermicompost for 1 kg soil and T_6 = 1 kg vermicompost for 2 kg soil. The experimental activities include fertilizer management of some vegetables, fruits and flowers; and influence of different ratio of soil and organic materials on the growth and yield of Bitter gourd for rooftop garden. Prior to setting the experiments initial soil samples as well as organic fertilizers were analyzed and nutrient statuses were determined. In case of 1st experiment, T_7 treatment (80% of T_1 + 2 kg vermicompost 6 kg^{-1} soil) showed best performance followed by T_3 treatment (80% of T_1 + 2 kg kitchen waste 6 kg^{-1} soil) for maximizing the yield of vegetables, fruits and flowers grown on the rooftop garden. In case of 2nd experiment,T_5treatment (1 kg vermicompost for 1 kg soil) performed better in compared to others in the experiments related to influence of different ratio of soil and organic materials on the growth and yield of Bitter gourd for rooftop garden. The lowest yield was recorded from the T_4 treatment (1 kg cowdung for 2 kg soil).

Introduction

Urban agriculture is a global and growing pursuit for economic development, job creation, food security, and community building. But major constrains for this are competition for space with other forms of urban development, a lack of formalized land use rights, and health hazards related to food contamination. The use of green roof technology in urban agriculture has the potential to alleviate some of these problems, without adversely affecting the benefits provided by urban agriculture. It would not only enable the use of land for development and agriculture, but may facilitate the formation of formal space and water use agreements and enable redistribution of ground level resources among urban farmers (Whittinghill and Rowe 2012). This could decrease the use of contaminated land and water at ground level and alleviate health concerns.

Rooftop gardening is going to popular in urban areas of Bangladesh. Bangladesh is one of the main victims of climate change. A country needs 25% of its land to be occupied by forests to maintain its ecological balance, but here the percentage is less than 8% (BBS, 2015). Due to the urbanization, our cultivable lands decrease day by day. As there is limited scope for horizontal expansion of agriculture, vertical expansion is one of the major ways to increase crop productivity. Rooftop gardening is one of the potential areas for vertical expansion. As it is estimated that, there are about 2 lac house buildings in Dhaka city. A rooftop garden not only can be a source of agricultural production but also can be able to fix CO_2 and some other gases causing greenhouse effect (BARI, 2019). So, there are many scopes for rooftop gardening.

Organic fertilizers are utilized globally to protect the soils against deterioration and food pollution. Organic nutrients increase soil enzyme activity, available nitrates, carbon to total organic carbon ratio and metabolic quotients resulting in enhanced soil fertility (Okwuagwu et al., 2003). Organic fertilizers improve soil fertility by modifying soil structure, pH, biophysical conditions and availability of essential nutrients (Atiyeh et al., 2002). Though some interested people are producing vegetables, fruits and flowers on their rooftop but research information on nutrient management for a rooftop garden is not available. Moreover, extensive literature review showed very little or no information regarding fertilizer trials on rooftop garden. With a view to generate information on these aspects of the rooftop garden, the experiment was formulated. The information might be useful and can play a great role to maximize the yield of a rooftop garden as well as ensure family nutrition of the urban people. Objective of the study was to develop fertilizer recommendation for rooftop garden and to find out the optimum soil and manure ratio as a media for better growth and development of crops under rooftop garden.

Materials and Methods

Expt.1. Fertilizer management of some vegetables, fruits and flowers for a rooftop garden

Experiment was conducted at the rooftop of Soil Science Division, BARI, Gazipur during 2020-2021 and 2021-2022. The initial soil sample, vermicompost, compost and cowdung collected before establishing the experiment were analyzed in the laboratory following standard methods. Chemical parameters of the experimental soil and others organic materials are presented in Tables 1a and 1b, respectively.

Nutrient management based research (organic and inorganic fertilizer combination) for food production in the rooftop garden was laid out in a completely randomized design with three replications. These were eight treatments viz. T_1 = 100% STB, T_2 = T_1 + 1 kg kitchen waste (decomposed) 6 kg^{-1} soil, T_3 = 80% of T_1 + 2 kg kitchen waste (decomposed) 6 kg^{-1} soil, T_4 = T_1 + 1 kg cowdung 6 kg^{-1} soil, T_5 = 80% of T_1 + 2 kg cowdung 6 kg^{-1} soil, T_6 = T_1 + 1 kg vermicompost 6 kg^{-1} soil, T_7 =80% of T_1 + 2 kg Vermicompost 6 kg^{-1} soil &T_8 = Absolute control were selected. Different types of pot (Tob, Half dram and Wood box) were used. Different vegetables namely Tomato (BARI Tomato-15), Indian Spinach (BARI Puishak-2) and Brinjal (BARI Bt. Brinjal-2) were cultivated. Three fruits namely Dragon fruit (BARI Dragon Fruit-1), Mango (BARI Mango-3) and Lemon (Seedless) were cultivated. Two flowers namely Tuberose (Single line) and Rose (Hybrid) were cultivated.

Fertilizer N-P-K-S-Zn and B were supplied from urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. In case of vegetables and seasonal flowers, all organic fertilizer and PKSZnB and $^{1}/_{3}$ of N were applied at the time of final soil preparation. The remaining two third of N were applied as top dress after sowing. In case of fruits and rose, all organic fertilizer and $^{1}/_{6}$PKSZnB and $^{1}/_{6}$ of N were applied at the time of final land preparation. The remaining fertilizers were applied as top dress at two month intervals after transplanting. Irrigations and other intercultural operations were done as when required.

The soil used in the rooftop garden is sandy loam in texture having pH 6.5 (Table 1a). The organic matter content was low (1.09%) and total N content was very low (0.08%). Available P, K,S & B were medium, low, medium & low, respectively but available Ca, Mg and Zn were exist in satisfactory level.

Table 1a. Chemical properties of soil (Initial) used in the rooftop experiment

Soil properties	pH	OM	Total N	K	Ca	Mg	P	S	Zn	B	Cu	Fe	Mn
		(%)		meq 100 g^{-1} soil						µg g^{-1} soil			
Analytical value	6.5	1.09	0.08	0.18	5.8	2.2	12.0	16	1.6	0.17	4.0	44	2.6
Critical level	-	-	0.12	0.12	2.0	0.5	7	10	0.6	0.2	0.2	4.0	1.0

Manural quality of compost, cowdung and vermicompost were present in Table 1b. Vermicompost was more nutrient rich followed by compost and cowdung.

Table 1b. Nutrient status of vermicompost, compost and cowdung used in the rooftop experiment

Name of the manure	pH	OC	Ca	Mg	K	Total N	P	S	Zn	B	Pb	Cd	As
						%						μg g^{-1}	
Compost	7.1	16.3	1.50	2.10	1.17	1.23	0.79	0.50	0.14	0.013	2.89	2.11	1.72
Cowdung	7.5	15.4	2.23	0.44	0.69	1.15	0.57	0.36	0.15	0.011	3.10	2.84	1.26
Vermicompost	7.2	17.9	2.10	2.60	1.94	1.68	1.26	0.89	0.16	0.015	2.61	2.19	1.14

Moisture content of Compost = 12.15 %, Cowdung = 12.46 % and Vermicompost = 11.96 %

Results and Discussion

The effect of different nutrient management packages on the yield and yield contributing characters of Tomato are presented in Table 2. Yield plant^{-1} and yield attributes like plant height, number of fruits plant^{-1} and individual fruit weight of tomato were significantly influenced by different nutrient packages in this study. The significantly highest plant height (76.5 cm) was obtained from T_7 treatment (80% of T_1 + 2 kg Vermicompost /6kg soil) whereas the lowest plant height (44.2 cm) was obtained from T_8 treatment (Control). Significantly highest number of fruits plant^{-1} (24.3) was obtained from T_7 treatment whereas there is no fruits in T_8 treatment. The maximum individual fruit weight (59.2 gm) was obtained from T_7 treatment followed by T_3 treatment whereas no individual fruit weight in control treatment due to no bearing of fruits in control treatment. The highest yield plant^{-1} (1.43 kg) was recorded from T_7 treatment (80% of T_1 + 2 kg Vermicompost /6kg soil) followed by T3 treatment whereas there is no fruit yield from T_8 treatment.

Table 2. Effect fertilizer doses on yield and yield contributing characters of Tomato (Variety: BARI Tomato-15) at at Rooftop of Soil Science Division, BARI, Gazipur

Treatments	Plant height (cm)	No. of fruits plant^{-1}	Individual fruit wt. (gm)	Yield plant^{-1} (kg)
T_1 = 100% STB ($N_{2.5}$ $P_{0.2}$ $K_{0.5}$ $S_{0.2}$ $Zn_{0.2}$ $B_{0.09}$ gm/15 kg soil)	60.5e	9.6e	23.3c	0.25f
T_2 = T_1 + 1 kg Kitchen waste (decomposed) /6kg soil	69.9cd	17.2c	53.6bc	0.92d
T_3 = 80% of T_1 + 2 kg Kitchen waste (decomposed)/6kg soil	72.4bc	20.4b	57.1ab	1.16b
T_4 = T_1 + 1 kg Cowdung/6kg soil	67.3d	15.5d	52.3c	0.82e
T_5 = 80% of T_1 + 2 kg Cowdung/6kg soil	69.2cd	19.1b	57ab	1.06c
T_6 = T_1 + 1 kg Vermicompost/6kg soil	73.7ab	19.4b	54.4bc	1.06c
T_7 =80% of T_1 + 2 kg Vermicompost /6kg soil	76.6a	24.3a	59.2a	1.43a
T_8 = Absolute control	44.3f	0.0f	0.0e	0.0g
CV (%)	3.02	5.96	4.16	3.22

The effect of different nutrient management packages on the yield and yield contributing characters of Bt. Brinjal are presented in Table 3. Yield plant^{-1} and yield attributes like plant height, number of fruits plant^{-1}, and individual fruit weight of brinjal were significantly influenced by different nutrient packages in this study. The significantly highest plant height 57.7 cm was obtained from T_7 treatment (80% of T_1 + 2 kg Vermicompost /6kg soil) whereas the lowest plant height 18.5 cm was obtained from T_8 treatment (Control). Significantly highest number of fruits plant^{-1} (13.4) was obtained from T_7 treatment whereas there is no fruits in T_8 treatment. The maximum individual fruit weight 86.3 gm was obtained from T_7 treatment followed by T_3 treatment whereas no individual fruit weight in control treatment due to no bearing of fruits in control treatment. The highest yield plant^{-1} 1.12 kg was recorded from T_7 treatment (80% of T_1 + 2 kg Vermicompost /6kg soil) followed by T_3 treatment whereas there is no fruit yield from T_8 treatment.

Table 3. Effect of fertilizer doses on yield and yield contributing characters of Bt. Brinjal (Variety: BARI Bt. Brinjal-2) at Rooftop of Soil Science Division, BARI, Gazipur

Treatment	Plant height (cm)	No. of fruits plant^{-1}	Individual fruit wt. (gm)	Yield plant^{-1} (kg)
T_1 = 100% STB (N_2 $P_{0.1}$ $K_{0.5}$ $S_{0.2}$ $Zn_{0.2}$ $B_{0.09}$ gm/15 kg soil)	39.7d	6.1e	52.1c	0.32f
T_2 = T_1 + 1 kg Kitchen waste (decomposed) /6kg soil	53.9bc	9.4cd	78.6ab	0.71d
T_3 = 80% of T_1 + 2 kg Kitchen waste (decomposed)/6kg soil	56.4ab	11.3b	81.2ab	0.93b
T_4 = T_1 + 1 kg Cowdung/6kg soil	51.2c	8.5d	74.9b	0.61e
T_5 = 80% of T_1 + 2 kg Cowdung/6kg soil	56.0ab	10.2bc	78.7ab	0.78c
T_6 = T_1 + 1 kg Vermicompost/6kg soil	54.3bc	10.0bcd	79.5ab	0.77c
T_7 =80% of T_1 + 2 kg Vermicompost /6kg soil	57.9a	13.4a	86.3a	1.12a
T_8 = Absolute control	18.7e	0f	0d	0g
CV (%)	4.16	12.09	8.45	3.06

The effect of different nutrient management packages on the yield and yield contributing characters of Indian Spinach are summarized in Table 4. The highest plant height (34.9 cm) was observed in T_7 treatment which was statistically identical with T_3 treatment whereas the lowest plant height (14.6 cm) was observed in T_8 (control) treatment. The maximum number of leaves plant^{-1} (42.5) was observed in T_7 treatment whereas the minimum number of leaves plant^{-1} (14.7) was observed in T_8 (control) treatment. The maximum fresh wt. plant^{-1} (132.7 gm) was observed in T_7 treatment whereas the minimum fresh wt. plant^{-1} (42.6 gm) was observed in T_8 (control) treatment. The maximum yield m^{-2} (2.9 kg) was observed in T_7 treatment followed by T_3 treatment whereas the minimum yield m^{-2} (1.0 kg) was observed in T_8 (control) treatment

Table 4. Effect fertilizer doses on yield and yield contributing characters of Indian Spinach (Variety: BARI Puishak-2) at at Rooftop of Soil Science Division, BARI, Gazipur

Treatment	Plant height (cm)	Leaves plant^{-1} (No.)	Fresh wt. plant^{-1} (gm)	Yield m^{-2} (kg)
T_1 = 100% STB (N_{19} $P_{2.5}$ K_8 S_2 $Zn_{0.8}$ $B_{0.2}$ gm/m^2)	21.5e	22.3e	69.2e	1.7cd
T_2 = T_1 + 1 kg Kitchen waste (decomposed) /6kg soil	29.8cd	32.1c	100.9c	2.2abcd
T_3 = 80% of T_1 + 2 kg Kitchen waste (decomposed)/6kg soil	33.7ab	37.2b	115.6b	2.6ab
T_4 = T_1 + 1 kg Cowdung/6kg soil	27.5d	27.8d	89.3d	2.0bcd
T_5 = 80% of T_1 + 2 kg Cowdung/6kg soil	31.3bc	34.4bc	107.8bc	2.4abc
T_6 = T_1 + 1 kg Vermicompost/6kg soil	31.2bc	36.2b	112.6b	2.5abc
T_7 =80% of T_1 + 2 kg Vermicompost /6kg soil	34.9a	42.5a	132.7a	2.9a
T_8 = Absolute control	14.6f	14.7f	42.6f	1.0d
CV (%)	5.35	6.47	5.19	7.72

Fruits

The effect of different nutrient management packages on the yield and yield contributing characters of Mango are presented in Table 5. The highest plant height (1.97 m) was observed in T_7 treatment which was statistically identical with T_6 treatments whereas the lowest plant height (1.12 m) was observed in T_8 (control) treatment. The maximum number of fruits plant^{-1} (12.33) was observed in T_7 treatment whereas the minimum number of fruits plant^{-1} (4.33) was observed in T_8 (control) treatment. The maximum yield plant^{-1} (1.825 kg) was observed in T_7 treatment followed by T_3 treatment whereas the minimum yield plant^{-1} (0.426 kg) was observed in T_8 (control) treatment.

Table 5. Effect of fertilizer doses on yield and yield contributing characters of Mango (Variety: BARI Aam-3) at Rooftop of Soil Science Division, BARI, Gazipur

Treatment	Plant height (m)	Flowering time	Fruit weight (g)	Fruits/plant (no.)	Yield (kg/plant)
T_1 = 100% STB (N_{16} P_{14} K_{13} S_{13} $Zn_{0.5}$ $B_{0.5}$ gm/75 kg soil)	1.51 c	Feb-Mar	118.30 bc	08.00 c	0.946 c
T_2 = T_1 + 1 kg Kitchen waste(decomposed) /6kg soil	1.72 ab	Feb-Mar	126.00 ab	10.00 b	1.260 ab
T_3 = 80% of T_1 + 2 kg Kitchen waste (decomposed)/6kg soil	1.80 ab	Feb-Mar	133.00 a	11.33 a	1.506 a
T_4 = T_1 + 1 kg Cowdung/6kg soil	1.59 b	Feb-Mar	121.90 ab	10.67 ab	1.300 ab
T_5 = 80% of T_1 + 2 kg Cowdung/6kg soil	1.64 b	Feb-Mar	134.60 ab	11.00 a	1.480 ab
T_6 = T_1 + 1 kg Vermicompost/6kg soil	1.88 a	Feb-Mar	136.00 a	12.00 a	1.632 a
T_7 = 80% of T_1 + 2 kg Vermicompost /6kg soil	1.97 a	Feb-Mar	148.07 a	12.33 a	1.825 a
T_8 = Absolute control	1.12 d	Feb-Mar	106.83 c	4.33 d	0.462 d
CV (%)	7.63	-	3.89	9.98	9.67

The effect of different nutrient management packages on the yield and yield contributing characters of Lemon are presented in Table 6. The highest plant height (99 cm) was observed in T_7 treatment which was statistically identical with T_6 treatments whereas the lowest plant height (70 cm) was observed in T_8 (control) treatment. The maximum number of fruits plant^{-1} (63.15) was observed in T_7 treatment whereas the minimum number of fruits plant^{-1} (10.12) was observed in T_8 (control) treatment. The maximum yield plant^{-1} (3.725 kg) was observed in T_7 treatment followed by T_3 treatment whereas the minimum yield plant^{-1} (0.546 kg) was observed in T_8 (control) treatment.

Table 6. Effect of fertilizer doses on yield and yield contributing characters of Lemon (Variety: Seedless) at Rooftop of Soil Science Division, BARI, Gazipur

Treatment	Plant height (cm)	Fruit weight (g)	Fruits/plant (no.)	Yield (kg/plant)
T_1 = 100% STB (N_{15} P_{15} K_{15} S_{12} $Zn_{0.5}$ $B_{0.5}$ gm/75 kg soil)	80 c	55 ab	18.00 e	0.990 c
T_2 = T_1 + 1 kg Kitchen waste (decomposed) /6kg soil	89 ab	57 a	35.00 d	1.995 ab
T_3 = 80% of T_1 + 2 kg Kitchen waste (decomposed)/6kg soil	90 ab	58 a	50.35 b	2.920 a
T_4 = T_1 + 1 kg Cowdung/6kg soil	92 b	57 a	42.97 c	2.449 ab
T_5 = 80% of T_1 + 2 kg Cowdung/6kg soil	94 b	58 a	51.05 b	2.960 ab
T_6 = T_1 + 1 kg Vermicompost/6kg soil	94 a	57 a	52.85 b	3.012 a
T_7 =80% of T_1 + 2 kg Vermicompost /6kg soil	99 a	59 a	63.15 a	3.725 a
T_8 = Absolute control	70 d	54 ab	10.12 f	0.546 d
CV (%)	8.35	4.21	13.98	10.03

The effect of different nutrient management packages on the yield and yield contributing characters of Dragon fruit are presented in Table 7. The highest plant height (2.78 m) was observed in T_7 treatment and the lowest plant height (1.98 m) was observed in T_8 (control) treatment. The maximum number of fruits plant^{-1} (19.12) was observed in T_7 treatment whereas the minimum number of fruits plant^{-1} (0.0) was observed in T_8 (control) treatment. The maximum yield plant^{-1} (4.60 kg) was observed in T_7 treatment and the minimum yield plant^{-1} (0.0 kg) was observed in T_8 (control) treatment.

Table 7. Effect of fertilizer doses on yield and yield contributing characters of Dragon fruit (Variety: BARI Dragon fruit-1) at Rooftop of Soil Science Division, BARI, Gazipur

Treatment	Plant height (m)	Individual fruit weight(g)	Fruits plant^{-1} (no.)	Yield (kg plant^{-1})
T_1 = 100% STB (N_{38} P_{28} K_{26} $S_{20}Zn_2$ B_2gm 75 kg^{-1} soil)	2.25 c	198.5 d	09.02 c	2.17 f
$T_2 = T_1$ + 1 kg kitchen waste(decomposed) 6 kg^{-1} soil	2.59ab	221.4 b	15.03 b	3.73 d
T_3=80% of T_1 + 2 kg kitchen waste (decomposed) 6 kg^{-1} soil	2.73 a	234.0 ab	18.01 a	4.64b
$T_4 = T_1$ + 1 kg Cowdung 6 kg^{-1} soil	2.54 b	211.9 c	14.45 bc	3.35e
T_5 = 80% of T_1 + 2 kg Cowdung 6 kg^{-1} soil	2.73 a	230.0 ab	17.91 a	4.33c
$T_6 = T_1$ + 1 kg Vermicompost 6 kg^{-1} soil	2.71 a	226.1 b	15.56 b	3.82d
T_7 = 80% of T_1 + 2 kg Vermicompost 6 kg^{-1} soil	2.82 a	241.0 a	19.12 a	4.95 a
T_8 = Absolute control	1.97 d	0.0 e	0.0 d	0.80 g
CV (%)	8.43	6.23	12.56	7.05

Flowers

The effect of different nutrient management packages on the yield and yield contributing characters of Tuberose are summarized in Table 8. The highest plant height (93.1 cm) was recorded in T_7 treatment (80% of T_1 + 2 kg Vermicompost /6kg soil) which was statistically identical with T_3, T_5& T_6 treatments whereas the lowest plant height (52.2 cm) was observed in T_8 (control) treatment. The maximum spike length(33.2 cm) was observed in T_7 treatment which was statistically at par with T_3 treatment whereas the minimum spike length(14.1 cm) was observed in T_8 (control) treatment. The maximum number of florets spike^{-1} (35.1) was observed in T_7 treatment whereas the minimum number of florets spike^{-1} (17.4) was observed in T_8 (control) treatment. The maximum flower wt. spike^{-1} (67.6 gm) was observed in T_7 treatment followed by T_3& T_5 treatments whereas the minimum flower wt. spike^{-1}(29.2 gm) was observed in T_8 (control) treatment.

Table 8. Effect of fertilizer doses on vegetative and floral characteristics of Tuberose (Variety: Single line) at Rooftop of Soil Science Division, BARI, Gazipur

Treatment	Plant height (cm)	Spike length (cm)	Florets spike^{-1} (No.)	Flower wt. spike^{-1} (gm)
T_1 = 100% STB (N_4 $P_{0.4}$ $K_{1.5}$ $S_{0.2}$ $Zn_{0.2}$ $B_{0.08}$ gm/15 kg soil)	72.3c	22.9d	26.9d	48.7e
$T_2 = T_1$ + 1 kg Kitchen waste(decomposed) /6kg soil	87.0b	27.6c	30.3c	59.6cd
T_3 = 80% of T_1 + 2 kg Kitchen waste (decomposed)/6kg soil	91.3ab	31.8ab	33.9ab	63.4b
$T_4 = T_1$ + 1 kg Cowdung/6kg soil	86.5b	26.2cd	29.5c	57.4d
T_5 = 80% of T_1 + 2 kg Cowdung/6kg soil	88.4ab	29.5bc	31.8bc	61.3bc
$T_6 = T_1$ + 1 kg Vermicompost/6kg soil	88.2ab	28.4bc	33.6ab	60.2bcd
T_7 = 80% of T_1 + 2 kg Vermicompost /6kg soil	93.1a	33.2a	35.1a	67.6a
T_8 = Absolute control	52.2d	14.1e	17.4e	29.2f
CV (%)	3.59	7.38	4.93	3.50

The effect of different nutrient management packages on the yield and yield contributing parameters of Rose are presented in Table 9. The highest plant height (57.6cm) was recorded in T_7 treatment (80% of T_1 + 2 kg Vermicompost /6kg soil) whereas the lowest plant height (33.7 cm) was observed in T_8 (control) treatment. The highestnumber of flowers plant^{-1} (18.3) was recorded in T_7 treatment which was statistically at par with T_3 treatment whereas the lowest number of flowers plant^{-1} (4.1) was observed in T_8 treatment. The maximum flower diameter (7.2 cm) was observed in T_7 treatment whereas the minimum flower diameter (5.6 cm) was observed in T_8 (control) treatment. The maximum single flower wt. (4.6 gm) was observed in T_7 treatment followed by T_3 treatment whereas the minimum flower (3.0 gm) was observed in T_8 (control) treatment.

Table 9. Effect of fertilizer doses on yield and yield contributing characters of Rose (Variety: Hybrid) at Rooftop of Soil Science Division, BARI, Gazipur

Treatment	Plant height (cm)	No. of flowers plant^{-1}	Flower diameter (cm)	Individual flower wt.(gm)
T_1 = 100% STB (N_{12} $P_{2.2}$ K_7 gm/75 kg soil)	45.8b	8.4e	6.2cd	3.4cd
T_2 = T_1 + 1 kg Kitchen waste(decomposed) /6kg soil	51.5ab	14.7cd	6.8ab	3.8bc
T_3 = 80% of T_1 + 2 kg Kitchen waste (decomposed)/6kg soil	55.2a	16.6ab	7.1a	4.2ab
T_4 = T_1 + 1 kg Cowdung/6kg soil	50.8ab	13.8d	6.5bcd	3.8bc
T_5 = 80% of T_1 + 2 kg Cowdung/6kg soil	54.3a	15.5bcd	6.7abc	4.0b
T_6 = T_1 + 1 kg Vermicompost/6kg soil	53.0a	16.2bc	7.0ab	3.9bc
T_7 = 80% of T_1 + 2 kg Vermicompost /6kg soil	57.6a	18.3a	7.2a	4.6a
T_8 = Absolute control	33.7c	4.1f	5.6e	3.0d
CV (%)	7.88	7.43	4.48	7.82

Conclusion

Based on the results, it may be concluded that 80% of STB doses along with 2 kg vermicompost 6kg^{-1} soil was more effective than other fertilizer management packages for maximizing the yield of different vegetables, fruits and flowers grown on the rooftop garden. So, T_7 treatment packages (80% of STB+ 2 kg vermicompost 6kg^{-1} soil) may be recommended for the rooftop gardeners for cultivation of different vegetables, fruits and flowers. The lowest growth and yield performance was obtained from the control treatment.

Expt. 2. Influence of different ratio of soil and organic materials on the growth and yield of Bitter gourd for rooftop garden

Materials and Methods

Experiment was conducted at the rooftop of Soil Science Division, BARI, Gazipur during 2020-2021 and 2021-2022. The initial soil sample, vermicompost, kitchen waste compost and cowdung collected before establishing the experiment were analyzed in the laboratory following standard methods. Chemical parameters of the experimental soil and others organic materials are same an Experiment 1 (Tables 1a and 1b). Organic based research (only used organic fertilizers) for crop production in the rooftop garden was laid out in a completelyrandomized design with three replications. Six different treatments viz. T_1 = 1 kg kitchen waste for 1 kg soil, T_2 = 1 kg kitchen waste for 2 kg soil, T_3 = 1 kg cowdung for 1 kg soil, T_4 = 1 kg cowdung for 2 kg soil, T_5 = 1 kg vermicompost for 1 kg soil and T_6= 1 kg vermicompost for 2 kg soil were selected. Half dram was used for vegetable crop production. Half of organic fertilizers were applied at the time of final soil and organic material ratio preparation. The remaining half organic fertilizer applied as top dress. Irrigations and other intercultural operations were done as when required.

Results and Discussion

Vegetables

The effect of different ratio of soil and organic matter on the growth and yield of Bitter gourd are presented in Table 10. The highest length of main vine (4.0 m) was obtained from T_5 treatment (1 kg Vermicompost for 1 kg soil) whereas the lowest length of main vine (3.5 m) was obtained from T_4 treatment (1 kg Cowdung for 2 kg soil). Significantly maximum number of fruits plant^{-1} (29.6) was obtained from T_5 treatment which was statistically at par with T_1 treatment(1 kg Kitchen waste for 1 kg soil). The minimum number of fruits plant^{-1} (14.3) was obtained from T_4 treatment (1 kg Cowdung for 2 kg soil). The maximum individual fruit weight (88.4 g) was obtained from T_5 treatment which was statistically similar with T_1 treatment followed by T_3 treatment whereas minimum individual fruit weight (79.5 g) was recorded from T_4 treatment. The highest fruit yield plant^{-1} (2.7 kg) was recorded from T_5 treatment followed by T_1 and T_3 treatment whereas the lowest yield (1.1 kg) was recorded in T_4 treatment.

Table 10.Effect of different ratio of soil and organic matter on the growth and yield of Bittergourd (Variety: BARI Korola-1) at Rooftop of Soil Science Division, BARI

Treatment	Length of main vine(m)	No. of fruits plant^{-1}	Individual fruit wt. (g)	Fruit yield plant^{-1} (kg)
T_1= 1 kg kitchen waste for 1 kg soil	3.9	26.2ab	87.3a	2.2b
T_2 = 1 kg kitchen waste for 2 kg soil	3.7	17.3cd	83.2b	1.4d
T_3 = 1 kg cowdung for 1 kg soil	3.8	24.1b	86.1ab	2.0bc
T_4 = 1 kg cowdung for 2 kg soil	3.5	14.3d	79.5c	1.1d
T_5 = 1 kg vermicompost for 1 kg soil	4.0	29.6a	88.4a	2.7a
T_6 = 1 kg vermicompost for 2 kg soil	3.8	22.1bc	85.0ab	1.8c
CV (%)	8.20	12.44	5.11	10.71

Conclusion

The overall results indicated that, Bitter gourd performed better in T_5 treatment (1 kg vermicompost for 1 kg soil) compared to others in terms of growth and yield in the rooftop garden. So, the application of 1 kg vermicompost for 1 kg soil could be recommended for cultivation of Bitter gourd. The lowest growth and yield performance was obtained from the T_4 treatment where 1 kg cowdung were applied for 2 kg soil.

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EFFICACY OF DIFFERENT FORM OF UREA ON NITROGENAVAILABILITY AND YIELD OF MAIZE

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Abstract

The experiment was conducted at BARI, Gazipur (AEZ 28) during rabi season of 2021-22 with the objectives: i) to find out use efficiency of different form of urea, ii) to find out the yield and yield components of maize as influenced by different form of urea and iii) to analyze cost and return of maize produced from different form of urea. There were four treatments viz. T_1: N-control, T_2: RD of nitrogen (225 kg ha^{-1}) in the form of Prilled urea, T_3: Application of 200 kg nitrogen ha^{-1} in the form of urea super granule (USG), T_4: Application of 205 kg nitrogen ha^{-1} in the form of neem coated urea. P, K, S, Zn & B were applied @ 60, 110, 40, 4 & 1.4 kg ha^{-1}. The experiment was laid out in RCB design with three replications. The highest yield (10.75 t ha^{-1}) of maize was obtained from T_3 treatment (200 kg N as USG) which was very close to T_4 treatment (10.69 t ha^{-1}). The lowest yield (6.48 t ha^{-1}) of maize was noted in N-control treatment (T_1).The actual nitrogen add (130 kg ha^{-1}), nitrogen uptake (162 kg ha^{-1}) and nitrogen balance (-33 kg ha^{-1}) by maize was highest in T_3 the treatment. If 1 kg extra nitrogen applied, 21.34 kg extra maize grain yield over N-control was observed in T_3 treatment. If 1 kg extra nitrogen applied, 0.32 kg extra nitrogen uptake by maize over N-control was observed in T_3 treatment. Cost and return analysis revealed that highest gross margin (72153 Tk. ha^{-1}) as well as MBCR of 7.0 was obtained from T_4 treatment (Neem coated urea applied maize plot). BCR in prilled urea and USG applied maize were 6.9 and 5.2, respectively.

Introduction

Neem Oil Coated (NOC) urea is the urea which is coated with neem seed oil. It has been scientifically established that *Neem* oil serves as an effective inhibitor if *coated* on *Urea*. Use of urea (46% N content) in Bangladesh is around 25 lakh tons per year (2014-15), of which almost 80% used in rice. Production of urea in the country is roughly 10 lakh tons against import of around 14 lakh tons. During the course of transformation in soil systems for availability as plant nutrient, urea converted to NH_4, NO_3, NO_2 and N_2. Rice uptake nitrogen from soil mainly as NH_4 while other crops uptake nitrogen as NO_3. Roughly the efficiency of prilled urea when broadcasted in rice field is ranged from 30-40% (depends upon the rate of hydrolysis of urea to NH_4 to NO_3 to NO_2 to N_2). The efficiency of USG is 10-15% higher in rice field. The benefit is found more in wetland rice than upland crops. But placement of USG using machine or manual is not user friendly, so even after much efforts of different organizations including IFDC for last few years, the product is still not becoming popular. For neem oil coated urea, application would not need any extra device like USG, so it is expected to be more user friendly, and would reduce the quantity without reducing any production loss. As reported neem oil coated urea enhanced production of crops per unit area than prilled urea due to its slow and steady supply of N in the plant root systems.

Loss of urea in crop production is a serious problem under tropical agriculture. The available results on the investigations indicate that 40-70 per cent of applied urea is lost from the crop fields. Urea losses include (a) volatilization in the form of ammonia, (b) leaching of nitrate, (c) de-nitrification of nitrate as elemental nitrogen, nitrogen mono-oxide and nitrous oxide, (d) microbial assimilation of urea and (e) fixation of ammonium by clay. It is now apparent from the above mentioned facts that a major portion of applied urea is not available to rice and other crop plants. As a result, urea fertilizer use efficiency is reduced to about 30-60%. Because of poor use efficiency of prilled/granular urea by plants, there is a need for application of urea much more than it requires. The part of urea fertilizer lost (40-70%) also cause environmental pollution. Thus, the best fertilizer practices should be to minimize losses from urea in crop fields, which will save both urea fertilizer losses and environment being polluted. Neem oilcoated urea can ensure both reduction of volume of urea fertilizer to be applied in crop fields by about 20% and improve environmental safety by reduction in gaseous losses of NH_3, and N_2O and leaching loss of NO_3^-.

Scientists around the world are concentrating their efforts on regulating the nitrogen supply to crops by reducing the rate of either hydrolysis or nitrification or both, so as to ensure continuous and optimal supply of nitrogen to match the requirements of crops at different stages of growth. Several synthetic chemicals capable of inhibiting hydrolysisof urea or nitrification in soils have been evaluated and found positive results. Examples include N-serve (nitrapyrin), dicyandiamide (DCD), AM (2-amino-4 chloro-6 methyle pyrimidine), sodium chlorate, sodium azide, and benzene hexachloride (C6 H6 Cl6). Many of these products, however, have been restricted to the experimental stage because of the high cost, limited availability, and adverse influence on beneficial soil microorganisms and, above all, poor extension and promotional activities for taking the technology to the farmers.

Plant based nitrification inhibitors, which are eco-friendly and biodegradable, therefore hold considerable promise. Indeed, suppression of soil nitrification has been observed in some natural ecosystems (natural nitrification inhibition). It aims conservation of soil N and improved N status through development of low NO_3 – ecosystems. Several empirical studies have indicated that some plants and their by-products inhibit the role nitrifying bacteria. Brachiariahumidicola (Rendle) Schweick, karanj (Pongamiaglabra Vent.), sweet-sorghum (Sorghum bicolor (L.)Moench), neem (AzadirachtaindicaAdr.Juss.), tea (Camellia sinensis (L) O'kuntze), linseed oil (Linumusitatissimum L.), mahuwa (Madhucalatifolia (Roxb.) J.F. Macbr.), Pyrethrum spp., Artemisia annua L. and mint (Menthaspicata L.) are important sources of natural nitrification inhibitors (NNI). However, the concept remained largely unsupported for lack of an appropriate methodology to conclusively demonstrate in situ inhibition of nitrification by such plant derived chemicals. The reason may be lack of commercial product development using such chemical compounds. The objective is to review the recent literature on NNI and highlight its potential to promote N use efficiency and prevent environmental contamination.

A considerable volume of data is available on the potential of the constituents of Neem (Azadirachtaindica) seeds known as triterpenes as effective nitrification inhibitors. In spite of the encouraging results obtained with the use of urea coated with Neem cake, this practice has not attracted the attention of farmers on a large scale because the process of coating urea with Neem cake is cumbersome and because Neem cake is not readily available at the farm level.

Depending upon the concentration of triterpenoids or neem bitters, the active nitrification inhibitor compounds, neem cake, extract or oil have been used in different quantities to coat urea. Although mean increase in the grain yield of rice and wheat by applying NCU/NOCU was around 5 to 6 % over the yields obtained by urea at same N level, in about 30% comparisons no increase was observed. As observed increase in yields have been obtained in researcher's plots, the yield benefits of using NOCU should be considerably less when managed by farmers. Same applies to other crops such as sugarcane, cotton where also respectively, 8.7 and 4.3 % increase in yields have been recorded in researcher's plots. There is large variation in fertilizer N rate for different crops depending upon land holding size, whether crop is irrigated or unirrigated and also because some farmers are accustomed to use heavy doses of fertilizer N. According to principles of fertilizer evaluation, the difference between the performances of the two sources narrows down at high application rates. Further, the nitrification inhibitors perform better in irrigated than in rainfed crops and in acidic soil conditions than in neutral and alkaline soils. As more than 50% of the total urea consumed in India is applied to rice and wheat, and more than 30% is applied to rainfed crops, overall impact of coating all urea supplied to farmers with neem is likely to be small.

Neem coated urea is inexpensive, less labor intensive and cost-effective fertilizer technology. Recently (2016) in all over India, use of neem coated urea has been made compulsory in crop fields (instead of using simple urea) because of its immense benefit in crop production and being less environmental pollutant. Neem is a reasonably inexpensive biological product, which shows great promise for resource poor farmers of developing countries like Bangladesh. On an average use of neem coated urea increases crop yield by roughly 10-15% over use of simple urea, which is significantly high. It slows the release of nitrogen by 20% to 25%, which also assist steady supply of nitrogen to plant and increase crop production. Some other benefits of the product on crop production are:

Neemcoated urea is environment friendly unlike urea which increases environmental pollution. Application of neemcoated urea reduces loss of urea fertilizer through leaching and de-nitrification by 30-35% (Vyas *et al*., 1993). Thus it also reduces atmospheric greenhouse gas (GHG) emission as well as ground water pollution through decreasing leaching loss of nitrate (NO_{-3}).By literature review and information from Indian Scientists through personal interaction it has been known that India is producing 100% neem coated urea instead of prilled urea. To collect and assess the opinion of eminent scientists of the country KGF organized a consultation meeting on 03 April, 2018 to discuss the prospects of neem coated urea in our country. After detailed discussion among the scientists of NARS institutes including members of advisory committee of MoAand representatives from private entrepreneurs the meeting suggested to design a CRP (Commission Research Program) project on the research and extension of NOC urea in the country. Based on the decision the present project has been planned to implement nvolving research, extension and private sectors. The project will need coating of urea with neem seed oil. In Bangladesh neem seed is available in limited quantity in Northern parts (Natore, Rajshahi, Pabna etc.) of the country. The coating of urea with neem oil will be done by ACI primarily by using special type of mixture machine using the formula suggested by Indian Scientists (0.50 kg neem oil per i.00 ton of urea). By the course of time when NOC urea will become popular among the farmers the device could be imported from India.

A lot of research works has been done internationally on decreasing losses of nitrogen from urea in crop fields, particularly in rice culture. Japan, USA and India had crediTable contributions in this direction. To decrease N losses from applied urea, slow release N fertilizers have been developed. NoTable of those are Urea Form (UF), Isobutylenediurea (IBDU), Polymer coated urea and sulphur coated urea (Katyal *et al*, 1985; Tandon, 1987; Thomas and Prasad, 1983; Vyas and Mistry, 1985). The basic principle used in developing slow release urea-N fertilizers is to ensure gradual release of nitrogen from urea so that plant can utilize urea-N over a longer period of time to optimize its nutritional needs. But the main problem with the slow release N fertilizers so far marketed is the high price of the product, which is beyond the purchase capacity of the poor farmers. So, research work on alternative slow-release urea fertilizers continued. Nimin, a self-adhesive urea coating material was developed in India. Urea is coated with Nimin, a commercial extract of Neem (AzadirachtaIndica) seed. Nimin is very cheap, easy to use and affordable by poor farmers of developing countries like Bangladesh. It is also environment friendly; helps reduce Greenhouse gas emission and ground water pollution. The main objectives are to:i. find out use efficiency of different form of urea. ii. find out the yield and yield components of maize as influenced by different form of urea.iii. analyze cost and return of maize produced from different form of urea.

Materials and Methods

An experiment was conducted on BARI Central Research Station, Gazipur during rabi season of 2021-2022. The initial soil samples at a depth of 0-15 cm from the experimental fields were collected and analyzed following standard methods (Table 1).

Table 1. Chemical properties of initial soil of experimental field during 2020-2021

Location	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			meq 100g^{-1}				µg g^{-1}						
Gazipur	5.7	1.39	2.9	1.1	0.14	0.097	11	12	0.19	6	69	10	0.7
Critical level	-	-	2.0	0.5	0.12	0.12	7	10	0.20	0.2	4	1	0.6

The experiment was laid out in a randomized complete block design with three replications in each treatment. Four different treatments viz. T_1: N-control, T_2: RD of nitrogen (225 kg ha^{-1}) in the form of Prilled urea, T_3: Application of 200 kg nitrogenha^{-1} in the form of urea super granule (USG), T_4: Application of 205 kg Nha^{-1} in the form of neem coated ureawere selected for different plots randomly. Properties of different form of urea are presented in Table 2.

Table 2. Properties of different form of urea

Form of urea	Physical appearance	Diameter	Nitrogen content
Prilled urea	Whitish Brown	Granular (2-3 mm)	46%
Urea super granule (USG)	Whitish Brown	Super granular (6-7 mm)	46%
Neem coated urea	Yellowish Brown	Granular (2-3 mm)	45.8%

For prilled urea, $^1/_3{}^{rd}$of urea is applied before sowing as basal. Remaining $^2/_3{}^{rd}$ urea is applied in two installments as broadcast; one at 40 days after sowing another at 75 days at sowing. For neem coated urea, ½ of urea is applied before sowing as basal. Remaining ½ urea is applied as broadcast at 40 days after sowing. For USG, whole urea are applied as band placement during sowing in between two maize rows at 10 cm apart. P, K, S, Zn & B were applied @ 60, 110, 40, 4 & 1.4 kg ha^{-1}. P-K-S-Zn-B was supplied from TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. All PKSZnB were applied at the time of final land preparation. The unit plot size was 4m x 3m. The tested crop was BARI Hybrid Maize-9. Maize was sown 60 cm line to line and 20 cm plant to plant. Maize seeds were sown first week of December, 2021. All the intercultural operations such as irrigation, weeding, insect control etc. were done as and when necessary.

Harvesting of maize was done on April 2021.Ten plants from each plot were tagged at random to take records on different agronomic parameters of maize. Data on yield and yield contributing parameters were recorded and statistically analyzed with the help of statistical package Crop-Stat and mean separation was tested by Least Significance Difference (LSD) (Steel and Torrie, 1960). Post harvest soil and plant samples were also collected and analyzed.

Nutrient use efficiency:

A. Agronomic use efficiency (AE):

Agronomic efficiency refers to the increase in crop yield per unit of an applied nutrient. It can be calculated as: AE = $(Y_{NA}-Y_{N0})/N_{RN}$, Where, AE : Agronomic efficiency, Y_{NA} : Yield (kg ha^{-1}) due to nutrient addition, Y_{NO} : Yield (kg ha^{-1}) due to nutrient omission, Y_{RN} : Nutrient addition rate (kg ha^{-1})

B. Recovery Efficiency (RE):

Recovery Efficiency (RE) refers to the increase in nutrient uptake by plants per unit of an applied nutrient. It can be calculated as: RE = $(NU_{NA}-NU_{N0})/N_{RN,}$ Where, RE : Recovery efficiency, NU_{NA} : Nutrient uptake (kg ha^{-1}) due to nutrient addition, NU_{NO} : Nutrient uptake (kg ha^{-1}) due to nutrient omission, Y_{RN} : Rate of nutrient addition (kg ha^{-1})

Methods of chemical analyses

Soil pH was measured by a combined glass calomel electrode (Jakson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Ca and Mg were determined by NH_4OAc extraction method. K, Cu, Fe, Mn and Zn were determined by DTPAextraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method (Acid soils). S was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric method with $BaCl_2$.

Results and Discussion

The effect of chemical fertilizers on the yield and yield parameters of maize are summarized in Table 3. Grain yield and all yield attributes were significantly influenced by different form of urea. Plant height and ear height are significantly influenced by different form of urea.Highest plant height (223cm) and No. of Cob/m^2 (16.93) was obtained from T_3 treatment (200 kg Nha^{-1} in the form of USG) which was very close to T_4 (205 kg Nha^{-1} in the form of neem coated urea) treatment (plant height = 217 cm & No. of Cob/m^2 =16.67). Moderate plant height of 215 cm and No. of Cob/$m^2$16.33 were obtained from T_2 treatment (225 kg Nha^{-1} in the form of Prilled urea). Lowest plant height (196) and lowest No. of Cob/m^2 (12.67) was obtained from N-control T_1 treatment.

Cob length and cob diameter are important yield parameter of maize. Both of cob length and cob diameter are significantly influenced by different form of urea. Highest cob length (19.41cm) and highest cob diameter (4.39 cm) was obtained from T_3 treatment (200 kg Nha^{-1} in the form of USG) which was very close to T_4 (205 kg Nha^{-1} in the form of neem coated urea) treatment (cob length = 19.26 cm & cob diameter 4.31cm). Moderate cob length of 18.94 cm and cob diameter of 4.23 cm were obtained from T_2 treatment (225 kg Nha^{-1} in the form of Prilled urea). Lowest cob length (15.46 cm) and lowest cob diameter (3.93 cm) was obtained from N-control T_1 treatment.

1000- Grain weight was significantly influenced by different form of urea. Highest 1000-grain weight (362 g) was obtained from T_3 treatment (200 kg Nha^{-1} in the form of USG) which was followed by T_4 (205 kg Nha^{-1} in the form of neem coated urea) treatment (351 g). Moderate 1000-grain weight of 332 g was obtained from T_2 treatment (225 kg Nha^{-1} in the form of Prilled urea). Lowest 1000- grain weight (297 g) was obtained from N-control T_1 treatment.

Stover yield of maize was significantly influenced by different form of urea. Highest stover yield of 12.84 t ha^{-1} was recorded in USG applied plot (T_3 treatment) which is followed by neem coated urea applied plot (T_4 treatment, stover yield = 12.78 t ha^{-1}). Statistically similar stover yield of 11.68 t ha^{-1} was obtained from prilled urea applied plot. Lowest stover yield of 9.67 t ha^{-1} were recorded in N-contril T_1 treatment.

Table 3. Effect of different treatments on the yield and yield attributes of maize during 2021-2022.

Treatment	Plant height	No. of Cob/m^2	Cob length	Cob diameter	1000 grain weight	Stover yield	Yield
			(cm)		(g)	(t ha^{-1})	
T_1	196b	12.67b	15.46a	3.93b	297b	9.67b	6.48b
T_2	215ab	16.33a	18.94a	4.23a	332ab	11.68a	9.80a
T_3	223a	16.93a	19.41a	4.39a	362a	12.84a	10.75a
T_4	217ab	16.67a	19.26a	4.31a	351a	12.78a	10.69a
CV (%)	6.45	5.83	5.36	5.97	6.33	7.90	7.77

Like stover yield, highest grain yield of 10.75 t ha^{-1} were recorded in USG applied plot (T_3 treatment) which was very close to neem coated urea plot (T_4 treatment, grain yield = 10.69 t ha^{-1}). Moderate grain yield of 9.80 t ha^{-1} was obtained from prilled urea treated plot (T_2 treatment). Lowest grain yield of 6.48 t ha^{-1} was obtained from N-control T_1 treatment. About 51.29, 65.95 and 65.02%

yield increase over control (T_1 treatment) were obtained from prilled urea (T_2 treatment), USG (T_3 treatment) and neem coated urea (T_4 treatment).

Agronomic use efficiency of nitrogen (N_{AUE}):

Agronomic use efficiency of nitrogen (N_{AUE}) refers to the increase in maize yield per kg of nitrogen applied (Table 4).

Table 4. Agronomic use efficiency of nitrogen (N_{AUE}) of different form of urea

Treatment	Quantity of nitrogen applied	Increase nitrogen over N-control (T_1 treatment)	Quantity of grain yield obtained	Increase grain yield over N control (T_1 treatment)	Agronomic use efficiency of nitrogen (N_{AUE})
	(kg ha^{-1})				
T_1	0	-	6480	-	-
T_2	225	225	9800	3320	14.76
T_3	200	200	10750	4267	21.34
T_4	205	205	10690	4207	20.52

Agronomic use efficiency of nitrogen (N_{AUE}) of different form of urea were ranged from 16.44 to 20.95 kg kg^{-1}. Highest Agronomic use efficiency of nitrogen (N_{AUE}) (21.34 kg kg^{-1}) was obtained from USG treated plot (T_3 treatment) which was close to neem coated treated plot (T_4 treatment, N_{AUE} = 20.52 kg kg^{-1}). Lowest nitrogen use efficiency of 14.76 kg kg^{-1}was obtained from prilled urea treated plot (T_3 treatment).

Nutrient uptake

Nitrogen add, uptake and balance by maize was influenced by different form of urea (Table 5). About 225 kg ha^{-1} N as prilled urea, 200 kg ha^{-1} as USG and 205 kg ha^{-1} as neem coated urea are applied in T_2, T_3 and T_4 treatment. Percent nitrogen utilized by plant in prilled urea, USG and Neem coated urea are 40%, 65% and 55%, respectively (Iqbal, 2009). Therefore, actual nitrogen added in T_2, T_3 and T_4 treatment are 90, 130 and 113 kg ha^{-1}. Nitrogen uptake by maize was highest (148kg ha^{-1}) in T_3 treatment because of producing highest yield (9.80 t ha^{-1}) which is very close to T_4 treatment (162kg ha^{-1}). Next nitrogen uptake by maize was in T_2 treatment (148kg ha^{-1}). Lowest nitrogen uptake of 99kg ha^{-1} by maize was obtained from N-control T_1 treatment. Nitrogen balance in all the treatments are negative ranging from -58 to -117kg ha^{-1}. Highest N balance obtained in T_3 treatment (-58 kg ha^{-1}) which was very close to T_4treatment (-423 kg ha^{-1}). Lowest N balance (-99kg ha^{-1}) was obtained in N-control T_1 treatment. N balance in prilled urea treated plot is -58kg ha^{-1}.

Table 5. Nitrogen add, uptake and balance by maize as influenced by different form of urea

Treatment	N gross added (kg ha^{-1})	% N utilized	N actual added	N uptake	N balance
			(kg ha^{-1})		
T_1	0	-	0	99	-99
T_2	225 as prilled urea	40%	90	148	-58
T_3	200 as USG	65%	130	162	-33
T_4	205 as Neem coated urea	55%	113	155	-42

Recovery Efficiency of nitrogen (N_{RE}) :

Recovery Efficiency of nitrogen (N_{RE}) refers to the increase in nitrogen uptake by maize per kg of nitrogen applied (Table 6).

Table 6. Recovery Efficiency of nitrogen (N_{RE}) of different form of urea

Treat ment	Quantity of nitrogen applied	Increase nitrogen over N-control (T_1 treatment)	Quantity of nitrogen uptake	Increase nitrogen uptake over N control (T_1 treatment)	Recovery Efficiency of nitrogen (N_{RE})
	(kg ha^{-1})				
T_1	0	-	99	-	-
T_2	225	225	148	49	0.22
T_3	200	200	162	64	0.32
T_4	205	205	155	56	0.27

Recovery Efficiency of nitrogen (N_{RE}) of different form of urea were ranged from 0.22 to 0.32 kg kg^{-1}. Highest Recovery Efficiency of nitrogen (N_{RE}) of 0.32 kg kg^{-1} was obtained from USG treated plot (T_3treatment) which was close to neem coated treated plot (T_4 treatment, N_{RE} = 0.27 kg kg^{-1}). Lowest Recovery Efficiency of nitrogen (N_{RE}) (0.22 kg kg^{-1}) was obtained from prilled treated plot (T_2 treatment).

Cost and return analysis

Cost and return of maize as influenced by different form of urea have been described in the Table 7. Among the four treatments, the highest gross return (161250 Tk ha^{-1}) was obtained from T_3 treatment (USG applied maize plot) although its total cost is high (90383 Tk ha^{-1}). Total cost in the T_3 treatment is high due to USG application cost which needs to be dibbled in soil manually. Highest gross margin (72153Tk. ha^{-1}) was obtained from T_4 treatment (Neem coated urea applied maize plot). Highest MBCR of 7.0 was obtained from T_4 treatment (Neem coated urea applied maize plot). MBCR in prilled urea and USG applied maize were 6.9 and 5.2, respectively. MBCR in neem coated urea is higher than MBCR in USG due to application cost of USG in the field.

Table 7. Cost and return analysis of maize as influenced by different form of urea

Treat ment	Maize yield (t ha^{-1})	Gross return	Fixed and variabl e cost	Total cost	Gross margin	Marginal variable cost	Margina l gross margin	MBCR
		(Tk ha^{-1})						
T_1	6.48	97200	60000	79038	18162	-	-	-
T_2	9.80	147000	60000	88350	58650	7812	40488	5.2
T_3	10.75	161250	60000	90383	70867	7595	52705	6.9
T_4	10.69	160350	60000	88197	72153	7659	53991	7.0

Market price (Tk.kg^{-1}): Maize = 15/-, 1 kg prilled urea = Tk. 16/-, 1 kg USG = Tk. 17.50/-, 1 kg Neem coated urea = Tk. 17/- (Neem coated urea containing 45.8% nitrogen)

Conclusion

Considering results of this year, the highest yield of maize (10.75 t ha^{-1}) was obtained from T_3 treatment (USG applied maize plot) which was very close to T_4 treatment (10.69 t ha^{-1}). Highest gross margin (72153Tk ha^{-1}) as well as MBCR (7.0) was obtained from T_4 treatment (Neem coated urea applied maize plot). For confirming the results, the experiment needs to be repeated next year.

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NUTRIENT MANAGEMENT OF SESAME IN BARISHAL REGION

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Abstract

A field experiment was conducted at Regional Agricultural Research Station, Rahmatpur, Barishal (AEZ 13) during April 2021 to June 2021 to develop nutrient management package for sesame in this region and to increase the yield of sesame through fertilizer management practice. The crop variety was BARI Til-4. There were five treatments viz. T_0: Native fertility, T_1:50:20:40:10:1:2 kg/ha NPKSZn & B (FRG-2018), T_2: Farmers practice (40:15:20 k/ha NPK) , T_3: 75% of T_1+ CD 5t/ha, T_4: 125% of T_1, which were replicated for four times. Coundung was used with chemical fertilizers for T_3 treatment. Chemical fertilizers had showed significant influences on plant height (cm), shoot and root dryweight, number of pod /plant, as well as yield of sesame.The highest seed yield was obtained from T_4 (901.50 kg ha^{-1}) treatment which was statistically similar with T_1 (887.25 kg ha^{-1}) treatment and significant over T_0 (608.0kg ha^{-1}) and T_2 (649.50 kg ha^{-1}) treatments. Use of chemical fertilizer found better in sésame cultivation in Barishal region (Non–calcareous Grey Floodplain Soils under AEZ 13).

Introduction

Sesame is the third highest edible oil of Bangladesh. It contained 42-45% oil and 20% of protein. It has also medicinal value. In Bangladesh sesame was cultivated both Rabi and Kharif season. It was mainly cultivated in Kharif season. It requires medium high land because stagnant water damages it. It is short durated crop. Farmers of this region interested to cultivated sesame. Sometimes the land is fallow in this region in mid February to mid April. So they can harvest a short durated crop in this time. Fertilizer management is big factor for crop production. Farmers do not know the actual rate of fertilizer for sesame cultivation. So this experiment is under taken for the actual rate of fertilizer in this region for sesame cultivation. The objectives of the experiment were as follows: i) To developed nutrient management package for sesame in this region. ii) To increase the yield of sesame through fertilizer management.

Materials and Methods

A field experiment was carried out from April 2021 to June 2021 for sesame at Regional Agricultural Research Station (RARS), Rahmatpur, Barishal. The experiment was laid out in Randomized Complete Block Design (RCBD) with four (4) replications. There were five treatment combinations viz T_0: Native fertility, T_1: 50:20:40:10:1:2 kg/ha NPKSZn & B, T_2: Farmers practice (40:15:20 k/ha NPK), T_3: 75% of T_1+ CD 5t/ha, T_4: 125% of $T_{1.}$ The tested crop was sesame (cv. BARI Til-4). The unit plots measured 6m × 4m in size. Plant spacing was 30cm × 5cm. Seeds were sown at 8th April of 2021. Nitrogen, phosphorus, potassium, sulphur, zinc and boron were used in the form of urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. Recommended fertilizer dose (BARC, 2018) for sesame (50:20:40:10:1:2 kg N-P-K-S-Zn-B ha^{-1}) were used as treatment T_1. Fertilizer was applied at final land preparation. All the intercultural operations such as irrigation, weeding, insect control etc. were done as and when necessary. Date of flowering was the 2nd week of May 2021. Plants were harvested in the last week of June. Data on yield and yield components will be recorded at maturity stages. The initial soil samples at a depth of 0-15 cm from the experimental fields were collected and send to SRDI, Barishal for analyzed .

Table 1. Initial fertility status of the experimental field soil samples of RARS, Rahmatpur, Barishal

Soil Properties	Texture	pH	EC	OM (%)	Total N (%)	K	P	S	B
						Meq/100g		µg/g	
Experiment field	Sandy clay loam	7.6	1.20	1.92	0.10	0.18	52.3	14.7	0.15
Critical limit	-	-	-	-	012	0.12	10.0	10.0	0.20

Results and Discussion

Response of different fertilizerson sesame, plant height (cm), root length (cm), shoot weight (g/ plant), branch /plant, 1000-seed weight (g), pods seed weight (g/ plant), plot yield (kg /plot) and seed yield (kg/ha) have been presented in Table 2 and Table 3.

Table 2. Effect of different fertilizer on dry matter production and plant height of sesame at RARS,Rahmatpur during 2020-2021

Treatments	Plant height (cm)	Root length (cm)	Shoot weight (gplant^{-1})	Branchs plant^{-1} (no.)	Pods Plant^{-1}(no.)
T_0 : Native fertility	133.5b	15.55ab	30.54bc	4.35b	39.37b
T_1 :50-20-40-10-1-2 kg ha^{-1}NPKSZnB	137.82ab	16.30ab	38.35a	5.45a	43.40ab
T_2 :Farmers practice (40-15-20-2 kg ha^{-1} NPK)	135.17b	14.90b	32.50b	4.80ab	42.70b
T_3 : 75% of T_1+ CD 5t/ha	135.45b	16.15ab	27.56c	4.65b	42.87b
T_4 : 125% of T_1	141.6a	17.00a	31.65b	5.00ab	45.00a
CV (%)	3.40	7.67	6.38	7.11	7.79
Level of sig	ns	**	**	**	**

Chemical fertilizer influenced on plants and produced higher shoot weight, pods/ plant, plot yield and seed yield (kg/ha) compared to native and farmers practices. The highest plant height (141.6cm) was observed from T_4 treatment where we used 125% chemical fertilizer, which was statistically significant over T_2 (135.17cm) and control (133.5cm) treatment. The highest root length (17.0cm) was observed from control treatment and this was due to the unavailability of nutrients. The highest shoot weight (38.45g) observed from T_1 treatment which was significant with all other treatments. The number of branches was highest (5.45) in T_2 treatments which are statistically similar with T_2 (4.80) and T_4 (5.00) treatment. The lowest no of branch (4.35) found in T_0 treatment. In case of pods/plant T_1 and T_4 treatments showed statistically identical performance (Table-2).Yield and yield attributes are significantly influenced by chemical fertilizer. The highest seed yield was obtained from T_4 ((901.50 kg ha^{-1}) treatment which was statistically similar with T_1 (887.25 kg ha^{-1}) treatment and significant over T_0 (608.0kg ha^{-1}) and T_2 (649.50 kg ha^{-1}) treatments (Table-3).

Table 3. Effect of different fertilizer on yield and yield attributes of sesame at RARS, Rahmatpur during in 2020-2021

Treatments	Pod seed wt/plant (g)	1000 seed weight (g)	Plot yield (kg/plot)	Yield (m^2/plot)	Yield (kg/ ha)
T_0 : Native fertility	1.99c	3.40c	1.30c	60.8c	608.0c
T_1 :50:20:40:10:1:2 kg/ha NPKSZn & B (FRG-2018)	2.39ab	3.90ab	1.90a	88.7a	887.25a
T_2 : Farmers practice (40:15:20 k/ha NPK)	2.28b	3.75bc	1.39c	64.9c	649.50c
T_3 : 75% of T_1+ CD 5t/ha	2.37b	3.57bc	1.74b	81.1b	811.25b
T_4 : 125% of T_1	2.68a	4.18a	1.93a	90.1a	901.50a
CV (%)	8.11	6.23	4.92	4.91	4.97
Level of sig	**	**	**		**

Conclusion

Considering all the experimental observations it can be concluded that 125% of recommended dose of chemical fertilizer showed better yield performanceof seasame in Barishal région. The crop yield was partially hampared by plant falldown at grain filling stage. To know the appropriate fertilizer recommendation for better yield of sesame, the experiment shoul be done for next year.

References

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EFFECT OF BIOCHAR ON YIELD AND NUTRIENT UPTAKE OF CABBAGE

M.M. MASUD, R. SEN, I. S. M. FARHAD AND H. M. NASER

Abstract

A field study was conducted at BARI research field under Grey Terrace Soil (AEZ 28) during rabi season of 2021-2022 to investigate the effects of rice husk biochar (RHB) on soil fertility, carbon sequestration and increase yield and nutrient uptake of cabbage.The experiment consisted of randomized complete block design with eight treatments i.e. control, 100% recommendation dose of chemical fertilizer (RDCF) and three rate of rice husk biochar (i.e. 1.5, 3.0 and 4.5 t ha^{-1}) with 100% or 80% RDCF. The application of RHB improved soil pH and concentrations of organic matter, N, P, K, Ca and Mg, root length, yield and yield components of cabbage ($p<0.05$). Soil fertilized with chemical fertilizers had lower soil pH (5.38) than all other treatments but 0.13 unit increased by 4.5 t ha^{-1} RHB with 80% RDCF treated soil. The increase in RHB decreased bulk density of soil and increased soil organic carbon (SOC) stock. Irrespective of treatments, the highest carbon accumulation was recorded in soil amended with 4.5 t ha^{-1} of RHB. Compare to control, more than 250% average yield increase by using 100% RDCF in soil. In addition, 100% RDCF with different dose of RHB yield increased varied 300 to 397% and 278 to 375% average yield increased by reduction of 20% RDCF. Compare to 100% RDCF with different dose of RHB yield increased varied 14 to 42% and 8 to 35% yield increased by reduction of 20% RDCF. The correlation coefficient between SOC and marketable yield were 0.945. The highest gross margin was obtained from T_5 treatment with a BCR 5.02 but imidiate lowest 4.48 was found in T_2 treatment where 100% RDCF anolng with 1.5 ton RHB were used. Our results demonstrate that application of more stable component such as biochar instead of easily degraded organic amendments seems to be a promising option to supply enough nutrients for the healthy growth and yield of cabbage Grey Terrace Soil (AEZ 28).

Introduction

Soil organic carbon (SOC) plays a vital role in enhancing soil fertility and crop productivity by serving as potential carbon sinks (Quijano *et al*., 2017). Low levels of SOC is caused by having a poor ability to store nutrients in the soil and negatively impacts crop yields, significantly affecting soil fertility and causing nutrient loss (Bationo *et al*., 2007) due to rapid mineralization of SOC (Jenkinson and Ayanaba, 1977) and further decreases cation exchange capacity (CEC) which correlates to soil nutrient depletion. Because of this, the long term agricultural productivity in the continent is under threat as crop harvest sufer from continuous soil nutrient mining (Namoi *et al.*, 2014). One of the critical factors for the decline of SOC is the removal of organic material by harvest but no C input to soil (Liu *et al*., 2010). To combat this situation, it was reported that the loss of “old” SOM may exceed the formation of “new” SOC (Aye *et al*., 2018). Soil fertility and nutrient contents can be successfully improved using either organic or inorganic fertilizers (Mando *et al*., 2005; Topoliantz *et al*., 2005). Application of organic fertilizers with mineral fertilizer can be more appropriate for nutrient retention than mineral fertilizers due to gradual release of nutrient (Burger and Jackson 2003; Steiner *et al*., 2007). Farmers often use inorganic fertilizers which are expensive and scarce; therefore, they are forced to depend on alternative nutrient source such as organic manures (Awopegba *et al*., 2017). However, the benefits of organic fertilizers are generally short term due to rapid decomposition and may last only for a few growing seasons (Bol *et al*., 2000; Glaser *et al*., 2002; Diels *et al*., 2004). Furthermore, while inorganic fertilizers are prone to losses its downside, priming effect on soil organic matter, soil structure weakening, volatilization, and leaching of nutrients (Cameron *et al*., 2013; Agegnehu *et al*., 2016). However, this approach has not achieved desired results due to low stability, poor efficiency of fertilizer utilization and potential environmental pollution (Zhao *et al*., 2016; Chaudhary *et al*., 2017). With separate application of chemical fertilizer, it is difficult to utilize the immediate availability of plant nutrients from mineral fertilizers and long term benefits of organic fertilizers. Alternatively, combined application of these two types has been considered as effective management strategy (Fairhurst, 2012).

Only the few studies have investigated the effect of combined organic and inorganic fertilization on organic C sequestration and sustainable crop production. For example, Wang *et al*. (2019) has observed the high crop yield and organic C accumulation in soil under combined application of inorganic fertilizer and organic fertilizer. However, the mechanism by which different fertilizers application influence the crop yield by changing soil OC is not clear. Soil nutrients are main factors limiting crop yield, therefore, high crop yield mainly depends on fertilizer (organic and/or inorganic fertilizers) application rates. Furthermore, excessive use of chemical fertilizers did not show surplus nutrient accumulation in soil (Galloway *et al*., 2008) as well as negative environmental impacts (Lu and Tian, 2013; Peñuelas *et al*., 2012) and degrade the soil quality such as acidification (Cai *et al*., 2015, Lin *et al*., 2014) and decreases SOC (Yaduvanshi, 2001).

Therefore, it becomes imperative to investigate sustainable ways of managing soils for maximizing and enhancing potential crop yield. Actualizing this will require the need to amend the soil with a biological inert material such as biochar, instead of easily degraded organic amendments seems to be a promising option to achieve the purposes. Biochar, a highly stable and recalcitrant form of organic matter produced by pyrolysis. The use of biochar as a soil amendment may effective for soil health regarding to increased yield. Production and use of biochar increase day by day. Like other organic fertilizer, biochar can apply with chemical fertilizer.

No field study has been conducted in Bangladesh to determine the effects of application of biochar in combination with inorganic fertilizer on crop yield. So, it is necessary to understanding the combined application of RHB with fertilizer effect in soil carbon input, SOC accumulation, and cabbage yield. In this point of view, the objective of the trial wereto: i. find out optimum dose of chemical fertilizer and biochar,ii. find out nutrient uptake pattern as influenced by various level of biochar andiii) increase soil fertility and sustain crop productivity.

Materials and Methods

Site description and treatments

Second year study was conducted in rabi season of November 2021 to February 2022 in the same experimental field (23°59´21.955´´N, 90°24´33.739´´E) at Soil Science Division, BARI, Gazipur. Initial soil samples were collected from 0 to 15 cm depth at experimental site. In this year, the experiment consisted of randomized complete block design (RCBD) with three replications of eight treatments. The treatments were: i. Native fertility; ii.100% RDCF (STB), iii.100% RDCF (STB)+ Rice husk biochar @ 1.5 t ha^{-1}, iv.100% RDCF (STB) + Rice husk biochar @ 3.0 t ha^{-1}, v.100% RDCF (STB) + Rice husk biochar @ 4.5 t ha^{-1}, vi.80% RDCF (STB) + Rice husk biochar @ 1.5 t ha^{-1}, vii.80% RDCF (STB) + Rice husk biochar @ 3.0 t ha^{-1}; and viii.80% RDCF (STB) + Rice husk biochar @ 4.5 t ha^{-1}. Each block comprised of 8 plots and each plot was 2 m × 3 m. Blocks were 1 m apart and plots were 0.5 m apart.

Soil analysis

Eight sampling locations were selected by dividing the trial area into 3 cells (10 m × 10 m). Three sampling points were randomly selected within each of the 3 cells. At each sampling point, surface debris and litters were cleared away and three samples from a 3-m radius were collected using a manual auger with 20 cm core barrel of 6 cm internal diameter. The 3 samples were combined, making a composite sample for each cell, resulting in 3 composite samples for analysis. Pest harvest soils were collected from individual treatment plot. Soil samples collected were homogenized and ground to pass through a 2-mm sieve. Soil samples were analyzed for pH using a ratio of 2.5 ml water to 1g soil (McLean, 1982); Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank *et al*., 1998). Soil organic carbon (OC) was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). Organic matter (OM) was calculated by multiplying C by 1.724. Total N was determined by the Kjeldahl digestion method (Nelson and Sommers, 1980); exchangeable cations and CEC using ammonium acetate method (Black, 1965) at the soil and plant analysis laboratory of the Soil Science Division, BARI. Table 1 shows the initial chemical characteristics of the trial soil.

Plant analysis

The clean plant samples were air-dried and placed in an electric oven, dried at 105ºC for 24 h, weighted for dry biomass. Again, place it in the oven at 105ºC for 2h. Cool it in a desiccator and weight it again. Repeat drying, cooling and weighing until the weight become constant. The dried plant samples were homogenized by grinding using willey mill and used for nutrient analysis. Then, the grains were ground and N, P, K, Ca, Mg, S, B and Zn contents were determined according to the method described by described by Jones and Case (2018).Atomic absorption spectrophotometer (Thermo Scientific-SOLAAR S Series AA spectrometer) was used for metal ion and spectrophotometer (Agiland Technologies, cary 60 UV-Vis) for anion analysis.The accumulation of nutrients in the grains was estimated by multiplying nutrient content by dry grain weight.

Carbon stock analysis

Composite soil samples were collected from soil surface at depth of 0-30 cm. Soil parameters were determined for soil bulk density using the core sampling method (Blake, 1965) and soil organic carbon (SOC) before the experiment and at the end of the three cropping year. Soil organic carbon stock (SOC stock) was estimated with the following equation by Milne (2008).

SOC stock= SOC content of soil x BD x A x D,
Carbon accumulation (t ha^{-1}) = Final C stock (t ha^{-1}) – Initial C stock (t ha^{-1})

Where: SOC stock = Soil organic carbon stock (ton ha^{-1}); SOC content of soil= soil organic carbon content of soil (%), BD=bulk density, Area= area of farm (m^2) and D= soil sampling depth (m).

Table 1. Initial properties (0-15 cm) of experimental soil

Location	pH	BD	%	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
		(g cm^{-3})	OC	meq $100g^{-1}$			(%)	μg g^{-1}						
Gazipur	5.40	1.48	0.87	3.28	1.32	0.16	0.08	8	12	0.12	2.1	75	10	2.0
Critical Level		-	-	2.0	0.5	0.12	-	7	10	0.20	0.2	4	1	0.6

Table 2. Properties of rice husk biochar used for this study

Material	pH	OC	Ca	Mg	K	Total	P	S	B	Cu	Fe	Mn	Zn
		(%)	%			N(%)	μg g^{-1}						
RHB	8.85	39.1	1.045	0.48	1.14	2.29	0.9	0.33	0.004	0.004	0.205	0.019	0.007

Biochar preparation and analysis

The rice husk was collected from Tuber Crops Research Center (TCRC) near experimental field. Rice husk was placed into biochar making device (made in Soil Science Division, BARI) and pyrolyzed under oxygen-limited conditions. The pyrolysis temperature was raised into 700°C at a rate of approximately 20°C per minute and held constant for 2 h (Rajkovich *et al*., 2012). Then the biochar was allowed to cool to room temperature and ground to pass a 0.25 mm sieve. Biochar samples were examined to determine their main characteristics without further treatment, and their characteristics are shown in Table 2. After being thoroughly mixed with deionized water at a ratio of 1:20 and equilibrated for 1.5 h, the pH of the biochars was measured by Metler Toledo S220 with a combine electrode (Rajkovich *et al*., 2012). Total N was determined by modified Kjeldahl method. The alkalinity of RHB was determined by using the back titration method. About 0.200 g of biochar was weighed into plastic bottles in duplicates, 40 mL of 0.03 m HCl solution was added into each bottle, and all the samples were shaken for 2 h at 25 ± 1º C and then samples were kept standing for 24 h. The residual HCl was titrated to pH 7.0 with 0.5 m NaOH using an automatic titration system (EasyPlus™ Automated Titrator, Mettler Toledo). The amount of HCl consumed by the biochar was equal to its alkalinity (Yuan and Xu, 2010). The CEC of the biochar was measured based on the method of Song and Guo (2012). Exchangeable base cations were extracted with 1.0 M ammonium acetate (pH 7.0) (Pansu and Gautheyrou, 2006). Cu, Fe, Mn and Zn were determined by $NaHCO_3$ extraction method followed by atomic absorption spectrophotometer (AAS) reading (Thermo Scientific-SOLAAR S Series AA spectrometer). Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method while S by turbidimetric method with $BaCl_2$. The phosphorus was determined colorimetrically after digesting the biochars with nitric acid and perchloric acid.

Incorporation of biochar, transplanting cabbage seedling and crop management

After land preparation (ploughing and harrowing), the experimental site was laid out to the required plot size of 2 × 3 m. The RHB were weighed and spread evenly on the plots according to the required rates over the soil. A hand held hoe was used to incorporate the amendments into the soil to the depth of approximately 10 cm. The RHB were incorporated to the soil 3 weeks before sowing of cabbage seedlings (grown at lit greenhouse, BARI). The treatments with RHB were applied at the beginning of the year for next three years and cabbage will grow the same plots without any destroy. During the period between the two crops of cabbage, no crop was grown on the land and weeds were cleared before preparation (ploughing and harrowing) of the land for next crop. Four weeks old two seedlings were planted at row and plant spacing of 50 and 50 cm and the seedlings were later thinned to one plant per stand respectively. Fertilizers were applied as per treatment based on BARC fertilizer recommendation guide-2018 (100% RDCF: $N_{240}P_{55}K_{140}S_{32}Zn_2B_{1.2}$ kg ha^{-1}). One third urea was applied after seedling stand on soil and top dressing of urea as mentioned above was done at 25 and 45 d after sowing (DAS), include in the control. Irrigation was given as per crop demand. Weeding was done manually at 25 days after transplanting followed by earthing up at 30 day after transplanting.

Determination of yield parameters

Yield and yield contributing character samples were collected inside a quadrant area of 1.0 m^2 per plot. At harvest, and various yield parameters as head weight, head height, head circumference, head diameter, dry matter production, and yield of cabbage were recorded on five randomly selected and tagged representative plants in each plot and expressed as mean values.

Statistical analysis

A software package, statistix 10 (Analytical Software, Tallahassee, Fla, USA) was employed for the statistical analysis of data. A one-way analysis of variance was undertaken for each time interval of the incubations to determine significant differences between treatments.The significant effects for various treatments were detected using a t- test.

Results and Discussion

Changes of soil pH

Soil pH increased by the incorporation of different rate of biochar ($p<0.05$). After one year, soil pH was varied -0.02 to 0.13 units by incorporation of chemical fertilizer and with RHB than that of controls, respectively. Soil fertilized with chemical fertilizers had lower soil pH (5.38) than all other treatments. The treatments with combination of chemical fertilizer with biochar had higher pH (5.43-5.53) than the untreated check (5.41). Compared with control, RHB applied with fertilizer slightly increased soil pH where chemical fertilizer decreased pH 0.02 unit. Nitrification of NH_4^+ in controls is the main reason for the decreased soil pH due to (NO_3^-+NO_2^-)-as consistent with the change of soil pH in the corresponding treatments.These results suggest that the inhibition of nitrification is the main mechanism for the ameliorating effect of the chemical fertilizer on soil acidity. The maximum value of soil pH increased with the increased addition level of the RHB.

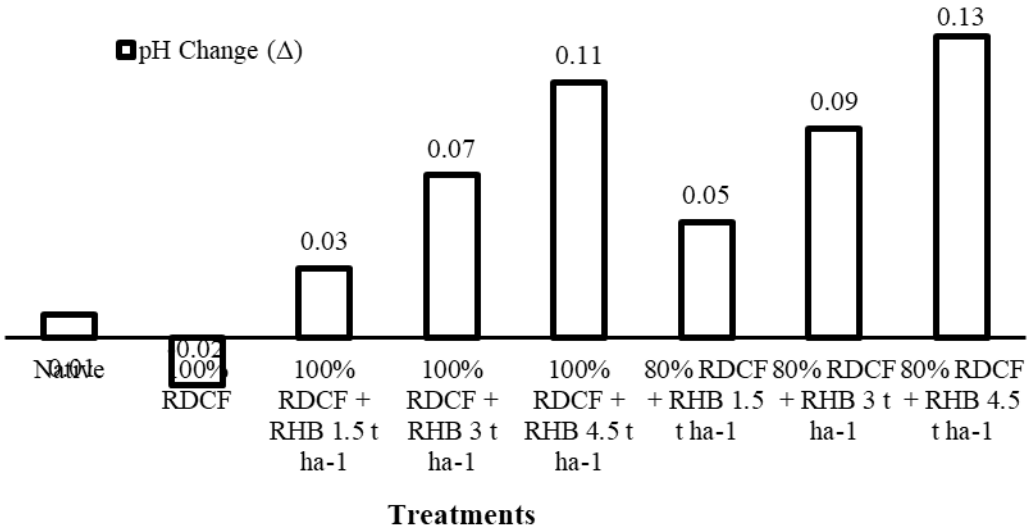

Fig 1.Changes of soil pH after cabbage harvest

Carbon accumulation in soil

The soil fertility attributes after year period shows data on Table 3. Organic amendments with RHB significantly reduced soil bulk density (BD) and increased soil organiccarbon (SOC). The soil bulk density decreased with increasing proportion of RHB as soil amendment. Soil bulk density ranged from 1.43 to 1.48 g cm^{-3}, where lower values of BD 1.43 g cm^{-3} in 4.5 t ha^{-1} RHB were applied.

Table 3. Soil carbon status at postharvest soil

Treatments	BD (g cm^{-3})	SOC (%)	SOC stock (t ha^{-1})	Carbon accumulation (t ha^{-1})
T_1(Absolute control)	1.48	0.87	19.36	0.04
T_2(100% RDCF)	1.48	0.87	19.24	-0.08
T_3 (100% RDCF + RHB @ 1.5 t ha^{-1})	1.46	0.89	19.49	0.18
T_4 (100% RDCF + RHB @ 3.0 t ha^{-1})	1.45	0.93	20.23	0.91
T_5(100% RDCF + RHB @ 4.5 t ha^{-1})	1.43	0.98	21.02	1.71
T_6 (80% RDCF + RHB @ 1.5 t ha^{-1})	1.46	0.90	19.71	0.40
T_7(80% RDCF + RHB @ 3.0 t ha^{-1})	1.44	0.94	20.30	0.99
T_8(80% RDCF + RHB @ 4.5 t ha^{-1})	1.43	0.99	21.24	1.92

Addition of RHB with chemical fertilizers has positive effect on carbon stock and carbon accumulation after one year (Table 3). The organic carbon content ranged from 0.87% to 0.99%. The initial soil organic carbon, bulk density and carbon stock in soil were 0.87%, 1.48 and 19.31 t ha^{-1}, respectively. Soil BD influences SOC stocks because the stocks are calculated by multiplying the SOC concentration by the BD. Data showed that, increased the RHB to the soil decreased bulk density of soil and increased SOC stock (Table 3). Irrespective of treatments, the highest SOC was recorded in soil amended with 4.5 t ha^{-1} of RHB.

Soil organic carbon content and mineralization

The result indicates that organic application initially increased soil organic carbon content of organic amended soils (Figure 1). Organic carbon content decreased significantly ($p < 0.05$) in control, 100% chemical used plot as well as biochar amended soils. By using chemical fertilizer, organic carbon decreased 2.74% after two harvest of cabbage. By using biochar @ 1.5 t ha^{-1}, 29% carbon increase from control soil and their after 28% at the end of two harvest. The rate of biochar increase the increases of carbon contentin soil. The higher content (81%) of organic carbon was found where 4.5 t ha^{-1} biochar applied.

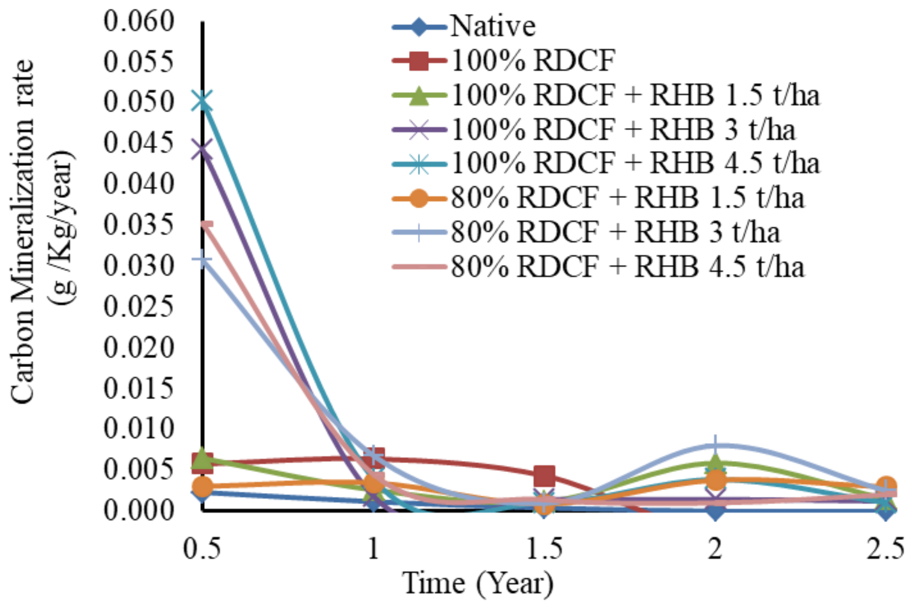

Fig 2. Carbon mineralization rate (g /kg/year) after three times cabbage harvest

Under field condition, initially C mineralization was observed when RHB applied into soil due to some water soluble C present in biochar. After one year, carbon minaralization was low in biochar treated soil.

Effect on cabbage growth

The application of RHB significantly (P< 0,05) reduced no. of unfold leaves plant^{-1}, increased head height, circumferences, stock length, stock diameter of cabbage compared with the application of inorganic fertilizer andcontrol treatment (Table 4). Highest head height, circumferences, stock length, stock diameterwere observed in T_5 and T_8 treatments. Maximum no. of unfold leaves plant^{-1} (17.33) was found in T_1 treatment. These results show that the addition of organic carbon into the soil can improve the physical, chemical and biological soil fertility so that the growth and yield increases. Swarup (2008) reported that the increase of soil organic carbon content will increases the nutrient availability in the soil.

Table 4.Effect of RHB on cabbage growth

Treatments	No. of unfold leaves plant^{-1}	Head height (cm)	Head circumference (cm)	Stock length (cm)	Stock diameter (cm)
T_1 (Absolute control)	15.33	8.76e	37.03d	13.93f	3.25b
T_2 (100% RDCF)	15.00	10.29d	46.13c	17.40e	3.59ab
T_3 (100% RDCF + RHB @ 1.5 t ha^{-1})	15.57	13.20bc	46.73c	20.23d	3.70a
T_4 (100% RDCF + RHB @ 3.0 t ha^{-1})	14.00	14.20ab	56.37ab	21.57bc	3.81a
T_5 (100% RDCF + RHB @ 4.5 t ha^{-1})	13.90	14.97a	61.27ab	22.6ab	3.78a
T_6 (80% RDCF + RHB @ 1.5 t ha^{-1})	15.27	11.86c	54.60bc	21.20cd	3.55ab
T_7 (80% RDCF + RHB @ 3.0 t ha^{-1})	14.77	13.80ab	64.10a	22.5ab	3.82a
T_8 (80% RDCF + RHB @ 4.5 t ha^{-1})	13.73	14.57ab	62.70ab	22.67a	3.55ab
CV (%)	7.19	6.6	9.24	3.07	6.75

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Effect on cabbage yield

Significant differences in total biomass, marketable yield and harvest index of cabbage were found among the treatments (Table 5). Current year, total biomass of cabbage varied from 36.62 ~ 118.87 t ha^{-1}and the highest marketable yield (96.69 t ha^{-1}) was found in 4.5 t ha^{-1} RHB with 100% chemical fertilizer treatment (T_5) and lowest in control (16.3 t ha^{-1}). Two years result showed that RDCF performed 69.12 t ha^{-1} cabbage yield which was three fold higher yield hen that of control. It this case, marketable yield of the 80% chemical fertilizer with 4.5 t ha^{-1} RHB was identical with T_5 treatment i.e. 100% chemical fertilizer with 4.5 t ha^{-1} RHB.

Table 5. Effect of RHB on cabbage yield

Treatments	Total Biomass (t ha^{-1})			Marketable Yield (t ha^{-1})			Average Yield
	2019	2020	2021	2019	2020	2021	
T_1 (Absolute control)	39.83e	39.17c	36.62e	22.97f	17.57e	16.3e	18.95f
T_2 (100% RDCF)	89.30d	89.27b	90.11d	64.20e	66.10d	69.12d	66.4e
T_3(100% RDCF + RHB @ 1.5 t ha^{-1})	105.7bc	91.20b	100.02cd	74.90cd	74.80cd	77.84cd	75.85d
T_4 (100% RDCF + RHB @ 3.0 t ha^{-1})	110.8ab	111.75a	106.39bc	82.61bc	87.00ab	85.19bc	84.9bc
T_5 (100% RDCF + RHB @ 4.5 t ha^{-1})	119.5a	120.27a	118.87a	91.74a	94.48a	96.69a	94.3a
T_6 (80% RDCF + RHB @ 1.5 t ha^{-1})	98.29cd	97.14b	98.99cd	69.71de	71.157cd	74.61d	71.8de
T_7 (80% RDCF + RHB @ 3.0 t ha^{-1})	112.2ab	111.25a	107.26bc	81.83bc	80.18bc	87.68abc	83.23c
T_8 (80% RDCF + RHB @ 4.5 t ha^{-1})	116.8a	114.79a	114.79ab	87.67ab	88.44ab	94.23ab	90.1ab
CV (%)	5.84	8.21	6.51	6.12	7.89	7.8	5.05

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Data showed that, increased the RHB to the soil increased total biomass of cabbage. Application of RHB in soils increased soil organic carbon stock. Irrespective of treatments, the highest yield was recorded in soil amended with 4.5 t ha^{-1} of RHB. On the contrary, most studies on the crop production performance of plant-based biochars have shown that the beneficial effect of such biochars are most evident when biochar is combined with mineral fertilizers (Asai *et al.*, 2009; Van Zwieten *et al.,* 2010; Alburquerque *et al.,* 2013). Higher values of yield parameters and yield of cabbage was mainly due to greater amount of SOC and reduction of soil bulk density could be responsible. SOC influencing the marketable yield could be related to its physical soil properties. The correlation coefficient between soil bulk density and marketable yield were – 0.649 ($p < 0.05$), while that between SOC and marketable yield were 0.945 ($p<0.05$), respectively. The reduced soil bulk density of soil would have reduced mechanical impedance to cabbage root growth and would have increase length of root resulted easily uptake nutrient from soil to head growth. All these favourable conditions might have resulted in greater translocation and accumulation of nutrients resulted in improved yield parameters and yield of cabbage (Figure 3).

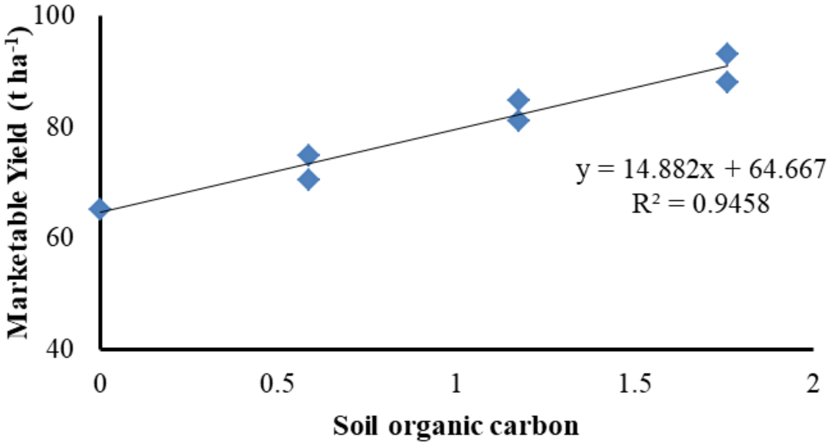

Fig 3.Relation between soil organic carbon with marketable yield cabbage

Nutrients uptake by cabbage

Application of chemical fertilizers in combination with RHB increased the N, P and K contents in cabbage over both sole application of inorganic fertilizers (T_2) and control (T_1) (Table 6). The increase of RHB significantly ($P< 0,05$) increasedthenutrients uptake by cabbage. The increased rate of biochar resulted in higher levels of N, P, K and S than the untreated control. Higher uptake of nutrients in vegetative parts as reported in combined treatment might be due to good proliferation of root system, resulting in better absorption in these plots. The lower nutrient accumulation generally observed for cabbage produced in the soil can be justified by the low availability of N and other nutrients in these treatments. Similarly, positive influence of combination of inorganic and organic treatment has also been reported by Sharma and Sharma (2002), Gupta*et al.* (2006) and Singh *et al.* (2011).

Table 6.Effect of RHB with chemical fertilizers on nutrient uptake by cabbage

Treatment	Nutrients uptake by cabbage (kg ha^{-1})							
	N	P	K	Ca	Mg	S	Zn	B
T_1 (Absolute control)	21.00e	11.1d	33.1f	56.2f	13.6c	21.93e	0.18e	0.13d
T_2 (100% RDCF)	54.67d	29.47c	83.1e	145e	35.5b	57.8d	0.43d	0.29bc
T_3 (100% RDCF + RHB @ 1.5 t ha^{-1})	63.96c	32.03bc	94.3cd	171d	36.2b	67.6c	0.48cd	0.28bc
T_4 (100% RDCF + RHB @ 3.0 t ha^{-1})	67.33bc	35.46ab	103bc	186bcd	41.3a	73.43bc	0.56b	0.31abc
T_5 (100% RDCF + RHB @ 4.5 t ha^{-1})	79.23a	39.27a	114a	208a	44.1a	82.57a	0.62a	0.33ab
T_6 (80% RDCF + RHB @ 1.5 t ha^{-1})	61.97c	33.13bc	92.6de	174cd	35.6b	65.1cd	0.50c	0.26c
T_7 (80% RDCF + RHB @ 3.0 t ha^{-1})	66.13c	35.7ab	102bcd	192abc	42.9a	71.93bc	0.54bc	0.31abc
T_8 (80% RDCF + RHB @ 4.5 t ha^{-1})	72.66b	38.57a	110ab	206ab	43.6a	79.33ab	0.59ab	0.35a
CV (%)	6.1	6.88	6.45	7.05	5.43	7.4	7.39	11.77

Cost and return analysis

The estimated total cost, gross return, gross margin and benefit cost ratio are presented in Table 7. The integration of different rate of chemical fertilizer with RHB increased the gross return and gross margin in all the treatments. The gross return ranged from 109435 to 233321 Tk./ha/year and gross margin ranged from 80065 to 709679 Tk./ha/year. The highest gross margin was obtained from T_5 treatment (100% RDCF + RHB @ 4.5 t ha^{-1}) with a BCR 4.04. Gross margin was obtained 671156 Tk./ha/year by reduction of 20% RDCF, i.e. 80% RDCF with 4.5 t ha^{-1} RHB (T_8 treatment) with BCR 3.92.

Table 7. Three years average cost benefit ratio of RHB with chemical fertilizers.

Treatment	Yield (t/ha)	Total input Cost (BDT/ha)	Total overhead cost (BDT/ha)	Total cost (BDT)	Gross return (Tk/ha/yr.)	Gross margin (Tk/ha/yr.)	BCR
T_1 (Absolute control)	18.95	99000.00	10435	109435	189500	80065	1.73
T_2 (100% RDCF)	66.4	120325.34	11821	132146	664000	531854	5.02
T_3(100% RDCF + RHB @ 1.5 t ha^{-1})	75.85	155325.34	14096	169421	758500	589079	4.48
T_4(100% RDCF + RHB @ 3.0 t ha^{-1})	84.9	185325.34	16046	201371	849000	647629	4.22
T_5(100% RDCF + RHB @ 4.5 t ha^{-1})	94.3	215325.34	17996	233321	943000	709679	4.04
T_6(80% RDCF + RHB @ 1.5 t ha^{-1})	71.8	152060.28	13884	165944	718000	552056	4.33
T_7 (80% RDCF + RHB @ 3.0 t ha^{-1})	83.23	182060.28	15834	197894	832300	634406	4.21
T_8 (80% RDCF + RHB @ 4.5 t ha^{-1})	90.1	212060.28	17784	229844	901000	671156	3.92

Conclusion

The yield of cabbage was greatly influenced by biochar addition. The highest marketable yield (94.31t ha^{-1}) was found in 4.5 t ha^{-1} RHB with 100% chemical fertilizer treatment and identical with 80% chemical fertilizer with 4.5 t ha^{-1} RHB. SOC influenced the marketable yield could be related to its physical and chemical properties. Therefore, RHB rate of 4.5 t ha^{-1} increased the growth, head yield of cabbage and soil N, P, K, Ca, Mg, pH and organic matter (OM) under the conditions of these experiments. Cost and return analysis showed that only RDCF is economically viable. But in case of soil health, it is not good practice. On the other hand, RHB have long term effect.So, further study requires to the long-term effects of this combination on crop productivity, nutrient availability and soil health.

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EFFECT OF KITCHEN WASTE COMPOST ON SOIL CARBON ACCUMULATION AND TOMATO YIELD

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Abstract

Two years field study was conducted on the effect of kitchen waste compost on tomato yield and carbon accumulation in soil at Regional Agricultural Research Station (RARS), Jamalpur, Bangladesh under Old Brahmaputra Floodplain (AEZ 9) during rabi season of 2020-2021 and 2021-2022.The objectives was to evaluate the effect of kitchen waste compost for better yield of tomato and to improve the stock of organic carbon in soil. The experiment was laid out in a randomized complete block design (RCBD) with 3 replications and BARI tomato-21 was used as test crop. There were seven treatments comprising T_1 = 100 % RDCF (control), T_2=100 % RDCF + Kitchen Waste Compost @ 2.5 t ha^{-1} , T_3 = 100 % RDCF + Kitchen Waste Compost @ 5 t ha^{-1}, T_4 = 85% RDCF + Kitchen Waste Compost @ 2.5 t ha^{-1}, T_5 = 85% RDCF + Kitchen Waste Compost @ 5 t ha^{-1} , T_6 =70% RDCF + Kitchen Waste Compost @ 2.5 t ha^{-1} and T_7 = 70% RDCF + Kitchen Waste Compost @ 5 t ha^{-1}. Data revealed that, combined application of kitchen waste compost and chemical fertilizer increased tomato production as compared to sole application of chemical fertilizers. The highest average tomato fruit yield (68.46 t ha^{-1}) was found in T_3 treatment (100 % RDCF + Kitchen Waste Compost @ 5 t ha^{-1}). T_1 treatment (100% RDCF) produced tomato yield of 55.82 t ha^{-1} which indicated that sole application of chemical fertilizer could not supply enough nutrients to plants. On the other hand, tomato yield was gradually decreased with decreasing chemical fertilizers. The lowest average tomato yield of 52.73 t ha^{-1} was recorded in the T_6 (70% RD + Kitchen Waste Compost @ 2.5 t ha^{-1}) treatment.Soil organic matter and N, P, K contents of post harvest soils were improved in integrated treatment compare to sole chemical treatment.Integrated treatment also increased organic carbon content, carbon stock and carbon accumulation in soil. So, application of100% recommended dose of chemical fertilizer with Kitchen Waste Compost @ 5 t ha^{-1} can be practiced for achieving higher tomato yield as well as economic benefit and keeps the soil and environment free from pollution.

Introduction

To achieve maximum productivity in agricultural systems, farmers have adopted the strategy of applying large amounts of chemical fertilizers and pesticides. At present, however, the negative effects of heavy applications of chemical inputs, in terms of production, environment and quality deteriorations are becoming apparent (Piqueres *et al*., 2005). The ultimate goal of sustainable agriculture is to develop farming systems that are productive, energy conserving, environmentally sound, conserving of natural resources such as soil and water and thus ensure food safety and quality.

Kitchen waste is defined as left-over organic matter from restaurants, hotels and households (Li *et al*., 2009).Kitchen waste forms a significant part of domestic waste.In 2014, it is estimated that Bangladesh generated soild waste of 23,688 tons per day in its urban areas and by 2025; the total waste generation is expected to reach 47,000 tons per day (Bangladesh Waste Database 2014).Most food waste has been land filled together with other wastes, resulting in various problems such as emanating odor, attracting vermin, emitting toxic gases, contaminating groundwater by the leachate and wasting landfill capacity (Shin *et al*., 2001). Methane (CH4) and carbon dioxide (CO2) emitted as a result of microbial activity under uncontrolled anaerobic conditions at dumping sites are released into the atmosphere and contribute to global warming (W.Parawira, 2004).

Composting is a good idea to reduce the amount of solid waste in the landfill. Composting is a controlled decomposition where natural breakdown process occurs. Organic fertilizers are the end product of composting. Organic fertilizers are crucial in agricultural sector because they have positive effect on soil without damaging ground water and plants (T.L.Min,2015).The study was aimed to explore the possibility of bioconversion of kitchen wastes to fertilizer that will helps to improve the yield, restore the soil fertility and will revive the microbial activities for sustainable crop production.

Materials and Methods

The trial was conducted at soil science field of Regional Agricultural Research Station (RARS), under Jamalpur district in Bangladesh. The site is located at Sonalata series under AEZ- 9, 24˚56′11′′N latitude and 89˚55´54´´E longitude and an altitude of 16.46m. The soil of the experimental site was silt clay loam in texture. Before initiation the experiment, the soil samples were collected from a depth of 0-15 cm for each replication and analyzed following standard methods. Nutrient status of initial soil is presented in Table 1.

Table 1. Initial soil status of the experimental soils

Location	pH	OM (%)	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
			meq $100g^{-1}$				µg g^{-1}						
RARS, Jamalpur	7.1	1.34	6.0	1.9	0.092	0.041	8.7	7.5	0.35	2.6	25	4.0	1.2
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4	1	0.6

The experiment was laid out in a randomized complete block design (RCBD) having 3 replications. The unit plot size was 3m x 2m and the variety was BARI Tomato-21. The 30 days old tomato seedlings were transplanted on 23 November, 2021 in a spacing of 60cm x 45cm. Recommended doses of chemical fertilizer for tomato were calculated on the basis of soil test values according to fertilizer recommendation guide.

Treatments were as follows

T_1 = 100 % RDCF (control)
T_2 = 100 % RDCF + Kitchen Waste Compost @ 2.5 t ha^{-1}
T_3 = 100 % RDCF + Kitchen Waste Compost @ 5 t ha^{-1}
T_4 = 85% RDCF + Kitchen Waste Compost @ 2.5 t ha^{-1}
T_5 = 85% RDCF + Kitchen Waste Compost @ 5 t ha^{-1}
T_6 = 70% RDCF + Kitchen Waste Compost @ 2.5 t ha^{-1}
T_7 = 70% RDCF + Kitchen Waste Compost @ 5 t ha^{-1}

Blanket dose: N_{150} P_{38} K_{50} S_{20} Zn_2 B_1 Kg ha^{-1} (FRG-2018)

Table 2.Treatments combinations for tomato crop

Treatments	Treatment combination						
	Chemical fertilizer (kg ha^{-1})						Organic manure (t ha^{-1})
	N	P	K	S	Zn	B	Kitchen Waste Compost
T_1	150	38	50	20	2	1	0
T_2	142	29	38	20	2	1	2.5
T_3	134	20	26	20	2	1	5.0
T_4	120	24	31	20	2	1	2.5
T_5	112	15	19	20	2	1	5.0
T_6	97	18	23	20	2	1	2.5
T_7	89	9	11	20	2	1	5.0

Note: T_1 =100 % RDCF (control), T_2 = 100 % RDCF + KWC @ 2.5 t ha^{-1},T_3= 100 % RDCF + KWC @ 5 t ha^{-1} T_4 = 85% RDCF + KWC @ 2.5 t ha^{-1} , T_5 = 85% RDCF + KWC @ 5 t ha^{-1} ,T_6 = 70% RDCF + KWC @ 2.5 t ha^{-1} and T_7 = 70% RDCF + KWC @ 5 t ha^{-1}

Preparation of Kitchen Waste Compost (KWC):

1. Composting material

In composting process, greens (high in Nitrogen) and browns (high in Carbon) are needed as the basic source as the composting materials. They are used to be called as Nitrogen and Carbon source. By greens we mean the kitchen waste, while browns mean dry leaves, sawdust, shredded paper and soil. Kitchen waste materials are collected from houses, then air dried and grinded into small pieces. This ground waste materials are mixed with brown in appropriate ratio (1:1 by volume which corresponds to 1: 3 by weight) to ensure homogeneity. The C/N ratio is calculated based on the weight percentages of the component wastes in the mixture.

2. Design of composting drums

The composting was carried out in plastic drum and were suitably modified by providing 10 mm equidistant holes in six layers on the circumference of the drums to facilitate the air circulation inside the drums.

3. Composting Method

The composting was basically done layer by layer. The browns and greens were layered alternatively in the container. Then, it was rotated for mixing and breaking down of the size of the materials.

Step 1: The bottom of the compost bin was filled with a thick layer of browns such as soil and shredded newspapers. These help to soak up excess moisture and improve aeration.

Step 2: The prepared greens was added into the composter. They should form a layer above the browns that were added in step 1.

Step 3: A few handful of compost starters were added into the composter. Then, they were mixed with the greens that are added in the previous step.

Step 4: Another layer of shredded browns was added into the composter. About the same amount of browns was added as greens from step 2. Then, this new layer was mixed with the greens and compost starters from the previous step. This introduces air spaces into the compost pile, ensuring an aerobic situation and effective composting process. It also prevents the compost pile from smells and pests.

After layering all the materials, a handful of water was sprinkled into the composter and some turmeric powder was added to avoid ants. The composter was avoided from direct sunlight as extreme temperatures would kill the beneficial microorganisms. Moisture content of the materials was controlled to 60% to 70%. The composter was then being rotated 3 days interval for mixing and aeration purpose and remoistened for sufficient microbial activity in order to get final composted material.

Table 3. Chemical composition of kitchen waste compost (KWC) used for the experiment

Name of the manure	pH	OC	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Zn
		%	meq 100g^{-1}			%	µg g^{-1}					
Kitchen waste compost (KWC)	7.9	22.0	7.50	3.65	0.51	0.31	0.36	1.42	0.01	0.04	0.57	0.09

Other intercultural operations were done as per requirement.The crop harvesting continued during the month of March to April, 2022. Data on yield and yield contributing characters were recorded from ten plants selected randomly for each plot. Data on vegetative and fruit characters were recorded and analyzed statistically using statistical software STAR which was developed by IRRI. Least significant differences (LSD) were used for means separation at 5% probability level. Carbon stock and Carbon accumulation were calculated using following formula.

Carbon stock (t ha^{-1}) = Carbon concentration (%) x bulk density (gcc^{-1}) x depth (cm)

Carbon accumulation (t ha^{-1}) = Final carbon stock (t ha^{-1}) - Initial carbon stock (t ha^{-1})

Results & Discussion

Effect of kitchen waste compost (KWC) on plant growth and yield of tomato

The information regarding yield and yield contributing of tomato as influenced by different treatments are summarized in Table 3.Integrated application of kitchen waste compost and inorganic fertilizers significantly increased the growth and yield of tomato. The highest plant height of 101.21 cm was recorded in the treatment T_3 where 100% chemical fertilizer + kitchen waste compost @ 5 t ha^{-1} was used. Significantly shortest plant highest of 89.59 cm was found in sole chemical fertilizer treatment.The better performance of tomato crop was observed when kitchen waste compost was combined with inorganic fertilizers. Application of compost and inorganic fertilizer statistically influenced the fruit length and fruit diameter. Fruit length and fruit diameter were increased from 5.04

cm to 5.78 cm and 4.09 cm to 4.51 cm, respectively due to different treatments.Number of fruits per plant was found highest (41.59) in T_3 treatment (100% RDCF + KWC @ 5 t ha^{-1}) which was statistically at par with T_2 treatment (100% RDCF + KWC @ 2.5 t ha^{-1}). Average fruit weight per plant was also highest (2.02 kg) in T_3 treatment which was statistically similar with T_2 treatment (100% RDCF + KWC @ 2.5 t ha^{-1}) and these values were found lowest in T_6 treatment (70% RDCF + KWC @ 2.5 t ha^{-1}).

The fruit yield of BRRI tomato 21 was significantly influenced due to the single and combined application of compost and fertilizers (Table 3). The highest fruit yield of 66.04 t ha^{-1} was obtained in the treatment T_3 (100% RDCF + KWC @ 5 t ha^{-1}) which was statistically identical to T_2 (100% RDCF + KWC @ 2.5 t ha^{-1}). The better performance of tomato yield was observed when compost was combined with chemical fertilizers. These results agreed with Ogundare *et al*. (2015) who reported that maximum nutrient availability due to integrated use of organic and inorganic fertilizers increased nutrient uptake by the plant which in turn lead to dry matter production and tomato fruit yield. Among all the treatments, T_3 (100% RDCF + KWC @ 5 t ha^{-1}) exhibited the maximum increase in tomato yieldwhich was 19.44 % higher over 100 % RDCF. T_1 treatment (100% RDCF) produced tomato yield of 55.29 t ha^{-1} which was lower than T_3 and T_2, and indicated that application of inorganic fertilizer could not supply enough nutrients to plants. Tomato yield was gradually decreased with decreasing inorganic fertilizers. The lowest fruit yield of 52.40 t ha^{-1} was recorded in the T_6 (70% RDCF + compost @ 2.5 t ha^{-1}) treatment.

Table 3. Effect of kitchen waste compost (KWC) on yield and yield components of tomato, 2021-22

Treat.	Plant height	Fruit length	Fruit diameter	Fruit no. $plant^{-1}$	Ave. fruit wt. plant $^{-1}$ (kg)	Tomato yield (t ha^{-1})	% increase over RD
	(cm)						
T_1	89.59 e	5.04 ab	4.27 b	28.46 d	1.16 d	55.29 d	-
T_2	98.27 b	5.78 a	4.44 a	41.29 a	1.86 ab	65.74 a	15.89
T_3	101.21 a	5.77 a	4.51a	41.59 a	2.02 a	66.04 a	19.44
T_4	91.05 cd	5.43 cd	4.25 bc	30.67 c	1.63 c	57.47 c	3.94
T_5	92.07 c	5.50 bc	4.27 b	32.19 b	1.71 bc	60.49 b	9.40
T_6	90.33 de	5.28 d	4.13 cd	25.23 f	0.99 d	52.40 e	-
T_7	91.01 d	5.35 cd	4.09 d	27.29 e	1.18 d	53.27 e	-
CV%	7.01	5.19	5.23	9.78	10.59	13.75	
LSD (0.05)	1.04	0.09	0.13	1.08	0.19	1.80	

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD.
Note:T_1 =100 % RDCF (control), T_2 = 100 % RDCF + KWC @ 2.5 t ha^{-1},T_3= 100 % RDCF + KWC @ 5 t ha^{-1} T_4 = 85% RDCF + KWC @ 2.5 t ha^{-1} , T_5 = 85% RDCF + KWC @ 5 t ha^{-1} ,T_6 = 70% RDCF + KWC @ 2.5t ha^{-1} and T_7 = 70% RDCF + KWC @ 5 t ha^{-1}

Nutrient status of post harvest soil

Soil analysis shows that integrated application of kitchen waste compost and inorganic fertilizers significantly increased soil nutrient status over the control. The pH of post harvest soil was affected by different treatments and ranged from 7.1 to 7.6 (Table 5). Maximum value of soil pH (7.6) was found from combined application of KWC @ 5 t ha^{-1} + inorganic fertilizer and minimum value of soil pH (7.1) was obtained in 100% RDCF treatment.The pH of post harvest soil was lowest in the 100% RDCF treatment might be due to the application of acid forming fertilizer (eg. Urea).Soil Organic carbon varies from 0.77% to 0.86%. Maximum organic carbon (0.86%) was found from KWC @ 5 t ha^{-1}+ inorganic fertilizer treatment and minimum (0.77%) in control treatment.On the other hand, treatments where kitchen waste compost was applied resulted in higher soil organic matter.Islam *et al*. (2013) and Manoj *et al*.(2012) found that the share duse of organic manure and chemical sources amplified soil organic matter content.Under T_3 (kitchen waste compost @ 5 tha^{-1} + inorganic fertilizer) treatment, about 54.76 % increases was observed in the available N content of the soil compared to control.Wiqar *et al*. (2013) concluded increase in soil total N by the integrated use of fertilizers.Likewise; remarkable increases of about 118.91% and 62.5% were recorded for P and K respectively in the T_3 in comparison to the control. Other soil nutrient status was higher in the treatments where kitchen waste compost were applied for slow released pattern of nutrients. On the other hand, in control treatment only chemical fertilizers were applied resulted lower nutrient status.

Table 5. Effect of kitchen waste compost application on nutrient status of post harvest soil, 2021-2022

Treatments	pH	SOM (%)	SOC (%)	Total N %	K meq $100g^{-1}$	P	S	B	Zn
						µg g^{-1}			
T_1	7.1	1.32	0.77	0.042	0.16	7.4	18.6	0.33	1.3
T_2	7.6	1.46	0.85	0.058	0.24	14.5	25.1	0.43	2.0
T_3	7.6	1.47	0.86	0.065	0.26	16.2	25.6	0.48	2.1
T_4	7.3	1.41	0.82	0.052	0.23	13.8	18.9	0.41	1.5
T_5	7.4	1.42	0.83	0.054	0.23	14.1	19.4	0.39	1.7
T_6	7.2	1.34	0.78	0.032	0.18	6.1	16.3	0.29	1.2
T_7	7.2	1.35	0.79	0.032	0.17	6.4	16.5	0.27	0.9
Initial soil	7.1	1.34	0.78	0.041	0.092	8.7	7.5	0.35	1.2

Note : T_1 = 100 % RDCF (control), T_2 = 100 % RDCF + KWC @ 2.5 t ha^{-1},T_3 = 100 % RDCF + KWC @ 5 t ha^{-1} T_4 = 85% RDCF + KWC @ 2.5 t ha^{-1} , T_5 = 85% RDCF + KWC @ 5 t ha^{-1} ,T_6 = 70% RDCF + KWC @ 2.5 t ha^{-1} and T_7 = 70% RDCF + KWC @ 5 t ha^{-1}

Table 6.Carbon accumulation in soil as influenced by different treatment combination,2021-2022

Treatments	Initial soil			Post harvest soil			Carbon accumulation ($t\ ha^{-1}$)
	SOC (%)	BD (gcc^{-1})	C Stock ($t\ ha^{-1}$)	SOC (%)	BD (gcc^{-1})	C Stock ($t\ ha^{-1}$)	
T_1	0.78	1.49	17.43	0.77	1.49	17.20	- 0.23
T_2	0.78	1.49	17.43	0.85	1.47	18.74	1.31
T_3	0.78	1.49	17.43	0.86	1.46	18.83	1.40
T_4	0.78	1.49	17.43	0.82	1.45	17.83	0.40
T_5	0.78	1.49	17.43	0.83	1.46	18.17	0.74
T_6	0.78	1.49	17.43	0.78	1.44	16.84	- 0.59
T_7	0.78	1.49	17.43	0.79	1.44	17.06	- 0.37

Note : T_1 = 100 % RDCF (control), T_2 = 100 % RDCF + KWC @ 2.5 t ha^{-1},T_3 = 100 % RDCF + KWC @ 5 t ha^{-1}, T_4 = 85% RDCF + KWC @ 2.5 t ha^{-1} , T_5 = 85% RDCF + KWC @ 5 t ha^{-1} ,T_6 = 70% RDCF + KWC @ 2.5 t ha^{-1} and T_7 = 70% RDCF + KWC @ 5 t ha^{-1}

Carbon accumulation in soil from different treatment combination

Integrated application of kitchen waste compost and inorganic fertilizers markedly improved the soil quality parameters. The initial soil organic carbon, bulk density and carbon stock in soil were 0.78 %, 1.49 gcc^{-1} and 17.43 tha^{-1}, respectively. After two years, bulk density varied from 1.44-1.49 gcc^{-1}.The soil organic carbon stock and carbon accumulation values are higher recorded in T_3 (100% RDCF + KWC @ 5 t ha^{-1}) treatment (18.83, 1.40) followed by T_2 (100% RDCF + KWC @ 2.5 t ha^{-1}) treatment(18.74, 1.31) and the lower values were recorded in control (17.20, -0.23) treatment. Result revealed that, integrated application of chemical fertilizers and organic manures treatments accumulated highest carbon compare to sole chemical fertilizer application. West and six (2007) reported that the duration of carbon sequestration varies between ecosystem, climate regimes and fertilization management (e.g. soil organic amendment inputs).

Cost and return analysis

Table 7 showed the economic performance of tomato as influenced by integrated application of inorganic fertilizers and organic manures. The highest gross return (Tk 1026900 ha^{-1}), gross margin (Tk 783800 ha^{-1}) and BCR (4.22) were recorded fromT_3 (100% RDCF + KWC @ 5 t ha^{-1}) treatment.

T_2 treatment (100% RDCF + KWC @ 2.5 t ha^{-1}) gave the second highest values for the said parameters.Among the treatment, the lowest gross return (Tk 790950 ha^{-1}), gross margin (Tk 562550 ha^{-1}) and BCR (3.46) were recorded fromT_6 treatment (70% RDCF + KWC @ 2.5 t ha^{-1}).

Table 7. Cost and return analysis of tomato production as influenced by different treatment combination,2021-2022

Treatments	Average Tomato yield (t ha^{-1})	Gross return	Total variable cost	Gross margin	BCR
		(Tk ha^{-1})			
T_1	55.82	837300	237500	599800	3.50
T_2	67.44	1011600	241000	770600	4.19
T_3	68.46	1026900	243100	783800	4.22
T_4	61.26	918900	233000	685900	3.94
T_5	63.39	950850	235700	715150	4.03
T_6	52.73	790950	228400	562550	3.46
T_7	53.81	807150	230800	576350	3.49

Note : T_1 = 100 % RDCF (control), T_2 = 100 % RDCF + KWC @ 2.5 t ha^{-1},T_3 = 100 % RDCF + KWC @ 5 t ha^{-1} T_4 = 85% RDCF + KWC @ 2.5 t ha^{-1} , T_5 = 85% RDCF + KWC @ 5 t ha^{-1} ,T_6 = 70% RDCF + KWC @ 2.5 t ha^{-1} and T_7 = 70% RDCF + KWC @ 5 t ha^{-1}

Input:Unit price **(**Tk.Kg^{-1}**):** Urea=16, TSP= 22, MoP = 15, Gypsum = 12, Zinc sulphate = 200, Boric acid = 250, Kitchen waste compost =10., Output:Price range of tomato 10 to 25 Tk Kg^{-1}, average price 15 Tk Kg^{-1}

Conclusion

Finally results revealed that, treatment package consists of 100% chemical fertilizer with kitchen waste compost @ 5 t ha^{-1} was found to be the most effective in increasing tomato yield and improved carbon accumulation in soil. From economic point of view, this treatment was suitable and economically viable. So, it can be concluded that, this combination (100% chemical fertilizer + kitchen waste compost @ 5 tha^{-1}) may be recommended for tomato cultivation in Jamalpur region (AEZ 9).

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NUTRIENT MANAGEMENT THROUGH COMPOST AND TRICHO COMPOST ON THE GROWTH AND YIELD OF GARLIC IN JAMALPUR

F S SHIKHA, M YASMIN , M A RAHMAN, R SEN AND H M NASER

Abstract

A field trial was conducted at Regional Agricultural Research Station (RARS), Jamalpur (AEZ 9) during the period of 2020 - 2022 to develop an optimum and economic tricho compost dose for maximizing the yield of garlic. There were five treatments comprising $T_1 =$ 100% NPKSZnB (STB), T_2 = Cowdung (3 t/ha.) + IPNS basis NPKSZnB , T_3 = Tricho compost (4 t/ha.) + IPNS basis NPKSZnB, T_4 = Tricho compost (2 t/ha. + IPNS basis NPKSZnB) and T_5 = Native fertility. The highest average yield (9.41 tha $^{-1}$) was obtained from T_3 (Tricho compost (4 t/ha.) + IPNS basis NPKSZnB) treatment which was followed by T_2 (Cowdung (3 t/ha.) + IPNS basis NPKSZnB.) treatment and the lowest (4.62 t ha $^{-1}$.) from T_5 (Native fertility) treatment. The highestindividual bulb wt. (20.77 g) was obtained from theT_3 (Tricho compost (4 t/ha.) + IPNS basis NPKSZnB) treatment) treatment which was statistically identical with T_2 (Cowdung (3 t/ha.) + IPNS basis NPKSZnB) treatment . The lowest individual bulb wt.(7.38 g) was obtained fromT_5 (Native fertility) treatment. Considering economics of the different treatments, the highest gross return (282300 TK ha-1), gross margin (160200 TK ha-1) and BCR (2.31) were obtained from T_3 treatment i.e., tricho compost (4 t/ha.) along with chemical fertilizer. The lowest gross return (138600 TK ha^{-1}) was found from T_5 i.e., native fertility treatment. From the trial, it can be concluded that tricho compost along with IPNS based chemical fertilizers is the best treatment.

Introduction

Garlic *(Allium sativum* L.) is an important bulb crop next to onion cultivated in Bangladesh. Garlic is one of the important and widely cultivated spice crops used for food as well as medicinal purposes (Diriba *et al*, 2013). Garlic has higher nutritive value than other bulb crops in addition to containing antibiotics like garlicin and allistatin (Maly *et al*., 1998). Moreover, it contains considerable amounts of Ca, P and K and its leaves are sources of protein, vitamin A and C (Mahmood, 2000). But the growth and yield of garlic is influenced by different nutrients management and other factors during their production in field. Among the cultural practices, nutrient supply and row spacing are of greater significance in garlic productivity. Farmers strive to produce high yield and good quality garlic both for consumption and economic value but soil fertility depletion is among the major impediments to sustained garlic production, especially in the less developed countries, because of limited application of suitable rate, type and sources of fertilizers. On the other hand, soil fertility is also reducing due to intensive cultivation of HYV and improper crop and soil management.

Garlic is very productive and profitable in Jamalpur region. In order to improve garlic production different fertilizers application (type, time and rate) is one of the limiting factors of garlic production that should be considered (Brewster and Butler, 1989) and the production of vigorous sprouts is one of the most important factors of successful garlic production through balanced nutrients applications (Potgieter, 2006). Application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation and nutrient needs of crops is according to their physiological requirements and expected yields (Ryan, 2008).Recently in Bangladesh, Trichoderma-fortified compost was found most effective in controlling different diseases as well as increased yield of other vegetables significantly (Liton, 2014). The quality and other quantity of compost applied to soil affects the growth of plants and its disease suppressive capability (Noble and conventry, 2005; Hadar and Papadopoulou, 2012 Compost and compost extracts considered as bio- fertilizers have been found to enhance plant growth and to suppress pathogens (Gharib et al., 2008; Naidu et al., 2010). Unbalanced use of chemical fertilizers was applied for getting high profit in garlic. It was known that this bad practicing has a adverse effect on soil health over all the environment. So overcome this problem a standard integrated fertilizer doses for Garlic is needed. To get the maximum return and crop production, fertilizer management with organic manuring is the most logical way to raise the total production. Therefore, the present study has been planned to find out the IPNS based nutrient management for garlic production.

Materials and Methods

The experiment was started in 2020-21 period at the field of Regional Agricultural Research Station (RARS) under Jamalpur district in Bangladesh. Before initiation the experiment, the soil samples were collected from a depth of 0-15 cm for each replication and analyzed following standard methods (Table 1). The chemical properties of soils in the experimental site was silt clay loam in texture belonging to Sonalata series under Agro-Ecological Zone-8 (AEZ-8), 24˚56´11´´N latitude and 89˚55´54´´E longitude and an altitude of 16.46m. Nutrient status of initial soil prior to fertilization is presented in Table 1.

Table 1. Initial soil status of the experimental soils

Location	pH	OM (%)	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
			meq $100g^{-1}$				μg g^{-1}						
RARS, Jamalpur	7.1	0.96	5.5	1.5	0.18	0.048	13.4	10.8	0.50	1.42	20	2.03	1.26
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4	1	0.6

Preparation of tricho compost:

Tricho compost was prepared according to the procedure suggested by BARI (2008). A plastic drum of around 230 liters (97cm height ×186 cm diameter) was used as a unit. A bucket and a tap were placed at the lower side in the unit. The bottom of the container was filled with 15-cm layer of broken pebbles, followed by a 15-cm layer of coarse sand. A consistent mixture was filled the container as follows:

- 25% cow dung (rich in nitrogen, with a carbon-to-nitrogen ratio (C:N) of 8)
- 5% sawdust (as a source of carbon)
- 36% poultry refuse (to provide calcium and nitrogen, and to reduce incidence of soilborne disease)
- 33% water hyacinth (to provide potassium)
- 0.5% ash (to provide potassium)
- 0.5% maize bran (as a feed for the inoculum). Half liter of *Trichoderma* inoculum was mixed with 0.5 kg of molasses and 5 liters of water, around 200kg of compost materials. These ingredients were mixed together and added to the compost recipe listed above. The compost and inoculum mixture were combined thoroughly before being placed in the compost drum and sprinkling the inoculant mixture over each layer. The leachate was collected using the tap and poured back onto the compost for the first 10 days. The leachate that comes out in first 10 days is not really the result of the decomposition process, but more from the seepage of the excess water (with *Trichoderma* spores) from the composting mix. Putting it back in the composting bin keeps the composting mixture moist and helps out with the decomposition process. From 15 days after setting up the composting process onward, the leachate was collected and bottled. During the tricho compost preparation, the temperature and pH inside the container ranged from 30–35°C and 7.0–7.8 respectively. the composting process takes roughly 50-70 days depending on temperature. The composted materials were then ground and used as trichocompost. The chemical compositions (such as organic carbon, P, K, S, B, Cu, Fe, Mn, Zn, Mg, Ca and pH) of trichocompost were determined (Table 2).

Table 2. Chemical composition of tricho compost samples used in experimental field

Properties	pH	OC (%)	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			meq $100g^{-1}$				μg g^{-1}					
Tricho compost	7.74	21	6	2.31	1.53	-	0.30	1.40	0.010	0.032	0.036	0.064

The experiment was laid out in Randomized Complete Block (RCB) design with five treatments replicated thrice. The unit plot size was 3 m x 2 m. There were five treatments viz. T_1 = 100% NPKSZnB (STB), T_2 = Cowdung (3 t/ha.) + IPNS basis NPKSZnB , T_3 = Tricho compost (4 t/ha.) + IPNS basis NPKSZnB, T_4 = Tricho compost (2 t/ha. + IPNS basis NPKSZnB) and T_5 = Native fertility. The seeds of garlic (var. BARI rasun – 2) was sown on 17 November 2021 spacing for garlic was 20 cm x 10 cm. Nitrogen, phosphorus, potassium, sulphur, zinc and boron were used in the form of urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. All P, K, S, Zn, B, tricho compost and $^{1}/_{3}$rd urea-N were applied at the time of final land preparation and the remaining $^{2}/_{3}$rd urea-N was applied in two equal installments at 30 and 50 days of sowing. All the intercultural operations such as irrigation, weeding, insect control etc. were done as and when necessary. Garlic was harvested on 27 March 2022. Bulb yield was calculated in ton per hectare considering the whole plot as harvested area. Ten plants of garlic from each plot were selected randomly to collect data on yield components. Data on yield and yield contributing characters were recorded and analyzed statistically using statistical software STAR which was developed by IRRI.

Results and Discussion

Garlic yield and yield contributing characters

Yield and yield contributing characters of garlic were influenced by the tricho compost with chemical fertilizers which was summarized in the table 3. The parameters like clove bulb $^{-1}$ (no.), individual bulb wt. (g) and bulb yield (t ha $^{-1}$.) were significantly influenced by different nutrient packages.

Plant population's m^{-2}

The highest plant populations m^{-2} (58.2) was obtained from T_3 = Tricho compost (4 t/ha.) + IPNS basis NPKSZnB treatment which was followed by T_1 (100% NPKSZnB) treatment and the lowest (50) from T_5 (Native fertility) treatment.

Plant height

The highest plant height (49.5 cm) was obtained from T_4 (Tricho compost (2 t/ha.) treatment which was followed by T_3 (Tricho compost (4 t/ha.) + IPNS basis NPKSZnB) treatment and The lowest (43.60) from T_5 (Native fertility) treatment/

Leaf no. per plant

The highest leaf no. per plant (7.3) was obtained from T_3 (Tricho compost (4 t/ha.) + IPNS basis NPKSZnB) treatment which was followed by T_1 (100% NPKSZnB) treatment and The lowest (6.5) from T_5 (Native fertility) treatment.

Bulb diameter

Bulb diameter progressively increased by using the manures. The maximum bulb diameter (4.56 cm) was obtained from the T_3 (Tricho compost (4 t/ha.) + IPNS basis NPKSZnB) treatment which was followed by T_2 (Cowdung (3 t/ha.) + IPNS basis NPKSZnB. The lowest bulb diameter (1.85 cm) was obtained fromT_5(Native fertility) treatment.

Number of clove bulb $^{-1}$

Number of clove bulb $^{-1}$ was positively affected by different treatment combinations. The highest clove bulb $^{-1}$ (no.) (24.15) was obtained from the T_3 (Tricho compost (4 t/ha.) + IPNS basis NPKSZnB) treatment) treatment which was followed by T_2 (Cowdung (3 t/ha.) + IPNS basis NPKSZnB) treatment . The lowest clove bulb $^{-1}$(no.) (16.85) was obtained fromT_5 (Native fertility) treatment.

Individual bulb weight

The different treatment combinations were statistically significant on the individual bulb wt. The highestindividual bulb wt. (20.77 g) was obtained from the T_3 (Tricho compost (4 t/ha.) + IPNS basis NPKSZnB)) treatment which was statistically identical with T_2 (Cowdung (3 t/ha.) + IPNS basis NPKSZnB) treatment . The lowest individual bulb wt.(7.38 g) was obtained fromT_5 (Native fertility) treatment.

Bulb yield

Garlic yield was increased by using the organic fertilizers. Significantly the highest ave. yield (9.41 tha $^{-1}$) was obtained from T_3 (Tricho compost (4 t/ha.) + IPNS basis NPKSZnB) treatment which was followed by T_2 (Cowdung (3 t/ha.) + IPNS basis NPKSZnB.) treatment and the lowest (4.62 t ha $^{-1}$.) from T_5 (Native fertility) treatment. The highest bulb yield performed by T_3 treatment might be due to application of tricho compost with chemical fertilizers.

Cost and return analysis

A cost-return analysis is the process used to measure the benefits of a decision or taking action minus the costs associated with taking that action. So, economics of the various treatments was worked out (Table 4). Considering economics of the different treatments, the highest gross return (282300 TK ha^{-1}), gross margin (160200 TK ha^{-1}) and BCR (2.31) were obtained from T_3 treatment i.e., tricho compost (4 t/ha.) with chemical fertilizer. The lowest gross return (138600 TK ha^{-1}) was found from T_5 i.e., native fertility treatment. Therefore, T_3 treatment (tricho compost 4 t/ha., + IPNS treatment) is more profitable than other treatment for cultivation of garlic.

Table 2. Effects on different treatments on the yield components and bulb yield of garlic during 2021-22

Treat.	Plant pop. m^{-2} (no.)	Plant height (cm)	Leaf no. $plant^{-1}$	Bulb dia. (cm)	Clove $bulb^{-1}$ (no.)	Indv. bulb wt. (g)	Bulb yield(t ha^{-1})		
							2020-21	2021-22	Ave. yield (t/ha)
T_1	55.3	45.5	7.2	3.43	21.75c	17.44bc	7b	7.14b	7.07
T_2	49.6	46.8	6.8	3.47	22.84b	19.04ab	7.5b	7.55b	7.52
T_3	58.2	48.7	7.3	4.56	24.15a	20.77a	9.7a	9.13a	9.41
T_4	51.2	49.5	7.1	2.76	18.69d	15.50c	5.8c	5.58c	5.79
T_5	50	43.6	6.5	1.85	16.85e	7.38d	4.6d	4.65d	4.62
CV (%)	11.65	9.3	7.53	9.4	8.76	7.12	9.7	5.97	-
LSD	-	-	-	-	1.08	2.14	0.89	0.77	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Note: T_1 = 100% NPKSZnB (STB), T_2 = Cowdung (3 t/ha.) + IPNS basis NPKSZnB , T_3 = Tricho compost (4 t/ha.) + IPNS basis NPKSZnB, T_4 = Tricho compost (2 t/ha. + IPNS basis NPKSZnB) and T_5 = Native fertility

Table 4. Cost and return analysis

Treat.	Ave. Bulb yield (t/ha)	Gross return (Tk/ha/yr.)	Total variable cost (BDT/ha)	Gross margin (Tk/ha/yr.)	BCR
T_1	7.07	212100	119010	93080	1.78
T_2	7.52	225600	125080	100520	1.80
T_3	9.41	282300	122090	160200	2.31
T_4	5.79	173700	135120	38580	1.28
T_5	4.62	138600	110240	28360	1.25

Input:Urea 16 TKKg-1, TSP 22 TKKg-1, MoP 15 TKKg-1, Zinc sulphate 120 TKKg-1, Boric acid 150 TKKg-1 and Tricho compost 5 $TKKg^{-1}$.

Output:garlic 30 $TKKg^{-1}$

Conclusion

From the trial, it can be concluded that tricho compost (4 t/ha.) with IPNS based chemical fertilizers is the best treatment in the RARS, Jamalpur under AEZ-9 of Bangladesh.

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NUTRIENT MANAGEMENT THROUGH ORGANIC MANURING AND BIOFERTILIZERS ON THE YIELD OF ONION AND SOIL HEALTH IMPROVEMENT

F S SHIKHA, M YASMIN, M A RAHMAN, R SEN AND H M NASER

Abstract

A field trial was conducted during the period of 2020-21 and 2021-22 at Regional Agricultural Research Station (RARS), Jamalpur (AEZ 9) to increase yield of onion using tricho compost and arbuscular mycorrhizal fungi to obtain a good economic return with good soil health for the onion cultivation. There were six treatments comprising T_1 = 100% NPKSZnB (STB), T_2 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB, T_3 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM, T_4 = 100% NPKSZnB (STB) + AM , T_5 = Tricho compost (5t/ha.) + AM, T_6 = Native fertility. The highest average bulb yield (22.65 tha^{-1}) of onion was obtained from T_3 (Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM) treatment. The lowest average bulb yield (9.14 tha^{-1}) obviously recorded from control (T_6) treatment. The highest bulb wt. (62.05 g) was obtained T_3 (Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM) treatment and lowest (40.54 g) was obtained from T_6 (native fertility) treatment. The highest root colonization and no. of spore population(80%) and (353) respectively was observed in the trial treated with tricho compost-AM combined application, while the lowest values (30%) and (70) respectively were recorded in the control trial. The pH of post-harvest soil was affected by different treatments and ranged from 7.1 to 7.4. The macronutrient and micronutrient uptake significantly increased over STB fertilizer dose by the application of tricho compost and AM along with STB fertilizer dose. Maximum organic carbon (0.82%) was found from application of tricho compost and AM with STB fertilizer and minimum (0.73%) in control treatment. Soil total nitrogen varies from 0.041% to 0.047%. Likewise, remarkable increases of P and K in the T_3 in comparison to the control. The soil organic carbon stock and carbon accumulation values (17.34 t ha^{-1} and 1.35 t ha^{-1}) respectively are higher recorded in T_3 (Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM) treatment and the lower values were recorded in T_5 and control treatment. Considering economics of the different treatments, the highest gross return (679500 TK ha-1), gross margin (530420TK ha-1) and BCR (4.56) were obtained from T_3 treatment i.e., tricho compost (5t/ha.), AM along with chemical fertilizer. The lowest gross return (274200 TK ha^{-1}) was found from T_6 i.e., native fertility treatment and lowest BCR (2.51) was obtained in T_6 treatment. From the trial, it can be concluded that tricho compost and AMF inoculant along with IPNS based chemical fertilizers is the best treatment.

Introduction

Onion (*Allium cepa L.*) belongs to family Alliaceae is the most commercially valuable spices grown in Bangladesh. It is used in curry and salad for more tasty and delicious food preparation. Moreover, it is rich source of carbohydrates, proteins, Vitamin C and minerals (P and Ca). Government imports onion from abroad paying high value for its low production and quality in Bangladesh. The continuous use of chemical fertilizer adversely affects the soil structure whereas biofertilizers when applied to soil improve the soil structure and quality of crop products, increase in crop yield by 20 - 30%, replacement of chemical nitrogen and phosphorus by 25%, also chemical fertilizers are toxic at higher dose while biofertilizers have no toxic effects (Gyaneshwar *et al*., 2002). Besides above facts, the long-term use of bio-fertilizers is economical, eco-friendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers (FEPSAN, 2011).

Trichoderma take part a natural composting process and enhance the process and itself play important an role in crop protection. Raw organic materials such as crop residues, animal wastes, food garbage and some municipal wastes, enhance their suitability for application to the soil as a fertilizing resource, after having undergone *Trichoderma* composting. It is not only influence yield of crop and improve of soil health but also enhance nutritional quality (Molla, Haque, Haque, & Ilias, 2012). Moreover, the application of Trichoderma-enriched bio-organic fertilizer minimizes NPK uses and most of the cases it reduced the 50-70% cost of N-fertilizer uses as optimal dose for corn, tomato and bottle gourd cultivation (Haque, Haque, Ilias, & Molla, 2011; Molla, Fakhru'l-Razi, Hanafi, & Alam, 2005; Molla et al., 2012)). Presently our poor farmers and /or women are not practicing it. But there is potential scope to involve poor farmers and women at composting process of organic wastes by ensuring availability of potential non-phytopathogenic, beneficial and capable of fast decomposing microbes. There are ample opportunities on production of value-added compost in Bangladesh.

Moreover, AMF functionally can improve by addition of soil amendment (Warnock et al. 2010). Due to an extended network of fine hyphae, the AM fungi can considerably improve the uptake of mineral nutrients to their host plant, whereas plant supports the fungus with assimilation products (Harley and Smith, 1983; Smith and Read, 1997; Aggarwal et al. 2011). Arbuscular mycorrhizal fungi and tricho compost has a great role in onion production. On the other hand, a judicious combination of organic and inorganic sources of nutrients might be helpful to obtain a good economic return with good soil health for the subsequent crop. The research is needed to study the nutrient uptake of onion influenced by AMF and tricho-compost. So, the present investigation was undertaken to study the effect of bio-fertilizer (AMF) and tricho compost on yield of onion and reduce the chemical fertilizer in onion cultivation.

Materials and Methods

A field trial was conducted at Regional Agricultural Research Station (RARS), Jamalpur during 2021-2022 to increase yield of onion using tricho compost and arbuscular mycorrhizal fungi. Nutrient status of initial soil prior to fertilization is presented in Table 1.

Table 1. Initial soil status of the experimental soils

Location	pH	OM	Ca	Mg	K	Total	P	S	B	Cu	Fe	Mn	Zn
		(%)	meq 100g^{-1}			N%	μg g^{-1}						
RARS, Jamalpur	7.1	1.26	5.3	1.6	0.13	0.045	8.4	7.2	0.34	1.8	24	2.3	1.35
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4	1	0.6

The experiment was laid out in Randomized Complete Block (RCB) design with six treatments replicated thrice. The unit plot size was 4m x 2m. There were six treatments comprising
T_1 = 100% NPKSZnB (STB)
T_2 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB
T_3 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM
T_4 = 100% NPKSZnB (STB) + AM
T_5 = Tricho compost (5t/ha.) + AM
T_6 = Native fertility (control)

Preparation of tricho compost:

Tricho compost was prepared according to the procedure suggested by BARI (2008). A plastic drum of around 230 liter (97cm height ×186cm diameter) was used as a unit. A bucket and a tap were placed at the lower side in the unit. The bottom of the container was filled with 15-cm layer of broken pebbles, followed by a 15-cm layer of coarse sand. A consistent mixture was filled the container as follows:
• 25% cow dung (rich in nitrogen, with a carbon-to-nitrogen ratio (C: N) of 8)
• 5% sawdust (as a source of carbon)
• 36% poultry refuse (to provide calcium and nitrogen, and to reduce incidence of soil borne disease)
• 33% water hyacinth (to provide potassium)
• 0.5% ash (to provide potassium)
• 0.5% maize bran (as a feed for the inoculum)

Half liter of *Trichoderma* inoculum was mixed with 0.5 kg of molasses and 5 liters of water, around 200kg of compost materials. These ingredients were mixed together and added to the compost recipe listed above. The compost and inoculum mixture were combined thoroughly before being placed in the compost drum and sprinkling the inoculant mixture over each layer. The leachate was collected using the tap and poured back onto the compost for the first 10 days. The leachate that comes out in first 10 days is not really the result of the decomposition process, but more from the seepage of the excess water (with *Trichoderma* spores) from the composting mix. Putting it back in the composting bin keeps the composting mixture moist and helps out with the decomposition process. From 15 days after setting up the composting process onward, the leachate was collected and bottled. During the tricho compost preparation, the temperature and pH inside the container ranged from 30–35°C and 7.0–7.8 respectively. the composting process takes roughly 50-70 days depending on temperature. The composted materials were then ground and used as trichocompost. The chemical compositions (such as organic carbon, N, P, K, S, B, Cu, Fe, Mn, Zn, Mg, Ca and pH) of trichocompost were determined (Table 2).

Table 2. Chemical composition of tricho compost samples used in experimental field

Properties	pH	OC %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			me_q $100g^{-1}$				μg g^{-1}					
Tricho compost	7.74	21	6	2.31	1.53	-	0.30	1.40	0.010	0.032	0.036	0.064

Onion var. BARI Piaz 5 was used for the study. The Arbuscular Mycorrhiza (AM) fungal inoculum used in this experiment was collected from microbiology laboratory, BARI, Joydebpur, Gazipur. Two nursery beds (with inoculated and without inoculated) of 3 m x 1m were prepared thoroughly and AMF inoculated with onion seeds and maintained systematically till the seedlings were ready for transplanting. Healthy and uniform seedlings were transplanted. Three replications were made for each treatment. AM inoculum was added in all treatments except T_1,T_2 and T_6 treatment. A control treatment was also included without fertilization and without inoculum addition. All PKSZnB, tricho compost and one third of nitrogen were applied at the time of final land preparation and the remaining two third nitrogen was applied in two equal installments. The seedlings were planted at 15 cm × 10 cm spacing on 22 December 2021. Irrigation and other intercultural management practices were done as and when necessary. The crop was harvested on 04 April 2022 and the necessary data on different parameters were recorded from 10 randomly selected plants. Yield data were taken from whole plot and were converted to per hectare yield. The initial soil samples at a depth of 0-15 cm from the experimental fields were collected and analyzed following standard methods (Table 1). The tricho compost used in this experiment were also analyzed (Table 2). Data on yield and yield contributing characters were recorded and analyzed statistically using statistical software STAR which was developed by IRRI. The analyzed data were compared with Least Significant Difference (LSD) test at 5% level.

Results and discussion

Yield and yield contributing characters influenced by the tricho compost and arbuscular mycorrhizal fungi on growth and yield of onion was significant compared with control treatment (Table 3).

Bulb yield

The highest ave. bulb yield (22.65tha^{-1}) of onion was obtained from T_3 (Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM) treatment which was followed by T_2 (17.98 t/ha) (Tricho compost (5t/ha.) + IPNS basis NPKSZnB) treatment. The lowest ave. bulb yield (9.14 tha^{-1}) obviously recorded from control (T_6) treatment.

Pant height

There was not statistically difference among the plant height in different treatment combination. The highest plant height (48.30 cm) was obtained from T_4 (100% NPKSZnB (STB) + AM treatment and the lowest (42.54 cm) from (T_6) control.

Bulb length

The highest bulb length (5.38 cm) was obtained from T_3 (Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM) treatment and the lowest (4.96 cm) obtained from T_1 treatment but there had no statistically difference in different treatment combination.

Bulb breadth

The highest bulb breadth (5.26 cm) was obtained from T_3 (Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM) treatment which was followed by T_2 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB treatment which produced bulb breadth (4.16 cm) and lowest (2.56 cm) was obtained from T_6 (control) treatment.

Bulb weight

The highest bulb wt. (62.05 g) was obtained T_3 (Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM) treatment which was followed by T_2 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB which produced bulb wt. (54.14 g) and lowest (40.54 g) was obtained from control. The highest bulb yield performed by T_3 treatment might be due to the combined effect of AMF inoculants and tricho compost. Under field conditions, an integrated management strategy that combined the use of T. harzianum with poultry substrates was appeared to be significantly more superior in improving growth promotion components and yield in onion when compared to dual and individual application of them although of all the treatments significantly increased all the promoting components and yield in comparison to the untreated control.(Akter et.al., 2016).

Table 3.Yield and yield contributing characters of onion during 2021-2022

Treat.	plant height (cm)	Populations m^{-2}	Bulb Length (cm)	Bulb breadth (cm)	Bulb weight (g)	Bulb yield (t ha^{-1})		
						2020-21	2021-22	Ave yield
T_1	44.52	56.7	5.23	3.23d	50.14bc	14.87bc	14.97cd	14.92
T_2	45.2	48.1	5.35	4.16b	54.14b	17.52b	18.44b	17.98
T_3	47.12	52.37	5.38	5.26a	62.05a	22.82a	22.49a	22.65
T_4	48.30	48.85	5.00	3.78bc	53.14bc	16.23b	15.42bc	15.82
T_5	45.68	45.36	5.13	3.04d	46.47cd	12.67bc	12.14d	12.40
T_6	42.54	51.14	4.96	2.56d	40.54d	9.93c	8.36e	9.14
CV(%)	7.28	10.32	6.35	6.57	4.65	11.17	7.16	-
LSD	-	-	-	0.68	6.73	4.96	3.10	-

Values in a column having same letter(s) do not differ significantly at 5% level by LSD.

Note:T_1 = 100% NPKSZnB (STB), T_2 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB, T_3 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM, T_4 = 100% NPKSZnB (STB) + AM , T_5 = Tricho compost (5t/ha.) + AM and T_6 = Native fertility

Root colonization (%) and No. of spore per 100 g soil

After completion of the experiment effect of tricho compost and AMwas presented (Table 4) which indicates that the application of tricho compost and AM produced significant variations in the root colonization (%) and spore population (no.) of the soil. The root colonization and no. of spore per 100 g soilof post-harvest soil was affected by different treatments and ranged from (30 % to 80%) and (70 to 353) respectively. The highest root colonization(80 %) was observed in the trial treated with tricho compost-AM-chemical fertilizer combined application and the highest no. of spore per 100 g soil(353) was observed in the trial treated with only tricho compost - AM combined application, while the lowest values (30%) and (70) respectively were recorded in the control trial.

Table 4. Effect of Tricho compost and AM on root colonization (%) and No. of spore per 100 g soilof post-harvest soil during 2021-2022

Treatments	root colonization (%)	No. of spore per 100 g soil
T_1	40	85
T_2	50	235
T_3	80	296
T_4	70	260
T_5	60	353
T_6	30	70

Note: T_1 = 100% NPKSZnB (STB), T_2 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB, T_3 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM, T_4 = 100% NPKSZnB (STB) + AM , T_5 = Tricho compost (5t/ha.) + AM and T_6 = Native fertility

Nutrient status of post-harvest soil

After completion of the experiment effect of tricho compost and AMwas presented (Table 5) which indicates that the application of tricho compost and AM produced significant variations in the chemical properties of the soil. The pH of post-harvest soil was affected by different treatments and ranged from 7.1 to 7.4. The highest pH value (7.4) was observed in the trial treated with tricho compost-AM combined application, while the lowest values (7.1)were recorded in the control trial. Application of tricho compost and AM along with STB fertilizer dose significantly increased the macronutrient and micronutrient uptake over STB fertilizer dose. Soil organic carbon varies from 0.73% to 0.82%. Maximum organic carbon (0.82%) was found from application of tricho compost and AM with STB fertilizer and minimum (0.73%) in control treatment. On the otherhand for slow released pattern of nutrients, soil nutrient status was higher in the treatments where organic fertilizers were applied. For this reason, the lower nutrient status in control treatment where no fertilizers were applied. SOM (%) was increased with organic fertilizer application. Soils constitute the largest C pool both in organic and inorganic forms. Although SOM usually constitutes less than 5% of soil weight, it is one of the most important components of a field ecosystem (Lal, 2015). On the other hand, treatments where tricho compost and AM was applied resulted in higher soil organic matter. Soil total nitrogen varies from 0.041% to 0.047%. P and K in the T_3 was also increased in comparison to the control. OM is also the key energy substrate for microorganisms in soil that facilitate various soil biogeochemical processes and via mineralisation, provides nitrogen (N), phosphorus (P) and sulfur (S) to plants (Murphy 2015).

Table 5. Effect of Tricho compost (5t/ha.)and AM on nutrient status of post-harvest soil during 2021- 2022

Treatments	pH	SOM (%)	SOC (%)	Total N %	K meq $100g^{-1}$	P	S	B	Zn
						µg g^{-1}			
T_1	7.1	1.24	0.73	0.046	0.18	9.3	17.6	0.38	1.4
T_2	7.3	1.31	0.76	0.042	0.25	12.5	18.8	0.45	1.42
T_3	7.4	1.41	0.82	0.047	0.25	18.3	23.6	0.47	1.48
T_4	7.2	1.27	0.74	0.041	0.23	17.4	19.4	0.43	1.41
T_5	7.3	1.35	0.78	0.044	0.20	14.9	18.9	0.40	1.39
T_6	7.1	1.25	0.73	0.045	0.15	7.3	6.4	0.25	1.03
Initial soil	7.1	1.26	0.74	0.045	0.13	8.4	7.2	0.34	1.35

Note: T_1 = 100% NPKSZnB (STB), T_2 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB, T_3 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM, T_4 = 100% NPKSZnB (STB) + AM , T_5 = Tricho compost (5t/ha.) + AM and T_6 = Native fertility

Soil carbon accumulation

After completion of the experiment effect of tricho compost and AM markedly improved the soil quality in different parameters (Table 6). The initial soil organic carbon, bulk density and carbon stock in soil were 0.74 %, 1.46 gcm^{-3} and 15.99 tha^{-1}, respectively. After two years, bulk density varied from 1.41-1.46 gcm^{-3}. The soil organic carbon stock and carbon accumulation values are higher recorded in T_3 (Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM) treatment (17.34 t ha^{-1}, 1.35 t ha^{-1} respectively) followed by T_5 (Tricho compost (5t/ha.) + AM) treatment (16.73 t ha^{-1}, 1.0.74 t ha^{-1} respectively) and the lower values were recorded in T_5 and control (15.98, -0.01) treatment. The result indicated that, integrated application of tricho compost and AM treatments accumulated highest carbon compared to sole chemical fertilizer application. The biotic and abiotic factors along with dynamics of labile C pools are required to evaluate management, land use, and climate change effects on SOC changes and soil functionalities (Kopittke et al., 2015).

Table 6. Soil fertility attributes under tricho compost and AMapplication, 2021-2022

Treatments	Initial soil			Post-harvest soil			Carbon accumulation ($t\ ha^{-1}$)
	SOC (%)	BD ($g\ cm^{-3}$)	C Stock ($t\ ha^{-1}$)	SOC (%)	BD ($g\ cm^{-3}$)	C Stock ($t\ ha^{-1}$)	
T_1	0.74	1.46	15.99	0.73	1.46	15.98	-0.01
T_2	0.74	1.46	15.99	0.76	1.42	16.18	0.19
T_3	0.74	1.46	15.99	0.82	1.41	17.34	1.35
T_4	0.74	1.46	15.99	0.74	1.44	15.98	-0.01
T_5	0.74	1.46	15.99	0.78	1.43	16.73	0.74
T_6	0.74	1.46	15.99	0.73	1.46	15.98	-0.01

Note: T_1 = 100% NPKSZnB (STB), T_2 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB, T_3 = Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM, T_4 = 100% NPKSZnB (STB) + AM , T_5 = Tricho compost (5t/ha.) + AM and T_6 = Native fertility

Table 7. Cost and return analysis

Treat.	Ave. bulb yield ($t\ ha^{-1}$)	Gross return (Tk/ha/yr.)	Total variable cost (BDT/ha)	Gross margin (Tk/ha/yr.)	BCR
T_1	14.92	447608	119012	328596	3.76
T_2	17.98	539400	144080	395320	3.74
T_3	22.65	679500	149080	530420	4.56
T_4	15.82	474600	124000	350600	3.82
T_5	12.40	372000	122345	245655	3.04
T_6	9.14	274200	109050	165150	2.51

Input:Urea 16 TKKg-1, TSP 22 TKKg-1, MoP 15 TKKg-1,Zinc sulphate 120 TKKg-1, Boric acid 150 TKKg-1 and Tricho compost 5 $TKKg^{-1}$.
Output:onion 30 $TKKg^{-1}$

Cost and return analysis

A cost-return analysis is the process used to measure the benefits of a decision or taking action minus the costs associated with taking that action. So, economics of the various treatments was worked out (Table 4). Considering economics of the different treatments, the highest gross return (679500 TK ha-1), gross margin (530420TK ha-1) and BCR (4.56) were obtained from T_3 treatment i.e., tricho compost (5t/ha.), AM along with chemical fertilizer. The lowest gross return (274200 TK ha^{-1}) was found from T_6 i.e., native fertility treatment. Highest BCR (4.56) was obtained in T_3 treatment and lowest BCR (2.51) was obtained in T_6 treatment. Therefore, T_3 treatment (tricho compost 5t/ha., AM + IPNS treatment) is more profitable than other treatment for cultivation of onion.

Conclusion

From the trial, it can be concluded that tricho compost (5t/ha.), arbuscular mycorrhizal fungi along with IPNS based chemical fertilizers treatment is the best treatment considering good economic return and soil health improvement.

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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON THE YIELD AND NUTRIENT UPTAKE OF FOXTAIL MILLET

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Abstract

A field experiment was conducted at Central Research Farm, BARI, Gazipur (AEZ 28) and Regional Agricultural Research Station (RARS), Jamalpur (AEZ 9) during Rabi season of 2019-22 to evaluate the effect of integrated nutrient management for better yield of foxtail millet; and to increase soil fertility and sustain crop productivity. Six treatment combinations viz. T_1 = Soil test based fertilizer dose for HYG, T_2= IPNS with 5.0 t ha^{-1} cowdung, T_3 = IPNS with 5.0 t ha^{-1} compost, T_4 = IPNS with 1.5 t ha^{-1} vermicompost, T_5 = IPNS with 3.0 t ha^{-1} poultry manure and T_6 = Native fertility were tested. The experiment was laid out in a randomized complete block design with 3 replications and BARI Kaon-2 was used as the test crop. The IPNS treatment combinations are significantly different from rest of the treatments in terms of yield and economic return. Application of treatment IPNS with 1.5 t ha^{-1} vermicompost significantly increased all of the parameters such as the plant height, number of tillers $plant^{-1}$, panicle length, 1000 grain weight, grain yield and straw yield. The significantly highest grain yield (2.38 t ha^{-1} and 2.26 t ha^{-1} at Gazipur and Jamalpur, respectively) was recorded in IPNS with 1.5 t ha^{-1} vermicompost treated plot (T_4) while the lowest grain yield (1.23 and 1.19 t ha^{-1} at Gazipur and Jamalpur, respectively) was observed in T_6 (Native fertility) treatment. The uptake of nutrients by foxtail millet was highest in the treatment T_4 receiving IPNS with 1.5 t ha^{-1} vermicompost which was followed by T_5 (IPNS with 3.0 t ha^{-1} poultry manure) in both the locations. The highest gross return (132010 Tk. ha^{-1} and 126060 Tk. ha^{-1} at Gazipur and Jamalpur, respectively), net return (73700 Tk. ha^{-1} and 68545 Tk. ha^{-1} at Gazipur and Jamalpur, respectively) as well as BCR (2.26 and 2.19 at Gazipur and Jamalpur, respectively) were obtained from T_4 treatment (IPNS with 1.5 t ha^{-1} vermicompost) whereas the lowest gross return (70400 Tk. ha^{-1} and 68020 Tk. ha^{-1} at Gazipur and Jamalpur, respectively), net return (27300 Tk. ha^{-1} and 25720 Tk. ha^{-1} at Gazipur and Jamalpur, respectively) and BCR (1.63 and 1.60 at Gazipur and Jamalpur, respectively) were obtained from T_6 (Native fertility) treatment. The overall results indicated that IPNS with 1.5 t ha^{-1} vermicompost is more effective than other fertilizer management packages in respect of yield as well as economic return for foxtail millet cultivation at Gazipur and Jamalpur.

Introduction

Foxtail millet (*Setaria italica* L.) is one of the world's most important ancient crops with its domestication in China dating back to 8700 years (Liu *et al.,* 2009). It is widely cultivated in Asia, Europe, North America, Australia and North Africa for grain or forage (Austin, 2006). Foxtail millet has attracted international research attention due to its high salinity stress tolerance, low incidence of pest and diseases, high photosynthetic efficiency and nutritional values (Liu *et al*., 2011; Vetriventhan *et al.,* 2012).

Foxtail millet is considered as minor cereals of Bangladesh. It can be cultivated easily with low input in the Char areas of Bangladesh. It can play partial role in fulfiling the food crisis of our country. The farmers of char areas usually use their own local varieties which was cultivated as a mixed crop with chilli, soybean etc. The average production of foxtail millet is quite low in our country. The lower productivity of foxtail millets mainly due to lack of high yielding varieties, its cultivation on marginal lands with inadequate nutrients and also continuous and imbalance use of inorganic fertilizer deteriorates soil health. Experimental evidences revealed that the crop was highly responsive to different fertilizers and the yield could be increased remarkably through judicious fertilization (Mohamed, 1984; Roy and Singh, 1986; Kazi *et al.,* 2002).

Integrated nutrient management practices applied for foxtail millet can contributes to sustainable growth of yield and quality, influences plant health and reduces environmental risks. Use of organic manures with optimum rate of fertilizers under intensive farming system increased the turnover of nutrients in the soil plant system. The organic manures help in reducing the dose of inorganic fertilizer, which in turn reduces the cost of cultivation and help in improving the soil health. Although foxtail millet cultivation in Bangladesh is rather limited, there is an ample scope of increasing its cultivation and productivity through integrated nutrient management.

Materials and Methods

A field experiment was conducted at Central Research Farm, BARI, Gazipur (AEZ-28) and Regional Agricultural Research Station, Jamalpur (AEZ-9) during *Rabi* season of 2019-20, 2020-21 & 2021-22 to evaluate the effect of integrated nutrient management for better yield of foxtail millet. Before conducting the experiment, initial composite soil samples (0-15 cm) were collected from the experimental plots and collected samples were analyzed in the laboratory following standard methods (Table 1). The chemical compositions of vermicompost, compost, decomposed cowdung and poultry manure used in the experimental field were also analyzed (Table 2). The experiment was laid out in a RCB design with three (3) replications. The unit plot size was 4 m × 3 m and BARI Kaon-2 was used as the test crop. Treatments were randomly distributed within the blocks as follows: T_1 = Soil test based fertilizer dose for HYG (62.2-15.3-31.2-7.2-0.4 kg ha^{-1} of N-P-K-S-Zn at Gazipur and 68.8-16.6-34.3-7.9-0.4 kg ha^{-1} of N-P-K-S-Zn at Jamalpur), T_2= IPNS with 5.0 t ha^{-1} cowdung, T_3 = IPNS with 5.0 t ha^{-1} compost, T_4 = IPNS with 1.5 t ha^{-1} vermicompost, T_5 = IPNS with 3.0 t ha^{-1} poultry manure and T_6 = Absolute control. The seeds were sown @ 8 kg ha^{-1} in line with the spacing of 25 cm x 8 cm on 1st week of December at Jamalpur and 1st week of February at Gazipur in all the three consecutive years. All of organic manure, phosphorous, potassium, sulphur, zinc & half of nitrogen were applied as basal during final land preparation. Remaining nitrogen was applied as top dress in two equal splits at 30 DAS and 60 DAS after irrigation. Different intercultural operations and plant protection measures were taken as and when necessary to raise healthy crops. The crop was harvested on 1st week of April and 3rd week of May at Jamalpur and Gazipur, respectively in all the three years.. Data were collected on an individual plant basis from ten (10) randomly selected plants of each plot in such a way that the border effect was avoided for high precision. Data on yield and yield contributing parameters were recorded and statistically analyzed with the help of statistical package statistix 10 (Analytical Software. Tallahassee, Fla, USA) and mean separation was tested by Duncan's Multiple Range Test (DMRT) (Steel and Torrie, 1960).

Table 1. Chemical properties of initial soil (0 -15 cm depth) of the experimental field at Central Research farm, BARI, Joydebpur, Gazipur and Regional Agricultural Research Station, Jamalpur during *Rabi* season

Location	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			meq $100g^{-1}$				$\mu g\ g^{-1}$						
Gazipur	6.3	1.38	2.7	2.1	0.16	0.08	11.0	12.0	0.18	5.0	68.0	9.0	1.2
Jamalpur	7.2	1.03	5.7	1.6	0.14	0.06	14.4	10.3	0.40	1.6	22	3.1	1.2
Critical Level	-		2.0	0.5	0.12	0.12	7/10	10	0.20	0.2	4	1	0.6

Table 2. Nutrient status of compost, cowdung, vermicompost and poultry manure used in the experimental field

Name of the manure	pH	OC	Ca	Mg	K	Total N	P	S	B	Zn
		%								
Compost	7.1	16.3	1.50	2.10	1.17	1.23	0.79	0.50	0.013	0.14
Cow dung	7.2	15.4	2.10	0.44	0.69	1.15	0.57	0.36	0.011	0.15
Vermicompost	7.3	17.9	2.23	0.60	1.94	1.68	1.26	0.89	0.015	0.16
Poultry Manure	7.5	17.0	7.15	4.90	0.97	1.92	1.13	0.52	0.029	0.11

Moisture content of Compost = 12.15%, Cowdung = 12.46%, Vermicompost = 11.96 % and Poultry manure=12.10%

Table 3a. Treatment combinations for Foxtail millet at Gazipur

Treatments	Treatment combination									
	Chemical fertilizer (kg ha^{-1})						Organic manure			
	N	P	K	S	Zn	B	Cowdung	Compost	Vermicompost	Poultry manure
							(t ha^{-1})			
T_1	62.2	15.3	31.2	7.2	0.4	-	0	0	0	0
T_2	39.2	3.9	17.4	0	0	-	5.0	0	0	0
T_3	37.6	0	7.8	0	0	-	0	5.0	0	0
T_4	52.2	7.7	19.5	1.9	0	-	0	0	1.5	0
T_5	39.1	1.8	19.6	1.0	0	-	0	0	0	3.0
T_6	Native fertility						-	-	-	-

T_1 = Soil test based fertilizer dose for HYG (FRG, 2018), T_2= IPNS with 5.0 t ha^{-1} cowdung, T_3 = IPNS with 5.0 t ha^{-1} compost, T_4 = IPNS with 1.5 t ha^{-1}vermicompost, T_5 = IPNS with 3.0 t ha^{-1} poultry manure and T_6 = Native fertility

Table 3b. Treatment combinations for Foxtail millet at Jamalpur

Treatments	Treatment combination									
	Chemical fertilizer (kg ha^{-1})						Organic manure			
	N	P	K	S	Zn	B	Cowdung	Compost	Vermicompost	Poultry manure
							(t ha^{-1})			
T_1	66.6	16.6	34.3	7.9	0.4	-	0	0	0	0
T_2	43.6	5.2	20.5	0.7	0	-	5.0	0	0	0
T_3	42.0	0.8	10.9	0	0	-	0	5.0	0	0
T_4	56.3	9.0	22.6	2.6	0	-	0	0	1.5	0
T_5	43.5	3.1	22.7	1.7	0	-	0	0	0	3.0
T_6	Native fertility						-	-	-	-

T_1 = Soil test based fertilizer dose for HYG (FRG, 2018), T_2= IPNS with 5.0 t ha^{-1} cowdung, T_3 = IPNS with 5.0 t ha^{-1} compost, T_4 = IPNS with 1.5 t ha^{-1}vermicompost, T_5 = IPNS with 3.0 t ha^{-1} poultry manure and T_6 = Native fertility

Methods of chemical analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Ca and Mg were determined by NH_4OAc extraction method. K, Cu, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method (Acid soils) and Modified Olsen method (Neutral + Calcareous soils). S was determined by $CaH_4 (PO_4)_2$. H_2O extraction followed by turbidimetric method with $BaCl_2$.

Nutrient uptake by the crop

The total uptake of nutrients by the crop was estimated by using following formula:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content in seed (\%) x Seed yield (kg/ha) + Nutrient content in straw (\%) x Straw yield (kg/ha)}}{100}$$

Results and Discussion

The effect of integrated nutrient management on the yield and yield parameters of foxtail millet are summarized in the Tables 4 and 5. Grain yield, straw yield and yield attributes like plant height, panicle length, number of tillers plant^{-1} and thousand seed weight of foxtail millet were significantly influenced by different nutrient management packages in this study.

Significantly the highest plant height (128.0 cm and 126.6 cm at Gazipur and Jamalpur, respectively) was observed in T_4 treatment (IPNS with 1.5 t ha^{-1} vermicompost) which was statistically identical with T_5 treatment. The lowest plant height (115.3 cm and 114.8 cm at Gazipur and Jamalpur, respectively) was obtained from T_6 (Native fertility) treatment. Significantly the maximum number of tillers $plant^{-1}$ (7.8 and 7.6 at Gazipur and Jamalpur, respectively) was recorded in IPNS with 1.5 t ha^{-1} vermicompost treated plot (T_4) whereas the minimum number of tillers $plant^{-1}$ (5.6 and 5.9 at Gazipur and Jamalpur, respectively) was observed in T_6 (Native fertility) treatment. Significantly the highest panicle length (20.4 cm and 19.6 cm at Gazipur and Jamalpur, respectively) was observed in T_4 treatment which was followed by T_5, T_3, T_2 and T_1 treatment whereas the lowest panicle length (15.8 cm and 15.3 cm at Gazipur and Jamalpur, respectively) was obtained from T_6 (Native fertility) treatment.

Table 4. Effect of integrated nutrient management on yield and yield contributing characters of BARI Kaon-2 at BARI, Gazipur during Rabi season (Pooled data of 3-years)

Treatments	Plant height (cm)	Tiller $plant^{-1}$ (no.)	Panicle length (cm)	1000 grain weight (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	120.6d	6.5c	16.6cd	2.52c	1.78d	5.10e
T_2	123.1cd	6.9bc	17.4c	2.55bc	1.99c	5.77d
T_3	124.4bc	7.3ab	18.5b	2.58b	2.13bc	6.24c
T_4	128.0a	7.8a	20.4a	2.71a	2.38a	6.48a
T_5	126.7ab	7.5ab	19.1b	2.67a	2.24ab	6.31b
T_6	115.3e	5.6d	15.8d	2.37d	1.23e	4.45f
CV (%)	6.32	5.98	4.54	3.11	8.61	7.92

Means followed by same letter (s) do not differ significantly at 5% level of significance
T_1 = Soil test based fertilizer dose for HYG (FRG, 2018), T_2= IPNS with 5 t ha^{-1} cowdung, T_3 = IPNS with 5 t ha^{-1} compost, T_4 = IPNS with 1.5 t ha^{-1}vermicompost, T_5 = IPNS with 3.0 t ha^{-1} poultry manure and T_6 = Native Fertility

Table 5. Effect of integrated nutrient management on yield and yield contributing characters of BARI Kaon-2 at RARS, Jamalpur during *Rabi* season (Pooled data of 3-years)

Treatments	Plant height (cm)	Tiller $plant^{-1}$ (no.)	Panicle length (cm)	1000 grain weight (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	119.5c	6.7c	16.2e	2.50cd	1.64d	5.24e
T_2	121.7c	6.8bc	17.9d	2.53c	1.81cd	5.73d
T_3	122.3bc	7.0bc	18.4c	2.59b	1.98bc	6.10c
T_4	126.6a	7.6a	19.6a	2.68a	2.26a	6.53a
T_5	124.9ab	7.3ab	19.1b	2.66a	2.10ab	6.41b
T_6	114.8d	5.9d	15.3f	2.32d	1.19e	4.26f
CV (%)	5.85	6.64	4.23	2.13	7.35	8.87

Means followed by same letter (s) do not differ significantly at 5% level of significance
T_1 = Soil test based fertilizer dose for HYG (FRG, 2018), T_2= IPNS with 5 t ha^{-1} cowdung, T_3 = IPNS with 5 t ha^{-1} compost, T_4 = IPNS with 1.5 t ha^{-1}vermicompost, T_5 = IPNS with 3.0 t ha^{-1} poultry manure and T_6 = Native fertility

Significantly the maximum 1000 grain weight (2.71 gm and 2.68 gm at Gazipur and Jamalpur, respectively) was recorded in T_4 treatment which was statistically at par with T_5 treatment whereas the minimum 1000 seed weight (2.37 gm and 2.32 gm at Gazipur and Jamalpur, respectively) was recorded in T_6 (Native fertility) treatment.Significantly the highest grain yield (2.38 t ha^{-1} and 2.26 t ha^{-1} at Gazipur and Jamalpur, respectively) was recorded in IPNS with 1.5 t ha^{-1} vermicompost treated plot (T_4) which was statistically at par with T_5 (IPNS with 3 t ha^{-1} poultry manure) treatment. The lowest grain yield (1.23 and 1.19 t ha^{-1} at Gazipur and Jamalpur, respectively) was observed from T_6 (Native fertility) treatment. The highest straw yield (6.48 t ha^{-1} and 6.53 t ha^{-1} at Gazipur and

Jamalpur, respectively) was recorded in IPNS with 1.5 t ha^{-1} vermicompost treated plot (T_4) whereas the lowest straw yield (4.45 t ha^{-1} and 4.26 t ha^{-1}at Gazipur and Jamalpur, respectively) was observed from T_6 (Native fertility) treatment.

Total nutrient uptake

Total nutrient uptake by foxtail millet was influenced by different treatments (Tables 6 & 7). The uptake of NPKS by foxtail millet was highest in the treatment T_4 receiving IPNS with 1.5 t ha^{-1} vermicompost which was followed by T_5 (IPNS with 3.0 t ha^{-1} poultry manure), T_3 (IPNS with 5.0 t ha^{-1} compost) and T_2 (IPNS with 5.0 t ha^{-1} cowdung) treatments in both the locations. Organic sources might play the key role in enhancing efficient utilization of native nutrients which increases plant uptake. The lowest uptake by foxtail millet was obtained from T_1 (Absolute control) treatment in both the locations.

Table 6. Effect of integrated nutrient management on nutrient uptake by foxtail millet at BARI, Gazipur during *Rabi* season (Pooled data of 3-years)

Treatments	Total nutrient uptake by foxtail millet (kg ha^{-1})			
	N	P	K	S
T_1 (Soil test based fertilizer dose for HYG)	45.56	9.12	44.70	7.63
T_2 (IPNS with 5 t ha^{-1} cowdung)	55.75	11.34	50.50	10. 12
T_3 (IPNS with 5 t ha^{-1} compost)	61.40	12. 15	55.46	10.70
T_4 (IPNS with 1.5 t ha^{-1}vermicompost)	73.35	16.83	66.31	12.93
T_5 (IPNS with 3.0 t ha^{-1} poultry manure)	68.69	14.72	60.22	12.25
T_6 (Native fertility)	35.17	5.20	22.30	4.62

Table 7. Effect of integrated nutrient management on nutrient uptake by foxtail millet at RARS, Jamalpur during *Rabi* season (Pooled data of 3-years)

Treatments	Total nutrient uptake by foxtail millet (kg ha^{-1})			
	N	P	K	S
T_1 (Soil test based fertilizer dose for HYG)	43.74	9.34	38.43	7.21
T_2 (IPNS with 5 t ha^{-1} cowdung)	53.20	10.13	44.14	9.20
T_3 (IPNS with 5 t ha^{-1} compost)	60.78	13.08	49.26	10.81
T_4 (IPNS with 1.5 t ha^{-1}vermicompost)	71.44	15.93	58.93	11.78
T_5 (IPNS with 3.0 t ha^{-1} poultry manure)	69.31	13.67	53.24	11.45
T_6 (Native fertility)	36.78	4.32	16.80	4.37

Cost and Return Analysis

Cost and return of foxtail millet as influenced by different nutrient management packages have been shown in the Tables 8 and 9. Among the treatments, the highest gross return (132010 Tk. ha^{-1} and 126060 Tk. ha^{-1} at Gazipur and Jamalpur, respectively), net return (73700 Tk. ha^{-1} and 68545 Tk. ha^{-1} at Gazipur and Jamalpur, respectively) as well as BCR (2.26 and 2.19 at Gazipur and Jamalpur, respectively) were obtained from T_4 treatment (IPNS with 1.5 t ha^{-1} vermicompost) whereas the lowest gross return (70400 Tk. ha^{-1} and 68020 Tk. ha^{-1} at Gazipur and Jamalpur, respectively), net return (27300 Tk. ha^{-1} and 25720 Tk. ha^{-1} at Gazipur and Jamalpur, respectively) and BCR (1.63 and 1.60 at Gazipur and Jamalpur, respectively) were obtained from T_6 (Native fertility) treatment.

Table 8. Cost and return analysis of BARI Kaon-2 as influenced by integrated nutrient management at BARI, Gazipur during *Rabi* season (Pooled data of 3-years)

Treatments	Yield (t ha^{-1})		Gross Return (Tk. ha^{-1})	Total Cost (Tk. ha^{-1})	Net Return (Tk. ha^{-1})	BCR
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})				
T_1	1.78	5.10	99200	49612	49588	1.99
T_2	1.99	5.77	111040	53715	57325	2.06
T_3	2.13	6.24	120330	68618	51712	1.75
T_4	2.38	6.48	132010	58310	73700	2.26
T_5	2.24	6.31	124620	55625	68995	2.24
T_6	1.23	4.45	70400	43100	27300	1.63

Input and output price per kg: Foxtail millet seed = Tk. 80, Urea = Tk. 16, TSP = Tk. 22, MoP = Tk. 15, Gypsum = Tk. 12, Zinc sulphate =Tk.150, Vermicompost = Tk. 10, Compost = Tk. 5, Cowdung= Tk.2, Poultry manure= Tk. 4, Foxtail millet = Tk. 50 and Straw = Tk. 2

Table 9. Cost and return analysis of BARI Kaon-2 as influenced by integrated nutrient management at RARS Jamalpur during *Rabi* season (Pooled data of 3-years)

Treatments	Yield (t ha^{-1})		Gross return (Tk. ha^{-1})	Total cost (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})				
T_1	1.64	5.24	92480	48323	44157	1.91
T_2	1.81	5.73	101960	52630	49330	1.93
T_3	1.98	6.10	111200	67400	43800	1.64
T_4	2.26	6.53	126060	57515	68545	2.19
T_5	2.10	6.41	117820	54418	63402	2.16
T_6	1.19	4.26	68020	42300	25720	1.60

Input and output price per kg: Foxtail millet seed = 80 Tk , Urea = Tk. 16, TSP = Tk. 22, MoP = Tk. 15, Gypsum = Tk. 12, Zinc sulphate =Tk.150, Vermicompost = Tk. 10, Compost = Tk. 5, Cowdung= Tk.2, Poultry manure= Tk. 4, Foxtail millet = Tk. 50 and Straw = Tk. 2

Conclusion

Based on the results, it may be concluded that IPNS with 1.5 t ha^{-1} vermicompost is superior to the other fertilizer management packages in respect of yield as well as economic return for cultivation of foxtail millet in the Gazipur (AEZ-28) and Jamalpur (AEZ-9) districts of Bangladesh. The uptake of nutrients by foxtail millets was also highest in the treatment T_4 receiving IPNS with 1.5 t ha^{-1} vermicompost in both the locations.

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EFFECT OF DIFFERENT FORM AND DOSES OF UREA FERTILIZER ON NITROUS OXIDE EMISSION, NITROGEN USE EFFICIENCY AND YIELD OF CAULIFLOWER

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Abstract

The experiment was conducted at BARI, Gazipur during rabi season of 2020-2021 with the objectives: i) to find out use efficiency of different form & rate of urea, ii) to find out the yield and yield components of cauliflower as influenced by different form & rate of urea and iii) to analyze cost and return of cauliflower produced from different form & rate of urea. There were ten treatments viz. T_1: 100 kg N ha^{-1} in the form of Prilled Urea (PU), T_2: 140 kg N ha^{-1} in the form of Prilled Urea (PU), T_3: 180 kg N ha^{-1} in the form of Prilled Urea (PU), T_4: 100 kg N ha^{-1}in the form of Neem Coated Urea (NCU), T_5: 140 kg N ha^{-1} in the form of Neem Coated Urea (NCU), T_6: 180 kg N ha^{-1} in the form of Neem Coated Urea (NCU), T_7: 100 kg N ha^{-1} in the form of Urea Super Granules (USG), T_8: 140 kg N ha^{-1} in the form of Urea Super Granules (USG), T_9: 180 kg N ha^{-1} in the form of Urea Super Granules (USG), T_{10}: N-control. P, K, S, Zn & B were applied @ 60, 90, 20, 3 & 1.5 kg ha^{-1}. The tested crop and variety was cauliflower (Snow white).The experiment was laid out in RCB design with three replications. The highest yield of cauliflower (42.44 t ha^{-1} was observed in T_9 treatment (180 kg N ha^{-1} as USG applied) which was very close to the yield of 42.04 t ha^{-1} and it was found in T_6 treatment (180 kg N ha^{-1} as NCU applied). The lowest yield (12.57 t ha^{-1}) of cauliflower was noted in N-control treatment (T_{10}). Highest agronomic use efficiency of nitrogen (166) was obtained from T_9:180 kg N ha^{-1} as USG treated plot. Highest yield increase over control(238%) was also obtained from T_9:180 kg N ha^{-1} as USG treated plotwhich was very close to T_6 treatment (180 kg N ha^{-1} as NCU treated plot) yield increase about 234%.Cost and return analysis revealed that the highest gross margin(3,32,019/-Tk ha^{-1}) as well as BCR (4.76) was obtained from T_6 treatment (180 kg N ha^{-1} as NCU applied).

Introduction

Neem oil basically acts as a ‘nitrification inhibitor’ when coated on urea. By slowing down urea hydrolysis and nitrification, it allows a more gradual release of nitrogen, which can be used by the plant. “Neem-coating urea increases nitrogen use efficiency. Also, since the urea action is prolonged, the plants stay greener for a longer time. Farmers apply urea when they notice the leaves turning yellowish. But if the crop here is retaining greenness for an extended period, they would reduce the frequency of application. When urea is applied to the soil, it is first hydrolysed or broken by water into ammonium ions (NH4+), followed by oxidation to nitrite (NO2-) and, then, nitrate (NO3-) forms. This nitrification process is what makes the nitrogen, which is 46 per cent in urea, available to the crops. In normal urea, however, the conversion to nitrate happens very rapidly. As a result, up to two-thirds of the nitrogen is lost either through underground percolation (‘leaching’) of nitrates or ‘volatilisation’ (escaping into atmosphere). But it’s not just urea. Reduced urea usage would have dragged down consumption of other fertilizers, too. In India, farmers usually give a first basal dose of DAP or NPKS complexes such as 28:28:0:0 and 20:20:0:13 independently of urea. However, subsequent doses are given along with urea, as it enables them to save on labour. “A worker hired for a day costs the same whether he/she applies only urea or urea plus DAP. If the frequency of urea application comes down, so will that of other fertilizers. Neem oil used to coat urea is supposed to contain 150 ppm of azadirachtin. This active ingredient in neem oil has a benzene ring structure somewhat like chlorobenzene that is present in transformer or cutting oil.

Urea Super Granule (USG) is one of the nitrogenous fertilizers that is now available in our country and the farmers are using it for Boro rice and banana cultivation (Nazrul *et al.*, 2007). But they generally use higher doses of N as normal PU with other fertilizers. In recent years, a deep understanding on mechanisms causing poor N utilization help to develop cultural practices to improve nitrogen use efficiency. Urea super granule (USG), is considered a slowly available N fertilizer and found efficient when properly deep placed (Savant and Stangel, 1990). Nazrul *et al.* (2007) reported that 5-8 cm deep placement of USG in cabbage cultivation could save 20% N than PU. Agronomic, economic and environment advantages of deep point placement of USG have been well established (Misra*et al*., 1995). It is possible to save 20% - 40% of the urea N for the same yield compared with conventional ureaapplication (Kumar *et al*.,1989). Deep placement of urea super granule increase grain yield and improve N use efficiency.

Farmers are not aware of vegetable cultivation practices and they use imbalanced fertilizers with a higher dose of nitrogenous fertilizer, which occurred declining soil fertility and created environmental pollution. Nitrogen is an important plant nutrient and is the most limiting element due to its high mobility and different types of losses (Zaman *et al*., 1993). To improve the N use efficiency, neem coated urea and urea super granule (USG) are most popular nitrogenous fertilizers and can be used for upland crops like cabbage, cauliflower, broccoli, brinjal, tomato, potato etc. The application of USG guarantees the better utilization of N throughout the growing period and ensures high yield reducing the nitrate level by 20-30%(Wojciechowska, 2002). Hussain *et al.* (2003) showed that 20% urea could be saved by the use of USG instead of PU for cabbage, cauliflower and brinjal. Therefore, to control the loss and to improve fertilizer use efficiency USG application may be a good option to minimize production cost as well as to increase crop yield of cauliflower. But there is a scanty of research findings to develop a fertilizer recommendation with neem coated urea and USG for cauliflower production. Therefore, the present study was undertaken to determine the effects of Neem coated urea, USG and PU on the growth and yieldof cauliflower with the objectives to:

i) find out the use efficiency of different form and rate of urea.
ii)evaluate the yield and yield components of cauliflower as influenced by different form and rate of urea.
iii) analyze cost and return of cauliflower produced from different form of urea.

Materials and Methods

A field experiment on the effect of different form and doses of urea fertilizer on nitrous oxideemission, nitrogen use efficiency and yield of cauliflowerwas conducted in the Grey Terrace Soil of Gazipur (AEZ-28) during the year of 2021-2022.The initial soil samples collected from the depth of 0-15 cm at the experimental plot and it was analyzed in the laboratory following standard methods. Initial values of some important chemical parameters of the experimental soil are presented in Table 1.

The experiment was laid out in a randomized complete block design with three replications. Ten different treatments viz. T_1: 100 kg N ha^{-1} in the form of Prilled Urea (PU), T_2: 140 kg N ha^{-1} in the form of Prilled Urea(PU), T_3: 180 kg N ha^{-1} in the form of Prilled Urea (PU), T_4: 100 kg N ha^{-1} in the form of Neem Coated Urea (NCU), T_5: 140 kg N ha^{-1} in the form of Neem Coated Urea (NCU), T_6: 180 kg N ha^{-1} in the form of Neem Coated Urea (NCU), T_7: 100 kg N ha^{-1} in the form of Urea Super Granules (USG), T_8: 140 kg N ha^{-1} in the form of Urea Super Granules (USG), T_9: 180 kg N ha^{-1} in the form of Urea Super Granules (USG), T_{10}: N- control. The unit plot size was 3m x 4m. The tested crop was cauliflower and the variety was Snow white. Thirty days old seedlings of cauliflower were transplanted in line with 50 cm row to row and 50 cm plant to plant on 12 November, 2021. Properties of different form of urea are presented in Table 2.

Nitrogen fertilizer were applied as three type & form of urea i. e. Prilled Urea (PU), Neem Coated Urea (NCU) and Urea Super Granules (USG).For prilled urea, $^{1}/_{3}{}^{rd}$ of urea is applied before transplanting as basal.The remaining two third of N were equally applied as top dress at 30 and 60 days after transplanting.For neem coated urea, ½ of urea is applied before transplanting as basal. Remaining ½ urea is applied as broadcast at 30 & 60 days after transplanting. For USG, whole urea is applied as band placement during transplanting in between two cauliflower rows at 8 cm apart. Fertilizers of P, K, S, Zn & B @ 60, 90, 20, 3 & 1.5 kg ha^{-1} were applied at the time of final land preparation as a form of TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. Three irrigation and other intercultural operations were done as and when required. The cauliflower was harvested on 17 February, 2022. Data on yield and yield contributing characters were recorded and analyzed statistically using Statistics-10 package. LSD test was used to determine the significant differences among treatments (Steel and Torrie, 1960). Plant samples and postharvest soil samples were collected from each plot for chemical analysis.

Table 1. Chemical properties of initial soil of experimental plot at BARI, Gazipur during 2020

Location	pH	OM	Ca	Mg	K	Total N	P	S	Zn	B
		(%)	meq $100g^{-1}$			(%)	µg g^{-1}			
Gazipur	6.8	1.50	4.0	2.1	0.14	0.10	8	10	0.65	0.18
Critical level	-	-	2.0	0.5	0.12	0.12	7	10	0.20	0.20

Table 2. Properties of different form of urea

Form of urea	Physical appearance	Diameter	Nitrogen content
Prilled urea (PU)	Whitish Brown	Granular (2-3 mm)	46%
Urea super granule (USG)	Whitish Brown	Super granular (6-7 mm)	46%
Neem coated urea (NCU)	Yellowish Brown	Granular (2-3 mm)	45.8%

Nutrient use efficiency :
Agronomic use efficiency (AE) :
Agronomic efficiency refers to the increase in crop yield per unit of an applied nutrient. It can be calculated as follows:
$AE = (Y_{NA}-Y_{N0})/N_{RN}$

Where,
AE : Agronomic efficiency
Y_{NA} : Yield (kg ha^{-1}) due to nutrient addition
Y_{NO} : Yield (kg ha^{-1}) due to nutrient omission
Y_{RN} : Rate of nutrient addition (kg ha^{-1})

Methods of chemical analyses

Soil pH was measured by a combined glass calomel electrode (Jakson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Ca and Mg were determined by NH_4OAc extraction method. K, Cu, Fe, Mn and Zn were determined by DTPAextraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method (Acid soils). S was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric method with $BaCl_2$.

Results and Discussion

The effect of chemical fertilizers on the yield and yield parameters of cauliflower are summarized in Table 3. Yield and yield attributes were significantly influenced by different form of urea. Plant height are significantly influenced by different form of urea. Highest plant height (55.57 cm) was obtained from T_9 treatment (180 kg N ha^{-1} in the form of USG) which were statistically similar to T_6 (180 kg N ha^{-1} in the form of NCU), T_3 (180 kg N ha^{-1} in the form of PU), T_5 (140 kg N ha^{-1} in the form of NCU) and T_8(140 kg N ha^{-1} in the form of USG) treatments. Lowest plant height (29.47 cm) was obtained from T_{10} (No nitrogen) treatment. The highest card height (9.40 cm) was found in T_9 treatment (180 kg N ha^{-1} in the form of USG) which were statistically similar to all treatments except T_{10} (N-control) treatment. The lowest card height (4.03 cm) was noted in T_{10} (No nitrogen) treatment.Curd circumference and marketable weight of single curd are important yield parameters of cauliflower. Both of curd circumference and marketable weight of single curd are significantly influenced by different form of urea. Maximum curd circumference (46.33 cm) was observed in T_9 (180 kg N ha^{-1} as USG) treatment which was statistically similar to T_6 (180 kg N ha^{-1} in the form of NCU) and T_3 (180 kg N ha^{-1} in the form of PU) treatments. The highest marketable weight of single curd (1.04 kg) was noted in T_9 (180 kg N ha^{-1} as USG) treatment and it was statistically similar to

T_6(180 kg N ha^{-1} in the form of NCU) and T_3 (180 kg N ha^{-1} in the form of PU) treatments. The lowest marketable weight of single curd (0.25 kg)and lowest card circumference (20.13 cm) was obtained from T_{10} (No nitrogen) treatment.The highest yield of cauliflower 42.44 t ha^{-1} was observed in T_9 (180 kg N ha^{-1} as USG) treatment which was statistically similar to T_6 (180 kg N ha^{-1} in the form of NCU) and T_3 (180 kg N ha^{-1} in the form of PU) treatments. The lowest yield (12.57 t ha^{-1}) was noted from T_{10} (No nitrogen) treatment. USG &NCU @ 180 treatments were attributed to availability of optimum nitrogen throughout the growing season which might be provided the optimum nitrogen that reflected in yield and yield contributing characters.

Table 3. Effect of different form of nitrogen treatments on the yield and yield attributes of cauliflower during 2020-2021

Treatments	Plant height (cm)	Card height (cm)	Card circumferences (cm)	Marketable weight of single card (kg)	Yield (t ha^{-1})	Yield (t ha^{-1})
					2020-21	2021-22
T_1 :100 kg N ha^{-1} as PU	40.90d	8.67a	34.73d	0.72d	27.49d	26.60e
T_2 :140 kg N ha^{-1} as PU	46.47bc	8.93a	39.07bcd	0.77cd	34.76c	30.67de
T_3 :180 kg N ha^{-1} as PU	53.67ab	9.20a	42.23ab	1.01a	42.44ab	38.83abc
T_4 :100 kg N ha^{-1} as NCU	47.87ab	9.03a	37.23cd	0.76cd	27.97d	28.31e
T_5 :140 kg N ha^{-1} as NCU	50.07ab	9.27a	40.13bc	0.88bc	38.67bc	35.0bcd
T_6 :180 kg N ha^{-1} as NCU	52.50ab	9.37a	42.57ab	1.02a	46.66a	42.04a
T_7 : 100 kg N ha^{-1} as USG	45.17cd	8.82a	37.60cd	0.76cd	29.10d	26.17e
T_8 : 140 kg N ha^{-1} as USG	52.70ab	9.07a	41.27bc	0.82cd	40.67b	33.85cd
T_9 : 180 kg N ha^{-1} as USG	55.57a	9.40a	46.33a	1.04a	46.77a	42.44a
T_{10} :No nitrogen	29.47e	4.03b	20.13e	0.25e	12.08e	12.57f
SE(±)	3.76	0.57	2.13	0.06	2.53	2.38
CV (%)	9.71	8.27	6.84	9.12	8.96	9.28

Means followed by the same letter in a column are not statistically significant at 5% level by LSD test.

Agronomic use efficiency of nitrogen (N_{AUE}):

Agronomic use efficiency of nitrogen (N_{AUE})refers tothe increase in cauliflower yield per kg of nitrogen applied (Table 4).

Table 4. Agronomic use efficiency of nitrogen (N_{AUE}) of different form and rate of urea

Treatments	Increase nitrogen over N-control (T_{10}) (kgha^{-1})	Quantity of yield obtained (kg ha^{-1})	Increase yield over N control (T_1) (kgha^{-1})	Agronomic use efficiency of nitrogen (N_{AUE})	Yield Increase over control (%)
T_1 :100 kg N ha^{-1} as PU	100	26600	14030	140	112
T_2 :140 kg N ha^{-1} as PU	140	30670	18100	129	144
T_3 :180 kg N ha^{-1} as PU	180	38830	26260	146	209
T_4 :100 kg N ha^{-1} as NCU	100	26170	15740	157	125
T_5 :140 kg N ha^{-1} as NCU	140	33850	22430	160	178
T_6 :180 kg N ha^{-1} as NCU	180	42040	29470	164	234
T_7 : 100 kg N ha^{-1} as USG	100	28310	13600	136	108
T_8 : 140 kg N ha^{-1} as USG	140	35000	21280	152	169
T_9 : 180 kg N ha^{-1} as USG	180	42440	29870	166	238
T_{10} :No nitrogen	-	12570	-	-	-

Agronomic use efficiency of nitrogen (N_{AUE}) of different form and type of urea were ranged from 140 to 166 kg kg^{-1}. Highest Agronomic use efficiency of nitrogen (N_{AUE}) (166) was obtained from USG treated plot (T_9:180 kg N ha^{-1} as USG). Lowest nitrogen use efficiency of 140 kg $kg^{-1}$was obtained from prilled urea treated plot (T_1:100 kg N ha^{-1} as PU). Highest yield increase over control(238%) was obtained from T_9 treatment(180 kg N ha^{-1} as USG treated plot) which was very close to T_6 treatment(180 kg N ha^{-1} as NCU treated plot) yield increase about 234%.

Cost and return analysis

Cost and return of cauliflower as influenced by different form and rate of urea have been described in the Table5. Among the ten treatments, the highest gross return (4,24,400 Tk ha^{-1}) was obtained from T_9 treatment (180 kg ha^{-1}USG). Total cost is also high (93,348Tk ha^{-1}) in T_9 treatment (180 kg N ha^{-1}USG). Total cost in the T_9treatment is high due to higher rate and application cost of USG which need to be dibbled in soil manually. Highest gross margin (3,32,019/-Tk ha^{-1}) was obtained from T_6 treatment (180 kg N ha^{-1}as NCU applied). Highest BCR (4.76) was obtained in T_6 treatment (180 kg N ha^{-1}as NCU applied). BCR in neem coated urea is higher than BCR in USG due to application cost of USG in the field.

Table 5. Cost and return of cauliflower production as influenced by different form and rate of urea

Treatments	Yield (t ha^{-1})	Gross return	Nitrogen fertilizer cost	Nitrogen application cost	Fixed and variable cost	Total cost	Gross margin	BCR
		(Tk ha^{-1})						
T_1 (100-PU)	26.6	26600	3472	1500	80000	84972	181028	3.13
T_2 (140-PU)	30.67	30670	4861	1600	80000	86461	220239	3.55
T_3 (180-PU)	38.83	38830	6250	1700	80000	87950	300350	4.42
T_4 (100-NCU)	26.17	26170	3712	1500	80000	85212	176488	3.07
T_5 (140-NCU)	33.85	33850	5196	1600	80000	86796	251704	3.90
T_6 (180-NCU)	42.04	42040	6681	1700	80000	88381	332019	4.76
T_7 (100-USG)	28.31	28310	3804	3500	80000	87304	195796	3.24
T_8 (140-USG)	35.00	35000	5326	5000	80000	90326	259674	3.87
T_9 (180-USG)	42.44	42440	6848	6500	80000	93348	331052	4.55
T_{10} (No nitrogen)	12.57	12570	-	-	80000	80000	45700	1.57

Market Price (Tk kg^{-1}): Cauliflower = 10/-,1 kgPrilled Urea = Tk. 16/-,1 kg Neem coated urea = Tk. 17/-, 1 kg USG = Tk. 17.5/-

Conclusion

Considering results of this year, the highest yield of cauliflower (42.44 t ha^{-1}) was obtained in T_9 treatment (180 kg N ha^{-1}USG applied) which was very close to the yield of 42.04 t ha^{-1}it was found in T_6 treatment (180 kg N ha^{-1}as NCU applied). Highest gross margin (3,32,019/-Tk ha^{-1}) as well as BCR (4.76) was obtained from T_6treatment (180 kg N ha^{-1}as Neem coated urea applied).

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EFFECT OF DIFFERENT ORGANIC MANURES ON CARBON ACCUMULATION IN SOIL AND YIELD OF CROPS IN MUSTARD-MUNGBEAN-T. AMAN CROPPING PATTERN

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Abstract

A field experiment on effect of different organic manures on carbon accumulation in soil and yield of crops in Mustard-Mungbean-T.Aman rice cropping pattern was conducted at Gazipur (AEZ-28) during the year of 2020-22 with the objectives: to increase soil organic carbon, improve soil fertility and increase sustainable yield of the crops. There were nine different treatments viz. T_1: 5 t ha^{-1} VC + IPNS,T_2: 7.5 t ha^{-1} VC + IPNS, T_3: 5 t ha^{-1}Bioslurry + IPNS, T_4: 7.5 t ha^{-1}Bioslurry + IPNS, T_5:5 t ha^{-1} Compost + IPNS, T_6:7.5 t ha^{-1} Compost + IPNS, T_7: 5 t ha^{-1} PM + IPNS, , T_8:7.5 t ha^{-1} PM + IPNS, T_9 : Native fertility. The experiment was laid out in RCB design with three replications. Tested crops and varieties were mustard (var. BARI Sarisha-17), mungbean (BARI mung 6) and T. Aman (BRRIdhan 75). Data revealed that the yield contributing characters and grain yield of mustard, mungbean and T. Aman was significantly influenced by different IPNS treatments. The highest grain yields of mustard (1.88 t ha^{-1}), mungbean (1.45 t ha^{-1}) and T. Aman (5.31 t ha^{-1}) was found in T_4 treatment where 7.5 t ha^{-1}Bioslurry with IPNS basis inorganic fertilizers was applied. Total rice equivalent yield of the crops (12.74 t ha^{-1}) was also highest in T_4 (7.5 t ha^{-1} Bioslurry + IPNS) treatment.Cost and return analysis showed that, the highest gross return (2,54,800/- Tk ha^{-1}) and highest gross margin (1,34,637/- Tk ha^{-1}) were noted in T_4 (7.5 t ha^{-1}Bioslurry + IPNS) treatment but the highest BCR (2.18) was found in T_3 (5 t ha^{-1}Bioslurry + IPNS) treatment.

Introduction

Mineralization of different organic materials varies with soil types and crop husbandry. Accumulation of carbon in soil would vary with different organic materials levels during decomposition process. Moreover, proper management of such organic materials coupled with inorganic fertilizer may improve soil biodiversity, microaggregation, and reduction in CO_2 emission from soil (Rastogi *et al.*, 2002; Lal, 2004; Russell *et al.*, 2005).The CO_2 released from soil through microbial decomposition of organic materials contributes 99% of the total emission and thus reduces soil organic pool. Soil organic manures are essential for sustainable agriculture because they help to improve plant growth, crop yield, soil carbon content, and microbial biomass and activity (Shrestha *et al.*, 2013). Organic manures affect the rate and extent of soil carbon sequestration. Investigating the impacts of type and rate of organic manures on GHG emission is thus important for sustainable agriculture and minimizing the impacts on the GHG emission.

Mustard is an important oil seed crop in Bangladesh. It belongs to Cruciferae family. It is a winter season crop grown throughout the world. It is miserable that average yield of mustard is low as compared to its potential yield. Numbers of factors have been responsible for low yield of mustard in our country. Use of organic manures have proved good response in yield of mustard.

The primary goal of this research work is to assess the impacts of organic amendment types and rates on the soil carbon accumulation under a green oil seed grown area at AEZ-28. The effects of organic amendments on soil organic carbon and CO_2 emission have received little attention from researchers. Most studies have focused on the impact of organic manures on crop yield, soil characteristics, and soil nutrition (Antonlous*et al.*, 2014). Few studies have been conducted to examine the impact of types and rates of organic manures on soil organic carbon content and CO_2 emission.

The present study was undertaken with the objectives: to enhance carbon accumulation in soil, to increase soil organic carbon, to improve soil fertility and to increase yield of crops under Mustard-Mungbean-T.Aman cropping pattern for sustainable yield.

Materials and Methods

A field experiment was conducted at Gazipur (AEZ- 28) during the year of 2020-2021. The initial soil samples collected before establishing the experiment from a depth of 0-15 cm was analyzed in the laboratory following standard methods. Initial values of some important soil physicaland chemical properties of the experimental soil are presented in Tables 1& 2.Chemical analysis of bioslurry (cowdung based), poultry manure (PM), vermicompost (VC) and compost were done which have been shown in Table 3.

Table 1. Initial physical properties of experimental soil at the Central Research Farm at BARI, Gazipur during 2020

Depth (cm)	Textural class	Particle size distribution (%)			Field capacity (%)	Bulk density (g cm^{-1})
		Sand	Silt	Clay		
0-15 cm	Clay loam	28.0	40.4	31.6	30.43	1.46

Table 2. Initial chemical properties of experimental soil at the Central Research Farm at BARI, Gazipur during 2020

Location	pH	SOC (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			meq $100g^{-1}$				µg g^{-1}						
Gazipur	5.7	0.75	4.0	2.1	0.13	0.08	9	10	0.12	3.0	96	18	0.65
Critical level		-	2.0	0.5	0.12	0.12	7	10	0.20	0.2	4	1	0.6

Table 3. Nutrient status of poultry manure, cowdung, vermicompost and compost used in the experimental field

Name of the manure	pH	OC	Ca	Mg	K	Total N	P	S	Zn	B
		%								
Poultry manure (PM)	6.7	18.7	2.2	1.3	0.42	1.34	1.14	0.34	0.027	0.013
Vermicompost (VC)	7.2	25.3	2.4	2.6	0.52	1.38	1.30	0.44	0.020	0.017
Compost	7.0	21.0	2.2	1.4	0.46	1.15	0.75	0.36	0.018	0.015
Bioslurry	6.8	28.0	4.0	2.1	0.28	1.35	1.59	0.45	0.022	0.019

% Moisture content of CD = 25, PM = 23, VC = 21 andBioslurry= 25

The experiment was laid out in a randomized complete block design with three replications. Nine different treatments viz. T_1: 5 t ha^{-1} VC + IPNS basis inorganic fertilizers,T_2: 7.5 t ha^{-1} VC + IPNS, T_3: 5 t ha^{-1}Bioslurry + IPNS, T_4: 7.5 t ha^{-1}Bioslurry + IPNS, T_5:5 t ha^{-1} Compost + IPNS, T_6:7.5 t ha^{-1} Compost + IPNS, T_7: 5 t ha^{-1} PM + IPNS, T_8:7.5 t ha^{-1} PM + IPNS, T_9: Native fertility were selected for different plots randomly. The unit plot size was 4m x 3m. Tested crops and varieties were mustard (var. BARI Sarisha-17), mungbean (BARI mung 6) and T. Aman (BRRIdhan 75).Mustard seeds were sown in line with 30 cm row to row on 20 November 2021 and 27 November 2021 at Gazipur. Mungbean seeds were sown in line with 30 cm row to row on 24 March 2021. Seedlings of T. Aman were transplanted in line to line with 20 cm row to row with 15 cm on 12 August 2021. Fertilizer N-P-K-S-Zn-B were supplied from urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. All PKSZnB and $^1/_3$ of N were applied at the time of final land preparation. The remaining two third of N were applied as top dress at 25 and 45 days after sowing. Three irrigations and other intercultural operations were done as and when required. The Mustard, mungbean and T. Aman was harvested on 24 February, 2022, 15 June 2022 and 10 October 2022, respectively. Data on yield and yield contributing characters were recorded and statistically analyzed. Statistics 10 was used to determine the significant differences between the treatments.

Table 4. Treatment combinations for Mustard

Treatments	Treatment combinations									
	Chemical fertilizers						Organic manures			
	N	P	K	S	Zn	B	VC	Bioslurry	Compost	PM
	(kg ha^{-1})						(t ha^{-1})			
T_1: 5 t ha^{-1} VC + IPNS	133	30	80	19	2.60	1.66	5	-	-	-
T_2: 7.5 t ha^{-1} VC + IPNS	118	27	75	15	2.40	1.49	7.5	-	-	-
T_3: 5 t ha^{-1}Bioslurry + IPNS	138	25	85	18	2.62	1.56	-	5	-	-
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	127	20	82	13	2.43	1.34	-	7.5	-	-
T_5:5 t ha^{-1} Compost + IPNS	133	21	81	20	2.64	1.70	-	-	5	-
T_6:7.5 t ha^{-1} Compost + IPNS	120	13	76	16	2.46	1.55	-	-	7.5	-
T_7: 5 t ha^{-1} PM + IPNS	134	22	82	21	2.46	1.74	-	-	-	5
T_8:7.5 t ha^{-1} PM + IPNS	121	3	78	18	2.19	1.61	-	-	-	7.5
T_9 : Native fertility	No fertilizer									

Table 4. Treatment combinations for T. Aman

Treatments	Treatment combinations									
	Chemical fertilizers						Organic manures			
	N	P	K	S	Zn	B	VC	Bioslurry	Compost	PM
	(kg ha^{-1})						(t ha^{-1})			
T_1: 5 t ha^{-1} VC + IPNS	120	20	80	15	2.40	-	5	-	-	-
T_2: 7.5 t ha^{-1} VC + IPNS	108	18	72	13	2.06	-	7.5	-	-	-
T_3: 5 t ha^{-1}Bioslurry + IPNS	120	20	80	15	2.40	-	-	5	-	-
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	105	15	70	11	2.06	-	-	7.5	-	-
T_5:5 t ha^{-1} Compost + IPNS	120	20	80	15	2.40	-	-	-	5	-
T_6:7.5 t ha^{-1} Compost + IPNS	110	13	70	14	2.06	-	-	-	7.5	-
T_7: 5 t ha^{-1} PM + IPNS	120	20	80	15	2.40	-	-	-	-	5
T_8:7.5 t ha^{-1} PM + IPNS	110	13	70	13	2.06	-	-	-	-	7.5
T_9 : Native fertility	No fertilizer									

Results and Discussion

Mustard

Data regarding mustard yield and yield contributing characters as influenced by rate of different organic manures with IPNS basis inorganic fertilizer has been presented in Table 5& 6. The tested fertilizer treatments significantly effect on plant height, no. of branches $plant^{-1}$, no. of pods $plant^{-1}$, no. of seeds pod^{-1}, 1000 seed weight and seed yield of mustard during the year of 2021-22. The highest seed yield of mustard (2.36 t ha^{-1}in the year of 2021 and 1.88 t ha^{-1}in the year of 2022) was found from the treatment T_4 where 7.5 t ha^{-1}bioslurry with IPNS basis inorganic fertilizers was used. This yield value was statistically similar to T_2 (7.5 t ha^{-1} VC + IPNS)and T_8 (7.5 t ha^{-1} PM + IPNS) treatments in both the years.Again T_4 (7.5 t ha^{-1}bioslurry + IPNS) produced better seed yield compare to other treatments showing better efficacy of bioslurry over other organic manure. Because mineral composition of the organic materials clearly indicated the superiority of bioslurry to other organic manure which was reflected in the seed yield of mustard.The native fertility treatment produced the lowest seed yield (0.22 t ha^{-1} in 2021 and 0.15 t ha^{-1}in 2022) of mustard.

Table 5.Effect of different IPNS treatments on the yield and yield contributing characters of mustard underMustard-Mungbean-T.Aman rice cropping pattern at BARI, Gazipur during the year of 2020-2021

Treatments	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000 seed weight (g)	Seed yield (t ha^{-1})
T_1: 5 t ha^{-1} VC + IPNS	80.77a	6.50a	113.1abc	30.62abc	4.05bc	1.73bcd
T_2: 7.5 t ha^{-1} VC + IPNS	82.00a	6.50a	120.9ab	32.02ab	4.38ab	2.16ab
T_3: 5 t ha^{-1}Bioslurry + IPNS	82.97a	5.97a	102.6bcd	29.38abc	4.02bc	2.07ab
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	83.03a	6.73a	126.5a	32.46a	4.63a	2.36a
T_5: 5 t ha^{-1} Compost + IPNS	80.47a	6.07a	100.7bcd	29.14bc	2.65e	1.51d
T_6: 7.5 t ha^{-1} Compost + IPNS	86.13a	6.03a	105.8abcd	30.87abc	3.64d	1.90bcd
T_7: 5 t ha^{-1} PM + IPNS	83.80a	6.00a	97.70cd	30.02abc	3.54d	1.63cd
T_8: 7.5 t ha^{-1} PM + IPNS	79.37a	6.20a	90.70d	27.94c	3.80cd	2.00abc
T_9: Native fertility	49.13b	2.00b	20.00e	16.58d	1.16f	0.22e
CV (%)	5.70	10.95	12.47	6.55	6.17	14.44

Means followed by the same letter in a column are not statistically significant at 5% level by LSD test

Table 6.Effect of different IPNS treatments on the yield and yield contributing characters of mustard underMustard-Mungbean-T.Aman rice cropping pattern at BARI, Gazipur during the year of 2021-22

Treatments	Plant height (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	Pod length (cm)	1000 seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1: 5 t ha^{-1} VC + IPNS	93.27a	82.8ab	30.90ab	4.75a	3.09a	1.49cd	2.43a
T_2: 7.5 t ha^{-1} VC + IPNS	94.00a	89.20a	31.73ab	4.87a	3.23a	1.73ab	2.54a
T_3: 5 t ha^{-1}Bioslurry + IPNS	89.90a	84.67ab	30.93ab	4.77a	3.09a	1.54cd	2.07a
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	92.23a	93.63a	32.20a	5.00a	3.40a	1.88a	2.25a
T_5: 5 t ha^{-1} Compost + IPNS	92.80a	71.37b	29.93b	4.43a	2.77a	1.32d	2.40a
T_6: 7.5 t ha^{-1} Compost + IPNS	95.23a	81.90ab	31.27ab	4.73a	3.10a	1.63bc	1.97a
T_7: 5 t ha^{-1} PM + IPNS	91.17a	84.33ab	30.57ab	4.77a	2.90a	1.18e	2.27a
T_8: 7.5 t ha^{-1} PM + IPNS	95.57a	86.27ab	31.73ab	5.13a	3.29a	1.54cd	2.10a
T_9: Native fertility	26.43b	13.90	4.83c	0.38b	0.09b	0.15f	0.31b
SE (±)	4.67	7.35	0.89	0.38	0.32	0.09	0.29
CV (%)	6.69	11.77	3.86	10.86	14.08	6.68	17.73

Means followed by the same letter in a column are not statistically significant at 5% level by LSD test

Table 7.Effect of different IPNS treatments on the yield and yield contributing characters of mungbeanunderMustard-Mungbean-T.Aman rice cropping pattern at BARI, Gazipur during the year of 2021-22

Treatments	Plant height (cm)	No. of pods $plant^{-1}$	Pod length (cm)	1000 seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1: 5 t ha^{-1} VC + IPNS	72.07a	15.07a	8.50a	45.70bc	1.11b	1.82
T_2: 7.5 t ha^{-1} VC + IPNS	73.70a	15.63a	8.97a	51.53a	1.22ab	2.22
T_3: 5 t ha^{-1}Bioslurry + IPNS	71.53a	14.87a	8.67a	46.07bc	1.16b	1.94
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	75.27a	15.97a	9.07a	52.53a	1.45a	2.27
T_5: 5 t ha^{-1} Compost + IPNS	72.37a	15.87a	8.80a	46.37bc	0.97bc	1.89
T_6: 7.5 t ha^{-1} Compost + IPNS	74.20a	16.23a	9.20a	50.37ab	1.06bc	2.12
T_7: 5 t ha^{-1} PM + IPNS	73.73a	15.87a	9.03a	45.40c	0.85c	1.87
T_8: 7.5 t ha^{-1} PM + IPNS	76.37a	16.63a	9.17a	51.93a	1.06b	2.13
T_9: Native fertility	52.23b	7.80b	5.20b	15.57d	0.49d	1.93
SE (±)	3.87	1.24	0.42	2.31	0.12	0.26
CV (%)	6.66	10.25	6.10	6.27	14.09	16.0

Means followed by the same letter in a column are not statistically significant at 5% level by LSD test

Mungbean

Data regarding mustard yield and yield contributing characters as influenced by rate of different organic manures with IPNS basis inorganic fertilizer has been presented in Table 7. The tested fertilizer treatments significantly effect on plant height, no. of pods $plant^{-1}$, no. of seeds pod^{-1}, 1000 seed weight and seed yield of mungbean. The highest seed yield of mungbean (1.45 t ha^{-1}) was produced from the treatment T_4 where 7.5 t ha^{-1}bioslurry with IPNS basis inorganic fertilizers was used. This yield value was statistically similar to T_2 (7.5 t ha^{-1} VC + IPNS) andT_8 (7.5 t ha^{-1} PM + IPNS)treatments. This might be due to steady supply of nutrients from treatments receiving 7.5 t ha^{-1}bioslurry in combination with inorganic fertilizers which enhanced grain yield.The native fertility treatment produced the lowest seed yield (0.49 t ha^{-1}) of mungbean.

Table 8.Effect of different IPNS treatments on the yield and yield contributing characters of T. amanunderMustard-Mungbean-T.Aman rice cropping pattern at BARI, Gazipur during the year of 2021-22

Treatments	Plant height (cm)	Panicle $hill^{-1}$	Panicle length (cm)	Grain $panicle^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1: 5 t ha^{-1} VC + IPNS	109.4a	13.67b	23.23cd	156.2cd	21.78a	4.16c	8.68a
T_2: 7.5 t ha^{-1} VC + IPNS	113.0a	14.87b	26.50ab	176.5ab	22.36a	4.95ab	8.89a
T_3: 5 t ha^{-1}Bioslurry + IPNS	110.6a	14.10b	22.0d	164.3bc	22.19a	4.37bc	9.87a
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	114.5a	17.90a	28.23a	182.8a	22.57a	5.31a	10.02a
T_5: 5 t ha^{-1} Compost + IPNS	103.6a	13.33b	23.78cd	150.6d	21.59a	4.16c	9.28a
T_6: 7.5 t ha^{-1} Compost + IPNS	110.2a	13.80b	24.40bc	168.9abc	22.33a	4.92ab	9.51a
T_7: 5 t ha^{-1} PM + IPNS	108.9a	13.87b	24.53bc	159.10cd	22.05a	4.27bc	9.15a
T_8: 7.5 t ha^{-1} PM + IPNS	112.2a	14.63b	26.38ab	170.0abc	21.43a	4.71abc	9.67a
T_9: Native fertility	79.4b	9.03c	15.53e	68.20e	15.33b	2.31d	6.58b
SE (±)	8.45	0.87	0.81	7.07	1.12	0.33	0.79
CV (%)	9.68	7.69	5.85	5.59	6.44	9.43	10.72

Means followed by the same letter in a column are not statistically significant at 5% level by LSD test

T.Aman

Yield and yield contributing characteristics of T. Aman were significantly influenced by different treatments during the year of 2021. Plant height, number of panicle hill^{-1}, number of grains panicle^{-1}, panicle length, 1000-grain weight, grain yield and straw yield of T. aman rice were significantly influenced by different treatments which presented in Table 9. The tallest plants height (114.5 cm) was found in T_4 treatment which was statistically similar to all other treatment except the control treatment. The highest number of panicles hill^{-1} (17.90) was found in T_4 (7.5 t ha^{-1}Bioslurry + IPNS) treatment. Highest panicle length (28.23) and grainspanicle^{-1} (182.8) was noted in T_4 treatment which was statistically similar to T_2 (7.5 t ha^{-1} VC + IPNS), T_6(7.5 t ha^{-1} Compost + IPNS) and T_8(7.5 t ha^{-1} PM + IPNS) treatments. Highest 1000 grain weight (22.57 g) was also shown in T_4 treatment which was statistically similar to all other treatment except the control treatment. The highest grain yield of 5.31 t ha^{-1}was obtained in T_4(7.5 t ha^{-1}Bioslurry + IPNS) treatment which was statistically similar to T_2(7.5 t ha^{-1} VC + IPNS), T_6(7.5 t ha^{-1} Compost + IPNS)and T_8(7.5 t ha^{-1} PM + IPNS)treatments. The higher grain yield obtained due to the use of organic manures especially bioslurry at the rate of 7.5 t ha^{-1} might have the consequence of continuous supply of sufficient nutrients to support growth and reproductive organs.
The lowest grain yield (2.31 t ha^{-1}) was observed in T_1 (control) treatment. The highest straw yield of 10.02 t ha^{-1} was found in T_4 treatment which was statistically similar to all other treatment except the control treatment.

Rice equivalent yield and Total rice (system) yield

Total rice (system) yield as influenced by different treatments has been presented in Table 9. Highest total rice (system) yield of 12.47 t ha^{-1}yr^{-1} was obtained from T_4 (7.5 t ha^{-1}Bioslurry + IPNS) treatment. Lowest total rice (system) yield of 4.21 t ha^{-1}yr^{-1} was obtained from control i.e. native fertility treatment (T_9).

Table 9. Grain yield, rice equivalent yield and total rice (system) yield (t ha^{-1}yr^{-1}) of Mustard-Mungbean-T.Aman cropping pattern during the year of 2021-2022

Treatments	Yield of crops in the pattern (t ha^{-1})			Rice equivalent yield of crops in the pattern		Total rice (system) yield
	Mustard	Munbean	T.Aman	Mustard	Munbean	
T_1: 5 t ha^{-1} VC + IPNS	1.49	1.11	4.16	1.86	3.89	9.91
T_2: 7.5 t ha^{-1} VC + IPNS	1.73	1.22	4.95	2.16	4.27	11.38
T_3: 5 t ha^{-1}Bioslurry + IPNS	1.54	1.16	4.37	1.93	4.06	10.36
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	1.88	1.45	5.31	2.35	5.08	12.74
T_5: 5 t ha^{-1} Compost + IPNS	1.32	0.97	4.16	1.48	2.98	9.21
T_6: 7.5 t ha^{-1} Compost + IPNS	1.63	1.06	4.92	2.04	3.71	10.67
T_7: 5 t ha^{-1} PM + IPNS	1.18	0.85	4.27	1.65	3.40	8.72
T_8: 7.5 t ha^{-1} PM + IPNS	1.54	1.06	4.71	1.93	3.71	10.35
T_9: Native fertility	0.15	0.49	2.31	0.19	1.72	4.21

Price : 1 kg mustard = Tk. 25, 1 kg mung bean = Tk. 70, 1 kg rice = Tk. 20

Carbon accumulation in soil

Addition of organic manures with chemical fertilizers provided to increase on carbon stock and carbon accumulation after completion of first year cropping cycle of the experiment (Table 8). The initial soil organic carbon, bulk density and carbon stock in soils were 0.75%, 1.46 g cc^{-1} and 16.43 t ha^{-1} respectively. Bulk density of post harvest soil was not influenced by different integrated treatments within a depth of 0-15 cm. The highest organic carbon content and carbon stock in post harvest soil was found in T_4 (7.5 t ha^{-1}Bioslurry + IPNS) treatment which was followed to T_3 (5 t ha^{-1}Bioslurry + IPNS) treatments. As a result, carbon accumulation was also increased by T_4 (7.5 t ha^{-1}Bioslurry + IPNS) treatment. The carbon accumulation in T_4 (7.5 t ha^{-1}Bioslurry + IPNS) treated plot was 14.23 t ha^{-1} yr^{-1} while it was 12.04t ha^{-1} yr^{-1} in the T_2 (7.5 t ha^{-1}VC + IPNS) treatments. The results indicated that, application of organic manure could enhance the OC content, carbon stock and carbon accumulation in soil although the decomposition rate of organic matter in high humid and temperature prevailing sub-tropical region is quicker. It also indicates that, Bioslurry and VC contains more nutrients among the other organic manures. So, it could play better results to accumulate organic carbon in soil.

Table 8. Effect of different treatments on carbon accumulation in soil during 2021-2022

Treatments	Initial soil			Post soil			Carbon accumulation (t ha^{-1} yr^{-1})
	OC (%)	BD (g/cc)	C stock (t ha^{-1})	OC (%)	BD (g/cc)	C stock (t ha^{-1})	
T_1: 5 t ha^{-1} VC + IPNS	0. 75	1.46	16.43	1.1	1.46	24.09	7.66
T_2: 7.5 t ha^{-1} VC + IPNS	0. 75	1.46	16.43	1.2	1.46	26.28	12.04
T_3: 5 t ha^{-1}Bioslurry + IPNS	0. 75	1.46	16.43	1.3	1.46	28.47	9.85
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	0. 75	1.46	16.43	1.4	1.46	30.66	14.23
T_5:5 t ha^{-1} Compost + IPNS	0. 75	1.46	16.43	0.9	1.46	19.71	3.28
T_6:7.5 t ha^{-1} Compost + IPNS	0. 75	1.46	16.43	1.0	1.46	21.90	5.47
T_7: 5 t ha^{-1} PM + IPNS	0. 75	1.46	16.43	0.9	1.46	19.71	3.28
T_8:7.5 t ha^{-1} PM + IPNS	0. 75	1.46	16.43	1.0	1.46	21.90	5.47
T_9 : Native fertility	0. 75	1.46	16.43	0.76	1.46	16.64	0.21

Cost and return analysis

The estimated gross return, total variable cost, gross marginand benefit cost ratio (BCR) is presented in Table 10. Gross margin was calculated by subtracting the variable cost from the gross return. BCR was calculated from the gross margin divided by total variable cost. Gross return was calculated as the market value of rice grain. The cost and return analysis of the cropping pattern demonstrated that, the highest gross return (2,54,800/- Tk ha^{-1}) and highest gross margin (1,34,637/- Tk ha^{-1}) were obtained in T_4 (7.5 t ha^{-1}Bioslurry + IPNS) treatment but the highest BCR (1.18) was found in T_3 (5 t ha^{-1}Bioslurry + IPNS) treatment.

Table 10. Cost and return analysis of mustard as influenced by different IPNS treatments

Treatments	Total Yield (t ha^{-1})	Gross return	Total variable cost	Gross margin	BCR
		(Tk.)			
T_1: 5 t ha^{-1} VC + IPNS	9.91	198200	95163	103037	2.08
T_2: 7.5 t ha^{-1} VC + IPNS	11.38	227600	120163	107437	1.89
T_3: 5 t ha^{-1}Bioslurry + IPNS	10.36	207200	95163	112037	2.18
T_4: 7.5 t ha^{-1}Bioslurry + IPNS	12.74	254800	120163	134637	2.12
T_5:5 t ha^{-1} Compost + IPNS	9.21	184200	95163	89037	1.94
T_6:7.5 t ha^{-1} Compost + IPNS	10.67	213400	120163	93237	1.78
T_7: 5 t ha^{-1} PM + IPNS	8.72	174400	85163	89237	2.05
T_8:7.5 t ha^{-1} PM + IPNS	10.35	207000	105163	101837	1.97
T_9 : Native fertility	4.21	84200	40000	44200	2.11

Legend: Urea = 16 Tk kg^{-1}, TSP = 25 Tk kg^{-1}, MoP= 15 Tk kg^{-1}, Gypsum= 12 Tk kg^{-1}, Zinc sulphate = 200 Tk kg^{-1}, Boric acid = 250 Tk kg^{-1}, VC = 10 Tk kg^{-1}, Bioslurry = 10 Tk kg^{-1}, Compost = 10 Tk kg^{-1}, PM = 8 Tk kg^{-1}, Mustard seed = Tk. 25 kg^{-1}, Mungbeanseed = Tk. 75 kg^{-1} and T. Amanseed = Tk. 75 kg^{-1}

Conclusion

Considering results of the experiment, treatment T_4 (7.5 t ha^{-1} Bioslurry + IPNS) produced highest yield of mustard (1.88 t ha^{-1}), mungbean(1.45 t ha^{-1})and T. Aman (5.31 t ha^{-1}). Total rice equivalent yield of the crops (12.74 t ha^{-1}) was also highest in T_4 (7.5 t ha^{-1} Bioslurry + IPNS) treatment. Cost and return analysis showed that, the highest gross return (2,54,800/- Tk ha^{-1}) and highest gross margin (1,34,637/- Tk ha^{-1}) were obtained in T_4 (7.5 t ha^{-1}Bioslurry + IPNS) treatment but the highest BCR (2.18) was found in T_3 (5 t ha^{-1}Bioslurry + IPNS) treatment. This is the result of first cropping cycle of first year experiment. For confirming the results, the experiment needs to be repeated next year.

EFFECT OF VERMICOMPOST ON GROUNDNUT YIELD AND SOIL FERTILITY IN CHARLAND

M YASMIN, F S SHIKHA, M A RAHMAN, R SEN AND H M NASER

Abstract

The experiment was conducted at farmers' field of Nouvanger char, Jamalpur Sadar, Jamalpur (AEZ 9) during the rabi season of 2020-2021 and 2021-2022.The objectives was to find out the effect of vermicompost with chemical fertilizer on groundnut yield, to increase soil fertility and to improve the stock of organic carbon in soil. The experiment was laid out in a randomized complete block design (RCBD) with 3 replications and BARI Chinabadam - 9 was used as test crop.There were seven treatments comprising, T_1 = 100 % RDCF(control), T_2 = 100 % RDCF + vermicompost @ 1 t ha^{-1}, T_3 = 100 % RDCF + vermicompost @ 3 t ha^{-1}, T_4 = 85% RDCF + vermicompost @ 1 t ha^{-1}, T_5 = 85% RDCF + vermicompost @ 3 t ha^{-1}, T_6 = 70% RDCF + vermicompost @ 1 t $ha^{-1}$and T_7 = 70% RDCF + vermicompost @ 3 t ha^{-1}. Two years average data revealed that, combined application of vermicompost and chemical fertilizer increased groundnut yield and BCR as compared to sole application of chemical fertilizers. Among the treatments, T_5 (85% RDCF + VC @ 3 t ha^{-1}) produced the highest average nut yield (2.16 t ha^{-1}) which was 19.33 % higher over 100% RDCF dose. On the other hand, groundnut yield was gradually decreased with decreasing chemical fertilizers. The lowest average groundnut yield of 1.55 t ha^{-1} was recorded in the T_6 (70% RD + vermicompost @ 1 t ha^{-1}) treatment.Soil organic matter and N, P, K contents of post harvest soils were improved in integrated treatment compare to sole chemical treatment.Integrated treatment also increased organic carbon content, carbon stock and carbon accumulation in soil.Considering the overall performance, farmers may be advised to cultivate groundnut in charland applying 85 % chemical fertilizer with vermicompost @ 3 t ha^{-1} application. This combination would enable farmers to increase productivity of groundnut so as to enhance farmers' income and livelihoods.

Introduction

Groundnut (*Arachis hypogaea* L.) is a very important oil seed producing crop in Bangladesh. Groundnut seed contain 44-56% oil and 22-30% protein on a dry seed basis and is a rich source of minerals (phosphorus, calcium, magnesium and potassium) and vitamins (E, K and B group). It is used as edible oil, to make cake, biscuit and bakery in the food industries. Traditionally it is eaten as fried 'badam'. In spite of its importance as an oil crop and of multifarious uses in everyday life, there is lack of information about its production performance. It is cultivated mostly in sandy soils and riverbeds. Among problematic soils, char land soils has less availability of nutrients (N, P, Ca, S, and B), besides inadequate organic matter. Groundnut being, exhaustive crops, removes large amount of macro and micro nutrients from soil.

With the improvement and perfection of market economy, the indiscriminate application of chemical fertilizers increases which decreases soil fertility and nutrient quality of crops.This situation is created by losing of soil organic matter, which is the primary attributes of the sustainable cultivating frameworks (Liu *et al*., 2009). The use of inorganic fertilizer to maintain cropping was found to increase yield just for exactly couple of years, however, on a long run, it has not be effective and prompts soil degradation (Satyanarayana *et al*., 2002).Application of organic materials along with inorganic fertilizers leads to increased productivity of the system and sustained soil health for a longer period (Gawai and Pawar, 2006).

Vermicomposting is a novel eco-friendly and cost effective technology which affects soil PH, microbial population and soil enzyme activities. Earthworms enhance soil fertility and raise crop productivity by excreting beneficial soil organisms and secreting polysaccharides, proteins and different nitrogenous compound into the dirt (Rekha *et al*., 2013). The combined use of vermicompost and chemical fertilizers help in keeping up yield stability through correction of minimal lacks of auxiliary and micronutrients, improving effectiveness of connected supplements and providing favorable soil physical conditions (Gill and Walia, 2014).However, information on the use of vermicompost in combination with inorganic fertilizers for groundnut production is scanty in Bangladesh. Therefore; an attempt will be made to study the response of groundnutto vermicompost application in charland.The ultimate goal is to optimize fertilizer management to maximize yields and quality while reducing the use of inorganic fertilizer and maintaining good-quality soil.

Materials and Methods

Two years field study was conducted on the effect of vermicompost on groundnut yield and soil fertility at the farmers' field of Nouvanger char under Jamalpur district in Bangladesh during rabi season of 2020-2021 and 2021-2022. The site is located at Sonalata series under AEZ-9 (Old Brahmaputra Floodplain Soil).The soil of the experimental site was sandy loam in texture. Before initiation the experiment, the soil samples were collected from a depth of 0-15 cm and analyzed following standard methods. Initial value of some chemical and physical properties of experimental soil is presented in Table 1and Table 2, respectively. The chemical composition (such as organic carbon, N, P, K, S, B, Cu, Fe, Mn, Zn, Mg, Ca and pH) of vermicompost was presented in Table 3.

Table 1. Initial chemical properties of experimental soil at Nouvanger char in Jamalpur

Location	pH	OC (%)	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
			meq / 100ml				ppm						
Nouvanger char, Jamalpur	7.78	0.72	2.63	1.18	0.22	0.093	13	4.2	0.4	2.12	50.5	4.59	0.83
CL	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4	1	0.6

Table 2. Initial physical properties of experimental soil at Nouvanger char in Jamalpur

Depth (cm)	Textural class	Particle size distribution			Bulk density (gcc^{-1})
		Sand	Silt	Clay	
0-15 cm	Sandy clay loam	38%	36%	26%	1.48 gcc^{-1}

Table 3. Chemical composition of vermicompost used for the experiment

Properties	pH	OC %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			meq $100g^{-1}$				µg g^{-1}					
Vermicompost	6.2	14.9	1.45	0.83	0.76	0.92	0.57	0.39	0.008	0.001	0.50	0.014

The experiment was laid out in a randomized complete block design (RCBD) with 3 replications. The unit plot size was 3m x 2m and the variety was BARI Chinabadam-9. Groundnut seeds were sown on 01 November, 2021 in a spacing of 30 cm x 15 cm. Recommended doses of chemical fertilizer for groundnut were calculated on the basis of soil test values. T_1 = 100 % RDCF (control), T_2 = 100 % RDCF + vermicompost @ 1 t ha^{-1}, T_3 = 100 % RDCF + vermicompost @ 3 t ha^{-1}, T_4 = 85% RDCF + vermicompost @ 1 t ha^{-1} ,T_5 = 85% RDCF + vermicompost @ 3 t ha^{-1}, T_6 = 70% RDCF + vermicompost @ 1 t ha^{-1},T_7 = 70% RDCF + vermicompost @ 3 t ha^{-1}, Blanket dose: N_{42} P_{33} K_{38} S_{30} Zn_2 B_1 Kg ha^{-1} (FRG-2018)

Table 4. Treatments combinations for groundnut crop

Treatments	Treatment combination						
	Chemical fertilizer (kg ha^{-1})						Organic manure (t ha^{-1})
	N	P	K	S	Zn	B	vermicompost
T_1	42	33	38	30	2	1	0
T_2	33	27	30	30	2	1	1
T_3	14	16	15	30	2	1	3
T_4	27	22	24	30	2	1	1
T_5	8	11	9	30	2	1	3
T_6	21	17	19	30	2	1	1
T_7	2	6	4	30	2	1	3

Other intercultural operations were done as per requirement.The crop was harvested in April, 2022. Data on yield and yield contributing characters were recorded from ten plants selected randomly for each plot and analyzed statistically using statistical software STAR which was developed by IRRI. Least significant differences (LSD) were used for means separation at 5% probability level.Carbon stock and Carbon accumulation were calculated using following formula.
Carbon stock (t ha^{-1}) = Carbon concentration (%) x bulk density (gcc^{-1}) x depth (cm)
Carbon accumulation (t ha^{-1}) = Final carbon stock (t ha^{-1}) - Initial carbon stock (t ha^{-1})

Results & Discussion

Effects of chemical fertilizer andvermicompost on plant growth and yield of groundnut

Application of different rates of chemical fertilizer (CF) and vermicompost (VC) significantly affected plant growth and yield of groundnut (Table 5). Significantly higher plant height of 48.09 cm was recorded in the treatment T_3 (100% RDCF + VC @ 3 t ha^{-1}). The number of branches $plant^{-1}$ was varied significantly due to the different combined applications of CF and VC. The highest number of branches $plant^{-1}$ (9.42) was observed in the plant treated 85 % RDCF with VC @ 3t ha^{-1} combination whereas the lowest number of branches $plant^{-1}$ was observed in the T_6 (70% RDCF + VC @ 1 t ha^{-1}) treatment.

T_5 treatment (85 % RDCF + VC @ 3 t ha^{-1}) exhibited maximum nut per plant (28.33), kernel per plant (43.68) which was statistically higher than the rest of the treatments. In this study, the combined use of CF and VC gave the highest 100 kernel weights (44.52 g) than that of sole CF (T_1) treatment. This might be because of use of good natural source i.e. vermicompost which enables great air movement of soil moisture and environmental elements. It also contained numerous humic acids, which enhances the number of leaf, leaf area index, plant height and increased the growth rate (Atarzadeh et al., 2013). Shelling percentage varies from 66.03 % to 71.69 % in different treatment.

Table 5. Effect of chemical fertilizer andvermicompost on yield and yield components of groundnut, 2021-22

Treatment	Plant height (cm)	Nut $plant^{-1}$	Kernel $plant^{-1}$	100 kernel Wt.(g)	Shelling (%)	Nut yield (t ha^{-1})		% increase over RD
						2020-21	2021-22	
T_1	45.43 b	18.33 c	30.45 d	38.05 d	67.67 c	1.86 c	1.77 d	-
T_2	46.47 b	24.33 b	35.57 c	42.32 b	70.33 ab	2.01 b	2.02 b	14.12
T_3	48.09 a	25.67 b	36.34 c	42.40 b	70.35 ab	2.03 b	2.04 b	15.25
T_4	45.44 b	24.00 b	42.50 b	40.56 c	70.01 b	2.00 b	1.89 c	6.77
T_5	43.36 c	28.33 a	43.68 a	44.52 a	71.69 a	2.17 a	2.16 a	22.03
T_6	40.89 d	14.67 d	23.04 f	35.37 e	66.03 d	1.56 e	1.54 e	-
T_7	41.21 d	16.00 d	24.32 e	36.37 e	67.02 cd	1.72 d	1.63 e	-
CV%	3.49	6.58	6.23	8.56	4.87	9.39	11.45	-
LSD(0.05)	1.60	1.78	1.06	1.58	1.34	0.13	0.10	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD
Note:T_1 = 100 % RDCF, T_2 = 100 % RDCF + VC @ 1 t ha^{-1}, T_3 = 100 % RDCF + VC @ 3 t ha^{-1}, T_4 = 85% RDCF+ VC @ 1 t ha^{-1}, T_5 = 85% RDCF + VC @ 3 t ha^{-1}, T_6 = 70% RDCF + VC @ 1 t ha^{-1} and T_7 = 70% RDCF +VC @ 3 t ha^{-1}

The nut yield of BARI Chinabadam-9 was significantly influenced due to the single and combined application CF and VC .In 2021-2022, the highest nut yield of 2.16 t ha^{-1} was obtained in the treatment T_5 (85 % RDCF + vermicompost @ 3 t ha^{-1}). It was also observed that, among all the treatments, T_5 (85% RDCF + VC @ 3 t ha^{-1}) exhibited the maximum increase in nut yieldwhich was 22.03 % higher over 100 % RDCF.This result corroborated with the findings of Bachman and Metzger (2008).They reported significant increase in growth parameters of plants after application of vermicompost in the growth media. Earthworms may stimulate microbial activities and metabolism and also influence microbial populations. As a consequence, more available nutrients and microbial metabolites are released into the soil (Tomati *et al.*, 1998).

On the other hand, T_1 treatment (100% RDCF) produced nut yield of 1.77 t ha^{-1} which was lower than T_2, T_3, T_4, andT_5 which indicated that application of inorganic fertilizer could not supply enough nutrients to plants. It is revealed from the result that combination of organic and inorganic fertilizers increased the nut yield than sole use of inorganic fertilizer. This may be because organic fertilizers are known to contain plant nutrients, growth promoting substances and beneficial microflora which in combination with inorganic fertilizers provide favourable soil conditions to enhance nutrient use efficiency. Similar results were reported by A.S. Channaveerswami (2005) in groundnut. Nut yield was gradually decreased with decreasing inorganic fertilizers. The lowest nut yield of 1.54 t ha^{-1} was recorded in the T_6 (70% RDCF + VC @ 1 t ha^{-1}) treatment.

Changes in soil chemical properties from different treatment combination

Nutrient contents of post harvest soil of groundnut experiment field have been shown in table 6.Integrated application of vermicompost with chemical fertilizer recorded an improvement in soil nutrient status over sole chemical fertilizer (control) treatment. The highest pH value was observed in T_5 (85% RDCF + VC @ 3 t ha^{-1}) treatment while the lowest values were recorded in chemical fertilizer (control) treatment. The highest amount of soil organic carbon was obtained in same treatment where 3 t ha^{-1} vermicompost was applied along with 85% RDCF. Under T_5 (85% RDCF + VC @ 3 t ha^{-1}) treatment, about 12.04 % increase was observed in the available N content of the soil compared to control. Likewise; remarkable increases of about 32.84 % and 17.39 % were recorded for P and K respectively in the T_5 in comparison to the control. This result was in agreement with Le Bayon and Binet (2006) who observed that the direct action of worm gut enzymes and the stimulation of microflora could increase phosphorus level in soil.Similarly, Delgado *et al* (1995) observed an increase in K content during the vermicomposting of sewage sludge.

Table 6. Changes in soil chemical properties as influenced by integrated use of vermicompost with chemical fertilizer in groundnut field, 2021-22

Treatments	pH	SOC (%)	Total N (%)	K meq $100g^{-1}$	P	S	B	Zn
					μg g^{-1}			
T_1	7.29	0.70	0.083	0.23	13.7	6.3	0.41	1.0
T_2	7.47	0.76	0.085	0.24	15.9	10.4	0.41	1.11
T_3	7.57	0.77	0.091	0.25	17.1	13.1	0.42	1.13
T_4	7.53	0.76	0.087	0.25	17.5	12.8	0.41	1.11
T_5	7.58	0.78	0.093	0.27	18.2	13.3	0.43	1.22
T_6	7.48	0.73	0.083	0.25	15.2	10.1	0.40	0.87
T_7	7.49	0.73	0.086	0.26	15.6	11.2	0.41	0.89
Initial soil	7.28	0.72	0.083	0.22	13.5	6.2	0.40	0.83

Note:T_1 = 100 % RDCF, T_2 = 100 % RDCF + VC @ 1 t ha^{-1}, T_3 = 100 % RDCF + VC @ 3 t ha^{-1}, T_4 = 85% RDCF+ VC @ 1 t ha^{-1}, T_5 = 85% RDCF + VC @ 3 t ha^{-1}, T_6 = 70% RDCF + VC @ 1 t ha^{-1} and T_7 = 70% RDCF +VC @ 3 t ha^{-1}

Carbon accumulation in soil from different treatment combination

Table 7 presents the data pertaining to soil fertility attributes in groundnut experimental field. Soil carbon status evaluated after two years experiment and found that vermicompost application had positive effect on carbon stock and carbon accumulation in soil. The initial soil organic carbon, bulk density and carbon stock in soil were 0.72%, 1.48 gcc^{-1} and 15.98 tha^{-1}, respectively. After two years, bulk density varied from 1.44-1.47 gcc^{-1}. Post harvest SOC concentration was found to be high (0.78%) in T_5 (85% RDCF + VC @ 3 t ha^{-1}) treatment which was about 11.42 % more than sole chemical treatment (0.70%).Data showed that, increased the vermicompost application in soil decreased bulk density of soil and increased carbon accumulation. Irrespective of treatments, the highest carbon accumulation 0.86 t ha^{-1} was obtained in soil amended with 3 t ha^{-1} vermicompost. This hence shows the highest soil carbon sequestration potential.

Table 7.Carbon accumulation in soil as influenced by different treatment combination, 2021-22

Treatments	Initial soil			Post harvest soil			Carbon accumulation ($t\ ha^{-1}$)
	SOC (%)	BD (gcc^{-1})	C Stock ($t\ ha^{-1}$)	SOC (%)	BD (gcc^{-1})	C Stock ($t\ ha^{-1}$)	
T_1	0.72	1.48	15.98	0.70	1.47	15.43	-0.54
T_2	0.72	1.48	15.98	0.76	1.45	16.53	0.55
T_3	0.72	1.48	15.98	0.77	1.44	16.63	0.65
T_4	0.72	1.48	15.98	0.76	1.44	16.41	0.43
T_5	0.72	1.48	15.98	0.78	1.44	16.84	0.86
T_6	0.72	1.48	15.98	0.73	1.46	15.98	00
T_7	0.72	1.48	15.98	0.73	1.45	15.87	-0.11

Note:T_1 = 100 % RDCF, T_2 = 100 % RDCF + VC @ 1 t ha^{-1}, T_3 = 100 % RDCF + VC @ 3 t ha^{-1}, T_4 = 85% RDCF + VC @ 1 t ha^{-1}, T_5 = 85% RDCF + VC @ 3 t ha^{-1}, T_6 = 70% RDCF + VC @ 1 t ha^{-1} and T_7 = 70% RDCF + VC @ 3 t ha^{-1}

Cost and return analysis

Cost and return of groundnut production as influenced by different treatment combinations have been shown in Table 8.Among the treatments, the highest gross return (Tk 216000 ha^{-1}), gross margin (Tk 110000 ha^{-1}) and BCR (2.03) were recorded fromT_5 (85% RDCF + VC @ 3 t ha^{-1}) treatment whereas the lowest gross margin (Tk 66000 ha^{-1}) and BCR (1.65) were recorded fromT_7 (70% RDCF + VC @ 3 t ha^{-1}) treatment.

Table 8. Cost and return of groundnut production as influenced by different treatment combination, 2021- 22

Treatments	Average groundnut yield ($t\ ha^{-1}$)	Gross return	Total variable cost	Gross margin	BCR
		(TK ha^{-1})			
T_1	1.81	181000	97500	83500	1.85
T_2	2.01	201000	107000	94000	1.87
T_3	2.03	203000	119000	84000	1.70
T_4	1.94	194000	98000	96000	1.97
T_5	2.16	216000	106000	110000	2.03
T_6	1.55	155000	85000	70000	1.82
T_7	1.67	167000	101000	66000	1.65

Note:T_1 = 100 % RDCF, T_2 = 100 % RDCF + VC @ 1 t ha^{-1}, T_3 = 100 % RDCF + VC @ 3 t ha^{-1}, T_4 = 85% RDCF+ VC @ 1 t ha^{-1}, T_5 = 85% RDCF + VC @ 3 t ha^{-1}, T_6 = 70% RDCF + VC @ 1 t ha^{-1} and T_7 = 70% RDCF +VC @ 3 t ha^{-1}

Input:Unit price **(**Tk.Kg^{-1}**):** Urea=16, TSP= 22, MoP = 15, Gypsum = 12, Zinc sulphate = 200, Boric acid = 250,vermicompost = 10

Output:Price of groundnut: 100 Tk kg^{-1}

Conclusion

Finally, results revealed that application of 85% chemical fertilizer with vermicompost @ 3 t ha^{-1} was found best in respect of groundnut yield and BCR. Integration of inorganic and organic fertilizer also helps to reduce the use of 15% chemical fertilizer at least. Application of vermicompost along with chemical fertilizer slightly increased the nutrient content in post harvest soil. So, it may be concluded that, this combination (85% RDCF + VC @ 3 t ha^{-1}) could be a superior recommendation for higher groundnut yield at char area of Jamalpur region (AEZ-9).

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EFFECT OF CO-COMPOSTING BIOCHAR ON CABBAGE- INDIAN SPINACH-T.AMAN PRODUTIVITY

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Abstract

A field study was conducted at BARI research field under Grey Terrace Soil (AEZ 28) from 2021-22 to investigate the effects of Co- Composting biochar (COMBI) on soil fertility, carbon sequestration and increase yield and nutrient uptake of Cabbage- Indian spinach- T.aman cropping pattern. The experiment consisted of randomized complete block design with six treatments i.e. 100% recommendation dose of chemical fertilizer (RDCF), 80% RDCF with 5 t ha^{-1} compost, 80% RDCF with 5 t ha^{-1} RHB, 80% RDCF with 5 t ha^{-1} COMBI or 3 t ha^{-1} COMBI and control. In this year, three crops harvested and found that, yield was increased by amending organic compound. The greater rice equvalant yield (REY) was found in T_4 treatment (80% RDCF with 5 t ha^{-1} co-composting biochar (COMBI). Compare to control, more than 133% REY increase by using 80% RDCF with 5 t ha^{-1} COMBI. Application of 5tha^{-1} organic compound, ie compost, Biochar and COMBI the increment varied from 9 to 24 percent REY where COMBI gave the greater yield. In addition, 15% REY was increase when COMBI 3tha^{-1} applied into soil. The highest gross margin was obtained from T_4 treatment with a BCR 6.99 but we do not add organic compound price in this year. Our results demonstrate that application of more stable component such as COMBI instead of easily degraded organic amendments seems to be a promising option to supply enough nutrients for the healthy growth and yield of cabbage Grey Terrace Soil (AEZ 28). For more confirmation, the trial need to continue in a same plot without any destroys.

Introduction

Momentous increase in global population accompanied with urbanization and industrial progress has directly increased the generation of complex solid waste. Wastes, such as sewage sludge, agricultural wastes, municipal solid waste (MSW), food and kitchen waste, garden wastes, agro-industrial wastes, animal wastes, etc. can be generally classifed as solid organic wastes comprising of organic biodegradable fraction with amoisture content below 85–90%. Integrated waste management hierarchy ascertains agricultural recycling of organic wastes to be more sustainable and eco-friendly approach than traditional methods of waste disposal and energy recovery. In accordance with principles of resource/nutrient recovery and recycling, scientific conversion (via. composting, biochar) and utilization of organic wastes for agronomic purposes can provide benefcial plant nutrients for enhancing growth and improve soil fertility as well. Biochar, a highly stable and recalcitrant form of organic matter produced by pyrolysis. The use of biochar as a soil amendment may effective for soil health regarding to increased yield. However, soil health is the foundation of vigorous and sustainable crop production. However, many studies used high biochar application amounts of >10 t ha^{-1}, which is not economically feasible. Recent research suggested that biochar should be combined with organic amendments to increase soil fertility even when biochar is applied at low (0.5-2 t ha^{-1}) biochar application rates.

Co-composting biochar (COMBI), which consists of mixing biochar with compost with high contents of both nutrients and labile organic carbon before starting an anerobic composting process, was shown to enhance the agronomic performance of biochar as a soil amendment. The co-composted biochar handpicked from the final biochar-amended compost was shown to promote plant growth beyond the combination of pristine biochar with either mineral fertilizer or mature non-biochar-amended compost. Soil received anthropogenic input of both nutrient-rich organic matter and pyrogenic carbon centuries ago and eventually for the development of low-cost biochar-based fertilizers that can promote high crop yields with comparably small application doses of biochar need determination. However, only a small portion of such researches was dedicated to the addition of biochar to the raw composting materials and its further impact on the composting process, the final COMBI product, and its application to agricultural soils. Most of the findings so far are undoubtedly positive although works focusing on the long-term effects of COMBI application are still scarce and, therefore, more research dedicated to evaluating the potential of COMBI aging in agricultural soils is strongly encouraged. In this point of view, the objectives of the trial were to: i. find out the soil health improvement after amendment, ii. Accelerate the sustainable carbon sequestration in to soil and iii. Develop a low-cost biochar-based fertilizer dose.

Materials and Methods

Site description and treatments

Second year (2021-2022) study was conducted in experimental field at Soil Science Division, BARI, Gazipur. Initial soil samples were collected from 0 to 15 cm depth at experimental site and chemical analysis are shown in Table 1. In this year, the experiment consisted of randomized complete block design (RCBD) with three replications of six treatments. The treatments were: i.T_1 (100% RDCF), ii. T_2 (80% RDCF + Compost @ 5 t ha^{-1}), iii. T_3 (80% RDCF + Biochar @ 5 t ha^{-1}), iv. T_4 (80% RDCF + COMBI @ 5 t ha $^{-1}$), v. T_5 (80% RDCF + COMBI @ 3 t ha $^{-1}$) and vi. T_6 (Native fertility). Each block comprised of 6 plots and each plot was 2 m × 3 m. Blocks were 1 m apart and plots were 0.5 m apart.

Table 1. Initial properties (0-15 cm) of experimental soil

Location	pH	BD	OC	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
		(g cm^{-3})	%	meq 100g^{-1}			(%)	µg g^{-1}						
Gazipur	5.40	1.48	0.87	3.28	1.32	0.16	0.08	8	12	0.12	2.1	75	10	2.0
Critical level		-	-	2.0	0.5	0.12	-	7	10	0.20	0.2	4	1	0.6

Preparation of biochar, compost and co-composting

Biochar(BC) was prepared using marketable waste as a feedstock. Pyrolysis was performed according to (Rajkovich *et al*., 2012). Briefly, material was dried and combusted in stainless steel pyrolyzer at 700°C. After cooling up to room temperature biochar ground to pass a 0.25 mm sieve and collected in plastic bags for further use. Farm yard manure (FM) was used for composting which was provided by ACI Company. The composting of BC and FM in 1:3 proportion was done and initially placed aboveground and sprayed with water and urea solution. Then, plastic perforated pipes were passed through piles to aerate the composts. The piles were finally covered with plastic sheets. The materials were mixed at regular intervals and composting was continued for a period of 2.5 months. After composting, amended samples were examined to determine their main characteristics without further treatment, and their characteristics are shown in Table 2.

Table 2. Chemical properties of the amendments used for the experiment

Amendments	pH	OC	Ca	Mg	K	Total	P	S	B	Cu	Fe	Mn	Zn
		(%)	%			N(%)	µg g^{-1}						
RHB	8.85	39.1	1.045	0.48	1.14	2.29	0.9	0.33	0.004	0.004	0.205	0.019	0.007
Compost	7.0	21.0	2.40	1.4	0.46	1.56	0.98	0.36	0.019	0.005	0.16	0.13	0.020
COMBI	7.55	27.4	2.03	1.15	0.62	1.78	0.96	0.34	0.012	0.005	0.172	0.103	0.015

Amendment characterization

After being thoroughly mixed with deionized water at a ratio of 1:20 and equilibrated for 1.5 h, the pH of the organic compound was measured by Metler Toledo S220 with a combine electrode (Rajkovich *et al*., 2012). Total N was determined by modified Kjeldahl method. Exchangeable base cations were extracted with 1.0 M ammonium acetate (pH 7.0) (Pansu and Gautheyrou, 2006). Cu, Fe, Mn and Zn were determined by $NaHCO_3$ extraction method followed by atomic absorption spectrophotometer (AAS) reading (Thermo Scientific-SOLAAR S Series AA spectrometer). Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method while S by turbidimetric method with $BaCl_2$. The phosphorus was determined colorimetrically after digesting the biochars with nitric acid and perchloric acid.

Soil analysis

Three sampling locations were selected and collected samples using a manual auger with 20 cm core barrel of 6 cm internal diameter. The 3 samples were combined, making a composite sample for each cell, resulting in 3 composite samples for analysis. Pest harvest soils were collected from individual treatment plot. Soil samples collected were homogenized and ground to pass through a 2-mm sieve. Soil samples were analyzed for pH using a ratio of 2.5 ml water to 1 g soil (McLean, 1982); Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank *et al*., 1998). Soil organic carbon (OC) was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). Organic matter (OM) was calculated by multiplying C by 1.724. Total N was determined by the Kjeldahl digestion method (Nelson and Sommers, 1980); exchangeable cations and CEC using ammonium acetate method (Black, 1965) at the soil and plant analysis laboratory of the Soil Science Division, BARI. Table 1 shows the pre-planting chemical characteristics of the trial soil.

Plant analysis

The clean plant samples were air-dried and placed in an electric oven, dried at 105ºC for 24 h, weighted for dry biomass. Again, place it in the oven at 105ºC for 2h. Cool it in a desiccator and weight it again. Repeat drying, cooling and weighing until the weight become constant. The dried plant samples were homogenized by grinding using willey mill and used for nutrient analysis. Then, the grains were ground and N, P, K, Ca, Mg, S, B and Zn contents were determined according to the method described by described by Jones and Case (2018). Atomic absorption spectrophotometer (Thermo Scientific-SOLAAR S Series AA spectrometer) was used for metal ion and spectrophotometer (Agiland Technologies, cary 60 UV-Vis) for anion analysis.The accumulation of nutrients in the grains was estimated by multiplying nutrient content by dry grain weight.

Incorporation of biochar, transplanting seedling and crop management

Co-composting biochar was used under Cabbage-Indian Spinach-T.aman cropping pattern. After land preparation (ploughing and harrowing), the experimental site was laid out to the required plot size of 2 × 3 m. The amendments were weighed and spread evenly on the plots according to the required rates over the soil. A hand held hoe was used to incorporate the amendments into the soil to the depth of approximately 10 cm. The treatments with amendment were applied at the beginning of the year for next three years and three crops will grow in a year at the same plots without any destroy. Cabbage seedlings were planted at row and plant spacing of 50cm and 40 cm, Indian spinach spacing of 50cm and 50cm and for T.aman 20 cm and 20cm, respectively. Fertilizers were applied as per treatment based on BARC fertilizer recommendation guide- 2018 (Cabbage: 100% RDCF: $N_{150}P_{40}K_{50}S_{36}Zn_{1.5}B_1$ $kgha^{-1}$, Indian spinach: 100% RDCF: $N_{60}P_{20}K_{20}S_{10}Zn_2B_{1.2}$ kg $ha^{-1}$and T.aman: 100% RDCF: $N_{100}P_{15}K_{33}S_{7.5}Zn_{0.5}$ kg ha^{-1}). One third urea was applied after seedling stand on soil and top dressing of urea as mentioned above was done at 25 and 45 days after sowing (DAS), include in the control. Irrigation was given as per crop demand. Weeding was done manually at 25 days after transplanting followed by earthing up at 30 days after transplanting.

Determination of yield parameters

Yield and yield contributing character samples were collected inside a quadrant area of 1.0 m^2 per plot. At harvest, and various yield parameters as head weight, head height, head circumference, head diameter, marketable yield, and yield of cabbage were recorded on five randomly selected and tagged representative plants in each plot and expressed as mean values. Marketable yield and dry matter yield were recorded for Indian spinach and plant height, grain yield, straw yield will be recorded for T. aman.

Statistical analysis

A software package, statistix 10 (Analytical Software, Tallahassee, Fla, USA) was employed for the statistical analysis of data. A one-way analysis of variance was undertaken for each time interval of the incubations to determine significant differences between treatments. The significant effects for various treatments were detected using a t- test.

Results and Discussion

Effect on cabbage growth and yield

The application of different amendment significantly increased head height, circumferences of cabbage compared with the application of inorganic fertilizer and control treatment (Table 4). Highest head height, circumferences were observed in T_4 treatment. These results show that the addition of organic carbon into the soil can improve the physical, chemical and biological soil fertility so that the growth and yield increases. Swarup (2008) reported that the increase of soil organic carbon content will increases the nutrient availability in the soil. Significant differences in total biomass, marketable yield and harvest index of cabbage were found among the treatments. Avarage biomass of cabbage varied from 30.1 to 86.6 t ha^{-1}. The highest marketable yield (86.6 t ha^{-1}) was found in 80% RDCF + COMBI 5 t ha^{-1} treatment (T_4) and lowest in control (30.1 t ha^{-1}). RDCF showed 71 t ha^{-1} yield which was more then double then that of control. Compost and RHB performed statistically identical with lower dose of COMBI i.e. 80% RDCF + COMBI 3 t ha^{-1}. This reflects the positive effect of co-composted biochar, which has significant growth in promoting features compared with biochar and compost alone (Kammann *et al*. 2016). This may be due to the higher amount of labile carbon that increases the amount of available nutrients which results in improved crop growth, quality and yield. In accordance with this, Agegnehu *et al*. (2016) reported beneficial effects following the amendment of co-composted biochar on soil available nutrients, and a subsequent positive effect on crop growth and development.

Table 3. Effect of different organic amendment on growth and yield of cabbage

Treatments	Head height (cm)	Head Circum-ference (cm)	Biomass yield (tha^{-1})	Head yield 2022 (tha^{-1})	Head yield 2021 (tha^{-1})	Avarage marketable Yield (tha^{-1})	Yield increase	
							Over T_6	Over T_1
T_1 (100% RDCF)	13.83b	61.6b	73.2c	61.5c	86.02ab	71.0c	58	-
T_2 (80% RDCF + Compost 5 t ha^{-1})	14.83ab	64.5ab	85.8ab	73.0ab	85.41ab	79.2b	62	10
T_3 (80% RDCF + RHB 5 t ha^{-1})	13.73ab	61.7b	81.6bc	68.2bc	80.51b	77.1bc	61	8
T_4 (80% RDCF + COMBI 5 t ha^{-1})	15.9a	67.6a	94.9a	81.7a	91.63a	86.6a	65	18
T_5 (80% RDCF + COMBI 3 t ha^{-1})	15.07ab	64.5ab	88.0ab	75.7ab	86.85ab	81.3ab	63	13
T_6 (Native)	8.93c	42.4c	24.0d	16.2d	44.00c	30.1d	-	-
CV (%)	5.70	5.19	7.77	8.03	7.10	5.10	-	-

100% RDCF: $N_{150}P_{40}K_{50}S_{36}Zn_{1.5}B_1$ $kgha^{-1}$

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Effect of Indian Spinach yield

The average yield varied from 17.3 to 36.3 tha^{-1} where greater yield was found in 80% RDCF + COMBI 5 t ha^{-1} treatment (T_4) and lowest in control. 100% RDCF showed 27.4 t ha^{-1} yield. Higher dose of Compost and RHB performed statistically identical. Lower dose of COMBI i.e. 80% RDCF + COMBI 3 t ha^{-1} showed the identical with T_4. Application of COMBI 5 t ha^{-1} can increase 33% indian spinach production over chemical fertilizer and 110% increaseover control field.

Table 4. Effects of different organic amendment on yield of Indian Spinach

Treatments	Yield (tha^{-1})			% yield increase	
	2021	2022	Avarage	Over T_1	Over T_6
T_1 (100% RDCF)	27.32b	27.5d	27.4c	-	59
T_2 (80% RDCF + Compost 5 t ha^{-1})	30.13b	31.7bc	30.9bc	13	79
T_3 (80% RDCF + RHB 5 t ha^{-1})	31.06ab	30.9c	31.0bc	13	80
T_4 (80% RDCF + COMBI 5 t ha^{-1})	35.51a	37.1a	36.3a	33	110
T_5 (80% RDCF + COMBI 3 t ha^{-1})	31.21ab	34.1ab	32.9ab	19	89
T_6 (Native)	15.02c	19.5e	17.3d	-	-
CV (%)	8.82	5.55	6.90	-	-

100% RDCF : $N_{120}P_{24}K_{60}S_{20}$ kg ha^{-1}

Effect of T.Aman yield

Incorporation of organic compound and chemical fertilizer influenced the grain and straw yield of T. aman significantly (Table 5). The highest grain and stover yield of 8.21 and 11.45 t ha^{-1} was obtained in T_4 treatment as compared to 5.41 and 6.54 t ha^{-1} in the native nutrient treatment (T_6). Almost 24% yield increase by using COMBI 5 t ha^{-1} into the field where 15% by using COMBI 3 t ha^{-1}. But 12% yield increase when 5 t ha^{-1} compost was use in the field.

Table 5. Effects of different organic amendment on yield and yield contributing characters of Rice (BRRIdhan 75). 2021

Treatments	Plant hight (cm)	1000 seed wt.(g)	Grains Yield (tha^{-1})	Stover Yield (tha^{-1})	Biological Yield (tha^{-1})
T_1 (100% RDCF)	90.3b	20.73bc	7.13b	8.74b	15.9
T_2 (80% RDCF + Compost 5 t ha^{-1})	96.3ab	22.67a	7.75ab	9.93ab	17.7
T_3 (80% RDCF + RHB 5 t ha^{-1})	94.9ab	21.79ab	7.36b	9.01b	16.4
T_4 (80% RDCF + COMBI 5 t ha^{-1})	103.0a	23.10a	8.21a	11.45a	19.7
T_5 (80% RDCF + COMBI 3 t ha^{-1})	96.2ab	22.96a	7.84ab	10.39ab	18.2
T_6 (Native)	76.8c	20.07c	5.41c	6.54c	12.0
CV (%)	5.29	3.89	6.2	10.97	-

100% RDCF: $N_{100}P_{15}K_{33}S_{7.5}Zn_{0.5}$ kg ha^{-1}

Total rice (system) yield

Total rice (system) yield as influenced by different treatments has been presented in Table 6. Highest total rice (system) yield of 58.98 t $ha^{-1}yr^{-1}$ was obtained from T_4 treatment. Lowest total rice (system) yield of 25.29 t $ha^{-1}yr^{-1}$ was obtained from control i.e. native fertility treatment (T_8) and 47.71 t $ha^{-1}yr^{-1}$ was found in chemical fertilizer use only.

Table 6. Rice equivalent yield (REY) (t $ha^{-1}yr^{-1}$) of Cabbage-Indian Spinach-T.aman

Treatment	Average yield of crops in the pattern (tha^{-1})				Rice equivalent yield (t $ha^{-1}yr^{-1}$)	% yield increase	
	Cabbage	Indian Spinach	T.aman			Over T_1	Over T_6
			Gain	Stover			
T_1	71.0	27.4	7.13	8.74	47.71	89	-
T_2	79.2	30.9	7.75	9.93	53.18	110	11
T_3	77.1	31.0	7.36	9.01	51.86	105	9
T_4	86.6	36.3	8.21	11.5	58.98	133	24
T_5	81.3	32.9	7.84	10.4	54.98	117	15
T_6	30.1	17.3	5.41	6.54	25.29	-	

Price : 1 kg Cabbage = Tk. 10, 1 kg Indian Spinach = Tk. 10, 1 kg Rice grain= Tk. 25, 1 kg Rice stover = Tk. 3.5

Nutrient uptake crops

Application of chemical fertilizers in combination with organic amendment increased the N, P and K contents in cabbage, Indian spinach and rice over both sole application of inorganic fertilizers (T_1) and control (T_6) (Table 7 to 9). The higher uptake of nutrients in vegetative parts as reported in combined treatment might be due to good proliferation of root system, resulting in better absorption in these plots. The lower nutrient accumulation generally observed for cabbage produced in the soil can be justified by the low availability of N and other nutrients in these treatments. Similarly, positive influence of combination of inorganic and organic treatment has also been reported by Sharma and Sharma (2002),Gupta*et al.*(2006) and Singh *et al.* (2011).

Table 7. Effect of different organic amendment with chemical fertilizers on soil nutrients uptake by Rice (BRRIDhan75) 2021

Treatment	Nutrient uptake by BRRIDhan 75 (kg ha^{-1})							
	N	P	K	Ca	Mg	S	Zn	B
T_1 (100% RDCF)	144.76	12.83	17.16	0.00	0.00	7.86	0.21	0.02
T_2 (80% RDCF + Compost 5 t ha^{-1})	158.39	13.68	19.95	0.00	0.00	9.83	0.23	0.03
T_3 (80% RDCF + RHB 5 t ha^{-1})	161.18	12.74	18.70	0.00	0.00	8.61	0.23	0.02
T_4 (80% RDCF + COMBI 5 t ha^{-1})	180.53	14.79	20.80	0.00	0.00	10.43	0.23	0.04
T_5 (80% RDCF + COMBI 3 t ha^{-1})	167.37	14.35	18.80	0.00	0.00	9.96	0.22	0.03
T_6 (Native)	104.91	9.33	12.22	0.00	0.00	5.67	0.16	0.02
CV (%)	10.42	5.15	12.56			11.40	9.23	12.59

Table 8. Effect of different organic amendment with chemical fertilizers on soil nutrients uptake by cabbage 2022

Treatment	Nutrients uptake by cabbage (kg ha^{-1})							
	N	P	K	Ca	Mg	S	Zn	B
T_1 (100% RDCF)	62.85	33.08	99.13	169.46	40.65	65.78	0.53	0.38
T_2 (80% RDCF + Compost 5 t ha^{-1})	78.07	41.95	118.83	207.95	50.85	82.55	0.61	0.41
T_3 (80% RDCF + RHB 5 t ha^{-1})	78.55	39.21	115.54	209.38	44.45	82.88	0.59	0.35
T_4 (80% RDCF + COMBI 5 t ha^{-1})	90.21	47.45	138.62	249.70	55.62	98.04	0.75	0.41
T_5 (80% RDCF + COMBI 3 t ha^{-1})	88.07	43.72	127.93	230.72	49.36	91.43	0.70	0.37
T_6 (Native)	22.64	12.14	33.62	63.98	12.67	23.63	0.18	0.09
CV (%)	8.36	10.55	8.23	8.28	10.75	6.46	7.10	11.2

The total N uptake ranged from 7.80 to 24.27 kg ha^{-1} having the significantly highest N uptake (24.27 kg ha^{-1}) in T_4 followed by T_5 (22.37 kg ha^{-1}) and T_4 (21.41 kg ha^{-1}) (Table 7). The ranking of the treatments with respect to total N uptake was in the order of $T_4>T_5>T_3>T_2> T_1>T_6$. Like N, treatment T4 showed the maximum P uptake (8.99 kg ha^{-1}) and the minimum P uptake (2.78 kg ha^{-1}) was observed in the control. Meena and Gautam (2005) reported that the application of FYM resulted in higher nutrient concentration and higher nutrient uptake. The K and S uptake by Indian spinach varied from 8.89 to 23.90 kg ha^{-1} and 1.29 to 4.93 kg ha^{-1}, respectively. The significantly highest K (23.92 kg ha^{-1}) and S (4.93 kg ha^{-1}) uptake were noted in T_4 and the lowest result was recorded in the control. Kumawat and Jat (2005) found higher K uptake by barely with combined application of vermicompost at 4.5 t ha^{-1} + 60 kg N ha^{-1}. Chaturvedi and Chandel (2005) also reported a highest K uptake with recommended NPK + FYM 10 t ha^{-1}.

Table 9. Effect of different organic amendment with chemical fertilizers on soil nutrients uptake by Indian spinach 2022

Treatment	Nutrient uptake by spinach (kg ha^{-1})							
	N	P	K	Ca	Mg	S	Zn	B
T_1 (100% RDCF)	17.11	6.06	16.57	42.40	9.46	3.23	0.13	0.09
T_2 (80% RDCF + Compost 5 t ha^{-1})	20.85	7.84	19.80	51.25	11.74	4.13	0.15	0.10
T_3 (80% RDCF + RHB 5 t ha^{-1})	21.32	7.43	19.93	52.95	10.58	4.34	0.15	0.09
T_4 (80% RDCF + COMBI 5 t ha^{-1})	25.37	9.41	24.98	65.02	13.70	5.16	0.19	0.11
T_5 (80% RDCF + COMBI 3 t ha^{-1})	24.48	8.56	22.78	59.61	12.05	4.91	0.18	0.09
T_6 (Native)	10.05	3.66	11.56	32.41	6.41	1.68	0.08	0.05
CV (%)	6.75	9.61	7.6	6.16	7.64	8.28	7.49	9.01

Cost and return analysis

The estimated total cost, gross return, gross margin and benefit cost ratio are presented in Table 7. Cost and return analysis shod that only RDCF is economically viable, because we use organic fertilizer into soil only first year and no more use for next years. The integration of reduction of 20% chemical fertilizer with different amendment increased the gross return and gross margin in all the treatments. The gross return ranged from 632250 to 1474500 Tk./ha/year and gross margin ranged from 434420 to 1263426 Tk./ha/year. The highest gross margin (1263426 Tk./ha/year) was obtained from T_4treatment with a BCR 6.99. Gross margin was obtained 1163426 Tk./ha/year by reduction of 20% RDCF with COMBI 3 t ha^{-1}, i.e. 80% RDCF with COMBI 3 t ha^{-1} (T_5 treatment) with BCR 6.51.

Table 7. Cost benefit ratio of different amendment with chemical fertilizers

Treatment	Rice Eq Yield (t/ha)	Total input Cost (BDT/ha)	Total overhead cost (BDT/ha)	Total cost (BDT)	Gross return (Tk/ha/yr.)	Gross margin (Tk/ha/yr.)	BCR
T_1 (100% RDCF)	47.71	177544	15540	193085	1192750	999665	6.18
T_2 (80% RDCF + Compost 5 t ha^{-1})	53.18	184435	15988	200424	1329500	1129076	6.63
T_3 (80% RDCF + RHB 5 t ha^{-1})	51.86	194435	16638	211074	1296500	1085426	6.14
T_4 (80% RDCF + COMBI 5 t ha^{-1})	58.98	194435	16638	211074	1474500	1263426	6.99
T_5 (80% RDCF + COMBI 3 t ha^{-1})	54.98	194435	16638	211074	1374500	1163426	6.51
T_6 (Native)	25.29	182000	15830	197830	632250	434420	3.20

Conclusion

From second year result, cabbage and Indian spinach were gently influence by organic uses in soil. The highest REY (58.98 t ha^{-1}) and BCR 6.99 was found in 80% RDCF with COMBI 5 t ha^{-1} treatment. But, in first year result showed that only 100% RDCF showed the highest BCR due to we add organic compound cost but this year we don’t use any organic compound in the same plot. This year we got good result on RHB, Compost, and COMBI treated soil.So, further study requires to the long-term effects of this combination on crop productivity, nutrient availability and soil health.

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NUTRIENT MANAGEMENT OF ONION TO REDUCE STORAGE ROTS

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Abstract

A field experiment in a randomized complete block design with three replications was conducted on onions(Allium cepa L.)(var. BARI Piaj-4) atLakkhaResearch Station, Bangladesh Agricultural Research Institute (BARI), Rajshahi (AEZ 26) during the rabi season of 2021-2022to investigate thenutrient management of onion to reduce storage rots. The five rates of soil amendments were: T_1= 100 % RD (FRG 2018), T_2 = $N_{60}P_{30}K_{80}S_{20}$ Ca_0Mg_0 kg/ha, T_3 = $N_{80}P_{50}K_{100}S_{30}$ $Ca_{30}Mg_{100}$ kg/ha, T_4 = $N_{100}P_{70}K_{120}S_{40}$ $Ca_{60}Mg_{200}$ kg/ha, T_5 = No application (control). Results revealed that the T_1(100% RD) produced the highest yield (17.33 t ha^{-1}) and the lowest yield (7.53 t ha^{-1}) in native fertility treatment (T_5).Disease incidence was recorded from storage of onion bulbs were found maximum in T_1 and minimum amount was found in T_5.

Introduction

Onion (*Allium cepa* L.) is an important herbaceous bulb and spice crop in the world which belongs to the family Alliaceae. Onion is mainly used as spices but it is also used as condiments for flavoring food and also as delicious vegetables and salad crop. Onion contains high medicinal properties having adequate vitamin B and C, iron and calcium (Vohra *et al.,* 1974). The leading onion growing countries of the world are the China, Netherlands, Korea, Israel, Japan, Turkey, Syria, Iran, Egypt, USA, Lebanon, Austria and India (FAO, 2012). In Bangladesh it is commercially cultivated in the greater districts of Dhaka, Mymensingh, Rajshahi, Rangpur, Rajbari, Khustia, Khulna, Barisal and Pabna (BBS, 2015). Among the spice crops grown in Bangladesh, onion ranks top in respect of production and second in respect of area (BBS, 2012).

On an average, the total annual requirement of onion in Bangladesh is about 16,50,000 metric tons but production is 10,52,000 metric tons. This production does not fulfill the country's demand so Bangladesh has to import onion from India and China every year (Hossain and Islam, 2006). This situation can be overcome mainly in two ways-firstly, extended the cultivable land and secondly, increases the yield of the crop. Fertilizer management is one of the important factors that contribute in the production and yield of onion. Among the nutrients nitrogen, phosphorus, potassium and sulphur play the most important role for vegetative growth of the crop, which ultimately helps in increasing bulb size and total yield of onion.

A balanced crop nutrition programmed can help to reduce onion storage rots by promoting healthier plants. Onions need a period of curing or drying in order to seal the neck, prevent invasion of diseases and rot and to create a bright, crack-free skin. Calcium, magnesium, boron and nitrogen all have an effect on onion storage rots.

Optimum nutrient management during establishment and vegetative growth are needed to ensure nutrients don't limit bulb quality. Onions are also very prone to foliar diseases and bulb rots, such as slimy or 'sour' outer scales, a bacterial disease that significantly reduces onion bulb quality. Fungal diseases such as neck rot, mildew, rust and leaf rot, are frequent too.

Materials and Methods

The study was conducted at Lakkha Research Station, BARI, Rajshahi using the onion variety BARI Piaj-4, was initiated from *robi* seasons of 2021. The initial soil samples of the experimental field were collected and analyzed following standard methods. The analytical report has been presented in Table 1.

Table 1. Analytical data of the experimental soils

Location	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			meq $100g^{-1}$				µg g^{-1}						
Chapainowab ganj	7.3	1.9	8.1	3.9	0.1	0.065	4	25	0.24	1.7	14	3.5	1.1
Critical level			2.0	0.5	0.12		7.0	10	0.2	0.2	4.0	1.0	0.6

The experimental area was slashed, ploughed and harrowed to a fine tilth. The debris was raked off the field and the area demarcated into 15 plots each measuring 3m x 1.2m. The experiment was a RCBD with three replications. Seedlings of onion variety, 'BARI piaj-4', were sown on 29th December, 2021. The seedlings were drilled at about 1-2 cm deep and at an inter row spacing of 15 cm and about 10cm between plants. Watering was done daily to keep the soil moist throughout the growing period. The spaces between the rows of onion plants were stirred with a hand fork fortnightly to remove weeds and to loosen the soil to improve infiltration and aeration. A chemical compound (Top cop) with fungicidal and bactericidal effect was applied as soil drench at a rate of 20 ml/l fifty days after sowing to check the spread of leaf blotch. There were five (05) trietments viz., T_1= 100 % RD (FRG 2018), T_2 = $N_{60}P_{30}K_{80}S_{20}$ Ca_0Mg_0kg/ha, T_3 = $N_{80}P_{50}K_{100}S_{30}$ $Ca_{30}Mg_{100}$kg/ha, T_4 = $N_{100}P_{70}K_{120}S_{40}$ $Ca_{60}Mg_{200}$kg/ha , T_5 = No application (control)

Data were collected on Plant height (cm) 45 DAT, Leaves per plant, Neck size (cm), Days to maturity, Dia. of Bulb (cm), Individual bulb wt. (g), Total soluble solid, Bulb wt. per plot (kg), Days to Physiological Maturity, Yield (ton/ ha), Dry matter of leaves (%), Dry matter of bulb (%). Rotting %at the end of 6th month of harvest at storage. Data collected were analyzed using ANOVA and means were separated by the Lsd at 5 % level of probability.Unbiased samples were collected from the stored bag of the retailers.Before storing in the cotton bag each sample of collected onion was sorted out into two categories, viz. healthy looking onions and symptombearing onions. Onion of all samples were counted, weighted, bagged and labeled. Storage of healthy onions was spread out at room temperature. The percentage of disease incidence was calculated using following equation: Disease incidence (%) = No. of diseased onion×100/ Total no. of onion

Results and Discussion

The growth parameters for onion under different fertilizers treatments were presented in Tables 2 and 3. Data revealed that, T_1 gave the highest values of all growth parameters compared to T_5, but T_4 were statistically identical with T_1.

Table 2: Response of growth properties of onion to different treatments

Treat	PH	LpP	NS	DtM	DiaoB	IBW	BWP	PM
T_1= 100 % RD (FRG 2018)	40.8a	5.26a	0.8a	105a	4.43a	27a	6.16a	120a
T_2 = $N_{60}P_{30}K_{80}S_{20}$ Ca_0Mg_0kg/ha	29.9bc	3.70c	0.60b	92bc	3.23c	17.63c	4.31c	109ab
T_3 = $N_{80}P_{50}K_{100}S_{30}Ca_{30}Mg_{100}$kg/ha	32.9b	4.36b	0.67b	100ab	3.77b	23.1b	5.07b	107ab
T_4 = $N_{100}P_{70}K_{120}S_{40}Ca_{60}Mg_{200}$kg/ha	39.6a	5.26a	0.87a	103ab	4.37a	27.5a	6.11a	113ab
T_5 = Control	26.5c	3.10d	0.46c	88c	2.67d	13.3d	2.71d	105b
CV (%)	7.53	6.68	9.3	6.63	7.34	8.12	6.02	6.76

PH= Plant height (cm) 45 DAT, LpP= Leaves per plant, NS= Neck size (cm), DtM= Days to maturity, DiaoB= Dia. of Bulb (cm), IBW= Individual bulb wt. (g), BWP= Bulb wt. per plot (kg), PM= Days to Physiological Maturity

The yield of onion increased significantly due to different combinations of fertilizers (Table. 3). The highest marketable yield (17.33 t ha^{-1}) was obtained from T_1 that received $N_{105}P_{45}K_{90}S_{30}Zn_3B_{1.4}OF_3$Kg ha^{-1} in an integrated manner, which was significantly higher over all other treatments. The second highest yield (17.11 t ha^{-1}) was obtained from $T_4$where$N_{100}P_{70}K_{120}S_{40}$ $Ca_{60}Mg_{200}$kg ha^{-1} were applied. The lowest yield (7.53 t ha^{-1}) was recorded from absolute control treatment (T_5).

Different types of inorganic manure application significantly increased total soluble solid (Table 03). T_1 treatment produced the most total soluble solid (10.87^0Brix) and the least value related to the native fertility (8.7^0Brix).

Table 3: Response of yield, TSS, DML. DMB and rot% of onion to different treatments

Treat	YIELD	TSS	DML%	DMB%	Rot%
T_1= 100 % RD (FRG 2018)	17.33a	10.87a	7.77a	17.2a	22.33a
$T_2 = N_{60}P_{30}K_{80}S_{20}\ Ca_0Mg_0$kg/ha	11.98b	9.13bc	6.18c	12.9b	20ab
$T_3 = N_{80}P_{50}K_{100}S_{30}\ Ca_{30}Mg_{100}$kg/ha	14.07b	10.13ab	6.65bc	15.47a	19.33ab
$T_4 = N_{100}P_{70}K_{120}S_{40}\ Ca_{60}Mg_{200}$kg/ha	17.11a	11.27a	7.38ab	15.8a	18.33b
T_5 = Control	7.53c	8.7c	4.76d	9.35c	9c
CV (%)	9.02	6.13	8.15	9.06	9.97

Yield= yield (ton/ ha), TSS= Total soluble solid,DM%L= Dry matter of leaves (%), DM%B= Dry matter of bulb (%). Rot = Rotting %at the end of 6^{th} month of harvest at storage, 100% RD= $N_{105}P_{45}K_{90}S_{30}Zn_3B_{1.4}OF_3$

Maximum dry weight of leaf and bulb were recorded in T_4 (7.77% and 17.2%) and minimum dry weight was recorded in T_5 (4.7% and 9.35%). The statistical analysis shows significant variation among dry wt. of leaves and bulbs.

Percentage of rotten bulbs of onion at storage was significantly influenced by different treatments (Table 3). The highest percentage of rotten bulbs (22.33%) after 180 days of storage was observed in the T_1 treatments. The minimum value of 9% (loss) being noted for T_5.

Conclusion

From the study, it may be concluded that application of $N_{105}P_{45}K_{90}S_{30}Zn_3B_{1.4}OF_3$ kg ha^{-1} can produce the maximum bulb yield of onion. On the other hand, $N_{100}P_{70}K_{120}S_{40}\ Ca_{60}Mg_{200}$kg ha^{-1}application increased the storage duration of onion bulbs and thereafter decreased slowly.

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DEVELOPMENT OF FERTILIZER RECOMMENDATION FOR CHILLI WITH ONION INTERCROPPING SYSTEM

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Abstract

An experiment was conducted at Central Research Farm, BARI, Gazipur (AEZ 28) during Rabi season of 2021-22 to develop a fertilizer recommendation for chilli with onion intercropping system. Six treatment combinations viz. T_1= 100% RDCF of chilli + 0% RDCF of onion, T_2= 100% RDCF of chilli +10% RDCF of onion, T_3= 100% RDCF of chilli + 20% RDCF of onion, T_4= 100% RDCF of chilli +30% RDCF of onion, T_5= 100% RDCF of chilli +40% RDCF of onion and T_6= 100% RDCF of chilli +50% RDCF of onion were tested. The experiment was laid out in randomized complete block design with 3 replications. Both chilli and onion significantly influenced by different treatment combinations. Significantly highest yield of chilli (12.21 t ha^{-1}) and onion (8.18 t ha^{-1}) were obtained from T_6 treatment (100% RDCF of chilli +50% RDCF of onion) which was statistically similar with T_5 treatment (100% RDCF of chilli +40% RDCF of onion). Chilli equivalent yield progressively increases with the increase of inorganic fertilizers. The results showed that T_6 provided the highest CEY (22.02 t ha^{-1}) followed by T_5 (21.97 t ha^{-1}).The highest net return (432028 Tk. ha^{-1}) as well as BCR (4.69) were obtained from T_5 treatment (100% RDCF of chilli +40% RDCF of onion) whereas the lowest net return (366661 Tk. ha^{-1}) as well as BCR (4.30) were observed in T_1 treatment (100% RDCF of chilli + 0% RDCF of onion). Though T_6 treatment gave higher yield over all the treatments yet it showed lower BCR compared to T_5 treatment due to higher cost involvement for inorganic fertilizer.

Introduction

Intercropping is an important tool for getting higher productivity per unit area by intensifying the use of land particularly densely populated countries which has limited per capita land for crop production. Recently it has been recognized as potentially beneficial system of crop production and evidence suggests that intercropping can provide substantial yield advantage compared to sole cropping (Singh*et al.,* 1992).On the other hand, soil fertility is also reducing due to intensive cultivation of HYV and other improper crop and soil management. Spice crop is now a very important sector. Recent onion production problem arose in Bangladesh which emphasised the need of nutrient management of spice crop.

Chilli is one of the major spices crop in Bangladesh which generally grow in char land as a sole crop. Farmers of different region especially char areas grow chilli as a sole or sometimes intercropping with onion. From the previous research findings of Begum *et al.* (2015), chilli with onion intercropping system found very productive and profitable for the char land. However, there is still no recommended fertilizer dose for chilli with onion intercropping system. To get the maximum return and crop production, fertilizer management is the most logical way to raise total production. Thus it is necessary to find out the optimum fertilizer dose for chilli with onion intercropping system.

Materials and Methods

A field experiment was conducted at Central Research Farm, BARI, Gazipur (AEZ-28) during *Rabi* season of 2020-21 to develop a fertilizer recommendation for chilli with onion intercropping system. The experiment confined with intercropping where chilli was transplanted as main crop and onion was transplanted as companion crop. The variety of chilli and onion were BARI Morich-4and BARI Piaj-4, respectively. Before conducting the experiment, initial composite soil samples at a depth of 0-15 cm from the experimental plots were collected and analyzed following standard methods (Table 1).

The experiment was laid out in a randomized complete block design with three replicates. The unit plot size was 4.0 m × 3.0 m. Chilli (30 days old seedlings)and onion (40 days oldseedlings) seedlings transplantation were done on 25 December, 2021. One row of onion was sown in between two rows of chilli. Line to line spacing of chilli was 40 cm and chilli to onion spacing was 20 cm. Plant to plant spacing of chilli and onion was 40 cm and 10 cm, respectively.

Table 1. Chemical properties of initial soil (0-15 cm depth) of the experimental field at Central Research farm, BARI, Joydebpur, Gazipur during *Rabi* season of 2021-22

Sample	pH	OM	Total N	K	Ca	Mg	P	S	Zn	B	Cu	Fe	Mn
		(%)	(%)	meq/100 g soil			µg g^{-1} soil						
Average	6.1	1.36	0.08	0.18	3.8	2.2	12.0	16	1.6	0.17	4.0	72	8
Critical level	-	-	0.12	0.12	2.0	0.5	7	10	0.6	0.2	0.2	4.0	1.0
Interpretation	Slightly acidic	Low	VeryLow	Low	Medium	Very high	Medium	Medium	Optimum	Low	Very high	Very high	Very high

The experiment was set up with six treatments viz.T_1= 100% RDCF of chilli + 0% RDCF of onion, T_2= 100% RDCF of chilli +10% RDCF of onion, T_3= 100% RDCF of chilli + 20% RDCF of onion, T_4= 100% RDCF of chilli +30% RDCF of onion, T_5= 100% RDCF of chilli +40% RDCF of onion and T_6= 100% RDCF of chilli +50% RDCF of onion.Recommended fertilizer dose was estimated based on the soil test value. Recommended dose of chemical fertilizer (RDCF) for chilli was $N_{99.5}$ $P_{32.6}$ K_{64} $S_{9.5}$ $Zn_{0.2}$ $B_{0.9}$ kg $ha^{-1}$and onion was $N_{108.8}P_{28.5}$ $K_{75.2}S_{19.6}$ $B_{1.3}$kg ha^{-1}.

The whole amounts of organic manure, phosphorus, sulphur, zinc, boron, half of nitrogen and potassium were applied as basal during final land preparation. Remaining nitrogen and potassium were applied in two equal installments at 30 and 60 days after transplantation from 10-12 cm away from the base of the plant which couldbe beneficial for the growth and yield of onion. Cowdung (5 t ha^{-1}) were applied as a basal in all the plots. All the intercultural operations such as irrigation, weeding, insect control etc. were done as and when necessary.

Chilli was harvested five times at 15 days interval starting from 3rd week of March and onion was harvested in its maturity on 05 April, 2022. Ten plants from each plot were tagged at random to take records on different agronomic parameters of chilli and onion. Data on yield and yield contributing parameters were recorded and statistically analyzed with the help of statistical package statistix 10 (Analytical Software. Tallahassee, Fla, USA) and mean separation was tested by Duncan's Multiple Range Test (DMRT) (Steel and Torrie, 1960). Chilli Equivalent Yield (CEY) was calculated after Bandyopadhyay, 1984:

$$\text{Chilli Equivalent Yield (kg/ha)} = \frac{\text{Yield of onion(kg/ha)x Price of onion (Tk./kg)}}{\text{Price of chilli(Tk./kg)}}$$

Methods of chemical analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Ca and Mg were determined by NH_4OAc extraction method. K, Cu, Fe, Mn and Zn were determined by DTPAextraction followed by AAS reading. Boron was determined by

$CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method (Acid soils) and Modified Olsen method (Neutral + Calcareous soils). S was determined by CaH_4 $(PO_4)_2.H_2O$ extraction followed by turbidimetric method with $BaCl_2$.

Results and Discussion

Chilli

The effect of chemical fertilizers on the yield and yield parameters of chilli are summarized in the Table 2. Green chilli yield and yield attributes like plant height, number of branches plant^{-1}, number of fruits plant^{-1} and average fruit weight plant^{-1} of chilli were significantly influenced by different nutrient packages in this study.

The significantly highest plant height (68.8 cm) was obtained from T_6 treatment (100% RDCF of chilli +50% RDCF of onion) which was statistically similar with T_5 treatment whereas the lowest plant height (63.3 cm) was obtained from T_1 treatment (100% RDCF of chilli + 0% RDCF of onion).

Table 2. Yield and yield components of chilli as influenced by different treatment combinations at Gazipur during *Rabi* season of 2021-22

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of fruits plant^{-1}	Average fruit weight plant^{-1}(gm)	Chilli yield (t ha^{-1})
T_1	63.3c	9.7c	132.1d	185.7e	10.13e
T_2	63.7c	10.5bc	136.7d	208.2d	10.51d
T_3	65.0c	10.8ab	141.6c	215.4c	10.93c
T_4	65.8bc	10.8ab	147.4b	221.3b	11.43b
T_5	68.3ab	11.2ab	159.8a	237.6a	12.18a
T_6	68.8a	11.4a	161.5a	240.2a	12.21a
CV (%)	6.51	5.78	3.89	3.27	9.30

Means followed by same letter (s) do not differ significantly at 5% level of significance

T_1= 100% RDCF of chilli + 0% RDCF of onion, T_2= 100% RDCF of chilli + 10% RDCF of onion, T_3= 100% RDCF of chilli + 20% RDCF of onion, T_4= 100% RDCF of chilli + 30% RDCF of onion, T_5= 100% RDCF of chilli + 40% RDCF of onion and T_6= 100% RDCF of chilli + 50% RDCF of onion

Number of branches plant^{-1} positively affected by different fertilizer treatment. Significantly highest number of branches plant^{-1} (11.4) was obtained from T_6 treatment whereas the lowest number of branches plant^{-1} (9.7) was recorded in T_1 treatment.

Number of fruits plant^{-1} progressively increases with the increase of inorganic fertilizers.The maximum number of fruits plant^{-1} (161.5) was obtained from T_6 treatment which was statistically similar with T_5 treatment while the minimum number of fruits plant^{-1} (132.1) was obtained from T_1 treatment.

The significantly highest average fruit weight plant^{-1} (240.2 gm) was obtained from T_6 treatment which was statistically similar with T_5 and superior to all other treatments. The lowest average fruit weight plant^{-1} (185.7 gm) was recorded in T_1 treatment.

Yield of chilli progressively increases with the increase of inorganic fertilizers. Significantly highest yield of green chilli (12.21 t ha^{-1}) was obtained from T_6 treatment (100% RDCF of chilli +50% RDCF of onion) which was statistically similar with T_5 treatment (100% RDCF of chilli +40% RDCF of onion) and superior to all other treatments.The lowest yield of green chilli (10.13 t ha^{-1}) was observed in T_1 treatment (100% RDCF of chilli + 0% RDCF of onion).

Onion

The effect of chemical fertilizers on the yield and yield parameters of onion are summarized in the Table 3. The results indicated that all of the yield attributes of onion were significantly influenced by different treatment combinations.

The highest plant height (54.6 cm) was obtained from T_6 treatment (100% RDCF of chilli +50% RDCF of onion**)** which was statistically at par with T_4 and T_5 treatment whereas the lowest plant height (49.5 cm) was obtained from T_1 treatment (100% RDCF of chilli + 0% RDCF of onion).

Table 3. Effect of different treatments on the yield and yield attributes of onion at Gazipur during *Rabi* season of 2021-22

Treatments	Plant height (cm)	Number of leaves plant^{-1}	Bulb length (cm)	Bulb diameter (cm)	Individual bulb weight (gm)	Bulb yield (t ha^{-1})
T_1	49.5b	8.0e	4.35c	4.11d	37.1c	7.49d
T_2	50.7b	8.3de	4.36c	4.17c	37.4c	7.55d
T_3	51.3b	8.5cd	4.41bc	4.20c	38.6b	7.82c
T_4	53.6a	8.9bc	4.46ab	4.26b	39.7ab	7.98b
T_5	54.5a	9.2ab	4.52a	4.31a	40.5a	8.16a
T_6	54.6a	9.4a	4.54a	4.33a	40.8a	8.18a
CV (%)	5.86	7.79	5.64	3.95	4.92	8.31

Means followed by same letter (s) do not differ significantly at 5% level of significance

T_1= 100% RDCF of chilli + 0% RDCF of onion, T_2= 100% RDCF of chilli + 10% RDCF of onion, T_3= 100% RDCF of chilli + 20% RDCF of onion, T_4= 100% RDCF of chilli + 30% RDCF of onion, T_5= 100% RDCF of chilli + 40% RDCF of onion and T_6= 100% RDCF of chilli + 50% RDCF of onion

The maximum number of leaves plant^{-1} (9.4) was obtained from T_6 treatment which was statistically similar with T_5 treatment whereas the minimum number of leaves plant^{-1}(8.0) was obtained from T_1 treatment (100% RDCF of chilli + 0% RDCF of onion).

Both of bulb length and bulb diameter are progressively increases with the increase of fertilizers. The highest bulb length (4.54 cm) and bulb diameter (4.33 cm) were obtained from T_6 treatment (100% RDCF of chilli +50% RDCF of onion) which was statistically similar with T_5 treatment (100% RDCF of chilli +40% RDCF of onion**).** The lowest bulb length (4.35 cm) and bulb diameter (4.11 cm) were obtained from T_1 treatment (100% RDCF of chilli +0% RDCF of onion**)**.

Individual bulb weight and yield of onion progressively increases with the increase of inorganic fertilizers. Significantly the highest individual bulb weight (40.8 g)and bulb yield (8.18 t ha^{-1}) of onionwere obtained from T_6 treatment (100% RDCF of chilli +50% RDCF of onion)which was statistically similar with T_5 treatment (100% RDCF of chilli +40% RDCF of onion) and superior to all other treatments.The lowest individual bulb weight (37.1 g)and bulb yield (7.49 t ha^{-1})were obtained from T_1 treatment (100% RDCF of chilli + 0% RDCF of onion).

Chilli Equivalent Yield (CEY)

After calculation of chilli equivalent yield it was observed that CEY progressively increases with the increase of inorganic fertilizers. The result showed that T_6 provided the highest CEY (22.02 t ha^{-1}) that was15.22% higher over T_1 (Fig. 1). The treatment T_5 also gave higher CEY (21.97 t ha^{-1}) followed by T_4, T_3 and T_2.

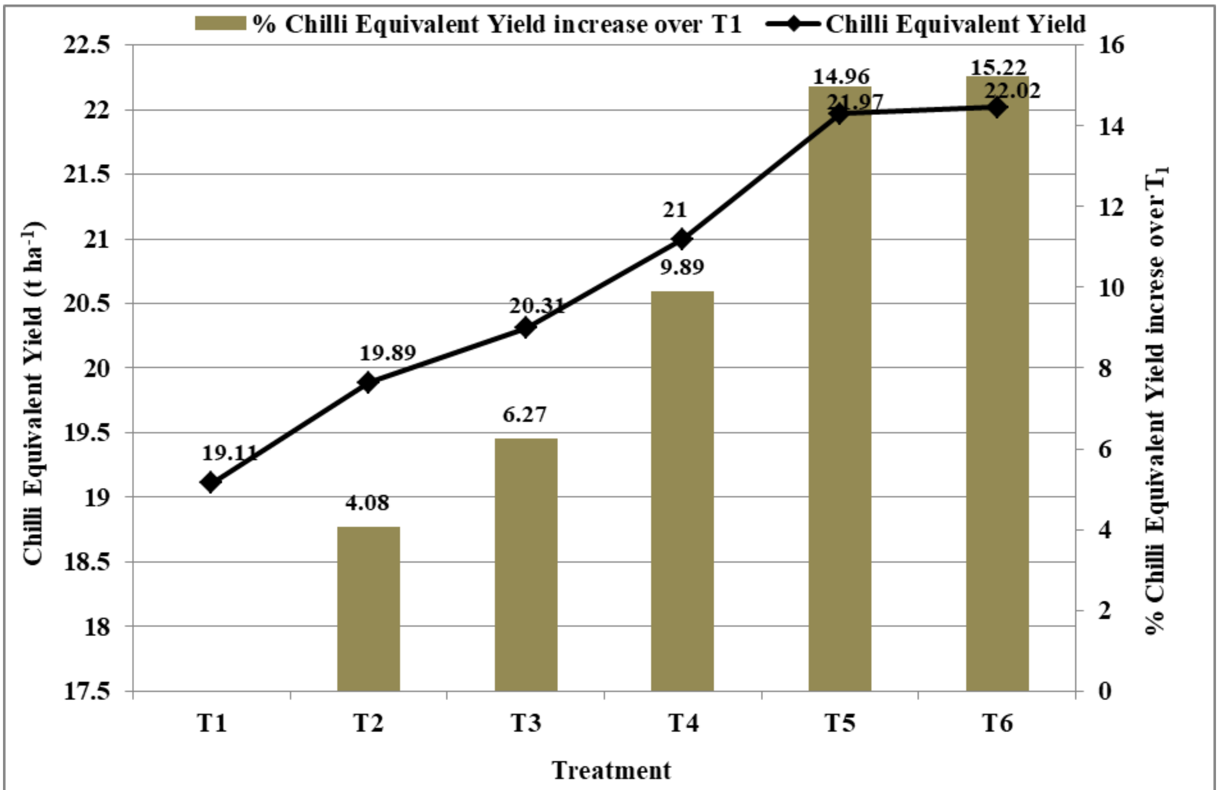

Fig.1. CEY and % CEY increase over T_1 in different treatment combinations

Cost and return analysis

Cost and return of chilli with onion intercropping have been described in the Table 4. Among the treatments, the highest net return (432028 Tk. ha^{-1}) as well as BCR (4.69) were obtained from T_5 treatment (100% RDCF of chilli +40% RDCF of onion) whereas the lowest net return (366661 Tk. ha^{-1}) as well as BCR (4.30) were observed in T_1 treatment (100% RDCF of chilli + 0% RDCF of onion). Though T_6 treatment gave higher yield over all the treatments yet it showed lower BCR compared to T_5 treatment due to higher cost involvement for inorganic fertilizer.

Table 4. Cost and return analysis of chilli with onion intercropping system as influenced by different fertilizer treatment combinations at Gazipur during *Rabi* season of 2021-22

Treatments	Yield (t ha^{-1})		Chilli equivalent yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Total cost (Tk. ha^{-1})	Net return (Tk. ha^{-1})	Benefit cost ratio (BCR)
	Chilli	Onion					
T_1	10.13	7.49	19.11	477750	111089	366661	4.30
T_2	10.51	7.55	19.89	497250	112566	384684	4.41
T_3	10.93	7.82	20.31	507750	114042	393708	4.45
T_4	11.43	7.98	21.00	525000	115520	409480	4.54
T_5	12.18	8.16	21.97	549250	116995	432028	4.69
T_6	12.21	8.18	22.02	550500	118472	429778	4.64

Input and output price per Kg: Urea = Tk. 16, TSP = Tk. 22, MoP = Tk. 15, Gypsum = Tk. 12, Zinc sulphate =Tk.150, Boric acid Tk. = Tk.220, chilli seed =Tk.600, onion seed =Tk.900, Chilli selling price = Tk. 25 and Onion selling price = Tk. 30

Conclusion

From the present study, it may be concluded that treatment package consists of 100% RDCF of chilli along with 40% RDCF of onion is most profitable for chilli with onion intercropping system in the study area (AEZ-28) and its extrapolation areas as well. Further investigation will be required for the confirmation of the findings.

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EFFECT OF KITCHEN WASTE COMPOST ON BROCCOLI YIELD AND CARBON ACCUMULATION IN SOIL

I.S.M. FARHAD, H.M. NASER, R. SEN, M.M. MASUD, R. KHATUN, M. SULTANA AND A. BARMAN

Abstract

A field experiment was conducted at Central Research Farm, BARI, Gazipur (AEZ 28) during Rabi season of 2021-22 to evaluate the effect of kitchen waste compost for better yield of broccoli; and to increase soil fertility and improve the stock of organic carbon in the soil. Six treatment combinations viz. T_1= 100% RDCF, T_2= 100% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_3= 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}, T_4= 80% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_5= 80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1} and T_6=Native fertility were tested. The experiment was laid out in a randomized complete block design with 3 replications. Application of treatment 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1} significantly increased all of the parameters such as the plant height, curd length, curd circumference, marketable weight of single curd, sprout yield and curd yield. The significantly highest curd yield (15.40 t ha^{-1}) was recorded in T_3 treatment (100% RDCF + Kitchen waste compost @5.0 t ha^{-1}) whereas the lowest curd yield (5.31 t ha^{-1}) was observed from T_6 (Native fertility) treatment. The uptake of nutrients by brocolli was highest in the treatment T_3 receiving 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1} which was followed by T_5 (80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) treatment. The highest gross return (462000 Tk. ha^{-1}), net return (291202 Tk. ha^{-1}) as well as BCR (2.70) were obtained from T_3 treatment (100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) whereas the lowest gross return (159300 Tk. ha^{-1}), net return (28700 Tk. ha^{-1}) and BCR (1.21) were obtained from T_6 (Native fertility) treatment. Application of kitchen waste compost along with chemical fertilizers slightly increased total N, available P, exchangeable K, available S and available Zn & B contents in post-harvest soil. It also slightly increased OC content, carbon stock & carbon accumulation in soil. The overall results indicated that 100% RDCF + Kitchen waste compost @ 5.0 t $ha^{-1}$is more effective than other fertilizer management packages in respect of yield as well as economic return for brocolli cultivation at Gazipur district of Bangladesh.

Introduction

Enormous amount of wastes are generated from plant, animals and industrial activities in day to day life. A considerable part of which remains unutilized and are either burnt or dumped nearby sites that create pollution, harbours pathogen for diseases and causes severe problem of disposal. Instead of disposing, it can be used as source of organic wastes and effectively recycled for the production of compost to meet the nutritional requirement of crops. Considering growing deficiency of plant nutrients in crop field, higher cost of synthetic fertilizers and poor efficiency of chemical fertilizers, the organic wastes recycling for plant nutrient supply is becoming more essential for replenishment of plant nutrients, sustaining soil health, reducing the pollution problem and creating employment opportunities. Organic inputs have higher photosynthetic capacity,physiological activities and also they improve the disease resistance capacity (Xu *et al.*,2000). Besides these organic manures can be prepared by using local materials which are *eco*friendly, economically viable to the farmers and safe to human health. In addition, because carbon stored in agricultural soils can be easily quantified using well-accepted scientific practices, it can provide benefits to farmers and to society by avoiding the cost of implementing expensive new technologies.More research is needed to ensure that farmers have access to improved carbon management technologies.The study was aimed to explore the possibility of bioconversion of different organic wastes to utilize the embedded nutrients for supplying enriched organic manure for better soil health and crop growth, which will not only improve the yield and quality of the produce but also conserve energy, minimize pollution, save foreign exchange and improve the fertilizer use efficiency subsequently that will helps to revitalize and restore the soil fertility and will revive the microbial activities for sustainable crop production.
The main objectives of the present study are:
i. To increase crop yield.
i. To minimize waste disposal problem and increase soil fertility.
ii. To improve the stock of organic carbon in the soil.

Materials and Methods

A field experiment was conducted in the Grey Terrace Soil of Central Research Farm, BARI, Gazipur (AEZ-28) during *Rabi* season of 2021-22 to evaluate the effect of kitchen waste compost for better yield of broccoli and to improve the stock of organic carbon in the soil as well as increase soil fertility. The initial soil samples collected from the depth of 0-15 cm at the experimental plot were analyzed in the laboratory following standard methods. Initial values of some important chemical & physical parameters of the experimental soil are presented in Table 1 & Table 2, respectively. Chemical analysis of kitchen waste compost has been shown in Table 3.

The experiment was laid out in a randomized complete block design with three replications.Six different treatments were randomly distributed within the blocks as follows:T_1= 100% RDCF, T_2= 100% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_3= 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}, T_4= 80% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_5= 80% RDCF + Kitchen waste compost @ 5.0 t $ha^{-1}$and T_6=Native fertility. The unit plot size was 3 m×2 m and broccoli (Green Crown) was used as the test crop. Thirty days old seedlings of broccoli was transplanted in line with 50 cm row to row and 50 cm plant to plant on 30 November 2021. Recommended fertilizer dose was estimated based on the soil test value. Recommended doses of chemical fertilizer (RDCF) for broccoli was N_{93} P_{24} K_{55} S_{14} $B_{1.3}$ kg ha^{-1}.

Half of kitchen waste compost and all of P, K, S and B were applied as basal. Remaining half kitchen waste compost was applied in pit before planting of seedlings. N and K were applied in three equal splits at 15, 30 and 50 days after transplantation as ring method under moist soil condition and mixed thoroughly with the soil as soon as possible for better utilization.The broccoli was harvested on 31 January 2022 and continued upto 18 February 2022. Data on yield and yield contributing characters were recorded and analyzed statistically using MSTATC. DMRT test was used to determine the significant differences among treatments (Steel and Torrie, 1960). Plant samples and post harvest soil samples were collected from each plot for chemical analysis.

Methods of chemical analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Ca and Mg were determined by NH_4OAc extraction method. K, Cu, Fe, Mn and Zn were determined by DTPAextraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method (Acid soils) and Modified Olsen method (Neutral + Calcareous soils). S was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric method with $BaCl_2$.

Table 1. Initial chemical properties of experimental soil at the Central Research Farm at BARI, Gazipur during *Rabi* season of 2021-22

Location	pH	SOC	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
		(%)	meq $100g^{-1}$			(%)	µg g^{-1}						
Gazipur	5.8	0.78	2.7	2.1	0.14	0.082	10.6	12.2	0.13	5.0	68.0	9.0	1.5
Critical Level		-	2.0	0.5	0.12	0.12	7	10	0.20	0.2	4	1	0.6

Table 2. Initial physical properties of experimental soil at the Central Research Farm at BARI, Gazipur during *Rabi* season of 2021-22

Depth (cm)	Textural class	Particle size distribution (%)			Field capacity (%)	Bulk density (gcc^{-1})
		Sand	Silt	Clay		
0-15 cm	Clay loam	29.0	41.4	29.6	30.93	1.47

Table 3. Nutrient status of ktchen waste compost used in the experimental field

Name of the manure	pH	OC	Ca	Mg	K	Total N	P	S	B	Zn
		%								
Kitchen waste Compost	7.1	16.3	1.50	2.10	1.17	1.23	0.79	0.50	0.013	0.14

Moisture content of Compost = 12.15 %

Results and discussion

The effect of kitchen waste compost on yield and yield contributing characters of broccoli are summarized in the Table 4. Curd yield, sprout yield and yield attributes like plant height, curd length, curd circumference and marketable weight of single curd were significantly influenced by different treatment combinations in this study.

Significantly the highest plant height (55.4 cm) was observed in T_3 treatment (100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) which was statistically identical with T_5 treatment (80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}). The lowest plant height (33.5 cm) was obtained from T_6 (Native fertility) treatment.

Table 4. Effect of kitchen waste compost on yield and yield contributing characters of broccoli (var. Green Crown) at Gazipur during *Rabi* season of 2021-22

Treatments	Plant height	Curd length	Curd circumference	Marketable wt. of single curd (g)	Sprout yield	Curd yield
	(cm)				(tha^{-1})	
T_1	49.9c	10.85c	34.44b	314.6e	6.33c	11.81d
T_2	53.1b	11.64ab	42.46a	375.8c	7.54b	14.13c
T_3	55.4a	11.79a	44.52a	403.5a	8.10a	15.40a
T_4	54.7b	11.22bc	41.99a	366.3d	7.34b	13.87c
T_5	54.2ab	11.44ab	43.71a	392.4b	7.70b	14.92b
T_6	33.5d	7.52d	26.99c	144.9f	2.49d	5.31e
CV (%)	5.42	6.63	5.77	9.21	10.18	9.14

Means followed by the same letter in a column are not statistically significant at 5% level by DMRT test.
T_1= 100% RDCF, T_2= 100% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_3= 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}, T_4= 80% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_5= 80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1} and T_6=Native fertility

Significantly the maximum curd length (11.79 cm) and curd circumference (44.52 cm) was recorded in 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1} treated plot (T_3) whereas the minimum curd length (7.52 cm) and curd circumference (26.99 cm) was observed in T_6 (Native fertility) treatment.

Significantly the maximum single curd weight (403.5 gm) was recorded in T_3 treatment which was statistically different with all other treatments whereas the minimum single curd weight (144.9 gm) was recorded in T_6 (Native fertility) treatment.

Significantly the highest sprout yield (8.10 t ha^{-1}) and curd yield (15.40 t ha^{-1}) was recorded in T_3 treatment (100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) whereas the lowest sprout yield (2.49 t ha^{-1}) and curd yield (5.31 t ha^{-1}) was observed from T_6 (Native fertility) treatment.

Total Nutrient uptake

Total nutrient uptake by broccoli (Curd & sprout) was influenced by different treatment combinations (Table 5). The uptake of NPKSB by broccoli was the highest in treatment T_3 receiving 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1} which was followed by T_5 treatment receiving 80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}. Organic sources might play the key role in enhancing efficient utilization of native nutrients which increases plant uptake. The lowest nutrient uptake by broccoli was obtained from T_6 (Native fertility) treatment.

Table 5. Effect of kitchen waste composton nutrient uptake by broccoli at BARI, Gazipur during *Rabi* season of 2021-22

Treatments	Total nutrient uptake by broccoli (kg ha^{-1})				
	N	P	K	S	B
T_1(100% RDCF)	81.56	9.82	46.31	10.37	1.10
T_2(100% RDCF + Kitchen waste compost @ 2.5 t ha^{-1})	104.7	18.43	75.58	17.20	1.41
T_3 (100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1})	119.41	22.32	90.64	21.31	1.46
T_4 (80% RDCF + Kitchen waste compost @ 2.5 t ha^{-1})	87.92	15.10	67.47	15.14	1.15
T_5 (80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1})	108.34	20.71	79.56	19.57	1.30
T_6 (Native fertility)	36.33	4.05	19.83	4.26	0.27

Table 6. Chemical properties of post harvest soil at broccoli field during *Rabi* season of 2021-22

Treatments	pH	Soil organic carbon %	Total N %	K meq 100 gm^{-1} soil	P	S	B	Zn
					µg g^{-1}			
T_1	5.83	0.78	0.082	0.14	11.31	12.44	0.13	1.7
T_2	6.19	0.81	0.083	0.15	12.62	13.40	0.14	2.4
T_3	6.24	0.83	0.084	0.15	13.60	14.43	0.15	2.6
T_4	6.17	0.80	0.082	0.14	12.15	13.17	0.13	2.4
T_5	6.21	0.82	0.083	0.15	13.24	14.80	0.14	2.5
T_6	5.80	0.78	0.077	0.13	10.73	12.20	0.12	1.5

T_1= 100% RDCF, T_2= 100% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_3= 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}, T_4= 80% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_5= 80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1} and T_6=Native fertility

Chemical properties of post harvest soil

The nutrient contents of post harvest soil of broccoli have been shown in the Table 6. The status of soil pH, OC, total N, exchangeable K and available P, S and Zn and B slightly increased with the application of kitchen waste compost. The highest amount of OC as well as other nutrients was obtained in T_3 treatment where 5.0 t ha^{-1} kitchen waste compost was applied along with 100% RDCF. It is noted that the buffering effect of organic manures might slightly increase the soil pH compared to non manuring treatments.

Carbon accumulation in soil from different treatment combinations

Addition of kitchen waste compost with chemical fertilizers provided to increase on carbon stock and carbon accumulation after completion of the experiment (Table 7). In the initial soil samples, organic carbon, bulk density and carbon stock in soils were 0.78%, 1.47 g cc^{-1} and 17.20 t ha^{-1}, respectively. Bulk density of post harvest soil influenced by different treatment combintions within a depth of 0-15 cm varied from 1.44-1.47 g cc^{-1}. Lowest bulk density (1.44g cc^{-1}) of soil was observed in T_3 (100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) and T_5 (80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) treatments. The highest organic carbon content (0.83%) and carbon stock (17.92 t ha^{-1}) in post harvest soil was found in T_3 (100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) treatment which was followed by T_5 (80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) and T_2 (100% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}) treatments. In post harvest soil, organic carbon content slightly decreased in control plot as compared to initial soil. The carbon accumulation in the T_3 (100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) treated plot was 0.72 t ha^{-1} while it was 0.63 t ha^{-1}, 0.53 t $ha^{-1}$and 0.32 t ha^{-1} in the T_5 (80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}), T_2 (100% RDCF + Kitchen waste compost @ 2.5

t ha^{-1}) and T_4 (80% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}) treatments, respectively. The results indicated that, application of kitchen waste compost could enhance the OC content, carbon stock and carbon accumulation in soil although the decomposition rate of organic matter in high humid and temperature prevailing sub-tropical region is quicker.

Table 7. Effect of different treatment cmbinations on carbon accumulation in soil at broccoli field during *Rabi* season of 2021-22

Treatments	Initial soil			Post harvest soil			Carbon accumulation (t ha^{-1})
	OC (%)	BD (g cc^{-1})	C stock (t ha^{-1})	OC (%)	BD (g cc^{-1})	C stock (t ha^{-1})	
T_1	0. 78	1.47	17.20	0.78	1.47	17.20	0.00
T_2	0. 78	1.47	17.20	0.81	1.46	17.73	0.53
T_3	0. 78	1.47	17.20	0.83	1.44	17.92	0.72
T_4	0. 78	1.47	17.20	0.80	1.46	17.52	0.32
T_5	0. 78	1.47	17.20	0.82	1.45	17.83	0.63
T_6	0. 78	1.47	17.20	0.78	1.47	17.20	0.00

T_1= 100% RDCF, T_2= 100% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_3= 100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}, T_4= 80% RDCF + Kitchen waste compost @ 2.5 t ha^{-1}, T_5= 80% RDCF + Kitchen waste compost @ 5.0 t ha^{-1} and T_6=Native fertility

Cost and Return Analysis

Cost and return of broccoli as influenced by different treatment combinations have been shown in the Table 8. Among the treatments, the highest gross return (462000 Tk. ha^{-1}), net return (291202 Tk. ha^{-1}) as well as BCR (2.70) were obtained from T_3 treatment (100% RDCF + Kitchen waste compost @ 5.0 t ha^{-1}) whereas the lowest gross return (159300 Tk. ha^{-1}), net return (28700 Tk. ha^{-1}) and BCR (1.21) were obtained from T_6 (Native fertility) treatment.

Table 8.Cost and return analysis of broccoli as influenced by different treatment ombinations at BARI, Gazipur during *Rabi* season of 2021-22

Treatments	Curd yield (t ha^{-1})	Gross Return (Tk. ha^{-1})	Total Cost (Tk. ha^{-1})	Net Return (Tk. ha^{-1})	BCR
T_1	11.81	354300	145798	208502	2.43
T_2	14.13	423900	158298	265602	2.67
T_3	15.40	462000	170798	291202	2.70
T_4	13.87	416100	156100	260000	2.66
T_5	14.92	447600	168600	279000	2.65
T_6	5.31	159300	130600	28700	1.21

Input and output price per kg: Broccoli seed = Tk. 40000, Urea = Tk. 16, TSP = Tk. 22, MoP = Tk. 15, Gypsum = Tk. 12, Boric acid = Tk. 220, Kitchen waste Compost = Tk. 5, Broccoli curd = Tk. 30

Conclusion

Based on the results, it may be concluded that 100% RDCF along with kitchen waste compost @ 5.0 t ha^{-1} is superior to the other fertilizer management packages in respect of yield as well as economic return for cultivation of broccoli in the Gazipur (AEZ-28) district of Bangladesh. The uptake of nutrients by broccoli was also highest in the treatment T_3 receiving 100% RDCF along with kitchen waste compost @ 5.0 t ha^{-1}. Application of kitchenwastecompost along with chemical fertilizers slightly increased total N, available P, exchangeable K, available S and available Zn & B contents in post harvest soil. It also slightly increased OC content, carbon stock & carbon accumulation in the soil. Further investigation will be required for the confirmation of the findings.

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INTEGRATED POTASH MANAGEMENT FOR MUSTARD

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Abstract

The experiment was conducted at Regional Agricultural Research Station (RARS), Jamalpur (AEZ 9) during the period of 2021-22.The objectives wereto evaluate the effect of integrated potash management for better yield of mustard and to increase potassium uptake.The experiment was laid out in a randomized complete block design (RCBD) with 3 replications and BARI Sarisha-14 was used as test crop. There were six treatments comprising T_1 = control, T_2= STB fertilizer dose, T_3 = STB+ rice husk ash @1 t ha^{-1}, T_4 = STB + rice husk ash @ 2 t ha^{-1}, T_5 = STB + rice straw compost @ 3 t $ha^{-1}$and T_6 = STB+ rice straw compost @ 5 t ha^{-1}. Among the various treatments, the highest seed yield (1448 Kg ha^{-1}) of mustard was obtained from treatment T_4 receiving STB fertilizer dose with rice husk ash @ 2 t ha^{-1} and the lowest yield (568 Kg ha^{-1}) was noted in control treatment.Cost and return analysis revealed that the highest gross margin (Tk 116820 ha^{-1}) as well as BCR of 2.87 were recorded from T_4 (STB + rice husk ash @ 2 t ha^{-1}) treatment. Results also demonstrated that, use of organic amendment such as rice husk ash,rice straw compost in integrated potash management practices also increased the potassium uptake and improved post-harvest soil K status over control or sole STB fertilizer dose. The overall results indicated that integrated potash management package of STB with rice husk ash @ 2 t $ha^{-1}$is more effective than other packages in respect of yield, economic return, nutrient availability and soil health.

Introduction

Mustard (Brassica sp.) is one of the most important oilseed crops throughout the world after soybean (FAO, 2014). Among the oilseed crops grown in Bangladesh, mustard holds the first position in terms of area and production as of 6,67,000 ha and 3,17,000 tons, respectively (BBS 2019). Mustard seeds contain 40-45% oil and 20-25% protein. Mustard is not only a rich source of energy (about 9 kcal g^{-1}), but also rich in fat soluble vitamins like A, D, E and K. The oil production is low compared to our demand. This quantity meets only a fraction of the country's cooking oil needs. Therefore, large quantity of soybean and sunflower oil is to be imported. Imported soybean oil is cheaper than local mustard oil, which has been further reducing mustard acreage in the country. The major reasons for low yields may be attributed to poor nutrient management and plant protection measures. Soils have generally been reported to be low in nitrogen, phosphorus and sulphur. Because of multiple cropping and introduction of high yielding varieties, the deficiency of these nutrients in soil is becoming wider.

Good potassium nutrition is vital to consistently improve crop productivity. Potassium’s role in the plant is primarily in plant/soil/air-water relations; it also activates certain enzymes, and it aids in moving captured carbon from plant biomass to reproductive material (grain, fruit, and fiber). Potassium is the third major plant nutrient recently identified as deficient in most Bangladesh soils. Inadequate potassium nutrition leaves the plant more susceptible to different stresses, including water deficit, insect pressure, and pathogen pressure. As low soil K status is an important limiting factor responsible for poor yields of the crops, it is imperative to evaluate the response of K nutrition on mustard productivity (Lakhan *et al*., 2017).

Integrated nutrient management is very essential which is not only sustains high crop production over the years (Verma *et al.*, 2016) but also improves soil health and ensures safer environment (Babu lal *et al.*, 2017). The nutrient supplied to crops through INM not only restoring the soil fertility but also sustain desired level of production over the years (Pal and Pathak, 2016).Agricultural activities produce billions of tons of other materials long regarded as waste. With appropriate techniques, agricultural wastes can be recycled to produce an important source of energy and natural fertilizer for crops. Rice husk ash ash increases the soil pH, thereby increasing available phosphorous, it improves the aeration in the crop root zone and also increases the water holding capacity and level of exchangeable potassium and magnesium (AICOAF, 2001).Application of rice straw compost and manure 5 t ha^{-1} could increase the N absorption and the content of leaf chlorophyll a and b (Iqbal 2008). Furthermore, Pramono (2004) reported that the application of organic fertilizer could increase the yield components like the number of stem, the weight of 1,000 grains and the grain weight per plots, also it could reduce the amount of chemical fertilizer especially potassium.Therefore, an attempt was made to study the effect of rice husk ash and rice straw compost as organic source of potassium along with chemical fertilizer. Accordingly, in the present study, main objective was to evolve integrated potash nutrient supply system for mustard on sustainable basis.

Materials and Methods

The experiment was conducted in 2021-22 period at the soil science field of RARS under Jamalpur district in Bangladesh. The site is located at Sonalata series under AEZ-9, 24˚56´11´´N latitude and 89˚55´54´´E longitude and an altitude of 16.46m. The soil of the experimental site was silt clay loam in texture. Before initiation the experiment, the soil samples were collected from a depth of 0-15 cm for each replication and analyzed following standard methods. Nutrient status of initial soil is presented in Table 1.

Table 1. Initial soil status of the experimental soils

Location	pH	OM (%)	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
			meq $100g^{-1}$				µg g^{-1}						
RARS, Jamalpur	7.2	1.27	6.3	1.8	0.11	0.051	7.8	6.1	0.22	2.3	28	4.2	1.6
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4	1	0.6

The experiment was laid out in a randomized complete block design (RCBD) having 3 replications. The unit plot size was 4m x 3m and the variety was BARI Sarisha-14. The seeds were sowing on 17 November, 2021. in a spacing of 30 cm x continuous in line. STB dose of chemical fertilizer for mustard production was calculated on the basis of soil test values according to fertilizer recommendation guide.

Treatments were as follows

T_1 = control

T_2 = STB fertilizer dose

T_3 = STB+ rice husk ash @ 1 t ha^{-1}

T_4 = STB + rice husk ash @ 2 t ha^{-1}

T_5 = STB + rice straw compost @ 3 t ha^{-1}

T_6 = STB + rice straw compost@ 5 t ha^{-1}

STB dose: N_{100} P_{23} K_{50} S_{10} Zn_2 B_1 Kg ha^{-1}

Table 2.Treatments combinations for mustard crop

Treatments	Treatment combination							
	Chemical fertilizer (kg ha^{-1})						Organic manure (t ha^{-1})	
	N	P	K	S	Zn	B	rice husk ash	rice straw compost
T_1	0	0	0	0	0	0	0	0
T_2	100	23	50	10	2	1	0	0
T_3	98	19	40	10	2	1	1	0
T_4	96	15	30	10	2	1	2	0
T_5	84	16	37	10	2	1	0	3
T_6	73	12	27	10	2	1	0	5

Collection and preparation of rice husk ash and rice straw compost:

Preparation of rice husk ash

Rice husk is a by-product of rice milling and rice husk ash is generated by combustion in a separate boiler. The burnt rice husk ash was collected from local rice mill.

Preparation of rice straw compost

In composting process, green source (high in Nitrogen) and brown source (high in Carbon) are needed. Composting was carried out in plastic drum and modified by providing small holes on the circumference of the drums to facilitate air circulation inside the drums. Than freshly threshed chopped rice straw and cowdung were arranged in alternate layers (V/V= 1foot: 1foot) in the drum for enriched compost. In between two layers, a mixture of 2 kg field soil, 1 Kg vermicompost has to be added as accelerator materials. After layering all the materials, a handful of water was sprinkled into the drum and some turmeric powder was added to avoid ants. The drum was avoided from direct sunlight as extreme temperatures would kill the beneficial microorganisms. Moisture content of the materials was controlled to 60% to 70%. The drum was then being rotated 3 days interval for mixing and aeration purpose and remoistened for sufficient microbial activity in order to get final composted material.

Table 3. Chemical composition of rice husk ash and rice straw compost used for the experiment

Name of the manure	pH	N (%)	P (%)	K (%)	Ca (ppm)	Na (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)
Rice husk ash	8.82	0.21	0.43	0.95	0.078	0.41	2.76	2.34	0.97
Rice straw compost	6.45	0.53	0.22	0.46	0.17	0.49	2.48	4.07	0.49

The uptake of potassium by the crop was estimated by using following formula

Potassium uptake (Kg ha^{-1}) in seed =Nutrient content in seed (%) x seed yield (Kg ha^{-1})/100

Potassium uptake (Kg ha^{-1}) in stover =Nutrient content in stover (%) x stover yield (Kg ha^{-1})/100

Other intercultural operations were done as per requirement.The crop was harvested on 8 February, 2022.Data on yield and yield contributing characters were recorded from ten plants selected randomly for each plot and analyzed statistically using statistical software STAR which was developed by IRRI. Least significant differences (LSD) were used for means separation at 5% probability level.

Results & Discussion

Effect of integrated potash management practices on yield and quality parameters of mustard

There was a significant effect of integrated potash management on the yield and yield attributes of mustard crop (Table 4). Maximum plant height (93.44 cm) was recorded in treatment T_4 (STB + rice husk ash @) 2 t ha^{-1}) followed by T_6 (90.34 cm) where (STB+ rice straw compost @ 5 t ha^{-1}) was used and the minimum (78.91cm) under control treatment.T_4 treatment exhibited the highest pods per plant (61.87) which was at par with T_3 (60.46) and the least in T_1 treatment (31.25 cm). Maximum seeds per pod (44.84) were also recorded from T_4 treatment and the minimum (28.59) was found in T_1 treatment. Thousand seed wt. of the treatments varied from 2.31g to 3.77g. Integrated use of organic fertilizer and STB significantly increased thousand seed weight and seed yield of mustard over sole STB fertilizer dose. The higher thousand seed weight can be attributed to better crop growth due to application of K or other nutrients and more translocation of photosynthates from source to sink (Tripathi *et al*., 2010).

The highest seed yield of mustard (1448 kg ha^{-1}) was recorded in T_4 (STB + rice husk ash @) 2 t ha^{-1}) treatment.T_5 treatment (STB+ rice straw compost @ 3 t ha^{-1}) produced the second highest yield (1349 kg ha^{-1}) which was at par with T_3 treatment (1343 kg ha^{-1}). The lowest yield (768 kg ha^{-1}) was under control treatment. Significant increase in seed yield of mustard due to potassium application was also reported by Singh *et al*. (2010).

Table 4. Effect of integrated potash management on yield contributing characters of mustard, 2021-22

Treat.	Plant height (cm)	Pods plant^{-1} (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	1000 seed wt.(g)	Seed yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})
T_1	78.91 e	31.25 e	3.47 d	28.59 c	2.31 d	568 d	1063 e
T_2	87.85 d	48.46 d	3.80 c	38.33 b	3.51 c	1235 c	2765 d
T_3	88.65 cd	60.46 a	4.03 b	42.94 a	3.59 bc	1343 b	3436 b
T_4	93.44 a	61.87 a	4.17 ab	44.84 a	3.77 a	1448 a	3580 a
T_5	89.53 bc	53.91 c	4.10 b	39.26 b	3.63 abc	1349 b	3268 c
T_6	90.34 b	56.45 b	4.27 a	42.73 a	3.73 ab	1398 ab	3331 c
CV (%)	6.21	13.42	8.43	10.43	11.52	12.20	14.57
LSD (0.05)	1.10	1.75	0.161	2.71	0.148	78.54	92.07

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD

Note: T_1 = control, T_2= STB fertilizer dose, T_3 = STB+ rice husk ash @1 t ha^{-1}, T_4 = STB + rice husk ash @ 2 t ha^{-1},
T_5 = STB + rice straw compost @ 3 t ha^{-1} and T_6 = STB+rice straw compost @ 5 t ha^{-1}.

Effect of integrated potash management on potassium uptake

Potassium uptake by mustard crop was influenced by integrated potash management practices. The highest potassium uptake was found in treatment T_4 receiving STB fertilizer dose with rice husk ash @ 2 t ha^{-1}which was followed by T_3 receiving STB fertilizer dose with rice husk ash @ 1 t ha^{-1}.On the other hand, rice straw compost application also increases potassium uptake over control or sole STB dose. Organic sources might play the role in enhancing efficient utilization of native nutrients which increases plant uptake. The lowest potassium uptake by mustard crop was obtained from T_1 (control) treatment.

Table 5. Effect of integrated potash management on potassium uptake by mustard, 2020-21

Treat.	Mustard yield (Kg ha^{-1})		K concentration (%)		K uptake (Kg ha^{-1})		Total K uptake (Kg ha^{-1})
	Seed yield	Stover yield	seed	stover	seed	stover	
T_1	568	1063	0.81	0.32	4.60	3.40	8.00
T_2	1235	2765	0.84	0.33	10.37	9.12	19.49
T_3	1343	3436	0.84	0.35	11.28	12.02	23.30
T_4	1448	3580	0.85	0.35	12.30	12.53	24.83
T_5	1349	3268	0.85	0.34	11.46	11.11	22.57
T_6	1398	3331	0.85	0.34	11.88	11.32	23.20

Note: T_1 = control, T_2= STB fertilizer dose, T_3 = STB+ rice husk ash @1 t ha^{-1}, T_4 = STB + rice husk ash @ 2 t ha^{-1}, T_5 = STB + rice straw compost @ 3 t ha^{-1} and T_6 = STB+rice straw compost @ 5 t ha^{-1}.

Effect of integrated potash management practices on nutrient status of post-harvest soil

Integrated potash management package had a positive influenced on post-harvest soil nutrient status. Application of rice husk ash and rice straw compost along with STB fertilizer dose significantly increased the macronutrient and micronutrient uptake over STB fertilizer dose. The pH of post-harvest soil was affected by different treatments and ranged from 7.2 to 7.6 (Table 5). Maximum value of soil pH (7.6) was found from STB fertilizer dose with rice husk ash @ 2 t ha^{-1} application and minimum value of soil pH (7.2) was obtained from control. Soil organic carbon varies from 0.73% to 0.96%. Maximum organic carbon (0.96%) was also found from STB fertilizer dose with rice husk ash @ 2 t ha^{-1} application and minimum (0.73%) in control treatment. On the other hand, treatments where organic manure was applied resulted in higher soil organic matter. The combined application of organic manure and chemical fertilizers increased organic matter content in soil (Zhang *et al*., 2009). Soil total nitrogen varies from 0.053% to 0.095%. Under T_6 (STB+ rice straw compost @ 5 t ha^{-1}) treatment, about 79.24% increases was observed in the available N content of the soil compared to control. On the otherhand, remarkable increases of about 128.39 % and 141% were recorded for P and

K respectively in the T_4 (STB + rice husk ash @) 2 t ha^{-1}) in comparison to the control. Singh *et al.* (2010) reported a significant increase in total N, P, K and S uptake by mustard with increase in the dose of NPKS and organic fertilizers.Other soil nutrient status was higher in the treatments where organic fertilizers were applied for slow released pattern of nutrients. On the other hand, in control treatment no organic and chemical fertilizers were applied resulted lower nutrient status.

Table 5. Effect of integrated potash management practices on nutrient status of post-harvest soil, 2021-22

Treatments	pH	SOM (%)	SOC (%)	Total N %	K meq 100g^{-1}	P	S	B	Zn
						µg g^{-1}			
T_1	7.2	1.25	0.73	0.053	0.12	8.1	7.1	0.21	1.6
T_2	7.2	1.27	0.74	0.061	0.16	9.6	10.5	0.28	1.7
T_3	7.5	1.59	0.93	0.065	0.23	15.3	13.1	0.44	2.3
T_4	7.6	1.65	0.96	0.066	0.29	18.5	15.3	0.52	2.4
T_5	7.4	1.53	0.89	0.091	0.17	12.1	14.2	0.31	1.8
T_6	7.4	1.56	0.91	0.095	0.18	12.9	14.5	0.39	1.9
Initial soil	7.2	1.27	0.74	0.051	0.11	7.8	6.1	0.22	1.6

Note: T_1 = control, T_2= STB fertilizer dose, T_3 = STB+ rice husk ash @1 t ha^{-1}, T_4 = STB + rice husk ash @ 2 t ha^{-1},
T_5 = STB + rice straw compost @ 3 t ha^{-1} and T_6 = STB+rice straw compost @ 5 t ha^{-1}.

Cost and return analysis

Table 6 showed the economic performance of mustard as influenced by integrated application of inorganic fertilizers and organic manures. The highest gross return (Tk 179220 ha^{-1}), gross margin (Tk 116820 ha^{-1}) and BCR (2.87) were recorded fromT_4 (STB + rice husk ash @ 2 t ha^{-1}) treatment. Among the treatment, the lowest gross return (Tk 61750 ha^{-1}), gross margin (Tk 25550 ha^{-1}) and BCR (1.70) were recorded fromcontrol treatment.

Table 6. Cost and return analysis of mustard as influenced by of integrated potash management, 2021-2022

Treatments	Seed yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})	Gross return	Total variable cost	Gross margin	BCR
			(Tk ha^{-1})			
T_1	568 d	1063 e	61750	36200	25550	1.70
T_2	1235 c	2765 d	138800	56700	82100	2.44
T_3	1343 b	4436 b	165230	58000	107230	2.84
T_4	1448 a	4890 a	179220	62400	116820	2.87
T_5	1349 b	4268 c	164090	64500	99590	2.54
T_6	1398 ab	4331 c	169130	65100	104030	2.59

Note: T_1 = control, T_2= STB fertilizer dose, T_3 = STB+ rice husk ash @1 t ha^{-1}, T_4 = STB + rice husk ash @ 2 t ha^{-1},T_5 = STB + rice straw compost @ 3 t ha^{-1} and T_6 = STB+rice straw compost @ 5 t ha^{-1}.

Input:Unit price **(**Tk. Kg^{-1}**):** Urea=16, TSP= 22, MoP = 15, Gypsum = 12, Zinc sulphate = 200, Boric acid = 250, rice husk ash = 5, rice straw compost = 10
Output:Unit price **(**Tk. Kg^{-1}**):** mustard seed = 90, mustard stover =10

Conclusion

Considering results of the experiment, treatment package consists of STB fertilizer dose with rice husk ash @ 2 t ha^{-1} was found to be the most effective. From economic analysis, highest gross margin (Tk 109580 ha^{-1}) as well as highest BCR (2.75) was obtained from same treatment. This is the results of first year experiment. So, further investigation will be required for confirmation of the findings.

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APPLICATION OF VERMIWASH ON GROWTH AND QUALITY OF TOMATO

M YASMIN, F S SHIKHA, M A RAHMAN, R SEN AND H M NASER

Abstract

The experiment was conducted at Regional Agricultural Research Station (RARS), Jamalpur (AEZ 9) during the period of 2021-2022 to investigate the effect of vermiwash on growth, yield and quality of tomato and to find out suitable foliar dose of vermiwash for optimizing the yield of tomato. There were five treatments comprising T_1= Chemical fertilizer (CF) (control), T_2= CF + foliar spray of 10 % vermiwash,T_3 =CF + foliar spray of 20 % vermiwash,T_4= CF + foliar spray of 30 % vermiwash,T_5= CF + foliar spray of 40 % vermiwash.Nutrients of the treatments was formulated through IPNS system.Results revealed that, vermiwash treated tomato plants showed better growth and yield parameters than the control plants.The highest average tomato fruit yield (70.51t ha^{-1}) was found in T_3 treatment i.e., foliar spray of 20% concentration of vermiwashand the lowest (61.82 t ha^{-1}) came from control. On the other hand, nutritional quality (moisture content, TSS, lycopene, β carotene and vitamin C) were seen to be higher in vermiwash treated treatment compared to control treatment. The study suggests that, 20% vermiwash could be used as effective foliar spray for eco-friendly and higher yield of tomato.

Introduction

Increased use of chemical fertilizers over a long period of time ultimately destroys the fertility of soil. Hazardous effect of chemical fertilizer can be reducing by the use of organic fertilizers. The new approaches to the use of organic amendments in farming have proven to be effective means of improving soil structure, enhancing soil fertility and increasing crop yields. Vermicomposting is a novel eco-friendly and cost effective technology of decomposing organic matter and producing organic manure that was the best in all aspects including the nutrient level. Application of vermicompost favourably affects soil PH, microbial population and soil enzyme activities (Shweta and Singh, 2006). The vermicomposting technology can also be utilized for generating a bioliquid termed as vermiwash (Ismail, 1997). Vermiwash is a brownish-red liquid extract collected during vermicomposting of organic waste. Vermiwash can also serve as a valuable foliar spray, because it is a combination of earthworm mucous discharges, nutrients, microorganisms and plant growth promoting materials (Gopal *et al*., 2010) composed of excretory products and mucus secretions from earthworms and micronutrients from the organic molecules in the soil. These nutrients are absorbed and then transported to the leaves, shoots, and other parts of a plant (Ansari & Sukhraj, 2010). Various experimental results have shown that application of vermiwash improves plant health, yield and nutritional quality (Naidu*et al*., 2013). Studies have shown that vermiwash contains plant growth-promoting substances (humic, fulvic and other organic acids); auxin-like substances and cytokinin-like substances. Vermiwash foliar spray is more advantageous from economical and environmental perspectives owing to the absence of nutrient leaching, which is often encountered when performing soil amendments. Even though much work has been done on vermicomposting, very few reports are available related to vermiwash and its impact and concentration of the foliar spray on the plant growth. The main objective of the present investigation was carried out the influence of vermiwash on growth and yield parameters of tomato plants.

Materials and Methods

The experiment was conducted in 2021-22 period at the soil science field of RARS under Jamalpur district in Bangladesh. The site is located at Sonalata series under AEZ- 8, 24˚56΄11΄΄N latitude and 89˚55΄54΄΄E longitude and an altitude of 16.46m. The soil of the experimental site was silt clay loam in texture. Before initiation the experiment, the soil samples were collected from a depth of 0-15 cm for each replication and analyzed following standard methods (Table 1). Nutrient status of initial soil is presented in Table 1.

Table 1. Initial soil nutrient status of the experimental soils

Location	pH	OM (%)	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
			meq $100g^{-1}$				$\mu g\ g^{-1}$						
RARS, Jamalpur	7.1	0.86	6.0	1.9	0.092	0.053	8.7	7.5	0.35	2.6	25	4.0	1.22
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4	1	0.6

The experiment was laid out in a randomized complete block design (RCBD) with 3 replications. The unit plot size was 2.5m x 2.3m and the variety was BARI Tomato-14. The 30 days old tomato seedlings were transplanted on 12 November, 2021 in a spacing of 100cm x 70cm. Recommended doses of chemical fertilizer for tomato were calculated on the basis of soil test values according to fertilizer recommendation guide.

Treatments were as follows

T_1 = Chemical fertilizer (CF) (control)
T_2 = CF + foliar spray of 10 % vermiwash
T_3 = CF +foliar spray of 20 % vermiwash
T_4 = CF + foliar spray of 30 % vermiwash
T_5 = CF + foliar spray of 40 % vermiwash

Recommended doses of chemical fertilizer : $N_{150}\ P_{38}\ K_{50}\ S_{20}\ Zn_2\ B_1$ Kg ha^{-1} (FRG-2018)

Preparation of vermiwash

Vermiwash preparation unit:Vermiwash preparation unit was prepared according to the procedure suggested by Ismail (1997) using a plastic container having capacity of 230 liter (97cm height ×186cm diameter). In brief, a tap was fixed on the lower side of the container and a bucket was placed near the container. The bottom of the container had a 15-cm layer of broken pebbles, followed by a 15-cm layer of coarse sand. Above this layer air-dried mixed waste (vegetable waste: paddy straw: water hyacinth; 1:1:1) at a height of 30 cm and cowdung at a height of 30 cm were put into the container as substrate and one thousand earthworms (*Eisenia fetida*) were introduced into the substrate. An appropriate level of moisture (60%) was maintained in the container by slowly sprinkling five liters of distilled water from the top at regular intervals. During the vermiwash preparation, the temperature and pH inside the container ranged from 29–32°C and 7.0–7.3 respectively.

Vermiwash collection:After 16 to 20 days of preparation, the brown-colored watery extract of vermiwash was allowed to drain out from the container. Everyday about 3-4 L of vermiwash was collected, stored at 4ºC and used for foliar spray on test crop.

Table 2. Chemical composition of vermiwash

Colour	pH	OC (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)
Gray	9.22	16.2	0.01	0.10	0.64	0.25	0.13	0.67	0.020	0.004	0.012	0.015	0.006

Vermiwash application: The treatments were of 4 levels of vermiwash rate (10%, 20%, 30%, 40% v/v).Plants were sprayed 3 times (at flowering, at fruiting and 30 days after first fruiting).Foliar sprays were applied using hand operated compressed air sprayer at the rate of 10 litre /plot.Time of foliar sprays was 4 P.M. Tomato plant did not receive any irrigation two days before and after the foliar spray.

Table 3.Various concentrations of vermiwash and distilled water

Treatment	Concentration of vermiwash and distilled water
Control	10 L distilled water
T_2 (10% vermiwash)	1 L vermiwash + 9 L distilled water
T_3 (20% vermiwash)	2 L vermiwash + 8 L distilled water
T_4 (30% vermiwash)	3 L vermiwash + 7 L distilled water
T_5 (40% vermiwash)	4 L vermiwash + 6 L distilled water

Other intercultural operations were done as per requirement.The crop harvesting continued during the month of February to April, 2021. Data on yield and yield contributing characters were recorded from ten plants selected randomly for each plot. Data on vegetative and fruit characters were recorded and analyzed statistically using statistical software STAR which was developed by IRRI. Least significant differences (LSD) were used for means separation at 5% probability level.

Results & Discussion

Effect of vermiwash on plant growth and yield of tomato

The effect of vermiwash application on plant growth and yield of tomato were presented in Table 4.A notably increases in various yield attributes of tomato was recorded after the foliar application. The highest plant height (118.58 cm) was observed in T_3 treatment and the lowest plant height (98.14 cm) was obtained from untreated (control) treatment.Fruit length and fruit diameter were increased from 5.22 cm (control) to 5.38 cm (20% vermiwash) and 5.66 cm (control) to 5.93 cm (20% vermiwash), respectively. Tomato plant treated with 20% concentrations of vermiwash led to a statistically significant increase fruit no. (28.51) and marketable fruit weight (1.97 kg per plant) in comparison with the control.

Table 4. Effect of vermiwash application on yield and yield components of tomato, 2021-2022

Treat.	Plant height	Fruit length	Fruit dia.	Fruit no. plant^{-1}	Av. fruit weight (kg)	Fruit yield (t ha^{-1})	% increase over control
	(cm)						
T_1	98.14 d	5.22 c	5.66 b	21.15 d	1.65 d	61.82 d	-
T_2	112.02 c	5.30 b	5.75 a	25.24 b	1.83 b	66.14 b	8.85
T_3	118.58 a	5.38 a	5.93 a	28.51 a	1.97 a	70.51 a	15.22
T_4	115.31 b	5.34 ab	5.81 a	27.23 b	1.85 b	67.23 b	9.50
T_5	11.34 c	5.29 bc	5.68 b	23.43 c	1.72 c	63.15 c	2.44
CV%	5.15	6.18	6.74	8.79	9.57	12.51	-
LSD (0.05)	1.16	0.05	0.14	0.99	0.08	0.63	-

Means in a column followed by same letter(s) do not differ significantly at 5% level by LSD
Note: T_1 = CF (control), T_2 = CF +10% vermiwash, T_3 = CF + 20% vermiwash,
T_4= CF + 30% vermiwash, T_5 = CF + 40% vermiwash

Among all the concentrations of vermiwash tested, 20% vermiwash exhibited the maximum increase in tomato fruit yield (70.51 t ha^{-1}). T_4 treatment (30% vermiwash) produced second highest tomato yield (67.23 t ha^{-1}) which was statistically at par with T_2 (10% vermiwash) (66.14 t ha^{-1}).Obviously, control plot (T_1) showed the lowest yield (61.82 t ha^{-1}). The highest average tomato yield was observed in T_3 treatment (20% vermiwash) which was15.22 % higher over control.These results agreed with earlier, Meghvansi*et al*. (2012) reported that application of 20 % vermiwash significantly improved the vegetative and yield attributes of both Okra and Naga chilli. Similarly, Muscolo *et al*. (1999) also found an auxin-like effect of earthworm worked humic substances on cell growth and nitrogen metabolism in *Daucus carota*. Parallel to these observations, Buckerfield et al. (1999) reported that the diluted extracts improved plant growth and increased radish yields significantly by up to 20%. However, a 30% concentration of vermiwash led to a decrease in the marketable weight of tomato in our study. It is postulated that occurrence of inhibition of growth at higher vermicompost substitution rates might be attributed to higher electrical conductivity and excessive nutrient levels (Buckerfield et al. 1999). Excessive nutrient levels can cause a micronutrient imbalance in the soil, which may have a negative influence on the crop.

Effect of vermiwash application on nutritional quality of tomato

The effects of vermiwash application on some nutritional composition of tomato were presented in Table 5.Moisture content was varies from 93.33% to 95.16 % in different treatment. The pH value of tomato fruits was found highest (4.46) in control treatment, might be due to application of higher lavel of chemical fertilizers. Almost similar results were reported by Naresh (2002) who reported that acidity of tomato fruits showed a marked increase with increasing level of chemical fertilizers. The total soluble solid (TSS) was influenced by the application of different concentrations of vermiwash.The highest TSS content (4.21 ^{0}Brix) was obtained from T_3 (20% vermiwash) treatment and the lowest TSS (3.73 ^{0}Brix) was found in control treatment.Lycopene andβ – carotene levels were higher in vermiwash treated tomato than control tomato.Application of vermiwash with chemical fertilizers significantly affected the vitamin C content. Among the treatments maximum vitamin C content (23.35 mg100 g^{-1}) was recorded in T_3 (20% vermiwash) treatment and minimum vitamin C content was found in control treatment. Rajya et al. (2015) reported that increase in quality parameters might be due to increased availability of macro as well as, micro nutrients especially nitrogen and potassium, as they play a vital role in enhancing the fruit vitamin C content of tomato and minimum might be due to lack of availability of sufficient nutrients. The results of the study are similar with Meherunnessa *et al.*(2011) who found that compost and chemical fertilizer alone or in combination has positive influence on vitamin C content of tomato fruit.

Table 5. Nutritional quality of tomato as influence by vermiwash application, 2021-2022

Treatment	Moisture (%)	pH	TSS (^{0}Brix)	Lycopene (mg 100 g^{-1})	β – carotene (µg100 g^{-1})	vitamin C (mg100g^{-1})
T_1 =CF (control)	93.33	4.46	3.73	3.13	317.51	17.04
T_2 = CF + 10% vermiwash	94.37	4.44	3.78	3.16	323.82	21.44
T_3 =CF + 20% vermiwash	95.16	4.42	4.21	3.45	345.17	23.35
T_4 =CF + 30% vermiwash	95.01	4.42	4.11	3.36	342.26	22.18
T_5 =CF + 40% vermiwash	94.28	4.40	4.15	3.35	336.45	21.69

Table 6. Cost and return analysis of tomato as influence by vermiwash application, 2021-2022

Treatments	Tomato yield (t ha^{-1})	Gross return	Total variable cost	Gross margin	BCR
		(TK ha^{-1})			
T_1 =CF (control)	61.82	927300	238500	688800	3.88
T_2 = CF + 10% vermiwash	66.14	992100	241100	751000	4.11
T_3 = CF + 20% vermiwash	70.51	1057650	244500	813150	4.32
T_4 = CF + 30% vermiwash	67.23	1008450	247300	761150	4.07
T_5 = CF + 40% vermiwash	63.15	947250	250300	696950	3.78

Note: Unit price **(**Tk.Kg^{-1}**):** Urea=16, TSP=22, DAP=16, MoP= 15, Gypsum = 6, Zinc sulphate = 120 and Boric acid = 150, vermiwash=10Tk/L , Price range of tomato 10 to 25 Tk Kg^{-1}, average price 15 Tk Kg^{-1}

Economic analysis

The economic performance of tomato as influenced by vermiwash application showed in Table 6. The highest gross return (Tk 1057650 ha^{-1}), gross margin (Tk 813150 ha^{-1}) and BCR (4.32) were recorded from T_3 (20% vermiwash application) treatment. The lowest gross return (Tk 927300 ha^{-1}) and gross margin (Tk 688800 ha^{-1}) came from control treatment.Among the treatment, the lowest BCR (3.78) was recorded in T_5 (40% vermiwash application) treatment. T_5 treatment demonstrated poor performance mainly due to low yield and high cost of production as the vermiwash concentration was high.From economic point of view, 20% concentration of vermiwash application would be the best for high yield and economic return.

Conclusion

Considering results of this year, the highest yield of tomato (70.51 t ha^{-1}) was obtained from foliar sprays of 20% concentration of vermiwash with recommended dose of chemical fertilizers.From economic point of view, this treatment was suitable and economically viable.This is the result of first year experiment.For confirming the results, the experiment need to be repeated next year.

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DEVELOPMENT OF FERTILIZER RECOMMENDATION FOR GROUNDNUT- LINSEED INTERCROPPING SYSTEM

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Abstract

A field trial was conducted at Regional Agricultural Research Station (RARS), Jamalpur (AEZ 9) during the period of 2021-2022 to develop a suitable and economic fertilizer dose for maximizing the yield for groundnut with linseed intercropping system. There were seven treatments comprising T_1 = 100% RDCF of groundnut+ 0% RDCF of linseed, $T_2 = T_1$ + 10% RDCF of linseed, $T_3 = T_1$ + 20% RDCF of linseed, $T_4 = T_1$ + 30% RDCF of linseed, $T_5 = T_1$+ 40% RDCF of linseed, $T_6 = T_1$ + 50% RDCF of linseed and $T_7= T_1$ + 60% RDCF of linseed. Significantly the highest yield (1.83a $tha^{-1}$for groundnut and 1.17a tha^{-1} for linseed) was obtained from T_6 (T_1 + 50% RDCF of linseed) treatment which was statistically identical with T_5 (T_1 + 40% RDCF of linseed) treatment for groundnut and T_5 and T_4 for linseed.The lowest yield (0.81 tha^{-1} and 0.55 tha^{-1} for groundnut and linseed respectively) from T_1 (100% RDCF of groundnut+ 0% RDCF of linseed) treatment. The highest net return (163735 Tk ha^{-1}) was obtained from $T_6 = T_1$ + 50% RDCF of linseed treatment which was followed by $T_5 = T_1$ + 40% RDCF of linseedtreatment (147705 Tk ha^{-1}) . But the highestBCR (2.31) was obtained from $T_6 = T_1$ + 50% RDCF of linseedtreatment which was followed by $T_5 = T_1$ + 40% RDCF of linseed treatment (2.20) and the lowest net return (13800 Tkha. $^{-1}$) from T_1 = 100% RDCF of groundnut+ 0% RDCF of linseed treatment. Although the highest groundnut equivalent yield (2.80 tha. $^{-1}$) was obtained from T_6 (T_1 + 50% RDCF of linseed) treatment, BCR was higher than T_7 (T_1 + 60% RDCF of linseed) treatment due to higher cost of inorganic fertilizers.

Introduction

The global human population is projected to increase beyond 9.8 billion by the end of the year 2050 (UN 2017). Agriculture must use the scientific technologies and inputs developed over the decades to meet this challenge to feed this burgeoning population (Dietrich *et al*. 2014). Thus, ensuring food security while sustaining the soil and environment is a major challenge to the agricultural planners and researchers (Drechsel *et al.* 2015). The productivity level of crops should be increased further without deteriorating the soil fertility, environment, and food quality (Bedoussac et al. 2015; Meena *et al.* 2015a). Indiscriminate and imbalanced use of synthetic fertilizers, however, deteriorates the soil health in the long term (Savci 2012). Intercropping system by intensification of cropping both in time and space gives an yield advantage of 11 to 199 % over sole cropping through effective use of natural *(i.e.* land, light) and added (fertilizer) resources (Sharma *et al.,* 2003). Intercropping is the most common practice which has an important role in increasing productivity and stability of yield. Intercropping is a management practice where two or more crops grow simultaneously in the same land area, particularly in the tropics (Andrews and Kassam, 1976). However, success and efficiency of an intercropping system depend upon various factors. Benjamin *et al.* (2000) opined that intercropping system is greatly influenced by the component or associated crops, though profitability is favoured by choice of sites with a high fertility, use of proper package of practices etc. Moreover labors, reduces the adverse effect of various biotic and abiotic stress, provides the diversity of food, generates more income, offers insurance against crop failure, higher return and total productivity per unit area (Farhad *et al*., 2014)

On the other hand,soil fertility is also reducing due to intensive cultivation of HYV and improper crop and soil management. Groundnut- linseed intercropping is very productive and profitable for the charland in Jamalpur region. Unbalanced use of chemical fertilizers was applied for getting high profit in groundnut- linseed intercropping system. It was known that this bad practicing have a adverse effect on soil health over all the environment. But there is till no standerd fertilizer doses for groundnut -linseedintercropping system. So overcome this problem a standerd fertilizer doses for groundnut- linseed intercropping system is needed. To get the maximum return and crop production, fertilizer management is the most logical way to raise the total production. Therefore, the present study has been planned to find out the optimum fertilizer dose for groundnut- linseed intercropping system.

Materials and Methods

The experiment was started in 2021-22 period at the field of Regional Agricultural Research Station (RARS) under Jamalpur district in Bangladesh. Before initiation the experiment, the soil samples were collected from a depth of 0-15 cm for each replication and analyzed following standard methods (Table 1). The chemical properties of soils in the experimental site was silt clay loam in texture belonging to Sonalata series under Agro-Ecological Zone-8/9 (AEZ-8/9), 24˚56′11′′N latitude and 89˚55′54′′E longitude and an altitude of 16.46m. Nutrient status of initial soil prior to fertilization is presented in Table 1.

Table 1. Initial soil status of the experimental soils

Location	pH	OM	Ca	Mg	K	Total	P	S	B	Cu	Fe	Mn	Zn
		(%)	meq $100g^{-1}$			N%	µg g^{-1}						
RARS, Jamalpur	7.2	0.98	5.7	1.6	0.14	0.040	14.4	10.3	0.40	1.62	22	2.13	1.16
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4	1	0.6

The experiment was laid out in Randomized Complete Block (RCB) design with six treatments replicated thrice. The unit plot size was 1. 2 m x 2.4 m. There were six treatments viz. T_1 = 100% RDCF of groundnut+ 0% RDCF of linseed, $T_2 = T_1$ + 10% RDCF of linseed, $T_3 = T_1$ + 20% RDCF of linseed ,$T_4 = T_1$ + 30% RDCF of linseed , $T_5 = T_1$+ 40% RDCF of linseed, $T_6 = T_1$ + 50% RDCF of linseed and $T_7= T_1$ + 60% RDCF of linseed.

The seeds of groundnut (var. BARI chinabadam - 9) and linseed (var. BARI tishi - 1) were sown on 30 November, 2021 spacing for groundnut was 40 cm X 15 cm (one rows of linseed in between two rows of groundnut). Nitrogen, phosphorus, potassium, sulphur, zinc and boron were used in the form of urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. All P, K, S, Zn, B and $^1/_3$rd urea-N were applied at the time of final land preparation and the remaining $^2/_3$rd urea-N was applied in two equal installments at 30 and 50 days of sowing. All the intercultural operations such as irrigation, weeding, insect control etc. were done as and when necessary. Linseed was harvested on 22 March, 2022 and groundnut was harvested on 19 May, 2022. Nut yield was calculated in ton per hectare considering the whole plot as harvested area. Ten plants of groundnut from each plot were selected randomly to collect data on yield components. Data on yield and yield contributing characters were recorded and analyzed statistically using statistical software STAR which was developed by IRRI.The analyzed data were compared with Least Significant Difference (LSD) test at 5% level. The Groundnut Equivalent Yield (GEY) was calculated by using formula given Prasad and Srivastava (1991), as follows –

$$\text{GEY (kgha}^{-1}\text{)} = \text{Yield of groundnut} + \frac{\text{Yield of linseed} \times \text{Price of linseed (Tkkg}^{-1}\text{)}}{\text{Price of groundnut (Tkkg}^{-1}\text{)}}$$

The economic analysis was calculated based on the existing market price at the harvesting period in the local market of groundnut and linseed. All production costs were calculated to find out the economic benefit.

Results and Discussions

Yield and yield contributing characters of groundnut were influenced by the effect of chemical fertilizers which was summarized in the table 2. All the parameters like Plant height(cm), Nut $plant^{-1,}$ Kernel $plant^{-1}$(no.),100-nut weight (g), 100- kernel weight (g), Nut yield(t ha^{-1}) (%) were singnificantly influenced by different nutrient packages. The highest plant height (65.51cm) was obtained from T_7 (100% RDCF of groundnut+60% RDCF of linseed) treatment which was followed by T_5 (100% RDCF of groundnut + 40% RDCF of linseed) and T_6 (100% RDCF of groundnut + 50% RDCF of linseed) treatment. The lowest (52.10 cm) from T_1 (100% RDCF of groundnut + 0% RDCF of linseed) treatment.Nut plant^{-1} progressively increased with the increasing trend of inorganic fertilizers. The maximum nut plant^{-1} (35.48a) was obtained from the T_6 (100% RDCF of groundnut + 50% RDCF of linseed) treatment which was statistically identical with T_5 (100% RDCF of garlic+ 40% RDCF of coriander) and $T_4 = T_1$ + 30% RDCF of linseed) treatment . The lowestnut plant^{-1} (27.10) was obtained from T_1 (100% RDCF of groundnut+ 0% RDCF of linseed) treatment.Kernel plant^{-1} was positively affected by treatments of different fertilizer . The highest No.of kernel plant^{-1} (59.10)was obtained from the T_6 (T_1 + 50% RDCF of linseed) treatment which was followed by T_5 (T_1+ 40% RDCF of linseed) treatment . The lowest no.of kernel plant^{-1} (36.57) was obtained from T_1 (100% RDCF of groundnut+ 0% RDCF of linseed) treatment.The different packages of inorganic fertilizers were statistically significant on the 100-nut weight (g). The highest 100-nut weight (81.22g) was obtained from the T_6 (T_1 + 50% RDCF of linseed) treatment which was followed by T_5 (T_1 + 40% RDCF of linseed) treatment. The lowest 100-nut weight (61.41g) was obtained from T_1 (100% RDCF of groundnut+ 0% RDCF of linseed) treatment.The highest 100- kernel weight (45.40g) was obtained from the T_6 (T_1 + 50% RDCF of linseed) treatment which was followed by T_5 (T_1 + 40% RDCF of linseed) treatment . The lowest 100- kernel weight (35.09g) was obtained from T_1 (100% RDCF of groundnut+ 0% RDCF of linseed) treatment.The shelling (%) was ranged from (65.68 - 73.76).Groundnut and linseed yield was increased with the increasing trend of inorganic fertilizers. Significantly the highest yield (1.83a tha^{-1}for groundnut and 1.17a tha^{-1} for linseed) was obtained from T_6 (T_1 + 50% RDCF of linseed) treatment which was statistically identical with T_5 (T_1 + 40% RDCF of linseed) treatment for groundnut and T_5 and T_4 for linseed.The lowest (0.81 tha.$^{-1}$ and 0.55 tha.$^{-1}$ for groundnut and linseed respectively) from T_1 (100% RDCF of groundnut+ 0% RDCF of linseed) treatment.

Table 2. Effect of different treantments on plant characters, yield and yield contributing characters of groundnut in linseed – groundnut intercropping system 2021-2022

Treatments	Plant height	Nut plant^{-1} (no.)	Kernel plant^{-1} (no.)	100-nut weight (g)	100- kernel weight (g)	Nut yield (t ha^{-1})	Shelling (%)
T_1	52.10d	27.10c	36.57g	61.41f	35.09e	0.81d	65.68
T_2	55.99c	28.30c	38.84f	65.25e	37.84d	1.15c	73.76
T_3	58.52bc	30.72bc	45.72e	68.00d	38.71cd	1.20c	68.07
T_4	58.67bc	33.96ab	52.47d	69.48cd	41.05bc	1.37bc	72.50
T_5	61.58b	34.58ab	58.03b	70.96bc	43.25ab	1.78a	73.36
T_6	60.57b	35.48a	59.19a	81.22a	45.40a	1.83a	70.57
T_7	65.51a	30.80bc	55.83c	72.47b	41.86b	1.49b	72.40
CV(%)	7.10	8.56	8.23	9.07	7.11	8.5	9.21
LSD	3.53	4.135	1.13	2.137	2.44	0.34	-

Values in a column having same letter(s) do not differ significantly at 5% level by LSD.

Note: T_1 = 100% RDCF of groundnut+ 0% RDCF of linseed, $T_2 = T_1$ + 10% RDCF of linseed, $T_3 = T_1$ + 20% RDCF of linseed ,$T_4 = T_1$ + 30% RDCF of linseed , $T_5 = T_1$+ 40% RDCF of linseed, $T_6 = T_1$ + 50% RDCF of linseed and $T_7 = T_1$ + 60% RDCF of linseed

On an average of 0.55 to 1.17 tha. $^{-1}$ weight of linseed was obtained from the different inorganic fertilizer packages (Table 3). Significantly highest yield (1.17 tha. $^{-1}$) of coriander was obtained from the T_6 (100 T_1 + 50% RDCF of linseed) treatment. The lowest yield of linseed (0.55 tha. $^{-1}$) was obtained from T_1 (100% RDCF of groundnut+ 0% RDCF of linseed) treatment.

Groundnut equivalent yield (GEY) was calculated and it was observed that GEY was increased with the increasing doses of fertilizers (Table 3). The highest groundnut equivalent yield (GEY)(2.8 tha. $^{-1}$) was obtained from T_6 (T_1+ 50% RDCF of linseed) treatment which was followed by T_5 (T_1+ 40% RDCF of linseed) treatment (2.70 tha. $^{-1}$)and the lowest GEY (1.30 tha. $^{-1}$) from T_1 (100% RDCF of groundnut + 0% RDCF of linseed) treatment. Considering all the treatment combinations, the productivity was increased with increasing doses of fertilizers except T_7 (T_1+ 60% RDCF of linseed) treatment.

Cost and return analysis

Cost and return analysis of intercropping groundnut with linseed was shown in (Table 3). Considering all the treatment combinations, the net return was increased with increasing doses of fertilizers. The highest net return (163735 Tk ha^{-1}) was obtained from T_6 = T_1 + 50% RDCF of linseedtreatment which was followed by T_5 = T_1 + 50% RDCF of linseedtreatment (147705 Tk ha^{-1}). But the highestBCR (2.31) was obtained from T_6 = T_1 + 50% RDCF of linseedtreatment which was followed by T_5 = T_1 + 40% RDCF of linseed treatment (2.20) and the lowest net return (13800 Tkha^{-1}) from T_1 = 100% RDCF of groundnut+ 0% RDCF of linseed treatment. Although the highest yield (2.80 tha^{-1}) was obtained from T_6 (T_1 + 50% RDCF of linseed) treatment, BCR was higher than T_7 (T_1 + 60% RDCF of linseed) treatment due to higher cost of inorganic fertilizers.

Table 3. Cost and return analysis of groundnut with linseed intercropping system as influenced by different treantment combinations 2021-2022

Treatments	Yield (tha^{-1})		Groundnut equivalent yield ($tha.^{-1}$)	Gross return	Total variable cost	Net return	Benefit cost ratio (BCR)
	Groundnut	linseed		Tk ha^{-1}			
T_1	0.81	0.55	1.30	130500	116700	13800	1.11
T_2	1.15	0.64	1.72	172600	118260	54340	1.45
T_3	1.20	0.66	1.79	179400	119815	59585	1.49
T_4	1.37	0.91	2.18	218900	121405	97495	1.80
T_5	1.78	1.03	2.70	270700	122995	147705	2.20
T_6	1.83	1.17	2.8	288300	124565	163735	2.31
T_7	1.49	0.82	2.22	222800	126140	96660	1.76

Input and output price per Kg : Urea = 8.3Tk. 16, TSP = Tk. 24, MoP = Tk. 15, Gypsum = Tk. 12, Zinc sulphate = Tk. 150, Boric acid = Tk. 220 Groundnut selling price = Tk.100 and linseed selling price = Tk. 90.

Conclusion

Considering the results of this year, the T_6 (T_1+ 50% RDCF of linseed) treatment was the most profitable compared to other fertilizer packages in groundnut- linseed intercropping system. This is the 1st year study, the experiment should be repeated to the next year for conformation of the result.

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DEVELOPMENT OF FERTILIZER RECOMMENDATION FOR KNOLKHOL MAIZE INTERCROPPING SYSTEM

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Abstract

An experiment was conducted at Central Research Farm, BARI, Gazipur (AEZ 28) during Rabi season of 2021-22 to develop a fertilizer recommendation for maize with knolkhol intercropping system. Seven treatment combinations viz. T_1 (100% RDCF of Maize + 0% RDCF of Knolkhol), T_2 (100% RDCF of Maize + 10% RDCF of Knolkhol), T_3 (100% RDCF of Maize + 20% RDCF of Knolkhol), T_4 (100% RDCF of Maize + 30% RDCF of Knolkhol), T_5 (100% RDCF of Maize + 40% RDCF of Knolkhol), T_6 (100% RDCF of Maize + 50% RDCF of Knolkhol) and T_7 (100% RDCF of Maize + 60% RDCF of Knolkhol) were tested. The experiment was laid out in randomized complete block design with 3 replications. Both maize and knolkhol significantly influenced by different treatment combinations. Significantly the highest yield of maize (8.86 t ha^{-1}) and knolkhol (32.17 t ha^{-1}) were obtained from T_7 treatment (100% RDCF of Maize +60% RDCF of Knolkhol) which was statistically similar with T_6 treatment (100% RDCF of Maize +50% RDCF of Knolkhol). Maize equivalent yield progressively increases with the increase of inorganic fertilizers. The results showed that T_7 provided the highest MEY (30.30 t ha^{-1}) followed by T_6 (30.13 t ha^{-1}). The highest BCR (3.87) were obtained from T_6 treatment (100% RDCF of maize +50% RDCF of knolkhol) whereas the lowest BCR (3.16) were observed in T_1 treatment (100% RDCF of maize + 0% RDCF of knolkhol). Though T_7 treatment gave higher yield over all the treatments yet it showed lower BCR compared to T_6 treatment due to higher cost involvement for inorganic fertilizer.

Introduction

Multiple cropping is defined as the intensification of cropping in time and space leading to growing two or more crops on the same field in a year (Andrews 1976, Joshi 2007, Degla et al., 2016).Recently intercropping has been recognized as potentially beneficial system of crop production and evidence suggests that intercropping can provide substantial yield advantage compared to sole cropping (Singh et al., 1992). These advantages may be especially important because they are achieved not by means of costly inputs but by the simple expedient of growing crops together (Willey, 1979). Maize is the top yielder cereal crop requires high amount of fertilizer, particularly nitrogenous, which is one of the problems for marginal farmers of Bangladesh.

Maize is a tall crop plant. Between the maize rows, short stature vegetables and spices crops can easily grown. Knolkholr is one of the important vegetable crops which can be grown in between maize rows. Intercropping of maize (hybrid) with knolkhol was found suitable under different combinations but the nutrient requirement information about intercropping system is very scanty. To increase the yield as well as maintain/improve the soil fertility it is felt necessary to use an integrated approach an integrated nutrient management system (INM)i.e. combination of organic and inorganic fertilizers. Thus, this experiment was carried at Gazipur with the objective to develope a fertilizer recommendation of mazie with knolkhol intercropping system.

Materials and Methods

An experiment was conducted on BARI Central Research Station, Gazipur during rabi season of 2021-2022. The experiment confined with intercropping where maize was sown as main crop and knolkhol was transplanted as compinion crop. The variety for Maize was BARI Hybrid Maize-9 and for knolkhol was Rapid. The initial soil samples at a depth of 0-15 cm from the experimental fields were collected and analyzed following standard methods (Table 1).

The experiment was laid out in a randomized complete block design with seven treatments replicated three times. The unit plot size was 4.0 m × 3.0 m. Maize was sown 60 cm line to line and 20 cm plant to plant. Equal sized healthy thirty days old seedlings of knolkhol were transplanted on

13 December, 2021. After 30 days of knolkhol seedlings transplanting, maize was sown in between knolkhol rows.

Table 1. Chemical properties of initial soil of experimental field during 2021-2022

Location	pH	OM	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
		(%)	meq $100g^{-1}$			(%)	µg g^{-1}						
Gazipur	5.7	1.39	30	1.6	0.14	0.095	12	12	0.19	8	69	7	1.0
Critical level	-	-	2.0	0.5	0.12	0.12	7	10	0.20	0.2	4	1	0.6

The experiment was set up with seven treatments viz. T_1 (100% RDCF of Maize + 0% RDCF of Knolkhol), T_2 (100% RDCF of Maize + 10% RDCF of Knolkhol), T_3 (100% RDCF of Maize + 20% RDCF of Knolkhol), T_4 (100% RDCF of Maize + 30% RDCF of Knolkhol), T_5 (100% RDCF of Maize + 40% RDCF of Knolkhol), T_6 (100% RDCF of Maize + 50% RDCF of Knolkhol) and T_7 (100% RDCF of Maize + 60% RDCF of Knolkhol). Recommended dose of chemical fertilizer (RDCF) for Maize = $N_{255}P_{50}K_{120}S_{40}Mg_{10}Zn_4B_{1.5}$ kg ha^{-1} and for Knolkhol = $N_{90}P_{25}K_{45}S_{15}Zn_1B_1$ kg ha^{-1} + 5 t CD ha^{-1}. Urea, TSP, MoP, gypsum and boric acid were used as a source of N, P, K, S and B, respectively. 1/6th N and half of all fertilizers will be applied as basal dose during knolkhol planting. Another 1/6th N and half of all fertilizers will be applied as basal dose during maize sowing. Rest of urea will be applied at 45 and 75 DAT as band placement in knolkhol and maize rows. All the intercultural operations such as irrigation, weeding, insect control etc. were done as and when necessary.

Harvesting of knolkhol was done on 08 Februray and maize was done on 22 May 2022.Ten plants from each plot were tagged at random to take records on different agronomic parameters of maize and knolkhol. Data on growth, yield and yield contributing parameters were recorded and statistically analyzed with the help of statistical package CropStat and mean separation was tested by Least Significance Difference (LSD) (Steel and Torrie, 1960). Post harvest soil and plant samples were also collected and analyzed. Maize Equivalent Yield (MEY) was calculated after Bandyopadhyay, 1984:

$$\text{Maize Equivalent Yield (kg/ha)} = \frac{\text{Yield of knolkhol(kg/ha) x Price of knolkhol (Tk./kg)}}{\text{Price of maize (Tk./kg)}}$$

Methods of chemical analyses

Soil pH was measured by a combined glass calomel electrode (Jakson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Ca and Mg were determined by NH_4OAc extraction method. K, Cu, Fe, Mn and Zn were determined by DTPAextraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method (Acid soils). S was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric method with $BaCl_2$.

Results and Discussion

Maize

The effect of chemical fertilizers on the yield and yield parameters of maize are summarized in Table 2. Grain yield and yield attributes like plant height, cob length, cob diameter, grains cob^{-1} and 1000 grain weight were significantly influenced by different nutrient packages. Response of ear height of maize to different chemical fertilizers was insignificant. Ear height of maize ranged from 118 to 139 cm. Plant height of maize significantly influenced by fertlizer treatments. The highest plant height (241 cm) was obtained from T_7 treatment (100% RDCF of Maize + 60% RDCF of Knolkhol) whereas the lowest plant height (212 cm) was obtained from T_1 treatment (100% RDCF of Maize + 0% RDCF of Knolkhol).

Cob length and cob diameter are important yield parameter of maize. Both of cob length and cob diameter are progressively increase with the increase of fertilizers. The highest cob length (21.2 cm) and cob diameter (4.69 cm) was obtained from T_7 treatment (100% RDCF of Maize + 60% RDCF of Knolkhol) while the lowest cob length (17.1 cm) and cob diameter (4.00 cm) was recorded in T_1 treatment (100% RDCF of Maize + 0% RDCF of Knolkhol).

No of grains cob^{-1} and 1000-grain weight are important yield parameter of maize. Both of number of grains cob^{-1} and 1000-grain weight are progressively increase with the increase of fertilizers. The highest grains cob^{-1} (516) and highest 1000-grain weight (409 g) was obtained from T_7 treatment (100% RDCF of Maize + 60% RDCF of Knolkhol).The lowest grains cob^{-1} (384) and lowest 1000-grain weight (322g) was recorded in T_1 treatment (100% RDCF of Maize + 0% RDCF of Knolkhol).

Table 2. Effect of different treatments on the yield and yield attributes of maize during 2021-2022

Treat ment	Plant height	Ear height	Cob length	Cob diameter	Grain cob^{-1}	1000-grain weight	Stover yield	Grain yield
	(cm)				(no.)	(g)	(t ha^{-1})	
T_1	212b	118	17.1c	4.00c	384e	322e	10.37e	7.02d
T_2	221ab	124	18.0bc	4.16bc	413de	336de	11.10d	7.48cd
T_3	226ab	126	18.9abc	4.28abc	443cd	360bcd	11.68c	7.88bc
T_4	230ab	128	19.6ab	4.32abc	465bc	370bcd	12.16bc	8.19abc
T_5	235ab	134	20.3ab	4.43abc	485abc	381abc	12.23bc	8.54ab
T_6	238a	137	20.9a	4.56ab	511ab	393ab	12.87ab	8.80a
T_7	241a	139	21.2a	4.69a	516a	409a	13.12a	8.86a
CV (%)	7.61	8.13	6.18	5.65	6.84	6.38	6.29	8.10

Means followed by same letter (s) do not differ significantly at 5% level of significance

T_1 (100% RDCF of Maize + 0% RDCF of Knolkhol), T_2 (100% RDCF of Maize + 10% RDCF of Knolkhol), T_3 (100% RDCF of Maize + 20% RDCF of Knolkhol), T_4 (100% RDCF of Maize + 30% RDCF of Knolkhol), T_5 (100% RDCF of Maize + 40% RDCF of Knolkhol), T_6 (100% RDCF of Maize + 50% RDCF of Knolkhol) and T_7 (100% RDCF of Maize + 60% RDCF of Knolkhol).

Stover yield of maize significantly influenced by different inorganic fertilizers. Significantly the highest stover yield of 13.12 t ha^{-1} was recorded in T_7 treatment (100% RDCF of Maize + 60% RDCF of Knolkhol) whereas the lowest stover yield of 10.37 t ha^{-1} was recorded in T_1 treatment (100% RDCF of Maize + 0% RDCF of Knolkhol).

Yield of maize progressively increases with the increase of inorganic fertilizers. Like stover yield, the highest grain yield of 8.86 t ha^{-1} was recorded in T_7 treatment (100% RDCF of Maize + 60% RDCF of Knolkhol) which was statistically similar (8.80 t ha^{-1}) with T_6 (100% RDCF of Maize + 50% RDCF of Knolkhol) treatment. The lowest grain yield (7.02 t ha^{-1}) was observed from T_1 treatment (100% RDCF of Maize + 0% RDCF of Knolkhol).

Knolkhol

The effect of chemical fertilizers on the yield and yield parameters of knolkhol are summarized in Table 3. Knob yield and yield attributes like plant height, number of leaves plant^{-1}, circumference and knob weight plant^{-1} of knolkhol were significantly influenced by different nutrient packages in this study. Significantly the highest plant height of 33.1 cm was recordrd in T_7 treatment **(**100% RDCF of Maize + 60% RDCF of knolkhol) whereas the lowest plant height (19.5 cm) was obtained from T_1 treatment **(**100% RDCF of Maize + 0% RDCF of Knolkhol).

No.of leaves plant^{-1} positively affected by different fertilizer management packages. Significantly the maxium number of leaves plant^{-1} (14.0) was noted in T_7 treatment and the lowest number of leaves plant^{-1} (8.3) was recorded in T_1 treatment.

Circumference of knolkhol progressively increases with the increase of inorganic fertilizers. Significantly the highest knob circumference (36.9 cm) was obtained from T_7 treatment which was statistically similar with all other treatment except T_1 treatment.The lowest circumference (30.3 cm) was obtained from T_1 treatment.

Table 3. Yield components of knolkhol as influenced by different fertilizer package during rabi season of 2021-2022

Treatment	Plant height (cm)	No. of leaves plant^{-1}	Knob Circumference (cm)	Knob weight plant^{-1} (kg)	Knob yield (t ha^{-1})
T_1	19.5c	8.3d	30.3b	0.60f	24.43e
T_2	22.9bc	8.9cd	32.2ab	0.63ef	26.45d
T_3	25.4bc	10.4bcd	31.5ab	0.67de	26.62cd
T_4	27.6ab	12.0abc	33.5ab	0.69cd	28.46bc
T_5	29.6ab	12.9ab	34.8ab	0.73bc	30.63ab
T_6	32.5a	13.7a	36.4ab	0.77ab	32.00a
T_7	33.1a	14.0a	36.9a	0.79a	32.17a
CV (%)	7.32	12.08	7.62	4.97	8.56

Means followed by same letter (s) do not differ significantly at 5% level of significance
T_1 (100% RDCF of Maize + 0% RDCF of Knolkhol), T_2 (100% RDCF of Maize + 10% RDCF of Knolkhol), T_3 (100% RDCF of Maize + 20% RDCF of Knolkhol), T_4 (100% RDCF of Maize + 30% RDCF of Knolkhol), T_5 (100% RDCF of Maize + 40% RDCF of Knolkhol), T_6 (100% RDCF of Maize + 50% RDCF of Knolkhol) and T_7 (100% RDCF of Maize + 60% RDCF of Knolkhol).

Knob weight plant^{-1} is the main economic part of knolkhol. Knob weight plant^{-1} progressively increases with the increase of inorganic fertilizers.The maximum knob weight plant^{-1}(0.79 kg) was obtained from T_7 treatment which was statistically similar with T_6 treatment (0.77 kg plant^{-1}) whereas the minimum knob weight plant^{-1} (0.60 kg) was obtained from T_1 treatment.

Knob yield of knolkhol progressively increases with the increase of inorganic fertilizers. The highest knob yield (32.58 t ha^{-1}) were recorded in T_7 treatment **(**100% RDCF of Maize + 60% RDCF of Knolkhol) which was statistically similar with T_6 **(**100% RDCF of Maize + 50% RDCF of Knolkhol) treatment (32.00 t ha^{-1}) and superior to all other treatments. The lowest knob yield of knolkhol (24.43 t ha^{-1}) was obtained from T_1 treatment **(**100% RDCF of Maize + 0% RDCF of knolkhol).

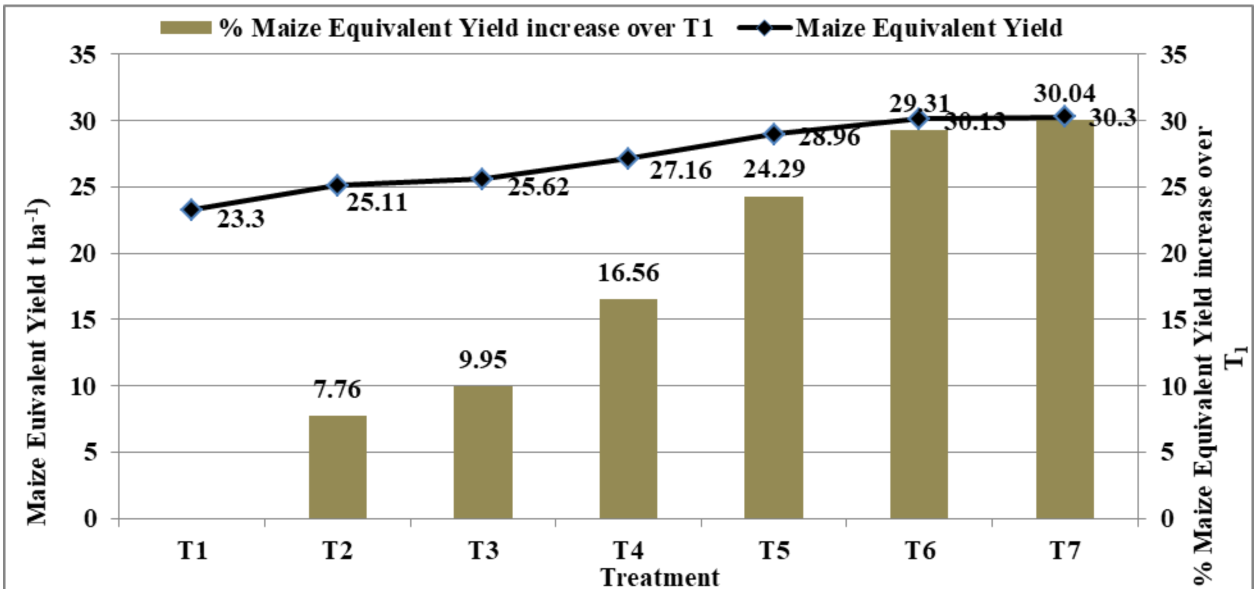

Fig.1. MEY & % MEY increase over T_1 in different treatment combinations

Maize Equivalent Yield (MEY)

After calculation of maize equivalent yield it was observed that MEY progressively increases with the increase of inorganic fertilizers. The result showed that T_7 provided the highest MEY (30.30 t ha^{-1}) that was 30.04% higher over T_1 (Fig. 1). The treatment T_6 also gave higher MEY (30.13 t ha^{-1}) followed by T_5, T_4, T_3 and T_2.

Cost and return analysis

Cost and return of maize with knolkhol intercropping have been described in the Table 4. Among the treatments, the highest BCR (3.87) was obtained from T_6 treatment (100% RDCF of maize +50% RDCF of knolkhol) whereas the lowest BCR (3.16) was observed in T_1 treatment (100% RDCF of maize + 0% RDCF of knolkhol). Though T_7 treatment gave higher yield over all the treatments yet it showed lower BCR compared to T_6 treatment due to higher cost involvement for inorganic fertilizer.

Table 4. Cost and return analysis of maize with knolkhol intercropping system as influenced by different fertilizer treatment combinations at Gazipur during Rabi season of 2021-22

Treatments	Yield (t ha^{-1})		Maize equivalent yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Total cost (Tk. ha^{-1})	Net return (Tk. ha^{-1})	Benefit cost ratio (BCR)
	Maize	Knolkhol					
T_1	7.02	24.43	23.30	419400	132616	286784	3.16
T_2	7.48	26.45	25.11	451980	134180	317800	3.36
T_3	7.88	26.62	25.62	461160	135743	325417	3.39
T_4	8.19	28.46	27.16	488880	137307	351573	3.56
T_5	8.54	30.63	28.96	521128	138870	382258	3.75
T_6	8.80	32.00	30.13	542340	140134	402206	3.87
T_7	8.86	32.17	30.30	545400	142997	402403	3.81

Input and output price per Kg: Urea = Tk. 16, TSP = Tk. 22, MoP = Tk. 15, Gypsum = Tk. 12, Zinc sulphate =Tk.150, Boric acid Tk. = Tk.220, Maize seed =Tk.350, Knolkhol seed =Tk.1000, Maize selling price = Tk. 18 and Knolkhol selling price = Tk. 12

Conclusion

From the present study, it may be concluded that treatment package consists of 100% RDCF of maize along with 50% RDCF of knolkhol is most profitable for maize with knolkhol intercropping system in the study area (AEZ-28) and its extrapolation areas as well.This is the results of 1st year study. So, further investigation will be required for the confirmation of the findings.

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INTEGRATED NUTRIENT MANAGEMENT OF YEAR ROUND FOUR VINE CROPS MODAL FOR A INTENSIVE ROOFTOP GARDEN

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Abstract

The study was conducted in Gazipur (rooftop of Soil Science Division) during the year of 2021-2022. The experiment activities includeIntegrated Nutrient Management of year round 4 vine crops modal for a intensive rooftop garden based research which have 5 treatments viz. T_1 = 100% STB (Soil Test Based Fertilization), T_2 = 80% of T_1 + (1:3) Kitchen waste compost and soil, T_3= 80% of T_1 + (1:3) Cowdung and soil, T_4= 80% of T_1 + (1:3) Vermicompost and soil& T_5 = absolute control. Prior to setting the experiments initial soil samples as well as organic fertilizers were analyzed and nutrient statuses were determined. Vegetables (Bottle gourd) performed better in T_4 treatment (80% of T_1 + (1:3) Vermicompost and soil) compared to others in the experiments related to integrated nutrient management for growth and yield of Bottle gourd on rooftop garden. The lowest yield was recorded from the control treatment.

Introduction

Rooftop gardening is going to popular in urban areas of Bangladesh. Bangladesh is one of the main victims of climate change. A country needs 25% of its land to be occupied by forests to maintain its ecological balance, but here the percentage is less than 8% (BBS, 2015). Due to the urbanization, our cultivable lands decrease day by day. As there is limited scope for horizontal expansion of agriculture, vertical expansion is one of the major ways to increase crop productivity. Rooftop gardening is one of the potential areas for vertical expansion. As it is estimated that, there are about 2 lac house buildings in Dhaka city. A rooftop garden not only can be a source of agricultural production but also can be able to fix CO_2 and some other gases causing greenhouse effect (BARI, 2019). So, there are many scopes for rooftop gardening. Organic fertilizers are utilized globally to protect the soils against deterioration and food pollution. Organic nutrients increase soil enzyme activity, available nitrates, carbon to total organic carbon ratio and metabolic quotients resulting in enhanced soil fertility (Okwuagwu et al., 2003). Organic fertilizers improve soil fertility by modifying soil structure, pH, biophysical conditions and availability of essential nutrients (Atiyeh et al., 2002). Though some interested people are producing vegetables, fruits and flowers on their rooftop but research information on nutrient management for a rooftop garden is not available. Moreover, extensive literature review showed very little or no information regarding fertilizer trials on rooftop garden. Therefore, there is a possibility to increase the yield of a rooftop garden through integrated nutrient management approach. Proper nutrient management can produce maximum yield of a rooftop garden. Objectives of the study was to develop fertilizer recommendation for year round 4 vine crops modal for an intensive rooftop garden.

Material and Methods

Experiment was conducted at the rooftop of Soil Science Division, BARI, Gazipur during 2021-2022. The initial soil sample, vermicompost, compost and cowdungwere collected before establishing the experiment and were analyzed in the laboratory following standard methods. Integrated nutrient management (Used organic and inorganic fertilizers) for vegetable production in the rooftop garden was laid out in a completely randomized design with three replications. For integrated nutrient management (Used five different treatments viz. T_1 = 100% STB (Soil Test Based Fertilization), T_2 = 80% of T1 + (1:3) Kitchen waste and soil, T_3 = 80% of T1 + (1:3) Cowdung and soil, T_4 = 80% of T1 + (1:3) Vermicompost and soil & T_5 = absolute controlwereused. Half dram was used for 4 vine crops (Lau (BARI Lau-4), Misty Kumra (BARI Misty Kumra-2), Korola (BARI Korola-1) and Chal Kumra (BARI Chal Kumra-1)modal. Frist crop bottle gourd was transplanted in November 2021 and 2nd crop is now in fruiting stage.Full of organic and $^1/_2$ of inorganic fertilizer was applied at the time of final soil preparation. The remaining half inorganic fertilizer was applied as four (15, 30, 45 and 60 DAT) top dress. Irrigations and other intercultural operations were done as when required.

Table 1. Chemical properties of soil (Initial) used in the rooftop experiment

Soil properties	pH	OM	Total N	K	Ca	Mg	P	S	Zn	B	Cu	Fe	Mn
		(%)		meq 100 g^{-1} soil						µg g^{-1} soil			
Analytical value	6.9	1.07	0.06	0.16	4.7	2.3	15.0	16	1.2	0.21	5.2	34	2.6
Critical level	-	-	-	0.12	2.0	0.5	7	10	0.6	0.2	0.2	4.0	1.0

Table 2. Nutrient status of vermicompost, compost and cowdung used in the rooftop experiment

Name of the manure	pH	OC	Ca	Mg	K	Total N	P	S	Zn	B	Pb	Cd	As
						%						µg g^{-1}	
Compost	7.2	15.2	1.43	2.15	1.18	1.21	0.77	0.51	0.12	0.012	2.88	2.12	1.71
Cowdung	7.7	14.6	2.19	0.46	0.67	1.12	0.56	0.37	0.11	0.011	3.11	2.80	1.25
Vermicompost	7.4	16.8	2.13	2.52	1.92	1.62	1.22	0.87	0.15	0.014	2.60	2.21	1.17

Moisture content of Compost = 12.14 %, Cowdung = 12.43 % and Vermicompost = 11.92 %

Results and discassion

Table-3. Effect of different organic and inorganicfertilizer doses on the growth and yield of 1st crop Bottle gourd (Variety: BARI Bottlegourd-4) at Rooftop of Soil Science Division, BARI, Gazipur

Treatment	Length of main vine(m)	No. of fruits $plant^{-1}$	Individual fruit wt. (kg)	Fruit yield $plant^{-1}$ (kg)
T_1= 100% STB (Soil Test Based Fertilization)	3.7a	5.5c	1.7b	9.8c
T_2= 80% of T_1 + (1:3) Kitchen waste and soil	4.2a	8.7ab	2.1a	17.5b
T_3= 80% of T_1 + (1:3) Cowdung and soil	4.1a	7.4b	2.0a	14.9b
T_4= 80% of T_1 + (1:3) Vermicompost and soil	4.3a	10.2a	2.2a	22.6a
T_5= Absolute control	2.8b	3.5d	1.2c	4.2d
CV (%)	8.03	13.3	6.21	10.42

Integrated nutrient management for growth and yield of Bottle gourd on rooftop gardenis presented in Table 3. The highest length of main vine (4.3 m) was observed in T_4treatment which was statistically similar with T_1, $T_2$and T_3 treatment whereas the lowest length of main vine(2.8 m) was observed in T_5 (control) treatment. The maximum number of fruits $plant^{-1}$(10.2) was observed in T_4 treatment whereas the minimum number of fruits $plant^{-1}$(3.5) was observed in T_5 (control) treatment. The maximum individual fruit wt. (2.2 kg) was observed in T_4treatment whereas the minimum individual fruit wt. (1.2 kg) was observed in T_5 (control) treatment. The maximum yield $plant^{-1}$(22.6 kg) was observed in T_4treatment followed by T_2 treatment whereas the minimum yield $plant^{-1}$(4.2 kg) was observed in T_5 (control) treatment.

Conclusion

The overall results indicated that, Bottle gourd performed better in 80% of T_1 + (1:3) Vermicompost and soil compared to others in terms of growth and yieldon the rooftop garden. The lowest growth and yield performance was obtained from the control treatment.

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STUDY ON SOIL PROPERTIES VARIATION THROUGH THE SOIL PROFILE IN SALINE AREAS OF SEVEN UPAZILAS OF SATKHIRA DISTRICT

O. A. FAKIR, R. SEN, J. ALAM AND H.M. NASER

Abstract

The spatial variability of salt accumulation through the soil profile was studied at seven locations covering seven upazila of Satkhira: Satkhira Sadar, Kolaroa, Assasuni, Tala, Kaligonj, Debhata and Shymnagar. Three locations were randomly selected from each upazila. From each location, soil samples were collected from five soil depths at D_1 = 0-7 cm, D_2 = 8-15 cm, D_3 =16-23 cm, D_4 =24-31 cm and D_5 =32-39 cm. The highest value of EC was found to be 7.92 dSm^{-1} in Shymnagar at 16-23 cm Soil depth and the lowest 0.42d dSm^{-1} in Tala upazila for the same soil depth. In case of soil depth 24-31 cm and 32-39 cm, the highest value of EC was found to be 8.74 and 9.82 dSm^{-1}respectively in Shymnagar while the lowest soil salinity for the same depths were observed in Tala upazila. All the soil depth mean pH value was neutral to slightly alkaline except in Debhata which was strongly alkaline. Most of the soils under study had very high to medium organic matter content that decreased significantly with increasing depths in various land uses. The highest value of sulphur was found 87.80 ppm in Satkhira Sadar at 0-7 cm soil depth and the lowest value was 37.09 ppm in Kolaroa at 24-31 cm soil depth. The results clearly reveal that the top soil of Saline areas is very much sensitive to salt stress and for studied chemical properties.

Introduction

The coastal region of Bangladesh occupies 20% area of the country. A number of environmental issues and problems are hindering the development of coastal livelihood. Salinity is one of the most important issue of them, which is expected to aggravate by climate change and sea level rise and eventually affect crop production (Hossain et al., 2015). The Satkhira region is recognized as an agro ecologically disadvantaged region. Soil salinity, water salinity and water-logging are major constraints for higher crop productivity in the south coastal region like Satkhira. In addition, climate change could result in increased soil surface salinity due to long periods of drought in winter season. A recent study indicates that the salinity affected area has increased from 8,330 km2 in 1973 to 10,560 km2 in 2009 (Soil Resource Development Institute (SRDI, 2010) in Bangladesh.

Saline soils contain sufficient soluble salts to suppress plant growth through a series of interacting factors such as osmotic potential effect, ion toxicity and antagonism, which induce nutrient imbalances (Neumann, 1995). Therefore, changes in salinity and sodicity affect soil physical and chemical properties, which subsequently alter nutrient cycles and decomposition processes (Wong et al. 2005). Apart from the effect on water availability to plants and the possible toxic effect of some constituents, excess neutral soluble salts in soils may also interfere with the normal nutrition of crops in saline soils. At a given level of salinity, growth and yield of crops are likely to be depressed more when nutrition is disturbed than when it is normal. At moderate salt concentrations in the soil solution, plants generally try to exclude unwanted ions, as far as possible, and promote the uptake of nutrients. With increasing salt concentration, the uptake of sodium and chloride ions increases sharply. This luxury consumption of ions is essential for the plants to compensate for the increased outside osmotic pressure but is responsible for growth retardation. Excessive uptake of certain ions, in turn, often results in reduced uptake of some essential plant nutrients causing nutrient imbalances and deficiencies. Thus, although the available status of a nutrient in a soil might not be in a deficient range per se, its application might compensate for the decreased uptake by plants resulting from the antagonistic effect of excess uptake of certain ions. Results of several studies tend to show that deficiencies of the elements K and Ca appear to play an important role in the observed growth depressions in many saline soils (Finck, 1977). Land degradation due to soil salinization has detrimental impacts on vegetation, crops, and human livelihoods, leading to a need for a methodologically consistent analysis of the variability of different aspects of salt-affected soils. However, previous studies on the soil salinity issue have been primarily spatial and localized, leaving the large-scale spatiotemporal variations of soil salinity widely ignored. Given the high dynamism in soil salinization processes, updated spatial and temporal information on the extent of salt-affected soils is indispensable for devising appropriate sustainable action programs for managing land and soil resources. This information can be also valuable for enhancing our understanding of terrestrial carbon dynamics, food security and agricultural modelling, climate change impacts, water resources and irrigation management, and efficiency of organic/inorganic reclamation practices.

For research planning and better crop production, the basic data on chemical properties of saline and non-saline soil are very much important. These characteristics of an area are very much important to determine the types of crop to be grown. However, the level of salt accumulation in different depths of soil for all upazillas of Satkhira is not adequately investigated. Through this research, the spatial variability of salt accumulation through the soil profile has been evaluated.

Materials and Methods

The study was conducted at seven different upazila of Satkhira district, Bangladesh. The experimental areas belonged to the agro ecological zone of AEZ-11 and AEZ-13 (Ganges Tidal Flood Plain). The soil samples were collected from seven locations covering seven upazila of Satkhira: Satkhira Sadar, Kolaroa, Assasuni, Tala, Kaligonj, Debhata and Shymnagar. Three locations were randomly selected from each upazila. From each location soil samples were collected from five soil depths at D_1 = 0-7 cm, D_2 = 8-15 cm, D_3 =16-23 cm, D_4 =24-31 cm and D_5 =32-39 cm. Thus total 105 soil samples (7 upazila × 3 locations per upazila × 5 depths per location) were collected in the study. Geographic positioning system (GPS) reading of the sampling location is given in Table 1. Soil samples were collected from each location by means of an auger from 10^{th} to 15^{th} December, 2021. The collected soil samples were carried to the laboratory, air dried, broken down large macro aggregates, ground and passed through a 2-mm sieve to remove weeds and stubbles from the soil. Physical and chemical analysis of the soil sample was done in the laboratory of the Division of Soil Science, Bangladesh Agricultural Research Institute, Gazipur. Chemical analysis was done for electrical conductivity, pH, and potassium and sodium contents following standard methods. Soil electrical conductivity (EC) was measured in 1:5 soil- water suspensions and multiplied by five and then match with tabulated value as described by Soil Resource Development Institute, Bangladesh (Petersen, 2002). The recorded data on various soil parameters were statistically analyzed using 'Analysis of variance technique' with the help of STAR (Statistical Tool for Agricultural Research; 2013) computer program developed by International Rice Research Institute and the mean difference were adjusted by Duncan's Multiple Range Test at 5% level of significance. For statistical interpretation, both soil depth effect and spatial effect/variation in upazilas were determined. To determine the soil depth effect each of five samples collected from respective soil depth of three different locations of same village were considered as replication. Accordingly for calculation of spatial effect (upazila effect) 15 soil samples collected from each upazila were considered as replication.

Table 1. Geographic positioning system (GPS) reading of the sampling locations

Upazila	Location-1		Location-2		Location-3	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
Assasuni	22°36'47.1"N	89°09'28.0"E	22°36'47.2"N	89°09'28.4"E	22°36'46.4"N	89°09'27.8"E
Debhata	22°38'19.2"N	88°59'30.4"E	22°38'19.9"N	88°59'29.6"E	22°38'19.4"N	88°59'30.9"E
Kolaroa	22°50'13.7"N	89°05'58.5"E	22°50'13.9"N	89°05'59.2"E	22°50'14.0"N	89°05'57.6"E
Kaligonj	22°28'53.6"N	89°00'55.5"E	22°28'53.7"N	89°00'55.9"E	22°28'54.1"N	89°00'55.2"E
Satkhira Sadar	22°37'54.7"N	88°56'43.5"E	22°37'56.6"N	88°56'43.2"E	22°37'54.8"N	88°56'43.6"E
Shymnagar	22°19'43.9"N	89°05'40.1"E	22°19'43.9"N	89°05'40.2"E	22°19'44.1"N	89°05'41.2"E
Tala	22°46'38.1"N	89°07'02.0"E	22°46'37.9"N	89°07'01.7"E	22°46'39.1"N	89°07'02.1"E

Results and Discussion

Electrical conductivity of Soil (dS/m)

Electrical conductivity (EC) of soil was significantly influenced by soil depth. In the 0-7 cm soil depth, the EC value was 6.65 dS/m (Table 2). The EC value was the lowest 0.69 dS/m in Tala for the same soil depth. The highest EC value (6.99 dS/m) was recorded for 8-15cm soil depth in Satkhira sadar while the lowest soil salinity for the same depth was observed in Tala.

Table 2. Soil EC (dS/m) as influenced by soil depths and locations

Soil depth	Upazila						
	Assasuni	Debhata	Kolaroa	Kaligonj	Satkhira sadar	Shymnagar	Tala
D_1 (0-7 cm)	1.82a	1.21a	0.71a	1.60c	6.96c	6.65d	0.69a
D_2 (8-15 cm)	1.03c	1.21a	0.61a	1.08d	6.99bc	6.10e	0.49c
D_3(16-23 cm)	1.14b	0.98b	0.70a	1.49c	6.73d	7.92c	0.42d
D_4(24-31 cm)	0.94d	0.83c	0.49a	1.97b	7.19ab	8.74b	0.50bc
D_5(32-39 cm)	0.65e	0.87c	0.60a	2.71a	7.26a	9.82a	0.55b
CV(%)	2.64	1.80	14.25	3.14	1.07	0.90	3.73

Interpretation of EC value: Non saline 0-2, Slightly saline 2-4, Moderately saline 4-8, Saline 8-12, Highly saline >12 dS/m

The highest value of EC was found to be 7.92 dSm^{-1} in Shymnagar at 16-23 cm Soil depth and the lowest 0.42d dSm^{-1} in Tala upazila for the same soil depth. In case of soil depth 24-31 cm and 32-39 cm, the highest value of EC was found to be 8.74 and 9.82 dSm^{-1}respectively in Shymnagar while the lowest soil salinity for the same depths were observed in Tala upazila. Considering soil depth, Out of 105 samples, only 60 was non-saline (57.15% of total samples) and 45 was moderately saline (42.85% of total samples) during the beginning of Rabi season. These results are consistent with Ceuppens et al. (1997) on paddy fields in the Senegal River delta showing that soil salinity progressively decreased with the increase in soil depth of rice cropping. However, some exception was found in case of Sadar and Shymnagar. Over the locations of same Upazila, the soils at Satkhira sadar and Shymnagar with all sorts of soil depth were moderately saline (4-8 dS/m) (Table 2) except one at 32-39 cm in Shymanagr. However, there was found a big variation among the samples.

The variation of EC value was statistically significant by different upazila (Table 3). Over the upazials, EC value varied from 0.53 to 7.84 dS/m. The lowest was in Tala which was statistically similar with Kolaroa and the highest was in Shymnagar followed by Satkhira Sadar (7.03 dS/m). Although the EC value was statistically similar for Assasuni and Debhata upzila.

Table 3. Upazila-wise chemical properties of soil inSatkhira district during *Rabi* season 2021-2022

Upazila	Chemical properties						
	Soil p^H	Soil EC (ds/m)	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq/100g soil)	Available S (ppm)
Assasuni	7.72bc	1.11d	2.49a	0.15a	25.71d	0.41c	59.84d
Debhata	8.63a	1.02d	2.08b	0.13b	37.28a	0.27e	67.99b
Kolaroa	8.27ab	0.62e	2.14b	0.14ab	30.37b	0.17f	45.03f
Kaligonj	7.22cd	1.77c	1.90c	0.12bc	23.37e	0.20f	63.15c
Satkhira Sadar	8.48ab	7.03b	2.12b	0.12bc	14.95f	0.67b	73.60a
Shymnagar	6.64d	7.84a	1.75d	0.11cd	11.43g	0.83a	67.81b
Tala	8.14ab	0.53e	1.37e	0.10d	29.35c	0.34d	51.19e
CV (%)	4.66	1.91	2.75	5.23	0.82	4.84	0.70

Table 4. Soil pH as influenced by soil depths and locations

Soil depth	Upazila						
	Assasuni	Debhata	Kolaroa	Kaligonj	Satkhira sadar	Shymnagar	Tala
D_1 (0-7 cm)	6.70c	8.20c	8.50a	7.10a	8.15b	6.55a	7.65d
D_2 (8-15 cm)	7.35b	8.35bc	8.15a	7.70a	8.55ab	6.65a	7.80cd
D_3(16-23 cm)	8.05a	8.50b	8.35a	7.95a	8.40ab	6.55a	8.15bc
D_4(24-31 cm)	8.30a	9.05a	8.25a	8.10a	8.50ab	6.65a	8.45ab
D_5(32-39 cm)	8.20a	9.05a	8.10a	8.25a	8.80a	6.80a	8.65a
CV (%)	1.19	1.24	3.56	26.18	1.92	2.13	1.78

Interpretation of pH value:Verystronglyacid<4.5,stronglyacid4.5-5.5,slightlyacid5.6-6.5,neutral6.6-7.3,slightlyalkaline7.4-8.4,strongly alkaline 8.5-9.0

Soil reaction (pH)

Considering soil depth effect, the lowest of 6.70 pH value was found in 0-7 cm soil depth. The pH value gradually increased with the increase of the soil depth. However, the rate of rise was not significant in case of Kolaroa, Kaligonj, Shymnagar. The highest pH value was recorded in Debhata while the lowest value was observed in Shymnagar. All the soil depth mean pH value was neutral to slightly alkaline except in Debhata which was strongly alkaline. Alam (2004) found pH value of saline soils of Bangladesh were 6.25 to 8.07 and 6.44 to 8.34 at 0-15 cm and 15-30 cm soil depth, respectively.

Vertical Distribution of Soil Organic Matter (%)

Most of the soils under study had very high to medium organic matter content that decreased significantly with increasing depths in various land uses (Table 5). The highest Organic Matter was found to be 3.35% in Assasuni at 0-7 cm Soil depth and the lowest 0.38% was observed in Tala upazila at 32-39 cm soil depth.

Table 5. Organic matter (%) as influenced by soil depths and locations

Soil depth	Upazila						
	Assasuni	Debhata	Kolaroa	Kaligonj	Satkhira sadar	Shymnagar	Tala
D_1 (0-7 cm)	3.35a	2.73a	3.03a	2.84a	2.46a	1.85b	2.07a
D_2 (8-15 cm)	3.02b	2.34b	2.65b	1.00d	2.18ab	1.72c	2.07a
D_3(16-23 cm)	2.68c	1.74d	2.30c	1.74c	2.07ab	1.72c	1.71b
D_4(24-31 cm)	2.53d	1.93c	1.46d	1.79c	2.00b	1.40d	0.65c
D_5(32-39 cm)	0.87e	1.65d	1.27d	2.15b	1.89b	2.07a	0.38d
CV (%)	1.20	1.78	5.37	3.80	7.06	0.88	1.48

The variation of organic Matter was statistically significant by different upazila (Table 3). Over the upazials, organic matter value varied from 2.49% to 1.37%. The highest was in Assasuniand the lowest was in Tala, whereas Kolaroa, Satkhira Sadar and Debhata shows the statistically similar value.

Table 6. Total N (%)as influenced by soil depths and locations

Soil depth	Upazila						
	Assasuni	Debhata	Kolaroa	Kaligonj	Satkhira sadar	Shymnagar	Tala
D_1 (0-7 cm)	0.16bc	0.13ab	0.20a	0.17a	0.13a	0.12a	0.15a
D_2 (8-15 cm)	0.20a	0.13ab	0.17b	0.09c	0.13a	0.10b	0.11ab
D_3(16-23 cm)	0.17b	0.11b	0.14c	0.11bc	0.11a	0.10b	0.13a
D_4(24-31 cm)	0.15c	0.12ab	0.10d	0.13b	0.13a	0.09b	0.08bc
D_5(32-39 cm)	0.07d	0.15a	0.09d	0.14ab	0.12a	0.13a	0.06c
CV (%)	4.00	9.30	4.65	11.12	9.16	5.91	12.72

When soil depth effect was considered on upazila basis it was found that the highest N content was found in Assasuni followed by Kolaroa (Table 3). However, the lowest N content was found in Tala followed by Shymnagar.

Total Nitrogen (%) content in soil

Total nitrogen (N) was significantly influenced by both soil depth and upazila (Table 6). The significantly higher total N was found in top soil depth. The depth-wise variation of total N content recorded in Debhata, Tala and Satkhira sadar was insignificant and statistically similar. However, Assasuni, Kaligonj, Shymnagar and Kolaroa upazila showed statistically significant variation for total N content.

Vertical Distribution of Soil Available Phosphorus (ppm)

The available P in soil was influenced remarkably and significantly with different depths under seven upazila of Satkhira (Table 7).The top soil (0-15) of Debhata, Kolaroa, Kaligonj and Tala shows the very high value of available P as per the interpretation of FRG-2018. The lowest value of available P was recorded in Assasuni at 32-39 cm soil depth. Phosphorus status in cultivated soils increased up to 23 cm depth and decreased from 24 cm below.

Table 7. Available P (ppm) as influenced by soil depths and locations

Soil depth	Upazila						
	Assasuni	Debhata	Kolaroa	Kaligonj	Satkhira sadar	Shymnagar	Tala
D_1 (0-7 cm)	41.72a	60.12a	59.19a	49.35a	14.96b	14.89a	40.98a
D_2 (8-15 cm)	23.34d	53.40b	52.82b	38.82b	15.15b	14.87a	40.91a
D_3(16-23 cm)	29.84b	42.01c	9.83d	14.24c	17.93a	10.88b	40.00a
D_4(24-31 cm)	26.62c	17.45d	20.70c	7.70d	12.80d	8.70c	10.81b
D_5(32-39 cm)	7.01e	13.42e	9.30d	6.76d	13.93c	7.80d	14.08c
CV (%)	0.08	0.13	3.24	2.66	0.96	0.91	2.30

In terms of upazila-wise comparison, the mean value of available P (ppm) showed statistically significant variation (Table 3). The highest value of available P was recorded in Debhata and the lowest value was observed in Shymnagar upazila.

Table 8. Exchangeable K (meq/100g soil)as influenced by soil depths and locations

Soil depth	Upazila						
	Assasuni	Debhata	Kolaroa	Kaligonj	Satkhira sadar	Shymnagar	Tala
D_1 (0-7 cm)	0.57a	0.27b	0.20a	0.23ab	0.73a	0.81c	0.41a
D_2 (8-15 cm)	0.55a	0.46a	0.20a	0.16b	0.71ab	0.86b	0.33b
D_3(16-23 cm)	0.46b	0.32b	0.16b	0.22ab	0.73a	0.73d	0.31c
D_4(24-31 cm)	0.31c	0.16c	0.17ab	0.25a	0.64b	0.85b	0.31c
D_5(32-39 cm)	0.20d	0.17c	0.15b	0.17b	0.56c	0.91a	0.34b
CV (%)	3.90	8.44	5.52	12.16	3.99	1.35	1.15

When soil depth effect was considered on upazila basis it was found that the highest K content was found in Shymnagar followed by Satkhira sadar (Table 3). However, the lowest K content was found in Kolaroa followed by Debhata.

Exchangeable K (meq/100g soil)content in soil

Potassium content was significantly influenced by both soil depth and upazila (Table 8). The significantly higher K was found in top soil depth. The K content found in D_1 and D_2 was statistically insignificant but similar for Asasuni, Kolaroa, Kaligonj and Satkhira sadar. But the K content found in D_4 and D_5 shows statistically significant variation in Asasuni, Kaligonj, Satkhira sadar, Shymnagar and Tala.

Available S(ppm) content in soil

There was statistically significant variation recorded in case of available S content in those sampling saline and non-saline areas (Table 9). The highest value of sulphur was found 87.80 ppm in Satkhira Sadar at 0-7 cm soil depth and the lowest value was 37.09 ppm in Kolaroa at 24-31 cm soil depth. In most case, the available sulphur content of soil also had showed decreasing trend from top soil to deeper soil. Our observation supported by Islam (1983) who reported that the sulphur deficiency in Bangladesh soils is becoming wide spread and acute. Our result is also supported by Chowdhury (1992) who reported that the available sulphur of soil decreased with increasing of soil depth.

Table 9. Available S (ppm)as influenced by soil depths and locations

Soil depth	Upazila						
	Asasuni	Debhata	Kolaroa	Kaligonj	Satkhira sadar	Shymnagar	Tala
D_1 (0-7 cm)	83.41a	79.54a	57.45a	76.25a	87.80a	83.70a	69.88a
D_2 (8-15 cm)	67.64b	77.58b	43.89bc	53.08c	82.76b	74.85b	52.76b
D_3(16-23 cm)	55.11c	69.85c	45.98b	47.75d	81.62c	68.18c	45.76c
D_4(24-31 cm)	40.03e	69.12c	37.09d	75.74a	61.13d	61.25d	41.43d
D_5(32-39 cm)	53.02d	43.85d	40.77cd	62.95b	54.73e	51.10e	46.13c
CV (%)	0.03	0.50	3.13	1.64	0.53	1.06	0.89

Conclusion

Soil depth affects soil properties and nutrient availability and thus plays a major role in influencing plant growth and yield. From the present study it can be concluded that under varying land uses, distribution of soil properties as well as nutrient elements is affected by soil depths in saline areas of Satkhira district. It was first year experiment. It should be continued for next three years.

Acknowledgement

The authors are grateful to honourable Director General, BARI along with all respected Directors, all Divisional CSO and In-charge, ARS, Satkhira for their inspiration, financial support and regular supervision.

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UTILIZATION OF BANANA PEEL FERTILIZER ON INCREASING TOMATO YIELD AND IMPROVING SOIL FERTILITY

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Abstract

Banana peel is an organic waste, which has nutrients that are useful for plants. A pot experiment on utilization of banana peel fertilizer on increasing tomato yield and improving soil fertility was conducted in the net house of Soil Science Division, BARI, Joydebpur, Gazipur during the year of 2021-2022with the objectives: i) to find out the effect of banana peel fertilizer on tomato yield, ii) to find out the nutrient uptake and to increase soil fertility by the application of banana peel fertilizer. There were six treatments viz. T_1: 100% RDCF, T_2: 100% RDCF + 10% Banana peel fertilizer, T_3: 100% RDCF + 20% Banana peel fertilizer, T_4: 80% RDCF + 10% Banana peel fertilizer, T_5: 80% RDCF + 20% Banana peel fertilizer, T_6: Native fertility.The tested crop and variety weretomato (BARI tomato 16).The experiment was laid out in CRD design with four replications. Growth and yield of tomato were significantly influenced by different treatments. The highest yield of tomato (58.2 t ha^{-1}) was observed in T_3 treatment (100% RDCF + 20% Banana peel fertilizer) which was very close to the yield of 53.5 t $ha^{-1}$and it was found in T_2 (100% RDCF + 10% Banana peel fertilizer) treatment. The lowest yield (5.5 t ha^{-1}) was noted in control treatment (T_1). Highest yield increase over control (91%) was also obtained from T_3: 100% RDCF + 20% Banana peel fertilizer treated pot which was very close to T_2 treatment (100% RDCF + 20% Banana peel fertilizer treated pot) yield increase about 90%. Nutrient uptake was also influenced by banana peel with chemical fertilizers treatments. NPKS uptake in tomato was highest by T_3 treatment. Nutrient content in post harvest soil is also improved compared to initial soil with the application of banana peel fertilizer.

Introduction

Banana peels are good for gardens because they contain 42 percent potassium. Banana peels have the highest organic sources of potassium. Potassium aids plants in moving nutrients and water between cells. Potassium strengthens plants' stems and also fights off disease. It is especially important to creating flowers, and even makes fruits taste better. Potassium will even make your plants more resistant to drought. In short, potassium helps plants grown for their fruiting and flowering. Banana peels are good fertilizer because of what they do not contain. They contain absolutely no nitrogen. Potassium-rich banana peels are excellent for plants like tomatoes, peppers or flowers. The average nitrogen in protein is 16%, so the 3.5% protein in banana skins is equivalent to 0.6% nitrogen. The potash and phosphate in banana peels is 11.5% and 0.4%. The NPK value for banana skins is 0.6-0.4-11.5. Banana peels also contain calcium, which prevents blossom end rot in tomatoes. The manganese in banana peels aids photosynthesis, while the sodium in banana peels helps water flow between cells. They even have traces of magnesium and sulfur, elements that help make chlorophyll.

Enormous amount of banana peel from rotten banana are generated from banana garden and fruit market in day by day in life. A considerable part of rotten banana & banana peel which remains unutilized and are dumped nearby sites that create pollution, harbours pathogen for diseases and causes severe problem of disposal. Instead of disposing, it can be used as source of organic fertilizers and effectively recycled to meet the nutritional requirement of crops. Considering growing deficiency of plant nutrients in crop field, higher cost of synthetic fertilizers and poor efficiency of chemical fertilizers, the banana peel & rotten banana recycling for plant nutrient supply is becoming more essential for replenishment of plant nutrients, sustaining soil health and reducing the pollution problem. The study was aimed to utilize the banana peel & rotten banana for supplying nutrient to enriched organic manure for better soil health and crop growth, which will not only improve the yield and quality of the produce but also conserve energy, minimize pollution and improve the fertilizer use efficiency subsequently that will help to revitalize and restore the soil fertility for sustainable crop production. Therefore, the present study was undertaken to determine the effects of Banana Peel on the growth and yieldof tomato with the objectives to:

i. To find out the effect of banana peel fertilizer on tomato yield
ii. To find out nutrient uptake and to increase soil fertility by the application of banana peel fertilizer
iii. To minimize rotten banana disposal problem

Materials and methods

A pot experiment on utilization of banana peel fertilizer on increasing tomato yield and improving soil fertility was conducted in the net house of Soil Science Division, BARI, Joydebpur, Gazipur during the year of 2021-2022.The silted (sandy clay loam) soils were collected from the bank of Turag river at Kodda, Gazipur mixed with cowdung at 5:1 ratio and was used as the potting media. Each pot (28 cm in diameter and 23 cm in height) was filled with approximately 8-kg soil leaving upper 3 inches of pot was vacant to facilitate watering. The initial soil and cowdung was analyzed in the laboratory following standard methods. Initial values of some important chemical parameters of the experimental soil are presented in Table 1.

Table 1. Chemical properties of initial soil used in experimental pot at BARI, Gazipur during 2021

Location	pH	OM	Ca	Mg	K	Total N	P	S	Zn	B
		(%)	meq $100g^{-1}$			(%)	µg g^{-1}			
Gazipur	6.8	1.50	4.0	2.1	0.14	0.10	8	10	0.65	0.18
Critical level	-	-	2.0	0.5	0.12	0.12	7	10	0.20	0.20

Table 2. Analytical results of Banana peel tea fertilizer

Specification	Banana peel tea fertilizer
Physical condition	Liquid
Colour	Light brown
pH (%)	7.2
P (%)	0.4
K (%)	11.5
S (%)	0.58
Zn (%)	0.003
Ca (%)	4.2
Mg (%)	2.2

The experiment was laid out in a completely randomized design with four replications. Six different treatments viz. T_1: 100% RDCF, T_2: 100% RDCF + 10% Banana peel fertilizer, T_3: 100% RDCF + 20% Banana peel fertilizer, T_4: 80% RDCF + 10% Banana peel fertilizer, T_5: 80% RDCF + 20% Banana peel fertilizer, T_6: Native fertility.The pot size was 10 cm x 8 cm. The tested crop and variety were tomato (BARI tomato 16). Thirty days old seedlings of tomato were transplanted in each pot on 12 November, 2021.Chemical properties of banana peel fertilizers are presented in Table 2.

Fertilizers of N, P, K, S, Zn & B @ 160, 50,70,25, 3 & 1.5kg ha^{-1} were applied as a form of Urea,TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. For urea and TSP, $^1/_3{}^{rd}$ of urea& TSPwas applied before transplanting as basal.The remaining two third of N & K were equally applied as top dress at 15 and 35 days after transplanting. For banana peel tea fertilizer, it was applied after transplantingas seven days interval and it is continueduntil harvest time.Irrigation and other intercultural operations were done as and when required. For making banana peel tea fertilizer, add 3-4 chopped ripe banana peel to a jar and fill the jar to the top with water, enough to cover the banana peel, close the jar and allow it to rest for 5-6 days, remove the peel and watered to plant with banana peel tea fertilizer. The tomato was harvested on 27 February, 2022. Data on yield and yield contributing characters were recorded and analyzed statistically using Statistics-10 package. LSD test was used to determine the significant differences among treatments (Steel and Torrie, 1960). Plant samples and postharvest soil samples were collected from each plot for chemical analysis.

Methods of chemical analyses

Soil pH was measured by a combined glass calomel electrode (Jakson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Ca and Mg were determined by NH_4OAc extraction method. K, Cu, Fe, Mn and Zn were determined by DTPAextraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method (Acid soils). S was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric method with $BaCl_2$.

Results and Discussion

Effect of banana peel fertilizer with chemical fertilizer treatments on the yield and yield parameters of tomato are summarized in Table 3. Yield and yield attributes were significantly influenced by different treatments. Plant height are significantly influenced by different treatments. Highest plant height (70.10 cm) was obtained from T_3 treatment (100% RDCF + 20% Banana peel fertilizer) which was statistically similar to T_2 (100% RDCF + 10% Banana peel fertilizer) treatment. Lowest plantheight (25.78 cm) was obtained from T_6(control) treatment. The highest tomatolength (46.38 mm) was found in T_3 (100% RDCF + 20% Banana peel fertilizer) which were statistically similar to T_2 (100% RDCF + 10% Banana peel fertilizer) and T_5 (80% RDCF+ 20% Banana peel fertilizer) treatments.

Table 3. Effect of banana peel fertilizer on the yield and yield attributes of tomato during 2021-2022

Treatments	Plant height (cm)	No. of fruits/plant (no.)	Fruit length (mm)	Fruit Diameter (mm)	Tomato yield (kgplant^{-1})	Tomato yield (t ha^{-1})	Yield increase over control (%)
T_1= 100% RDCF	61.27c	36.25b	40.36b	56.52d	1.43b	35.8b	85
T_2= 100% RDCF + 10% Banana peel fertilizer	68.93ab	43.50a	44.93ab	68.93ab	2.14a	53.5a	90
T_3= 100% RDCF + 20% Banana peel fertilizer	70.10a	44.75a	46.38a	70.10a	2.33a	58.2a	91
T_4= 80% RDCF + 10% Banana peel fertilizer	62.92c	35.75b	40.79b	62.92c	1.55b	38.8b	86
T_5= 80% RDCF + 20% Banana peel fertilizer	63.79bc	37.75b	44.47ab	63.79bc	1.60b	40.0b	86
T_6= Native fertility	25.78d	6.50c	17.21c	21.78e	0.22d	5.5d	-
SE(±)	2.67	2.35	2.26	2.57	0.22	0.22	-
CV (%)	6.42	9.76	8.20	6.35	20.24	20.24	-

Means followed by the same letter in a column are not statistically significant at 5% level by LSD test.

The lowest tomatolength (17.21 mm) was noted in T_6(control) treatment.Tomato diameter and no. of fruitper plant are important yield parameters of tomato. Both of yield parameters i.e., tomato diameter and no. of fruitper plantare significantly influenced by banana peel fertilizer. Maximum tomato diameter (70.10 mm) was observed in T_3 (100% RDCF + 20% Banana peel fertilizer) treatment which was statistically similar to T_2 (100% RDCF + 10% Banana peel fertilizer)treatment. The highest no. of fruitper plant (44.75) was noted in T_3 (100% RDCF + 20% Banana peel fertilizer) treatment which was statistically similar to T_2 (100% RDCF + 10% Banana peel fertilizer) treatment. The lowest no. of fruitper plant (6.50 no.) and lowest tomato diameter (21.78mm) was obtained from T_6(control) treatment.The highest yield of tomato2.33kgplant^{-1}and 58.2 t ha^{-1}was observed in T_3 (100% RDCF + 20% Banana peel fertilizer) treatment which was very close to the yield of 1.47kgplant^{-1}and 53.5t ha^{-1}and it was found in T_2treatment (100% RDCF + 10% Banana peel fertilizer). The lowest yield (0.22kgplant^{-1} and 5.5t ha^{-1}) of tomato was noted in control treatment (T_1). Banana peel fertilizer@ 10% & 20% with 100% recommendedchemical fertilizer treatments were attributed to availability of optimum nutrients throughout the growing season which might be provided the optimum nutrients that reflected in yield and yield contributing characters.

Table 4. Effect of banana peel fertilizer on nutrient uptake by tomato during 2021-2022

Treatments	N	P	K	S
	(kg ha^{-1})			
T_1= 100% RDCF	130.7bc	23.17c	117.7c	23.17c
T_2= 100% RDCF + 10% Banana peel fertilizer	145.4ab	32.40b	148.7ab	32.2b
T_3= 100% RDCF + 20% Banana peel fertilizer	150.2a	40.03a	161.2a	40.10a
T_4= 80% RDCF + 10% Banana peel fertilizer	129.7bc	24.60c	120.9c	25.03c
T_5= 80% RDCF + 20% Banana peel fertilizer	127.6bc	28.53bc	136.4b	27.4bc
T_6= Native fertility	113.5c	11.17d	72.5d	11.17d
SE(±)	8.61	2.62	6.16	3.09
CV (%)	7.93	12.05	5.98	14.28

Nutrient Uptake

Nutrient uptake by tomato was significantly influenced by different treatments which presented in Table 4. Highest nutrient uptake by tomato was observed in T_3 (100% RDCF + 20% banana peel fertilizer) treatment. The highest N uptake (150.2 kg ha^{-1}) was found in T_3 (100% RDCF + 20% Banana peel fertilizer) treatment which was statistically similar to T_2treatment (100% RDCF + 10% Banana peel fertilizer). Similar trend was noted with K uptake by tomato. The highest P (40.03 kg ha^{-1}) and S uptake (25.03 kg ha^{-1}) was found by T_3 (100% RDCF + 20% Banana peel fertilizer) treatment. The lowest nutrient uptake was recorded by control treatment. N uptake by tomato ranged from 113.5 to 150.2, P uptake ranged 11.17 to 40.03, K uptake ranged from 72.5 to 161.2 and S uptake ranged from 11.17 to 40.10kg ha^{-1}. 20% Banana peel fertilizer with 100% recommendedchemical fertilizer were attributed to availability of optimum nutrients throughout the growing season which might be provided the optimum nutrientsuptake by tomato.

Chemical properties of post harvest soil

After completion of the experiment, the contents of organic carbon, total N, exchangeable K, available P, S, Zn and B in post-harvest soils were increased with the combined application of banana peel fertilizer and inorganic fertilizers compared to that of initial soil (Table 5). TreatmentT_3 (100% RDCF + 20% Banana peel fertilizer) showed better performance in case of all nutrient content in post harvest soil. Highest organic carbon of 2.0% was obtained in T_3 treatment. Highest nitrogen content of 0.18% was obtained in T_3 treatment. The lowest total N content in soil (0.10%) was obtained from T_6 (control) treatment. The maximum P content in soil (88 ppm)was recorded in T_3 treatment followed by T_2(100% RDCF + 10% Banana peel fertilizer) treatment. The minimum P content in soil was found in T_6 (control) treatment. The range of exchangeable K content in post harvest soils was 0.13 to 0.27 meq/100 ml. The lowest value was observed in T_6 (control) treatment. The available S content in the post harvest soils ranged from 16 to 26 ppm. The highest available S content 26 ppm in post harvest soil was recorded in T_3 treatment. Available Zn & B content of the post harvest soils ranged from 13 to 24 ppm and .20 to .24 ppm respectively. The highest available Zn & B content of 24 ppm and 0.24 ppm were recorded in T_3treatment. Soil pH of post harvest soil was slightly increased; it might be due to buffering effect of applying banana peel liquid fertilizer in soil.

Table 5. Chemical properties of post harvest soil as influenced by different treatments

Treatments	pH	OC %	K meq/100 ml	Total N %	P	S	B	Zn
					ppm			
T_1	7.2	1.8	0.20	0.14	77	21	0.20	17
T_2	7.4	1.7	0.26	0.16	84	22	0.23	23
T_3	7.3	2.0	0.27	0.18	88	26	0.24	24
T_4	7.3	1.7	0.25	0.15	77	20	0.22	18
T_5	7.4	1.8	0.26	0.16	79	21	0.22	17
T_6	7.2	1.1	0.13	0.10	59	16	0.21	13
Critical Level			0.12	-	**7	10	0.20	0.6
					*10			

Conclusion

Considering results of this year, the highest yield of tomato58.2 t ha^{-1} was observed in T_3 (100% RDCF + 20% Banana peel fertilizer) treatment which was very close to the yield of 53.6t $ha^{-1}$and it was found in T_2treatment (100% RDCF + 10% Banana peel fertilizer). The lowest yield (5.5t ha^{-1}) of tomato was noted in control treatment (T_1).Nutrient uptake by tomato was also highest in T_3 (100% RDCF + 20% Banana peel fertilizer) treatment.Banana peel fertilizer @ 10% & 20% with 100% recommendedchemical fertilizer treatments were attributed to availability of optimum nutrients throughout the growing season which might be provided the optimum nutrients that reflected in yield and yield contributing characters. Nutrient content in post harvest soil is improved compared to initial soil with application of banana peel fertilizer. This is the result of first year experiment. For confirming the results, the experiment needs to be repeated next year.

SUSTAINABLE SUBSTRATE COMPOSITION AS INFLUENCED BY ORGANIC AMENDMENT ON DRAGON FRUIT IN AN EXTENSIVE GREEN ROOF

M A RAHMAN, F S SHIKHA, M YASMIN AND H M NASER

Abstract

Green roof substrates are an artificial mixture of compounds designed to provide proper conditions for plant growth.A study was done to assess the improvement of soil-substrate properties and dragon fruit growth and yield at the rooftop of the laboratory building in Regional Agricultural Research Station (RARS) under Jamalpur Sadar upazila. There were nine treatment combinations- control (only farm soil), and the rest eight organic amendments (biochar and vermicompost). The rates of biochar and vermicompost were 0, 30 and 40% of the total substrate volume. The results demonstrate that substrate moisture content, plant canopy and plant dry matter content increased in biochar and vermicompost treated soil over non amended soil. It appeared that substrate moisture content was increased with the increase of the rate of biochar and vermicompost. Crop response study showed that the use of 30% biochar plus 30% vermicompost with farm soil produced a significantly higher plant canopy and plant dry matter content over the treatments. The use of biochar and vermicompost with farm soil produced a 12-73 % at North-South and 32- 53 % at East-West direction plant canopy and that was 1-87 % for dry matter content.

Introduction

Rooftop garden plays an important role in the mental well-being of the gardeners as well as in amelioration of the physical environment. The production of fresh fruits and vegetables of the rooftop garden can increase nutritional status of household members of the urban citizens and it will make a positive contribution to the environment. Many studies worldwide have investigated the potential benefits achievable by transforming brown roofs of buildings to green roofs. Green roof substrates are an artificial mixture of compounds designed to provide proper conditions for plant growth. When fresh or even composted organic materials are added to soil, usually a fast oxidation is observed, and it is therefore difficult to increase the soil organic matter content. Bangladesh is experiencing such problem particularly due to its warm-humid climatic condition. Therefore, most soils of Bangladesh contain 1.7-2.0% organic matter and some soils have even less than 1.0% whereas a good soil should contain more than 3.5% organic matter. This low organic matter content has been considered as one of the main reasons for low productivity of many of our soils as well as rooftop substrate.

This could be overcome through addition of pyrolysed organic materials into soil i.e., biochar. Biochar is charred biomass, produced under limited oxygen supply or in the absence of oxygen at a high temperature. Being rich in aromatic carbon, biochar can persist for hundreds or thousands years in soil. Biochar application has multiple benefits. It helps carbon sequestration (Ahmed *et al.*, 2017), improves soil properties - increases water holding capacity (Shafie *et al*., 2012), decreases soil acidity (Obed *et al*., 2016), increases CEC, N, P & K content (Novak *et al*., 2016). Another soil amending tools is Vermicompost which benefits the environment by reducing the need for chemical fertilizers and decreasing the amount of waste going to landfills. Vermicompost enhances plant growth, suppresses disease in plants, increases porosity and microbial activity in soil, and improves water retention and aeration. Coincided use of biochar and vermicompost provide the soil substrate both stable and labile forms of organic matter. Considering this fact, a trial was designed with soil amended with biochar and vermicompost in different rates to assess the improvement of soil-substrate properties and crop yield in an extensive green roof.

Materials and Methods

A rooftop pot trial was set up at the roof of the laboratory building in Regional Agricultural Research Station (RARS) under Jamalpur Sadar upazila. The experiment was laid out in a randomized complete block factorial design with three replications where factor A was three labels of biochar and factor B was three levels of vermicompost. The unit pot size was 50cm x 50 cm plastic drum. The tested crop was BAU dragon fruit 1 that was planted 10 February 2021 maintaining the spacing 1-meter x 1 meter. There were 9 treatment combinations of T_1 =B0V0 (biochar 0% X vermicompost 0%), T_2

=B0V30, T_3 = B0V40, T_4 = B30V0, T_5=B30V30, T_6=B30V40, T_7=B40V0, T_8= B40V30 and T_9 = B40V40. The blanked dose of P, K, S @ 20,25, 10 g, respectively was applied and each pot would be top dressed 3 times per year with N, P, K @ 50, 20, 25 g, respectively. Full dose of all fertilizers was mixed with the soil-substrate at the time of final mixture. Substrate moisture content was taken by digital moisture meter at five times or days (D1, D2, D3, D4 and D5 for 8/11/2021, 28/11/2021, 03/01/2022, 31/01/2022 and 09/03/2022, respectively), plant canopy was recorded by measuring tape from North-South and East-West direction and plant dry matter was calculated by volumetric method. Statistical analysis was done using R software version 4.0.5.

Results and Discussion

The experiment was conducted at the rooftop of the laboratory building in Regional Agricultural Research Station (RARS) under Jamalpur Sadar upazila. Data on the substrate moisture, plant canopy and plant dry matter percentage from every pot were recorded. The results are shown in tabular and graphical forms. The parameters under record as affected by the different treatments are described below under some sub- headings.

Substrate Moisture

Substrate moisture increased significantly due to different organic treatments over control at all days. The substrate moisture range was 13.03 to 26.96% at day-1, 10.80 to 23.73% at day-2, 9.60 to 16.30% at day-3, and 12.04 to 20.33% at day-4 and at day-5 that was 14.10 to 27.75% (Table 1). The highest moisture contents of 26.96, 23.73, 16.30, 20.33 and 27.75% were obtained from T9 treatment receiving biochar 40% plus vermicompost 40% and the lowest values (13.03,10.80, 9.60, 12.40 and 14.10%) were noted in control treatment (T1) contained only farm soil. The treatment T5, T6, T7 and T8 receiving B30V30, B30V40, B40V0 and B40V30, respectively showed statistically similar with the treatment T9 of highest moisture content and the treatments T2, T3, T4 having B0V30, B0V40 and B30V0, respectively responded however statistically at par with the control. It was observed that, the moisture content increased with the increase of organic matter in substrate media. The moisture content benefits due to biochar and vermicompost treatments are shown in Fig. 1. It indicates that the moisture content for the different treatments (T2-T9) increased by 25 –106%, 48-120%, 8-70%, 5-64% and 23-97%, respectively over control during five days.

Table1. Moisture percentage of dragon fruit growing substrate as influenced by integrated use of biochar and vermicompost with farm soil

Treatment	D1	D2	D3	D4	D5
T1	13.03d	10.80e	9.60c	12.40d	14.10 d
T2	16.36de	16.03d	10.36c	12.96cd	17.41de
T3	18.46cd	16.93cd	10.36c	15.06bcd	19.40cd
T4	21.63bc	17.50cd	12.16bc	18.60ab	22.59bc
T5	25.23ab	19.53abcd	12.06bc	18.60ab	26.31ab
T6	25.23ab	21.83abc	13.26abc	17.23abc	26.23ab
T7	22.93abc	18.00bcd	12.03bc	19.30ab	23.83a
T8	25.70ab	22.70ab	15.50ab	20.13a	26.71ab
T9	26.86a	23.73a	16.30a	20.33a	27.75a
Sig. level	***	**	*	*	***
LSD	4.79	5.08	4.08	4.79	3.86
SE (±)	1.02	0.90	0.60	0.75	0.87

T1=B0V0 (biochar 0% X vermicompost 0%), T2=B0V30, T3= B0V40, T4= B30V0, T5=B30V30, T6=B30V40, T7=B40V0, T8= B40V30 and T9= B40V40. In a column, treatments with the same letter are not significantlydifferent at 5% level, ***,** and * means Significant at 0.1, 1 and 5 % level, LSD means Least Significant Difference and SE (±) = Standard error.

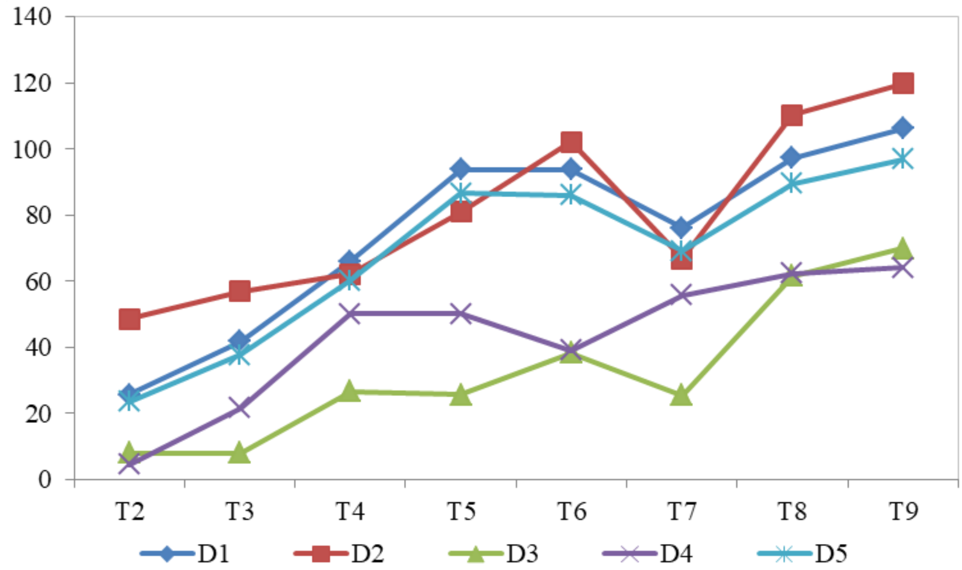

Figure 1.Increase in percent moisture of dragon fruit growing substrate due to integrated use of biochar and vermicompost with farm soil.

Plant Canopy

Organic amendments significantly influenced the Canopy of dragon fruit. Plant canopy was measured from north to south (N-S) and east to west (E-W) directions. The plant canopy of both N-S and E-W significantly increased due to different biochar and vermicompost treatments. The canopy varied from 1.71 to 2.96 meter and 1.78 to 2.73 meter at N-S and E-W direction, respectively (Table 2). For both cases, the T6 treatment having biochar 30% and vermicompost 40% recorded the maximum canopy (2.96 and 2.73 m at N-S and E-W, respectively) and the control treatment (T1) contributed the lowest (1.71 and 1.78 m at N-S and E-W, respectively). The treatment T4 (B30V0) and the control treatment T1 (B0V0) containing only soil showed statistically similar. It was observed that the treatment T2 (B0V30), T3 (B0V40), T5 (B30V30), T7 (B40V0), T8 (B40V30) and T9 (B40V40) responded statistically alike and similar with the treatment T6 of highest value.The increase in plant canopy due to the treatment of different ratio of biochar and vermicompost with farm soil is shown in Fig.2. It indicates that the canopy of dragon fruit over the different treatments increased by 12-73% and 32-53% at N-S and E-W directions, respectively. The highest increase was noted from T6 treatment and the lowest from T4 treatment.

Dry matter

The dry matter percentage of dragon fruit plant responded significantly to different treatments. The percentage ranged from 9.62 to 17.05 over the treatments where the highest dry matter percent was recorded from T6 treatment consisted of biochar 30% and vermicompost 40% followed by T5 treatment having 30% each of biochar and vermicompost. It is observed that treatment T9 (B40V40) exhibited statistically at par with the treatment T5 (B30V30) contributing 15.95 and 17.05% plant dry matter, respectively. Treatment T7 (B40V0) and T4 (B30V0) showed statistically alike and similar with control treatment. Treatment T2 (B0V30) and T3 (B0V40) also contributed the same statistically. The lowest plant dry matter was found in control (T1) treatment.Compared to control treatment, the addition of biochar and vermicompost to soil resulted in a 2-87% increased plant dry matter (Fig.3) where T6 treatment contributed the highest increase and the lowest was obtained from T4 treatment.

Table 2. Plant canopy and plant dry matter percent of dragon fruitas influenced by integrated use of biochar and vermicompost with farm soil

Treatment	N-S (m)	E-W (m)	DM (%)
T1	1.71b	1.78b	9.62e
T2	2.64a	2.41a	11.95cd
T3	2.66a	2.53a	11.99cd
T4	1.92b	2.35ab	9.76e
T5	2.92a	2.70a	17.05ab
T6	2.96a	2.73a	17.99a
T7	2.57a	2.39a	10.57de
T8	2.69a	2.59a	12.58c
T9	2.78a	2.66a	15.95b
Sig. level	***	*	***
LSD	0.39	0.58	1.48
SE (±)	0.09	0.08	0.59

T1=B0V0 (biochar 0% X vermicompost 0%), T2=B0V30, T3= B0V40, T4= B30V0, T5=B30V30, T6=B30V40, T7=B40V0, T8= B40V30 and T9= B40V40.N-S means North-South, E-W means East-West direction, DM means Dry matter. In a column, treatments with the same letter are not significantlydifferent at 5% level, ***, ** and * means Significant at 0.1, 1 and 5 % level, LSD means Least Significant Difference and SE (±) = Standard error.

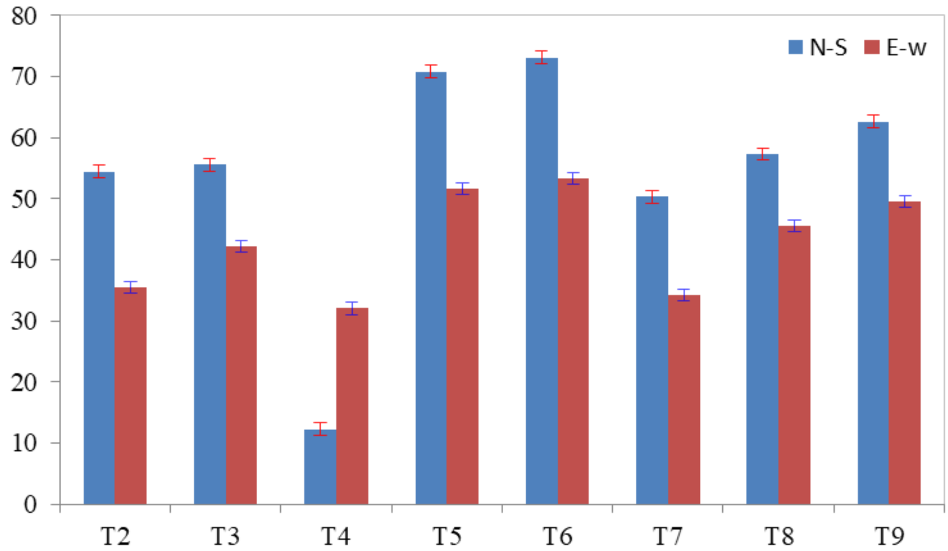

Figure 2.Increase in plant canopy of dragon fruit due to integrated use of biochar and vermicompost with farm soil.

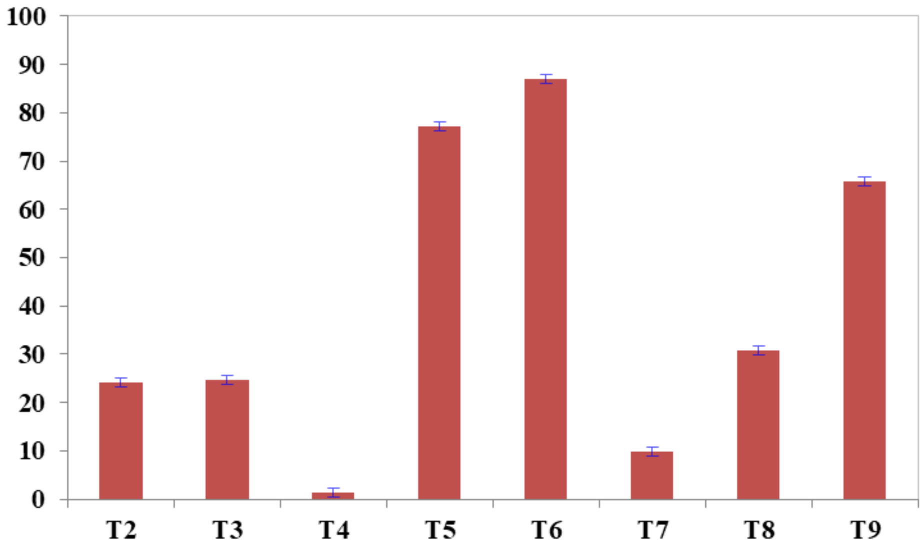

Figure 3.Increase in percent dry matter of dragon fruit due to integrated use of biochar and vermicompost with farm soil.

Conclusion

After first year it could be concluded that the substrate moisture content, dragon fruit plant canopy and plant dry matter markedly varied with different treatments of biochar and vermicompost with farm soil. This trial should be continued for the confirmation of the result.

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FERTILIZER REQUIREMENTS FOR DOUBLE RICE CROPPING (T. AUS –T. AMAN RICE SYSTEM) PATTERN ON SALINE SOILS AT SOUTH COASTAL REGION OF BANGLADESH

S. AKHTER AND M.F.A. ANIK

Abstract

A field experiment was conducted during kharf-I and kharif-II season 2020-2021in the farmers field at khatail, Dacope, khulna under the supervision of Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur to find out the best fertilizer doses for cultivating T.aus-T.aman rice cropping pattern and also monitor the soil fertility status.The experiment was laid out in RCBD with three replications. There were six treatments viz. T_1: 0 (control), T_2: 100% RD (STB), T_3: 120% RD of NPZn (STB), T_4: 120% RD of N (STB), T_5: 120% RD of P (STB)and T_6: 120% RD of Zn (STB). In comparison to all other treatments, yield contributing traits and rice yield performed better in plots which were treated with 120% of recommended dose of NPZn. In the T.aus-T.aman rice cropping pattern, the 120% recommended dose of NPZn applied plots produced the highest grain and straw yield (Grain 5.28 t/ha and 5.44 t/ha., Straw 6.89 t/ha and 6.92 t/ha)compared to all other treatment combinations. Harvest Index (%) was also higher in the same treatment in both T.aus and T.aman rice cultivation. In terms of all parameters of the rice-rice cropping pattern, the T_1 (Control) treatment performed worst in the south coastal region of Bangladesh.

Introduction

Bangladesh has a total size of 147,570 km^2, with the coastal area accounting for around 20% of the total area and over 30% of the net cultivable land. Soil salinity affects the cultivable areas in coastal districts in varied degrees. Salinity has risen in both level and area over time. The saline area has increased from 0.83 mha in 1973 to 1.06 mha today. Soil and water salinity, poor soil fertility, heavy soil consistency, and low osmotic potential are all restrictions to crop productivity. Salinity rises in dry months, peaking in March-April, and falls in wet months, with the lowest levels in July-August. Farmers in the coastal region often grow traditional types and produce 2.0-2.5 tons per hectare per year. The current challenge is to increase crop yields above current levels while remaining sustainable on our limited land resources. Nutrient inputs to soil must be at least balanced against nutrient removal by crops in order for a crop production system with high yield targets to be viable (Bhaiyan et al., 1991). As a result, one of the most important aspects of increasing agricultural output is proper soil fertility management. The majority of studies in southern Bangladesh has focused on nitrogen as the principal component limiting crop productivity, but there is rising evidence that other nutrients like phosphorus, potassium, sulfur, and other micronutrients are also restricting crop production (Debnath et al., 2011; Howlader et al. 2013; Liza et al. 2013). Nitrogen was the most yield-limiting nutrient, followed by P, and finally K. (Chuan et al. 2013). Other factors that affect fertilizer efficiency, such as soil acidity, salinity, and submergence, must also be considered. Dacope, the district's second-largest Upazila in terms of area, is made up of plain land, lower floodplains, rivers, canals, and beels. Due to salt issues, farmers in this area tend to grow exclusively T.aman rice. They are not interested to grow T.aus rice due to salinity. The other crops in this area have poor nutrient management. But our target is to establish T.aus-T.aman rice cropping pattern on that specific area. As a result, the current study was carried out to identify nutrients and other soil restrictions that limit crop yield in T.aus rice-T.aman rice cropping pattern in Bangladesh's south coastal saline soils, as well as to investigate crop response diversity among saline soils. Objectives of the study ware to (i) to find out optimum rate of fertilizer for growing T.aus and T.aman rice in double cropping system (ii) to monitor soil health after each cropping cycle

Materials and method

The experiment was carried out during kharif I and kharif II season from 26 June 2021 to 22 September 2021 and 03 October 2021 to 23 December 2021 in the farmer's field at Dacopeupzila, Khulna in respect of T.aus and T.aman rice cultivation. The experiment was laid out in Randomized

Complete Block Design (RCBD) with three replications. Unit plot size was 6×5 m^2. The treatments were six which were replicated into three blocks. There were 06 treatments of the experiment viz. T_1: 0 (control), T_2: 100% RD (STB), T_3: 120% RD of NPZn (STB), T_4: 120% RD of N (STB), T_5: 120% RD of P (STB)and T_6: 120% RD of Zn (STB). The tested crop was rice (cv. BRRI dhan82 for T.aus and BRRI dhan67 for T.aman). Transplanting of rice plants in the field, we used 35 days old seedlings for this experiment. Nitrogen, Phosphorus, Potassium, Sulphur and Zinc @ $N_{100}P_{15}K_{15}S_3Zn_1$ kg ha^{-1} were used in the form of Urea, TSP, MoP, Gypsum and Zinc sulphate, respectively. All N, P, K, S, Zn fertilizers were applied at the time of land preparation except N. Urea fertilizer was applied in the field as three equal splits just after 20- 30- and 40-days of transplanting. We did all types of intercultural operations in our crop fields as required such as irrigation, weeding, insect-pest control and disease management. For recording data, we cut 2 m^2 of rice field from every treatment. Randomly selected 5 plants were used for data collection. Data on yield and yield contributing traits were recorded just after harvest of rice plants. The rice plants were harvested on 22 September and 23 December 2021. The initial and post-harvest soil samples at a depth of 0-15 cm from the experimental fields were collected and analyzed by well-established standard methods.

Soil and plant sample analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Soil texture was determined by hydrometer method (Beverwijk, 1967). Organic carbon was determined by wet oxidation method (Walkley and Black). Total N was determined by modified Kjeldahl method. Calcium, K and Mg were determined by NH_4OAc extraction method. Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$.

Table 1a. The EC (dS/m) and pH of the soil and water in the experimental field at Khatail, Dacope, Khulna during 2020-2021

Parameters	Soil	Plot water	Khal water	Pond water
EC	2.3	7.2	4.8	1.86
pH	7.8	7.5	7.2	7.8

Table 1b. Chemical properties of initial and post-harvest soil at Dacope during 2020-2021

Treatments	pH	SOM	Total N	Ca	Mg	K	P	S	B	Cu	Fe	Mn	Zn
		%		meq/100 gm			ppm						
T_1: 0 (control),	7.0	1.0	0.05	7.8	2.4	0.38	1.7	119	0.35	0.80	27	5	0.66
T_2: 100% RD (STB)	7.5	1.6	0.08	12.0	3.7	0.52	2.3	161	0.52	1.33	40	8	1.16
T_3: 120% RD of NPZn (STB)	7.6	1.3	0.06	12.3	3.8	0.43	3.7	155	0.52	1.31	33	6	1.01
T_4: 120% RD of N (STB)	7.5	1.4	0.07	12.4	3.7	0.49	2.7	156	0.48	1.24	35	7	0.96
T_5: 120% RD of P (STB)	7.4	1.5	0.07	12.2	3.7	0.47	2.7	152	0.47	1.27	36	7	0.98
T_6: 120% RD of Zn (STB)	7.1	1.1	0.06	8.0	2.4	0.38	2.0	124	0.38	0.83	34	5	0.89
Initial soil	8.2	1.0	0.05	14.0	4.2	0.49	4.0	80	0.44	1.2	35	5	0.44
Critical level	-	-	-	2	0.5	0.12	7	10	0.2	0.2	4	1	0.6

Growth analysis

All the yield and yield contributing characters such as plant height (cm), number of tillers per hill, number of effective tillers per hill, number of ineffective tillers per hill, number of filled grains per panicle, number of unfilled grains per panicle, panicle length (cm), 1000-grain weight (g), seed yield (t/ha) and straw yield (t/ha) were recorded. Five (05) randomly plants were selected to take the data of above mention parameters.

Statistical analysis

Data were statistically analyzed using Analysis of Variance (ANOVA) following Crop Stat package while the all-pair comparisons were done by Statistix-10 software (Gomez and Gomez, 1984).

Results and discussion

Effects of different fertilizer doseson yield attributes of T. aus rice

The number of filled grains, panicle length and 1000-grain weight of T. aus rice was significantly varied by the different fertilizer levels (Table 3). Statistically the maximum filled grains panicle^{-1} was observed in 120% STB of NPZn levels which was followed by 120% STB of N and P levels and the minimum was observed in control treatment. The 120% STB of NPZn levels produced the longest panicle with the highest thousand grain weight and the control treatment produced the shortest panicle with the lowest thousand grain weight (Table 3).

Table 3. Effects of fertilizer doses on yield attributes of T. aus rice at south coastal region of Bangladesh at Dacope, Khulna during 2020-2021.

Treatments	No. of filled grains panicle^{-1}	Panicle length (cm)	1000- grain weight (g)
Control	83.93c	19.10d	19.43c
100% RD (STB)	100.47ab	22.40c	24.30b
120% RD of NPZn (STB)	106.43a	24.33a	27.06a
120% RD of N (STB)	104.17ab	23.66ab	25.26b
120% RD of P (STB)	103.46ab	23.30abc	25.10b
120% RD of Zn (STB)	102.21b	23.10bc	24.96b
CV (%)	4.13	5.88	5.83

Means followed by same letter (s) do not differ significantly at 5% level of significance

Table 4.Effects of fertilizer doses on yield attributes of T. aus rice at south coastal region of Bangladesh at Dacope, Khulna during 2020-2021.

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Control	3.70d	4.83c	43.37
100% RD (STB)	4.76c	6.13b	43.70
120% RD of NPZn (STB)	5.28a	6.89a	43.38
120% RD of N (STB)	5.12ab	6.69a	43.35
120% RD of P (STB)	4.96bc	6.48ab	43.35
120% RD of Zn (STB)	4.93bc	6.43ab	43.39
CV (%)	5.70	6.07	-

Means followed by same letter (s) do not differ significantly at 5% level of significance

The grain and straw yields of T. aus rice was significantly varied by the different fertilizer levels (Table 4). Statistically the highest grain yield was observed in 120% STB of NPZn application and the lowest yield was observed in control treatment. On the other hand, the highest straw yield was observed in 120% STB of NPZn levels whereas the lowest straw yield was observed in control treatment (Table 4).

Effects of different fertilizer doseson yield attributes of T. aman rice

The number of filled grains, panicle length and 1000-grain weight of T. aman rice was significantly varied by the different fertilizer levels (Table 5). Statistically the maximum filled grains panicle^{-1} was observed in 120% STB of NPZn levels and the minimum was observed in control treatment. The 120% STB of NPZn levels produced the longest panicle with the highest thousand grain weight and the control treatment produced the shortest panicle with the lowest thousand grain weight (Table 5).

Table 5. Effects of fertilizer doses on yield attributes of T. aman rice at south coastal region of Bangladesh at Dacope, Khulna during 2020-2021.

Treatments	No. of filled grains $panicle^{-1}$	Panicle length (cm)	1000- grain weight (g)
Control	111.20d	23.66c	19.43c
100% RD (STB)	132.80c	25.76b	24.80b
120% RD of NPZn (STB)	146.73a	28.63a	27.06a
120% RD of N (STB)	139.43b	26.53b	26.40a
120% RD of P (STB)	139.20b	26.40b	25.26b
120% RD of Zn (STB)	136.00bc	25.83b	24.96b
CV (%)	4.44	5.32	4.14

Means followed by same letter (s) do not differ significantly at 5% level of significance

The grain and straw yields of T. aman rice was significantly varied by the different fertilizer levels (Table 6). Statistically the highest grain yield was observed in 120% STB of NPZn application which was followed by 120% STB of N level and the lowest yield was observed in control treatment. On the other hand, the highest straw yield was observed in 120% STB of NPZn levels which was followed by 120% STB of N level whereas the lowest straw yield was observed in control treatment (Table 6).

Table 6.Effects of fertilizer doses on yield attributes of T. aman rice at south coastal region of Bangladesh at Dacope, Khulna during 2020-2021.

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Control	3.77c	4.76c	44.19
100% RD (STB)	4.83b	6.18b	43.86
120% RD of NPZn (STB)	5.44a	6.92a	44.01
120% RD of N (STB)	5.12ab	6.50a	44.06
120% RD of P (STB)	5.02b	6.38b	44.03
120% RD of Zn (STB)	4.96b	6.30b	44.04
CV (%)	4.05	3.90	-

Means followed by same letter (s) do not differ significantly at 5% level of significance

Conclusions

After completion of first year trial it may be summarized that the yield contributing traits, as well as rice yield, performed better in 120% recommended doses of NPZn treated plots than all other treatments. In T.aus-T.aman rice cropping pattern, 120% recommended doses of NPZn prescribed nutrient plots produced the maximum grain and straw yield (In grain 5.28 t/ha and 5.44 t/ha., In straw 6.89 t/ha and 6.92 t/ha) compare to all other treatment combinations.Harvest Index (%) was also better in the same treatment in both T.aus and T.aman rice cultivation. Finally we can say that if there is a deficiency of nitrogen in the saline area then it will drastically reduce the rice yield. Further trial is needed to confirm the above mention findings of the study.

Acknowledgements

All gratefulness is due to the Almighty Allah, who has enabled me to submit this report.I would like to express my deepest sense of gratitude, heartfelt honor and the sincerest appreciation to CSO, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701. Also, I would like express my gratitude to all the field staff thathelps me a lot to collect data in different stages of this experiment. This work was supported by Nutrient Management for Diversified Cropping in Bangladesh (NUMAN) project funded by KGF and ACIAR.

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DEVELOPMENT OF FUNCTIONALIZED BIOCHAR AND THEIR CHARACTERIZATION

M.M. MASUD, A. BARMAN, SHAMIM MIA AND H. M. NASER

Abstract

Fertilizer use efficiency in agricultural systems of Bangladesh is often quite low due to low reactive surfaces of our soils. An increment in soil reactive surfaces can increase nutrient use efficiency while nutrient binding directly to reactive surfaces could further enhance it. Biochar, a pyrolysized biomass, can be used for developing such reactive surface blended fertilizer. In this experiment, biochar enriched fertilizers will be tailored blending function specific biochars with nutrients. To achieve these objectives, we first developed technologies to produce biochar with variable surface charges (positive, neutral and negative). Next, different biochars (pre-doped, post-doped, normal biochar) were produced following the developed methods while normal biochar was modified using chemical with hydrogen peroxide and biological with composting and incubation with soil inoculants and nutrients. The produced biochars were then characterized using Fourier Transform Infrared Spectroscopy (FTIR), cation exchange capacity (CEC), potentiometric charge determination and nutrient concentration analysis. Based on the results, several biochars were selected for biochar enriched N and composite fertilizer preparation. Next, a pre-trial was made to determine the formulation composition using different ratios of biochar, nutrient and additives. The quality (firmness and stability) of the pellets are examined and best mixing ratio was selected.

Introduction

Food security is one of the most stressing challenges for Bangladesh. Because, meeting the increasing food demand for our people from the constrained resources in the context of changing climate means that our agricultural systems must be both more productive and resilient. For maintaining agricultural productivity, efficient resource management, particularly the soil resources (soil nutrients and health) is one of the crying needs for Bangladesh. However, soil health and nutrient management have not been received sufficient attention in the past causing a severe deterioration of soil resources including a declinein soil organic matter and nutritional imbalance. However, the cropping intensity has increased from 153 in 1981 to 194 in 2015 (BBS, 2011 and 2017). As a result, soil productivity is diminishing and thus, compelling the food security under a serious threat, which will definitely be intensified in the near future. Additionally, the cropping intensity is proposed to increase up to 400%, which would create additional pressure on our soils (BRRI, 2017). Therefore, novel technologies are needed for sustaining agricultural productivity while maintaining soil health.

In Bangladesh a considerable amount of urea estimating 2219, 000 tones is used in a year while a part of the cost is subsidized by the government costing over Tk. 4825crore (Economic Review, 2016). Similarly, the government of Bangladesh pays more than Tk. 7150 crore for subsidizing non-urea fertilizers (i.e., phosphorus and potassium). Considering a 50% reduction in loss, government can save the subsidies of Tk. 3000 crore while the farmers could lessen half of the costs for fertilizer purchase. Fertilizer use efficiency in agricultural systems of Bangladesh is often quite low due to low reactive surfaces of our soils. An increment in soil reactive surfaces can increase nutrient use efficiency while nutrient binding directly to reactive surfaces could further enhance it. Biochar, a pyrolysized biomass, can be used for developing such reactive surface blended fertilizer. In this context, biochar enriched fertilizers will be tailored blending function specific biochars with nutrients. We firmly believe that these high performance fertilizers would provide a sustainable mean for increasing fertilizer use efficiency for agricultural crops.

Materials and Methods

Biochar was produced from municipal organic waste at ~450°C for 4 hr using PSTU slow pyrolysis kiln (Mia et al., 2015). The biochar was functionalized using mineral doping before and after pyrolysis. Chemical treatments were carried out in some cases. The treatments of the experiment included-

Pre-doped biochar	Post-doped biochar	Activation
Fe Al Mg Combination of Fe, Al and Mg	Fe Al Mg Combination of Fe, Al and Mg	Chemical activation with H2O2 Biological activation

Quality assessment of biochars

The produced biochar was characterized using advanced chemical and spectroscopic techniques including Fourier transform Infrared (FTIR) spectroscopy, and CEC determination.Potentiometric charge determination is under way. Moreover, we are trying to get our samples analyzed for elemental composition- C, N, H, and O analysis, andScanning Electron Microscope (SEM).

Normal and pre-doped biochar production

For the production of positively charged biochar, biomass (sawdust) was collected from local saw mill and then dried at 105 °C. Next, biomass was loaded with different minerals (Fe, Al, Mg) and their combinations (treatments were listed in the earlier part of the report). The minerals were used at strength of 0.5 M while the biomass to solution ratio was 1:2. The mixture was then dried at 60 °C for overnight. The biomass were then wrapped inside into aluminum foil and placed in the slow pyrolysis kiln (Fig. 2). Biochars were then produced using the method discussed elsewhere (Mia et al. (2015): Pedosphere, 25 (5):696-702). The production rate of biochar was recorded at the end of pyrolysis while the temperature of the pyrolysis kiln was recorded during the pyrolysis process.

Post-doped biochar production

After production of biochar (without any mineral addition), post-doping was performed by adding different minerals at the same strength of pre-doping (i.e., 0.5 M). The biochar to mineral was added at a ratio of 1:2. The produced biochars were then dried at 105°C for 24 h.

Activation of biochar using hydrogen peroxide

Normal biochar was activated using hydrogen peroxide (H2O2) at different concentrations (5, 10 and 15%). The activation was carried out in water batch after adding biochar to H2O2 (1:30) at 80 °C for 6 h(Fig. 3). After oxidation, the excess H2O2 was removed by heating at 120 °C and then washing thoroughly with water. The biochar was then dried at 105°C for 24 h.

Biological activation of biochar

Biochar was activated using soil micro-organisms supplemented with nutrients. First, soil micro-organisms were collected from diverse land use patterns following soil to water extraction ratio of 1:10. Next, biochar was moisten up to 60% field capacity with water containing soil inocula and nutrients. The biochar was then incubated in an incubator for 15 d at alternative temperature of 40/25 °C (Fig. 4).

Data analysis

Spectroscopic data will be analyzed using professional software such as PeakFit and OriginLab. The functional groups and extent of their existence will be examined following the procedure of Mia et al. (2017b).

Result and discaussion

Biochar production

For the production of biochar, we monitored pyrolysis temperature at different residence time. It seems that the temperature increased from ~300 °C at 2 h to 807 °C at 28 h (Fig. 1). The temperature was then decreased gradually to 350 °C at 48 h. From the temperature of pyrolysis kiln, it can be assumed that the quality of the biochar might be good with quite some aromatic carbon. Moreover, we recorded the production of rate of different biochar. As it can be seen in the Table 2, the production of biochar was significantly higher in the mineral loaded treatments (~60%) while it was lowest in the control treatment (~30%). A higher production rate possibly due to a higher metal content in the biomass. Because metal are less prone to loss with heating. Moreover, it is not known yet whether mineral doping can reduce the carbon loss through chemical interactions.

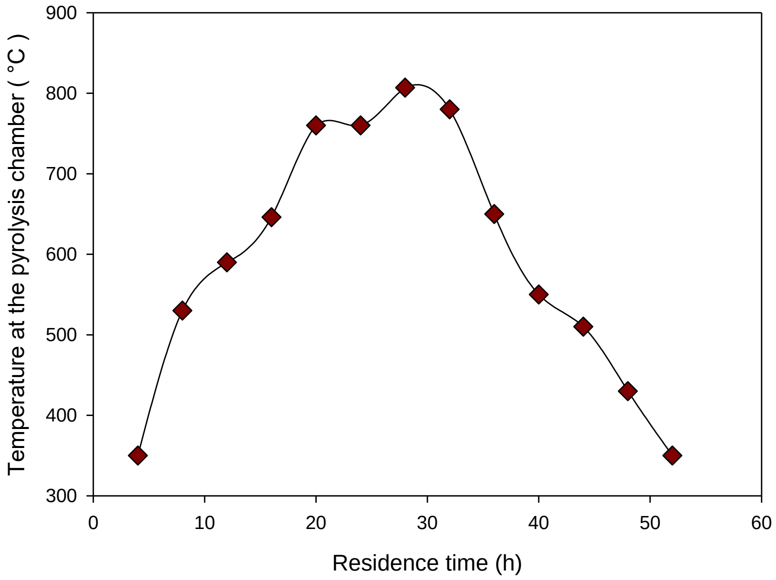

Fig. 1. Pyrolysis temperature of kiln at different residence times.

Table 2. Biochar production rate with different treatments

Treatments	Biochar production rate (% of initial biomass)
Control	29.57±0.48 c
Al-doped biochar	61.53±0.54 a
Fe- doped biochar	64.23±2.83 a
Mg-doped biochar	60.17±1.34 ab
Fe, Al and Mg	53.65±1.93 b

Chemical analysis of biochar

Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldhal method. Cation and anion contents were determined according to the method described by Jones and Case (2018). Specifically, 0.2g dry biochar was taken into a 50 ml boiling flask. An amount of 5 ml di-acid mixture (nitric and perchloric acid ratio=5:1) was added and allow to stand overnight or until the vigorous reaction phase was over. After the preliminary digestion, boiling flask was thenplacedon a hot plate, and then raised temperature to 100 °C for 1 hour and then temperature wasraisedup to 200°C until color change was changed to white. After that, the suspension as cooled and filtered with Whatman no#42. Next the solution was volume up to 30 ml with distill water. The supernatant solution was analyzed forCa, Mg, K, Zn, Fe, Mn, andCu in atomic adsorption spectrophotometer (AAS,Thermo Scientific - SOLAAR S Series AA spectrometer) by takingan aliquot of samples. Boron was determined by CaCl2 extraction method. Phosphorus was determined by Bray and Kurtz method while S was measured by turbidimetric method with BaCl2in spectrophotometer (Agiland Technologies, cary 60 UV-Vis).

The results of nutrient concentration analysis are presented in Table 5 while statistical analysis of the samples (partial) is included in Table 6. As expected, the negative surface charge and CEC of doped biochar was relatively low while these are high the chemically and biologically oxidized biochars. Based on the properties, positively charged and negatively charged biochars were selected.

Table 5. Chemical composition of different type of Biochar

Biochar	OC	Ca	Mg	K	N	P	S	B	Cu	Fe	Mn	Zn
	%											
Fe- doped biochar (pre- pyrolysis)	36.6	5.1	2.8	0.52	0.50	0.34	0.14	0.06	0.012	0.040	0.010	0.010
Fe- doped biochar (post- pyrolysis)	35.3	5.1	2.7	0.42	0.49	0.18	0.12	0.07	0.012	0.039	0.019	0.010
Al- doped biochar (pre- pyrolysis)	31.5	3.5	1.8	0.53	0.56	0.11	0.29	0.04	0.011	0.041	0.017	0.010
Al- doped biochar (post- pyrolysis)	45.1	3.7	2.0	0.43	0.53	0.12	0.76	0.04	0.011	0.042	0.015	0.011
Mg- doped biochar (pre- pyrolysis)	44.0	5.6	3.0	0.62	0.59	0.11	0.79	0.04	0.011	0.042	0.012	0.010
Mg- doped biochar (post- pyrolysis)	42.2	3.9	2.1	0.60	0.52	0.15	0.30	0.04	0.011	0.019	0.016	0.011
Fe Al Mg doped (pre- pyrolysis)	34.2	3.9	2.1	0.53	0.5	0.11	0.10	0.05	0.010	0.040	0.015	0.017
Fe Al Mg doped (post- pyrolysis)	40.6	4.2	2.2	0.40	0.55	0.13	0.10	0.04	0.012	0.041	0.014	0.011
Activated with co-composting	56.0	2.1	1.1	0.74	0.91	0.25	0.33	0.05	0.014	0.026	0.015	0.010
Activation with H_2O_2 (post- pyrolysis)	57.5	3.5	1.9	0.40	0.70	0.17	0.49	0.05	0.012	0.042	0.019	0.017
Biologically activated biochars	53.8	2.1	1.1	0.47	0.70	0.22	0.20	0.05	0.013	0.021	0.019	0.010
Fresh Biochar	50.5	6.1	3.2	0.68	0.61	0.13	0.08	0.05	0.010	0.038	0.018	0.010

Biochar quality assessment

The spectra of different FTIR spectra were shown in the figures 2-4. It can be seen the spectra that there significant differences in transmission signal of different biochars. Further analysis are required to understand the difference in peak area under different spectra (Table 3).

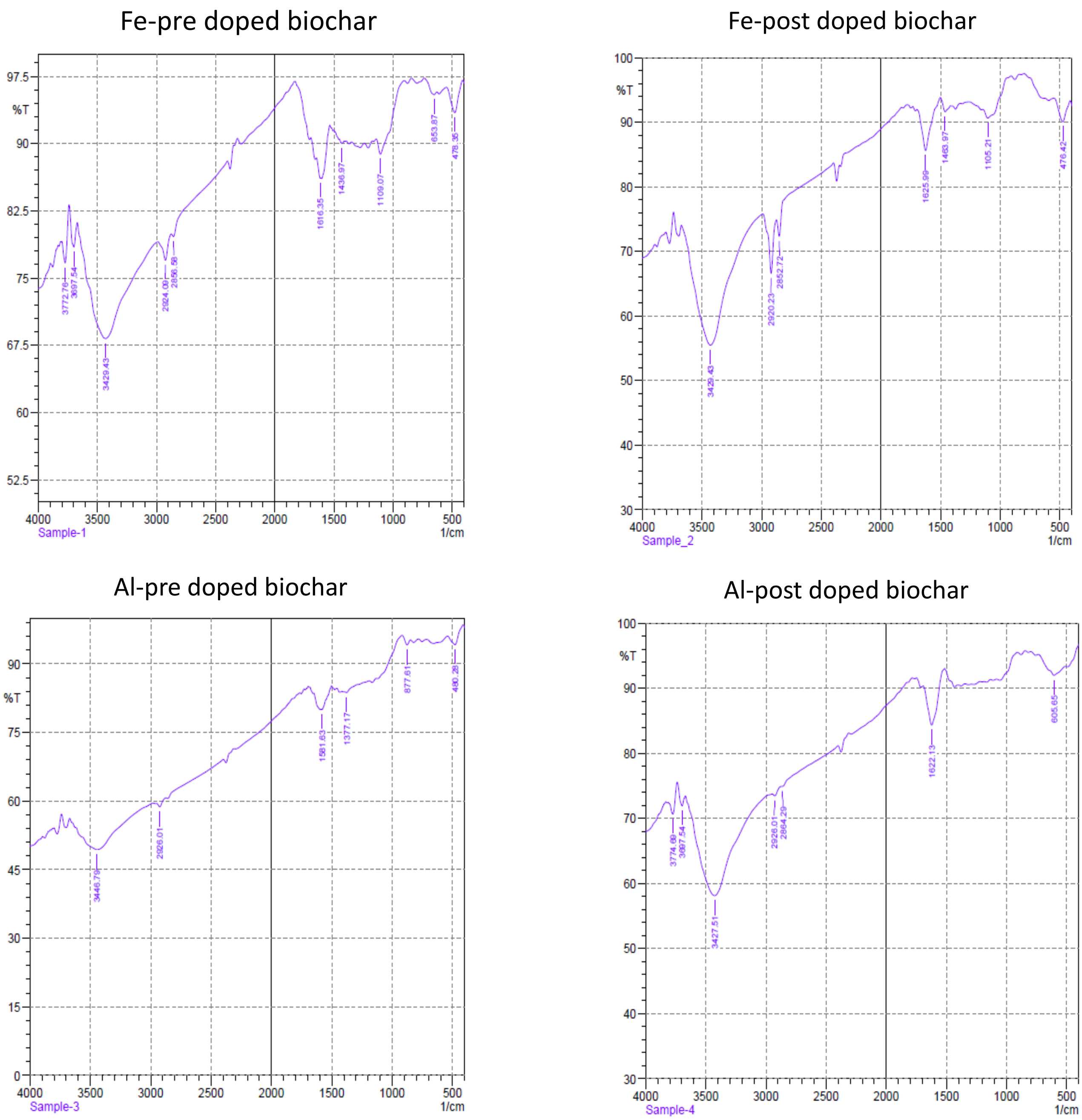

Fig. 2. Spectra of FTIR analysis of different biochar samples

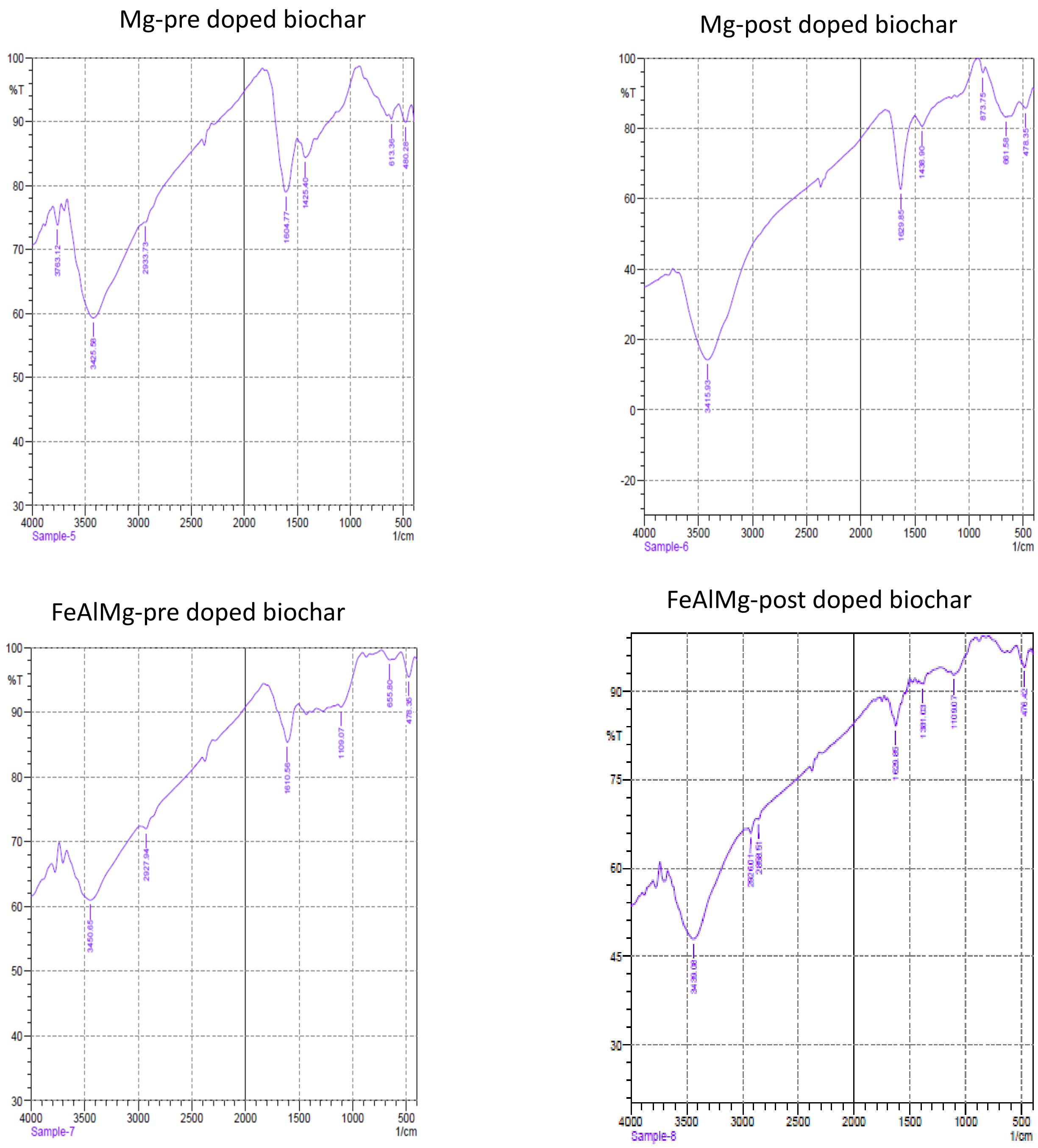

Fig. 3. Spectra of FTIR analysis of different biochar samples

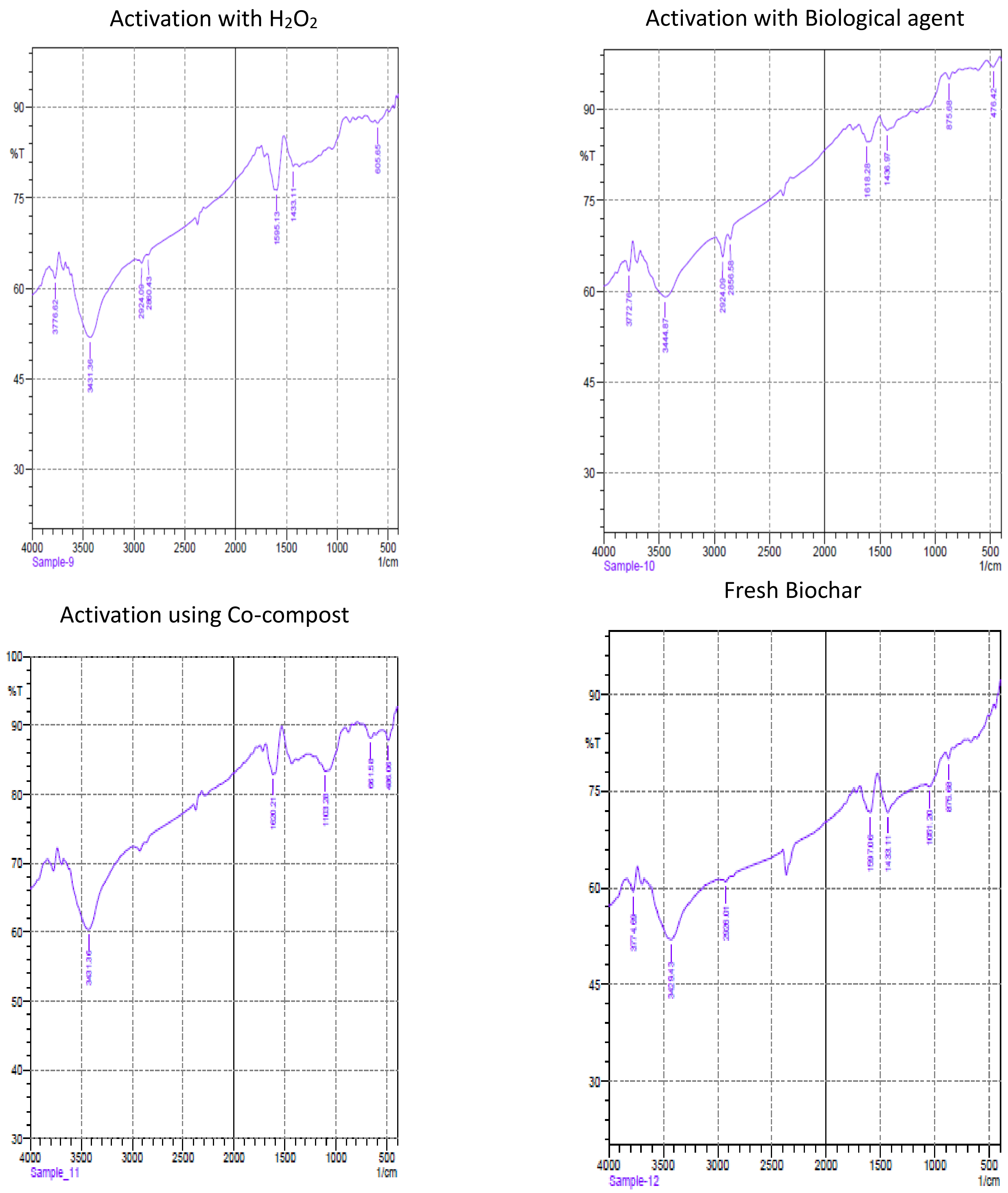

Fig. 4. Spectra of FTIR analysis of different biochar samples

Functional groups in different biochars

The FT-IR spectra of fresh biochar (FBC), oxidized biochar (OBC) and doped biochar (DBC) and the variation in surface functional groups are displayed in Fig. 2-4. For fresh biochar, prior to any treatment, peaks at frequencies 3400 to 3800 cm-1, 1597 cm-1, 1051 cm-1, and, were ascribed to the vibration of hydroxyl, carbonyl and carboxyl groups respectively. Band within 700-900 cm-1 were considered as aromatic C-H out of plane. For doped biochar, peaks at frequencies of 3450 cm-1 and 1610 cm-1 were corresponded to -OH stretching and vibrations of hydrogen-bonded groups, while peaks at 2927 cm-1 were attributable to –CH2 stretching aliphatic functional groups, and peaks at 1109 cm-1 were attributable to C-O stretching vibrations. Moreover, the bond between 400 and 700 cm-1 in the modified biochars were assigned to Mg, Al-O vibrations by other researcher, while peak at frequencies around 478 cm-1 and 3450 cm-1 could be the stretching vibration of Mg-OH. It is also suggested that, the bending vibration at 655 cm-1 could be the bond between Fe-O. The relative peak area of each spectra is presented in table 4. It can be seen that there are clear signal for impregnation of mineral in the biochar when loaded with minerals.

Table 4: Peak assignment and relative peak area of different biochar composites

Functional Group	**FBC**		**OBC**		**DBC**		**References**
	Peak	**Area (%)**	**Peak**	**Area (%)**	**Peak**	**Area (%)**	
Aromatic C-H out of plane, Mg/Al/Fe-O bonding and Mg-OH stretching	875.68	2.2	605.65	2.3	478.35 655.8	1.2 0.5	Jung et al., 2017; Pentrák et al., 2018; Wu et al., 2015; Yin et al., 2018; Yang et al., 2022
C-O stretching	1051.2	7.5			1109.07	4.4	Arbelaez et al., 2021; Yin et al., 2018
-COOH stretching	1433.1	17.0	1433.1	3.5			Chun et al., 2004
Aromatic C=C, C=O, H-O-H stretching and –OH groups	1597.0	4.0	1595.1	2.9	1610.56	10.6	Shen et al., 2014; Arbelaez et al., 2021
C-H stretching			2860.4	28.2			Singh et al., 2016
$-CH_2$ stretching	2926.0	6.1	2924.0	5.2	2927.94	50.2	Yin et al., 2020
Mg–OH stretching, -OH groups	3429.4 3774.6	57.1 6.1	3431.3 3776.6	53.3 4.6	3450.65	33.0	Ahangaran et al., 2013; Kirmizakis et al., 2022

*FBC=fresh biochar; OBC=oxidized biochar; DBC=doped biochar

Acknowledgements

All gratefulness is due to the Almighty Allah, who has enabled me to submit this report.I would like to express my deepest sense of gratitude, heartfelt honor and the sincerest appreciation to PSTU and BARI. Also, I would like express my gratitude to all the field staff thathelps me a lot to collect data in different stages of this experiment. This work was supported by KGF.

MODELING CLIMATE CHANGE IMPACT ON AGRICULTURE AND DEVELOPING MITIGATION AND ADAPTATION STRATEGIES FOR SUSTAINING AGRICULTURAL PRODUCTION IN BANGLADESH

S. Akhter, R. Sen, M. Haque

Progress Summary

Climate change is a concern for future agriculture in Bangladesh. Frequencies of extreme climate events are increasing and damaging agricultural sectors severely. It requires understanding such events and mapping out the risks and impact of climate change (CC) on agriculture, nature and extent of climate variability/CC and vulnerability of crops and natural resources for adaptation. The "Modeling Climate Change Impact on Agriculture and developing mitigation and adaptation strategies for sustaining agricultural production in Bangladesh "(MCCA) project is working on this aspect which is being funded by KGF, Bangladesh. A group of scientists from BARI, BRRI, and BSMRAU together with KGF were involved in implementing the activities of CRP-II of KGF for three years (2015-2018). Now, this project was extended from December 2020-November 2023 as the 2nd phase. It is a collaborative project involving two NARS Institutes including BARC, BARI and BRRI; two universities including BAU and BSMRAU. The KGF funding project MCCA is being coordinated by BARC. Soil Science Division, BARI leads the Objective -4 of the project. Under this objective, some activities were done to fulfil the objectives.

Introduction

Realizing the importance of accelerating and strengthening research and scientific studies on Climate change (CC) and its variability impacts on Bangladesh agriculture, KGF initiated multi-stakeholder consultations and trained about 120 professionals on various aspects of CC for research on CC impacts on crops and soils in first phase as CRP-II project of KGF. The project was initiated from July 2015 for three years (. Four organizations- BARI, BRRI, BSMRAU and KGF were involved in implementing pre-proposal activities, which mainly included climatic variability/future climate change characterization, effects on growth and yield of crops through use of DSSAT and INFOCROP, adaptation and mitigation options for agriculture sustenance. Measurement of GHG emissions from rice and non-rice crops were initiated at Gazipur but need to be extended for other parts of the country for making inventory of GHG emissions. GHG emissions from other agricultural sectors also need to be determined. The project will help in evaluating the impact on soil-crop-fish-livestock processes, vulnerability assessment, and mitigation and adaptation strategies to be adopted for sustainable agriculture. The project is inter-institutional, inter-disciplinary and deals with both research and teaching aspects. The major objectives are climatic variability/CC characterization, impact of climatic variations on soil and crop processes along with fish and aquaculture and livestock and poultry for sustaining growth and development under changing climate. The project will prepare the group of scientists using advanced tools like simulation models, machine learning, R program, GIS and remote sensing for CC impacts studies. The knowledge gained will also help the group to use these tools for yield forecasting, NRM, soil health service and agro-advisory platforms.

Keeping this in mind, Soil Science Division, BARI was assigned with some activities to fulfil the project objectives. The Soil Science Division, BARI is responsible for **Objective 4.** Mitigation/adaptation strategies for agri-production in relation to climate change.

Materials and Methods

The 2nd phase of the MCCA project was started from rabi season, 2020. Under Objective-IV, the technical coefficients is to be generated for GHGs emission for rice-based cropping systems throughout Bangladesh and identifying suitable management options to reduce the GHGs emission for entire Bangladesh. So, we conducted need based field experiments in various ecological zones and ongoing trials on crops and cropping pattern. Three experiments were conducted to estimate the emission of CO_2 and N_2O at different growth stages of maize, wheat and potato as influenced by nitrogen fertilizer application and to find out the suitable form of N fertilizer application for minimizing greenhouse gas emission for maize (BARI Hybrid Maize 9), wheat (variety- BARI Gom 30) and Potato (BARI Alu 25) cultivation *during the* rabi season of 2021-2022. The experiments were conducted at the Bangladesh Agricultural Research Institute (BARI), Joydebpur (24°00′ N, 90°25′ E and 8.4 m elev.). Joydebpur soil belongs to the Chhiata series of Grey Terrace Soil (Inceptisol; AEZ-28) (FRG- 2018). The experiments were laid out in a randomized complete block design (RCBD) with four treatments replicated three times. The treatments were: T_1= Native fertility, T_2 = 100% RDCF (N applied as prilled urea), T_3 = 100% RDCF (NPK briquette), T_4 =100% RDCF (N applied as USG). The rate of USG or Urea briquette and NPK briquette was 10 percent less than the rate of recommended prilled urea. The recommended fertilizer doses were used to supply N, P, K, S, Zn and B from Urea, TSP, MoP, gypsum, zinc sulphate (hepta) and boric acid, respectively. The unit plot size was 4m x 2.5m. The potato and wheat seed was sown on 27 December 2021 and maize was sown on 28 December, 2021. Harvest of potato was done on 31 March, 2022, wheat on 3 April, 2022 and maize on 19 May, 2022.

For prilled urea (T_2 treatment), all PKSZnB and $2/3^{rd}$ N was applied at the time of final land preparation. In case of USG and NPK briquette, the sizes of USG and NPK briquette were 1.8 g and 2.4 g, respectively. The USG and NPK briquettes were placed at 8-10 cm depth between four hills at alternate rows manually in respective treatments. Different intercultural operations such as irrigation, weeding, pest control, etc. were done as and when required. The USG, NPK briquette and first split of PU were applied at CRI stage of wheat.

Gas sampling and analysis

Static closed-chamber method (Ali *et al.*, 2009; Haque *et al.*, 2013, 2015b, 2015c) was used to estimate CO_2, and N_2O emission rates during maize, wheat and potato season. In acrylic column chambers which have diameter 20 cm and height 20 cm were placed inner plant excluded soil surface between maize, wheat and potato plants for evaluating heterotrophic respiration rates (CO_2 emission) and N_2O emission during maize, wheat and potato season (Lou *et al.*, 2004; Xiao *et al.*, 2005; Iqbal *et al.*, 2008; Haque *et al.*, 2015b). The bottom 20 cm of chamber was interred inner soil to prevent plant root intrusion, and weeds inner the chamber were continually removed to minimize plant CO_2 uptake loss during the investigation. All chambers were kept open throughout the investigation period except during the gas sampling in the experimental fields. The chamber was equipped with a circulating fan for gas mixing and a thermometer inside to monitor the temperature during the sampling time.

Air gas samples were collected using 50 mL gas-tight syringes at 0 and 30 min after chamber placement. Gas samplings were carried out at three times (8:00–12:00–16:00) in a day to get the average GHGs emission rates. Three gas samples in each replicate of each treatment were then drawn off from the chamber headspace equipped with 3-way stop cock. Collected gas samples were immediately transferred into 20-ml air-evacuated glass vials sealed with a butyl rubber septum for gas analysis.

Two GHGs concentrations in the collected air samples were measured by Gas Chromatography (Shimadzu, GC-2014, Japan) with Porapak NQ column (Q 80–100 mesh). A thermal conductivity detector (TCD) and ^{63}Ni electron capture detector (ECD) were used for quantifying CO_2 and N_2O concentration, respectively. The temperatures of the column, injector and detector were adjusted at 45, 75, and 270°C for CO_2, and 70, 80, and 320°C for N_2O, respectively. Argon, Helium and H_2 gases were used as the carrier and burning gases, respectively.

Carbon dioxide and N_2O emission rates were calculated from the increase in CO_2 and N_2O concentrations per unit surface area of the chamber for a specific time interval. A closed-chamber equation (Lou *et al*., 2004) was used to estimate seasonal fluxes from each treatment.

$$F = \rho \times (V/A) \times (\Delta c/\Delta t) \times (273/T)$$

where, F is the CO_2 (mg m^{-2} hr^{-1}), and N_2O flux (μg N_2O m^{-2} hr^{-1}), ρ is the gas density of CO_2, and N_2O under a standardized state (mg cm^{-3}), V is the volume of chamber (m^3), A is the surface area of chamber (m^2), $\Delta c/\Delta t$ is the rate of increase of CO_2, and N_2O gas concentrations in the chamber (mg m^{-3} hr^{-1}) and T (absolute temperature) is 273 + mean temperature in (°C) of the chamber.The seasonal CO_2, and N_2O flux for the entire crop period was computed as reported by Singh et al. (1999):

Seasonal CO_2 and N_2O flux = $\sum_i^n (R_i \times D_i)$

Where R_i is the rate of CO_2 and N_2O flux (g m^{-2} d^{-1}) in the *i*th sampling interval, D_i is the number of days in the *i* th sampling interval, and *n* the number of sampling.

RESULTS AND DISCUSSIONS

Greenhouse gas emission BARI farm at Gazipur

Nitrous oxide emissions

During the study period, NPK briquette and prilled urea showed higher total N_2O flux than USG urea fertilization plot during maize, wheat and potato cultivations (Table 1).

Table 1. Total N_2O (g ha^{-1}) flux during maize, wheat and potato cultivations fertilized with prilled urea, NPK briquette and USG

Crops	Fertilizer application			
	Prilled urea	USG	NPK briquette	Control
	Total N_2O (g ha^{-1})			
Potato	361	304	393	254
Maize	415	400	420	280
Wheat	420	411	446	290

Determination of CO_2 under Maize, Wheat and Potato and gas from other experiments are under process.

Conclusion

NPK briquette and prilled urea showed the highest peak than USG urea fertilization plot during maize, wheat and potato cultivations. Nitrous oxide emission rates were significantly increased by additional N fertilization during crop growing stage. In long term experiment in BSMRAU, Carbon contents and stocks were found higher in the compost treated plot compared to other treatments. Application of N at higher rates significantly decreased soil C which emphasized optimization and judicial supply of N as per crop requirements.

Acknowledgement: The authors gratefully acknowledge the funding from “Krishi Gobeshona Foundation (KGF)” of Ministry of Agriculture, The Peoples Republic of Bangladesh through "Modeling climate change impact on agriculture and developing mitigation and adaptation strategies for sustaining agricultural production in Bangladesh" project (CRP-II) and BARI authority for partial funding and continuous support.

Funding: The research is funding by CRP-II of Krishi Gobeshona Foundation (KGF) and Bangladesh Agricultural Research Institute (BARI), Gazipur

VALIDATION OF CROP INTENSIFICATION TECHNOLOGIES FOR IMPROVING SYSTEM PRODUCTIVITY, SOIL HEALTH AND FARM INCOME IN SOUTH CENTRAL COASTAL REGION.

S. AKHTER, F. ALAM AND A. BARMAN

Abstract

This coordinated project of NATP-2 (PBRG 051) was implemented jointly by Soil Science Division (SSD) and Oilseed Research Center (ORC), Bangladesh Agricultural Research Institute (BARI) collaborated with Agrarian Research Foundation (ARF) component started from January, 2019. Three components were conducted research on validation of crop intensification of three major cropping pattern in which two cropping pattern were executed in Goplalganj (Goplalganj Sadar, Kasheani upazilla), Madaripur (Madaripur sadar, Kalkini upazilla), Pirojpur (Pirojpur Sadar, Vandaria), and another one pattern was executed in Barishal (Babugonj, Gouronodi), Bagerhat (Bagerhat sadar, Mollarhat) and Jhalakati (Jhalakati Sadar, Rajapur upazilla) for the target of improving system productivity, soil health and farm income.The baseline survey was completed for existing crops practiced by the local farmers. After baseline survey, three crop based cropping pattern were introduced like Mustard-Mungbean-T.aman and Kheshari-Gimakolmi-T.aman at Goplalganj, Madaripur and Pirojpur region against the existing two or single crop based cropping pattern like Rabi-Jute-Fallow or Rabi-Fallow-T.aman or Rabi-Boro-Fallow or Boro-Fallow-Fallow. In Barishal, Bagerhat and Jhalakati location, the cropping pattern was Sweet gourd-Sesame-T. aman. By June 2022, the Soil Science Division, BARI component conducted experiments starting with the mungbean and gimakolmi crops in Kharif-1 season and harvested with good yield. From the first and second year trial, it was observed that IPNS based fertilizer application performed better than farmers practice with BARI Gimakolmi-1 yield 15% higher than local varieties. Among the mungbean varieties, BARI-Mung-6 yield better than BINA Mung-8 and BARI Mung-8. The second crop T. aman in both the cropping pattern was transplanted in last week of July 2019 and harvested at full maturity in October 2019. Among the three T. aman rice varieties, the variety BRRI dhan71 resulted better than BRRI dhan57, and BRRI dhan75 in all fertilizer levels. Among the three Mustard varieties, the variety BRRI mustard-17 resulted better than others variety and among the three khesari, Till and sweet gourd variety BARI Khesari-3, BARI Till-3 and BARI Hybried mistikumra-3 resulted better than others variety in all fertilizer levels. Highest total rice (system) yield of was obtained from IPNS based fertilizer management. Also highest gross margin and BCR were obtained from IPNS based fertilizer management.

Introduction

Coastal agriculture relies heavily on rainfall and tidal water. Irrigation remains scarce. Rainfall is becoming more erratic probably because of climate change. Climatic and hydrological conditions constrain intensive agricultural production in the south-central coastal regions. With highest poverty incidence this region has the lowest cropping intensity. Tidal flooding submerges lands for an extended period during monsoon; and drought and salinity make crop growing in dry season difficult after aman rice harvest. Sea level rise due to climate change is predicted to worsen flooding and salinity problems. Technologies generated for irrigated crop production in the northern districts are not generally suitable for coastal region. In absence of appropriate HYVs, farmers use mostly local rice varieties in aman season. Vegetables are in short supply while most land remains fallow during post-rice dry season. Crop production in medium low land (MLL) and medium high land(MHL) is vulnerable to tidal submergence for 4-5 months annually. The duration of submergence is predicted to be extended in future as the time of overflowing river banks is gradually advancing due to sea level rise. Open water fishery is widely practiced but the yield is low and unpredictable. Farmers very often convert their low lying cultivated land into woodland following ditch and dyke system. Normally ditches are not used for any productive purpose. Ditch and dyke system can be further improved introducing vegetables and quick growing fruits on the dyke and fish spp. in the ditch. Alternatively, medium high- and medium lowland can be converted to pond and a parcel of raised to grow HYV rice and vegetables on the raised bed and fish in the pond. The major driver of farmers' economic development in the southern coastal region is agricultural production since agriculture is the source of income. However, biophysical and environmental factors are the major barriers in increasing agricultural production and crop productivity (Poulton and Rowson, 2011) as the region is fraught with low productivity trap (Hamid, 2010). Hamid *et al* (2015) showed how tidal flooding prohibits growing and expanding high yielding rice varieties in the southern districts. Poulton (2011) analyzed the climatic conditions in the coastal regions that act as barriers for expanding production in the dry season. Consequential upon the biophysical and socio-economic factors, greater segment of cultivable land remains fallow in Barishal, Jhalakati, and Pirojpur districts during dry season.Despite adverse soil physical and hydrological conditions constraining dry season cropping (Hamid, 2010). With the rising temperature and predicted sea level rise, southern delta will get warmer rendering more difficulty in growing cool season crops like wheat, chickpea (Islam and Peterson, 2009). Poulton and Rawson (2011) suggested that on the basis of daily radiation alone, ignoring temperature differences, the southern coastal zones might have higher potential biomass production and yield than the north. Rahman and Kazal (2015) explained socio-economic factors contributing crop diversity particularly expansion of pulses production. Recent data (BBS, 2017) on area and production show upward trend of pulses crops in general but the reality seems to be in contrary. This controversy over production figures needs to be resolved through participatory research and socio-economic surveys. BARC survey (2011) showed that the cropping intensity in the southern districts is lowest in the country. Xenarios *et al*. (2014) report that the flood prone upazilas of the Barishal region in South Bangladesh lack transportation, agricultural education and health infrastructure on a regional level and suggested introduction of cash crops and the improvement of market conditions in agriculture. Rahman and Kazal (2015) suggested growing cash crops and developing infrastructure for improving farm income and livelihood of farmers. However, biophysical and socioeconomic factors constraining agricultural production in the tidal floodplain has not been adequately described or analyzed and hence it is proposing to conduct a baseline survey to generate information on socio-economic conditions of farmers; evaluate physical factors constraining crop production both in wet season and post-rice dry season. The main objectives of this experiment are: 1/ To develop integrated nutrient management packages for high yielding oilseed, pulses vegetables varieties under climate vulnerable area of south central coastal region. 2/ To monitor the changes in physico-chemical properties of soils under climate vulnerable area of south central coastal region. And 3/ To asses soil microbial populations and their seasonal variation from the crop intensification under the changing climate.

Materials and Methods

Activity-1: Benchmark status of the physio-chemical properties and microbial population of soils in South Central Coastal Region.

Baseline survey on the physio-chemical properties and microbial population of soils in Goplalganj (Jalalabad, Sadar and Kashiani) and Barishal (Gouronodi and Babugang) were conducted. About 12 soil sampleeach from Goplalganj (Jalalabad, Sadar and Kashiani) and 20 soil sample each from Barishal (Gouronodi and Babugang) were collected from cultivable land (0-15 cm layer) and analyzed.Summary of soil nutrient status of Goplalganj (Jalalabad, Sadar and Kashiani) and Barishal (Gouronodi and Babugang) has been mentioned in Tables 1 to 4.

Results:

Table 1a. Banchmark survey of soil physical properties and microbial population of Sadar upazilla Gopalganj

Property	Minimum	Maximum	Mean
%Sand	2	8	4
%Silt	23	31	27
%Clay	65	73	69
Moisture (%)	14.12	27.23	19.95
Rhizobium Population g^{-1} soil	5.0×10^2	$1.0\text{x}10^5$	5.0×10^3
PSB Population g^{-1} soil	$5.0\text{x}10^2$	1.0×10^5	2.5×10^3
Azotobacter Population g^{-1} soil	$1.0\text{x}10^4$	3.0×10^5	2.0×10^4

Table 1b.Banchmark survey of soil chemical properties of Sadar upazilla Gopalganj

Property	Minimum	Maximum	Mean
pH	7.3	8.4	7.9
OM (%)	0.7	2.8	1.48
Total N (%)	0.04	0.10	0.07
Ca (meq $100g^{-1}$)	10.1	27.2	18.7
Mg (meq $100g^{-1}$)	2.0	8.2	2.4
K (meq $100g^{-1}$)	0.2	0.7	0.4
P ($\mu g\ g^{-1}$)	2.00	28.00	12.2
S ($\mu g\ g^{-1}$)	19.00	35.00	26.4
B ($\mu g\ g^{-1}$)	0.04	0.42	0.19
Zn ($\mu g\ g^{-1}$)	0.01	5.48	1.76

All soils of Gopalganj Sadar are alkaline. Moisture content ranging from 14.12%-27.23%.Soils are low in nitrogen content (Table 1a & 1b).

Table 2a.Banchmark survey of soil physical properties and microbial population of kashiani upazilla Gopalganj

Property	Minimum	Maximum	Mean
%Sand	3	5	3.8
%Silt	27	35	28
%Clay	60	71	67
Moisture (%)	13.83	25.97	18.45
Rhizobium Population g^{-1} soil	5.0×10^2	$5.0\text{x}10^4$	2.0×10^3
PSB Population g^{-1} soil	$1.1\text{x}10^4$	1.0×10^5	3.0×10^4
Azotobacter Population g^{-1} soil	$5.0\text{x}10^3$	2.0×10^5	3.5×10^4

Table 2b. Banchmark survey of soil chemical properties of kashiani upazilla Gopalganj

Property	Minimum	Maximum	Mean
pH	7.1	8.6	7.7
OM (%)	0.2	1.7	1.18
Total N (%)	0.02	0.07	0.05
Ca (meq $100g^{-1}$)	9.9	23.8	17.8
Mg (meq $100g^{-1}$)	2.1	6.5	4.1
K (meq $100g^{-1}$)	0.1	1.2	0.6
P ($\mu g\ g^{-1}$)	3.00	42.00	17.6
S ($\mu g\ g^{-1}$)	25.00	43.00	29.8
B ($\mu g\ g^{-1}$)	0.06	0.68	0.34
Zn ($\mu g\ g^{-1}$)	0.72	3.81	1.97

All soils of kashiani upazilla Gopalganj are alkaline. Moisture content ranging from 13.83%-25.97%.Soils are low in nitrogen content (Table 2a &2b).

Table 3a.Banchmark survey of soil physical properties and microbial population of Babuganj upazilla Barisal

Property	Minimum	Maximum	Mean
%Sand	7	12	9.4
%Silt	45	53	48
%Clay	34	41	37
Moisture (%)	12.23	27.15	17.25
Rhizobium Population g^{-1} soil	1.0×10^{2}	$1.0x10^{5}$	5.0×10^{3}
PSB Population g^{-1} soil	$2.0x10^{4}$	5.5×10^{5}	5.5×10^{4}
Azotobacter Population g^{-1} soil	$1.0x10^{4}$	7.5×10^{5}	6.5×10^{4}

Table 3b. Banchmark survey of soil chemical properties of Babuganj upazilla Barisal

Property	Minimum	Maximum	Mean
pH	6.4	8.4	7.4
OM (%)	1.6	2.1	1.8
Total N (%)	0.07	0.12	0.09
Ca (meq $100g^{-1}$)	4.4	16.6	12.9
Mg (meq $100g^{-1}$)	1.5	4.4	3.1
K (meq $100g^{-1}$)	0.1	0.3	0.2
P ($\mu g\ g^{-1}$)	4.00	17.00	10
S ($\mu g\ g^{-1}$)	22.00	52.00	33
B ($\mu g\ g^{-1}$)	0.1	1.0	0.5
Zn ($\mu g\ g^{-1}$)	0.4	0.9	0.6

All soils of Babuganj upazilla Barisal are alkaline. Moisture content ranging from 12.23%-27.15%.Soils are low in nitrogen content (Table 3a &3b).

Table 4a.Banchmark survey of soil physical properties and microbial population of Gouranodi upazilla Barisal

Property	Minimum	Maximum	Mean
%Sand	8	14	11
%Silt	48	56	50
%Clay	35	42	38
Moisture (%)	11.36	28.02	16.82
Rhizobium Population g^{-1} soil	1.5×10^{2}	$1.5x10^{4}$	5.0×10^{2}
PSB Population g^{-1} soil	$1.5x10^{4}$	1.0×10^{5}	5.0×10^{4}
Azotobacter Population g^{-1} soil	$2.5x10^{4}$	2.0×10^{5}	2.5×10^{4}

Table 4b. Banchmark survey of soil chemical properties of Gouranadi upazilla Barisal

Property	Minimum	Maximum	Mean
pH	6.2	8.6	7.5
OM (%)	0.6	2.8	1.9
Total N (%)	0.04	0.15	0.07
Ca (meq $100g^{-1}$)	6.7	25.8	15.2
Mg (meq $100g^{-1}$)	1.4	7.1	3.7
K (meq $100g^{-1}$)	0.1	0.4	0.2
P ($\mu g\ g^{-1}$)	4.00	60.00	13
S ($\mu g\ g^{-1}$)	13.00	54.00	37
B ($\mu g\ g^{-1}$)	0.02	0.70	0.35
Zn ($\mu g\ g^{-1}$)	0.2	2.1	0.8

All soils of Gouranodi upazilla Barisal are alkaline. Moisture content ranging from 11.36%-28.02%.Soils are low in nitrogen content (Table 4a & 4b).

Activity-2: Varietal intensification and integrated plant nutrition systems on Mustard-Mungbean-T. *aman* cropping pattern in South Central Coastal Region of Bangladesh.

Objective:

1. To find out varietal performance of mustard to increase oilseed production, farm productivity and income generation in south central coastal regions.
2. To find out judicious fertilizer recommendation for Mustard-Mungbean-T.*aman*cropping pattern and monitoring soil health

This field trial has been conducted in High Ganges Floodplain Soils (AEZ-11) of Gopalgonj Sadar and Kasheani during 2019. A description of nutrient status of initial soils prior to fertilization has been presented in Table 1. This cropping cycle was started from the second crop mungbean. After harvest, T.aman rice was transplanted in both the locations.

Table 5. Initial soil chemical properties of experimental plots of Kasheani and Gopalgonj Sadar upazila

Soil parameters	Kasheani	Gopalgonj Sadar	Critical level
pH	7.28	8.47	-
Organic matter (%)	2.00	1.79	-
Total N (%)	0.105	0.094	-
Exchangeable Ca (meq 100^{-1} g)	6.10	6.00	2.00
Exchangeable Mg (meq 100^{-1} g)	2.10	2.10	0.50
Exchangeable K (meq 100^{-1} g)	0.19	0.20	0.12
Available P (μg g^{-1})	37.0	44.0	10.0
Available Zn (μg g^{-1})	0.65	0.70	0.60
Available B (μg g^{-1})	0.18	0.19	0.20
Available Cu (μg g^{-1})	2.80	3.00	0.20
Available Fe (μg g^{-1})	79.0	101.0	4.00
Available S (μg g^{-1})	22.5	14.4	10.0

The experiment was laid out in a randomized complete block design with three replications. There were three crop varieties and three fertilizer levels which consisted of nine treatments. The treatments were as follows:

A. Crop variety: 3

Mungbean	T.aman	Mustard
T_1 = BARI Mung-6	BRRIdhan 57	BARI Sarisha-11
T_2 = BARI Mung-8	BRRIdhan 71	BARI Sarisha-14
T_3 = BINA Mung-8	BRRIdhan 75	BARI Sarisha-17

B. Fertilizer : 3 level

F_1 = Recommended Fertilizer Dose (RFD) from inorganic source on STB (FRG'2018)
F_2 = RFD on STB + 5 t ha^{-1} cowdung (IPNS approach)
F_3 = Farmers practices

Recommended dose of fertilizer for the mungbean was N_{24} P_{12} K_{24} S_{12} Zn_2 B_2 kg ha^{-1}. Urea, TSP, MoP, gypsum, Zinc sulphate, boric acid were used as a source of N, P, K, S, Zn and B, respectively. All PKSZnB was applied as basal during final land preparation. Cowdung@ 5 t ha^{-1} was applied as treatment only. All the intercultural operations such as irrigation, weeding, insect control etc were done as and when necessary. The mungbean seeds were sown in 17 March and 19 March, 2019 in Gopalgonj Sadar and Kasheani, respectively. The first picking was started on 20 May, 2019 and continued up to 7 June, 2019 in Gopalgonj Sadar. In case of Kasheani, the first picking was started on 21 May, 2019 and continued up to 7 June, 2019. The same sequence was maintained in T.aman rice for fertilizer treatments. Recommended dose of fertilizer for the T.aman was N_{90} P_{10} K_{50} S_5 Zn_1kg ha^{-1}. The entire quantity of PKSZn (as per STB), was applied during the final land preparation. Nitrogen was applied in three equal splits at seedling establishment stage 5-7 day after transplanting (DAT), active tillering stage (25-30 DAT) and 5-7 days before panicle initiation stage (45-50 DAT). The seedlings of three varieties of T.aman rice were transplanted in row to row 25 cm and hill to hill 15 cm spacing in 27 July and 28 July, 2019 in Gopalgonj Sadar and Kasheani, respectively and harvested 02 October and 01October, 2019, respectively in Gopalgonj Sadar and Kasheani. Records on some yield parameters were taken at certain growth stages of all the crops of the pattern. Data were analyzed by ANOVA (using MSTAT 10) to evaluate differences between treatments, and the means were separated using least significant difference (LSD) at the 5% level of significance ($p<0.05$). After T. aman harvest. Mustard was sown on 15 November 2019 and the crops are in the field.

Results:

Mustard-Mungbean-T.*aman* cropping pattern

Table 6.Average yield, rice equivalent yield, total rice (system) yield, gross margin and BCR of Mustard-Mungbean-T.aman cropping pattern at sadar and kashiani upazilla of Gopalganj.

Treat ment	Average yield of crops in the pattern (tha^{-1})			Rice equivalent yield of the pattern (tha^{-1})		Total rice (system) yield (tha^{-1})	Gross return (TK)	Total variable cost (TK)	Gross margin (TK)	BCR
	Mustard	Mungbean	T. aman	Mustard	Mungbean					
V1F1	1.56	1.57	5.05	3.90	5.57	14.53	348955	181107	167848	1.9
V1F2	1.63	1.64	5.32	3.40	5.81	14.55	349248	180105	169143	1.9
V1F3	1.45	1.46	4.60	3.03	5.17	12.80	307396	171101	136295	1.7
V2F1	1.48	1.49	6.82	3.09	5.28	15.20	364816	179503	185313	2.0
V2F2	1.54	1.55	7.46	3.21	5.50	16.18	388519	178023	210496	2.1
V2F3	1.19	1.20	5.79	2.49	4.25	12.54	300973	171349	129624	1.7
V3F1	1.52	1.52	6.18	3.18	5.40	14.76	354379	185567	168812	1.9
V3F2	1.56	1.58	6.57	3.26	5.60	15.44	370646	183098	187548	2.0
V3F3	1.19	1.20	5.00	2.48	4.26	11.74	281807	175789	106018	1.6

Total rice (system) yield is influenced by different treatment has been presented in Table 15. Highest total rice (system) yield of 16.18 t $ha^{-1}yr^{-1}$ was obtained from T_5 treatment. Lowest total rice (system) yield of 11.74 t $ha^{-1}yr^{-1}$ was obtained from T_9 treatment. Highest gross margin and BCR are obtained from T_5 treatment.

Activity-3: Varietal intensification and integrated plant nutrition systems on Sweet gourd – Sesame - T. *aman* cropping pattern in South Central Coastal Region of Bangladesh.

Objectives:

1. To find out varietal performance of sesame to increase oilseed production, farm productivity and income generation in south central coastal regions.
2. To find out judicious fertilizer recommendation for Sweet gourd-Sesame -T. *aman*cropping pattern and monitoring soil health

The second cycle of the pattern were conducted in Young Meghna Estuarine Floodplain (AEZ 18) soils of Barishal (Babugonj and Gouronodi) during 2020-2021. The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 6m × 3m in Gopalgonj Sadar and 3m X 1.5m in Kasheani. There were three crop varieties and three fertilizer levels which consisted of nine treatments. The treatments were as follows:

A. Crop variety: 3

Sweet gourdSesameT.aman

	Sweet gourd	Sesame	T.aman
T_1	= BARI Misti Kumra-1	BARI Til-2	BRRI dhan57
T_2	= BARI Hybrid Misti Kumra-2	BARI Til-3	BRRI dhan62
T_3	= BARI Hybrid Misti Kumra-3	BARI Til-4	BRRI dhan74

B. Fertilizer : 3 level

F_1 = Recommended Fertilizer Dose (RFD) from inorganic source on STB (FRG'2018)
F_2 = RFD on STB + 5 t ha^{-1} cowdung (IPNS approach)
F_3 = Farmers practices

Location: Gouronodi, Barishal

Crops	**Sweet gourd**		**Sesame**		**T.*aman***	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
Sowing/Transplanting date	-	25-11-2020	-	11-03-2021	29-07-2020	25-06-2021
Harvesting date	-	12-02-2021 to 01-03-2021	-	15-06-2021 to 03-07-2021	16-10-2020 to 01-11-2020	20-10-2021

Location: Babugonj, Barishal

Crops	Sweet gourd		Sesame		T.*aman*	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
Sowing/Transplanting date	-	28-11-2020	-	16-03-2021	24-07-2020	25-06-2021
Harvesting date	-	21-02-2021 to 06-03-2021	-	18-06-2021 to 05-07-2021	17-10-2020 to 30-10-2020	12-10-2021

Recommended dose of fertilizer for the Sweet gourd was $N_{75}P_{24}$ K_{40} S_{14} Zn_1B_1kg ha^{-1}. Urea, TSP, MoP, gypsum, Zinc sulphate and boric acid were used as a source of N, P, K, S, Zn and B, respectively. All PKSZnB was applied in pit 5-7 days before planting and mix thoroughly with soil. Nitrogen was applied around the plant as side dressing at 15, 35, 55, 75 DAT under moist soil condition and mixed thoroughly with the soil as soon as possible for better utilization. Cowdung@ 5 t ha^{-1} was applied as treatment only at final land preparation. The sweet gourd seedlings were transplanted on 25 and 28 November, 2020 in Gouronodi and Babugonj, respectively. All the intercultural operations such as irrigation, weeding, insect control etc were done as and when necessary. In Gouronodi , the first harvest was started on 12 February, 2021 and continued up to 1 March, 2021. The crop harvesting was started on 21 February, 2021 and continued up to 6 March, 2021 in Babugonj.The same sequence was maintained in Sesame for fertilizer treatments. Recommended dose of fertilizer for the Sesame was N_{75} P_{14} K_{26} S_7 kg ha^{-1}. Urea, TSP, MoP, and gypsum were used as a source of N, P, K, S, respectively. All PKS was applied as basal during final land preparation. Nitrogen as urea was applied in two equal splits - half of the dose used as basal during sowing and rest at 25 – 30 DAS (flower initiation stage).Seeds of Sesame were sown on 11 and 16 March, 2021 in Gouronodi and Babugonj, respectively. The crop harvesting was started on 15 June, 2021 and continued up to 3 July, 2021 in Gouronodi. In case of Babugonj location, the first harvest was started on 18 June, 2021 and continued up to 5 July, 2021. Records on some yield parameters were taken at certain growth stages of all the crops of the pattern. Data were analyzed by ANOVA (using Crop Stat 7.2) toevaluate differences between treatments, and the means were separated using least significant difference (LSD) at the 5% level of significance ($p<0.05$).

Results:

Table 7.Average yield, rice equivalent yield, total rice (system) yield, gross margin and BCR of Sweetgourd-Seasum-T.aman cropping pattern at Babuganj and Gournadiupazilla of Barisal.

Treatment	Average yield of crops in the pattern (tha^{-1})			Rice equivalent yield of the pattern (tha^{-1})		Total rice (system) yield (tha^{-1})	Gross return (TK)	Total variable cost (TK)	Gross margin (TK)	BCR
	Sweet gourd	Seasum	T. aman	Sweet gourd	Seasum					
V1F1	26.87	1.50	4.24	11.19	3.44	18.88	453208	259999	193209	1.74
V1F2	29.07	1.56	4.53	12.11	3.58	20.23	485528	240233	245299	2.02
V1F3	22.82	1.42	3.62	9.51	3.27	16.40	393703	251101	142602	1.56
V2F1	35.22	1.67	5.17	14.67	3.82	23.68	568360	292908	275452	1.94
V2F2	39.55	1.71	5.76	16.47	3.93	26.17	628263	272505	355758	2.30
V2F3	34.65	1.61	4.50	14.43	3.68	22.62	543050	281975	261075	1.92
V3F1	37.72	1.56	4.42	15.71	3.57	23.72	569310	286890	282420	1.98
V3F2	40.32	1.66	4.76	16.80	3.81	25.38	609245	282705	326540	2.15
V3F3	34.75	1.48	3.85	14.47	3.40	21.74	521893	283997	237896	1.83

Total rice (system) yield is influenced by different treatment has been presented in Table 7. Highest total rice (system) yield of 26.17 t ha^{-1}yr^{-1} was obtained from T_5 treatment. Lowest total rice (system) yield of 16.40 t ha^{-1}yr^{-1} was obtained from T_3 treatment.Highest gross margin and BCR are obtained from T_5 treatment.

Activity-4: Varietal intensification and integrated plant nutrition systems on Grasspea-Gimakolmi- T.*aman* cropping pattern in South Central Coastal Regionof Bangladesh.

Objectives:

1. To find out varietal performance of khesari to increase pulse seed production, farm productivity and income generation in south central coastal regions.
2. To find out judicious fertilizer recommendation for Khesari-Gimakolmi-T.*aman*cropping pattern and monitoring soil health

This field trial has been conducted in High Ganges Floodplain Soils (AEZ-11) of Gopalgonj Sadar and Kasheani during 2019. A description of nutrient status of initial soils prior to fertilization has been presented in Table 1. This cropping cycle was conducted with the second crop in the pattern Gimakolmi (Gimakolmi). After harvest, T.aman rice was transplanted in both the locations.

The experiment was laid out in a randomized complete block design with three replications. There were three crop varieties and three fertilizer levels which consisted of nine treatments. The treatments were as follows:

A. Crop variety: 3

	Gimakolmi	T.aman	Kheshari
T_1 =	BARI Gima Kalmi -1	BRRI dhan 57	BARI Khesari-2
T_2 =	Sabuj pata (Local-1)	BRRI dhan 71	BARI Khesari-3
T_3 =	Golden seed(Local-2)	BRRI dhan 75	Khesari Local

Fertilizer: 3 levels

F_1 = Recommended Fertilizer Dose (RFD) from inorganic source on STB (FRG'2018)

F_2 = RFD on STB + 5 t ha^{-1} cowdung (IPNS approach)

F_3 = Farmers practices

Recommended dose of fertilizer for the gimakolmi was N_{90} P_{20} K_{30} S_{10} kg ha^{-1}. Urea, TSP, MoP, and gypsum were used as a source of N, P, K, S, respectively.All PKS and 1/3rd N was applied as basal during final land preparation. The remaining N as top dressed was applied after each harvest under moist soil condition and mixed thoroughly with the soil as soon as possible for better utilization. Cowdung@ 5 t ha^{-1} was applied as treatment only at final land preparation.The gimakolmi seeds were sown in 18 March and 20 March, 2019 in Gopalgonj Sadar and Kasheani, respectively. All the intercultural operations such as irrigation, weeding, insect control etc were done as and when necessary. The crop harvesting was started on 17 April, 2019 and continued up to 7 July 2019 in Gopalgonj Sadar. In case of Kasheani, the first harvest was started on 18 April, 2019 and continued up to 8 July 2019. The same sequence was maintained in T.aman rice for fertilizer treatments. Recommended dose of fertilizer for the T. aman was N_{90} P_{10} K_{50} S_5 Zn_1 kg ha^{-1}. The entire quantity of PKSZn (as per STB), was applied during the final land preparation. Nitrogen was applied in three equal splits at seedling establishment stage 5-7 day after transplanting (DAT), early tillering stage (25-30 DAT) and 5-7 days before panicle initiation stage (45-50 DAT). The seedlings of three varieties of T.aman rice were transplanted in row to row 25 cm and hill to hill 15 cm spacing in 28 July and 29 July, 2019 in Gopalgonj Sadar and Kasheani, respectively and harvested 03 October and 04 October, 2019, respectively in Gopalgonj Sadar and Kasheani. Records on some yield parameters were taken at certain growth stages of all the crops of the pattern. Data were analyzed by ANOVA (MSTAT10) to evaluate differences between treatments, and the means were separated using least significant difference (LSD) at the 5% level of significance ($p<0.05$). After T.aman harvest. Khesari was sown November 10, 2019 and the crops are in the field.

Table 8. Initial soil chemical properties of experimental plots of Kasheani and Gopalgonj Sadar upazila, before Gimakolmi 2019.

Soil parameters	Kasheani	Gopalgonj Sadar	Critical level
pH	7.56	7.99	-
Organic matter (%)	2.00	1.85	-
Total N (%)	0.105	0.10	-
Exchangeable Ca (meq 100^{-1} g)	6.10	6.20	2.00
Exchangeable Mg (meq 100^{-1} g)	2.10	2.20	0.50
Exchangeable K (meq 100^{-1} g)	0.19	0.18	0.12
Available P (µg g^{-1})	37.0	35.0	10.0
Available Zn (µg g^{-1})	0.65	0.56	0.60
Available B (µg g^{-1})	0.18	0.18	0.20
Available Cu (µg g^{-1})	2.80	2.70	0.20
Available Fe (µg g^{-1})	79.0	85.0	4.00
Available S (µg g^{-1})	22.5	20.7	10.0

Results:

Table 9. Average yield, rice equivalent yield, total rice (system) yield, gross margin and BCR of gimakolmi-Khesari-T. aman cropping pattern at sadar and kashiani upazilla of Gopalganj.

Treat ment	Average yield of crops in the pattern (tha^{-1})			Rice equivalent yield of the pattern (tha^{-1})		Total rice (system) yield (tha^{-1})	Gross return (TK)	Total variable cost (TK)	Gross margin (TK)	BCR
	Gimakolmi	Khesari	T. aman	Gimakolmi	Khesari					
V1F1	96.06	1.36	5.16	20.01	3.11	28.29	679053	290305	388748	2.33
V1F2	106.46	1.47	5.32	22.18	3.38	30.88	741178	285308	455870	2.59
V1F3	84.40	1.30	4.30	17.58	2.99	24.88	597233	280905	316328	2.12
V2F1	88.78	1.55	7.40	18.49	3.55	29.45	706984	298997	407987	2.36
V2F2	95.80	1.63	7.79	19.95	3.75	31.50	756223	289003	467219	2.61
V2F3	77.41	1.49	6.38	16.12	3.41	25.92	622313	287978	334335	2.16
V3F1	85.90	1.28	6.49	17.89	2.93	27.32	655740	291678	364062	2.24
V3F2	92.15	1.33	6.89	19.19	3.05	29.14	699478	285765	413713	2.44
V3F3	73.90	1.21	5.88	15.39	2.79	24.06	577623	281097	296526	2.05

Total rice (system) yield is influenced by different treatment has been presented in Table 9. Highest total rice (system) yield of 31.50 t $ha^{-1}yr^{-1}$ was obtained from T_5 treatment. Lowest total rice (system) yield of 24.88 t $ha^{-1}yr^{-1}$ was obtained from T_3 treatment. Highest gross margin and BCR are obtained from T_5 treatment.

Conclusion

IPNS based fertilizer application performed better than farmers practice with BARI Gimakolmi-1 yielded 15% higher than local varieties. Among the mungbean varieties, BARI-Mung-6 yielded better than BINA Mung-8 and BARI Mung-8. Among the three T. aman rice varieties, the variety BRRI dhan71 resulted better than BRRI dhan57, and BRRI dhan75 in all fertilizer levels. Among the three Mustard varieties, the variety BRRI mustard-17 resulted better than others variety and among the three khesari, Till and sweet gourd variety BARI Khesari-3, BARI Till-3 and BARI Hybried mistikumra-3 resulted better than others variety in all fertilizer levels. Highest total rice (system) yield of was obtained from IPNS based fertilizer management. Also highest gross margin and BCR are obtained from IPNS based fertilizer management.

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Acknowledgement

The authors gratefully acknowledge the funding from PIU-BARC, NATP-2 through "Validation of crop intensification technologies for improving system productivity, soil health and farm income in south central coastal region (PBRG-051) and BARI authority for continuous support.

NANOSCALE ZINC OXIDE PARTICLES FOR IMPROVING YIELD AND QUALITY OF TOMATO

H. M. NASER, S. SULTANA, M. AKTER, AND M. B. BANU

Abstract

A field experiment was carried out to study the effectiveness of soil and foliar application of Zn on the yield of tomato (*Lycopersicon esculentum* Mill.) at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, located at 23º59′26″ N and 90º24′52″ E. The micronutrients zinc (Zn) in the form of ZnO nanoparticles and zincsulphate heptahydrates ($ZnSO_4.7H_2O$) were applied as foliar spray at two different stages of plant growth i.e (i) before flower initiation; (ii) after fruit set when it becomes approximately marble sized. Significantly higher yield (94.5 and 94.2 t ha^{-1}) was produced, when plants were treated with $ZnSO_4$. $7H_2O$ @ 150 ppm and ZnO nano particles @ 15 ppm, respectively. Minimum fruit yield (78.2 t ha^{-1}) was produced by untreated plants - control. Comparatively lower yield was recorded in plants which sprayed with ZnO nanoparticles @ 10 ppm, (85.3 t ha^{-1}) than that of plants sprayed ZnO nanoparticles @ 15 ppm. Zinc supplied to the soil boosted yields, however they were lower than Zn nutrients foliar applied either ZnO nanoparticles or $ZnSO_4$, $7H_2O$. The increment of yield were 9.08 to 20.8, 0.34 to 6.18 and 1.37 to 7.63%, respectively over control, soil application ZnO nanoparticles and soil application of $ZnSO_4$, $7H_2O$. The treatment with 15 ppm of ZnO nanoparticles produced the highest levels of TSS (5.17 °Brix) and beta-carotene (23.3 mg $100g^{-1}$). Nanotechnology has provided better results than conventional method.

Introduction

Zinc (Zn) is an essential nutrient required by all living organisms and represents the 23rd most abundant element on earth (Broadley*et al.,* 2007) and the 2nd most abundant transition metal, subsequent to iron (Jain *et al.,* 2010). It is the required in six different classes of enzyme, which include oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases (Auld, 2001). Zinc has been considered as an essential micronutrient for metabolic activities in plants and animals including humans. Zinc is also necessary for chlorophyll production, pollen functionality, fertilization, and germination, and also plays an important role in biomass production.

Nanoparticles (NPs) with small size and large surface area are expected to be the ideal material for use as a Zn fertilizer in plants. Currently use of nanomaterials has been expanded in every fields of science including agriculture. It has been stated that application of micronutrient fertilizers in the form of NPs is an important route to release required nutrients gradually and in a controlled way, which is essential to mitigate the problems of fertilizer pollutions (Naderi and Abedi, 2012). It is well known that bulk zinc oxide (bZnO) is highly insoluble; moreover, by decreasing the size of the particle at the nanoscale level, the surface/volume ratio increases substantially, making it more soluble and bioavailable (Juan Estrada-Urbina *et al.,* 2018).

However, the use of zinc oxide nanoparticles (ZnO NPs) to improve the yield and quality of tomato has not yet been reported. Consequently, the present research aims to: i. To study the effects of ZnO nano particles on the yield and quality of tomato; ii. To calculate zinc content and uptake of tomato; and iii. To evaluate the efficiency of $ZnSO_4$ and ZnO nanoparticles. In this study, it was hypothesized that ZnO nanoparticles is more efficient compared to conventional sources of Zn fertilizer in terms of improving yield and postharvest quality.

Materials and Method

Experimental details

The study was conducted at micronutrient experimental field, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, located at 23º59′26″ N and 90º24′52″ E during December 2021 to April 2022. The experiment was organized in Randomized complete block design **(**RCBD) with three replications. The unit plot size was 2.0 m × 2.0 m along with crop spacing of 50 cm × 50 cm. Two adjacent unit plots were separated by 75 cm and 1m space was given between the blocks. Land was separated in to two part viz., a. – part for foliar application and b. – part for soil application. Part (a) was consist of 12 unit plot and (b) part was consists of 3 unit plot. During final land preparation on 30 November 2021, fertilizers were applied to the soil at the rate of N_{140}, P_{45}, K_{90} and S_{18} kg ha^{-1} as urea, triple supper phosphate, muriate of potash and gypsum respectively, in both (a) and (b) applications plot. For soil fertilization, at the same time ZnO nanoparticle and $ZnSO_4$, $7H_2O$ was applied at the rate of 0.2 and 6 kg ha^{-1} in soil application part (b). BARI Tomato-15 was used in this experiment. Healthy and uniform sized 30 days old seedlings were transplanted on 2 December 2021. Inter cultural operations were done as and when needed. Nitrogen was applied in three equal splits as urea; 1st dose was applied prior to tomato planting, while 2nd, and 3rd splits were given with succeeding irrigations.

Foliar and soil application:

Zinc oxide nanoparticle`s are nanoparticles of zinc oxide (ZnO) that have diameters less than 100 nanometers. They have a large surface area relative to their size and high catalytic activity. The exact physical and chemical properties of zinc oxide nanoparticles depend on the different ways they are synthesized. Nanoparticles are chemically similar to other preparations of the same material. Advanced Chemical Industries *(*ACI*)* Limited provided the ZnO nanoparticles used in this investigation. Compared to the widely used zinc fertilizer, this nanoparticle is significantly more useful and has a much smaller use.

Foliar application frequency: (i) before flower initiation; and (ii) after fruit set when it becomes approximately marble sized. Foliar application rate: 1. ZnOnano particles @ 10 and 15 ppm. 2. $ZnSO_4$. $7H_2O$ @ 100 and 150 ppm. Soil application before transplanting: (i) ZnO nano particles @ 0.2 kg Zn ha^{-1} (ii) Soil application @ 6 kg Zn ha^{-1}

Treatment combination:

The treatment combinations of foliar spray were T_1: ZnO nano particles (0.0 %) + $ZnSO_4$. $7H_2O$ (0.0%) – control; T_2: ZnO nano particles @ 10 ppm; T_3: ZnO nano particles @ 15 ppm; and T_4: $ZnSO_4$. $7H_2O$ @ 100 ppm; T_5: $ZnSO_4$. $7H_2O$ @ 150 ppm. Soil fertilization treated as T_6 = ZnO nano particles @ 0.2 kg Zn ha^{-1} and T_7 = $ZnSO_4$. $7H_2O$ @ 6 kg Zn ha^{-1} was applied basal as stated above.

The solution of all treatments were prepared and contained urea at the rate of 0.08 % to activate mineral absorption and surf (detergent) used as wetting agent at the rate of 0.01 % for reducing contact angle between the liquid and leaf surface. The volume of water 1.0 liter $plant^{-1}$ was estimated (2 split at two different stages of plant growth viz., 500 ml + 500 ml of solution, approximate) to wet completely the tomato plant. Urea at the rate of 1.74 mg and surf 0.1 mg $liter^{-1}$ as a wetting agent were applied along with each treatment. The foliar spray contained ZnOnano particles @ 10 and 15 ppm and $ZnSO_4$. $7H_2O$ @ 100 and 150 ppm, amended with surfactant to curtail water desertion during the spray process, to ensure the nutrients adhered to the leaf surface, and to maximize uptake by foliage.

Tomatoes were harvested in four installments, from March 10 to April 10, 2022. Data were collected on plant height, fruit length, fruit diameter, No fruit $plant^{-1}$, fruit weight $plant^{-1}$, fruit weight

m^{-2}, and fruit yield ha^{-1} of tomato and recorded data were analyzed statistically to observe differences among the treatments. The analysis of variance (ANOVA) was performed using statistical package STATISTIX-10 (Analytical Software, Tallahassee, FL, USA) computer software. The variations among the treatments were assessed by Tukey's test at 0.05 *P* value.

Results and discussion

The soil characteristics of the experimental site, prior to tomato plantation indicate that the soil at depths (0-15 cm) was near neutral in nature (pH 6.90), low in organic matter content (0.90%). Total nitrogen content (0.14%) and exchangeable potassium (0.20 meq 100g), however quite high in available phosphorus (13.0 µg g^{-1}) than critical level (Table 1). The status of B (0.08 µg g^{-1}) was below the critical level and Zn (1.90 µg g^{-1}).

The tomato yield and its contributing yield traits were significantly affected by foliar fertilizer treatments against soil application of ZnO nanoparticles and $ZnSO_4$ fertilizers, as depicted by the significance of F-values from the analysis of variance (Table 2 & 3). A significant variation was observed for tomato yield when the plants treated with foliar application of ZnO nanoparticles and $ZnSO_4$ fertilizers. Significantly higher yield (94.5 and 94.2 t ha^{-1}) was produced, when plants were treated with $ZnSO_4$. $7H_2O$ @ 150 ppm and ZnO nano particles @ 15 ppm, respectively. Minimum fruit yield (78.2 t ha^{-1}) was produced by untreated plants - control. Comparatively lower yield was recorded in plants which sprayed with ZnO nanoparticles @ 10 ppm, (85.3 t ha^{-1}) than that of plants sprayed ZnO nanoparticles @ 15 ppm. Zinc supplied to the soil boosted yields, however they were lower than Zn nutrients foliar applied either ZnO nanoparticles or $ZnSO_4$, $7H_2O$.

Soil of this experiment is neutral in nature and content of Zn was 1.90 µg g^{-1}, which was higher than the critical limit. But due to neutrality Zn is unavailable to uptake by plant. For that reason, only Zn application in soil did not help to maximize the yield of tomato. Mousavi (2011) reported that soils with high pH, in this type of soils solvability of micronutrients are less and cause decline uptake these elements by plant. On the other hand, higher yield in treatment sprayed with 0.05% Zn alone, perhaps these increases in fruit yields were due to the significant increase in leaf Zn concentration which in turn induced more flowering and minimized the fruit drop in potato plant (Garcia *et al*. 1984). The positive impacts of Zn fertilization on growth and yield have been reported in many crops (Khan *et al*., 2007; Abbas *et al*., 2009; Ali *et al*., 2013). The positive effects may be attributed to role of Zn in plants physiological functions. Zn is a component of various enzymes, promotes growth hormones, starch formation, seed maturation and production (Brady and Weil, 2002; Ibrahim, 2013). Higher yield in foliar application of both nano Zn or $ZnSO_4$ might be due to foliar application of zinc increased Zn uptake by plants in the soils with sufficient stores (Rengel *et al*., 1998). Plants sprayed with Zn in the form of either ZnO nanoparticles or $ZnSO_4$, $7H_2O$ showed maximum response in fruit length, fruit diameter, and fruit weight $plant^{-1}$ compared with control and soil application of both elements. Gitte *et al*. (2005) observed that the application of micronutrient exhibited yield increases over unfertilized controls. Mehraj *et al.*, (2015) reported that the foliar application of boron and zinc increased number of fruit, fruit weight, fruit length, fruit diameter and yield.

The main purpose of this study is to find out how to get higher yields using less fertilizer and compare the effectiveness between nano and conventional fertilizer. This study showed that 15 ppm ZnO nanoparticles produced tomatoes statistically equal to 150 ppm $ZnSO_4$,$7H_2O$; ZnO nanoparticles @ 0.2 kg Zn ha^{-1} soil application; and $ZnSO_4$. $7H_2O$ @ 6 kg Zn ha^{-1} soil application. When compared the fruit yield from control or soil application plot with foliar applications, the increment of yield were 9.08 to 20.8, 0.34 to 6.18 and 1.37 to 7.63%, respectively over control, soil application ZnO nanoparticles and soil application of $ZnSO_4$ (Table 4).

Zinc concentration and uptake of tomato fruit

Tomato contains 0.00517 to 0.00570 per cent (51.7 to 57.0 ppm) of zinc (Table 5). Of these, 150 ppm $ZnSO_4,7H_2O$ and 15 ppm ZnO nanoparticles applied tomatoes showed the highest zinc content (57 pp). Compared to soil application, foliar application resulted in greater zinc content in tomatoes.

TSS, vitamin C and β Carotene content in cauliflower

The highest TSS (5.17 °Brix) was found in the treatment with 15 ppm of ZnO nano particles (Table 6). The highest vitamin C (33.8 mg 100 g^{-1}) was found in treatment 5 where 150 ppm of zinc sulfate heptahydrate was applied as foliar. Zinc oxide nano particles 15 ppm applied as foliar showed the highest amount of β carotene (23.3 mg100g^{-1}).

Conclusion

Above results indicated the positive impact of foliar application on tomato cultivation and treatment effects is visible. The increment of yield were 9.08 to 20.8, 0.34 to 6.18 and 1.37 to 7.63%, respectively over control, soil application ZnO nanoparticles and soil application of $ZnSO_4$, $7H_2O$. The yield is the same with one-tenth the application of ZnO nano fertilizer as it is with currently used zinc fertilizers. We need to do this study for two more years to get more precise results since this is only the first year's outcome.

Acknowledgements

Director General & his associates, BARI, Gazipur – would like to thank for providing the essential facilities throughout the research work. The author is thankful to the Director HRC, BARI, Gazipur for supply seeds of BARI Tomato-15 variety. Thanks to my colleagues who oversee the start of the research work throughout the research period and were engaged in collecting the necessary data. I am thankful to my colleagues, particularly those who are responsible for the analytical aspects of this research and other important laboratory works. At the same time, I like thank to the person who typed this study paper on a computer.

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Table 1. Initial properties of the soil samples of experimental field

Soil Properties	pH	OM %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			meq $100g^{-1}$				$\mu g\ g^{-1}$					
Result[§]	6.90	0.90	9.20	1.70	0.20	0.14	13.0	25	0.08	2.0	65.0	1.90
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.2	0.2	4.0	0.6

[§] Method of analysis: Zn - DTPA-extractable**,** K - NH_4OAc-extractable, and B - Hot water azomethane-H procedure.

Table 2. Agronomic traits of tomato as affected by foliar and soil application of ZnO nanoparticles and $ZnSO_4$, $7H_2O$

Treatment	Agronomic traits			
	plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	No fruit $plant^{-1}$
1. Zn nanoparticles (0.0 %) + $ZnSO_4$. $7H_2O$ (0.0%) – control	89.3	5.19c	4.67c	33.8d
2. ZnO nanoparticles @ 10 ppm foliar application	94.4	5.44abc	4.84abc	40.5c
3. ZnO nanoparticles @ 15 ppm foliar application	97.6	5.57a	5.00ab	46.4a
4. $ZnSO_4$. $7H_2O$ @ 100 ppm foliar application	98.0	5.30bc	4.83abc	41.8bc
5. $ZnSO_4$. $7H_2O$ @ 150 ppm foliar application	94.3	5.47ab	5.04a	45.9a
6. ZnO nanoparticles @ 0.2 kg Zn ha^{-1} soil application	97.8	5.35abc	4.84abc	44.2ab
7. $ZnSO_4$. $7H_2O$ @ 6 kg Zn ha^{-1} soil application	92.7	5.34abc	4.75bc	42.4bc
CV (%)	4.33	2.8	2.5	6.25

Mean values in the column followed by the same letters are not significantly different ($P < 0.05$).
[*] Plot size: 4 m^{-2}

Table 3. Yield of tomato as affected by foliar and soil application of ZnO nanoparticles and $ZnSO_4$, $7H_2O$

Treatment	Yield		
	Fruit weight (kg $plant^{-1}$)	Fruit weight (kg m^{-2})	Fruit yield (t ha^{-1})
1. Zn nanoparticles (0.0 %) + $ZnSO_4$. $7H_2O$ (0.0%) – control	1.87c	7.82c	78.2c
2. ZnO nanoparticles @ 10 ppm foliar application	2.13bc	8.53bc	85.3bc
3. ZnO nanoparticles @ 15 ppm foliar application	2.50ab	9.42a	94.2a
4. $ZnSO_4$. $7H_2O$ @ 100 ppm foliar application	2.23bc	8.93ab	89.3ab
5. $ZnSO_4$. $7H_2O$ @ 150 ppm foliar application	2.72a	9.45a	94.5a
6. ZnO nanoparticles @ 0.2 kg Zn ha^{-1} soil application	2.29b	8.90ab	89.0ab
7. $ZnSO_4$. $7H_2O$ @ 6 kg Zn ha^{-1} soil application	2.15bc	8.78ab	87.8ab
CV (%)	6.01	5.09	5.09

Mean values in the column followed by the same letters are not significantly different ($P < 0.05$).
[*] Plot size: 4 m^{-2}

Table.4. Yield comparison between foliar and soil application of ZnO nanoparticles and $ZnSO_4$, $7H_2O$

Treatment	Fruit yield (t ha^{-1})	Yield increased (%)		
		Over control	Over soil application of ZnO nanoparticles	Over soil application of $ZnSO_4$, $7H_2O$
1. Zn nanoparticles (0.0 %) + $ZnSO_4$. $7H_2O$ (0.0%) – control	78.2	–	−12.1	−10.9
2. ZnO nanoparticles @ 10 ppm foliar application	85.3	9.08	−4.16	−2.85
3. ZnO nanoparticles @ 15 ppm foliar application	94.2	20.5	5.84	7.29
4. $ZnSO_4$. $7H_2O$ @ 100 ppm foliar application	89.3	14.2	0.34	1.71
5. $ZnSO_4$. $7H_2O$ @ 150 ppm foliar application	94.5	20.8	6.18	7.63
6. ZnO nanoparticles @ 0.2 kg Zn ha^{-1} soil application	89.0	12.1	–	1.37
7. $ZnSO_4$. $7H_2O$ @ 6 kg Zn ha^{-1} soil application	87.8	10.9	1.36	–

Table.5. Zinc concentration and uptake in tomato fruit by foliar and soil application of ZnO nanoparticles and $ZnSO_4$, $7H_2O$

Treatment	Fruit yield (t ha^{-1})	Fruit yield (kg ha^{-1})	Zinc concentration (%)	Zinc uptake (kg ha^{-1})
1. Zn nanoparticles (0.0 %) + $ZnSO_4$. $7H_2O$ (0.0%) – control	78.2	78200	0.00517	4.04
2. ZnO nanoparticles @ 10 ppm foliar application	85.3	85300	0.00521	4.44
3. ZnO nanoparticles @ 15 ppm foliar application	94.2	94200	0.00570	5.37
4. $ZnSO_4$. $7H_2O$ @ 100 ppm foliar application	89.3	89300	0.00560	5.00
5. $ZnSO_4$. $7H_2O$ @ 150 ppm foliar application	94.5	94500	0.00570	5.39
6. ZnO nanoparticles @ 0.2 kg Zn ha^{-1} soil application	89.0	89000	0.00551	4.90
7. $ZnSO_4$. $7H_2O$ @ 6 kg Zn ha^{-1} soil application	87.8	87800	0.00547	4.80

Table 6: Total Soluble Solid (TSS), Vitamin-C and β-carotene content in Tomato

Treatments	TSS (^{0}Brix)	Vitamin-C (mg 100 g^{-1})	β carotene (mg100g^{-1})
1. ZnO nanoparticles (0.0 %) + $ZnSO_4$. $7H_2O$ (0.0%) – control	4.60	26.9	19.5
2. ZnO nanoparticles @ 10 ppm foliar application	5.10	28.4	19.8
3. ZnO nanoparticles @ 15 ppm foliar application	5.17	33.8	23.3
4. $ZnSO_4$. $7H_2O$ @ 100 ppm foliar application	4.83	21.1	18.4
5. $ZnSO_4$. $7H_2O$ @ 150 ppm foliar application	4.93	38.3	18.5
6. ZnO nanoparticles @ 0.2 kg Zn ha^{-1} soil application	4.83	26.9	17.8
7. $ZnSO_4$. $7H_2O$ @ 6 kg Zn ha^{-1} soil application	4.97	28.4	17.6
Methodology/equipment used	Digital hand refractometer (Model NR 151)	Ranganna 1995	AOVC, 2019

EFFECT OF BORON ON YIELD AND QUALITY OF BITTER GOURD

M. B. BANU, M. AKTER, S. SULTANA AND H. M. NASER

Abstract

A field experiment was carried out to study the effect of boron on yield and quality of bitter gourd (cv. BARI Karola-4) at Soil Science Division, BARI, Joydebpur, Gazipur(AEZ-28)during kharif-I2021 - 2022.The objectives of the study wereto study the effect of B on number of flower setting and yield of bitter gourd; and to find out the optimum level of B for maximizing the yield and quality of bitter gourd.Design of the experiment was RCB with 3 (three) replications. The micronutrient boron (B) in the form of boric acid (H_3BO_3) having 17% boron were applied. The treatment combinations were T_1: Control, T_2: RDF (STB), T_3: 1.0 Kg B ha^{-1} +NPKSZn (STB), T_4: 1.5 Kg B ha^{-1} + NPKSZn (STB) and T_5: 2.0 Kg B ha^{-1} +NPKSZn (STB). The yield and yield contributing character of bitter gourd were significantly influenced by B application. All yield parameters showed higher tendency in T_4 treatment accept flower sheddings. The highest yield (24.52t ha^{-1}) was observed in T_4 (1.5 Kg B ha^{-1}) treatmentand it was significantly higher than control plants. Highest lowering of flower shedding (50.21%) was also observed in T_4 (1.5 Kg B ha^{-1}) treatmentand it was higher than control plants. Nutrients concentration in bitter gourd was also influenced by B. P and K concentration was increased nonsignificantly while N concentration was increased significantly. The concentration of Zn was increased up to a certain level of B (1.5 kg ha^{-1}) then decreased. Nutrients uptake was maximum in the treatment where 1.5 Kg B ha^{-1} was added except K uptake. K uptake was maximum in T_5 treatment which was similar where 1.5 Kg B ha^{-1} was added. Application of B is effective for flower shedding, yield and quality of bitter gourd.

Introduction

Bitter gourd has a high nutrient requirement particularly macro and micronutrient such as nitrogen, phosphorus, potash, zinc and boron. Bitter gourd fruit yield has been set aside by the deficiency of micronutrients, which leads to certain physiological disorders. Green fruits of bitter gourd are used as vegetables. The fruits rank first among the cucurbits in respect of iron and ascorbic acid (vit. C). It also contains proteins, fats, minerals, carotein, thiamine, riboflavins and very rich in phytonutrients like anti-oxidants. The alkaloid momordicasoides imparts the bitter taste to the fruit. Bitter gourd (*Momordicacharantia*) is monoecious crop, where male and female flowers borne on the same plant. The production of staminate flower is normally much more than pistillate flowers ultimately only pistillate flowers contribute to the yield (Vala and Savaliya, 2014). During the plant growth period, micronutrients play various roles in physiological and biochemical processes and among those nutrients, B is a vital element involves in flowering and fruiting of the plant so its deficiency causes floral deformities inducing male bareness (Nonnecke, 1989). Boron deficiency also results in stunted growth because it is a part of structure (Sharma, 2006). Boron deficiency affects the growing points of roots and youngest leaves and its involves in the growth of cells in newly emerging shoots and roots while in some plants it is crucial for boll formation, flowering, pollination, seed development and sugar transport (Takano *et al*., 2008 and Miwa *et al*., 2008). Boron plays a supportive role in cell wall synthesis, lignification (Loomis and Durst, 1992) and cell wall structure (Flescher*et al*., 1998). Boron deficiency plays a significant role in yield reduction of many vegetables, including bitter gourd due to premature flower, square or boll shedding. Bitter gourd is a very popular vegetable in Bangladesh and its yield maximization is a major concern of local farmers. Information regarding B effect on major crops is although available in Bangladesh, but the vegetables response to boron is not available. So keeping in view the importance of B and bitter gourd, this study was planned i. to study the effect of B on number of flower setting and yield of bitter gourd; and ii.to find out the optimum level of B for maximizing the yield and quality of bitter gourd.

Materials and Methods

A field experiment was conducted at micronutrient experimental field, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during kharif-Iseason in 2021-2022. The study area was under the agro-ecological zone Madhupur Tract (AEZ-28). The experiment was laid out in a RCB design with three replications. Treatments combinations were T_1: Control, T_2: RDF (STB), T_3: 1.0 kg B ha^{-1} + NPKSZn (STB), T_4: 1.5 kg B ha^{-1} + NPKSZn (STB) and T_5: 2.0 kg B ha^{-1} + NPKSZn (STB).The unit plot was 2m × 1.5m. BARI Karola-4 variety was used in the experiment. Fertilizers were applied at the rate of 120-20-42-10-0.5 of N-P-K-S-Zn in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively. Boron 1.0 kg ha^{-1}, 1.5 kg ha^{-1} and 2.0 kg ha^{-1} wereused as Boric acid (H_3BO_3). A basal application was made with 5t ha^{-1}cowdung.The entire amount of cowdung and all P, K, S, Zn and B were applied at the time of sowing as basal dose.N was appliedaround the plant as side dressing in six splits (1st split was applied during transplanting, while 2nd, 3rd, 4th, 5th and 6th splits were applied with irrigation when necessary). Before sowing the seeds were soaked in water for 24 hours to enhance germination. Then through away the water and cover it with a wet cloth until the seed is cracked. Then sowed the seeds in polybags after the seed cover cracked. When the seedlings are 8-10 cm long, seedlings were planted in the pit. Seeds were sown on 20 January, 2022 in polybag. Seedlings were transplanting on 16February, 2022 with a spacing of 1.5 m from row to row and 2.0 m from plant to plant. When the seedlings are 15-20 cm long, put bamboo sticks in the ground near the base of the tree. Then built a loft 1.5 m high. Irrigation was given according to need throughout the period to keep the soil moist. Pheromone trap were used after 1st week of transplanting in the field and change it after 50-60 days. Intercultural operations were done as and when necessary.

Initial soil samples were collected from a depth of 0-15 cm and analyzed prior to application of different fertilizers are presented in Table 1.The pHof experimental field soil(developed soil) was (6.7). The status of B was low.

Chemical analysis

For initial soil analysis, soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon determination was done by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Elements K, Ca and Mg were determined by NH_4OAC extractable method and Cu, Fe, Mn and Zn were determined by DTPA extraction method followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Olsen method while S was determined by turbidimetric method with $BaCl_2$.

Determination of TSS and vitamin C content of bitter gourd

Total soluble solids content (TSS) was determined with a digital hand refractometer and reported as Brix. Vitamin C was determined by classical titration method using 2, 6- dichlorophenol indophenols solution and express as 100 mg g^{-1} of fresh weight (Ranganna, 1995).

Sample preparation

The plant samples from each plant were dried at 65°C in an electric oven for 72 h then ground to pass through a 20 mesh sieve and analyzed following standard procedures. Plant samples were digested with H_2SO_4 for N and HNO_3-$HClO_4$ (3:1) for other nutrients determination. After harvest, the soil from each plot was thoroughly mixed and approximately 100 g soil was sampled for laboratory analysis.

Fruits were harvested at maturity stage. Harvested fruits were selected from each treatment for recording necessary yield data. Recorded data were initial soil status, time of planting, nutrient uptake by bitter gourd at harvesting stages, number of flower sheds, fruit length (cm), weight (g), diameter (cm), and yield (t ha^{-1}), and vit. C and TSS. Data were analyzed STATISTIX-10 and means were compared by multiple comparison test using LSD (Statistix for Windows, 1998).

Boron uptake

Boron uptake were determined by the following relationship (Fegeria *et. al*., 1997)

Nutrient uptake (kg ha^{-1}) = Nutrient % × Dry weight (kg ha^{-1}) /100

Results and Discussion

Effect of B on the flowering of bitter gourd presented in Table 2. Significant variation was observed among the treatment combination of B coupled with other fertilizers resulting to higher number of female flowering ultimately decrease in flower shedding. Maximum number of female flowers was recorded in T_4 treatment (72 no./plant^{-1}) which was identical with T_5 (70.67 no. plant^{-1}) and followed by T_3 (66.00 no. plant^{-1}) and T_2 (61.67 no. plant^{-1}). The lowest number of female flowers recorded in control (46.33 no. plant^{-1}) treatment. Here it is observed that T_5 and T_4 treatments are identical. So T_4 was best suited in female flowering [1.5 Kg B ha^{-1} +NPKSZn (STB)]. Increased level of B did not increase number of female flower. Number of female flowers found to be increased in bitter gourd with added B in the study of Fouzia*et al.* (2018) and Karthick*et al.* (2018). Number of flower shedding plant^{-1} significantly varied among the treatments. The minimum number of flower shedding (40.00) in T_4 treatment. But the maximum number of flower shedding recorded in T_1 (80.33 nos. plant^{-1}) treatment. The highest decrease in flower shedding was also recorded in T_4 (50.21%) treatment leading to higher number of flower setting. The percent decrease in flower shedding was maximum in the study of Sadia *et al.* (2017).

Effect of B on the yield components and yield of bitter gourd have been shown in Table 3. Significant variations were observed in case of all the parameters. Number of fruit plant^{-1} ranged 44.00-70.00. The maximum Number of fruit plant^{-1} (70) were observed in T_4 which was identical with T_5 (68.33) and followed by T_3 (64.33) and T_2 (62.00) treatment. That was in accordance with Verma*et al.* (1984). The longest fruit length was recorded in T_4 (18.60 cm) followed by T_5 (17.25 cm), T_3 (16.68 cm) and T_2 (14.41 cm) treatment. Fruit diameter ranged from 4.16cm to 4.72cm. The maximum diameter was identified in T_4 (4.72cm) and followed by T_5 (4.62cm), T_3 (4.55cm) and T_2 (4.38cm) treatment.

Significant variations were observed in case of individual fruit weight. The maximum value was found in T_4 (105.13g) which was identical with T_5 (103.63 g) and followed by T_3 (100.10 g), T_2 (95.33 g) treatment. The lowest value was recorded in control treatment (90.27 g). Fruit weight (kg/plant) ranged from 3.97 kg to 7.36 kg. The maximum value was observed in T_4 (7.36 kg) which was followed by T_5 (7.10 kg), T_3 (6.45 kg) and T_2 (5.91 kg) treatment.

Significant variation also observed in total yield (t ha^{-1}) of bitter gourd among the treatment combinations. The highest yield was obtained in T_4 (24.52 t ha^{-1}) which was followed by T_5 (23.60 t ha^{-1}), T_3 (21.49 t ha^{-1}) and T_2 (19.71 t ha^{-1}) treatment. The lowest yield was identified in T_1 (13.24 t ha^{-1}). It was evident that T_4 treatment was the best that was the combination of 1.5 kg B ha^{-1} +NPKSZn (STB). Added boron compared to control increased yield that was mentioned by several workers such as Fozia *et al.* (2018), Ashraf *et al.* (2020), Bharati*et al.* (2018). Fruits plant^{-1} were found to increase in the study of Verma*et al.* (1984).

Fruit dry yield, nutrient content and uptake of B, Zn, N, P and K presented in Table 4 and 5. Here significant differences were observed in fruit dry yield (kg ha^{-1}). The highest dry yield was recorded in T_4 (2229.0 kg ha^{-1}) which was followed by T_5 (2145.0 kg ha^{-1}), T_3 (1953.7 kg ha^{-1}) and T_2 (1791.5 kg ha^{-1}) but the lowest amount was recorded in T_1 (1203.3 kg ha^{-1}) treatment. Boron conc. (ppm) recorded maximum in T_5 (47.00 ppm) which was identical with T_4 (45.33 ppm) and followed by T_3 (41.33 ppm) treatment. The minimum amount was recorded in control treatment (33.00 ppm). Percent B was ranged from 0.0033% to 0.0047% that ultimately resulted in maximum B uptake (0.1010 kg ha^{-1}) in T_4 treatment. Here T_4 identical with T_5 (0.1007). The maximum Zn conc. (ppm) was recorded in T_4 (53.93 ppm) that was followed by T_5 and T_3 treatment. Zn concentration in bitter gourd was increased by the application of B to a certain level then its concentration was decreased. Percent Zn varied from 0.0044% to 0.0054% that also reflected in maximum Zn uptake by the T_4 (0.120 kg ha^{-1}). Marked differences were observed in case of Zn uptake by bitter gourd ranging from 0.0534 kg ha^{-1} to 0.120 kg ha^{-1}.

The effect of B on the concentration of N, P, and K showed that B increased the concentration of P and K in bitter gourd fruit nonsignificantly. Minimum N (3.360%) and P concentration (0.390%) was found in control while maximum N (3.610%) was found in T_5 and maximum P (0.453%) was found in T_4. N uptake by fruit (kg ha^{-1}) was maximum in T_4 (80.07 kg ha^{-1}) treatment which was identical with T_5 (77.45 kg ha^{-1}). P conc. (%) identified in between 0.390% to 0.453% that also reflected in P uptake by fruit kg ha^{-1} limiting between 4.68 kg ha^{-1} to 10.11 kg ha^{-1}. K conc. (%) was maximum in T_5 (2.80%) and there is no significance difference among the treatment. K uptake by fruit (kg ha^{-1}) was maximum in T_5 (60.17 kg ha^{-1}) treatment which was identical with T_4 (59.32 kg ha^{-1}). The present findings indicated that up to a certain level of B in soil, N P, K, Zn and B showed synergistic relation.

Minimum Zn content was observed in control while maximum Zn content was found with higher dose of B in the study of Sultana *et al.* (2017). It was also noted by Grewal *et al.* (1998) and Sultana *et al.* (2017) that certain level of B in soil, Zn and B showed synersism. Sultana *et al.* (2017) also noticed that B increased the conc. of N and P in bitter gourd non significantly. They again cited B and K were synergistic having coinciding role in physiological approaches.

In case of biomass yield (kg ha^{-1}) significant variation was observedamong the treatments (Table 6). The maximum yield was identified in T_4 (1486.9 kg ha^{-1}) that was followed by T_5 (1436.4 kg ha^{-1}) and T_3 (1281.8 kg ha^{-1}) and T_2 (1098.2 kg ha^{-1}). The minimum amount was found in T_1 (880.9 kg ha^{-1}), the control one. Boron conc. (ppm) ranged from 41.33 ppm to 58.33 ppm, likewise in concentration (%) with the range from 0.0041% to 0.0058%. Finally, B uptake by plant (kg ha^{-1}) was measured maximum in T_5 (0.084 kg ha^{-1}) which was identical with T_4 (0.083 kg ha^{-1}) treatment. Rahman *et al*. (1992) reported that the fresh and dry weights of plants significantly increased in bitter gourd by the application of 2.5 ppm concentration of B.

Likewise pattern of fruit dry yield and biomass yield shown in root dry weight (kg ha^{-1}) (Table 7). The root dry weight was maximum in T_4 (27.14 kg ha^{-1}) which was identical with T_5 (26.35 kg ha^{-1}) and followed by T_3 (24.92 kg ha^{-1}) and T_2 (22.54 kg ha^{-1}) treatment. Boron content (ppm) ranged from 33.67 ppm to 49.33 ppm, likewise in concentration (%) with the range from 0.0034% to 0.0049%. B uptake by root varied from (0.19 g ha^{-1}) to (0.43 g ha^{-1}) in control and T_5 treatment respectively. T_5 (0.43 g ha^{-1}) treatment was similar with T_4 (0.40 g ha^{-1}) treatment. Fozia*et al.* (2018) reported that the dry weight of root significantly increased by the application of boric acid.

TSS and vitamin C content of bitter gourd

Quality characters such as Vit. C and TSS (^{0}Brix) of bitter gourd have been presented in Table 8.Vit. C ranged from 82.05 mg/100g to 91.19 mg/100g. The maximum amount of Vit. C was recorded in T_4 (91.21 mg/100g) which was identical with T_5 (90.19 mg/100g) and followed by T_3 (88.29 mg/100g) and T_2 (85.74 mg/100g) treatment but they were statistically similar. The maximum TSS was recorded in T_4 (3.77) and followed by T_5 (3.50), T_3 (3.20) and T_2 (30.7) treatment. Vit. C and TSS were recorded to increase with B application in the study of Bharati*et al.* (2018). Ashraf *et al.* (2020) mentioned maximum amount of TSS showed with B application. TSS content in fruits differed significantly due to foliar spray of micronutrient but vit. C didn’t touch the level of significance. The highest TSS content in fruit was obtained with all micronutrients which might be due to higher conc. of N, P, K and micronutrient in leaves and fruits, which might have boosted the accumulation of assimilates resulting in better quality in bitter gourd (Meenakshi*et al.*, 2007).

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	Texture	pH	OM	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Zn
			(%)	meq $100g^{-1}$			%	ppm					
Result	Sandy clay loam	6.7	1.46	7.20	1.80	0.11	0.08	11	15	0.18	1.03	48.90	3.20
Critical level	-			2.0	0.5	0.12	-	10	10	0.2	0.2	4.0	0.6

Table 2. Effect of B on the flowering of bitter gourd during 2021-2022

Treatment	No. of female flowers plant[1]	No. of flower sheds plant^{-1}	Decrease in flower shedding (%)
T_1: Control	46.33c	80.33a	-
T_2: RDF (STB)	61.67b	65.00b	19.08
T_3: 1.0 Kg B/ha +NPKSZn (STB)	66.00ab	55.00c	31.53
T_4: 1.5 Kg B/ha +NPKSZn (STB)	72.00a	40.00d	50.21
T_5: 2.0 Kg B/ha +NPKSZn (STB)	70.67a	42.00d	47.71
CV(%)	5.70	5.67	

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Table 3. Effect of B on the yield components and yield of bitter gourd during 2021-2022

Treatment	No. of fruit plant^{-1}	Length of fruit (cm)	Fruit dia. (cm)	Individual fruit wt. (g)	Fruit wt./plant (kg)	Yield (t ha^{-1})
T_1: Control	44.00c	12.50c	4.16b	90.27c	3.97d	13.24d
T_2: RDF (STB)	62.00b	14.61bc	4.38ab	95.33bc	5.91c	19.71c
T_3: 1.0 Kg B/ha +NPKSZn (STB)	64.33ab	16.68ab	4.55ab	100.10ab	6.45bc	21.49bc
T_4: 1.5 Kg B/ha +NPKSZn (STB)	70.00a	18.60a	4.72a	105.13a	7.36a	24.52a
T_5: 2.0 Kg B/ha +NPKSZn (STB)	68.33a	17.25ab	4.62ab	103.63a	7.10ab	23.60ab
CV(%)	5.01	10.97	6.30	5.03	5.84	5.84

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Table 4. Fruit dry yield, nutrient content and uptake of B and Zn in bitter gourd fruit

Treatment	Fruit yield (kg ha^{-1})	B conc. (ppm)	Zn conc. (ppm)	B conc. (%)	Zn conc. (%)	B uptake by fruit (kg ha^{-1})	Zn uptake by fruit (kg ha^{-1})
T_1: Control	1203.3d	33.00c	44.42c	0.0033c	0.0044c	0.0398d	0.054d
T_2: RDF (STB)	1791.5c	37.00bc	48.00bc	0.0037bc	0.0048bc	0.0664c	0.086c
T_3: 1.0 Kg B ha^{-1} + NPKSZn (STB)	1953.7bc	41.33ab	49.47ab	0.0041ab	0.0049ab	0.0804d	0.096bc
T_4: 1.5 Kg B ha^{-1} + NPKSZn (STB)	2229.0a	45.33a	53.93a	0.0045a	0.0054a	0.1010a	0.120a
T_5: 2.0 Kg B ha^{-1} + NPKSZn (STB)	2145.0ab	47.00a	51.17ab	0.0047a	0.0051ab	0.1007a	0.110ab
CV(%)	5.84	7.63	5.96	7.63	5.96	7.48	7.81

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Table 5. N, P and K content and uptake in bitter gourd fruit

Treatment	N conc. (%)	P conc. (%)	K conc. (%)	N uptake by fruit (kg ha^{-1})	P uptake by fruit (kg ha^{-1})	K uptake by fruit (kg ha^{-1})
T_1: Control	3.360b	0.390	2.28	40.44d	4.68d	27.46c
T_2: RDF (STB)	3.477ab	0.413	2.43	62.33c	7.42c	43.59b
T_3: 1.0 Kg B ha^{-1} + NPKSZn (STB)	3.547ab	0.420	2.58	69.36bc	8.16bc	49.97ab
T_4: 1.5 Kg B ha^{-1} + NPKSZn (STB)	3.593ab	0.453	2.66	80.07a	10.11a	59.32a
T_5: 2.0 Kg B ha^{-1} + NPKSZn (STB)	3.610a	0.430	2.80	77.45ab	9.22ab	60.17a
CV(%)	5.55	9.07	7.87	7.39	8.69	9.21

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Table 6. Effect of B on biomass yield, nutrient content and uptake of bitter gourd plant

Treatment	Biomass yield (kg ha^{-1})	B conc. (ppm)	B conc. (%)	B uptake by plant (kg ha^{-1})
T_1: Control	880.9d	41.33d	0.0041d	0.037d
T_2: RDF (STB)	1098.2c	48.00c	0.0048c	0.053c
T_3: 1.0 Kg B ha^{-1} + NPKSZn (STB)	1281.8b	52.67bc	0.0053bc	0.068b
T_4: 1.5 Kg B ha^{-1} + NPKSZn (STB)	1486.9a	56.00ab	0.0056ab	0.083a
T_5: 2.0 Kg B ha^{-1} + NPKSZn (STB)	1436.4ab	58.33a	0.0058a	0.084a
CV(%)	7.80	5.51	5.51	9.44

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Table 7. Root dry weight, content and uptake of B in bitter gourd root

Treatment	Root dry weight (kg ha^{-1})	B conc. (ppm)	B conc. (%)	B uptake by root (g ha^{-1})
T_1: Control	17.78c	33.67c	0.0034c	0.19c
T_2: RDF (STB)	22.54b	38.67b	0.0039b	0.27b
T_3: 1.0 Kg B ha^{-1} + NPKSZn (STB)	24.92ab	42.00b	0.0042b	0.30b
T_4: 1.5 Kg B ha^{-1} + NPKSZn (STB)	27.14a	47.33a	0.0047a	0.40a
T_5: 2.0 Kg B ha^{-1} + NPKSZn (STB)	26.35a	49.33a	0.0049a	0.43a
CV(%)	7.17	5.13	5.13	9.52

Table 8. Quality character of bitter gourd fruit as influenced by different B levels

Treatment	Vit. C (mg/100g)	TSS (^{0}Brix)
T_1: Control	82.05b	2.90c
T_2: RDF (STB)	85.74ab	3.07bc
T_3: 1.0 Kg B ha^{-1} + NPKSZn (STB)	88.29ab	3.20bc
T_4: 1.5 Kg Bha^{-1} + NPKSZn (STB)	91.21a	3.77a
T_5: 2.0 Kg B ha^{-1} + NPKSZn (STB)	90.19a	3.50ab
CV(%)	4.55	7.55

Conclusion

Application of B enhanced fruit length (cm), weight (g), diameter (cm), yield (t ha^{-1}), vit. C, and TSS and decrease flower sheddings in bitter gourd. The highest yield (24.52t ha^{-1}) was observed in T_4 (1.5 kg B ha^{-1}) and it was significantly higher than control plants. Maximum lowering of flower shedding (50.21%) was also observed in the same treatment. Nutrients concentration and uptake in bitter gourd was also influenced by B.It was, therefore, concluded that 1.5 kg B ha^{-1} + NPKSZn (STB)application could be used to increase bitter gourd yield and quality. This is 2nd year result, it is needed for further study of this experiment.

Acknowledgements

At first, I express my deepest sense of gratefulness to Almighty Allah who enables me to complete this work successfully. Sincere thanks to Dr. Habib Mohammed Naser, CSO and Head, Soil Science Division, BARI, Gazipur for providing necessary facilities, guidance and valuable suggestions during the period of investigation. The author is thankful to HRC, Gazipur for providing seeds (BARI Karola-4) under this study. I am grateful to my colleagues and other staffs of the Soil Science Division, BARI,Gazipur for their help in the field and laboratory.

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FOLIAR APPLICATION OF BORON ON REPRODUCTIVE GROWTH OF SUNFLOWER

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Abstract

Foliar application may be used to supply boron (B) to a crop when B demands are higher than can be supplied via the soil. A field experiment was carried out to study the foliar application of B on reproductive growth of sunflower (cv. BARI Surjamukhi-3)at Soil Science Division, BARI, Joydebpur, Gazipur (AEZ-28) during rabi 2021 - 2022.The objectives of the study were to determine the effect of foliar spray of B on yield contributing characters of sunflower and to find out the optimum rate of B for maximizing the yield and quality of sunflower. The experiment was laid out in RCBD replicated thrice. The micronutrient B in the form of boric acid (H_3BO_3) having 17% B were applied at 20-25 and 40-45 days after sowing (DAS). The treatment combinations of foliar spray of B were T_1: control (spray with distilled water), T_2: 50 mg L^{-1}B, T_3: 100 mg L^{-1}B and T_4: 150 mg L^{-1} B. The yield and yield contributing character of sunflower were significantly influenced by foliar application of B. All parameters showed higher tendency in T_4 treatment except number of empty seedshead^{-1}. The highest seed yield (2.27 t/ha) was observed in T_4 (150 mg L^{-1}B) and it was significantly higher compared with untreated plants. Lowest empty seed% (19.99%) was observed in T_4 (150 mg L^{-1}B) treatment. Foliar application of B is effective on reproductive growth of sunflower in the study area of Grey Terrace Soil of Gazipur (AEZ-28).

Introduction

Sunflower (*Helianthus annuus* L.) is the most important oilseed crop. It is cultivated in different countries of the world. Sunflower, has been found to be particularly sensitive to B deficiency and is sometimes used as an indicator for assessing available B in soils (Oyinlola, 2007). Although B is essential for crop growth and can be applied to meet crop demands, harmful effects can be induced by excessive applications during early phases of growth (Oyinlola, 2007 and Shorrocks, 1997). Yield and the component in vegetative and reproductive stages of sunflower may both be affected both positively and negatively by B depending upon the dose used as a fertilizer. Boron requirement of sun flower during reproductive growth is higher than during vegetative growth (Asad*et al*., 2003). At flowering, B deficiency can affect pollen viability and abortion of stamens and pistils which contribute to poor seed set due to malformed capitulums and consequently low seed yield (Chatterjee and Nautiyal, 2000). Information regarding B foliar spray on sunflower is not available in Bangladesh. So keeping in view the importance of B and sunflower, this study was planned with the objectives i) to determine the effect of foliar spray of B on yield contributing characters of sunflower and ii) to find out the optimum rate of B for maximizing the yield and quality of sunflower.

Materials and Methods

A field experiment was conducted at micronutrient experimental field, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur (Grey Terrace Soil)during rabi 2021 - 2022.The study area was under the agro-ecological zone Madhupur Tract (AEZ-28). The experiment was laid out in a RCB design with three replications. The unit plot size was 2 m × 2 m. BARI Surjamukhi-3 variety was used in the experiment as test crop. Fertilizers were applied at the rate of 140-43-81-29-3 kg ha^{-1} of N-P-K-S-Zn in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively. A basal application was made with 5 t ha^{-1}cowdung.The entire amount of cowdung and all P, K, S, and Zn were applied at the time of sowing as basal dose, while N was applied in three splits (half at sowing and remaininghalf N was applied as top dress in two equal splits at 20-25 and 40-45 DAS).Before sowing the seeds were treated with vitavax. Seed were sown on 22 November, 2021 with a spacing of 50cm from row to row and 25 cm from plant to plant. Irrigation was given according to need throughout the period to keep the soil moist. Intercultural operations were done as and when necessary.

Initial soil samples were collected from a depth of 0-15 cm and analyzed prior to application of different fertilizers are presented in Table 1. Experimental field soil was acidic in reaction (pH 5.3). The status of B was low.

Chemical analysis

For initial soil analysis, soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon determination was done by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Elements K, Ca and Mg were determined by NH_4OAC extractable method and Cu, Fe, Mn and Zn were determined by DTPA extraction method followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method while S was determined by turbidimetric method with $BaCl_2$.

Sample preparation

The plant samples from each plot were dried at 65°C in an electric oven for 72 h then ground to pass through a 20 mesh sieve and analyzed following standard procedures. Plant samples were digested with H_2SO_4 for N and HNO_3-$HClO_4$ (3:1) for other nutrients determination.

Nutrient uptake

Nutrient uptake was determined by the following relationship (Fegeria*et al*., 1997)
Nutrient uptake (kg ha^{-1}) = Nutrient % × Dry weight (kg ha^{-1}) /100

Foliar application

To study the effect of B as foliar spray on reproductive growth of sunflower, boric acid (H_3BO_3) having 17% B were applied at 20-25 and 40-45 days after sowing (DAS). The treatment combinations of foliar spray of B were T_1: control (spray with distilled water), T_2: 50 mg L^{-1}B, T_3: 100 mg L^{-1}B and T_4: 150 mg L^{-1} B. Foliar sprays were applied using a hand sprayer. All treatments were applied as a foliar spray on plants using hand operated compressed air sprayer at the 10 literperplot (2.5 Lm^{-2}). The time of foliar spray was 8:00A.M.

Sunflower head was harvested at maturity stage. Five plants were randomly selected from each and every treatment for recording necessary yield data such as dry matter, head diameter, number of seed, number of empty seed, seed weight, % empty seed, seed yield (t ha^{-1}), B and oil content. Data were analyzed STATISTIX-10 and means were compared by multiple comparison test using LSD.

Results and Discussion

Effect of foliar application of B on yield contributing traits and yield have been presented in Table 2. Significant differences were observed among the treatments for head diameter. It was observed that the head diameter was recorded the highest in T_4 (16.67 cm) which was followed by T_3 (15.60). The lowest diameter was recorded with the control treatment (12.27 cm). Number of seeds $head^{-1}$ was the highest in T_4 (601.27) treatment which was followed by T_3 (528.30) and T_2 (455.33) and they were statistically dissimilar. The number of empty seeds $head^{-1}$ was recorded the highest in control (136.83) treatment which was followed by T_2 and T_3 treatments. But the less numbers were recorded in the T_4 (120.20) treatment leading to higher yield. This was in agreement with Al-Amery *et al* (2011). In case of seed yield $plant^{-1}$ the treatment T_4 was recorded the highest (40.00 g $plant^{-1}$) followed by T_3 (33.27 g $plant^{-1}$) but the lowest was recorded in the control (21.07 g $plant^{-1}$).

Head diameter, number of seeds $head^{-1}$ and seed yield $plant^{-1}$ of sunflower was found to increase with higher dose of foliar application of B in the study of Mekki (2015), Brighenti and Castro (2008), Sharker and Mohammed (2011) and Al–Amery *et al*. (2011). Bhattacharyya *etal.* (2015) observed the highest sunflower yield and maximum B efficiency with foliar spray of B.

The hundred seed weight was recorded the maximum in T_4 treatment (7.29g) which was followed by T_3 (6.32g) and T_2 (5.36g). In case of yield (t ha^{-1}) significant differences were observed among the treatments. The highest yield (2.25 t ha^{-1}) was recorded with the T_4 treatment where 150 mgL^{-1} of B were applied. The empty seed percentage was highest in control (36%) treatment where deformed capitulum were produced but the lowest in T_4 treatment (19.99%) that was also responsible for higher yield with T_4 treatment. Seed yield might be increased with the increased application of B due to prolonged photosynthetic capacity during flowering and seed set or through improved partitioning from increased biomass. According to Al-Amery *et al.* (2011) application of B resulted in increased seed yield partly may be due to decreased seed sterility. Boron requirement of sunflower during reproductive growth is higher than vegetative growth. So adequate supply of B might have resulted enhanced growth (Asad*etal*., 2003). In Table 2 contd., oil% ranged from 38.33% to 41.15%, likewisein oil yield with the range from 8.06 to 16.47 g/plant. Application of B up to 150 mgL^{-1}significantly increased oil% and oil yield in BARI Surjamukhi-3. The highest oil% (41.15%) and oil yield (16.47g) was recorded in T_4 treatment. The increase in seed yield and oil% in BARI Surjamukhi-3 with applying 150 mgL^{-1} of B may be due to the increase of other yield components. The significant increase in oil yield might be due to the increase in oil content by foliar application of 150 mgL^{-1} B.Renukadevi and Savithri(2003) reported that application of B had brought out a tremendous increase in the oil yield of sunflower. Soil application of 2.0 kg B ha^{-1} recorded the highest oil yield.

In Table 3, significant differences were identified in case of biomass yield (t ha^{-1}). The T_4 treatment recorded the highest biomass (3.29 t ha^{-1}) which was followed by T_3 (2.79 t ha^{-1}) and T_2 (2.28 t ha^{-1})treatment. The control treatment recorded the lowest value (1.79 t ha^{-1}). Dry matter of sunflower was found to be increased with B application in the study of Al-Amery *etal*. (2011).

Boron conc. (ppm) was recorded the highest in T_4 treatment (59.67ppm) which was followed by T_3 (53.67 ppm) and T_2 (47.00 ppm) but T_4 and T_3 were statistically identical and T_3 identical with T_2 treatment. The lowest amount was recorded in the control treatment (41.00 ppm). Boron conc. (%) was varied from 0.0060% to 0.0041%. The highest amount was recorded in T_4 (0.0060%) but the lowest in the T_1 (0.0041%).

Boron uptake (kg ha^{-1}) was significantly varied among the treatments. The highest amount was recorded in T_4 (0.196 kg ha^{-1}) that was followed by T_3 (0.150 kg ha^{-1}) and T_2 (0.107 kg ha^{-1}). But the lowest amount was observed in the control treatment (0.073 kg ha^{-1}). Foliar application of B in sunflower recorded yield maximization followed by the uptake of the plant in the study of Bhattacharyya *et al*. (2015).

Seed dry yield (kg ha^{-1}), B conc. (ppm), B conc. (%) and B uptake by seed (kg ha^{-1}) have been described in Table 4. In case of seed yield (kg ha^{-1}) sufficient variation observed among the treatments. The highest seed yield was recorded in T_4 (1570.83 kg ha^{-1}) which was followed by T_3 (1513.33 kg ha^{-1}) and T_2 (1458.00 kg ha^{-1}). The T_1 treatment was identified as the lowest one (1397.83 kg ha^{-1}). Seed yield was found to be increased with the application of B in the study of Ahmed *etal*. (2011), Jyothi *etal*. (2018) and Al-Amery *et al*. (2011).

Boron conc. (ppm) was recorded the highest in T_4 (23.00 ppm) that was followed by T_3 (20.33 ppm) and T_2 (17.33 ppm) but the lowest was in T_1 (14 ppm), the control treatment. Boron conc. (%) varied from 0.0014% to 0.0023% that was recorded in T_1 and T_4 treatment, respectively. Significant differences were recorded among the treatments in case of B uptake by seed (kg ha^{-1}). The maximum amount was identified in T_4 treatment (0.0361 kg ha^{-1}) which was followed by T_3 (0.0308 kg ha^{-1}) and T_2 (0.0253 kg ha^{-1}). The minimum amount was identified in control treatment (0.0196 kg ha^{-1}).

Root dry weight, B conc. (ppm), B conc. (%) and B uptake by root (kg ha^{-1}) have been described in Table 5. Sufficient variation was recorded among the treatments in case of root dry weight. The maximum root dry weight was recorded in T_4 (498.67 kg ha^{-1}) followed by T_3 (416.00 kg ha^{-1}) and T_2 (333.33 kg ha^{-1}). The minimum amount was found in the control (248.00 kg ha^{-1}).

Boron content either form of ppm and percent was significantly visible. The highest amount (ppm) was observed in T_4 (19.33 ppm) followed by T_3 (16.00 ppm) and T_2 (13.00 ppm). The lower amount was recorded in the control (10.00 ppm) treatment. The conc. (%) ranged from 0.0019% to 0.0010% from T_4 to T_1 treatment.

Boron uptake by root (g ha^{-1}) significantly varied among the treatments. The highest amount was recorded in T_4 (8.0 g ha^{-1}) followed by T_3 (6.0 g ha^{-1}) and T_2 (4.2 g ha^{-1}) treatment. The lowest amount was recorded in T_1 (2.7 g ha^{-1}) treatment.Asad*etal*. (2003) reported improved growth with foliar application of B with little dependence of B concentration in root environment in sunflower.

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	Texture	pH	OM (%)	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
				meq 100g^{-1}			%	ppm						
Result	Sandy clay loam	5.3	1.3	6.4	1.9	0.16	0.07	6	32	0.17	0.93	154	17.5	3.49
Critical level	-	-	-	2.0	0.5	0.12	-	7	10	0.2	0.2	4.0	1.0	0.6

Table 2. Effect of foliar application of B on the yield components and yield of sunflower during 2021 - 2022

Treatment	Head diameter (cm)	No. of seeds head^{-1}	No. of empty seeds head^{-1}	Seed yield (g plant^{-1})	Weight of 100 seed (g)	Yield (t ha^{-1})	Empty seed%
T_1: Control	12.27c	380.20d	136.83a	21.07d	4.40d	2.11d	36.00a
T_2 :50 mgL^{-1}B	14.13bc	455.33c	131.95b	27.40c	5.36c	2.16c	28.98b
T_3:100 mgL^{-1}B	15.60ab	528.30b	126.72c	33.27b	6.32b	2.20b	23.99c
T_4:150 mgL^{-1}B	16.67a	601.27a	120.20d	40.00a	7.29a	2.25a	19.99d
CV(%)	6.97	5.60	5.88	8.26	6.02	6.49	5.70

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Table 2. Contd.

Treatment	Oil %	Oil Yield (g/plant)
T_1: Control	38.33b	8.06d
T_2 :50 mgL^{-1}B	39.93ab	10.96c
T_3:100 mgL^{-1}B	40.55ab	13.49b
T_4:150 mgL^{-1}B	41.15a	16.47a
CV(%)	5.53	9.39

Table 3. Biomass yield, content and uptake of B in sunflower plant

Treatment	Biomass yield ($t\ ha^{-1}$)	B conc. (ppm)	B conc. (%)	B uptake by plant ($kg\ ha^{-1}$)
T_1: Control	1.79d	41.00c	0.0041c	0.073d
T_2 :50 $mgL^{-1}B$	2.28c	47.00bc	0.0047bc	0.107c
T_3:100 $mgL^{-1}B$	2.79b	53.67ab	0.0054ab	0.150b
T_4:150 $mgL^{-1}B$	3.29a	59.67a	0.0060a	0.196a
CV(%)	6.63	7.17	7.17	7.45

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Table 4. Seed dry yield, content and uptake of B in sunflower seed

Treatment	Seed yield ($kg\ ha^{-1}$)	B conc. (ppm)	B conc. (%)	B uptake by Seed ($kg\ ha^{-1}$)
T_1: Control	1397.83d	14.00d	0.0014d	0.0196d
T_2 :50 $mgL^{-1}B$	1458.00c	17.33c	0.0017c	0.0253c
T_3:100 $mgL^{-1}B$	1513.33b	20.33b	0.0020b	0.0308b
T_4:150 $mgL^{-1}B$	1570.83a	23.00a	0.0023a	0.0361a
CV(%)	6.145.65	5.65	5.89	

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Table 5. Root dry weight, content and uptake of B in sunflower root

Treatment	Root dry weight ($kg\ ha^{-1}$)	B conc. (ppm)	B conc. (%)	B uptake by root ($g\ ha^{-1}$)
T_1: Control	248.00d	10.00c	0.0010c	2.7d
T_2 :50 mgL^{-1}	333.33c	13.00bc	0.0013bc	4.2c
T_3:100 mgL^{-1}	416.00b	16.00ab	0.0016ab	6.0b
T_4:150 mgL^{-1}	498.67a	19.33a	0.0019a	8.0a
CV(%)	5.32	12.98	12.98 6.84	

Mean values in the same column followed by the same letters are not significantly different at the 5% level of significance.

Conclusion

Foliar application of B enhanced number of seed, hundred seed weight, seed yield (g $plant^{-1}$), oil%, oil yield (g/plant) and yield of seed of sunflower and decreased in empty seed. It was, therefore, concluded that 150 mg L^{-1} of B as foliar application with the volume of 10 liters per plot (2.5 Lm^{-2}) could be used to increase seed yield(g $plant^{-1}$), yield (2.25 tha^{-1}), oil%, oil yield (g/plant), B uptake by seed, plant and root,and decrease seed sterility (19.99%) of sunflower. This is second year result; it is needed for further study of this experiment.

Acknowledgements

At first, I express my deepest sense of gratefulness to Almighty Allah who enables me to complete this work successfully. Sincere thanks to Dr. Habib Mohammed Naser, CSO andHead, Soil Science Division, BARI, Gazipur for providing necessary facilities, guidance and valuable suggestions during the period of investigation. I am grateful to my colleagues and other staffs of the Soil Science Division, BARI,Gazipur for their help in the field and laboratory.

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EFFECT OF SEED PRIMING ON YIELD AND NUTRIENT UPTAKE OF CAULIFLOWER

S. SULTANA, M. AKTER, M. B. BANU AND H. M. NASER

Abstract

This study was conducted at the research field of Soil Science Division,Bangladesh Agricultural Research Institute (BARI),Gazipur under AEZ-28 during rabi season 2021-2022.A field experiment on effect of seed priming on yield and nutrient uptake of cauliflower was conducted in Grey Terrace Soil to determine concentration of seed priming on growth, yield and quality of cauliflower. There are six treatments viz. T_1: Control (without priming), T_2: Hydropriming (Seed soaked with distilled water), T_3: Seed soaked with 0.5% zinc, T_4: Seed soaked with 0.01% boron, T_5: Seed soaked with 0.5% zinc and 0.01% boron and T_6: Seed soaked with sand matrix. The experiment was RCB design with three replications. The combined use of micronutrients (Zn,B) seed priming gave the highest yield (56.8 t ha^{-1}). The same trend was observed in the yield contributing characters of cauliflower. The untreated treatment produced the lowest yield (25.4 t ha^{-1}). The highest zinc and boron uptake was found in T_5 treatment (seed soaked with zinc and boron).Quality characters like TSS, ascorbic acid and β carotene content also found high in combined use of seed priming treatments. The combined application of boron and zinc (0.01% + 0.5) for seed priming was the most effective treatment technique for cauliflower production.

Introduction

Cauliflower is one of the most important vegetable crop which is high in vitamin C and a good source of fiber and vitamin K. It is also rich in phytochemicals and antioxidants, two naturally occurring compounds thought to play a role in preventing chronic diseases. This, however, requires application of higher doses of fertilizer to soils because of low nutrient-use efficiency (Singh, 2007). In crop plants, micronutrients may be applied to the soil, foliar sprayed or added as seed treatments. Although the required amounts of micronutrients can be supplied by any of these methods, foliar sprays have been more effective in yield improvement and grain enrichment; but high cost has restricted its wider adaption, particularly by resource-poor farmers (Johnson et al., 2005). Moreover, foliar application occurs at later growth stages when crop stands are already established. Seed treatment is a better option from an economical perspective as less micronutrient is needed, it is easy to apply and seedling growth is improved (Singh *et al.,* 2003).

Micronutrients often act as co-factors in enzyme systems and participate in redox reactions, in addition to having several other vital functions in plants. Most importantly, micronutrients are involved in the key physiological processes of photosynthesis and respiration (Marschner, 1995; Mengel *et al.,* 2001) and their deficiency can impede these vital physiological processes thus limiting yield gain. Micronutrient priming has several beneficial effects in the morphophysiological, biochemical and molecular aspects of the plants. In most cases, micronutrient application through seed treatment has astonishingly performed better than other application methods. Being an easy and cost effective method of micronutrient application, seed priming offer an attractive option for resource-poor farmers. Seed priming with Zn significantly improved yield and related traits (Kaya *et al.,* 2007).

Seed priming substantially improved mineral (Zn and P) uptake and dry matter accumulation in barley and also enhanced water use efficiency by 44% in drought stressed plants (Ajouri *et al.,* 2004). Seed priming with B also has a profound influence on advanced growth stages. (Kumar et al. 2008). Keeping this point of view, the experiment were undertaken i) to investigate the role of seed priming on growth, yield and quality of cauliflower and ii) to find out the interactive effect of seed priming on nutrient uptake of cauliflower.

Materials and Methods

A field experiment was carried out in the micronutrient experimental field, Soil Science Division of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur on 28 November, 2021 with a view of study the effect of seed priming on yield and nutrient uptake of. cauliflower. The experiment was laid out in a randomized block design with three replications having plot size 3m×3m. Six different treatments viz. T_1: Control (without priming), T_2: Hydropriming (soaked with distilled water), T_3: Seed soaked with 0.5% zinc, T_4: Seed soaked with 0.01% boron, T_5: Seed soaked with 0.5% zinc and 0.01% boron and T_6: Seed soaked with sand matrix.

The tested variety was snow white. Healthy and equal sized thirty five days age seedlings of cauliflowers were transplanted in line with 50 cm line to line and 50 cm plant to plant spacing. N, P, K, S were supplied from urea, TSP, MoP and gypsum respectively. All PKS and 1/3 of N were supplied at the time of final land preparation. The remaining two third of N were applied as top dress at 30 and 60 days after transplanting. Irrigation was applied in three times. Other intercultural operations were done as and when necessary. The source of micro nutrient for boron and zinc were boric acid and zinc sulphate, respectively. The cauliflower was harvested on 15 to 23 February, 2022. Data on yield and yield contributing characters were recorded and analyzed statistically using Statistics-10 software. Significant differences were tested among treatments by one-way ANOVA and via Tukey HSD tests for multiple comparisons at a 5% significance level. Plants samples were collected from each plot for laboratory analysis.

Methods of chemical analysis of soil

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). Standard methods were used in these determinations. Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by the wet oxidation method (Walkley and Black). Total N was determined by a modified Kjeldahl method. Calcium (Ca), magnesium (Mg) and K were determined by NH_4OAc extractable method, copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were determined by DTPA extraction followed by AAS reading. Boron (B) was determined by $CaCl_2$ extraction method. Available P was determined by the Bray and Kurtz method while S was determined using the turbidimetric method with $BaCl_2$.

Digestion and analytical procedure

One gram of each sample was weighed into 50-ml beakers, followed by the addition of 10 ml mixture of analytical grade acids HNO_3: $HClO_4$ in the ratio 5:1, and left overnight for complete contact of material. Next day, the digestion was performed at a temperature of about 190ºC for 1.5 h. After cooling, the samples were transferred into 100 ml volumetric flask and solution was made up to a final volume raised up to the mark with distilled water. Zinc was determined by DTPA extraction followed by AAS reading. Boron (B) was determined by $CaCl_2$ extraction method. Analysis of each sample was carried out three times to obtain representative results and the data reported in µg g^{-1} (on a dry matter basis).

Seed priming techniques

Cauliflower seeds was soaked in aerated solutions of 0.5% Zn, 0.01% B, in sand matrix and in various combinations of these for 8 h. All solutions were prepared in distilled water and seed to solution ratio was kept 1:5 (w/v *i.e.* 1 kg seed in 5 liters of solution) for seed priming. Aeration was provided throughout the priming to avoid anaerobic condition development. After soaking, seeds were rinsed thoroughly three times with distilled water and re-dried under shade to their original weight. Both treated and untreated seeds were sown in the well-prepared field.

Total soluble solid and ascorbic acid content:

Cauliflower from each treatment were cut into small slices and pooled. Samples were homogenized in a blender and portion of the homogenate were taken to determine the bulb quality. Total soluble solids content (TSS) was determined at 20^0 C with a refractometer and reported as ^{0}Brix.Ascorbic acid contents (vitamin C) was measured by classical titration method using 2,6-dichlorophenol indophenols solution and express as mg 100 g-^{1}of fresh weight (Miller, 1998).

Results and Discussion

There was a significant effect of different priming treatments on the yield and yield contributing characters of cauliflower (Table 2). Yield contributing characters i.e. plant height, curd height, marketable weight of single curd and curd circumferences were highest in T_5 treatment. The highest plant height (68.3 cm) was recorded in T_5 treatment which was significantly higher than other treatments. The increase in plant height in all treatments except control was indicated the potential of nutripriming in improving yield components. The lowest plant height (63.6 cm) was found in control treatment.

Maximum curd height (16.1 cm) was found in T_5 treatment which was statistically similar with T_2, T_3 and T_4 treatment. Curd circumference and marketable weight of single curd are important yield parameter of cauliflower. Both of curd circumference and marketable weight of single curd are significantly influenced by different priming treatments. Combined use of zinc and boron (T_5 treatment) gave the maximum curd circumference (67.5 cm).The highest marketable weight (1.42 kg) of single curd was observed in T_5 treatment which was significantly higher than other treatments. Lowest (0.63 kg) was found from control treatment.

The highest yield of cauliflower (56.8 t ha^{-1}) was obtained in T_5 treatment receiving both zinc and boron. This might be due to seed treatment with micronutrients has the potential to meet crop micronutrient requirements and improve seedling emergence and stand establishment, yield, and grain micronutrient enrichment. Combining seed treatments also increased fertilizer application efficiency, indicating better use of resources (Pattanayak *et al.*, 2000), thus highlighted the involvement of micronutrient in physiological processes during early seedling development, possibly in protein synthesis, cell elongation membrane function and resistance to abiotic stresses (Cakmak, 2000).The lowest curd yield (25.4 t ha^{-1}) of cauliflower was found in control treatment.

Boron and zinc content and uptake in cauliflower

Boron and zinc concentration and uptake by cauliflower curd and plant were influenced by seed priming of boron and zinc. The highest zinc and boron uptake in curd was found in T_5 treatment (zinc 0.42 kg ha^{-1}, boron 0.37 kg ha^{-1}) and the lowest from control (zinc 0.18 kg ha^{-1} and boron 0.13

kg ha^{-1}).Same trend was also found in plant. The highest zinc and boron uptake in plant was found in T_5 treatment (zinc 0.52 kg ha^{-1},boron 0.42 kg ha^{-1}) and the lowest from control(zinc 0.21 kg ha^{-1} and boron 0.14 kg ha^{-1}).Seed priming with a combination of micronutrients significantly improved nodulation, N fixation, nutrient uptake, plant growth and yield (Pattanayak *et al.,* 2000). In seed priming, oxygen supply during seed soaking improved its effectiveness (Farooq *et al.,* 2009). Combination of both the element and single application of either boron or zinc gave the higher content as compared to control treatments (Table 3 & table 4). Seed priming with a combination of micronutrients improved nutrient uptake**.** Seed priming with Zn increased grain zinc content by 12% in wheat (mean of three trials) and by 29% in chickpea (one trial) (Harris et al., 2008). The treatment T_1 (control) always recorded with the least amount of nutrient uptake.

TSS, Ascorbic acid and β Carotene content in cauliflower

A total soluble solid which is an indicator of shelf life in cauliflower was influenced by priming of zinc and boron. T_5 treatment (seed priming with zinc and boron) produced higher TSS of 7.0 ^{0}B whereas, control recorded lower value 5.6 ^{0}B (Table 5).Highest vitamin C content (81 mg 100g^{-1}) in T_5 treatment and the lowest was found in control (34 mg 100g^{-1}).β carotene content was also found high in T_5 (27 mg 100g^{-1}) and lowest from control (14 mg 100g^{-1}). The increased TSS content evidently showed that the stored food materials undergo either partial or complete hydrolysis and provide substrate for respiration. Lashkari et al., (2008) recorded that increase TSS (7.200 Brix) was obtained with combine foliar sprays of zinc and iron at 0.5% concentration each. Kumar et al., (2010) recorded that foliar application of o.3 per cent of borax has significantly positive effect on the ascorbic acid content of cauliflower curd.

Conclusion

Seed treatment with micronutrients has the potential to meet crop micronutrient requirements and improve seedling emergence and stand establishment, yield, and grain micronutrient enrichment. Seed treatment, by seed priming or seed coating, seems pragmatic, inexpensive and an easy method of micronutrient delivery. T_5 treatment (seed treated with both zinc and boron) was found to be the most effective for cauliflower cultivation. Seed priming of micronutrients (zinc and boron) significantly affected the growth, yield and yield parameters of cauliflower.

Acknowledgements

Sincere thanks to Dr. Habib Mohammed Naser, CSO andHead, Soil Science Division, BARI, Gazipur for providing necessary facilities, guidance and valuable suggestions during the period of investigation. I am grateful to my colleagues and other staffs of the Soil Science Division, BARI,Gazipur for their help in the field and laboratory.

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	Texture	pH	OC (%)	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
				meq 100 g^{-1}				µg g^{-1}					
Result	-	7.05	1.2	7.3	2.1	0.23	0.10	5	18	0.12	1.16	37.6	1.4
Critical level	-			2.0	0.5	0.12	-	7.0	10	0.2	0.2	4.0	0.6

Table 2. Effect of different seed priming on the yield and yield components of cauliflower

Treatment	Plant height (cm)	Curd height (cm)	Curd circumference (cm)	Marketable wt. of single curd (kg)	Curd weight (kg plot^{-1})	Yield (t ha^{-1})
T_1 (Control)	63.6c	9.6c	61.8b	0.63c	22.8c	25.4c
T_2 (Hydropriming)	64.9bc	13.4ab	65.0ab	1.13b	40.9b	45.4b
T_3 (Soaked with 0.5% Zn)	65.9bc	14.3ab	66.0a	1.16b	42.0b	46.7b
T_4 (Soaked with 0.01% B)	64.9bc	15.6a	65.3ab	1.26ab	45.3ab	50.4ab
T_5 (Soaked with Zn & B solution)	68.3a	16.1a	67.5a	1.42a	51.1a	56.8a
T_6 (Soaked with sand matrix)	65.6bc	11.7bc	64.6ab	1.16b	41.8b	46.4b
CV (%)	1.15	8.01	1.92	4.25	4.25	4.25

Mean values in the same column followed by the same letters are not significantly different (*P*< 0.05)

Table 3. Effect of different seed priming on nutrient uptake by cauliflower curd

Treatment	Dry yield (kg ha^{-1})	Zn conc. (ppm)	B conc. (ppm)	Zn conc. (%)	B conc. (%)	Zn uptake by curd (kg ha^{-1})	B uptake by curd (kg ha^{-1})
T_1 (Control)	3629	48.5	36.0	0.0049	0.0036	0.18	0.13
T_2 (Hydropriming)	6586	49.1	45.0	0.0049	0.0045	0.32	0.30
T_3 (Soaked with 0.5% Zn)	7172	55.0	50.0	0.0055	0.0050	0.39	0.36
T_4 (Soaked with 0.01% B)	6557	56.9	48.0	0.0057	0.0048	0.37	0.31
T_5 (Soaked with Zn & B solution)	7329	57.8	51.0	0.0058	0.0051	0.42	0.37
T_6 (Soaked with sand matrix)	6814	50.2	47.0	0.0050	0.0047	0.34	0.32

Table 4. Effect of different seed priming on nutrient uptake by cauliflower (plant)

Treatments	Dry yield (kg ha^{-1})	Zn conc. (ppm)	B conc. (ppm)	Zn conc. (%)	B conc. (%)	Zn uptake by curd (kg ha^{-1})	B uptake by curd (kg ha^{-1})
T_1 (Control)	3629	58.4	38.0	0.0058	0.0038	0.21	0.14
T_2 (Hydropriming)	6586	59.6	50.0	0.0060	0.0050	0.39	0.33
T_3 (Soaked with 0.5% Zn)	7172	70.0	53.0	0.0070	0.0053	0.50	0.38
T_4 (Soaked with 0.01% B)	6557	66.7	52.0	0.0067	0.0052	0.44	0.34
T_5 (Soaked with Zn & B solution)	7329	71.0	57.0	0.0071	0.0057	0.52	0.42
T_6 (Soaked with sand matrix)	6814	63.1	56.0	0.0063	0.0056	0.43	0.38

Table 5: Total Soluble Solid (TSS), Ascorbic acid and β-carotene content in cauliflower

Treatments	TSS (^{0}Brix)	Vitamin-C (mg 100 g^{-1})	β carotene(mg/100g^{-1})
T_1 (Control)	5.6	34	14
T_2 (Hydropriming)	6.1	56	16
T_3 (Soaked with 0.5% Zn)	6.6	78	25
T_4 (Soaked with 0.01% B)	6.5	61	24
T_5 (Soaked with Zn & B solution)	7.0	81	27
T_6 (Soaked with sand matrix)	6.0	58	20

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FOLIAR APPLICATION OF MANGANESE ON GROWTH AND YIELD OF GROUNDNUT

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Abstract

This study was conducted at the research field of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Gazipur under AEZ-28 during rabi season 2021-2022.A field experiment on effect of foliar application of manganese on growth and yield of groundnut was conducted in Grey Terrace Soil to determine the effect of manganese on growth, yield and quality of groundnut (BARI chinabadam 9). There are five treatments viz. T_1: Control, T_2: Foliar spray of 0.02% Mn, T_3: Foliar spray of 0.04% Mn, T_4: Soil application of Mn 0.5 kg ha^{-1}, T_5: Soil application of Mn 1.0 kg ha^{-1}. The experiment was RCB design with three replications. The highest nut yield (2.59 t ha^{-1}) was found in T_3 treatment. The same trend was observed in the yield contributing characters of groundnut. The untreated treatment produced the lowest yield (1.72 t ha^{-1}). Crude oil and protein% and micronutrient content also high in foliar treated treatments. The highest content of Mn, Fe, Zn and B was found in T_3 treatment (0.04% foliar applied Mn). Foliar application of manganese is an effective technology for increasing the yield and quality of groundnut.

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the world's fundamental sources of vegetable oil. United States Department of Agriculture (USDA) databases illustrated that, groundnut was ranked fifth worldwide in vegetable oil production among oilseed crops. Although groundnut is widely known as an oilseed crop, utilization of groundnut varies extremely from one country to another (Tillman and Stalker, 2009). Micronutrients are essential for healthy growth and reproduction of plants i.e. boron, manganese, molybdenum, chlorine, copper, iron, nickel and zinc. Manganese plays an important function in many biological processes i.e., oxidation reactions, reduction, carboxylation, carbohydrates metabolism, phosphorus reactions and citric acid cycle as well as electron transport in photosynthesis, also, it acts as an activator for many enzymes i.e., protein-manganese in Photosystem II and superoxide dismutase. Manganese (Mn) also is a heavy metal micronutrient, the functions of which are fairly known. It is involved in the oxygen-evolving step of photosynthesis and membrane function, as well as serving as an important activator of numerous enzymes in the cell (Wiedenhoeft, 2006). Soil application of Mn is problematic, since its efficiency depends on many soil factors, including soil pH. A suitable method for the correction and /or prevention of Mn deficiency in plants is the foliar application of ionic or chelated solution forms of this nutrient (Papadakis *et al.,* 2007). Keeping in view the key role played by manganese in plant growth, this study is designed to find out the suitable dose and method of manganese application of groundnut production.

Materials and Methods

A field experiment was carried out in the micronutrient experimental field, Soil Science Division of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur on 20 December, 2021 with a view of study to investigate the effect of manganese on growth, yield and quality of groundnut. The experiment was laid out in a randomized block design with three replications having plot size 2m×2m. Six different treatments viz. T_1: Control, T_2: Foliar spray of 0.02% Mn, T_3: Foliar spray of 0.04% Mn, T_4: Soil application of Mn 0.5 kg/ha^{-1}, T_5: Soil application of Mn 1.0 kg/ha^{-1}.

The tested variety was BARI chinabadam-9. Seeds were used at the rate of 1.5 kg ha^{-1}.N, P, K, S were supplied from urea, TSP, MoP and gypsum respectively. All PKS and 1/3 of N were supplied at the time of final land preparation. The remaining two third of N were applied as top dress at 30 and 60 days after sowing. Irrigation was applied in three times. Other intercultural operations were done as and when necessary. The source of micro nutrient for boron and zinc were boric acid and zinc sulphate, respectively. The groundnut seeds were sown on 20 December, 2021 in a spacing of 30 cm×15 cm. The groundnut was harvested on 18 May, 2022. Data on yield and yield contributing characters were recorded from ten plants selected randomly for each plot. Data and pod characters were recorded and analyzed statistically using Statistics-10 software. Significant differences were tested among treatments by one-way ANOVA and via Tukey HSD tests for multiple comparisons at a 5% significance level. Plants samples were collected from each plot for laboratory analysis.

Methods of chemical analysis of soil

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). Standard methods were used in these determinations. Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by the wet oxidation method (Walkley and Black). Total N was determined by a modified Kjeldahl method. Calcium (Ca), magnesium (Mg) and K were determined by NH_4OAc extractable method, copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were determined by DTPA extraction followed by AAS reading. Boron (B) was determined by $CaCl_2$ extraction method. Available P was determined by the Bray and Kurtz method while S was determined using the turbidimetric method with $BaCl_2$.

Digestion and analytical procedure

One gram of each sample was weighed into 50-ml beakers, followed by the addition of 10 ml mixture of analytical grade acids HNO_3: $HClO_4$ in the ratio 5:1, and left overnight for complete contact of material. Next day, the digestion was performed at a temperature of about 190ºC for 1.5 h. After cooling, the samples were transferred into 100 ml volumetric flask and solution was made up to a final volume raised up to the mark with distilled water. Zinc was determined by DTPA extraction followed by AAS reading. Boron (B) was determined by $CaCl_2$ extraction method. Analysis of each sample was carried out three times to obtain representative results and the data reported in µg g^{-1} (on a dry matter basis).

Foliar application

Manganese sulphate ($MnSO_4.H_2O$) having 36% Mn were applied at 20-25 and 30-35 days after sowing (DAS). Foliar sprays were applied using a hand sprayer. All treatments were applied as a foliar spray on plants using hand operated compressed air sprayer at the 10 liter $plot^{-1}$. The time of foliar spray was 8:00A.M.

Results and discussion

The yield and yield contributing components of groundnut were significantly affected by different rate of manganese(Table 2).Yield contributing characters of groundnut i.e. plant height(46.0cm),nut/plant(27.2),karnel/plant(42.6),100 karnel wt(48.7 g) was found highest in T_3 treatment. The highest plant height (46.0cm) was found in T_3 treatment which was significantly higher than other treatments. The lowest plant height was recorded from T_1 (control). Manganese (Mn) is an important micronutrient for plant growth and development and sustains metabolic roles within different plant cell compartments. Manganese (Mn) plays a substantial role in oxidation and reduction processes in plants.

The highest nut/plant (27.2) was found in T_3 treatment which was statistically higher than others treatments.The highest karnel/plant (42.6) was found in T_3 treatment which was statistically higher than other treatments. This might be due to the important role of manganese micronutrients foliar spraying treatments. With Mn foliar application, crop yield increased due to increasing photosynthesis efficiency and carbohydrate synthesis such as starch (Diedrick, 2010). Manganese plays an important role in chlorophyll production and its presence is essential in Photo system II, also involved in cell division and plant growth (Mousavi, 2007 and Anderson, 1996).

The highest nut yield (2.59 t ha^{-1}), stover yield (4.66 t ha^{-1}) were observed in T_3 treatment which is significantly higher than other treatments and the lowest from T_1 (control).This might be due to the positive effect of managanese as manganese increases the photosynthetic efficiency and development of dry matter in plants as an important micronutrient for plant metabolic processes.

. Using fertilizers with manganese increases qualifications of photosynthesis and carbohydrates synthesis such as starch, thus photosynthesis efficiency decreases with manganese deficiency due to reduction on crop yield and quality. These results in harmony with these obtained by Singh and Chaudhari (1997), Ali and Mowafy (2003), Gobarah, et al. (2006), Helmy and Shaban (2007), El-Habbasha et al. (2013), Abd EL-Kader and Mona (2013), Gowthami and Rao (2014) and Der et al. (2015). Mekki (2015) stated that increasing in pods and seeds weight and 100 seed weight for some groundnut cultivars by applying foliar application comparison to untreated plants. With Mn foliar application, crop yield increased due to increasing photosynthesis efficiency and carbohydrate synthesis such as starch (Diedrick, 2010).

Crude oil and protein content of groundnut

Crude oil and protein content of groundnut were shown in table 3.Groundnuts is valued for their high quality oil content and protein. The nutritive value of food is high as the groundnut is affordable and serves as good source of oil and protein (Atasie et al., 2009).Crude oil% ranged from 32.62%-41.20% and protein% ranged from 22.37%-32.58%.Foliar application of 0.04% Mn gave the highest crude oil%(41.20%) and protein%(32.58%).The lowest was noted in T_1 treatment.

Micronutrient content of groundnut seed

Micronutrient content increased due to application of manganese have been presented on table 4.The highest content of Mn,Fe,Zn and B was found in T_3 treatment(0.04% foliar applied Mn).The lowest micronutrient content was found in control treatment.

Conclusion

Foliar application of manganese significantly affected the growth, yield and yield parameters of groundnut. Foliar application of Mn in groundnut remains an important and economically sound choice to prevent yield loss and nutrient imbalance in soils. On the basis of the research, it can be concluded that foliar application of 0.04% manganese (T_3 treatment) was found to be the most effective for groundnut cultivation.

Acknowledgements

Sincere thanks to Dr. Habib Mohammed Naser, CSO andHead, Soil Science Division, BARI, Gazipur for providing necessary facilities, guidance and valuable suggestions during the period of investigation. I am grateful to my colleagues and other staffs of the Soil Science Division, BARI,Gazipur for their help in the field and laboratory.

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	Texture	pH	OC (%)	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
				meq 100 g^{-1}			%	µg g^{-1}						
Result	-	7.55	1.1	6.9	2.0	0.12	0.10	8	29.3	0.11	1.1	36.8	3.0	1.6
Critical level	-			2.0	0.5	0.12	-	7.0	10	0.2	0.2	4.0	1.0	0.6

Table 2. Effect of manganese on the yield and yield components of groundnut

Treatment	Plant height (cm)	Nut/plant	Karnel/plant	Karnel wt of 100 nut(g)	Nut yield(t ha-[1])	Stover yield (t ha^{-1})
T_1 (Control)	41.1cd	18.4c	35.3a	39.3c	1.72c	2.73c
T_2 (FS of 0.02% Mn)	40.8d	21.0bc	40a	42.8bc	1.92bc	3.37bc
T_3 (FS of 0.04% Mn)	46.0a	27.2a	42.6a	48.7a	2.59a	4.66a
T_4 (SA of Mn @ 0.5 kg/ha)	43.1bc	25.1a	41.4a	43.3bc	2.01bc	4.31a
T_5 (SA of Mn @ 1.0 kg/ha)	44.0ab	24.5ab	42.0a	44.4ab	2.12b	4.15ab
CV (%)	1.71	6.15	7.02	6.10	6.10	8.21

Mean values in the same column followed by the same letters are not significantly different ($P < 0.05$)

Note: T_1=Control, T_2=Foliar spray of 0.02% Mn, T_3=Foliar spray of 0.04% Mn, T_4=Soil application of Mn 0.5 kg ha^{-1}, T_5=Soil application of Mn 1.0 kg ha^{-1}

*FS-Foliar Spray; *SA-Soil Application

Table 3. Crude oil and protein content in groundnut

Treatments	Crude oil%	Protein%
T_1 (Control)	32.62	22.37
T_2 (FS of 0.02% Mn)	39.37	29.66
T_3 (FS of 0.04% Mn)	41.20	32.58
T_4 (SA of Mn @ 0.5 kg/ha)	39.95	29.72
T_5 (SA of Mn @ 1.0 kg/ha)	40.25	30.28

Table 4. Micronutrient contents in groundnut seed

Treatments	Fe	Mn	Zn	B
	ppm			
T_1 (Control)	10.90	3.21	22.70	35.33
T_2 (FS of 0.02% Mn)	14.88	4.00	27.03	38.67
T_3 (FS of 0.04% Mn)	34.94	4.90	33.30	66.00
T_4 (SA of Mn @ 0.5 kg/ha)	24.91	4.27	27.54	41.67
T_5 (SA of Mn @ 1.0 kg/ha)	31.75	4.51	27.74	55.67

Table 5. Micronutrient uptake in groundnut seed

Treatments	Zn uptake	B uptake	Fe uptake	Mn uptake
T_1 (Control)	0.0390	0.0608	0.0187	0.0055
T_2 (FS of 0.02% Mn)	0.0519	0.0742	0.0286	0.0077
T_3 (FS of 0.04% Mn)	0.0862	0.1709	0.0905	0.0127
T_4 (SA of Mn @ 0.5 kg/ha)	0.0554	0.0838	0.0501	0.0086
T_5 (SA of Mn @ 1.0 kg/ha)	0.0588	0.1180	0.0673	0.0096

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DETERMINATION OF CRITICAL LIMIT OF ZINC FOR CHICKPEA

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Abstract

A pot experiment was conducted to determine the critical limit of zinc for chickpea cultivation at the net house of Soil Science Division of Bangladesh Agricultural Research Institute, Gazipur during Rabi season of 2021-2022 grown in twenty soils collected from the five AEZs such as Tista Meander Floodplain (AEZ-3), Karatoya –Bangali Floodplain (AEZ-4), High Ganges River Floodplain (AEZ-11), Low Ganges River Floodplain (AEZ-12) and Madhupur Tract (AEZ-28). The experiment was laid out in a factorial and completely randomized design with two levels of Zn (0 and 5 ppm) applied to 20 different soil samples using three replications. The available Zn content of soils was estimated by the extraction method as 0.005 M Diethylene Triamine Pentaacetic Acid (DTPA). The amount of DTPA extractable Zn in different soils ranged from 0.50–3.1 mg kg^{-1}. The soils contained pH 4.27-7.57 and organic matter 0.67-1.87 %. The soil available Zn was negatively and significantly correlated with soil pH, Ca and Mg. However, the point bellow which chickpea shows Zn deficiency were 0.63 mg kg^{-1} in soils and 25.3 mg kg^{-1}in plant tissue as determined by Cate and Nelson's graphical procedure.

Introduction

Chickpea is an important pulse crop, rank second after common bean in world consumption (FAOSTAT, 2015) and is one of the important pulse crops in Bangladesh considering consumers choice and consumption. Chickpea is an excellent source of both soluble and insoluble fiber, complex carbohydrates, vitamins, folate and minerals especially calcium, phosphorus, iron, zinc and magnesium. Protein content is also high in chickpea where fat and sodium content is low. It plays a vital role in reducing micronutrient deficiencies in global population acting as a nutritious potential staple food. Being a good source of protein and minerals, it is regarded as poor man's meat in low-income countries and healthy food in the developed world. It is traditionally cultivated in Bangladesh under rainfed condition. Nowadays, chickpea production is decreasing day by day in Bangladesh with an increasing rate of demand of consumption that leads to a copious amount of import bill. The production of chickpea lessened from 61,485 tons (1997) to 6,237 tons (2017) in the last two decades even though yield soared from 0.73 to 1.05 t ha^{-1} over the period (DAE, 2019). In order to meet the consumption demand, Bangladesh imported 190322 tons chickpea in 2017 that was 96% of the total chickpea supply in the market in that year (FAO, 2019). Yield reduction of chickpea is happened due to the chickpea growing without almost any monetary input after rice production (ICRISAT, 2017). Hence, it is urgent to increase chickpea production in the country by proper nutrient management. Among different nutrients, Zinc plays a vital role in chickpea production. Zinc deficiency is not only the cause of low productivity of the crops, but it also results in low Zn concentration in seeds, which leads to poor dietary Zn intake when consumed (Pathak *et al.*, 2012). Zinc is an important micronutrient involved in various biochemical processes in plants, including photosynthesis, respiration, chlorophyll biosynthesis, and protein, lipid, carbohydrate and nucleic acid synthesis and degradation (Auld, 2001; Nishizawa, 2005), as well as pollen functionality and fertilisation (Pandey et al., 2006). The consequences of Zn deficiency include reduced yield and a delay in crop maturity. Furthermore, Zn deficiency reduces water use, water use efficiency (Khan et al., 2004), nodulation and nitrogen fixation (Shukla & Yadav, 1982; Ahlawat et al., 2007), which further contributes to a decrease in crop yield. Chickpea is generally considered sensitive to Zn deficiency (Khan, 1998). According to Mayer *et al.*, (2008) more than half of the world population, particularly in developing countries are facing a common key problem acknowledged as hidden hunger called micronutrient deficiency affecting mostly women, infants, and children. Cakmak, 2010 reported that Fe and Zn deficiencies are mainly happen due to low dietary intake of these elements. The low Zn content crops being grown in the deficient areas can lead to Zn deficiency in human and thereby, may result in health complicacies (Alloway, 2009). Cropping intensity (194% at present) is increasing day by day resulting continuous mining of soil nutrients which causes nutrient deficiency. Nearly half of the soils all over the world are deficient in zinc.

The Critical limit (CL) of a nutrient in soils can be defined to a level below which the crops will readily respond to the added nutrient is highly expected. It is important to know the critical limit of zinc for proper zinc fertilizer application to ensure better yield. The critical limits are quite often employed for a wide variety of soils and crops, even though these critical limits may be different not only for soils, crop species but also for different varieties of a given crop (Singh and Aggarwal, 2007). In our country, zinc deficiency is more common and information is still lacking regarding the critical level of Zn for prediction of chickpea responses to applied Zn. An attempt was therefore, made to determine the critical concentration of Zn for chickpea in different soils for making zinc application more rational.

Materials and Methods

Experimental location, Soil Collection, Analysis and Test Crop

A Pot experiment was conducted in the net house of the Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Gazipur with 20 top soils (samples collected at 0–15 cm soil depth) during (December to February) 2021- 2022. All the twenty soil samples were collected from 5 AEZs of Bangladesh such as Tista Meander Floodplain (AEZ-3), Karatoya –Bangali Floodplain (AEZ-4), High Ganges River Floodplain (AEZ-11), Low Ganges River Floodplain (AEZ-12) and Madhupur Tract (AEZ-28) encompassing six districts such as Rangpur, Nilphamari, Pabna, Bogra, Rajshahi, and Gazipur. Bangladesh was divided into 30 AEZS where soil characteristics and climatic conditions get priority for development of AEZs. The crop used in this experiment was chickpea (cv. BARI chola 9). Each of the 20 soils was collected from three different locations of the same soil series for pot trials. All soil samples were air dried, finely ground, and finally sieved ($\geq$2 mm) and mixed until homogenous. After that the soil samples were analyzed to determine the different physico-chemical properties of soil such as texture, pH, organic matter, soil Zn status etc following standard methods. Soils were comprising with five high (>1.21 ppm), eight medium (0.91–1.21 ppm) and seven low (<0.91 ppm) Zn-containing soils. Soils are sandy to loamy in nature. The available Zn content of soils was estimated by the extraction method as 0.005 M Diethylene Triamine Penta Acetic Acid (DTPA). The physico-chemical properties of the analyzed soil samples presented in Table 1.

Experimental Design and Approach

The experiment was conducted during winter season (2021–2022) in the net-house of Soil Science Division of Bangladesh Agricultural research institute (BARI), Gazipur. The factorial experiment consisted of two levels of Zn and 20 selected soil samples collected from different AEZs with varying available Zn (ranging from 0.50–3.1 mg kg^{-1} soil). Treatments were replicated three times for each soil in a completely randomized design (CRD) to give a total of 6 (2 zinc rates× 3 replication) pots for each soil. Therefore, the total number of pots used in this study was 120 (6 pots×20 soils). Pot dimension was 24 cm ×28 cm (height ×diameter). 10 kg soils were weighed in each pot. Next all soils were amended with the following basal nutrients (in mg/kg soil) mixed through the entire soil volume and then 10 chickpea seeds were sown in each pot. N (15 ppm) from urea, P (16 ppm) from triple super phosphate, K (20 ppm) from muriate of potash and B (1 ppm) from boric acid and Mo (0.6 ppm) from ammonium molybdate applied in each pot (weight basis) as basal to support normal plant growth. In all pots 7 ppm N as urea was applied at vegetative stage after 28 days of planting. Zinc sulfate heptahydrate served as the source of Zn which was applied with other fertilizers. After germination, 7 plants were allowed to grow. Soils of all pots were kept moist with distilled water as per requirement; weeding and other intercultural operations were carried out as and when required.

Data collection

The plants were cut at the stage of 100% flowering, then washed with distilled water and dried in an oven at 65º C for 48 hr for recording DM yield. Dried plant samples from each pot were powdered separately by a stainless still grinder. After that, the powdered plant samples were digested in a mixture of 10:4:1 of HNO_3:$HClO_4$:H_2SO_4 on a hot plate and filtered by Whatman no. 42 to estimate Zn by atomic absorption spectrophotometer. Fertilizers were given according to the soil test values.

CL determination

Critical limit of Zn for chickpea cultivation was determined by graphical method followed as described by Cate and Nelson (Cate and Nelson, 1965). In this procedure, a scatter diagram of the relative yields (Bray's percent DM yield) as Y-axis versus soil test values as X-axis was plotted. Bray's percent DM yield was determined via the following equation

$$\text{Bray's percent dry matter yield} = \frac{\text{Dry matter yield without Zn treatment}}{\text{Dry matter yield with Zn treatment}} \times 100$$

Results and Discussion

Dry Matter Accumulation of Chickpea

Dry matter yield of chickpea grown in low, medium and high Zn status soils as influenced by Zn application (Zn_0 and Zn_5) are presented in Table 2. The results clearly stated that highest and significant dry matter yield was found in high Zn status soils (13.5 g pot^{-1}) as compared to medium (11.2 g pot^{-1}) and low (8.83 g pot^{-1}) Zn status soils. The results also showed that dry matter yield of chickpea plants was tends to an increase significantly due to the application of 5 kg Zn per hectare (8.35 g pot^{-1}) over control (7.13 g pot^{-1}). But interaction effect between Zn and different soils condition produces a non significant relationship with respect to the dry matter yield of chickpea.

Correlation among soil properties with soil Zn status

Correlation among chemical soil properties with soil Zn were showed in Table 3. According to the table, the DTPA extractable Zn was negatively correlated with soil pH (r =–0.458*), available P (r =–0.445*), exchangeable Ca (r =–0.468*), exchangeable Mg (r =–0.459*) and was positively correlated with K and OM content. The extractable Zn indicated a negative and significant relationship with soil pH, available P, Ca and Mg. The negative relationship between soil Zn by DTPA extractants and soil pH has been observed by many workers in the past (Agarwal and Sastry, 1995; Jahiruddin *et al.*, 1992).

Zinc concentration and dry matter yield in plant biomass

Chickpea plant biomas showed greater Zn concentration in high Zn status soils as compared to low Zn status soils (Table 4). Zinc concentration of chickpea plant biomass in Zn treated pots varied from 37.1 mg kg^{-1} and 56.6 mg kg^{-1} compared to 22.0 mg kg^{-1} and 45.0 mg kg^{-1} in the Zn control pots (Table 4). Zinc application also increased the DM yield of chickpea in all the soils used in the study (Table 4). The results indicate that, DM weight of chickpea plants in Zn treated pots varied from 5.00 g pot^{-1} and 14.3 g pot^{-1} compared to 3.33 g pot^{-1} and 12.7 g pot^{-1} in the Zn control pots (Table 4). According to the soils characteristics, The Bray's percent yield ranged from 66.7 % and 96.0%. Zinc application with other fertilizer is a promising way of increasing crop performance and yield, as well as tissue Zn concentrations (Khan et al., 2003).

Critical levels of soil available Zn and plant tissue

In the graphical procedure, the critical levels of Zn for chickpea were found to be 0.63 mg kg^{-1} in soils (DTPA extractable) (Figure 1) and 25.3 mg kg^{-1} in plant tissue (Figure 2). Here, the Zn available in the soil and plant were arranged separately in rows and then Bray's percent was arranged in column.

Sarangthem et al., (2018) reported that the critical limit of zinc was 0.69 mg kg^{-1} in soils and pea tissue was 0.21% in cultivated valley fields of Manipur in India. Sarode et al., (2018) showed that critical limit of DTPA Zn in chickpea crop in swell-shrink soil of India was established as 21.08 mg kg^{-1} and 23.05 mg kg^{-1}. Akter et al., (2020) also reported that the critical limit of Zn in maize plant tissue was 26.1 mg kg^{-1}in Bangladesh. It is expected that the soils of representative soil series will likely respond to Zn application where the soils contain less than 0.63 mg kg^{-1} DTPA extractable Zn.

Table 1. Selected soil properties of the collected soil samples during 2021-2022

Sl.no.	Soil location	Soil series	AEZs	pH	% OM	DTPA Zn (mg kg^{-1})	Texural class
1	Kishoregonj	Gangachara	AEZ-3	6.40	1.10	0.60	Loamy sand
2	Nilphamari Sadar	Gangachara	AEZ-3	6.57	1.50	1.00	Loamy sand
3	Jaldhaka	Gangachara	AEZ-3	7.57	1.60	1.10	Loamy sand
4	Taragonj	Pirgacha	AEZ-3	7.00	0.67	1.20	Loamy sand
5	kaunia	Jamun	AEZ-3	7.13	1.37	1.30	Sandy loam
6	Pirgacha	kaunia	AEZ-3	6.37	1.20	0.75	Sandy loam
7	Gangachara	Polashbari	AEZ-3	5.87	1.20	1.70	Sandy loam
8	Rangpur Sadar	Polashbari	AEZ-3	6.90	1.20	1.10	Sandy loam
9	Shibgonj	Gangachara	AEZ-4	7.33	1.20	1.00	Sandy loam
10	Godagari	Nachol	AEZ-11	5.23	1.73	1.00	Sandy loam
11	Godagari	Amnura	AEZ-11	5.30	1.17	1.00	Loam
12	Godagari	Ghior	AEZ-11	5.27	1.17	1.70	Loam
13	Pabna Sadar	Gopalpur	AEZ-12	5.47	1.53	0.50	Sandy loam
14	Ishurdi	Sara	AEZ-12	5.97	1.53	0.85	Sandy loam
15	Nondonpur	Bera	AEZ-12	5.40	1.67	0.65	Loam
16	Gazipur sadar	Chiata	AEZ-28	4.27	1.57	3.10	Sandy loam
17	kapasia	Sonatola	AEZ-28	6.50	1.87	0.70	Sandy loam
18	kapasia	Tejgaon	AEZ-28	5.33	1.57	1.10	Sandy loam
19	kapasia	Belabo	AEZ-28	6.34	1.10	0.80	Loam
20	kaliakoir	Chiata	AEZ-28	5.21	1.57	2.10	Sandy loam
Range				4.27-7.57	0.67-1.87	0.50-3.1	

Table 2. Effect of Zn application on dry matter yield (g pot-^{1}) of chickpea on high, medium and low Zn containing soils in response to Zn amendment

Soil Zn effect

Range	Dry matter yield (g pot-^{1})
High	13.5
Mediam	11.2
low	8.83
SE ±	0.55
CD at 5%	2.02

Treatment (T) effect

Treatment	Dry matter yield (g pot-[1])
Zn_5	8.35
Zn_0	7.13
SE ±	0.17
CD at 5%	0.35

Interaction (Zn × soil) effect

Interaction of Zn fertilizer and soil	Dry matter yield (g pot-[1])
SE ±	0.78
CD at 5%	NS

Table 3. Relationship (r value) of extractable Zn with soil chemical properties in 2021-2022

Extractable Zn	pH	OM	Available P	Exchangeable K	Exchangeable Ca	Exchangeable Mg
DTPA–Zn	-0.458*	0.037^{ns}	-0.445^{*}	0.018^{ns}	-0.468^{*}	-0.459*

ns = Not significant,*=5% level of significant

Table 4. Effect of zinc application on the % Relative yield and Zn content of chickpea plants at 100% flowering stage during 2021-2022

Sl.no.	soil location	Soil series	AEZs	Zn content (mg kg^{-1})		Total dry matter yield pot^{-1} (g)		% Relative yield
				Zn+	Zn-	Zn+	Zn-	
1	Kishoregonj	Gangachara	AEZ-3	37.20	25.1	5.00	3.33	66.7
2	Nilphamari Sadar	Gangachara	AEZ-3	51.0	45	7.33	6.67	90.9
3	Jaldhaka	Gangachara	AEZ-3	47.5	35.1	7.33	6.67	90.9
4	Taragonj	Pirgacha	AEZ-3	55.3	33.7	7.67	7.00	91.3
5	kaunia	Jamun	AEZ-3	49.4	38.4	6.67	6.33	95.0
6	Pirgacha	kaunia	AEZ-3	41.8	28.8	6.00	5.00	83.3
7	Gangachara	Polashbari	AEZ-3	54.0	42	7.00	5.33	76.2
8	Rangpur Sadar	Polashbari	AEZ-3	43.6	32.4	10.3	9.00	87.1
9	Shibgonj	Gangachara	AEZ-4	42.5	29.1	12.0	10.3	86.1
10	Godagari	Nachol	AEZ-11	50.0	37	11.0	9.00	81.8
11	Godagari	Amnura	AEZ-11	52.6	41.9	10.3	9.33	90.3
12	Godagari	Ghior	AEZ-11	51.0	40	14.3	12.7	88.4
13	Pabna Sadar	Gopalpur	AEZ-12	55.0	22	7.33	4.67	63.6
14	Ishurdi	Sara	AEZ-12	42.4	31	8.33	8.00	96.0
15	Nondonpur	Bera	AEZ-12	37.1	25.4	10.00	7.67	76.7
16	Gazipur sadar	Chiata	AEZ-28	56.6	45	8.67	7.33	84.6
17	kapasia	Sonatola	AEZ-28	37.8	26.2	10.3	8.67	83.9
18	kapasia	Tejgaon	AEZ-28	55.6	44.1	5.33	5.00	93.8
19	kapasia	Belabo	AEZ-28	53.5	42.8	6.33	5.67	89.5
20	kaliakoir	Chiata	AEZ-28	55.4	44.8	5.67	5.00	88.2
Mean				48.5	25.1	8.35	7.13	85.2
Range				37.1-56.6	22.0-45.0	5.00-14.3	3.33-12.7	66.7-96.0

Results are the means of three replications, Zn^{+} = addition of Zn, Zn^{-} = without addition of Zn.

Conclusions

It can be concluded that, the critical values of Zn for chickpea were 0.63 mg kg^{-1} in soil and 25.3 mg kg^{-1} in plant tissue. Zinc addition significantly increased shoot dry matter yield in chickpea. Overall, the additional Zn supply will provide a yield benefit in a soil with a Zn content of less than 0.63 mg kg^{-1}. This is first year result. Further research will be required to confirm the current study's finding.

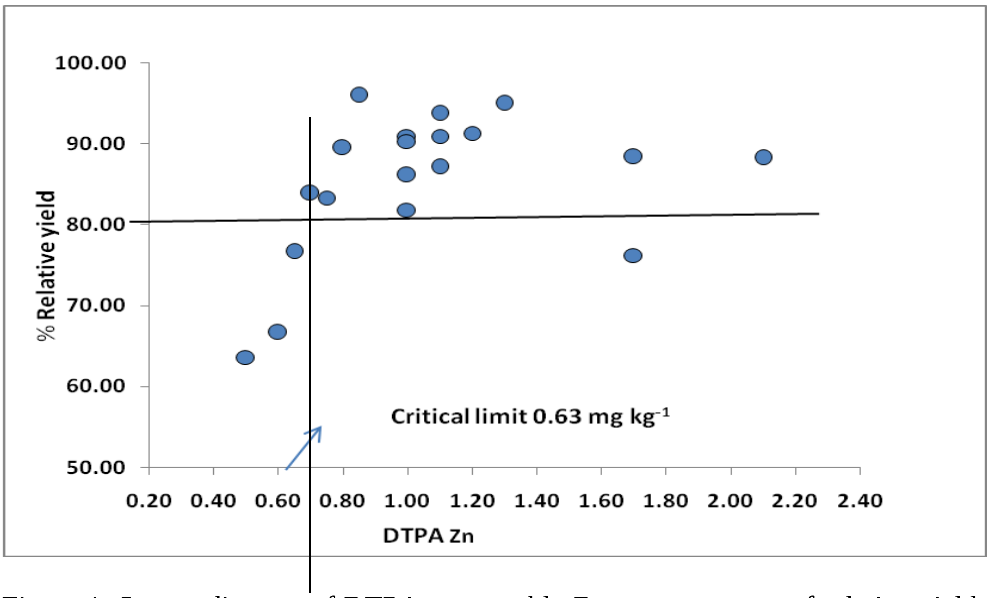

Figure 1. Scatter diagram of DTPA–extractable Zn vs. percentage of relative yield of chickpea grown in some soils of Bangladesh, 2021-2022.

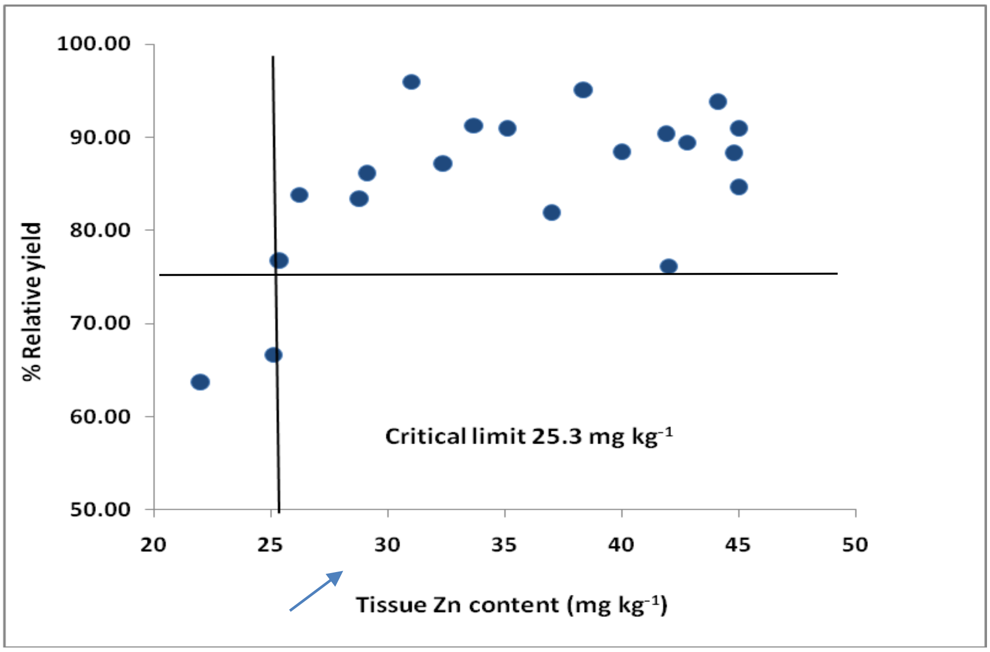

Figure 2. Scatter diagram of Zn in plant tissue vs. percentage of relative yield of chickpea grown in some soils of Bangladesh, 2021-2022

Acknowledgments

The authors express their appreciation to the officers and staffs of the Soil Science Division who provided necessary support that helped to complete the analytical work. The authors also express their appreciation to the officers and staffs of the Soil Science Division labs who provided necessary support that helped to complete the analysis.

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EFFECT OF BORON ON YIELD AND NUTRIENT UPTAKE OF MUNGBEAN

M. AKTER, S. SULTANA, M.B. BANU AND H. M. NASER

Abstract

A field experiment was carried out in Tista Meander Floodplain Soil (AEZ-3) at On Farm Research Division, Rangpur during Kharif 1 season of 2021- 2022. Boron deficiency has appeared as a serious threat to mungbean production in the northern part of Bangladesh. Supply of required amount of boron fertilizer is therefore needed to increase mungbean yield. The objectives were to study the effect of boron on yield and nutrient uptake of mungbean (BARI Mung 8), estimate optimum dose of boron for higher yield of mungbean and find out the boron use efficiency of mungbean. The experiment was designed in Randomized Complete Block Design (RCBD) with three replications. BARI Mung 8 with five levels of boron along with a blanket dose $N_{18}P_{18}K_{24}S_{12}Zn_2Mo_{0.8}$ was used in the study. Maximum seed yield was observed in T_4 treatment (1.60 t ha^{-1}) by the application of 1.5 kg B ha^{-1} as compared to the other treatment. Highest boron uptake (0.026 Kg ha^{-1}), highest B use efficiency (agronomic efficiency 280 and recovery efficiency 0.008) were found in the treatment having B at 1.5 kg ha^{-1} but highest B concentration (16.3 ppm) was found in 2 kg ha^{-1} B rate. BARI Mung 8 was performed better with application of 1.5 kg B ha^{-1} as compared to the other treatment.

Introduction

Mungbean (*Vigna radiata* L.) ranks thirds in protein content and fourth in both acreage and production in Bangladesh (Sarkar *et al.,* 2012). Among pulses, mungbean is an important grain legume not only in Bangladesh but also in Asia. Mungbean is widely grown in Bangladesh. But major area of mungbean is replaced by cereals (Abedin, et al., 1991). It is growing three times in a year in Bangladesh covering 109305 acres with a total yield of 41189 M.ton (BBS. 2021). The average yield of different varieties of Mungbean in Bangladesh is much less than the most countries of the world. It is a rich source of protein, easily digestible and also plays an important role in human and animal diet. It contains 24.2 % protein, 60.4% carbohydrate and 1.3% fat (Afzal *et al.,* 2004). The foliage and stem are a good source of fodder for livestock. It synthesizes N in symbiosis with Rhizobia and enriches the soil. Total biomass of the soil is increased which improves the fertility status of soil through atmospheric N fixation and can fix N in soil by 63-342 kg/ha per season (Kaisher *et al*., 2010).The yield of Mungbean depends on variety, location and agronomic management. Nowadays, per capita availability of pulse of the country is decreasing day by day. To overcome this situation, it is necessary to improve the pulse production in country. Proper nutrient management is absolutely essential to boost up pulse production especially yield of mungbean. Among the micronutrients deficiencies for Mungbean cultivation in Bangladesh, boron is more common and next to zinc. Boron deficiency causes poor seed quality, male sterility (Rawsan, 1996). Thus, boron deficiency results a significant loss of yield and quality of Mungbean. B deficiency is widespread in the country (Jahiruddin *et al.*, 1992; Rabman *et al.,* 1993; Islam *et al.*, 1997). The soils of different parts of northern site (AEZ-3) of Bangladesh are more or less deficient in boron which causes poor yield of mungbean. Very recently deficiencies of boron have been identified in localised areas in calcareous alluvium, non-calcareous floodplain, piedmont, terrace and hill soils (Banglapedia, 2015).

Boron is very important in cell division and in pod and seed formation (Vitosh *et al.*, 1997). Rate of water adsorption and carbohydrate translocation restricted due to boron deficiency. Boron influences the absorption of N, P, K, and its deficiency changed the equilibrium of optimum of those three macronutrients. Inadequate supply of B decreased the economic yield of legume (Raj, 1985). It increases the yield and growth of plants by increasing the leaf area expansion, 1000 seed weight, nodule formation, seed yield and biological yield. It influences the major cellular functions and metabolic activities in plants and required for cell differentiation at all growing tips of plants (meristems) where cell division is active (El-Hamdaoui *et al.,* 2003). Kaisher *et al.* (2010) researched about the effect of boron on pulses and concluded that it is important for protein synthesis and improved protein content. In accordance with Renukadevi *et al.* (2002) boron application maximize the light interception ratio, biomass production, leaf area index, net assimilation rate, crop growth rate and seed yield in pulses. The N and B concentrations of grain for mungbean were markedly influenced by B treatment indicating that the B had a positive role on protein synthesis. lqtidar and Rahman (1984) indicated that essential amino acid increased with increasing B supply. On the other hand, boron deficiency decreases pollen size, pollen germination etc of mungbean. It also influences growth parameters and filling up of seeds. Therefore, application of boron in addition to essential major elements has gained practical significance in the boron deficient soil. Recently, a number of new mungbean varieties have been released by Pulse Research Centre, BARI. BARI mungbean 8 is a recently released mungbean variety. Information regarding boron content, uptake and use efficiency of that variety is not details. From the above consequences, the present study was undertaken with the following objectives:

i. To study the effect of boron on yield and B uptake of mungbean
ii. To estimate optimum dose of boron for higher yield of mungbean and
iii. To find out the boron use efficiency of mungbean

Materials and Methods

Experimental site and initial soil status

A field experiment was conducted at On Farm Research Division, Rangpur during Kharif 1 season in 2021-2022. The study area was under the agro-ecological zone Tista Meander Floodplain Soil (AEZ-3). The experimental field was a piece of well-drained medium high land. The soil type was sandy loam in texture; having low organic matter content. Initial soil samples were collected from a depth of 0-15 cm and analyzed prior to application of different fertilizers are presented in Table 1. The initial soil analysis was an indicative of B deficiency in the experimental field. The critical level of boron with reference to crops in general was reported to a range from 0.3 to 0.8 ppm depending on soil types (Shorrocks, 1984).

Treatments and fertilizers

Five treatments having three replications were used for mungbean production. Treatments were built up by using five levels of boron (0, 0.5, 1, 1.5 and 2 kg ha^{-1}). The design of the experiment was randomized complete block design (RCBD). A basal application was made with 9 kg ha^{-1} N, 18 kg ha^{-1} P, 24 kg ha^{-1} K and 12 kg ha^{-1} S, 2 kg ha^{-1} Zn and 0.08 kg ha^{-1} Mo in each plot to support normal plant growth. The entire amount of P from TSP, K from MOP, S from gypsum and half of N from urea, Zn from zinc sulfate heptahydrate and Mo from ammonium molybdate were applied during final land preparation. Rest of the N from urea was top dressed after 20 days of sowing.

Experimental work

The unit plot size was 2m x 3 m and seeds of BARI mung 8 were sown at 16 March, 2022. The soils of all plots were kept moist to confirm sufficient moisture with addition of light water for quick germination. Irrigation was given according to need throughout the period to keep the soil moist. Necessary intercultural operations were done throughout the cropping season for proper growth and development of the plant. Mungbean were harvested at 26 May, 2022. Five plants were taken from each plot to measure the yield attributes. Seeds were dried in an oven at 70°C for 72 hours and the dried samples were then finely ground in a grinder for laboratory analysis. After harvest, the soil from each plot was thoroughly mixed and approximately 100 g soil was sampled for laboratory analysis.

Methods of analysis

For initial soil analysis, soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon determination was done by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Elements K, Ca and Mg were determined by NH4OAC extractable method and Cu, Fe, Mn and Zn were determined by DTPA extraction method followed by AAS reading. Boron was determined by CaCl2 extraction method. Phosphorus was determined by Bray and Kurtz method while S by turbidimetric method with $BaCl_2$.

Boron uptake and its use efficiency

B uptake (kg ha^{-1}) = B % × Dry weight (kg ha^{-1}) /100

Agronomic efficiency, (AE) = (SYNA-SYNO)/ NRN (FRG, 2018)

Where, AE = Agronomic efficiency

SYNA = Seed yield (kg ha^{-1}) with addition of nutrient
SYNO = Seed yield (kg ha^{-1}) without addition of nutrient

NRN = Rate of added nutrient (kg ha^{-1})

Recovery efficiency, (RE) = (NUNA-NUNO)/ NRN (FRG, 2018)

Where, RE = Recovery efficiency

NUNA = Nutrient uptake due to nutrient addition

NUNO = Nutrient uptake due to nutrient omission

NRN = Rate of nutrient addition

Results and discussion

Various treatments were influenced significantly on different parameters and yield in comparison to control (Table-2 and Table- 3). According to Table 2, maximum plant height (59.2 cm) was recorded with T_3 treatment. ButT_4 treatment provided maximum no. of pod/plant (23.9), no. of seed pod^{-1} (12.2), pod weight $plant^{-1}$(18.2 g) and seed weight pod^{-1}(0.42 g). The marked response in seed weight $plant^{-1}$ due to boron application was found in T_4 treatment (10.0 g) which was statistically higher over others but similar to T_5 Treatment (9.01 g) and T_3 Treatment (8.04 g) respectively. Statistically highest 1000 seed weight was found in T_4 treatment (31.2 g) but with the increasing rate of boron it decreases.

According to Table 3, 1.5 kg ha^{-1} boron application provided maximum no. of seed yield m^{-2} (160 g), seed yield (kg ha^{-1}) (1600 kg ha^{-1}) and seed yield t ha^{-1} (1.60 t ha^{-1}) where in every cases T_4 treatment statistically superior over others. The seed yield increased progressively with the increase of B levels up to 1.5 kg B ha^{-1} and beyond the dose, the yield fallen off. Highest dry matter yield was found in T_3 treatment (2.66 t ha^{-1}) which was statistically higher over others except T_4 and T_5 treatment. All the parameters showed better performance by using 1.5 kg B ha^{-1} because soils of the study area were B deficient. The results also showed that plant growth and development declined with increasing boron levels. Chowdhury et al. (2010) proved that plant height, total dry matter; number of pods per plant, number of seeds per pod, 1000-seed weight and seed yield was enhanced with exogenous application of boron. Ayvaz et al. (2012) studied the effect of boron on barley and concluded that plant growth and development declined with increasing boron concentrations. Muhammad et al. (2013) reported that shoot and root fresh and dry weights decreased with increasing the concentration of boron.

Boron content and uptake

The highest B concentration (16.3 ppm) was recorded in 2 kg ha^{-1} B rate (Table 4). In 2 kg ha^{-1} B rate, B content was higher over the rest of the boron levels. The lowest B concentrations were found in B control treatment (11.7 ppm). On the other hand, highest boron uptake (0.026 Kg ha^{-1}) was found in the treatment having B at 1.5 kg ha^{-1}. B uptake by plants is affected by a number of soil and environmental factors like pH, soil texture, soil moisture, temperature and management practices such as liming and so on (Evans and Sparks, 1983; Munson and Nelson, 1990; Sims and Johnson, 1991; Smith and Loneragan, 1997). Plant species differ in their capacity to take up B, even when they are grown in the same soil and these differences exhibit different B requirements for growth (Gupta, 1979).

Boron use efficiency

Boron use efficiency was influenced by different treatments (Table 5). The nutrient use efficiency can be expressed as agronomic efficiency, recovery efficiency and physiological efficiency. In this paper, agronomic efficiency and recovery efficiency were shown. Agronomic efficiency refers to the increase in crop yield per unit of an applied nutrient. Recovery efficiency is the increase in nutrient uptake by plants per unit of an applied nutrient. According to the table 5, the highest B use efficiency were recorded (agronomic efficiency 280 and recovery efficiency 0.008) at 1.5 kg ha^{-1}boron rate and the lowest B use efficiency were found (agronomic efficiency 153 and recovery efficiency 0.003) at 0.5 kg ha^{-1} boron rate. BARI mung 8 showed the highest boron use efficiency @1.5 kg ha^{-1} B rate.

Cost and return analysis

The benefit cost analysis of BARI mung 8 has been presented in Table 4. According to the table 6, highest marginal benefit cost ratio (MBCR), gross return and net return were found from T_4 ($B_{1.5}$) treatment. However, 1.5 kg B ha^{-1} in combination with other fertilizers was acting as the most suitable combination for BARI mung 8 production.

Table 1. Initial properties of the soil samples of experimental field, 2021-2022

Soil Properties	Texture	pH	OC (%)	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Mn	Zn
				meq 100g^{-1}				µg g^{-1}						
Result	Sandy loam	4.80	1.8	0.80	0.22	0.19	0.12	51	36.4	0.18	1.27	71.08	8.2	1.14
Critical level		-	-	2.0	0.5	0.12	-	7	10	0.2	.2	4	1.0	0.6

Table 2. Yield attributes of BARI mung-8 as influenced by the effect of different boron levels, 2021-2022

Treatment	Plant height (cm)	No. of pod plant^{-1}	No.of seed pod^{-1}	Pod weight (g plant^{-1})	seed weight (g pod^{-1})	seed weight (g plant^{-1})	1000 seed weight (g)
T_1 (B_0)	53.3 b	17.2 c	10.4 c	12.0 d	0.32 c	6.22c	25.8 c
T_2 ($B_{0.5}$)	54.5 ab	18.1 c	10.6 bc	13.0 cd	0.34 bc	6.83 bc	27.6 bc
T_3 (B_1)	59.2 a	20.1 bc	10.7 bc	15.1 bc	0.37 bc	8.04 abc	28.1 bc
T_4 ($B_{1.5}$)	58.6 a	23.9 a	12.2 a	18.2 a	0.42 a	10.0 a	31.2 a
T_5 (B_2)	55.5 ab	22.1ab	11.7 ab	17.0 ab	0.38 ab	9.01 ab	29.4 ab
CV (%)	3.10	6.23	3.86	5.29	5.09	9.69	3.27

Means followed by same letter (s) in a column do not differ significantly at 5% level of significance by Tukey HSD test.

Table 3. Yield of BARI mung-8 as influenced by the interaction effect of different boron levels, 2021-2022

Treatment	Seed yield (g m^{-2})	Seed yield (kg ha^{-1})	Seed yield (t ha^{-1})	Dry matter yield (t ha^{-1})
T_1 (B_0)	118 d	1183 d	1.18 d	1.72 c
T_2 ($B_{0.5}$)	126 cd	1260 cd	1.26 cd	2.08 bc
T_3 (B_1)	140 bc	1400 bc	1.40 bc	2.66 a
T_4 ($B_{1.5}$)	160 a	1600 a	1.60 a	2.63 ab
T_5 (B_2)	153 ab	1533 ab	1.53 ab	2.30 ab
CV (%)	4.35	4.35	4.35	8.59

Means followed by same letter (s) in a column do not differ significantly at 5% level of significance by Tukey HSD test.

Table 4. Effect of boron application on the boron content and uptake of mungbean seed, 2021-2022

B level (kg ha^{-1})	Boron content (ppm)	Boron uptake (Kg ha^{-1})
B_0	11.7	0.014
$B_{0.5}$	12.3	0.015
B_1	13.0	0.018
$B_{1.5}$	16.0	0.026
B_2	16.3	0.025

Table 5. Effect of boron application on the boron use efficiency of mungbean, 2021-2022

B level (kg ha^{-1})	Agronomic efficiency	Recovery efficiency
B_0	-	-
$B_{0.5}$	153	0.003
B_1	217	0.004
$B_{1.5}$	280	0.008
B_2	175	0.006

Table 6. Variable cost , Gross return, Net return and Marginal Benefit Cost Ratio (MBCR) of BARI mung 8 in 2021-2022

Treatment	Yield (kg ha^{-1})	Variable cost	Gross return	Net return	MBCR
$T_1(B_0)$	1183	17760	118300	100540	–
$T_2(B_{0.5})$	1260	18642	126000	107358	9
$T_3(B_1)$	1400	19524	140000	120476	12
$T_4(B_{1.5})$	1600	20406	160000	139594	16
$T_5(B_2)$	1533	21300	153300	132000	10

Urea 16 Tk kg^{-1}, TSP 22 Tk kg^{-1}, MOP 15Tk kg^{-1},Gypsum 15 Tk kg^{-1},Zinc sulphate 150 Tk kg^{-1},Boric acid 300 Tk kg^{-1}, mungbean seeds 150 Tk kg^{-1}

Output: Mungbean 100 Tk kg^{-1}

Conclusion

Nutrient management greatly affects the growth and yield of mungbean. The decreasing per capita availability of mungbean of the country has been serious concern especially in the boron deficient area. To overcome this it is necessary to boost up the production of mungbean in that area with different high yielding varieties in combination with boron fertilization. In AEZ-3, BARI mung 8 produces highest yield (1.60 t ha^{-1}) by the application of 1.5 kg ha^{-1} boron rate and it is expected that 1.5 kg B ha^{-1} in combination with other fertilizers is the most suitable combination for BARI mung 8 crop growing.

Acknowledgments

The authors express their appreciation to the officers and staffs of the On Farm Research Division (OFRD), Rangpur who provided necessary support that helped to complete the analytical work. The authors also express their appreciation to the officers and staffs of the Soil Science Division labs who provided necessary support that helped to complete the analysis.

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EFFECT OF FOLIAR APPLICATION OF ZINC IN SWEET ORANGE

M. M. H BHUIYAN, M. A. SIDDIKY, M. O. KAISAR AND H. M. NASER

Abstract

Afield experiment was carried out to determine the efficiency of foliar application of Zn on sweet orange yield at Regional Agricultural Research Station, BARI, Cumilla in 2020-21. The experiment was laid out in Randomized Block Design (RCBD) with 4 treatments and three replications. Observations were recorded on the growth and yield parameters of sweet orange. The treatments were Zn @ 0, 500, 1000, and 1500 mg per liter. The results revealed that there were significant variations inthe growth and yield of sweet oranges due to the foliar application of zinc.The values of vegetative growth parameters like plant height, fruit length, and diameter showed a non-significant effect by treatments but canopy volume, fruit number per plant, and individual fruit weight showed significant effect by the treatments.The chemicalparameters of fruit like TSS (%) also showed a non-significant effect by foliar spray. But the fruit yield was influenced by the treatments and the highest yield (12.5 kg tree^{-1}) was recorded with Zn @1500 mg per liter and the lowest yield was noted in the control treatment i.e. Zn @ 0 mg per liter.This is the first year of the trial and the trial should be continued before making the final conclusion of the results.

Introduction

Micronutrient deficiencies not only hamper crop productivity but also deteriorate produce quality. The low micronutrient foods and foodstuffs are causing health hazards in human beings and animals. Micronutrients act as catalysts in the uptake and use of certain micronutrients. Fruit size and quality as well as produce quality of some crops are improved with micronutrient use.Oranges are a very much important commercial crop in Bangladesh. Appropriate fertilizer management influences on yield and quality of sweet oranges. Proper soil fertility management is the most important endeavor to increase crop productivity. The application of adequate fertilizers led to an increase the crop yields and improved the nutrient element concentrations in plant tissue and soil macro as well as micronutrient status. The sweet orange is mainly an acid soil-loving plant but can be cultivated in acid to neutral pH soils. It requires a regular supply of Zn, otherwise, fruit production becomes poor. Leaf application has been an effective and preferred management practice followed by growers for micronutrient fertilization in the field. It also considers the nearness of distribution of small amounts of products and mixture with defensives. Soluble salts such as sulfate, chloride, and nitrate micronutrients signify the main fertilizer sources for spraying on leaves in citrus. Sparingly soluble sources of Zn fertilizer, such as oxides and carbonates, have been required by sustainable production systems. The efficacy of traditional foliar fertilizers depends on water solubility, while sparingly soluble sources rely upon the size of particles. It facilitates a constant supply of nutrients for longer periods and reduced the risk of leaf tissue injury.Considering the necessity to confirm the efficiency of new Zn sources, the present research study was undertaken to determine the efficiency of Zn sources in providing the plants with sufficient micronutrients; and to compare new doses of sweet orange orchards with traditionally used sources.

Materials and Methods

The experiment was carried out at the previously planted sweet orange orchard of Regional Agricultural Research Station, BARI, Cumilla located $23^0$28'16.05" N and $91^0$9'19.38" E from May 2020 to October 2021. BARI Malta-1 was used as a test crop with four treatments ina randomized complete block design and replicatedthree times. The treatments were the different levels of Zn as T_0: Control (without Zn fertilizer), T_1: 500 mg of Zn L^{-1}, $T_{2:}$ 1000 mg of Zn L^{-1}, and T_3: 1500 mg of Zn L^{-1}. Same aged sweet orange plants (about 6-7 years) were selected for applying treatments. Individual plants were fertilized with 9 kg cow dung, 512 g urea, 300 g TSP, 226 g MoP, 187.5 g gypsum,and 10 g boric acid in the month of March, May, and October in three equal splitsfollowed by irrigation. Weeding and other intercultural operations were done as per requirement throughout the year. The soil samples were collected before applying treatments and analyzed in the laboratory (Table 1). To study the effect of Zn as a foliar spray on the yield of sweet orange different concentrations of $ZnSO_4.7H_2O$ containing 23% Zn was applied as per treatments. The spray was done at the time of blanket recommended fertilizer application.

Table 1. Analytical data of the experimental soils (Initial soil)

Location	pH	OM%	Ca	Mg	K	Total N	P	S	B	Zn
			meq $100g^{-1}$			%	µg g^{-1}			
RARS, Cumilla	5.8	0.98	3.2	1.72	0.21	0.07	10	8.9	0.2	1.9
Critical level	-	-	2.0	0.8	0.20	-	7	10	0.2	2.0

The height of a plant was measured with the help of a measuring stick having meter marking from the ground level to the tip of the highest shoot of the plant in each replication and the average was calculated and was expressed in meters. The volume occupied by the plant canopy was measured in E-W and N-S direction and canopy height with the help of a measuring stick and plant canopy volume was calculated by taking E-W and N-S plant spread in $(m)^3$. The following formula was used for the calculation of canopy volume.

$$\text{Canopy volume} = \text{canopy height} \times (\text{East-west spread} + \text{North-south spread})$$

The volume of water 1.0 liter $plant^{-1}$ was estimated to wet completely the sweet orange plant. The foliar spray contained Zn @ 500, 1000, and 1500 mg per liter. Treatment effects were determined by analysis of variance with the help of the statistical package STATISTIX-10 and mean separation was done by Tukey HSD.

Results

The foliar spray application of Zn showed a non-significant effect on plant height. Data presented in table 2 revealed that the maximum plant height was observed in T_3 (1.96 m) treatment. Zinc is an essential nutrient element and it has a positive effect on the height of plants.This effect may be due to the one-year result of the experimentation. But tree volume was found statistically significant and the maximum volume (6.96 m^3) of the tree was noticed T_3 treatment but it was identical to T_2 treatment. The minimum volume was calculated in T_1 treatment which was statistically par with T_0 treatment. On the other hand, individual fruit weight was also exhibited as statistically significant due to different amounts of Zn application. The heaviest fruit was noted in T_3 (137.7 g) but it was statistically identical to T_2 treatment and the lightest fruit was recorded in T_0 (93.7 g) treatment i.e. without a foliar spray of Zn fertilizer.

Table 2. Effect of foliar application of ZnO on various growth characteristics of sweet orange at RARS, Cumilla in 2020-21

Treatments	Plant height (m)	Tree volume (m^3)	Number of fruits per tree	Individual fruit weight (g)
T_0	1.60	4.97 b	57.0 b	93.7 c
T_1	1.56	4.49 b	64.6 b	108.0 bc
T_2	1.80	6.60 a	95.0 a	117.0 ab
T_3	1.96	6.96 a	99.3 a	137.7 a
F-Test	NS	**	**	**
CV (%)	12.28	8.47	3.72	7.14

*, ** and NS Significant at the 5% and 1% probability level and non-significant, respectively. T_0: Control (without Zn fertilizer), T_1: 500 mg of Zn L^{-1}, T_2: 1000 mg of Zn L^{-1}, and T_3: 1500 mg of Zn L^{-1}.

Table 3 represents the yield attributing traits of sweet orange influenced by foliar spray of Zn fertilizer. Fruit length, fruit diameter, and TSS (%) showed non-significant effects due to the spray of Zn as a solution in the leaf. But fruit yield presented a statistically significant effect due to Zn application. The highest yield per tree was recorded in the treatment T_3 (12.5 kg) i.e. foliar application of Zn @ 1500 mg L^{-1} which was statistically identical to T_2 (10.4 kg). The lowest fruit yield per tree was recorded in T_0 (6.3 kg) and it was identical to T_1 treatment. This may be due to the increment of chlorophyll production and photosynthesis processes which lead to an increase in yield.The maximum fruit diameter was recorded in treatmentsT_2 and T_3 (5.73 cm) i.e. foliar spray of Zn@ 1000 & 1500 mg L^{-1}, the minimum fruit diameter was noted in T_1 treatment i.e. foliar spray of Zn @ 500 mg L^{-1}. A similar result was observed in the case of the fruit length of sweet orange with the applied treatments.

Table 3. Effect of foliar application of ZnO on yield attributing traits of sweet orange at RARS, Cumillain 2020-21

Treatments	Fruit length (cm)	Fruit diameter (cm)	TSS (%)	Fruit yield per tree (kg)
T_0	5.43	5.66	8.66	6.3 b
T_1	5.47	5.46	8.83	7.3 b
T_2	5.66	5.73	9.33	10.4 a
T_3	5.80	5.73	8.67	12.5 a
F-Test	NS	NS	NS	**
CV (%)	5.05	2.41	4.69	8.87

*, ** and NS Significant at the 5% and 1% probability level and non-significant, respectively. T_0: Control (without Zn fertilizer), T_1: 500 mg of Zn L^{-1}, T_2: 1000 mg of Zn L^{-1}, and T_3: 1500 mg of Zn L^{-1}.

Conclusion

The above result indicated the positive impact of foliar application of Zn on the growth and yield of sweet orange. The effect of the treatmentsis visible. A higher sweet orange yield can be achieved by foliar application of Zn @ 1500 mg per liter. The predefined treatments may be readjusted due to the positive effect on sweet orange yield and growth parameters. Production cost will be minimized and yield can be maximized by using Zn @ 1500 mg per liter as a foliar spray in the leaf. In the next year, anadditional dose *i.e.*Zn @ 2000 mg per liter will be included in the treatment. This is the first year of the trial. The experiment needs to be continued for up to 5 years for a more precise result.

Acknowledgments:

The author is greatly thankful to the “Upgrading Regional Horticulture Research Station, Cumilla to Regional Agricultural Research Station project” for the financial and technical support during the experimentation.

EFFECT OF BORON FERTILIZATION ON LENTIL IN BARISHAL REGION

M.R. ISLAM, M. R. UDDIN AND H. M. NASER

Abstract

A field experiment was carried out at Regional Agricultural Research Station, Rahmatpur, Barishal during November 2020 to March 2021 and November 2021 to March 2022 to develop proper dose of boron fertilizer for lentil production in Barishal region of Bangladesh. The crop variety was BARI Masur-8. There were five treatments viz. T_0: 0.0 kg B/ha, T_1: 1.0 kg B/ha,T_2: 1.5 kg B/ha, T_3: 2.0 kg B/ha, and T_4 : 2.5 kg B/ha which were replicated for four times. Boron had influence on plant height (cm), number of branches, no of pods/plant, pods weight /plant, pod yield/ plant, stover yield, as well as seed yield of BARI Masur-8. The highest seed yield (1960 kg ha^{-1}) was observed in T_2 ($B_{1.5}$) treatment in 2020-2021 which was statistically identical to all other treatments except control and T_4 ($B_{2.5}$) treatment, but in 2021-2022 year, the highest seed yield (1459 kg ha^{-1}) was obtained from T_1 ($B_{1.0}$) treatment which was statistically significant with all other treatments except T_2 ($B_{1.5}$) treatment in Barishal region, (Non–calcareous Grey Floodplain Soils under AEZ 13).

Introduction

Lentil (*Lens culinaris* L) is the second most important pulse crop in terms of both area (1.93 lakh ha) and production (2.52 lakh MT) respectively (Krishi Diary 2020). About 80% of total lentil in the country is grown in Faridpur, Kustia, Jessore, Rajshahi and Pabna. Lentil seed is rich in protein and rates the highest consumer's preference. It is a cheap protein source with the comparison of high cost animal protein (Quddus *et.al.* 2009). Lentil is a direct source of protein of our daily life and also for animals (Satter *et al.,* 1996). It has the capacity to fix atmospheric nitrogen. Lentil production in Bangladesh is decreasing day by day due to fertilizer management and disease of *stemphylium* blight and insect pest of pod borer. There are few recommended varieties of lentil in our country. Among them BARI Masur-8 is prominent and newly released variety. Yield performance of BARI Masur-8 is well. There is a great possibility to increase its production by micronutrients like boron. Boron is an essential factor for pollen formation and which help to increase the production by pod formation. Boron is an essential element for crop production specially seed formation for different crops. In Barishal region farmers use NPK fertilizer but maximum farmers not use micronutrients like boron. Hence this study has been undertaken to find out suitable dose of boron fertilizer for better production of lentil in Barishal region. The proper combination of chemical fertilizers and micro nutrients enhances the growth and yield of the crop. The objectives of the experiment were as follows:

i)To find out the response of BARI Masur-8 to boron fertilizer.

ii)To determine optimum dose of boron for maximizing the yield of BARI Masur-8.

Materials and Methods

The experiment was conducted at the experimental field of Regional Agricultural Research Station (RARS), Rahmatpur, Barishal in the Rabi season of 2020-21 and 2021-22 to evaluate the performance of lentil BARI Masur-8 to boron fertilization. The experiment was laid out in Randomize Complete Block Design with four replications. The unit plot was 10 rows and 4m long with spacing 30cm×10cm. Seeds were sown in the rows on 25th November 2020 and 21th November 2021. The physical and chemical properties of the initial soil samples from experimental fields at a depth of 0-15 cm were collected and analyzed following standard methods and presented in Tables 1 and Table 2.

Table 1. Initial fertility status of the experimental field soil samples of RARS, Rahmatpur, Barishal in 2020-2021.

Soil Properties	Texture	pH	EC	OM (%)	Total N (%)	K	P	S	B
						Meq/100g	µg/g		
Experiment field	Sandy clay loam	7.7	1.0	2.02	0.10	0.23	67.4	15.7	0.19
Critical limit	-	-	-	-	012	0.12	10.0	10.0	0.20
Interpretation	-	Slightly base	non saline	Medium	Very low	Medium	High	Low	Low

Table 2. Initial fertility status of the experimental field soil samples of RARS, Rahmatpur, Barishal in 2021-2022.

Soil Properties	Texture	pH	EC	OM (%)	Total N (%)	K	P	S	B
						Meq/100g	µg/g		
Experiment field	Sandy clay loam	7.7	1.0	2.02	0.10	0.35	26.1	7.06	0.47
Critical limit	-	-	-	-	012	0.12	10.0	10.0	0.20
Interpretation	-	Slightly base	non saline	Medium	Very low	Medium	High	Low	Low

$N_{20}P_{40}K_{22}S_{20}Zn_5$ kgha^{-1} fertilizer were used as basal dose . As source of nutrients: nitrogen, phosphorus and potassium will be applied in the forms of urea, Triple super phosphate and murate of potash, sulphur as gypsum, zinc as zinc sulphate and boron as the form of boric acid to increase the nutrient use efficiency of the crop. All nutrients (N-P-K-S-B) will be applied as final land preparations and Zn fertilizer used in layout time. Two weeding were done at 25 days and 45 days after sowing. Provax-200 and Autostin was sprayed 2-3 times for the management of foot rot diseases. Plants were harvested on 15 March 2021 and 11 March 2022. Data on yield contributing characters were recorded from 10 randomly selected plants from each plot. Data on plant height, 1000-seed weight (g), stover yield, seed yield, pods plant^{-1} and seeds pod^{-1} were also taken. All data were analyzed statistically by using software (Statistics10).

Results and Discussion

Response of B fertilization on lentil, plant height (cm), No of branch/plant 1000-seed weight (g), pods plant^{-1}, seeds pod^{-1}, stover yield (t ha^{-1}), seed yield (t ha^{-1}) and percent yield increase over control have been presented in Tables 3 and Table 4.

Table 3. Effect of B fertilizer on lentil at RARS, Rahmatpur during 2020-2021 and 2021-2022

Treatments	Plant height (cm)		No of branch/plant		Pods/plant		Seeds/pod	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
T_0 ($B_{0.0}$)	41.35	41.30ab	3.65b	3.62ab	123.1b	59.32bc	1.67	1.67ab
T_1 ($B_{1.0}$)	45.02	38.85b	4.10ab	3.95a	131.3a	64.02a	1.80	1.80a
T_2 ($B_{1.5}$)	46.60	41.67ab	4.35a	3.40b	137.3a	62.45ab	1.85	1.55b
T_3 ($B_{2.0}$)	42.15	41.90a	4.15ab	3.67ab	121.5b	62.52ab	1.70	1.58b
T_4 ($B_{2.5}$)	41.65	40.55ab	3.75b	3.57b	118.9c	57.70c	1.70	1.75a
CV (%)	8.97	6.17	10.92	3.65	6.58	6.25	9.32	8.91
*Sig at 5 % level	ns	*	*	*	*	*	ns	*

Boron fertilizer influenced plants and produced higher number of branch, pods/ plant, stover yield and seed yield compared to non B fertilization. Plant height, seeds /pod and 1000-seed weight yield in all treatments were found non-significant in 2020-2021 year. The number of branch and stover yield

Table 4. Effect of B fertilizer on yield and yield attributes and % yield increase over control of lentil at RARS, Rahmatpur during in 2020-2021 and 2021-2022.

Treatments	1000 seed weight (g)		Stover yield (kg/ ha)		Seed yield (kg/ha)		% Yield over control	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
T_0 ($B_{0.0}$)	19.20b	20.25b	1290c	1780a	1730b	1338b	-	-
T_1 ($B_{1.0}$)	22.50a	21.25ab	1420a	1658ab	1890ab	1449a	9.23	8.29
T_2 ($B_{1.5}$)	22.10a	22.50a	1460a	1439c	1960a	1341ab	13.29	-
T_3 ($B_{2.0}$)	21.00a	21.50ab	1400a	1723ab	1870ab	1388b	8.09	3.73
T_4 ($B_{2.5}$)	20.80ab	21.75a	1340b	1576bc	1790b	1313b	3.45	-
CV (%)	7.59	5.18	8.43	6.29	5.20	7.46	-	-
*Sig at 5 % level	*	ns	*	*	*	*	-	-

(kgha^{-1}) was found highest in T_2 ($B_{1.5}$) treatment which was statistically significant over T_0 ($B_{0.0}$) treatment. The highest seed yield (1960 kgha^{-1}) was recorded in 2021-2022 year from the application of 1.5 kg boron/ha which was 13.29% highest over without boron (B_0) application. In case of year 2021 to 2022, boron fertilizer effects on lentil production. The highest number of branches (3.95), pods/plant (64.02) seeds/pod (1.80) and seed yield (1449 kgha^{-1}) yield was found in T_1 ($B_{1.0}$) treatment which was statistically similar with T_2 ($B_{1.5}$) treatment but significant over control T_0 ($B_{0.0}$) treatment.The highest stover yield (1780 kgha^{-1}) was found in T_0 ($B_{0.0}$) treatment and lowest (1439 kgha^{-1}) in T_2 ($B_{1.5}$) treatment. The significant highest seed yield (1449 kgha^{-1}) was found when we use 1.0 kg boron ha^{-1} which was 8.29% higher over contrl T_0 ($B_{0.0}$) treatment. The lowest seed yield (1313 kgha^{-1}) was found when we use 2.5 kg boron/ha which was lower than control treatment (1338 kgha^{-1}). This is may be due to the soil fertility status or dense plant population.

Conclusion

Application of boron fertilizer enhances the seed yield of lentil. The variation of yield and yield contributing characters was found in amount of boron application between the results of 2020-2021 and 2021-2022 years. To confirm the actual B fertilizer recommendation for lentil (BARI Masur-8) in this southern region, the experiment should be conducted for next year.

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ASSESSMENT OF ARBUSCULAR MYCORRHIZAL ASSOCIATION IN SOME FRUITS AND FIELD CROPS

M.E. ALI, M.F.A. ANIK, M. RAHMAN AND H.M. NASER

Abstract

Rhizosphere soils including fine roots of some field crops were collected from Pabna region during 2021-2022 for counting Arbuscular Mycorrhiza (AM) spore population and determining colonization (%) in their roots. The spore numbers of 100-gram rhizosphere soil were recorded ranging from 74.60 (Black cumin) to a maximum of 192.0 (Linseed). A considerable variation was observed in average spore numbers recorded in different field crops. Among the field crops, the highest root colonization (50.0%) was found in potato and linseed and lower colonization (10.0%) was found in some of the crops likecabbage, lentil, garlic etc.

Introduction

Mycorrhizae are symbiotic association between beneficial soil fungi and plant roots. Vesicular-arbuscular mycorrhizae (VAM) are the mycorrhizae of crop plants and most annual and woody natives. They do not produce visible mushroom-type reproductive structures, but form spores that are the largest of any fungi. They donot grow in laboratory conditions, but grow with a wide variety of host plants. They have an important role in increasing plant uptake of P and other poorly mobile micronutrients particularly Zn and Cu (O'Keefe and Sylvia, 1991). It is also well known that mycorrhizal plants are better able to withstand drought than non-mycorrhizal plants. Mycorrhizal container stock has a higher rate of survival and better performance after transplanting. Mycorrhizal plants are more resistant to some pathogens, have altered production of plant hormones, and have more highly branched root systems than non-mycorrhizal plants. Cuttings of some species have an improved rooting ability when the medium contains mycorrhizal fungi. Many of the benefits, even those which seem unrelated to phosphorus, appear to actually be side benefits of improved phosphorus nutrition. The soil, as well as the plants, is affected by mycorrhizal fungi. The hyphae are an important component of soil structure, holding together crumbs that allow penetration of water and air, and encourage the growth of roots through the soil. Out of the different types of mycorrhizae, the AM fungi are the most widely occurring mycorrhizae and are very important in relation to the improvement of agricultural and horticultural crops and forest trees in hilly areas (Mridha and Xu, 2001). They form three-way associations involving plants, fungi and soils. Bangladesh produces a variety of field crops. It seems that there is an important role of arbuscular mycorrhizal fungi in nutrient availability for these field crops. But still no work has been done to assess the mycorrhizal association with different field crops. So, this present work was taken to know the percent root colonization of field crops and the number of AM spores in the rhizosphere soils for producing suitable inoculum for future use in different crops.

Materials and Methods

Rhizosphere soils of some field and fruit crops from Pabna region were collected during 2021-2022 for the assessment of arbuscular mycorrhizal association. Rhizosphere soils with thin root were collected from the plants.

Assessment of spore population density

Assessment of spore population was done by following the Wet Sieving and Decanting Method (Gerdemann and Nicolson, 1963). Soil samples from the rhizosphere of the respective plant species were mixed thoroughly by breaking up any large lumps. Unwanted particles such as stone, roots, twigs etc. were removed during this process. Then 100 g of mixed soil was kept in a bucket (8 litres) and filled three quarters with tap water. The soil with water was agitated by stirring vigorously by hand and washed into the bucket and left to settle for one minute. The suspension was sieved by following the wet sieving and decanting method (Gerdemann and Nicolson, 1963). Two sieves (400 μm and 100 μm mesh) were used throughout the experiment. The supernatant was poured through a 100 μm sieve into the second bucked (10 litres) to avoid the loss of useful materials. After allowing the suspension to settle for one minute, the supernatant was decanted into the 400 μm sieve. This time water was discarded and the material was again washed from the sieve into a beaker (250 mL) with a small quantity of water. The solution with spores was distributed in 4 equal size test tubes evenly and balanced up the tubes with water for equal weight. The tubes were plugged properly and then centrifuged for 4 minutes at 3,000 rpm. The supernatant was poured in test tubes and the test tubes were filled with sucrose solution and stirred vigorously with the round-ended spatula to re-suspend the precipitate. The test tubes were balanced properly to equal weight and they were plugged. Then the plugged test tubes were centrifuged for 15 seconds at 3,000 rpm. After centrifuge, the sucrose supernatant was poured through a 400 μm sieve and rapidly washed with water to remove the sucrose from AM spores by back washing the materials from the sieve into watch glass for observation.

Counting of AM spores

All the AM spores were isolated from the extract with the help of a fine forcep into a watch glass with small quantity of water. The extract, with AM spores, was observed under stereomicroscope and the number of spores was counted. Spore numbers from the three replicates per samples were averaged and the result was expressed as number 100 g^{-1} of dry soil basis.

Assessment of root colonization infection

The percentage of AM infection was estimated by root slide technique (Read *et al*., 1976). One hundred root segments were examined for each sample. The stained root pieces were mounted in acidic glycerol on slides and the cover slip was placed and slightly pressed. The roots were observed under microscope. A root segment was considered as positively AM infection, when mycelium, vesicles and arbuscules or their combinations were seen under stereomicroscope. The presence or absence of infection in the root pieces was recorded and the percent infection was calculated as follows:

$$\% \text{ root colonization} = \frac{\text{Number of AM positive segments}}{\text{Total number of segments scored}} \times 100$$

Chemical properties of composite soil sample were determined and presented in Table 1.

Table 1. Chemical characteristics of initial soil during 2020-2021

Station	pH	OC %	Ca	Mg	K	Total	P	S	B	Cu	Fe	Mn	Zn
			meq 100g^{-1}			N %	μg g^{-1}						
Pabna	8.17	0.87	15.54	4.34	0.10	0.08	4	16.3	0.2	1.1	25.1	2.90	1.3
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4.0	1.0	0.6

Methods of chemical analysis:

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Calcium, K and Mg were determined by NH_4OAc extraction method. Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method. Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$.

Results and Discussion

Spore population of AM fungi

Crop species variation showed different number of spore population of AM fungi (Table 2). The highest number of spores per 100 g of dry soil was recorded from the rhizosphere soil of linseed (192.0), which was followed by onion, wheat, shlok and coriander (Table 2). Poor number of spores (74.6) was recorded in red blackcumin. Among the crop species, most of the crop plants recorded more than 100 sopre population $100g^{-1}$ rhizosphere soil. The spore numbers with rhizosphere soil varied in different crop species which were supported by Muthukumer *et al*. (1994b) who reported that the intensity of spore density varied on different factors like plant species and genera and nature of rhizosphere soil.

In present study, the spore density in the rhizosphere soil varied in different fruit plants which was supported by Howeler *et al*. (1987) who reported that the intensity of spore density varied on different factors like plant species and genera and nature of rhizosphere soil. Bhuiyan *et al*. (2013, 2014, 2015) also found that variation in spore density in the rhizosphere soil of different fruit and spices plants at Ramgarh, Khagrachari, Raikhali, Jointapur, Jessore, Rangpur, Rajshahi was observed. Moreover, higher spore population was observed in some fruit plants. The stimulating effects of organic matter, comparatively high level of N and P might have created a favourable condition for maximum sporulation of AM fungi in that particular field.

Table 2. Spore population of arbuscular mycorrhizae in rhizosphere soil and root infection of different field crops of Pabna during 2021-2022

Sl. No.	Local name	English name	Spore number per 100 g soil[a]	Root colonization[a] (%)	AM structure[b]			
					H	A	V	VS
1	Badhakopi	Cabbage	96.6 ± 6.9	10.0 ± 0.0	+	-	-	-
2	Sem	Bean	94.4 ± 6.7	16.6 ± 3.3	+	-	-	-
3	Begun	Brinjal	134.0 ± 23.0	23.3 ± 6.7	+	+	-	-
4	Piyaj	Onion	174.6 ± 13.8	30.0 ± 10.0	+	+	+	O
5	Tomato	Tomato	120.0 ± 3.4	47.6 ± 8.7	+	-	-	-
6	Mosur	Lentil	169 ± 26.9	10.0 ± 0.0	+	-	-	-
7	Alu	Potato	104.0 ± 2.6	50.0 ± 10.0	+	-	-	-
8	Gom	Wheat	152.6 ± 9.8	20.0 ± 0.0	+	-	+	O,S
9	Fulkopi	Cauliflower	88.0 ± 6.1	10.0 ± 0.0	+	-	-	
10	Broccoli	Broccoli	92.6 ± 3.8	13.3 ± 3.3	+	-	+	O
11	Lau	Bottle gourd	28.6 ± 6.7	16.7 ± 6.7	+	-	-	-
12	Rosun	Garlic	90.0 ± 10.4	10.0 ± 0.0	+	-	+	O,S
13	Sarisa	Mustard	140.0 ± 18.8	16.7 ± 3.3	+	-	-	-
14	Khesari	Grasspea	111.0 ± 32.4	23.3 ± 6.7	+	-	-	-
15	Palongshak	Spinach	136.0 ± 6.7	30.0 ± 0.9	+	-	-	-
16	Solok	Shlok	180.0 ± 15.0	20.0 ± 5.7	+	-	-	-
17	Joan	Carom seeds	148.0± 6.9	10.0 ± 0.0	+	-	-	-
18	Tisi	Linseed	192.0 ± 23.7	50.0 ± 10.0	+	-	+	O,S
19	Dhonia	Coriander	175.0 ± 10.0	20.0 ± 0.0	+	-	-	-
20	Kalojira	Black cumin	74.6 ± 3.6	10.0 ± 0.0	+	-	+	O
21	Kolmishak	Kangkong	102.3 ± 7.2	13.3 ± 3.3	+	-	-	-
22	Letus	Lettuce	91.4 ± 7.9	16.7 ± 6.7	+	-	-	-

[a]Percent root colonization & spore population are the means ± S.E. of three independent counts.
[b] H= Hypae, A=Arbuscle, V=Vesicle, VS= Vesicle Shape, O=Oval, S=Spherical

Root colonization

Different field crops showed different percentages of root colonization by arbuscular mycorrhizal fungi (Table 2). Percent root colonization varied from 10.0% to 50.0%. Thirty percent root colonization was recorded in some crops. Most of the plants showed 20% colonization. The highest root infection percent (50%) was recorded in potato and linseed. A large variation was observed in the colonization among different crop plants. This variation might be due to the differences in the structure of root system, phosphorus uptake (Hetrick *et al*., 1992) and also might be due to genetic variations (Mercy *et al*., 1990; Bhuiyan *et al*., 2013, 2014, 2015).

AM structure

The AM fungal structure in the root system of the selected fruit plants varied irrespective of fruit species (Table 2). Hyphae were present in all the plants. Some of the plant species had vescicle and arbuscules. Oval shape vesicles were found in this study, which was supported, by Muthukumar *et al*. (1994) and Khanam *et al*. (2003, 2004).

Conclusion

Spore population and root colonization varied from plant to plant in the present study. But variations in spore numbers in different plants were not related to percent root colonization. As a wide range of host, fungal and environmental factors are known to influence AM formation and subsequent spore production; these two phenomena may not necessarily be related.

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COLLECTION, ISOLATION AND SCREENING OF INDIGENOUS RHIZOBIAL STRAINS FOR DIFFERENT LEGUMES

M.E. ALI, M.F.A. ANIK, M. RAHMAN AND H.M. NASER

Nodules were collected from different legume crops grown under different locations in Bangladesh during 2021-2022. Eight legume crops namely grasspea, lentil, chickpea, mungbean, gardenpea, groundnut, soybean, and cowpea were selected for collecting nodules from different locations. Grasspea from five, lentil from eight, chickpea from seven, mungbean from one, gardenpea from two, groundnut from three, soybean from four and cowpea from three locations. Culture and sub-culture were done and preserved in the loboratory. Their infectivity test, laboratory and field study will be done.

Table 1. Rhizobial strains collected from different legume crops from different locations

Crop	Location	Status	
		Screening	Sub-culture
01. Grasspea	Pabna Kustia Jashore Ishurdi Madaripur	Done	Done
02. Lentil	Joydebpur Ishurdi Pabna Kustia Jashore Chuadanga Faridpur Madaripur	”	”
03. Chickpea	Joydebpur Kustia Jashore Chuadanga Faridpur Madaripur Ishurdi	”	”
04. Mungbean	Noakhali	”	”
05. Gardenpea	Joydebpur Ishurdi	”	”
06. Groundnut	Rangpur Cox’s Bazar Noakhali	”	”
07. Soybean	Joydebpur Noakhali Patuakhali Cox’s Bazar	”	”
08. Cowpea	Hathazari Joydebpur Cox’s Bazar	”	”

This programme will be continued in the next year.

STUDY ON MICROBIAL POPULATION STATUS IN RHIZOSPHERE SOILS OF DIFFERENT CROPS OF SOME AEZs OF BANGLADESH

M.E. ALI, M.F.A. ANIK, M. RAHMAN AND H.M. NASER

Abstract

Soil microbes play a major role in legumes to supply nutrient to plants as well as decomposition of organic materials and cycling of nutrients. Sixteen rhizosphere soil samples were collected from selected locations of different AEZs of Bangladesh to know the total bacteria, Rhizobium, Freeliving bacteria, Phosphate Solubilizing bacteria (PSB), Actinomycetes and Fungal population at different AEZs of Bangladesh. Rhizobium was grown in YMA media and Rhizobium colonies were counted. The highest total bacacteria (6.6×10^{9} g^{-1} soil) was recorded in the rhizosphere soils of cabbage and the lowest number of total bacterial colony (1.0×10^{7} g^{-1} soil) was observed in the the rhizosphere soils of bitter gourd and bottle gourd. The highest Rhizobium (9.2×10^{8} g^{-1} soil) was found in the rhizosphere soils of Wheat and the lowest population (6.0×10^{5} g^{-1} soil) was observed in the rhizosphere soils of Chilli. Free living bacteria was grown in N free media and colonies were counted. The highest free-living bacterial population (5.4×10^{9} g^{-1} soil) was found in the rhizosphere soils of Bean and the lowest population (1.0×10^{5} g^{-1} soil) was observed in the rhizosphere soils of Wheat and onion. Phosphate solubilizing bacteria was grown in Pikovskaya's media and PSB colonies were counted. The highest PSB population (1.6×10^{9} g^{-1} soil) was found in the rhizosphere soils of Tobacco and the lowest population (1.0×10^{5} g^{-1} soil) was observed in the rhizosphere soils of Cauliflower. Actinomycetes was grown in Actinimycetes agar media and colonies were counted. The highest Actinomycetes population (8.0×10^{7} g^{-1} soil) was found in the rhizosphere soils of Bean and the lowest population (1.0×10^{5} g^{-1} soil) was observed in the rhizosphere soils of Tobacco. Fungus was grown in PDA media and colonies were counted. The highest fungal colonies (5.3×10^{8} g^{-1} soil) was found in the rhizosphere soils of Tobacco and the lowest population (2.0×10^{5} g^{-1} soil) was observed in the rhizosphere soils of Sugarcane and Sunflower.

Introduction

Soil microbial populations play an influential role in the biological management of soil fertility and productivity. They are harnessed and processed in a way to hook the beneficial effects on the soil and structure the soil-biological relation in an ameliorating manner. *Rhizobium* is symbiotic nitrogen fixing microorganism. It is primarily found in neutral to alkaline soils. It can fix a considerable amount of nitrogen. The main use of *Rhizobium* in agriculture is as a bacterial fertilizer called *Rhizobium* biofertilizer or bacterial fertilizer or inoculum used for pulses and oilseed legumes. The most widely used method of applying *Rhizobium* is that of seed inoculation prior to sowing seeds. *Rhizobium* plays a vital role in every ecosystem, working to make nitrogen available to all organisms. *Rhizobium* bacteria turn nitrogen into ammonia through the process of nitrogen fixation, after which the ammonia is turned into proteins. Nitrogen fixation is used in agriculture in relation to crop rotation and fertilization as *Rhizobium* is especially useful in gauging the health and virility of the ground. It is hoped that complex bacterial fertilizers will be available in the near future and these would contain various groups of microorganisms in strictly determined proportions amenable to control. There are indications that use of *Rhizobium* inoculant leads to an increase in the total number of soil microorganisms in the rhizosphere of various legume crops. Thus, *Rhizobium* helps in the enhancement of the activity of microbiological processes in the soil. *Rhizobium* species may have a greater role to play in the near future either as symbiotic nitrogen organisms as substitutes of synthetic and natural nitrogenous fertilizers to alleviate nitrogen deficiency of the different soil tracts of Bangladesh. Besides their role in soil-forming processes, soil organisms make an important contribution to plant growth through their effect on the fertility level of the soil. Particularly important in this respect are the microscopic plants (microflora) which function in decomposing organic residues and releasing available nutrients for growing plants. Nitrogen fixing bacteria also play an important role in the growth of higher plants since they are capable of converting atmospheric nitrogen into useful forms in the soil. There is as yet no explanation for the unique geographical distribution of *Rhizobium* and the environmental adaptation of the organisms remains as one of the few documented instances of bacterial geography.

Azotobacter is aerobic, non-symbiotic nitrogen fixing and free-living organism. It is primarily found in neutral to alkaline soils, in aquatic environments, and on some plants. It has several metabolic capabilities, including atmospheric nitrogen fixation by conversion to ammonia. Their unique system of three distinct nitrogenase enzymes makes these bacteria of particular interest to scientists, who may work toward a better understanding of nitrogen fixation and its role in agriculture. *Azotobacter* has the highest metabolic rate of any organisms. It has been suggested that *Azotobacter* may add to field soils on an average about 11.23 kg of N_2 $ha^{-1}yr^{-1}$ (Rubenchik, 1960). Recently it has been developed as crop inoculants for cereals, oil seeds, cotton and vegetables because of its ability to produce plant growth regulators, siderophores and antimicrobial substances as well as excreting ammonia (Brammar, 1966). The main use of *Azotobacter* in agriculture is as a bacterial fertilizer called *Azotobacter*in. The most widely used method of applying *Azotobacter* in is that of seed treatment or inoculation prior to sowing or treatment of the planting material.

Diazotrophic organisms such as *Azotobacter* play a vital role in every ecosystem, working to make nitrogen available to all organisms. *Azotobacter* and similar bacteria turn nitrogen into ammonia through the process of nitrogen fixation, after which the ammonia is turned into proteins. Nitrogen fixation is used in agriculture in relation to crop rotation and fertilization; soil-dwelling diazotrophs such as *Azotobacter* are especially useful in gauging the health and virility of the ground. It is hoped that complex bacterial fertilizers will be available in the near future and these would contain various groups of microorganisms in strictly determined proportions amenable to control. There are indications that use of *Azotobacterin* leads to an increase in the total number of soil microorganisms in the rhizosphere of various plants. Thus, *Azotobacter* helps in the enhancement of the activity of microbiological processes in the soil. *Azotobacter* species may have a greater role to play in the near future either as free-living organisms or as *Azotobacterin* or other complex forms of fertilizers as substitutes of synthetic and natural nitrogenous fertilizers to alleviate nitrogen deficiency of the different soil tracts of Bangladesh. Besides their role in soil-forming processes, soil organisms make an important contribution to plant growth through their effect on the fertility level of the soil. Particularly important in this respect are the microscopic plants (microflora) which function in decomposing organic residues and releasing available nutrients for growing plants. Nitrogen fixing bacteria also play an important role in the growth of higher plants since they are capable of converting atmospheric nitrogen into useful forms in the soil. There is as yet no explanation for the unique geographical distribution of *Azotobacter* and the environmental adaptation of the organisms remains as one of the few documented instances of bacterial geography.

Phosphate solubilizing bacteria (PSB) may have a greater role to play as substitutes of synthetic and natural phosphatic fertilizers to alleviate phosphorus deficiency. Phosphorus (P) is one of the major plant nutrients, lack of which limited plant growth. Most agricultural soil contains large reserves of total P, commonly in range of 200-5,000 mg P kg^{-1} with an average of 600 mg P kg^{-1} and a part of P accumulates depends on regular application of commercial fertilizers (Fernandez *et al.,* 2007). Both P fixation and precipitation occur in soil because of large reactivity of phosphate ions with numerous soil constituents (Alikhani *et al.,* 2006). Interest has been focussing on the inoculation of phosphate solubilizing microorganisms (PSB) into the soil so as to increase the availability of native fixed P and to reduce the use of fertilizers (Illmer and Schinner, 1992). Many phosphate solubilizing microorganisms (PSB) belonging to the *Psedumunas, Bacillus, Rhizobium, Agrobacterium, Acromobacter, Micrococcus, Aerobacter, Enterobacter, Flavobacterium,* and *Erwinia* genera have been isolated from soil (Rodriguez and Fraga, 1999; Gulati *et al.,* 2007). These bacteria can grow in media containing calcium phosphate complexes as the sole sources of P, solubilize a large proportion of P, assimilate it and release in higher amounts. Phosphate solubilizing microorganisms brings about mobilization of insoluble phosphates in the soil and increase plant growth under conditions of poor phosphorus availability (Tripura *et al*., 2007). Soil enzyme activities indicate the potential of the soil to support biochemical processes essential for the maintenance of fertility of soil. The determination of enzyme activities in conjunction with soil respiration and composition of the soil microflora provide the most reliable index of microbial activity (Singh and Rai, 2004). The solubilization ability of microorganisms has been employed for improving soil microbial activities and crop yield in agriculture and horticulture (Kapoor *et al.,* 1989), Rodriguez and Fraga, 1999).

Phosphate solubilizing organisms have significant role in solubilizing the insoluble P in the soil and hence P nutrient of plants. This is much relevant when the P is applied as insoluble form such as rook phosphate. Keeping in view of the role prayed by these organisms an attempt was made to isolate and screen new and efficient phosphate solubilizing bacteria from the rhizosphere of crop plants. There is as yet no explanation for the unique geographical distribution of PSB and the environmental adaptation of the organisms remains as one of the few documented instances of bacterial geography. Hence, the present study has been undertaken to know the Rhizobium, Azotobacter and phosphate solubilizing bacteria (PSB) population status in soils of different AEZs of Bangladesh.

Materials and Methods

Twenty soil sample were collected from different AEZs for analysing the population status of Total bacteria, Rhizobium, Freeliving bacteria, PSB, Actinomycetes and Fungal colonies. Land areas of these agro ecological zones were recognized on the basis of hydrology, physiography, soil types, tidal activity, cropping patterns, and seasons. Representative soil samples have been collected from different crop fields of these agro ecological zones. Soils were taken from three different places of each crop field from 0-6 inches depth and then the soils were placed in plastic bags. The plastic bags were pin holed for aeration, and stored in laboratory prior to analysis. Different types of media were prepared for growing of Total bacteria, Rhizobium, Freeliving bacteria, Phosphate Solubilizing bacteria (PSB), Actinomycetes and Fungal colonies. After serial dilution one drop of solution was poured in a petridish having different types of media. The petriplates were incubated three days for counting Total bacteria, Rhizobium, Freeliving bacteria, PSB, Actinomycetes and Fungal colonies.

Results and Discussion

Bangladesh is sub-tropical country where the atmospheric conditions are favourable for microorganisms. The abundances of Total bacteria, Rhizobium, Freeliving bacteria, Phosphate Solubilizing bacteria (PSB), Actinomycetes and Fungal population are presented in Table 1.

Total Bacteria

It was observed that the highest total bacacteria (6.6×10^9 g^{-1} soil) was recorded in the rhizosphere soils of cabbage and the lowest number of total bacterial colony (1.0×10^7 g^{-1} soil) was observed in the the rhizosphere soils of bitter gourd and bottle gourd. (Table 1). The population of total bacteria in soils of collected samples were higher than other estimated microbial population in selected regions.

Rhizobium

The population of *Rhizobium* in soils of collected soils were ranged from 6.0×10^5 g^{-1} to 9.2×10^8 g^{-1} soil (Table 1). It was revealed that the highest Rhizobium (9.2×10^8 g^{-1} soil) was found in the rhizosphere soils of Wheat and the lowest population (6.0×10^5 g^{-1} soil) was observed in the rhizosphere soils of Chilli.Most of the soils of selected locations showed more than 10^6 colony g^{-1} soil.

Table 1. Microbial population status in rhizosphere soils of different crops of some AEZs of Bangladesh

	Location	Crop	GPS	AEZ(s)	*Total Bacteria*	*Rhizobium*	*Free living bacteria*	PSB	*Actinomycetes*	*Fungus*
					cfu g^{-1} soil					
01	Taraganj, Rangpur	Potato	N: 25.48505 E: 89.02865	2	9.0×10^7	1.0×10^5	3.0×10^5	4.0×10^5	2.0×10^5	2.2×10^8
02	Taraganj, Rangpur	Wheat	N: 25.48257 E: 89.02945	2	8.2×10^8	9.2×10^8	1.0×10^5	2.9×10^8	2.0×10^5	1.0×10^8
03	Taraganj, Rangpur	Mango	N: 25.48518 E: 89.01884	2	1.4×10^7	2.3×10^6	4.0×10^6	9.7×10^8	2.0×10^5	3.8×10^6
04	Taraganj, Rangpur	Tobacco	N: 25.47050 E: 89.02182	2	1.2×10^9	5.0×10^6	1.0×10^7	1.6×10^9	1.0×10^5	5.3×10^8
05	Taraganj, Rangpur	Banana	N: 25.45882 E: 89.01752	2	9.4×10^8	1.0×10^5	1.7×10^8	5.3×10^8	5.0×10^5	6.0×10^6
06	Badarganj, Rangpur	Sunflower	N: 25.43071 E: 89.04040	2	8.7×10^8	8.0×10^7	9.0×10^7	2.5×10^8	5.0×10^5	2.0×10^5
07	Badarganj, Rangpur	Sugarcane	N: 25.42460 E: 89.03542	2	2.8×10^9	7.3×10^8	3.0×10^7	3.0×10^8	8.0×10^5	2.0×10^5
08	Badarganj, Rangpur	Garlic	N: 25.41415 E: 89.03376	2	1.6×10^9	2.0×10^8	6.0×10^8	4.0×10^7	5.0×10^5	2.0×10^7
09	Fulbari, Kurigram	Cauliflower	N: 25.57269 E: 89.32930	2	2.0×10^7	1.1×10^8	2.0×10^7	1.0×10^5	1.0×10^7	1.0×10^7
10	Fulbari, Kurigram	Brinjal	N: 25.55478 E: 89.32811	2	1.7×10^9	3.0×10^7	2.4×10^6	3.0×10^5	1.0×10^7	5.0×10^7
11	Fulbari, Kurigram	Onion	N: 25.55457 E: 89.32331	2	7.8×10^8	1.0×10^5	1.0×10^5	1.3×10^9	1.0×10^7	3.0×10^7
12	Fulbari, Kurigram	Bottle Gourd	N: 25.57017 E: 89.31912	2	1.0×10^7	2.0×10^7	6.7×10^8	4.0×10^5	1.0×10^7	1.0×10^7
13	Fulbari, Kurigram	Bitter Gourd	N: 25.57916 E: 89.30921	2	1.0×10^7	1.0×10^5	1.0×10^7	6.0×10^5	1.0×10^7	3.0×10^7
14	Nagessori, Kurigram	Bean	N: 25.57648 E: 89.44065	2	1.8×10^9	2.0×10^7	5.4×10^9	1.4×10^6	8.0×10^7	1.0×10^7
15	Nagessori, Kurigram	Chilli	N: 25.58032 E: 89.44511	2	7.2×10^8	6.0×10^5	1.2×10^6	7.0×10^7	1.0×10^7	5.0×10^7
16	Nagessori, Kurigram	Cabbage	N: 25.58640 E: 89.45479	2	6.6×10^9	4.2×10^8	5.0×10^5	5.0×10^7	8.0×10^5	1.0×10^7

Free living Bacteria

From Table 1 it was observed that the highest free-living bacterial population (5.4×10^9 g^{-1} soil) was found in the rhizosphere soils of Bean and the lowest population (1.0×10^5 g^{-1} soil) was observed in the rhizosphere soils of Wheat and onion.

Phosphate solubilizing bacteria (PSB)

From Table 1 it was found that the highest PSB population (1.6×10^9 g^{-1} soil) was found in the rhizosphere soils of Tobacco and the lowest population (1.0×10^5 g^{-1} soil) was observed in the rhizosphere soils of Cauliflower (Table 1).

Actinimycetes

The highest Actinomycetes population (8.0×10^7 g^{-1} soil) was found in the rhizosphere soils of Bean and the lowest population (1.0×10^5 g^{-1} soil) was observed in the rhizosphere soils of Tobacco (Table 1).

Fungus

The highest fungal colonies (5.3×10^8 g^{-1} soil) was found in the rhizosphere soils of Tobacco and the lowest population (2.0×10^5 g^{-1} soil) was observed in the rhizosphere soils of Sugarcane and Sunflower (Table 1).

Conclusion

Microbial population in soil was found in different numbers in different locations. Further studies in soils of different AEZs of Bangladesh are needed to verify the microbial population.

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EFFECT OF AZOTOBACTER ON GROWTH AND YIELD OF CHILLI

M.E. ALI, M.F.A. ANIK, M. RAHMAN, AND H.M. NASER

Abstract

The experiment was carried out during Robi season of 2021 - 2022 in research field of Soil Science Division, BARI, Joydebpur, Gazipur to find out the effect of Azotobacter inoculum along with different doses of N fertilizer on growth and yield of Chilli. The experiment was designed in RCBD with 6 treatments and 4 replications. Chilli (BARI morich-2) was used as a test crop. Liquid azotobacter inoculum was used in this experiment. The population density of used inoculum was more than 10^8 cfu g^{-1} inoculant. There were six treatments viz. T_1: 100% N of Recommended Dose, T_2: 90% N + Azotobacter inoculum, T_3: 80% N + Azotobacter inoculum, T_4: 70% N + Azotobacter inoculum, T_5: Azotobacter inoculum and T_6: Control. Results of the experiment revealed that highest fruit yield of chilli (12.52 t ha^{-1}) found in T_3 treatments which was statistically identical with T_1 (12.27 t ha^{-1}) and T_2 (12.06 t ha^{-1}) treatment. This result suggested that use of azotobacter inoculum in combination with reduced dose of N fertilizer was beneficial for chilli and onion and we could reduce 20% of nitrogenous fertilizer.

Introduction

Global interest in biological nitrogen fixation is a direct consequence of input constraint in nitrogenous fertilizers which are in short supply. The increasing cost of these chemical fertilizers and soil health hazards have reduced their use considerably. This has necessitated searching for cheaper source of nitrogen to meet the needs of crops. Farmers use chemical fertilizers to increase production to meet their needs, but the excessive use of fertilizers leads to contamination of soil and groundwater and reduce soil fertility. On the other hand, for marginal farmers in Bangladesh, the purchase of chemical fertilizers is difficult and expensive. So, biofertilizers can replace partially chemical fertilizers. Hence, there is a need to search for alternative strategies to improve soil health without causing damage to environment as well as soil. Therefore, biofertilizers are gaining importance as they are ecofriendly, non-hazardous and nontoxic products (Sharma *et al*., 2007). Biofertilizers include mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting microorganisms. Biofertilizers benefiting the crop production are Azotobacter, Azospirillum, blue green algae, Azolla, P-solubilizing microorganisms, mycorrhizae and sinorhizobium (Selvakumar *et al*, 2009). Among the biofertilizers, Azotobacter represents the main group of heterotrophic, non-symbiotic, gram negative, free living nitrogen-fixing bacteria. They are capable of fixing an average 20 kg N/ha/year. The genus Azotobacter includes 6 species, with A. chroococcum most commonly inhabiting in various soils all over the world (Mahato *et al*., 2009). Besides nitrogen fixation, Azotobacter also produces thiamin, riboflavin, indole acetic acid and gibberellins. When Azotobacter is applied to seeds, seed germination is improved to a considerable extent, so also it controls plant diseases due to above substances produced by Azotobacter. The exact mode of action by which Azotobacteria enhances plant growth is not yet fully understood. Three possible mechanisms have been proposed: N_2 fixation; delivering combined nitrogen to the plant; the production of phytohormone-like substances that alter plant growth and morphology, and bacterial nitrate reduction, which increases nitrogen accumulation in inoculated plants (Mrkovacki and and Milic, 2001). In Bangladesh very limited studies were carried out on the effect of Azotobacter on crop growth and productivity.

Chilli (Capsicum annuum L.) is one of the important spice crops of Bangladesh. It has different types of protein, vitamin, and ascorbic acid contents, and is a good source of medicinal potential. Th is crop is very important for agricultural economy and is used in processing industries. According to the Food and Agriculture Organization (FAO) of the United Nations (FAO, 2003), globally the percentage change in the area and production of chilli are consistently increasing but the productivity of chilli in Bangladesh is very poor. The indiscriminate use of chemicals resulted in degradation of soil health, erosion, and loss of organic matter, nitrate pollution and also health hazard for human beings. So, application of biofertilizers like Azotobacter results in increased mineral and water uptake, root development, vegetative growth and nitrogen fixation also stimulate production of growth promoting substance like vitamin-B complex, Indole acetic acid (IAA) and Gibberellic acids etc. They liberate growth promoting substances and vitamins and help to maintain soil fertility. (Pratap 2012). Sevral studies shows that presence of Azotobacter spp. in soils has beneficial effects on plants, i.e, soil physico-chemical and microbiological properties. So, keeping in view the above facts the present experiment was undertaken to find out the most effective dose of Azotobacter for growth and yield of onion (Allium cepa L.) and Chilli (Capsicum annuum L.).

Materials and Methods

Seedling collection and Soil preparation

The experiment was carried out during Robi season of 2021 - 2022 in the research field of Soil Science Division, BARI, Joydebpur, Gazipur. Seeds of chilli (BARI morich-2) were collected from Regional Spices Research Centre, BARI, Gazipur. Seedlings of chilli (BARI morich-2) were raised on the net house of Soil Science Division, BARI, Joydebpur, Gazipur. The silted (sandy clay loam) soils were collected from the bank of Turag river at Kodda, Gazipur was used in the seed bed. Cowdung was used at 1 kg m^{-2} in the seed bed. The pH of cowdung was 6.7 and the nutrient contents were: organic matter 14.1%, N 0.8%, P 1.26%, K 0.88%, Ca 1.55%, Mg 0.82%, S 0.62%, Fe 0.25% and Mn 0.112%. The physical and chemical properties of the soil are presented in Table 1. The soil contained 158 AM (100^{-1} g soil) spores of indigenous mixed AM fungal species and each gram of soil contain population of rhizobium, azotobacter and phosphate solubilizing bacteria (PSB) were 4.5×10^4, 5.0×10^4 and 3.5×10^4, respectively. The experiment was conducted under unsterilized soil condition.

Table 1. Initial fertility status of the soil samples

Soil Properties	Texture	pH	OC (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
				meq 100 g^{-1}				µg g^{-1}						
Result	Sandy clay loam	6.69	0.56	7.9	2.2	0.19	0.06	8.0	17.8	0.4	1.8	162	18	5.2
Critical level	-	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4.0	1.0	0.60

Soil analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by Wet Oxidation Method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method (Jackson, 1962). Calcium, K and Mg were determined by NH_4OAc extraction method (Black, 1965). Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils) according to Olsen *et al.* (1954). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$.

Fertilizer application

Chemical fertilizers @ 110 kg N ha^{-1} from urea, 45 kg P ha^{-1} from TSP, 75 kg K ha^{-1} from MoP, 20 kg S ha^{-1} from gypsum, 5 kg Zn ha^{-1} from $ZnSO_4 .7H_2O$ for chilli were applied (BARC, 2018). All other fertilizers except urea-N and $^2/_3$rd of MoP was applied as basal during final land preparation and urea-N were applied at three equal splits and $^2/_3$rd of MoP was applied as two equal splits.

Preparation of azotobacter inoculum

Azotobacter inoculum was prepared following standard microbiological procedure. Azotobzcter strains were inoculated on Jensen's N-free medium (Jensen 1951) slants. From the slants, sub culture wsa done by N-free Jensen's medium (Jensen 1951). From the sub culture plate, pure culture of

Azotobacter was inoculated in conical flux containing Jensen's N-free broth (Jensen 1951). The broth was shaking in a horizontal shaker for 3-4 days for sufficient growth of bacterial cell. Bacterial growth was determined by plate count dilution method. After proper growth of azotobacter, the broth was used as Azotobacter inoculum. The seedling of chilli were soaked in to the liquid inoculum for 2-3 hours. After soaking the seedling, the seedlings were transplanted in pot.

Design of experiment and treatments

The experiment was designed in RCBD with 6 treatments and 4 replications. There were six treatments viz. T_1: 100% N of Recommended Dose, T_2: 90% N + Azotobacter inoculum, T_3: 80% N + Azotobacter inoculum, T_4: 70% N + Azotobacter inoculum, T_5: Azotobacter inoculum and T_6: Control. A blanket dose of PKSZn was applied for each treatment.

Seedling transplanting:

Healthy seedlings of chilli (BARI morich-2) were collected from the seed bed, net house of soil science division, BARI, Joydebpur, Gazipur. Six square meter (2m × 3m) plot was prepared in the experimental field of soil science division, BARI, Joydebpur, Gazipur. After preparing the experimental plot, seedlings were transplanted at a spacing of 60 cm × 50 cm. Chilli seedlings were transplanted on 2nd December 2021.

Intercultural operations

Intercultural operations like watering, weeding, insect pest managements etc, were done when necessary. Top dressing of urea fertilizer was done as per schedule.

Crop harvest

Three plants of chilli from each pot were harvested after 45 days after transplanting for recording some growth parameter like, number of leafs per plant, shoot weight and root weight. Chilli were harvested at several times. First harvest was done on 16th January 2022. Different parameters like number of fruit plant^{-1}, fruit length, fruit diameter, fruit yield t ha^{-1} were measured.

Statistical analysis

Data were statistically analyzed using Analysis of Variance (ANOVA) following CropStat package while the all pair comparisons were done by Statistix 10.

Results and Discussion

Effect of different doses of nitrogen and azotobacter inoculum on growth parameter of Chilli

Effect of different doses of nitrogen and azotobacter inoculum on growth parameter of chilli has been presented in Table 2. Significant differences were found in case of number of branch plant^{-1}, root weight and shoot weight but plant height exhibited non-significant difference among the treatment combination.

Table 2: Effect of different doses of nitrogen and Azotobacter inoculum on growth parameter of Chilli

Treatment	Plant height (cm)	No. of branch $plant^{-1}$	Root wt. (g $plant^{-1}$)	Shoot wt. (g $plant^{-1}$)
T_1: 100% N of Recommended Dose	70.10a	9.42b	0.93bc	5.06b
T_2: 90% N + Azotobacter inoculum	68.50a	9.25b	0.99bc	5.38ab
T_3: 80% N + Azotobacter inoculum	69.90a	11.91a	1.71a	6.79a
T_4: 70% N + Azotobacter inoculum	67.30ab	10.33ab	1.21b	5.01b
T_5: Azotobacter inoculum	62.00b	10.16ab	1.12b	5.33ab
T_6: Control	53.60c	8.83b	0.63c	3.25c
SE (±)	2.77	0.68	0.13	0.54
F test	**	*	*	*
CV (%)	6.02	17.42	21.24	9.25

The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. **Significant P≤0.01, *significant P≤0.05, NS non-significant

The maximum plant height 70.10 cm was observed in T_1 where with 100% recommended dose of N was used which was identical with T_2 and T_3 treatment where 90% and 80% N was used with Azotobater inoculum and the lowest plant height was recorded in T_6 treatment where no inoculum and no N was used. Other treatments produced similar plant height. The highest number of branches per plant 10.91 was observed in T_3 treatment which was statistically identical with T_4 treatment where 70% of recommended N was used along with azotobacter inoculum and the lowest number of branches per plant was recorded in T_6 (control) treatment. Statistically identical number of branches per plant was observed in T_1, T_2, T_4 and T_5 treatment. The maximum number of leaves per plant 40.50 was recorded in T_3 treatment which was statistically identical with all other treatments except control (T_6). The lowest number of leaves per plant was observed in T_6 treatment. The highest root weight and shoot weight of chilli 1.71 g and 6.79 g were observed under treatment T_3 where azotobacter inoculum was used with 80% recommended dose of N which were identical with T_2 treatment. The lowest root and shoot weight were recorded with uninoculated control treatment.

Effect of different doses of nitrogen and azotobacter on yield and yield attributes of chilli

Effect of different doses of nitrogen and Azotobacter on yield and yield attributes of chilli have been shown in Table 3. Significant differences were found in case of number of fruit $plant^{-1}$, length of fruit, breadth of fruit and fresh fruit yield gm $plant^{-1}$ among the treatment combination.

Table 3: Effect of different doses of nitrogen and Azotobacter on yield and yield attributes of Chilli

Treatment	No. of fruit $plant^{-1}$	Length of fruit (cm)	Breadth of fruit (mm)	Fresh yield (t ha^{-1})
T_1: 100% N of Recommended Dose	134.00a	6.73a	8.10a	12.27a
T_2: 90% N + Azotobacter inoculum	130.00a	6.63a	7.75ab	12.06a
T_3: 80% N + Azotobacter inoculum	144. 25 a	6.94a	7.75ab	12.52a
T_4: 70% N + Azotobacter inoculum	132.75 a	6.66a	7.20ab	11.18b
T_5: Azotobacter inoculum	121.25a	6.61a	6.55ab	9.50c
T_6: Control	96.75b	6.23b	6.10b	4.27d
SE (±)	5.44	0.16	0.55	0.97
F test	**	*	**	**
CV (%)	12.17	3.46	15.34	4.46

The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. **Significant P≤0.01, *significant P≤0.05, NS non-significant

The most effective treatment for number fruit plant^{-1} was found to be T_3 where 80 % nitrogen was applied with azotobacter inoculum which were statistically identical with T_1(100% N of Recommended dose), T_2 and T_4 where azotobacter inoculum was used in combination with reduced dose of nitrogen fertilizer. The lowest number of fruits plant^{-1} was recorded in T_6 treatment which was uninoculated and unfertilized (N) control. The highest fruit length 6.94 cm was observed in T_3 where azotobacter inoculum was used with 80% recommended dose of N which was statistically similar with T_1 (100% N of Recommended dose) and T_2(90% N + Azotobacter inoculum) treatments. The use of only azotobacter inoculum without N fertilizer produced 6.61 cm length fruit which was statistically identical with T_4 treatment where 70% N fertilizer was used along with azotobacter inoculum. The lowest fruit length of chilli 6.23 cm was recorded in control treatment where no inoculum and no N fertilizer was used. Statistically similar fruit breadth was found in all the treatments except uninoculated control. Maximum fruit breadth was recorded in T_3 where azotobacter inoculum was used with 80% recommended dose of N and the lowest fruit breadth was found in control treatment. The highest fruit yield 12.52 t ha^{-1} was found in T_3 (80% recommended dose of N with azotobacter inoculum) which was statistically similar with T_1(100% N of Recommended dose) and T_2 (90% N + Azotobacter inoculum) where azotobacter inoculum was used in combination with reduced dose of nitrogen fertilizer. The lowest fruit yield t ha^{-1} was recorded in T_6 treatment which was uninoculated and unfertilized (N) control.

Effect of different doses of nitrogen and azotobacter on microbial population of postharvest soil of Chilli

Effects of different doses of nitrogen and azotobacter on microbial population of postharvest soils of onion have been shown in Table 4. From this table, it was revealed that the use of azotobacter inoculum along with chemical fertilizers improve the micobial population in soil specially azotobacter and phosphate solubilizing bacteria

Table 4. Effect of different doses of nitrogen and azotobacter on microbial population of postharvest soil of chilli

Treatment	*Rhizobium*	PSB	*Azotobacter*
T_1: 100% N of Recommended Dose	5.2×10^3	7.5×10^5	4.2×10^5
T_2: 90% N + Azotobacter inoculum	2.6×10^4	1.2×10^6	2.0×10^5
T_3: 80% N + Azotobacter inoculum	2.5×10^3	2.5×10^5	1.5×10^5
T_4: 70% N + Azotobacter inoculum	2.7×10^3	1.2×10^5	6.5×10^4
T_5: Azotobacter inoculum	5.0×10^3	2.7×10^5	5.2×10^5
T_6: Control	5.0×10^3	5.0×10^5	2.5×10^5

Conclusion

The use of Azotobacter inoculum in combination with nitrogenous fertilizer has positive effect on growth and yield attributes chilli. It also helps to reduce the use the chemical nitrogenous fertilizers which save money and maintain safe soil environment. This is first year study. It should be continued for confirming the results.

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RESPONSE OF LENTIL VARIETIES TO ELITE STRAINS OF *RHIZOBIUM*

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Abstract

Field experiment was conducted at research field of Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute, Jamalpur, during 2021-2022 with the objectives to study the response of Rhizobium inoculation with different varieties of BARI released lentil. Four varieties of lentil viz. BARI Masur-6, BARI Masur-7, BARI Masur-8 and BARI Masur-9 and rhizobial inoculum (Rhizobium strain RLc-104) were used in this experiment. Unit plot size was 4 m x 3 m. The experiment was designed in randomized complete block having 3 replications in each treatment. Each variety was tested with/without Rhizobium inoculation. Inoculated plants gave significantly higher nodule number, nodule weight, shoot weight and seed yield compared to non-inoculated plants. Among 4 varieties, BARI Masur-8 produced the highest nodule number and nodule weight. The interaction effect revealed that the highest seed yield of 1.02 t ha^{-1} was recorded by inoculated BARI Masur-8.

Introduction

The increasing demand for production of crops and food for such a vast population has led to an interest and necessity for the use of biofertilizers (*Rhizobium*) for the betterment of these crops and even for the health of soil. Biofertilizers can be a very good complimentary to the chemical pesticides as they not only kill the harmful insects but also the beneficial insects such as pollinators. By the turn of this century, Bangladesh estimated food requirement for huge number of populations. One of the key limiting factors in crop productivity is the availability of nitrogen. Because of the constraints on the production, availability and use of chemical nitrogenous fertilizers, biologically fixed nitrogen will play an important role in increasing the crop production. To ensure an optimum rhizobial population in the rhizosphere, seed inoculation of legumes with an efficient rhizobial strain is necessary. This helps improve nodulation, N_2 -fixation solicit crop growth and yield of leguminous crops (Henzell, 1988). The process of nitrogen fixation is quite complex requiring interaction between bacterium and the host plant, *Rhizobium* sp. invade the root hairs of chick-pea and result in the formation of nodules, where free air nitrogen is fixed. These bacteria, although present in most of the soils vary in number, effectiveness in nodulation and N-fixation.

Lentil (*Lens culinaris* L.) is an important rabi pulse crop extensively grown in Bangladesh. Total production area of lentil is 359367 acres and total production is 167261 metric tons (Agricultural statistics, 2015). The yield level of lentil is generally low because it is less cared crop and mostly grown in poor soil without manures and fertilizers. Regular depletion of nutrient resources of soil has led to emergence of several nutrient deficiencies in many crops including lentil. This is because the greater is the production, the higher and faster are the rate of nutrients exhation from the soil. As a leguminous crop, it utilizes atmospheric nitrogen to meet its partial nitrogen requirement and thus occupies an important place in crop rotation in different part of the country. It is the most suitable crop for rainfed conditions, because of its deep root system and capability to stand in drought condition. In comparison to any other rabi crops of similar condition, except gram, it is greatly esteemed for its ability to give satisfactory yield even under sub-optimum condition and in year of low winter rainfall. Lentil seeds contain about 11.20 percent water, 25.0 percent protein, 1.0 percent fat, 55.8 percent carbohydrate, 3.7 percent fiber and 3.3 percent ash. The role of lentil as a legume crop in building up soil fertility is well known. Biofertilizers are gaining importance as they are ecofriendly, non-hazardous and non-toxic. A substantial number of bacterial species, mostly those associated with the plant rhizosphere, may exert a beneficial effect upon plant growth. Biofertilizers include mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting micro-organism. Inoculating pulse crops with rhizobia to add nitrogen is routine for most growers. The presence of efficient and specific strains of *Rhizobium* in the rhizosphere is one of the most important requirements for proper establishment and growth of grain legume plant. Some of the lentil varieties are waiting for cultivation in the farmers' level but were not screened in respect to nodulation, nitrogen fixation and as well as yield. There is a great possibility to increase its production by exploiting better colonization of the roots and rhizospheres through the application of effective nitrogen fixing bacteria to the seed or to the soil. This can minimize uses of nitrogenous fertilizer, which is very costly in our country. Using high yielding varieties of lentil in combination with effective rhizobial strains along with management practices including manures and fertilizers can enhance the yield. The present investigation was undertaken to study the response of inoculation with different varieties of lentil.

Materials and Methods

Lentil was sown on 24 November in 2021 at research field of Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jamalpur. The experiment was designed in randomized complete block having 3 replications in each treatment. Four varieties of lentil viz. BARI Masur-6, BARI Masur-7, BARI Masur-8 and BARI Masur-9 and rhizobial inoculum (*Rhizobium* strain RLc-104) were used in these experiments. Each variety was treated with or without *Rhizobium* inoculant. Unit plot size was 4 m × 3 m. There were 8 treatment combinations. Basic doses of phosphorus @ 22 kg P ha^{-1} as TSP, potash @ 42 kg K ha^{-1} as muriate of potash, sulphur @ 20 kg S ha^{-1} as gypsum and zinc @ 5 kg Zn ha^{-1} as zinc oxide were applied in the field. Urea was applied neither in the inoculated nor in the non-inoculated plots. Peat based rhizobial inoculum (*Rhizobium* strain RLc-104) @ 1.5 kg ha^{-1} was used for seed inoculation. Peat based rhizobial inoculum was used containing about 10^8 cells g^{-1} inoculum. During the course of the experiment growth and development of plants in the field were carefully observed. At 50% flowering stage, 10 randomly selected plants were uprooted from each unit plot. Dry weight of roots, shoots and nodules including nodule numbers were recorded. The plants were harvested on 24 February to 15 March, 2022 for different varities. Data on plant height, 1000-seed weight (g), No. of pods $plant^{-1}$, No. of seeds pod^{-1}, seed yield and stover yield were also taken. All data were analyzed statistically.

Methods of chemical analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Calcium, K and Mg were determined by NH_4OAc extraction method. Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$.

Table 1. Nutrient status and rhizobial population of the initial soil sample during 2021-2022

Properties	Nutrient contents													Rhizobial population/g soil
	pH	OC	Ca	Mg	K	Total	P	S	B	Cu	Fe	Mn	Zn	
		(%)	meq 100 g^{-1} soil			N (%)	µg g^{-1}							
Results	6.82	0.77	6.19	1.7	0.09	0.07	20.0	23.5	0.2	1.9	87	9.9	1.8	6.2 x 10^5
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.2	0.2	04	1.0	0.60	-

Results and Discussion

Effect of variety

Results on effects of different varieties on nodule number $plant^{-1}$, plant height (cm), shoot dry weight (g $plant^{-1}$), root dry weight (g $plant^{-1}$), 1000-seed weight (g), and seed yield (t ha^{-1}) have been presented in Table 2. BARI Masur-8 variety gave the highest nodule number (39.83 $plant^{-1}$) which was statistically identical with BARI Masur-6 and BARI Masur-7 and the lowest was observed at BARI Masur-9 variety. BARI Masur-8 produced the highest plant height (29.67 cm) which was statistically identical with BARI Masur- 6, 7 and 9 variety. The highest shoot dry wt. (2.18 g $plant^{-1}$)

was recorded in the lentil variety BARI Masur-8 which had no significantly differences among the other treatments and the maximum root dry wt. (0.29 g plant^{-1}) was observed in the variety BARI Masur-7 which had no significantly differences among the other treatments. In case of thousand seed weight (23.90 g) were produced by the lentil variety BARI Masur-8 which was followed by BARI Masur- 9. The highest seed yield (0.97 t ha^{-1}) of lentil was produced by the variety BARI Masur- 8 which was statistically identical with BARI Masur- 6 and 7 variety.

Effect of Inoculum

Results on effects of rhizobial inoculum on nodule number plant^{-1}, plant height (cm), shoot dry weight (g plant^{-1}), root dry weight (0.27 g plant^{-1}), 1000-seed weight (g), and seed yield (t ha^{-1}) have been presented in Table 3. During the course of study, inoculated plants gave the highest nodule number plant^{-1} (37.75), plant height (27.83 cm), shoot dry weight (1.96 g plant^{-1}), root dry weight (0.27 g plant^{-1}), 1000-seed weight (25.93 g), and seed yield (0.70 t ha^{-1}) compared to non-inoculated control. This might be due to the effect of inoculum. Giri *et al.* (2010), Yadegari *et al.* (2008) reported the increase in nodules and yield due to inoculation of *Rhizobium* as per also increase in nodules per plant. Solaiman *et al.* (2005) reported that inoculation of chickpea with *Rhizobium* increase nodule number and seed yield. The results are in agreements with the findings of Bhuiyan *et al.* (2008, 2009), who reported that inoculation with *Rhizobium* of chickpea increased yield.

Table 2. Effects of different varieties on nodulation, plant characters and yield of lentil during 2021-2022

Variety	Nodule number plant^{-1}	Plant height (cm)	Shoot dry wt. (g plant^{-1})	Root dry wt. (g plant^{-1})	1000- seed weight (g)	Seed yield (t ha^{-1})
BARI Masur-6	33.67a	26.53b	1.67	0.27	17.43c	0.60b
BARI Masur-7	37.50a	26.47b	1.82	0.29	18.30c	0.57b
BARI Masur-8	39.83a	29.67a	2.18	0.20	23.90a	0.97a
BARI Masur-9	23.67b	25.40b	1.67	0.13	20.75b	0.51c
SE (±)	4.23	0.77	0.22	0.05	0.67	0.02
F-test	**	**	NS	NS	**	**

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significant and (*) indicates at 5% level of significant. NS means non-significant

Table 3. Effects of rhizobial inoculum on nodulation, plant characters and yield of lentil during 2021-2022

Variety	Nodule number plant^{-1}	Plant height (cm)	Shoot dry wt. g plant^{-1}	Root dry wt. g plant^{-1}	1000- seed weight (g)	Seed yield (t ha^{-1})
Uninoculated	29.58b	26.37b	1.71	0.17	24.29b	0.63b
Inoculated	37.75a	27.83a	1.96	0.27	25.93a	0.70a
SE (±)	3.05	0.56	0.15	0.04	0.60	0.02
F-test	*	*	NS	NS	*	**

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significant and (*) indicates at 5% level of significant. NS means non-significant

Interaction Effect

Interaction effects of varieties and rhizobial inoculation on nodule number plant^{-1}, plant height (cm), shoot dry weight (g plant^{-1}), root dry weight (g plant^{-1}), 1000-seed weight (g), and seed yield (t ha^{-1}) have been presented in Table - 4. From the Table 4, it was observed that non-significant interaction effects of varieties and rhizobial inoculation recorded on nodule number plant^{-1}, plant height (cm), shoot length (cm), root length (cm), number of pods plant^{-1}, 1000-seed weight (g) and seed yield (t ha^{-1}).

Table 4. Interaction effects of varieties and rhizobial inoculum on nodulation, plant characters and yield of lentil

Variety	Nodule number plant^{-1}	Plant height (cm)	Shoot dry wt. (g plant^{-1})	Root dry wt.	1000- seed weight (g)	Seed yield (t ha^{-1})
BARI Masur-6×U	29.0	26.00	1.49	0.20	16.40	0.57
BARI Masur-6×I	38.3	27.07	1.85	0.33	18.47	0.62
BARI Masur-7×U	32.3	25.73	1.77	0.21	17.33	0.56
BARI Masur-7×I	42.7	27.20	1.89	0.38	19.27	0.59
BARI Masur-8×U	36.7	28.60	2.05	0.17	23.27	0.92
BARI Masur-8×I	43.0	30.73	2.32	0.23	24.53	1.02
BARI Masur-9×U	20.3	25.13	1.55	0.11	20.30	0.47
BARI Masur-9×I	27.0	25.67	1.79	0.15	21.20	0.56
SE (±)	6.11	0.55	0.31	0.08	0.94	0.04
F-test	NS	NS	NS	NS	NS	NS
CV (%)	12.24	4.99	21.04	9.27	5.75	6.96

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significant and (*) indicates at 5% level of significant. NS means non-significant

Conclusion

From the first-year trial it may be concluded that the highest seed yield of 1.02 t ha^{-1} was recorded by inoculated BARI Masur-8. This experiment should be continued for next year.

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VALIDATION OF BIOFERTILIZER ON DIFFERENT LEGUME CROPS

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Abstract

Field experiments by Rhizobium biofertilizer were carried out during rabi 2021-2022 at Kumerkhali, Kushtia on lentil, and Naovanghar Char, Jamalpur on Groundnut with the objectives i) to evaluate the response of pulse and oilseed legume to Rhizobium biofertilizer under farmers' field condition, and ii) to motivate uses of biofertilizer instead of N-fertilizer for pulse and oilseed legume cultivation. The experiment was laidout in RCBD with 4 dispersed replications. Unit plot size was 15 m × 10 m. Three fertilizer treatments viz. T_1: 22-42-20-5 kg P-K-S-Zn ha^{-1}, T_2: 22-42-20-5 kg P-K-S-Zn ha^{-1} + Rhizobium Inoculum and T_3: 50-22-42-20-5 kg N-P-K-S-Zn ha^{-1} was studied (N dose were different in respect of crops). BARI Masur-8 of lentil and BARI Chinabadam-9 of groundnut and peat based rhizobial inoculum (strain BARI RLc-104 for lentil and strain BARI RAh-803 for groundnut) @ 1.5 kg ha^{-1} were used in demonstration trial. Experimental result revealed that application of biofertilizer along with PKSZn produced higher seed yield and yield attributes of lentil at Faridpur lentil and groundnut at Jamalpur. It is evident from the experiment that application of biofertilizer instead of applying nitrogenous fertilizer can achieve the higher yield of lentil at farmers' field in Faridpur and groundnut in Jamalpur. Higher BCR was noted in T_2 treatment where Rhizobium plus chemical fertilizers (PKSZn) were used.

Introduction

Lentil (*Lens culinaris* L.) occupies the top position in terms of popularity and has been placed first in respect of area and production in Bangladesh (BBS, 2019). About 351,930 ha of land is under lentil cultivation and the total production is about 175,384 metric tons (BBS, 2019). It is cultivated during rabi season under rainfed condition. About 80% of total lentil in the country is grown in Faridpur, Kustia, Jessore, Rajshahi and Pabna. The yield of lentil is very poor. Groundnut (*Arachis hypogaea*) is an important and leguminous oilseed crop. It is cultivated during rabi and kharif seasons under rainfed condition. It contains high protein and fat. *Rhizobium* bacteria forms nodules in the roots of groundnut plant which fixes atmospheric nitrogen and used for its own and groundnut plants are being benefited simultaneously. It is learnt that one hectare of groundnut crop adds benefit of about 80 kg nitrogen in a year.

Groundnut (Arachis hypogaea L.), is a highly demanded legume crop worldwide and is predominantly cultivated in tropical, subtropical and warm areas in over 100 countries. It is grown on 26.54 million ha for a total production of 43.91 million t with an average yield of 1.65 t ha^{-1} in 2014 (FAO, 2014). Groundnut seeds contain about 45–56% oil and 22–30% protein (Savage and Keenan 1994) and many benefcial nutrients such as minerals, vitamin E, folic acid, niacin and antioxidants (Bishi et al. 2015), biologically active polyphenolics, favonoids and isofavones (Francisco and Resurreccion 2008). These nutritional benefts provide higher commercial activity for groundnut evaluated over 70 industrial products (Birthal et al., 2010). About 53% of the global production is used for edible oil, while 32% is consumed in foods (Dwivedi et al., 2003). Therefore, the crop is one of the major edible oil sources in many developing countries (Liao and Holbrook 2007). However, groundnut is an important oil crop of Bangladesh. In Bangladesh groundnut cultivated in an area 34,857 hectare of land and production are 66,744 ton. (BBS, 2021). *Bradyrhizobium* bacteria forms nodules in the roots of groundnut plant which fixes atmospheric nitrogen and used for its own and groundnut plants are being benefited simultaneously. Farmers of different char land areas of Bangladesh grow groundnut after receding of flood water. The low yield of groundnut is associated with poor management practices, unavailability of quality seeds and specially lack of proper fertilizer management. Fertilizer play important role for yield reduction and we should manage or minimize the yield reduction by means of using biofertilizer instead of using chemical fertilizers. Biological nitrogen fixation resulting from symbiosis between legume crops and root nodule bacterium Bradyrhizobium can ameliorate these problems by reducing the chemical N-fertilizer required to ensure productivity (Hayat et al., 2004; Khanum and Bhuiyan, 2007) Bhuiyan et al. (2007) also reported that Rhizobium inoculation significantly increase root nodules, plant height, total biomass, number of pods plant^{-1} and seed yield in pulses.

Bangladesh has been developing a good number of varieties of pulses and oilseed legumes. Some of these varieties are waiting for cultivation in the farmers' level but were not screened in respect to nodulation, nitrogen fixation and as well as yield. There is a great possibility to increase its production by exploiting better colonization of their root and rhizosphere through *Rhizobium* bacteria, which can reduce nitrogenous fertilizer use and protect environment. But there is still lacking of sufficient, effective and resistant *Rhizobium* strains in soil. Moreover, degradation of *Rhizobium* occurs regularly. So, collection and screening of new *Rhizobium* strains and their sub-culturing and testing are necessary. For this reason, few indigenous *Rhizobium* strains were collected from different AEZs of Bangladesh and were screened, tested at research stations. Now their efficiency in crop production needs to be tested at farmers' level. The present study was, therefore under taken i) to evaluate the response of some pulse and oilseed legume crops to biofertilizer under farmers' field condition, and ii) to reduce the uses of N-fertilizer for pulse and oilseed legume cultivation.

Materials and Methods

The experiment was laid out in randomized complete block design having four dispersed replications with three treatments. The unit plot size was 15m × 10m. The variety BARI Masur-8 of lentil and BARI Chinabadam-9 of groundnut and peat based rhizobial inoculum strain BARI RLc-104 for lentil and strain BARI RAh-803 for groundnut @ 1.5 kg ha^{-1} were used in demostration trial. There were three treatments viz. T_1: 22-42-20-5 kg P-K-S-Zn ha^{-1}, T_2: 22-42-20-5 kg P-K-S-Zn ha^{-1} + Inoculum, T_3: 50-22-42-20-5 kg N-P-K-S-Zn ha^{-1} was studied. The above peat based rhizobial inoculum was used @ 1.5 kg ha^{-1} containing about 10^8 cells g^{-1} inoculum. Chemical fertilizers i.e. P, K, S and Zn were applied in all treatments as basal dose @ 22 kg P ha^{-1} from TSP, 42 kg K ha^{-1} from MP, 20 kg S ha^{-1} from gypsum and 5 kg Zn ha^{-1} from zinc sulphate for lentil, chickpea. In T_3 treatment, 50-22-42-20-5 kg N-P-K-S-Zn ha^{-1} for lentil and 100-22-42-40-5 kg N-P-K-S-Zn ha^{-1} for groundnut were used. Lentil seeds were sown in line maintaining 30 cm from line to line distance during 20 November 2021 and the groundnut seeds were sown in line maintaining spacing of 40 cm x 10 cm during 08 February, 2022. The rhizobial population of *Rhizobium* inoculant was about 10^8 cells g^{-1} of inoculant.

During the course of the experiment, growth and development of plants in the field were carefully observed. Lentil was harvested on 18 March 2022. Groundnut was harvested on 17 June 2022 at Jamalpur. All the data were analyzed statistically.

Results and Discussion

Results of rhizobial inoculum and chemical fertilizers on dry matter production, and yield and other parameters have been presented in different Tables.

Location: Kumerkhali, Kustia
Crop: Lentil
The effect of biofertilizer on yield and yield components of lentil at farmer's field of Kumerkhali, Kustia were presented in (table 1 & 2). Plant height, number of pod plant^{-1} and thousand seed weight was highest in with rhizobium inoculant plot. The highest seed yield was also obtained (1.45 t ha^{-1}) in with rhizobium inoculant plot and it followed by only NPKSZn plot (1.42 t ha^{-1}) and without rhizobium inoculant plot (1.35 t ha^{-1}). Gross return and gross margin were higher with rhizobium inoculant than that of without rhizobium inoculant and NPKSZn plot.

Table1. Effect of biofertilizer on yield and yield components of lentil in farmer's field during 2021-22

Treatment	Days to maturity	Plant population m^{-2}	Plant height (cm)	No. of pod $plant^{-1}$	1000 Seed wt (g)	Seed yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
Lentil:							
T_1	110	68	60.00	72	21.27	1.35	1.30
T_2	115	69	62.00	74	22.53	1.45	1.34
T_3	115	67	64.00	73	22.23	1.42	1.35

N.B: T_1= Without Rhizobium inoculant + PKSZn; T_2= With Rhizobium inoculant + PKSZn and T_3= NPKSZn

Table2. Cost, return and profitability of lentil in farmer's field during 2021-22

Treatment	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
Lentil			
T_1	108000	48942	59058
T_2	116000	48942	67058
T_3	113600	49042	64558

Rate: Lentil @ 80Tk.kg^{-1}

Farmer's Opinion

Farmer's were impressed with the performance of rhizobium inoculant due to higher yield, bold size seed in lentil. They were interested to use this rhizobium inoculant if it will be available in market.

Location: Naovanghar Char, Jamalpur

Crop: Groundnut

Results obtained from the study have been presented in table 3 and 4. In table 1, the yield and yield contributing characters of Groundnut have been mentioned. Table 4 represents the economic analysis of the study. The tallest plant (68.95 cm) was obtained from T_2 treatment and the shortest (57.92 cm) was found from T_1 treatment. The highest number of nut/plant (20.80) was found from T_2 treatment and the lowest (19.70) in T_1 treatment. The maximum yield of nut (1.97 t ha^{-1}) was found from T_2 which was followed by T_3 treatment (1.92 t/ha) and the minimum (1.81 t ha^{-1}) from T_1 treatment. The higher gross return (1,37,900/-ha^{-1}) and gross margin (Tk. 60,580 /-ha^{-1}) were observed from T_2 treatment due to its higher yield. The lowest gross return (Tk.1,26,700/-ha^{-1}) and gross margin (Tk.50,686/-ha^{-1}) were found from T_1 treatment due to its lower yield.

Table-3. Yield and yield attributes of Groundnut variety at Naovanghar Char, Jamalpur during rabi season, 2021-22

Treatment	Duration (days)	Plant height (cm)	No. baraches plant^{-1}	Nut plant^{-1} (no.)	Nut yield (t ha^{-1})
T_1	127	57.92	4.60	20.55	1.81
T_2	127	68.95	4.45	20.80	1.97
T_3	127	61.08	5.20	19.70	1.92
CV (%)	-	4.01	10.92	2.80	5.16
Level of sig.	-	**	NS	*	NS

T_1=Without Rhizobium inoculant + PKSZn, T_2=With Rhizobium inoculant + PKSZn and T_3=NPKSZn

Table-4. Cost and return analysis of Groundnut at Naovanghar Char, Jamalpur during rabi season, 2021-22

Treatment	GR (Tk/ha)	TVC (Tk/ha)	GM (Tk/ha)
T_1	1,26,700/-	76,014/-	50,686/-
T_2	1,37,900/-	77320/-	60,580/-
T_3	1,34,400/-	79534/-	54,866/-

T_1=Without Rhizobium inoculant + PKSZn, T_2=With Rhizobium inoculant + PKSZn and T_3=NPKSZn
Price of groundnut = Tk 70.00 kg^{-1}

Farmer's opinion

Farmers are interested to grow BARI Chinabadam-9 with applied rhizobium inoculant due to its higher yield as well as higher income.

Conclusion

The result of biofertilizer in lentil and groundnut production seem to be promising in respective locations. The highest seed yield obtained from plants treated with PKSZn chemical fertilizer along with Rhizobium inoculum in all the locations which might be suitable and economically viable for legume cultivation in respective locations.

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EFFECT OF DIFFERENT BIOFERTILIZER ON YIELD OF ONION

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Abstract

The experiment was carried out during Rabi season of 2021-2022 in the research field of Soil Science Division, BARI, Joydebpur, Gazipur to find out the effect of different biofertilizer inoculum along with different doses of N & P fertilizer on the yield of Onion. The experiment was designed in RCBD with 9 treatments and 4 replications. Onion (BARI piaj-4) was used as a test crop. Liquid azotobacter and phosphate solubilizing bacterial (PSB) inoculum was used in this experiment. The population density of Azotobacter and PSB inoculum were more than 10^8 cell ml^{-1} liquid inoculant. Arbuscular mycorrhiza (AM) was used in the seed bed while producing seedling There were nine treatments viz. T_1 : 100% NPKSZn of RD (Recommended Dose), T_2 : 80% N + *Azotobacter inoculum,* T_3 : 80% P + *PSB inoculum,* T_4 : 50% P + *AM inoculum,* T_5 : 80% NP +*Azotobacter + PSB,* T_6 : 80% N+ 50% P +*Azot.+ AM,* T_7 : 50% P + *AM+PSB,* T_8 : 80% N+ 50% P + Azot. +*AM+PSB and* T_9: Control. Results of the experiment revealed that the highest bulb yield of onion (23.77 t ha^{-1}) was found in T_7 (50% P + *AM+PSB*) treatments which was statistically identical with all other treatments except control. This result suggested that use of azotobacter PSB and AM inoculum in combination with reduced dose of N and P fertilizer was beneficial for onion in the Grey Terrace soils of Gazipur (AEZ 28) and we could reduce 20% of nitrogenous and 50% of phosphatic fertilizer. The experiment should be continued for conforming the findings.

Introduction

Global interest in biological nitrogen fixation is a direct consequence of input constraint in nitrogenous fertilizers which are in short supply. The increasing cost of these chemical fertilizers and soil health hazards have reduced their use considerably. This has necessitated searching for cheaper source of nitrogen to meet the needs of crops. Farmers use chemical fertilizers to increase production to meet their needs, but the excessive use of fertilizers leads to contamination of soil and groundwater and reduce soil fertility. On the other hand, for marginal farmers in Bangladesh, the purchase of chemical fertilizers is difficult and expensive. So, biofertilizers can replace partially chemical fertilizers. Hence, there is a need to search for alternative strategies to improve soil health without causing damage to environment as well as soil. Therefore, biofertilizers are gaining importance as they are ecofriendly, non-hazardous and nontoxic products (Sharma *et al*., 2007). Biofertilizers include mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting microorganisms. Biofertilizers benefiting the crop production are Azotobacter, Azospirillum, blue green algae, Azolla, P-solubilizing microorganisms, mycorrhizae and sinorhizobium (Selvakumar *et al.,* 2009). Among the biofertilizers, Azotobacter represents the main group of heterotrophic, non-symbiotic, gram negative, free living nitrogen-fixing bacteria. They are capable of fixing an average 20 kg N ha^{-1} yr^{-1}. The genus Azotobacter includes 6 species, with A. chroococcum most commonly inhabiting in various soils all over the world (Mahato *et al*., 2009). Besides nitrogen fixation, Azotobacter also produces thiamin, riboflavin, indole acetic acid and gibberellins. When Azotobacter is applied to seeds, seed germination is improved to a considerable extent, so also it controls plant diseases due to above substances produced by Azotobacter. The exact mode of action by which Azotobacteria enhances plant growth is not yet fully understood. Three possible mechanisms have been proposed: N_2 fixation; delivering combined nitrogen to the plant; the production of phytohormone-like substances that alter plant growth and morphology, and bacterial nitrate reduction, which increases nitrogen accumulation in inoculated plants (Mrkovacki and and Milic, 2001). In Bangladesh very limited studies were carried out on the effect of Azotobacter on crop growth and productivity.

Onion (*Allium cepa* L.) is important spices crop of Bangladesh. It is number one spices crop in Banladesh. It occupies about 426157 acres of land and produces about1802868 metric ton in the year 2018-2019 (BBS 2019). It also contributes significantly to the human diet and has a therapeutic property. The indiscriminate use of chemicals resulted in degradation of soil health, erosion, and loss of organic matter, nitrate pollution and also health hazard for human beings. (Yang *et al*., 2004).

Onion is a source of ascorbic acid and dietary fiber too. It also possesses a high content of flavanoids (mainly quercetin and its conjugates) and sulpher compounds (i.e. thiosulphinates), both of which have a high level of antioxidant activity (Griffiths *et al*., 2002). The indiscriminate use of chemicals resulted in degradation of soil health, erosion, and loss of organic matter, nitrate pollution and also health hazard for human beings. So, application of biofertilizers like Azotobacter results in increased mineral and water uptake, root development, vegetative growth and nitrogen fixation also stimulate production of growth promoting substance like Vitamin-B complex, Indole acetic acid (IAA) and Gibberellic acids etc. They liberate growth promoting substances and vitamins and help to maintain soil fertility (Pratap, 2012). Sevral studies shows that presence of Azotobacter spp. in soils has beneficial effects on plants, i.e, soil physico-chemical and microbiological properties. So, keeping in view the above facts the present experiment was undertaken to find out the most effective dose of Azotobacter for growth and yield of onion (*Allium cepa* L.).

Materials and Methods

Seedling collection and Field preparation

The experiment was carried out during Rabi season of 2021-2022 in the research field of Soil Science Division, BARI, Joydebpur, Gazipur. Seedlings of onion (BARI piaj-4) were raised on the net house of Soil Science Division, BARI, Joydebpur, Gazipur. The silted (sandy clay loam) soils were collected from the bank of Turag river at Kodda, Gazipur was used in the seed bed. Cowdung was used at 1 kg m^{-2} in the seed bed. The pH of cowdung was 6.7 and the nutrient contents were: organic matter 14.1%, N 0.8%, P 1.26%, K 0.88%, Ca 1.55%, Mg 0.82%, S 0.62%, Fe 0.25% and Mn 0.112%. The physical and chemical properties of the soil are presented in Table 1. The soil contained 158 AM (100^{-1} g soil) spores of indigenous mixed AM fungal species and each gram of soil contain population of rhizobium, azotobacter and phosphate solubilizing bacteria (PSB) were 5.5×10^4, 5.6×10^4 and 3.0×10^5, respectively. The experiment was conducted under unsterilized soil condition.

Table 1. Initial fertility status of the experimental plot

Soil Properties	Texture	pH	OC (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
				meq 100 g^{-1}				µg g^{-1}						
Result	Silty clay loam	6.60	0.74	8.12	1.2	0.21	0.06	5.0	12	0.4	2.4	69	7.9	3.1
Critical level	-	-	-	2.0	0.5	0.12	-	10	10	0.2	0.2	4.0	1.0	0.60

Soil analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by Wet Oxidation Method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method (Jackson, 1962). Calcium, K and Mg were determined by NH_4OAc extraction method (Black, 1965). Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils) according to Olsen *et al.* (1954). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$.

Fertilizer application

Chemical fertilizers @ 100 kg N ha^{-1} from urea, 55 kg P ha^{-1} from TSP, 75 kg K ha^{-1} from MoP, 22 kg S ha^{-1} from gypsum, 5 kg Zn ha^{-1} from $ZnSO_4$ for onion were applied (FRG, 2018). All other fertilizers except urea-N and $^2/_3$rd of MoP was applied as basal during final land preparation and urea-N were applied at three equal splits and $^2/_3$rd of MoP was applied as two equal splits.

Preparation of azotobacter inoculum

Azotobacter inoculum was prepared following standard microbiological procedure. Azotobzcter strains were inoculated on Jensen's N-free medium (Jensen 1951) slants. From the slants, sub culture was done by N-free Jensen's medium (Jensen 1951). From the sub culture plate, pure culture of Azotobacter was inoculated in conical flux containing Jensen's N-free broth (Jensen 1951). The broth was shaking in a horizontal shaker for 3-4 days for sufficient growth of bacterial cell. Bacterial growth was determined by plate count dilution method. After proper growth of azotobacter, the broth was used as Azotobacter inoculum. The seedling of onion was soaked in to the liquid inoculum for 2-3 hours. After soaking the seedling, the seedlings were transplanted in the field.

Preparation of azotobacter inoculum

Soil based arbuscular mycorrhizal (AM) inoculum and infected root pieces of the host plant were used at the rate of 1 kg soil m^{-2} in seedbed for producing onion seedlings. A layer of AM inoculum was firstly placed in each bed and it was covered with a thin soil layer of 1 cm. Seeds were sown in seed bed and AM infected seedlings were transplanted in the field.

Design of experiment and treatments

The experiment was designed in RCBD with 6 treatments and 4 replications. There were six treatments viz. T_1: 100% NPKSZn of RD (Recommended Dose), T_2: 80% N + *Azotobacter inoculum,* T_3 : 80% P + *PSB inoculum,* T_4 : 50% P + *AM inoculum,* T_5 : 80% NP +*Azotobacter + PSB,* T_6 : 80% N+ 50% P +*Azot.,* T_7 : 50% P + *AM+PSB,* T_8 : 80% N+ 50% P + Azot. +*AM+PSB and* T_9: Control. A blanket dose of KSZn was applied for each treatment.

Seedling transplanting

Healthy seedlings of onion (BARI piaj-4) were collected from the seed bed, net house of soil science division, BARI, Joydebpur, Gazipur. Six square meter (2m × 3m) plot was prepared in the experimental field of soil science division, BARI, Joydebpur, Gazipur. After preparing the experimental plot, seedlings were transplanted at a spacing of 25 cm × 10 cm. Onion seedlings were transplanted on 5th December 2021.

Intercultural operations

Intercultural operations like watering, weeding, insect pests' managements etc, were done when necessary. Top dressing of urea and MoP fertilizer were done as per schedule.

Crop harvest

Five plants of onion from each plot were collected after 45 days after transplanting for recording some growth parameter like plant height, number of leaves $plant^{-1}$, shoot weight and root weight. Onion were harvested on 25th March 2022. Some parameters like plant height, individual bulb weight, bulb length, bulb diameter and bulb yield $plot^{-1}$ were recorded.

Statistical analysis

Data were statistically analyzed using Analysis of Variance (ANOVA) following CropStat package while the all pair comparisons were done by Statistix 10.

Results and Discussion

Effect of different biofertilizers on yield and yield attributes of Onion

Effect of different doses of nitrogen & P and different biofertilizers on yield and yield attributes of onion have been shown in Table 2. Significant differences were found in case of plant height, root length, number of leaves plant^{-1} and collar diameter among the treatment combinations.

Table 2. Effect of different biofertilizers on yield and yield attributes of onion

Treatment	Plant height	Root length	No. of leaves (plant^{-1})	Collar Diameter (mm)
	(cm)			
T_1 : 100% NPKSZn of RD (Recommended Dose)	54.80a	6.32	8.50abc	12.08a
T_2 : 80% N + *Azotobacter inoculum*	53.05a	5.80	8.50abc	12.18a
T_3 : 80% P + *PSB inoculum*	50.85a	5.86	8.25bc	13.20a
T_4 : 50% P + *AM inoculum*	52.30a	6.74	9.50a	12.90a
T_5 : 80% NP +*Azotobacter* + *PSB*	53.30a	5.06	8.75ab	12.70a
T_6 : 80% N+ 50% P +*Azot.+AM*	51.30a	5.51	8.25bc	12.30a
T_7 : 50% P + *AM+PSB*	54.45a	5.92	9.00ab	13.08a
T_8 : 80% N+ 50% P + Azot. +*AM+PSB*	53.60a	6.04	9.50a	13.25a
T_9 : Control	46.40b	5.82	7.50c	9.75b
SE (±)	1.93	0.45	0.59	0.56
F test	**	ns	*	**
CV (%)	5.23	15.31	9.66	9.16

The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test Crop Stat and Statistix 10. **Significant P≤0.01, *significant P≤0.05, NS non-significant

The highest plant height 54.80 cm was observed in T_1 where 100% recommended dose of NPKSZn was used without biofertilizer inoculum which was statistically similar with all other treatments except control. The lowest plant height was recorded in control treatment. It suggests that plant height was significantly influenced due to nitrogen and phosphorus amendment with different biofertilizer inoculation (Balemi *et al*., 2007). The highest root length was recorded in T_8 treated plot where 80% N+ 50% P + Azot. +*AM+PSB* was used. Number of leaves plant^{-1} and collar diameter were also influenced by the use of biofertilizerr inoculum with reduced doses of recommended nitrogen and phosphorus. Statistically identical root length, number of leaves plant^{-1} and collar diameter were produced by the treatment where 100% recommended dose of NPKSZn was used as well as the treatment where different types of biofertilizer inoculum were used with reduced doses of recommended N and P. Length of bulb, bulb diameter, individual bulb weight and bulb yield ha^{-1} was shown in Table 3.

Table 3. Effect of different biofertilizers on yield and yield attributes of onion

Treatment	Bulb length (mm)	Bulb diameter (mm)	Bulb wt (g $bulb^{-1}$)	Bulb yield (t ha^{-1})
T_1 : 100% NPKSZn of RD (Recommended Dose)	70.00a	51.30a	86.23a	22.29a
T_2 : 80% N + *Azotobacter inoculum*	71.78a	50.13a	76.24a	22.38a
T_3 : 80% P + *PSB inoculum*	70.48a	50.30a	80.54a	22.70a
T_4 : 50% P + *AM inoculum*	70.10a	49.68a	76.14a	20.92a
T_5 : 80% NP +*Azotobacter + PSB*	69.88a	50.28a	77.95a	20.16a
T_6 : 80% N+ 50% P +*Azot.+AM*	64.55ab	51.30a	77.64a	20.39a
T_7 : 50% P + *AM+PSB*	71.53a	51.73a	85.95a	23.77a
T_8 : 80% N+ 50% P + Azot. +*AM+PSB*	68.53a	49.20a	82.33a	21.14a
T_9 : Control	60.13b	41.63b	48.09b	15.22b
SE (±)	0.25	1.08	4.85	1.25
F test	**	**	**	**
CV (%)	7.30	9.16	12.65	11.95

The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. **Significant P≤0.01, *significant P≤0.05, NS non-significant

The maximum bulb length 71.78 mm was produced by the T_2 treatment where 80% N of Recommended dose + Azotobacter inoculum was used which was statistically similar all other treatments except control. The highest bulb diameter 51.73 mm was observed in T_7 where 50% P + *AM+PSB was* used which was statistically similar with other treatments except control. Similar result was recorded for bulb diameter by other researchers like Banjare *et al*., 2015, Yadav *et al*., 2015 and Bhandari *et al*., 2012.

The highest individual bulb weight 86.23g was recorded in T_1 treatment where 100% NPKSZN of Recommended dose was used, this result was statistically identical with T_2 : 80% N + Azotobacter inoculum, T_3 : 80% P + PSB inoculum, T_4 : 50% P + AM inoculum, T_5 : 80% NP +Azotobacter + PSB, T_6 : 80% N+ 50% P +Azot., T_7 : 50% P + AM+PSB, T_8 : 80% N+ 50% P + Azot. +AM+PSB where azotobacter, PSB and AM inoculum was used in combination with reduced dose of nitrogenand phosphorus fertilizer. The lowest individual bulb weight was recorded in T_9 control treatment. The highest bulb yield 23.77 t ha^{-1} was recorded in T_7 (50% P + AM+PSB inoculum was used) treaments which was statistically similar with other treatment where different biofertilizres were used in combination with chemical N and P. The lowest bulb yield 15.23 t ha^{-1} was recoded in T_9 control treatment. Similar results were observed in last year. The present study was supported by other researchers like Pratap *et al*., 2012 and Balemi *et al*., 2007.

Effect of different doses of nitrogen and azotobacter on microbial population of postharvest soil of onion

Effects of different doses of nitrogen and azotobacter on microbial population of postharvest soils of onion have been shown in Table 4. From this table, it was revealed that the use of azotobacter inoculum along with chemical fertilizers improve the micobial population in soil specially azotobacter and phosphate solubilizing bacteria.

Table 4. Effect of different doses of nitrogen and azotobacter on microbial population of postharvest soil of onion

Treatment	Population (cfu/g soil)		
	Rhizobium	PSB	*Azotobacter*
T_1 : 100% NPKSZn of RD (Recommended Dose)	4.5×10^3	6.5×10^5	3.5×10^5
T_2 : 80% N + *Azotobacter inoculum*	4.0×10^4	2.5×10^5	2.5×10^5
T_3 : 80% P + *PSB inoculum*	5.2×10^4	3.5×10^5	3.0×10^5
T_4 : 50% P + *AM inoculum*	3.0×10^3	2.8×10^5	5.8×10^4
T_5 : 80% NP +*Azotobacter + PSB*	6.0×10^3	2.5×10^5	6.0×10^5
T_6 : 80% N+ 50% P +*Azot.+AM*	2.5×10^3	4.0×10^5	1.5×10^5
T_7 : 50% P + *AM+PSB*	5.0×10^3	5.5×10^5	5.8×10^5
T_8 : 80% N+ 50% P + Azot. +*AM+PSB*	6.8×10^3	4.5×10^5	6.2×10^5
T_9 : Control	5.5×10^3	3.8×10^5	1.5×10^5

Conclusion

The use of different biofertilizer inoculum in combination with nitrogenous and phosphatic fertilizer had positive effect on growth and yield attributes of onion. It also helps to reduce the use the chemical nitrogenous and phosphatic fertilizers which save money and maintain safe soil environment. It should be continued for confirming the results.

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EFFECT OF ARBUSCULAR MYCORRHIZAL FUNGI AND PHOSPHORUS ON BROCCOLI

M.E. ALI, F. ALAM, M.F.A. ANIK, M. RAHMAN AND H.M. NASER

Abstract

A field experiment was conducted at Central Farm, Soil Science Division, Bangladesh Agricultural Research Institute, during rabi season of 2021-2022 with the objectives to study the effect of combined use of arbuscular mycorrhizal fungi and phosphorus on growth and yield of broccoli, and to reduce to use of P-fertilizer under field condition. The experiment was designed in factorial RCBD with six treatments and four replications. The cauliflower variety was snow white as test crop. Soil based arbuscular mycorrhizal (AM) inoculum and infected root pieces of the host plant were used at the rate of 1 kg soil m^{-2} in seedbed for producing broccoli seedlings. The treatment combinations were: T_1P_1U: 0% P × without AM, T_2P_2U: 50% P × without AM, T_3P_3U: 100% P × without AM, T_4P_1AM: 0% P × with AM, T_5P_2AM: 50% P × with AM, T_6P_3AM: 100% P × with AM. Mycorrhizal inoculation significantly increased root length (cm), root colonization (%), spore population (100 g^{-1} soil) and curd yield (t ha^{-1}). Collar diameter, Plant height (cm), Plant weight (kg), number of leaf ($plant^{-1}$), curd height (cm) and curd circumstances (cm) were non-significant. The plant that received AM in nursery bed produced higher curd yield than without AM in all phosphorus levels of broccoli. The highest broccoli curd yield 29.40 t ha^{-1} was recorded in 50% P with AM (AM was used in nursery bed) in Madhupur Tract soil (AEZ 28). The result indicates that inoculation of AM used in nursery bed can save 50% P in the field. The plant which did not receive AM in nursery bed produced lower yield in all phosphorus levels in the field.

Introduction

Arbuscular mycorrhizal fungi (AMF) are known to improve plant growth mainly by improving plant uptake of nutrient, particularly the immobile nutrient. Under low soil P concentrations, most plant species are developed on a symbiotic association with arbuscular mycorrhizal fungi for the acquisition of P (Smith and Read, 1997). AMF can increase plant growth by enhancing uptake of mineral nutrients from soil, particularly diffusion limited ions such as phosphorus (Bryla and Koide, 1990). Arbuscular mycorrhizal fungi (AMF) are pervasive and they are found in 80% of vascular plant families in existence today and fungi belonging to the order glomeromycota. AMF have been shown to promote plant growth (Hameed *et al*., 2014; Hashem *et al*., 2014), enhance nutrient uptake such as nitrogen, phosphorus, magnesium, and micronutrients from the soil (Evelin *et al*., 2012), improve soil structure, and also able to enhance plant tolerance under different stresses (Wu *et al*., 2014). Although soil P status is recognized as one of the primary factors affecting AM, only a few studies have been reported on the long-term effects of cumulative P fertilization on AM. Even fewer studies have appeared on the long-term impact on AM effectiveness in the field (Thingstrup *et al*., 1998).

The Broccoli variety snow white most is widely cultivated as vegetables in Bangladesh. Availability of phosphorus to plant roots is limited both acidic and alkaline soils, mainly due to formation of sparingly soluble phosphate compounds with AI and Fe in acidic and Ca in alkaline soils (Marschner. 1994). Every year, large amounts of phosphorus fertilizers are applied to soils for crop production globally, and only 10 to 20 percent of the applied phosphorus fertilizers can be absorbed by plant (Holford, 1997). As such seedlings of vegetables, spices and legumes crops might be grown better with mycorrhiza studied under seed bed which reduced the dose of P fertilizer. For this reason, this study was undertaken to know the effect of AM inoculation and phosphorus on growth and yield of broccoli and to reduce the use of P-fertilizer under field condition.

Materials and Methods

A field experiment was carried out for broccoli at Central Farm, Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur (24.00º N latitude, 90.25º E longitude and 8.4 m elevation) during rabi season of 2021-2022. The experiment was laid out in Factorial Randomized Complete Block Design (RCBD) with four replications. There were six treatment combinations viz.

T_1P_1U: 0% P × without AM, T_2P_2U: 50% P × without AM, T_3P_3U: 100% P × without AM, T_4P_1AM: 0% P × with AM, T_5P_2AM: 50% P × with AM, T_6P_3AM: 100% P × with AM. The tested crop was broccoli (cv. Green Crown). The unit plots measured 3 m × 2 m in size. Soil based arbuscular mycorrhizal (AM) inoculum and infected root pieces of the host plant were used at the rate of 1 kg soil m^{-2} in seedbed for producing broccoli seedlings. A layer of AM inoculum was firstly placed in each bed and it was covered with a thin soil layer of 1 cm. Seeds were sown in seed bed and transplanted after 30 days in field. The physical and chemical properties of the soil of seed bed and initial soil samples at a depth of 0-15 cm from the experimental fields were collected and analyzed following standard methods and presented in Table 1.

Table 1. Initial fertility status of the soil samples of seed bed and experimental field of Soil Science Division, BARI, Gazipur

Soil properties	Texture	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
				meq 100 g^{-1}				µg g^{-1}						
Seed bed	Sandy clay loam	6.7	0.82	7.2	2.5	0.19	0.012	25	10	0.15	1.8	82	4.1	0.94
Expt. field	Sandy clay loam	6.60	0.74	8.12	1.2	0.21	0.06	5.0	12	0.4	2.4	69	7.9	3.1
Critical level	-	-	-	2.0	0.5	0.12	-	10	10	0.2	0.2	4.0	1.0	0.6

Methods of chemical analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by Wet Oxidation Method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method (Jackson, 1962). Calcium, K and Mg were determined by NH_4OAc extraction method (Black, 1965). Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils) according to Olsen *et al.* (1954). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$.

Nitrogen, phosphorus, potassium, sulphur, zinc and boron were used in the form of urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. Recommended fertilizer dose (BARC, 2012) for cauliflower (220 kg N, 50 kg P, 60 kg K, 24 kg S, 2.5 kg Zn, 1 kg B ha^{-1}) were used. Phosphorus was used in three levels (0%, 50% and 100%). All K, S, Zn, B and 1/3rd amount of urea-N were applied at the time of final land preparation and the remaining 2/3rd amount of urea N were applied in two equal installments at 25 and 45 days of transplanting. All the intercultural operations such as irrigation, sticking, weeding, insect control etc. were done as and when necessary. Data on yield and yield components were recorded at maturity.

Statistical analyses were conducted using standard statistical procedures (Gomez and Gomez 1984) implemented in Statistix 10. The data were examined by analysis of variance (ANOVA). Differences between the treatments were determined by ANOVA, and Fisher's protected least significant difference (LSD) was calculated at the 0.05 probability level for treatment mean comparisons.

Results and Discussion

Effect of AM inoculation:

The effects of mycorrhizal inoculation on collar diameter, root weight, plant height, root length, whole plant weight, spore population and root colonization have been presented in Tables 2; and number of unfolded leaves, curd height, curd circumstance, and curd yield of cauliflower have been presented in Tables 3. Mycorrhizal inoculated cauliflower plant significantly increased plant height, root length, whole plant weight, spore population, root colonization and curd yield, and other parameters were non-significant. The highest plant height (58.50 cm), root length (18.38 cm), whole plant weight (1.58 kg), spore population (71.3 spore per 100g soil), root colonization (47.8 %), and curd yield (27.47 t ha^{-1}) were recorded with mycorrhizal inoculated treatment which was differed from non-inoculated treatment, respectively. Curd height and curd circumstance were also recorded in non-significant in all treatments. Such increase the above parameters of the crop might be due to production of significantly higher AM root colonization and AM spore population enhancing higher P uptake.

Table 2. Mycorrhizal activity on growth parameters and root inoculation of broccoli 2021-2022

Mycorrhizal inoculant	Plant height	Root length	Whole plant weight	Spore population	Root colonization
	(cm)		(kg)	(100 g^{-1} soil)	(%)
Uninoculated	56.67b	18.20	1.57	47.3b	13.3b
Inoculated	58.50a	18.38	1.58	71.3a	47.8a
SE (±)	0.76	0.50	0.04	2.88	2.42
F test	*	NS	NS	*	**

Means followed by different letter are significantly different at 5% level by LSD.
**Significant at P≤0.001, *Significant at P≤0.05, NS-Non significant

Table 3. Mycorrhizal activity on yield parameters of broccoli 2021-2022

Mycorrhizal inoculant	No. of unfolded leaves $plant^{-1}$	Curd height (cm)	Circumference (cm)	Curd yield (t ha^{-1})	Yield increase over control
Uninoculated	24.57b	17.23b	47.27	24.87b	-
Inoculated	27.67	18.55a	49.80	27.47a	10.45
SE (±)	2.02	1.22	1.25	0.68	-
F test	NS	NS	NS	**	-

Means followed by different letter are significantly different at 5% level by LSD.
*Significant at P≤0.05, NS-Non significant

Effect of phosphorus

Performance of different phosphorus levels on plant height, root length, whole plant weight, spore population and root colonization have been presented in Table 4, and number of number of leaves, curd height, curd circumstance, and curd yield of broccoli have been presented in Table 5. Phosphorus application significant increased root colonization and curd height, curd yield, and other parameters were non-significant. The highest root colonization (33.3 %), curd height (18.08 cm), and curd yield (27.70 t ha^{-1}) were recorded with 100% P treatment which was identical with 50% P but differed from 0% P treatment, respectively. Collar diameter, Plant height, root length, unfolded leaves, and curd circumstance were also recorded in non-significant in all treatments.

Table 4. Effect of phosphorus on growth parameter and root inoculation of broccoli 2021-2022

Phosphorus level	Plant height	Root length	Whole plant weight	Spore population	Root colonization
	(cm)		(kg)	($100\ g^{-1}$ soil)	(%)
0% P	54.40b	17.90	1.56	56.8	26.7b
50% P	59.90a	18.73	1.58	60.3	31.7ab
100% P	58.45a	18.25	1.59	60.8	33.3a
SE (±)	0.93	0.50	0.05	3.13	2.26
F test	**	NS	NS	NS	*

Means followed by different letter are significantly different at 5% level by LSD. NS-Non significant
**Significant at P≤0.01, *Significant at P≤0.05, NS-Non significant

Table 5. Effect of phosphorus on yield parameters of broccoli 2021-2022

Phosphorus level	No. of unfolded leaves $plant^{-1}$	Curd height	Circumference	Curd yield	Yield increase over control
		(cm)		($t\ ha^{-1}$)	
0% P	25.60	17.58	46.83	24.70b	-
50% P	25.48	18.03	49.38	26.10ab	5.67
100% P	27.28	18.08	49.40	27.70a	12.15
SE (±)	1.42	0.53	1.53	1.83	-
F test	NS	NS	NS	**	-

Means followed by different letter are significantly different at 5% level by LSD.
*Significant at P≤0.05, NS-Non significant

Interaction effect of mycorrhizal inoculation and phosphorus:

Interaction effect of phosphorus and mycorrhizal inoculants on collar diameter, root weight, plant height, root length, whole plant weight, spore population and root colonization have been presented in Table 6, and number of unfolded leaves, curd height, curd circumstance, whole plant weight, and curd yield of cauliflower have been presented in Table 7. Interaction effect of mycorrhizal inoculation and phosphorus were significant in root length (19.00 cm), spore population (74.2 spore per 100g soil), root colonization (53.3 %) and non-significant in plant height, whole plant weight, number of leaves, curd height and curd circumference in all the tested parameters. The heighest broccoli curd yield (29.40 t ha^{-}) were recorded in mycorrhizal inoculation plant with using phosphorus. This indicates that mycorrhizal inoculation was effective to all the phosphorus fertilizer levels. The plant which received AM in nursery bed produced higher yield than without AM in all phosphorus levels at field soil. The highest broccoli curd yield 29.40 t ha^{-1} was recorded in 50% P with AM which was 24.58 % higher over control in year of 2022.

Table 6. Interaction effect of AM and P on growth parameters of broccoli 2021-2022

Treatment	Plant height	Root length	Whole plant weight	Spore population	Root colonization
	(cm)		(kg)	($100\ g^{-1}$ soil)	(%)
T_1: 0%P x without AM	52.50	17.85	1.52	45.8	11.7
T_2: 50% P x without AM	59.50	18.45	1.62	48.6	13.3
T_3: 100%Px without AM	58.00	18.85	1.59	47.5	15.0
T_4: 0% P x with AM	56.30	17.95	1.55	67.8	41.7
T_5: 50% P x with AM	60.30	19.00	1.61	71.9	53.3
T_6: 100%P x with AM	58.90	17.65	1.60	74.2	48.3
SE (±)	1.32	0.71	0.07	4.54	3.46
Sig.	NS	NS	NS	**	**
CV	5.48	5.48	6.26	9.38	13.9

Means followed by different letter are significantly different at 5% level by LSD.
***Significant at P≤0.001, **Significant at P≤0.01, *Significant at P≤0.05, NS-Non significant

Table 7. Interaction effect of AM and P on yield components of broccoli 2021-2022

Treatment	No. of leaves plant^{-1}	Curd height (cm)	Circumference (cm)	Curd yield (t ha^{-1})	Yield increase over control
T_1: 0% P × without AM	24.35	17.05	46.70	23.60	-
T_2: 50% P × without AM	25.05	17.35	47.15	25.00	5.93
T_3: 100%P × without AM	24.30	17.37	47.95	26.00	10.17
T_4: 0% P × with AM	26.85	18.10	46.95	25.80	9.22
T_5: 50% P × with AM	25.90	18.70	51.60	29.40	24.58
T_6: 100%P × with AM	30.25	18.85	50.85	27.20	15.26
SE (±)	2.01	0.43	2.17	2.17	-
Sig.	NS	NS	NS	NS	-
CV	10.91	5.93	6.32	7.12	-

Means followed by different letter are significantly different at 5% level by LSD.
**Significant at P≤0.01, *Significant at P≤0.05, NS-Non significant

Economic analysis

The benefit cost ratio for inoculum was higher. The cost of fertilizers, and AM inoculum varied but other costs were constant (Table 8). The AM inoculum with 50% P was more profitable based on benefit cost ratio. The highest benefit cost ratio BCR (3.21) was achieved with T_5 treatment, indicating economic variability of inoculation in cauliflower. The second highest BCR (1.55) was observed with T_4 followed by T_6, T_2 and T_3.

Table 8. The benefit cost ratio analysis of broccoli

Treatment	Curd yield	Variable cost	Gross return	Net return	Net return over control	Benefit cost ratio
	(t ha^{-1})	(Tk. ha^{-1})				
T_1	23.6	13896	236000	222104	-	-
T_2	25	16896	250000	233104	11000	0.65
T_3	26	19896	260000	240104	18000	0.90
T_4	25.8	14096	258000	243904	21800	1.55
T_5	29.4	17096	294000	276904	54800	3.21
T_6	27.2	20096	272000	251904	29800	1.48

Note: Urea=16 Tk. kg^{-1}, TSP= 24 Tk. kg^{-1}, MoP= 15 Tk. kg^{-1}, Gypsum= 12 Tk. kg^{-1}, ZnSO4= 145 Tk. kg^{-1}, Boric acid=280 Tk. kg^{-1}, Inoculum= 100 Tk. kg^{-1}, Broccoli= 10 Tk. kg^{-1}.

Conclusion

The highest broccoli curd yield (29.4 t ha^{-1}) was recorded in 50% P with AM (AM was used in nursery bed). The result indicates that inoculation of AM used in nursery bed can save 50% P in the field. The AM inoculum with 50% P was more profitable based on benefit cost ratio. The plant which did not receive AM in nursery bed produced lower yield in all phosphorus levels in the field.

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EFFECT OF ARBUSCULAR MYCORRHIZAL FUNGI, BIOCHAR AND VERMICOMPOST ON MAIZE (Zey *mays*) IN SALINE SOIL

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Abstract

The present study was carried out to evaluate the effect of indigenous Arbuscular Mycorrhizal Fungi (AMF), biochar, and vermicompost on growth parameters, biomass, colonization, and yield characters of maize in 8 dS m^{-1} saline soil. The experiment was carried out under pot culture conditions in the net house of Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur in 2022. The experiment was designed in CRD with eight treatments and four replications. The ten treatments were T_1 : Control, T_2 : Arbuscular mycorrhiza (AM), T_3 : Biochar @10 t ha^{-1}, T_4 : Vermicompost@ 3 t ha^{-1},T_5 : AM + Biochar @ 5 t ha^{-1}, T_6 : AM + Biochar @ 10 t ha^{-1}, T_7 : AM + Vermicompost @ 3 t ha^{-1}, T_8 : AM + Vermicompost @ 6 t ha^{-1}, T_9 : Biochar @ 5 t ha^{-1} + Vermicompost @ 3 t ha^{-1} and T_{10} : AM + Biochar @ 5 t ha^{-1} + Vermicompost @ 3 t ha^{-1}. The result showed that AM + Vermicompost @ 3 t ha-1 treatment produced the highest growth parameters, biomass, colonization, and yield characteristics of maize in 8 dS m-1 saline soil, and the control treatment produced the lowest growth parameters, biomass, colonization, and yield characters of maize in saline soil. It was noticed that AM + Vermicompost @ 3 t ha-1 treatment (T7) produced the highest kernel yield (101.25 g pot-1, 91.94% higher over control) of maize which was significantly different from the rest of the treatments. Therefore, the combination mentioned above could sustain soil health, and ensure better growth and productivity in a saline environment compared to the other mixes.

Introduction

Soil salinity is a land degradation problem and globally results in a more significant loss in agricultural productivity. With the rise in sea level due to global warming, the area coverage of salt-affected soils is rising. Out of 2.86 million hectares, around 1.06 million ha of land in Bangladesh's southern coastal region is salt-affected (SRDI 2010).

To resolve this rising concern, we underscore the use of biological soil amendments such as arbuscular mycorrhizal fungi, biochar, and vermicompost at different rates. Arbuscular mycorrhizal fungi are pervasive and found in 80% of vascular plant families in existence today and fungi belonging to the order glomeromycota. Plants inoculated with mycorrhiza have been reported to improve plant growth and yield under salinity or NaCl stress conditions, such as Ocimum basilicum (Ashoori et al., 2015) and Lens culinaris (Rahman et al., 2017). Biochar is a porous, fine-grained substance similar to charcoal and decomposed much more slowly than other organic matter in the soil. Although biochar has little plant nutrient content, its high surface area and porous structure increase the soil surface area, provide a habitat for beneficial soil microorganisms, aid in water retention, and reduce leaching out of nutrients. All of these functions increase the availability of nutrients to plants (Schahczenski, 2010). Vermicompost is a hummus-like substance formed when organic matter is broken down by the joint action of earthworms and microorganisms (Lazcano et al., 2008). Vermicompostare is highly porous, well-aerated, well-drained, and has good water holding capacity. They also contain essential nutrients like nitrogen, phosphorous, and potassium. Increased biomass and plant height have been attributed to these properties of vermicomposts (Darzi et al., 2012).

However, maize is an important cereal crop in Bangladesh, and we can’t deny the usefulness of the horizontal expansion of this vital crop. There is no evidence of the combined use of AM fungi, biochar, and vermicompost in saline soil reclamation using test crop maize. So, we hypothesize that using AM fungi, biochar, and vermicompost can improve maize yield in saline conditions. Considering the above information, the present investigation was carried out to evaluate the effect of indigenous Arbuscular Mycorrhizal Fungi (AMF), biochar, and vermicompost on nodulation, colonization, and yield character of maize in 8 dS m^{-1} saline soil.

Materials and Methods

The experiment was carried out during Rabi and Kharif season from January, 2022 to June, 2022 in the net house of Soil Science Division, BARI, Joydebpur, Gazipur. Seeds of maize (BARI Hybrid Maize-9) were collected from Bangladesh Wheat and Maize Research Institute, Regional Office, Gazipur. The silted (sandy clay loam) soils were collected from the bank of Turag river at Kodda, Gazipur mixed with cowdung at 5:1 ratio and was used as the potting media. Each pot (28 cm in diameter and 23 cm in height) was filled with approximately 8-kg soil leaving upper 3 inches of pot was vacant to facilitate watering. The physical and chemical properties of the soil and cowdung are presented in Table 1. Required concentrations of salinity were prepared according to New South Wales (NSW), Australia and applied three times during the experimentation period.

Table 1. Initial fertility status of the soil and cowdung used in the investigational pot

Samples	Texture	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
				meq 100 g^{-1}				µg g^{-1}						
Soil	Sandy clay loam	7.1	0.51	7.2	2.5	0.11	0.026	9.9	21.1	0.22	1.8	15	1.1	0.38
Cowdung	-	6.7	14.1	1.55	0.82	0.88	0.84	1.26	0.62	0.02	0.01	0.25	0.11	0.02
Critical level	-	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4.0	1.0	0.60

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by Wet Oxidation Method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method (Jackson, 1962). Calcium, K and Mg were determined by NH_4OAc extraction method (Black, 1965). Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils) according to Olsen *et al.* (1954). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$. Chemical fertilizers were applied as a soil test basis according to the method described in the fertilizer recommendation guide (BARC, 2018). All fertilizer except urea was applied as basal during final land preparation, and urea was applied as a top dressing in two equal splits after 25 and 45 days after sowing. Mycorrhiza, Biochar, and Vermicompost were collected from Soil Science Division, BARI, Gazipur, and applied as per the requirement described in the treatment. The chemical composition of biochar and nutrient status of vermicompost used in the investigational pot are presented in Table 2 and Table 3.

Table 2. Chemical composition of biochar used in the investigational pot

Carrier Materials	Content (%)							
	OC	Total N	Ca	Mg	K	P	S	Fe
Sawdust based biochar	91.50	1.08	3.85	1.59	1.16	0.55	0.21	0.14

Table 3. Nutrient status of vermicompost used in the investigational pot

Organic manure	pH	OC	N	P	K	Ca	Mg	S	B	Zn	C:N
		(%)									
Vermicompost	6.90	15.1	2.04	1.16	1.06	2.12	1.19	0.33	0.014	0.016	7.40:1

The experiment was designed in CRD with eight treatments and four replications. The ten treatments were T_1 : Control, T_2 : Arbuscular mycorrhiza (AM), T_3 : Biochar @10 t ha^{-1}, T_4 : Vermicompost@ 3 t ha^{-1},T_5 : AM + Biochar @ 5 t ha^{-1}, T_6 : AM + Biochar @ 10 t ha^{-1}, T_7 : AM + Vermicompost @ 3 t ha^{-1}, T_8 : AM + Vermicompost @ 6 t ha^{-1}, T_9 : Biochar @ 5 t ha^{-1} +

Vermicompost @ 3 t ha^{-1} and T_{10} : AM + Biochar @ 5 t ha^{-1} + Vermicompost @ 3 t ha^{-1}. The treatments were sustained with 03 well established vigorous seedlings pot^{-1} and were harvested after maturity. Assessment of spore population was done following the Wet Sieving and Decanting Method (Gerdemann and Nicolson, 1963). All the AM spores were isolated from the extract with the help of a fine forcep into a watch glass with small quantity of water. The extract, with AM spores, was observed under stereomicroscope and the number of spores was counted. Spore numbers from the three replicates per samples were averaged and the result was expressed as number per 100 g of dry soil basis. The percentage of AM colonization was estimated by root slide technique (Read *et al*., 1976). A root segment was considered as positively infected, if it showed mycelium, vesicles and arbuscules or any other combination of these structural characteristics of AM colonization. The presence or absence of colonization in the root pieces was recorded and the percent colonization was calculated as dividing the number of AM positive segments by total number of segments scored and multiplied this value by 100. Data were statistically analyzed using Analysis of Variance (ANOVA) following Statistix 10 package.

Results and Discussion

Effect on growth parameters, biomass, colonization and spore population of maize

The effects of Arbuscular Mycorrhizal Fungi (AMF), biochar, and vermicompost on growth parameters, biomass, colonization, and spore population of maize are presented in Table 4. Significant differences were found in all the parameters except leaf number plant.

The highest plant height (216.69 cm), leaf number (12.67 plant^{-1}), root fresh weight (117.50 g plant^{-1}), shoot fresh weight (161.83 g plant^{-1}), root oven dry weight (25.83 g plant^{-1}), shoot oven dry weight (79.72 g plant^{-1}), root colonization (53.33 %) and spore population (67.500, 100 g^{-1} soil) were observed in AM + Vermicompost @ 3 t ha^{-1} treatment. The lowest plant height (200.57 cm), leaf number (12.08 plant^{-1}), root fresh weight (85.25 g plant^{-1}), shoot fresh weight (130.00 g plant^{-1}), root oven dry weight (17.75 g plant^{-1}), shoot oven dry weight (57.68 g plant^{-1}), root colonization (03.34 %) and spore population (30.50, 100 g^{-1} soil) were observed in control treatment.

Table 4. Effect of Arbuscular Mycorrhizal Fungi (AMF), biochar and vermicompost on growth parameters, biomass, colonization and spore population of maize

Treatments	Plant height (cm)	Leaf number plant^{-1}	Fresh weight (g plant^{-1})		Oven dry weight (g plant^{-1})		Root colonization (%)	Spore population (100 g^{-1} soil)
			Root	Shoot	Root	Shoot		
T_1	200.57c	12.08	85.25b	130.00b	17.75e	57.68b	03.34d	30.50d
T_2	201.08c	12.67	88.50b	137.00b	23.25a-d	61.54b	50.84a	53.00c
T_3	215.08ab	12.67	89.33b	143.00b	23.67abc	62.17b	6.67d	37.00d
T_4	216.42a	12.67	117.08a	160.50a	25.25ab	79.47a	13.33c	38.00d
T_5	215.31a	12.67	84.58b	131.50b	20.08de	61.47b	43.34b	59.50abc
T_6	214.89ab	12.17	85.83b	130.83b	21.33cd	59.17b	48.34ab	66.50a
T_7	216.69a	12.67	117.50a	161.83a	25.83a	79.72a	53.33a	67.00a
T_8	214.23ab	12.25	114.42a	134.17b	25.00ab	63.83b	53.33a	57.50bc
T_9	205.30abc	12.58	90.58b	160.75a	21.83bcd	77.84a	16.67c	32.00d
T_{10}	202.46bc	12.33	85.83b	136.83b	20.83cde	61.44b	43.34b	62.50ab
SE (±)	4.42	0.20	5.93	4.81	1.23	3.44	2.26	2.87
F test	*	ns	**	**	**	**	**	**
CV (%)	4.20	3.13	12.36	6.75	10.98	10.36	13.60	11.38

T_1 : Control, T_2 : Arbuscular mycorrhiza (AM), T_3 : Biochar @ 10 t ha-1, T_4 : Vermicompost @ 3 t ha-1, T_5 : AM + Biochar @ 5 t ha-1, T_6 : AM + Biochar @ 10 t ha-1, T_7 : AM + Vermicompost @ 3 t ha-1, T_8 : AM + Vermicompost @ 6 t ha-1, T_9 : Biochar @ 5 t ha-1 + Vermicompost @ 3 t ha-1 and T_{10} : AM + Biochar @ 5 t ha-1 + Vermicompost @ 3 t ha-1. The values represent means of 04 replicates. Different letters within each column indicate significant differences between treatments. Test Statistix 10. **Significant $P \leq 0.01$, *Significant $P \leq 0.05$, ns non significant.

Effect on yield and yield contributing characters of maize

Results on the effect of Arbuscular Mycorrhizal Fungi (AMF), biochar, and vermicompost on yield and yield contributing characters of maize are presented in Table 5. Significant differences were found in all the parameters except ear length and number of rows ear^{-1}.

The highest ear length (10.17 cm), number of rows (18.09 ear^{-1}), number of kernel (498.75 pot^{-1}), 50 kernel weight (11.96 g), ear weight (161.50 g pot^{-1}) and kernel yield (101.25 g pot^{-1}) were observed in AM + Vermicompost @ 3 t ha^{-1} treatment. The lowest ear length (9.52 cm), number of rows (14.08 ear^{-1}), number of kernel (220.00 pot^{-1}), 50 kernel weight (10.52 g), ear weight (96.25 g pot^{-1}) and kernel yield (52.75 g pot^{-1}) were observed in control treatment. It was noticed that AM + Vermicompost @ 3 t ha^{-1} treatment (T_7) produced the highest kernel yield (101.25 g pot^{-1}, 91.94% higher over control) of maize which was significantly different from the rest of the treatments.

Table 5. Effect of Arbuscular Mycorrhizal Fungi (AMF), biochar and vermicompost on yield and yield contributing characters of maize

Treatments	Ear length (cm)	No. of rows ear^{-1}	No. of kernel pot^{-1}	50 kernel weight (g)	Ear weight (g pot^{-1})	Kernel yield (g pot^{-1})	Kernel yield increase over control
T_1	9.52	14.08	220.00d	10.52c	96.25e	52.75d	-
T_2	9.71	15.95	254.00d	11.46abc	101.75cde	56.25d	6.64
T_3	9.85	16.67	346.25c	11.69ab	116.25bcd	75.75bc	43.60
T_4	9.88	17.33	362.50bc	11.94a	116.50bcd	78.00b	47.87
T_5	9.71	17.41	354.75bc	10.75bc	108.75cde	77.75b	47.39
T_6	9.67	16.66	366.50bc	10.75bc	120.00bc	86.00b	63.03
T_7	10.17	18.09	498.75a	11.96a	161.50a	101.25a	91.94
T_8	10.08	17.83	396.25b	10.98abc	128.50b	86.50b	63.98
T_9	9.75	16.30	342.75c	10.46c	103.50cde	64.25cd	21.80
T_{10}	9.83	15.08	257.00d	10.54c	98.00de	55.25d	4.74
SE (±)	0.38	1.08	16.78	0.40	6.52	4.29	-
F test	ns	ns	**	*	**	**	-
CV (%)	7.69	13.01	9.88	7.13	11.33	11.70	-

T_1 : Control, T_2 : Arbuscular mycorrhiza (AM), T_3 : Biochar @10 t ha^{-1}, T_4 : Vermicompost@ 3 t ha^{-1}, T_5 : AM + Biochar @ 5 t ha^{-1}, T_6 : AM + Biochar @ 10 t ha^{-1}, T_7 : AM + Vermicompost @ 3 t ha^{-1}, T_8 : AM + Vermicompost @ 6 t ha^{-1}, T_9 : Biochar @ 5 t ha^{-1} + Vermicompost @ 3 t ha^{-1} and T_{10} : AM + Biochar @ 5 t ha^{-1} + Vermicompost @ 3 t ha^{-1}. The values represent means of 04 replicates. Different letters within each column indicate significant differences between treatments. Test Statistix 10. **Significant $P \leq 0.01$, *Significant $P \leq 0.05$, ns non significant.

Conclusion

The result showed that AM + Vermicompost @ 3 t ha^{-1} treatment produced the highest growth parameters, biomass, colonization, and yield characteristics of maize in 8 dS m^{-1} saline soil, and the control treatment produced the lowest growth parameters, biomass, colonization, and yield characters of maize in saline soil. It was noticed that AM + Vermicompost @ 3 t ha^{-1} treatment (T_7) produced the highest kernel yield (101.25 g pot^{-1}, 91.94% higher over control) of maize which was significantly different from the rest of the treatments. Therefore, the combination mentioned above could sustain soil health, and ensure better growth and productivity in a saline environment compared to the other mixes.

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EFFECT OF ARBUSCULAR MYCORRHIZAL INOCULATION ON MAIZE AT DIFFERENT SALINITY LEVELS

M. RAHMAN, M.E. ALI, M.F.A. ANIK, AND H.M. NASER

Abstract

Arbuscular mycorrhizal (AM) fungi increase host plants' tolerance to the different salinity levels. A pot experiment was carried out in the net house of Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, in 2022. The study's objectives were to evaluate the potentiality of arbuscular mycorrhizal inoculation on the plant height, leaf number, root colonization, spore population, yield, and yield attributes of maize treated with different salinity levels. The experiment was designed in factorial randomized completely block design with four replications. Five salinity treatments (0, 2, 4, 6 and 8 dSm^{-1}) possessed salinity levels as the first factor and the second factor consists of mycorrhizal and non-mycorrhizal treatments. Soil based mixed arbuscular mycorrhizal (AM) inoculum containing about approximate 252 ± 20 spores and infected root pieces of the host plant was used pot^{-1}. With increasing salinity concentration plant height, leaf number, root colonization, spore population, yield and yield attributes decreased significantly. It was observed that 0 dSm^{-1} + AM treatment produced the highest ear weight (101.75 g pot^{-1}) and kernel yield (58.50 g pot^{-1}) of maize. In contrast, 8 dSm^{-1} treatments produced the lowest ear weight (51.75 g pot^{-1}) and kernel yield (31.25 g pot^{-1}) of maize. The study indicates that mycorrhizal inoculation could reduce the harmful effects of salinity on the host plants, thus increasing plant survival and allowing the plants growth under extreme conditions.

Introduction

Soil salinity is one of the significant monstrous environmental hazards of the present world, including in Bangladesh, which affects significantly on agricultural production as well as procuring food security. Abiotic and biotic stresses hamper the production of our cultivated land at an alarming rate. Over 30% of the cultivable area of Bangladesh lies in the coastal and offshore zones. Out of 2.86 million hectares of coastal and offshore lands, about 1.05 million hectares are affected by varying salinity (SRDI, 2010).

Agriculture is the most important sector of Bangladesh's economy. Usually, 30-50% yield losses occur depending on the soil salinity. It is our challenge to feed this increasing population as the productive land is decreasing daily. Keeping this in mind, researchers are trying their best to find suitable techniques to combat these concerning problems, i.e., looking for an alternative to bring uncultivated land under cultivation. But these techniques seem very costly and unaffordable to underdeveloped countries. In contrast, microorganisms, especially arbuscular mycorrhizal, can potentially reduce the sodium and chloride toxicity in crops and could be a more cost-effective, environmentally friendly option available in a shorter time frame. Arbuscular mycorrhizal (AM) fungi are pervasive and found in 80% of vascular plant families today and fungi belonging to the order glomeromycota. AMF has been shown to promote plant growth (Hameed et al., 2014; Hashem et al., 2014), enhance nutrient uptakes such as nitrogen, phosphorus, magnesium, and micronutrients from the soil (Evelin et al., 2012), improve soil structure, and also able to enhance plant tolerance under different stresses such as drought and salinity (Wu et al., 2014), and protect host plants against pathogens (Sikes et al., 2009). Plants treated with AM fungi have been shown to enhance the growth and yield and maintain the osmotic and ionic balance to an average level so that plants will thrive well under these stress conditions (Hameed et al., 2014).

An ideal sustainable agricultural system maintains and improves human health, benefits producers and consumers both economically and spiritually, protects the environment, conserves the ecosystem, and produces enough food for an increasing world population. Plant-associated microorganisms, i.e., arbuscular mycorrhizal, can play an important role in conferring resistance to alleviating plant salinity stresses. On the other hand, maize is an important cereal crop in Bangladesh and an essential source of carbohydrates and animal food. Taking the current leads available, concerted future research is needed to appraise or sum up the present state of land areas affected by salinity. Therefore, the overall goal of the investigation was to evaluate the potential of arbuscular mycorrhizal inoculation on the plant height, leaf number, root colonization, spore population, yield, and yield attributes of maize treated with different salinity levels.

Materials and Methods

Seed collection and Soil preparation

The experiment was carried out during Rabi season from January, 2022 to June, 2022 in the net house of Soil Science Division, BARI, Joydebpur, Gazipur. Seeds of maize (BARI Hybrid Maize-9) were collected from Bangladesh Wheat and Maize Research Institute, Regional Office, Gazipur. The silted (sandy clay loam) soils were collected from the bank of Turag river at Kodda, Gazipur mixed with cowdung at 5:1 ratio and was used as the potting media. Each pot (28 cm in diameter and 23 cm in height) was filled with approximately 8-kg soil leaving upper 3 inches of pot was vacant to facilitate watering. The pH of cowdung was 6.7 and the nutrient contents were: organic matter 14.1%, N 0.8%, P 1.26%, K 0.88%, Ca 1.55%, Mg 0.82%, S 0.62%, Fe 0.25% and Mn 0.112%. The physical and chemical properties of the soil are presented in Table 1. The soil contained 14 AM (100^{-1} g soil) spores of indigenous mixed AM fungal species and the experiment was conducted under unsterilized soil condition.

Table 1. Initial fertility status of the soil and cowdung used in the investigational pot

Samples	Texture	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
				meq 100 g^{-1}				µg g^{-1}						
Soil	Sandy clay loam	7.1	0.51	7.2	2.5	0.11	0.026	9.9	21.1	0.22	1.8	15	1.1	0.38
Cowdung	-	6.7	14.1	1.55	0.82	0.88	0.84	1.26	0.62	0.02	0.01	0.25	0.11	0.02
Critical level	-	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4.0	1.0	0.60

Methods of chemical analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by Wet Oxidation Method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method (Jackson, 1962). Calcium, K and Mg were determined by NH_4OAc extraction method (Black, 1965). Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils) according to Olsen *et al.* (1954). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$.

Chemical fertilizers were applied as soil test basis according to the method describe in fertilizer recommendation guide (BARC, 2018). All fertilizer except urea was applied as basal during final land preparation, and urea was applied as a top dressing in two equal splits after 25 and 45 days after sowing.

Preparation of salinity solution and mycorrhizal inoculum

Different concentrations of salinity were prepared according to New South Walles (NSW) Department of Primary Industries 2005, Australia and applied three times during the experimentation period. Firstly, applied before planting of maize, next after 25 DAS and then after 35 DAS.

The arbuscular mycorrhizal inoculum was prepared from the roots and rhizosphere soils of Sorghum. Mycorrhizal species was originally isolated from different AEZ region, using the wet sieving and decanting method. The spores were left to multiply for 6 months on sorghum plants using unsterilized soil, collected from the same site, in the net house of Soil Science Division, BARI. Plants were irrigated with tap water as needed. A mixture of infected sorghum root and soil which contained spores was used as mycorrhizal inoculum. The soil-based AM fungal inoculum containing 150 g of rhizosphere soil (approximate 252 ± 20 spores/100 g soil) and infected sorghum root fragments with a minimum colonization level was inoculated to each mycorrhizal pot. The mycorrhizal inoculum was first placed in each pot at 3-5 cm depth and was covered with a thin soil layer of 1 cm immediately prior to the seed sowing of groundnut to facilitate fungal colonization of plant roots.

Experimental design

The experiment was designed in factorial RCBD with ten treatments combination and four replications. The ten (10) treatment combinations were: T_1: 0 dsm^{-1}, T_2: 0 dsm^{-1} + AM, T_3: 2 dsm^{-1} , T_4: 2 dsm^{-1} + AM, T_5: 4 dsm^{-1} , T_6: 4 dsm^{-1} + AM, T_7: 6 dsm^{-1}, T_8: 6 dsm^{-1} + AM, T_9: 8 dsm^{-1} and T_{10}: 8 dsm^{-1} + AM. Ten seeds were sown in each pot at 1 cm soil depth. The treatments were sustained with 03 well established vigorous seedlings pot^{-1} and were harvested after maturity.

Plant harvest

Maize was harvested after maturity and required parameters were measured.

Assessment of spore population density and root colonization

Assessment of spore population was done following the Wet Sieving and Decanting Method (Gerdemann and Nicolson, 1963). All the AM spores were isolated from the extract with the help of a fine forcep into a watch glass with small quantity of water. The extract, with AM spores, was observed under stereomicroscope and the number of spores was counted. Spore numbers from the three replicates per samples were averaged and the result was expressed as number per 100 g of dry soil basis. The percentage of AM colonization was estimated by root slide technique (Read *et al*., 1976). A root segment was considered as positively infected, if it showed mycelium, vesicles and arbuscules or any other combination of these structural characteristics of AM colonization. The presence or absence of colonization in the root pieces was recorded and the percent colonization was calculated as dividing the number of AM positive segments by total number of segments scored and multiplied this value by 100.

Statistical analysis

Data were statistically analyzed using Analysis of Variance (ANOVA) following Statistix 10 package.

Results and Discussion

Effect of AM inoculation

Results on the effect of mycorrhizal inoculation on plant height, leaf number, root colonization, spore population, yield and yield attributes are presented in Table 2 and Table 3. Mycorrhizal inoculation significantly increased plant height, leaf number, root colonization, spore population, yield and yield attributes of maize.

Table 2. Effect of AM on plant height, colonization and spore population of maize

Treatments	Plant height (cm)	Leaf number $plant^{-1}$	Root colonization (%)	Spore population (100 g^{-1} soil)
Without AM	172.82b	8.95b	26.00b	45.50b
With AM	194.65a	10.13a	57.60a	57.90a
SE (±)	7.17	0.28	1.57	2.43
F test	**	**	**	**

AM: Arbuscular mycorrhizal fungi. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. **Significant $P \leq 0.01$, NS non-significant

Table 3. Effect of AM on yield and yield attributes of maize

Treatments	Ear length (cm)	No. of rows ear^{-1}	No. of kernel pot^{-1}	50 kernel weight (g)	Ear weight	Kernel yield
					(g pot^{-1})	
Without AM	8.11a	14.25b	160.25b	10.74b	76.10b	42.25b
With AM	8.55a	15.57a	214.25a	11.64a	83.35a	48.45a
SE (±)	0.40	0.64	7.80	0.30	3.34	1.96
F test	*	*	**	*	*	**

AM: Arbuscular mycorrhizal fungi. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. **Significant P≤0.01, *significant P≤0.05, NS non-significant

Effect of salinity

Results on the effect of different salinity levels on maize are presented in Table 4 and Table 5. Significant differences were found in all the parameters. With increasing salinity concentration plant height, leaf number, root colonization, spore population, yield and yield attributes decreased significantly.

The highest plant height (231.95 cm), leaf number (12.42 plant^{-1}) root colonization (65.00%), spore population (57.75, 100 g^{-1} soil), ear length (10.00 cm), number of rows (17.15 ear^{-1}), number of kernel (243.88 pot^{-1}), 50-kernel weight (12.09 g), ear weight (99.00 g pot^{-1}) and kernel yield (56.50 g pot^{-1}) were observed in 0 dSm^{-1} treatment. The lowest plant height (133.05 cm), leaf number (7.17 plant^{-1}) root colonization (17.50%), spore population (46.25, 100 g^{-1} soil), ear length (06.50 cm), number of rows (12.19 ear^{-1}), number of kernel (140.50 pot^{-1}), 50-kernel weight (09.93 g), ear weight (55.50 g pot^{-1}) and kernel yield (33.50 g pot^{-1}) were observed in 8 dSm^{-1} treatment.

Table 4. Effect of salinity on plant height, colonization and spore population of maize

Effect of salinity	Plant height (cm)	Leaf number plant^{-1}	Root colonization (%)	Spore population (100 g^{-1} soil)
0 dSm-1	231.95a	12.42a	65.00a	57.75a
2 dSm-1	198.34b	10.75b	56.50b	54.75ab
4 dSm-1	185.85bc	9.38c	42.50c	51.50abc
6 dSm-1	169.48c	8.00d	27.50d	48.25bc
8 dSm-1	133.05d	7.17d	17.50e	46.25c
SE (±)	11.33	0.44	2.49	3.84
F test	**	**	**	*

AM: Arbuscular mycorrhizal fungi. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. **Significant P≤0.01, *significant P≤0.05

Table 5. Effect of salinity on yield and yield attributes of maize

Effect of salinity	Ear length (cm)	No. of rows ear^{-1}	No. of kernel pot^{-1}	50 kernel weight (g)	Ear weight	Kernel yield
					(g pot^{-1})	
0 dSm-1	10.00a	17.15a	243.88a	12.09a	99.00a	56.50a
2 dSm-1	9.06ab	16.00ab	199.88b	11.80a	89.25ab	50.13b
4 dSm-1	8.39bc	14.92b	186.75bc	11.32ab	82.88b	44.63bc
6 dSm-1	7.69cd	14.29b	165.25cd	10.81bc	72.00c	42.00c
8 dSm-1	6.50d	12.19c	140.50d	9.93c	55.50d	33.50d
SE (±)	0.64	1.01	12.33	0.47	5.27	3.09
F test	**	**	**	**	**	**

AM: Arbuscular mycorrhizal fungi. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. **Significant P≤0.01

Interaction effects of mycorrhizal inoculation and salinity levels

Results on the interaction effects of mycorrhizal inoculation and salinity levels on maize are presented in Table 6 and Table 7. Interaction effects of mycorrhizal inoculation and salinity levels of maize on plant height, leaf number, root colonization, spore population, yield and yield attributes were non-significant except root colonization. This indicates that mycorrhizal inoculation was equally effective to all the salinity levels in all the parameters. It was observed that 0 dSm^{-1} + AM treatment produced the highest ear weight (101.75 g pot^{-1}) and kernel yield (58.50 g pot^{-1}) of maize. In contrast, 8 dSm^{-1} treatments produced the lowest ear weight (51.75 g pot^{-1}) and kernel yield (31.25 g pot^{-1}) of maize.

Table 6. Interaction effect of AM and salinity levels on plant height, colonization and spore population of maize

Treatments	Plant height (cm)	Leaf number $plant^{-1}$	Root colonization (%)	Spore population (100 g^{-1} soil)
0 dSm-1	218.44	12.17	45.00	52.00
0 dSm-1 + AM	245.47	12.67	85.00	63.50
2 dSm-1	186.20	9.75	40.00	49.50
2 dSm-1 + AM	210.47	11.75	73.00	60.00
4 dSm-1	177.94	8.75	25.00	45.00
4 dSm-1 + AM	193.77	10.00	60.00	58.00
6 dSm-1	155.70	7.42	15.00	42.00
6 dSm-1 + AM	183.26	8.58	40.00	54.50
8 dSm-1	125.81	6.67	5.00	39.00
8 dSm-1 + AM	140.30	7.67	30.00	53.50
SE (±)	16.03	0.62	3.52	5.43
F test	ns	ns	**	ns
CV (%)	12.34	9.13	11.91	14.87

AM: Arbuscular mycorrhizal fungi. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. *significant P≤0.05, NS non-significant.

Table 7. Interaction effect of AM and salinity on yield and yield attributes of groundnut

Treatments	Ear length (cm)	No. of rows ear^{-1}	No. of kernel pot^{-1}	50 kernel weight (g)	Ear weight (g pot^{-1})	Kernel yield (g pot^{-1})
0 dSm-1	9.64	15.67	223.75	11.66	96.25	54.50
0 dSm-1 + AM	10.35	18.63	264.00	12.52	101.75	58.50
2 dSm-1	8.98	15.38	168.00	11.40	85.75	47.50
2 dSm-1 + AM	9.15	16.63	231.75	12.19	92.75	52.75
4 dSm-1	8.18	14.50	152.00	10.98	79.00	40.00
4 dSm-1 + AM	8.61	15.33	221.50	11.66	86.75	49.25
6 dSm-1	7.51	14.08	134.00	10.56	67.75	38.00
6 dSm-1 + AM	7.88	14.50	196.50	11.06	76.25	46.00
8 dSm-1	6.25	11.63	123.50	9.10	51.75	31.25
8 dSm-1 + AM	6.75	12.75	157.50	10.75	59.25	35.75
SE (±)	0.90	1.43	17.44	0.66	7.46	4.37
F test	ns	ns	ns	ns	ns	ns
CV (%)	15.27	13.56	13.17	8.35	13.23	13.64

AM: Arbuscular mycorrhizal fungi. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. NS non-significant

Conclusion

With increasing salinity concentration plant height, leaf number, root colonization, spore population, yield and yield attributes decreased significantly. It was observed that 0 dSm^{-1} + AM treatment produced the highest ear weight (101.75 g pot^{-1}) and kernel yield (58.50 g pot^{-1}) of maize. In contrast, 8 dSm^{-1} treatments produced the lowest ear weight (51.75 g pot^{-1}) and kernel yield (31.25 g pot^{-1}) of maize. Conclusively, efforts should be made in such a way for improving the quality of AM fungi as a complete commercial supplement for maize in saline areas owing to enhancement of productivity for a sustainable agriculture as well as a green, safe and food secure world.

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EFFECT OF BIOFERTILIZER, BIOCHAR AND CHEMICAL FERTILIZERS ON YIELD AND QUALITATIVE PROPERTIES OF GROUNDNUT

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Abstract

A field experiment was conducted at BARI Central Farm, Joydebpur, Gazipur to evaluate the effect of biofertilizer, biochar, and chemical fertilizers on groundnut yield and qualitative properties during the rabi season of 2021-2022. The crop variety was BARI Chinabadam-8, and the Rhizobium strain was BARI RAh-229. There were nine treatments, viz. T_1: Control (non-inoculated and non-fertilized), T_2: Biochar @ 5 t ha^{-1}, T_3: Biochar @ 10 t ha^{-1}, T_4: Biochar @ 5 t ha^{-1} + IPNS based NPKS, T_5: Biochar @ 10 t ha^{-1} + IPNS based NPKS, T_6: Biochar @ 5 t ha^{-1} + Rhizobium + IPNS based PKS, T_7: Biochar @ 10 t ha^{-1} + Rhizobium + IPNS based PKS, T_8: 100% NPKS, T_9: Rhizobium inoculant + 100% PKS which were replicated three times. The peat-based rhizobial inoculum was used at a 1.5 kg ha^{-1} as seed inoculant. The result showed that the highest nut yield (2.42 t ha^{-1}, 49.4% higher over control) and stover yield (4.09 t ha^{-1}) were observed in T_7 (Biochar @ 10 t ha^{-1} +Rhizobium+IPNS based PKS) treatment which was identical with the T_6 (Biochar @ 5 t ha^{-1} +Rhizobium+IPNS based PKS) treatment having nut yield and stover yield 2.40 t ha^{-1}(48.2% higher over control) and 3.81 t ha^{-1}, respectively. So, we can reduce biochar and inorganic fertilizer without affecting the quality and productivity of groundnut. From the trial, it can be concluded that Biochar @ 5 t ha^{-1}+Rhizobium+IPNS based PKS may be recommended for groundnut cultivation in Grey Terrace Soil of Joydebpur (AEZ-28).

Introduction

In recent decades, the injudicious application of inorganic fertilizers has created hazardous environmental problems. The cost of these inorganic fertilizers is very high, and sometimes it is not available to the farmers causing fail to apply the inorganic fertilizers to the crop field at an optimum time. On the other hand, bio-fertilizers are considered an essential source of nutrients in sustainable agriculture. Nowadays, applying various types of biofertilizers and soil amendments is crucial to maintaining the balance of soil fertility (Mariya Dainya and Ushab 2016).

Biofertilizers contain beneficial soil microorganisms that have the potential to not only reduce dependence on non-renewable input like chemical fertilizers but also be effective in environmental protection. On the other hand, biochar has been widely studied. Biochar as a stable, highly porous, fine-grained carbon compound is produced from biomass pyrolysis under limited oxygen conditions (Sohi et al. 2010; Abbas et al. 2018). With greater effectiveness than manure, biochar can reduce soil bulk density and enhance soil's water holding capacity (Malik et al. 2018). Besides this, it has other beneficial effects on both soil and crop.

Groundnut is an essential oil crop of Bangladesh that is not widely cultivated in AEZ-28 soil due to its poor production potential. Therefore, this study explored the effect of mixed bio-fertilizers and biochar on groundnut yield and yield components and the quality of agricultural soils under investigation to fulfill sustainable agriculture.

Materials and Methods

A field experiment was carried out from December 2021 to May 2022 during the Rabi season at Central Farm, Bangladesh Agricultural Research Institute (BARI), Joydebpur (24.00° N latitude, 90.25° E longitude and 8.4 m elevation). Joydebpur soil belongs to the Chhiata series of Grey Terrace Soil (AEZ-28). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were nine treatments viz. T_1: Control (non-inoculated and non-fertilized), T_2: Biochar @ 5 t ha^{-1}, T_3: Biochar @ 10 t ha^{-1}, T_4: Biochar @ 5 t ha^{-1} + IPNS based NPKS, T_5: Biochar @ 10 t ha^{-1} + IPNS based NPKS, T_6: Biochar @ 5 t ha^{-1} + *Rhizobium* + IPNS based PKS, T_7: Biochar @ 10 t ha^{-1} + *Rhizobium* + IPNS based PKS, T_8: 100% NPKS, T_9: *Rhizobium* inoculant + 100% PKS.

The tested crop was groundnut (cv. BARI Chinabadam-8). Peat based rhizobial inoculum (*Rhizobium* strain BARI RAh-229) was used containing 10^8 cells g^{-1} inoculum was used at the rate of 1.5 kg ha^{-1}. Groundnut seeds were mixed thoroughly with the inoculum before sowing. The unit plots measured 2 m × 3 m. Groundnut seeds were used at the rate of 75-100 kg ha^{-1}. Row to row distance was 40 cm and plant to plant distance was 10 cm. Nitrogen, phosphorus, potassium, sulphur, zinc and boron were used in the form of urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. Chemical fertilizers were applied as soil test basis according to the method describe in fertilizer recommendation guide (BARC, 2018). All P, K, S, Zn, B, biochar and $^1/_3$rd urea-N were applied at the time of final land preparation and the remaining $^2/_3$rd urea-N was applied in two equal installments at 25 and 45 days of sowing. All the intercultural operations such as irrigation, weeding, insect control, etc. were done as and when necessary. Biochar was prepared in the net house of the Soil Science Division and mixed with unit plot soil as per the required amount during the Rabi season of November-December, 2019, keeping in mind that biochar application will be recommended after three years interval. The unit plot size was fixed, and the previous cropping pattern was Groundnut-Fallow-Fallow (2019-2020) and Groundnut-Fallow-Rice (2020-2021) during the last two years. The subsequent cropping pattern will be followed as Groundnut-Dhaincha-T. Aman rice cropping pattern (2021-2022). Data on yield and yield components were recorded at maturity. The crop groundnut was planted in December, 2021 and harvested in May, 2022. The initial soil samples at 0-15 cm depth from the experimental fields were collected and analyzed following standard methods (Table 1). The biochar used in this experiment was also analyzed (Table 2). Data on yield and yield contributing characters were recorded and analyzed statistically following Statistix 10 package, while the mean separation was done by Duncan's Multiple Range Test (DMRT).

Table 1. Initial fertility status of the soil samples used in the experimental field

Soil Properties	pH	OM %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			meq 100 g^{-1}				µg g^{-1}					
Result	7.0	0.73	5.6	1.9	0.21	0.038	7.0	20	0.48	1.8	60	1.71
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.20	0.20	4.0	0.6

Table 2. Chemical composition of biochar used in the experimental field

Carrier materials	Mois %	pH	Content (%)										
			OC	Ca	Mg	N	P	K	S	B	Cu	Fe	Zn
Biochar	29.10	10.41	54.53	1.66	0.71	0.70	0.15	1.55	0.47	0.036	0.002	0.16	0.087

Methods of chemical analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by wet oxidation method (Walkley and Black). Total N was determined by modified Kjeldahl method (Jackson, 1962). Calcium, K and Mg were determined by NH_4OAc extraction method. Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils) according to Olsen *et al.* (1954). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$.

Results and Discussion

Nodulation and plant characters of groundnut

Results on the effect of biofertilizer, biochar, and chemical fertilizers on nodulation and plant characteristics of groundnut are presented in table 3. Significant differences were found in all the cases except fresh shoot weight and number of branches $plant^{-1}$. The highest nodule number (55.0 $plant^{-1}$), nodule weight (86.7 mg $plant^{-1}$), root fresh weight (1.39 g $plant^{-1}$), shoot fresh weight (48.4 g $plant^{-1}$), root dry weight (0.48 g $plant^{-1}$), shoot dry weight (18.8 g $plant^{-1}$), plant heigth (48.0 cm), and number of branch (5.50 $plant^{-1}$) were observed in T_7 (Biochar @ 10 t ha^{-1} +*Rhizobium*+IPNS based

PKS) treatment. The lowest nodule number (39.7 plant^{-1}), nodule weight (55.7 mg plant^{-1}), root fresh weight (1.08 g plant^{-1}), shoot fresh weight (41.8 g plant^{-1}), root dry weight (0.33 g plant^{-1}), shoot dry weight (15.2 g plant^{-1}), plant heigth (35.6 cm), and number of branch (4.56 plant^{-1}) were observed in T_1 (Control) treatment.

Table 3. Effect of biofertilizer, biochar and chemical fertilizers on nodulation and plant characters of groundnut

Treatment	Nodule number plant^{-1}	Nodule weight (mg plant^{-1})	Fresh weight (g plant^{-1})		Dry weight (g plant^{-1})		Plant height (cm)	No. of branch plant^{-1}
			Root	Shoot	Root	Shoot		
T_1: Control	39.7b	55.7d	1.08b	41.8	0.33b	15.2a	35.6c	4.56
T_2: Biochar @ 5 t ha^{-1}	46.2ab	75.6abc	1.28ab	44.7	0.39ab	16.4a	40.1bc	4.88
T_3: Biochar @ 10 t ha^{-1}	45.1ab	74.4abc	1.22ab	46.0	0.41ab	18.3a	41.8abc	5.22
T_4: T_2 + NPKS	53.1a	82.2ab	1.28ab	47.8	0.43ab	16.6a	41.0abc	4.83
T_5: T_3 + NPKS	54.0a	78.9ab	1.28ab	48.0	0.44ab	18.6a	41.4abc	5.45
T_6: T_2 + R* + PKS	54.1a	85.6ab	1.33ab	47.4	0.47a	18.6a	47.0ab	4.89
T_7: T_3 + R* + PKS	55.0a	86.7a	1.39a	48.4	0.48a	18.8a	48.0a	5.50
T_8: 100% NPKS	40.2b	62.2cd	1.17ab	43.8	0.34b	16.3a	36.5c	4.60
T_9: R* + 100% PKS	48.0ab	71.1bc	1.28ab	43.9	0.42ab	16.5a	37.9c	4.67
SE (±)	3.59	5.10	0.09	3.17	0.04	1.28	2.37	0.44
Level sig.	*	**	*	ns	*	*	*	ns
CV (%)	12.85	11.82	12.89	12.01	15.95	12.80	10.00	15.22

**R=Rhizobium*, NPKS was used as Integrated Plant Nutrient System (IPNS). The values represent means of 03 replicates. Different letters within each column indicate significant differences between treatments. Test Statistix 10. **Significant P≤0.01. *significant P≤0.05, ns Non-significant.

Yield and yield contributing character of groundnut

Results on the effect of biofertilizer, biochar, and chemical fertilizers on yield and yield contributing character of groundnut are presented in Table 4. Significant differences were found in all the cases except kernel plant nut^{-1}, and 100-seed weight of groundnut. The highest plant heigth at harvest (77.5 cm), filled nut (20.5 plant^{-1}), unfilled nut (6.40 plant^{-1}), kernel (37.6 plant nut^{-1}), 100-kernel weight (60.3 g), stover yield (4.09 t ha^{-1}), nut yield (2.42 t ha^{-1}) and shelling (71%) were observed in T_7 (Biochar @ 10 t ha^{-1} +*Rhizobium*+IPNS based PKS) treatment. The lowest plant heigth at harvest (62.7 cm), filled nut (15.4 plant^{-1}), unfilled nut (5.00 plant^{-1}), kernel (28.1 plant nut^{-1}), 100-kernel weight (53.7 g), stover yield (2.56 t ha^{-1}), nut yield (1.62 t ha^{-1}) and shelling (66%) were observed in T_1 (Control) treatment.

The highest nut yield (2.42 t ha^{-1}, 49.4% higher over control) and stover yield (4.09 t ha^{-1}) were observed in T_7 (Biochar @ 10 t ha^{-1} +*Rhizobium*+IPNS based PKS) treatment which was identical with the T_6 (Biochar @ 5 t ha^{-1} +*Rhizobium*+IPNS based PKS) treatment having nut yield and stover yield 2.40 t ha^{-1} (48.2% higher over control) and 3.81 t ha^{-1}, respectively. So, we can reduce biochar and urea fertilizer application rate without affecting the quality and productivity of groundnut.

Table 4. Effect of biofertilizer, biochar and chemical fertilizers on yield and yield contributing characters of groundnut

Treatment	Plant height (cm at harvst)	Filled nut	Unfilled nut	Kernel plant nut^{-1}	100-kernel weight (g)	Stover yield	Nut yield	Shelling (%)	Nut yield incre. over contrl
		Number plant^{-1}				t ha^{-1}			
T_1: Control	62.7b	15.4b	5.00a	28.1	53.7	2.56d	1.62d	66b	-
T_2: Biochar @ 5 t ha^{-1}	68.2ab	17.5ab	5.00a	29.9	57.0	2.98cd	2.18abc	68ab	35.6
T_3: Biochar @ 10 t ha^{-1}	68.1ab	18.8ab	5.16a	33.6	57.0	3.12cd	2.31ab	69ab	42.6
T_4: T_2 + NPKS	70.5ab	18.6ab	5.87a	36.1	57.3	3.37bc	2.32ab	69ab	43.2
T_5: T_3 + NPKS	78.6a	20.3a	5.40a	33.5	58.7	3.32bc	2.17abc	69ab	34.0
T_6: T_2 + R* + PKS	73.1ab	19.3ab	6.00a	36.3	59.7	3.81ab	2.40a	71a	48.2
T_7: T_3 + R* + PKS	77.5a	20.5a	6.40a	37.6	60.3	4.09a	2.42a	71a	49.4
T_8: 100% NPKS	67.9ab	17.3ab	6.00a	28.6	56.7	2.89cd	1.91cd	69ab	17.9
T_9: R* + 100% PKS	72.5ab	17.7ab	5.67a	29.4	56.0	3.04cd	1.92bcd	68ab	18.5
SE (±)	4.11	1.63	0.50	2.39	1.33	0.21	0.13	1.64	-
Level sig.	*	*	*	ns	ns	**	**	*	-
CV (%)	10.03	15.34	15.42	12.70	4.01	11.20	10.74	3.70	-

**R=Rhizobium*, NPKS was used as Integrated Plant Nutrient System (IPNS). The values represent means of 03 replicates. Different letters within each column indicate significant differences between treatments. Test Statistix 10. **Significant P≤0.01. *significant P≤0.05, ns Non-significant.

Conclusion

The highest nut yield (2.42 t ha^{-1}, 49.4% higher over control) and stover yield (4.09 t ha^{-1}) were observed in T_7 (Biochar @ 10 t ha^{-1} +*Rhizobium*+IPNS based PKS) treatment which was identical with the T_6 (Biochar @ 5 t ha^{-1} +*Rhizobium*+IPNS based PKS) treatment having nut yield and stover yield 2.40 t ha^{-1} (48.2% higher over control) and 3.81 t ha^{-1}, respectively. From the trial, it can be concluded that Biochar @ 5 t ha^{-1}+*Rhizobium*+IPNS based PKS may be recommended for groundnut cultivation in Grey Terrace Soil of Joydebpur (AEZ-28). Further one or two years studies at Joydebpur and at different AEZs, and economic analysis are required for final recommendation.

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EFFECT OF BIOFERTILIZER AND CHEMICAL FERTILIZERS ON SOIL MICROBIAL POPULATION STATUS, NODULATION PATTERN, NODULE INITIATION DATE AND YIELD OF GRASSPEA VARIETIES

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Abstract

A field experiment was conducted at central farm of Bangladesh Agricultural Research Institute (AEZ-28) during rabi season 2021-2022 to evaluate the effects of biofertilizer and chemical fertilizer on soil microbial population status, nodulation pattern, nodule initiation date and yield of grasspea varieties. The experiment was designed in randomized complete block (RCBD) with 2 factors (fertilizer doses and varieties) having 3 replications in each treatment. Three fertilizer doses were 100% PKSZnB, *Rhizobium* + 100% PKSZnB, 100% NPKSZnB and three varieties were BARI khesari-3, BARI khesari-5 and BARI khesari-6. Unit plot size was 3 m x 2 m. There were 9 treatment combinations. Basic doses of fertilizers were 15-11-20-7-1-1 kg N-P-K-S-Zn-B ha^{-1}. All the fertilizers except N were applied as basal at final land preparation. N was applied in three equal splits at 10, 20 and 30 days after sowing. Peat based rhizobial inoculum (BARI RLs-10) @ 1.5 kg ha^{-1} was used for seed inoculation. Peat based rhizobial inoculum was used containing about 10^8 cells g^{-1} inoculum. From the investigated study, BARI khesari-5 has the greater ability to produce maximum number of nodule than all other varieties. In this experiment we found that grasspea varieties required 16-17 days for their first nodulation. The nodulation pattern trend was BARI khesari-5> BARI khesari-6> BARI khesari-3 at Gazipur during 2021-2022. In three varieties, nodule initiation was increased during the pre-flowering stages but decreases when it turns into reproductive stages. The better nodulation was observed after 73 days of grasspea seeds sowing specially at BARI khesari-5 varieties. 100% NPKSZnB and *Rhizobium* + 100% PKSZnB treated plot performed better than 100% PKSZnB treated plot. In respect of variety, BARI khesari-5 gave better results than others. Combined effects of fertilizer doses and varieties, *Rhizobium* + 100% PKSZnB with BARI khesari-5 and 100% NPKSZnB with BARI khesari-6 significantly gave the highest straw yield and seed yield at Gazipur. In case of microbial population status, *Rhizobium* + 100%PKSZnB treated plot showed the maximum number of populations in Gazipur during 2021-2022. *Rhizobium* + 100% PKSZnB and 100% NPKSZnB with BARI kheasri-5 and BARI khesari-6 showed the maximum nutrient uptake from soil. All the nutrients during grasspea production exhibited the negative apparent nutrient balances at Gazipur during 2021-2022.

Introduction

Today, global agriculture is at crossroads as a consequence of climatic change, increased population pressure and detrimental environmental impacts. Increased population needs more food to live on the earth. Bangladesh is a developing country. Most of the people are closely related to the cultivation of land. They only produce rice to feed the family members as well as to feed the nation. Pulse crops are a cheapest source of protein for the poor people. They are not interested to produce pulse crops because of their low yielding potential. If we want to increase the yield of pulse crops then we have to use biofertilizer besides chemical fertilizer to save the environment as well as to improve the soil fertility. Biofertilizers have attracted greater attention particularly in developing countries like Bangladesh as a substitute for costly chemical fertilizers. They can be applied to seed, root or in order to soil mobilize the availability of nutrients by their biological activity and turn the soil health in general. Biofertilizers provide eco-friendly organic agro input and are more cost effective then chemical fertilizers. Biofertilizers are living cells of different types of microorganism (bacteria, algae, fungi), which have an ability to mobilize nutritionally important elements from non-useable form. These microorganisms require organic matter for their growth and activity in soil and provide valuable nutrients to the plant (Saini *et al.*, 2004). Biofertilizers are ecofriendly fertilizer, which improve soil quality and provide yield increments. It greatly benefits farmer with only very small input cost. Use of biofertilizer and organic manure in agriculture is becoming popular nowadays not only in order to minimize the cost of chemical fertilizers but also to reduce the adverse effects of chemical fertilizers on soil and plant environment and to ensure more crop productivity.

Grasspea (khesari) is a member of the pulse family Leguminosae. Khesari or Grasspea (*Lathyrus sativus* L.) is a native of southern Europe and western Asia. In Bangladesh it is grown as a cold-weather crop. It is very hardy and can germinate and grow on land too dry for other crops. It can tolerate water-logging and a wide range of soil conditions, including poor soil. It occupies the first position in terms of area and production among pulses in Bangladesh. Seed yield is about 730-2000 kg/ha. Khesari is cultivated in about 6,02,000 acres of land, and the total annual production is about 1,77,000 m tons. Khesari is an herbaceous annual with slender, glabrous, freely-branched, winged procumbent stem, and its tap root is well-developed. Leaves are alternate and pinnate, and terminate in 3-5 tendrils. Flowers are solitary in the leaf axils. Pods are oblong and flattened. Seeds are wedge-shaped, angled, brown or grey. Germination is hypogeal. The seeds contain about 10.0% water, 28.2% protein, 0.6% fat, 58.2% carbohydrate, and 3.0% minerals. It is a robust legume crop that is considered one of the most resilient to climate changes and to be survival food during drought-triggered famines. The hardy penetrating root system allows the cultivation of grasspea in various soil types, including marginal ones. Overemphasis of their suspected toxic properties has led to disregard the plant's exceptionally positive agronomic properties and dietary advantages. In normal socio-economic and environmental situations, in which grasspea is part of a balanced diet, neurolathyrism is virtually non-existent. The etiology of neurolathyrism has been oversimplified and the deficiency in methionine in the diet has been overlooked. In view of the global climate change, this very adaptable and nutritious orphan crop deserves more attention. Grasspea can become a wonder crop if the double stigma on its reputation as a toxic plant and as food of the poor can be disregarded. Additionally, recent research has exposed the potential of grasspea as a health-promoting nutraceutical. Development of varieties with an improved balance in essential amino acids and diet may be relevant to enhance the nutritional value without jeopardizing the multiple stress tolerance of this promising crop. Therefore, the present study was undertaken the to fulfill the following objectives such as

I. To know the effects of biofertilizer and chemical fertilizers on soil microbial population status, nodulation pattern, nodule initiation date of grasspea varieties
II. To increase the yield of grasspea crops
III. To monitor the soil fertility status

Materials and Methods

Location and treatments of the experiment

A field experiment was conducted at the Central Research Field of Soil Science Division, BARI, Joydebpur, Gazipur. The tested crop was Grasspea (cv. BARI khesari-3, BARI khesari-5 and BARI khesari-6). The experiment was laid out in RCBD factorial with three replications. There were two factors such as i) Varieties (03) and ii) Fertilizer doses (03). The varieties were i) BARI khesari-3 ii) BARI khesari-5 iii) BARI khesari-6 and fertilizer doses were i) 100% PKSZnB ii) 100% PKSZnB +*Rhizobium* iii) 100% NPKSZnB. By combining these two factors we obtained nine (09) treatment combinations viz. T_1: 100% PKSZnB + BARI Khesari-3, T_2: 100% PKSZnB + BARI Khesari-5, T_3: 100% PKSZnB + BARI Khesari-6, T_4: 100% PKSZnB + *Rhizobium* with BARI Khesari-3, T_5: 100% PKSZnB + *Rhizobium* with BARI Khesari-5, T_6: 100% PKSZnB + *Rhizobium* with BARI Khesari-6, T_7: 100% NPKSZnB + BARI Khesari-3, T_8: 100% NPKSZnB + BARI Khesari-5 and T_9: 100% NPKSZnB + BARI Khesari-6, respectively. *Rhizobium* strains isolation was done by the following standard methods. Plot size was 3m × 2m. All the fertilizers were applied as a treatment on the STB basis by following FRG 2018. Grasspea seeds were well mixed up with *Rhizobium* biofertilizer under a cool place before sowing. Intercultural operations like watering, weeding, insect pest's managements etc, were done as and when necessary. Top dressing of urea fertilizer was done as per schedule. Grasspea seeds were sown on 18 November 2021 and harvested on 20 March 2022. Initial soil sample was collected and analyzed. We also collected the post-harvest soil and plant samples for different nutrients content and microbial population status determination.

Soil and plant sample analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Soil texture was determined by hydrometer method (Beverwijk, 1967). Organic carbon was determined by wet oxidation method (Walkley and Black). Total N was determined by modified Kjeldahl method. Calcium, K and Mg were determined by NH_4OAc extraction method. Cu, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$. *Rhizobium* population status was determined by plate counting method.

Table 1a. Physical, chemical and microbiological status of initial soil during 2021-2022 at Gazipur

Location	Soil Texture	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	Cu	Fe	Mn	Zn	B	Rhizobial population g^{-1} soil
				meq $100g^{-1}$				µg g^{-1}							
Gazipur	Clay loam	6.44	1.32	6.1	2.1	0.17	0.05	14.7	18.5	2.0	70	2.6	5.14	0.20	1.0×10^3
Critical level		-	-	2.0	0.5	0.12	-	10	10	0.2	04	1.0	0.60	0.2	-

Table 1b. Chemical properties of post-harvest soil during 2021-2022 at Gazipur

Treatment combinations	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	Cu	Fe	Mn	Zn	B
			meq $100g^{-1}$				µg g^{-1}						
T_1	6.53	1.33	5.2	1.8	0.21	0.07	10.0	20.2	2.5	52	9.40	2.67	0.22
T_2	6.65	1.32	5.3	1.6	0.17	0.07	10.0	22.4	2.2	54	11.0	2.66	0.28
T_3	6.67	1.35	5.5	1.8	0.19	0.06	11.0	22.0	2.3	55	12.3	2.56	0.26
T_4	6.80	1.36	5.6	1.8	0.18	0.07	11.0	23.5	2.2	63	14.5	2.62	0.32
T_5	6.75	1.37	5.6	1.8	0.21	0.07	12.0	20.3	2.1	58	12.1	2.46	0.34
T_6	6.85	1.39	5.7	1.8	0.18	0.07	13.0	23.5	2.0	53	11.3	2.52	0.32
T_7	6.80	1.35	5.7	2.1	0.19	0.07	10.0	20.3	2.2	56	10.3	2.24	0.39
T_8	6.64	1.34	6.0	2.3	0.18	0.08	10.0	20.1	2.3	70	12.4	2.89	0.38
T_9	6.80	1.33	5.8	2.3	0.19	0.08	12.0	20.1	2.2	64	12.5	2.68	0.40
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.2	04	1.0	0.60	0.2

T_1: 100% PKSZnB + BARI Khesari-3, T_2: 100% PKSZnB + BARI Khesari-5, T_3: 100% PKSZnB + BARI Khesari-6, T_4: 100% PKSZnB + *Rhizobium* with BARI Khesari-3, T_5: 100% PKSZnB + *Rhizobium* with BARI Khesari-5, T_6: 100% PKSZnB + *Rhizobium* with BARI Khesari-6, T_7: 100% NPKSZnB + BARI Khesari-3, T_8: 100% NPKSZnB + BARI Khesari-5 and T_9: 100% NPKSZnB + BARI Khesari-6

Table 1c. Microbial population status (*Rhizobium*) of post-harvest soil during 2021-2022 at Gazipur

Locations	Treatment combinations								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Gazipur	1.0×10^5	1.0×10^5	1.5×10^4	3.5×10^5	4.0×10^5	3.0×10^5	3.5×10^5	3.0×10^5	2.5×10^5

T_1: 100% PKSZnB + BARI Khesari-3, T_2: 100% PKSZnB + BARI Khesari-5, T_3: 100% PKSZnB + BARI Khesari-6, T_4: 100% PKSZnB + *Rhizobium* with BARI Khesari-3, T_5: 100% PKSZnB + *Rhizobium* with BARI Khesari-5, T_6: 100% PKSZnB + *Rhizobium* with BARI Khesari-6, T_7: 100% NPKSZnB + BARI Khesari-3, T_8: 100% NPKSZnB + BARI Khesari-5 and T_9: 100% NPKSZnB + BARI Khesari-6

Nodule initiation Date

To record the nodule initiation date of grasspea plants, we observed the grasspea field regularly just after germination of grasspea plants. First time we recorded the nodule initiation just after 16 to 17 days of grasspea seeds sowing.

Nodulation data

Every seven (7) days interval, nodulation data was recorded after nodule initiation of grasspea plants. At 50% flowering stage of grasspea plants, maximum nodulation data was taken.

Growth analysis

All the yield and yield contributing characters such as nodule number per plant, nodule weight (mg), plant height (cm), shoot weight (g), root length (cm), root weight (mg), number of pods per plant, 1000-seed weight (g), seed yield (t/ha) and stover yield (t/ha) data were recorded. Ten (10) randomly plants were selected and uprooted to take the data of above mention parameters.

Statistical analysis

Data were statistically analyzed using Analysis of Variance (ANOVA) following Crop Stat package while the all-pair comparisons were done by Statistix-10 software (Gomez and Gomez, 1984).

Results and Discussion

Results

Bangladesh is a densely populated country. Most of the people of this country are poor. They are mainly suffered from protein. Pulses are the cheapest and rich source of protein. The weather of this country is most favorable for pulse crop cultivation but land is so limited. So, we have to produce more in our limited land. Only pulse crops have the ability to produce nodule which fix the atmospheric nitrogen for their growth and development. It is not essential to apply additional urea fertilizer during pulse crops production. In this section we discussed about the nodulation pattern of different grasspea varieties, yield and yield contributing characters. The nodulation pattern and yield data were presented by different figures and tables.

Nodulation pattern of different grasspea varieties at Gazipur

In respect of three different varieties of grasspea, we observed that nodulation rate was gradually increased during the advancement of crop growing period. The maximum number of nodules per plant was recorded after 50% flowering stages of grasspea varieties. Statistically the maximum nodulation rate was recorded at BARI khesari-5 compare to all other varieties after 73 days of sowing and the lowest number was observed at BARI khesari-3 in the year of 2021-2022 at Gazipur. After 73 days of sowing, their nodulation capability was gradually declined. Among three different varieties of grasspea, the highest number of nodules was 24.66 which was observed at BARI khesari-5 and the lowest number was 17.66 at BARI khesari-3. After 73 days of grasspea sowing, we noticed that number of nodules was drastically decreased in respect of all varieties of grasspea crops because crops come into the ripening stages. They don’t need any nitrogen for the completion of their crop cycle (Figure 1a).

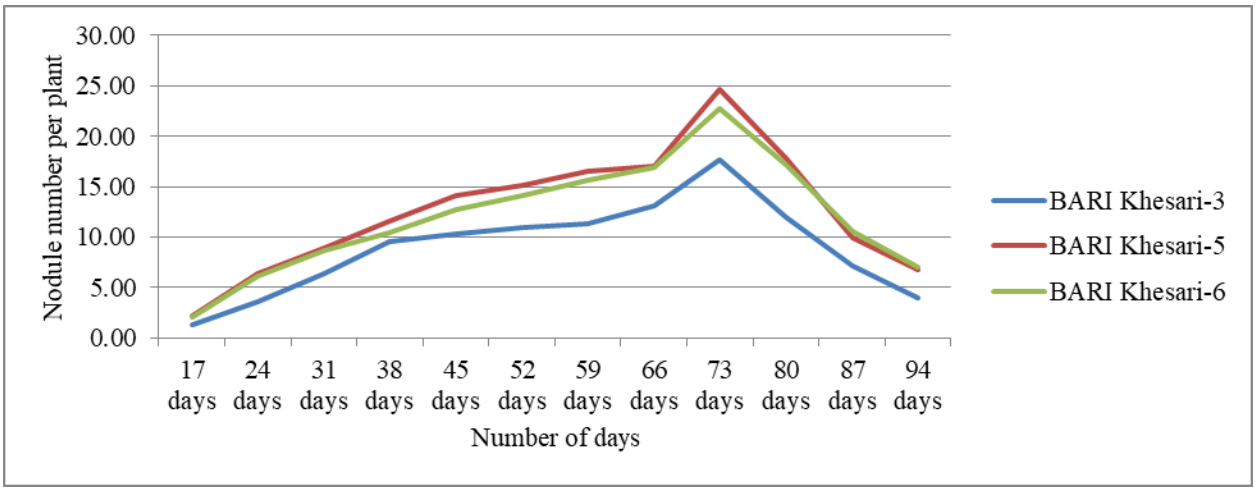


Figure 1a. Effect of varieties on nodulation pattern of grasspea at red brown terrace soil, Gazipur during 2021-2022

Nodulation pattern of different fertilizer doses of grasspea varieties at Gazipur

Among three different fertilizer treated plot, we observed that 100% NPKSZnB and 100% PKSZnB with *Rhizobium* fertilizer packages showed the maximum nodulation rate compared to rest one during the crop growing period of grasspea. In the year of 2021-2022, we noticed that up to 73 days, nodulation rate was maximum under 100% NPKSZnB fertilizer packages compared to remaining fertilizer doses which was applied in the experimental trial. The maximum number of nodules was 23.00 recorded at 100% NPKSZnB treated plot. After 73 days of sowing, nodulation rate was gradually decreased in all fertilizer packages. The minimum numbers of nodulations were documented at 100% PKSZnB treated plot at Gazipur (Figure 1b).

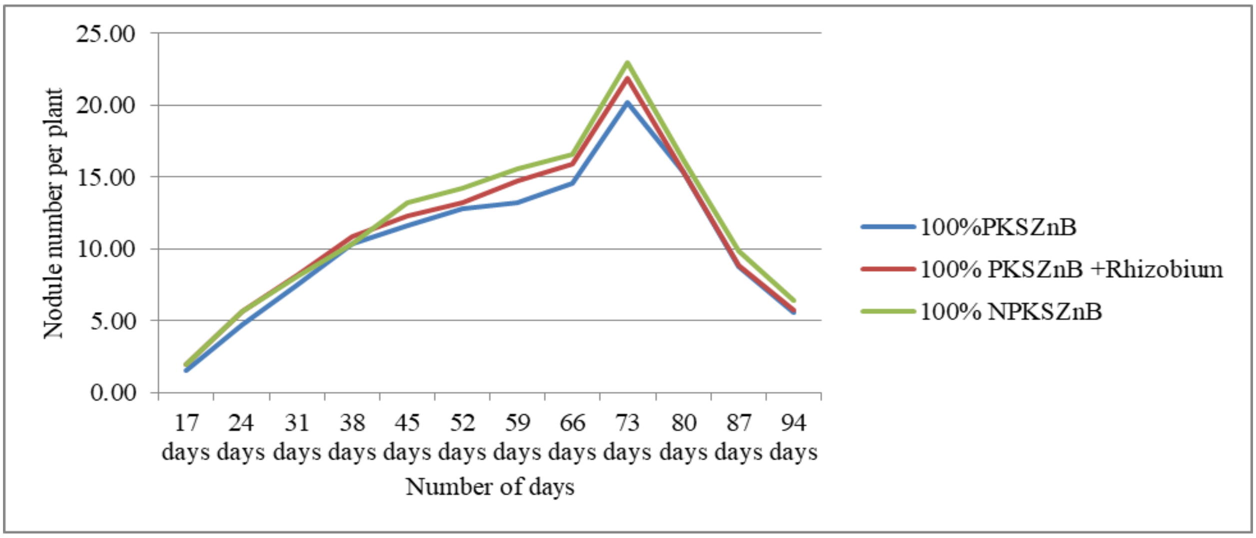
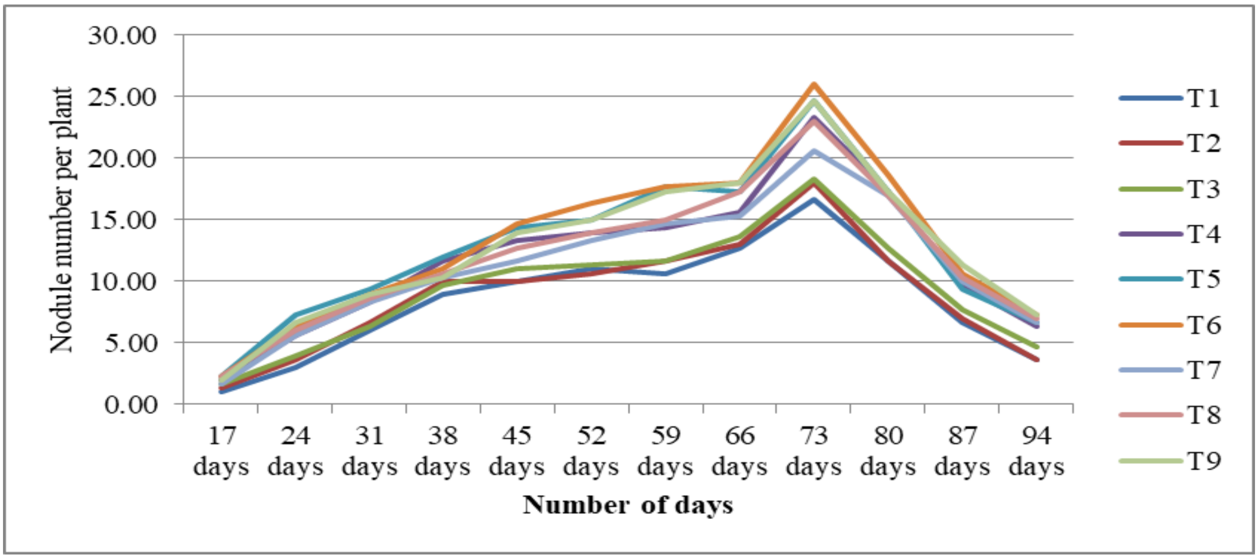


Figure 1b. Effect of fertilizer doses on nodulation pattern of grasspea at red brown terrace soil, Gazipur during 2021-2022

Cumulative effect of varieties and fertilizer doses on nodulation pattern of grasspea

Blending effects of fertilizer doses and varieties, we observed that 100% PKSZnB + *Rhizobium* with BARI khesari-5 (26.00) produce the maximum nodule number after 73 days of seeds sowing which was followed by 100% NPKSZnB with BARI khesari-6 and the lowest nodule number was observed at 100% PKSZnB with BARI khesari-3 treated plot which was 16.66. But after 73 days of sowing, we observed that nodulation capability was gradually decreased in all combinations at Gazipur (Figure 1c).



T_1: 100% PKSZnB + BARI Khesari-3, T_2: 100% PKSZnB + BARI Khesari-5, T_3: 100% PKSZnB + BARI Khesari-6, T_4: 100% PKSZnB + *Rhizobium* with BARI Khesari-3, T_5: 100% PKSZnB + *Rhizobium* with BARI Khesari-5, T_6: 100% PKSZnB + *Rhizobium* with BARI Khesari-6, T_7: 100% NPKSZnB + BARI Khesari-3, T_8: 100% NPKSZnB + BARI Khesari-5 and T_9: 100% NPKSZnB + BARI Khesari-6

Figure 1c. Cumulative effect of varieties and fertilizer doses on nodulation pattern of grasspeaat red brown terrace soil at Gazipur during 2021-2022

Yield and yield contributing characters of grasspea varieties at Gazipur

In respect of three different grasspea varieties, analytical data revealed that BARI khesari-5 performed better in respect of nodule number per plant, nodule weight (mg), plant height (cm), root length (cm), root weight (mg), shoot weight (g), number of pods per plant, 1000- seed weight (g), seed yield (t/ha) and stover yield (t/ha) significantly. The highest nodule number was 24.6 per plant which was observed at BARI khesari-5 statistically. BARI khesari-5 produced the maximum nodule weight (mg), plant height (cm), root length (cm), root weight (mg), shoot weight (g), 1000- seed weight (g), seed yield (t/ha) and stover yield (t/ha) than other two varieties of grasspea. The maximum nodule weight was 422.2 mg in at BARI khesari-5 and the lowest value was 206.6 in at BARI khesari-3 varieties. Among three varieties of grasspea, we deeply observed that BARI khesari-5 gave the highest plant height (65.7 cm), root length (9.91 cm), root weight (461.1 mg) shoot weight (2.32 g), number of pods per plant (4.60), seed yield (1.75 t/ha), stover yield (3.00 t/ha), respectively and all the parameters showed the lowest value in at BARI khesari-3 in our study at Gazipur during 2021-2022. (Table 2a).

Table 2a. Effect of varieties on growth and yield of grasspea during 2021-2022 at red brown terrace soil, Gazipur

Varieties	Nodule no. plant^{-1}	Nodule wt. Plant^{-1} (mg)	Plant height (cm)	Root length (cm)	Root wt. (mg)	Shoot wt. (gm)	No. of pods plant^{-1}	1000-seed wt. (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
BARI Khesari-3	17.2c	206.6c	59.6c	8.0b	376.6b	1.22b	3.67b	56.2	1.11c	1.86b
BARI Khesari-5	24.6a	422.2a	65.7a	9.91a	461.1a	2.32a	4.60a	58.9	1.75a	3.00a
BARI Khesari-6	23.6b	388.8b	64.5b	9.75a	448.8a	2.30a	4.55a	58.6	1.67b	2.93a
SE (±)	0.34	14.98	0.45	0.11	8.27	0.04	0.09	1.30	0.01	0.05
F test	**	**	**	**	**	**	**	NS	**	**

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significance, NS means non-significant.

Among three different doses of fertilizer treated plot, we recognized that 100% NPKSZnB fertilizer dose gave better results in nodule number per plant, nodule weight (mg), plant height (cm), root length (cm), root weight (mg), shoot weight (g), number of pods per plant by competing rest of two fertilizer doses significantly but 1000-seed weight (g), seed yield (t/ha) and stover yield (t/ha) gave better result in at 100% PKSZnB with *Rhizobium* treated plot. The highest nodule number per plant (23.1), nodule weight (381.1 mg), plant height (65.4 cm), root length (9.68 cm), root weight (464.4 mg), shoot weight (2.16 g) and number of pods per plant (4.56) were recorded at the 100% NPKSZnB treated plot compare to others. But the lowest value of all the parameters were recorded at 100% PKSZnB treated plot of the study. The highest 1000-seed weight was (60.0 g) recorded at 100% PKSZnB with *Rhizobium* treated plot. Besides, seed yield and stover yield showed the maximum value in 100% PKSZnB with *Rhizobium* fertilizer doses which was 1.60 t/ha and 2.70 t/ha, respectively (Table 2b).

Table 2b. Effect of fertilizer doses on growth and yield of grasspea during 2021-2022 at red brown terrace soil, Gazipur

Fertilizer doses	Nodule no. plant^{-1}	Nodule wt. Plant^{-1} (mg)	Plant height (cm)	Root length (cm)	Root wt. (mg)	Shoot weight (gm)	No. of pods plant^{-1}	1000-seed weight (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
100% PKSZnB	20.4c	290.0c	61.2c	8.70c	395.5c	1.67c	3.96c	54.6b	1.41c	2.40b
100% PKSZnB + *Rhz.*	22.0b	346.6b	63.3b	9.28b	426.6b	2.01b	4.30b	60.0a	1.60a	2.70a
100% NPKSZnB	23.1a	381.1a	65.4a	9.68a	464.4a	2.16a	4.56a	59.1a	1.51b	2.69a
SE (±)	0.35	14.97	0.44	0.12	8.26	0.05	0.08	1.31	0.01	0.05
F test	**	**	**	**	**	**	**	**	**	**

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significance

Table 2c. Cumulative response of fertilizer doses and varieties on growth and yield of grasspea during 2021-2022 at red brown terrace soil, Gazipur

Fertilizer doses x varieties	Nodule no. plant^{-1}	Nodule wt. Plant^{-1} (mg)	Plant height (cm)	Root length (cm)	Root weight (mg)	Shoot weight (gm)	No. of pods plant^{-1}	1000-seed weight (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
T_1	16.3	186.6	58.5	7.5	353.3	1.19d	3.36	52.5	1.06	1.71f
T_2	17.3	210.0	59.5	7.9	373.3	1.23d	3.73	59.1	1.21	1.80f
T_3	18.0	223.3	60.9	8.5	403.3	1.25d	3.93	57.0	1.12	2.06e
T_4	23.3	353.3	63.6	9.3	426.6	1.94c	4.26	55.3	1.64	2.69d
T_5	24.6	433.3	65.5	10.0	456.6	2.40b	4.60	60.7	1.85	3.25a
T_6	26.0	480.0	68.1	10.3	500.0	2.63a	4.93	60.8	1.75	3.07ab
T_7	21.6	330.0	61.6	9.2	406.6	1.90c	4.26	56.0	1.59	2.79cd
T_8	24.0	396.6	64.8	9.8	450.0	2.42b	4.56	60.3	1.74	3.05ab
T_9	25.3	440.0	67.2	10.1	490.0	2.59a	4.83	59.7	1.67	2.94bc
SE (±)	0.59	25.95	0.79	0.20	14.33	0.06	0.15	2.26	0.02	0.10
F test	*NS*	*NS*	*NS*	*NS*	*NS*	**	*NS*	*NS*	*NS*	**
CV (%)	3.35	9.37	2.00	2.75	4.09	4.39	4.49	4.79	2.15	4.73

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significance, NS means non-significant.

T_1: 100% PKSZnB + BARI Khesari-3, T_2: 100% PKSZnB + BARI Khesari-5, T_3: 100% PKSZnB + BARI Khesari-6, T_4: 100% PKSZnB + *Rhizobium* with BARI Khesari-3, T_5: 100% PKSZnB + *Rhizobium* with BARI Khesari-5, T_6: 100% PKSZnB + *Rhizobium* with BARI Khesari-6, T_7: 100% NPKSZnB + BARI Khesari-3, T_8: 100% NPKSZnB + BARI Khesari-5 and T_9: 100% NPKSZnB + BARI Khesari-6

Interaction effects of fertilizer doses and varieties, the analytical data of explored study focused that all the parameters of grasspea plants showed non-significant relation among them except shoot weight (g) and stover yield (t/ha). Significantly the maximum value of shoot weight (2.63 g) was recorded at 100% PKSZnB + *Rhizobium* with BARI khesari-6 and stover yield (3.25 t/ha) was found higher in at 100% PKSZnB + *Rhizobium* with BARI khesari-5, respectively. The lowest value of shoot weight (1.19 g) and stover yield (1.71 t/ha) was found at 100% PKSZnB with BARI khesari-3 treated plot. Above all, among nine different treatment combinations, 100% PKSZnB + *Rhizobium* with BARI khesari-5 and 100% PKSZnB + *Rhizobium* with BARI khesari-6 gave better results compare to rest of the combinations (Table 2c). These findings agreed with Dileep Kumar *et al.* (2001), Mekki and Amel (2005) also claimed that application of biofertilizer increases plant height, stover yield and seed yield of lentil, grasspea and grasspea. El Kramany*et al.* (2007) also obtained the highest number of pods per plant when they treated it with biofertilizer and chemical fertilizer.

Effect of varieties and fertilizer doses on nutrient uptake of grasspea

In our investigated research study, we observed that among different treatment combinations, the higher amount of N uptake (35.82 kg ha^{-1}) was occurred at seed in *Rhizobium* + 100% PKSZnB with BARI khesari-5 treated plot. But the highest amount of N uptake (29.11 kg ha^{-1}) was done by straw in at *Rhizobium* + 100% PKSZnB with BARI khesari-6 fertilizer doses. In respect of P and K content, we found that the maximum uptake was occurred in *Rhizobium* + 100% PKSZnB with BARI khesari-5 varieties in seed of grasspea which was 9.61 kg ha^{-1}, 22.14 kg ha^{-1}, respectively. But in straw, 100% NPKSZnB with BARI khesari-6 and *Rhizobium* + 100% PKSZnB with BARI khesari-5 showed the maximum P, K uptake which was 13.49 kg ha^{-1} and 50.34 kg $ha^{-1,}$ respectively. In S content study, seed showed the higher uptake in *Rhizobium* + 100% PKSZnB with BARI khesari-6 and BARI khesari-5 varieties (4.00 and 11.15 kg ha^{-1}). The lowest uptake rate was recorded at 100% PKSZnB with BARI khesari-3 varieties in both seed and straw of grasspea plants, respectively (Table 2d).

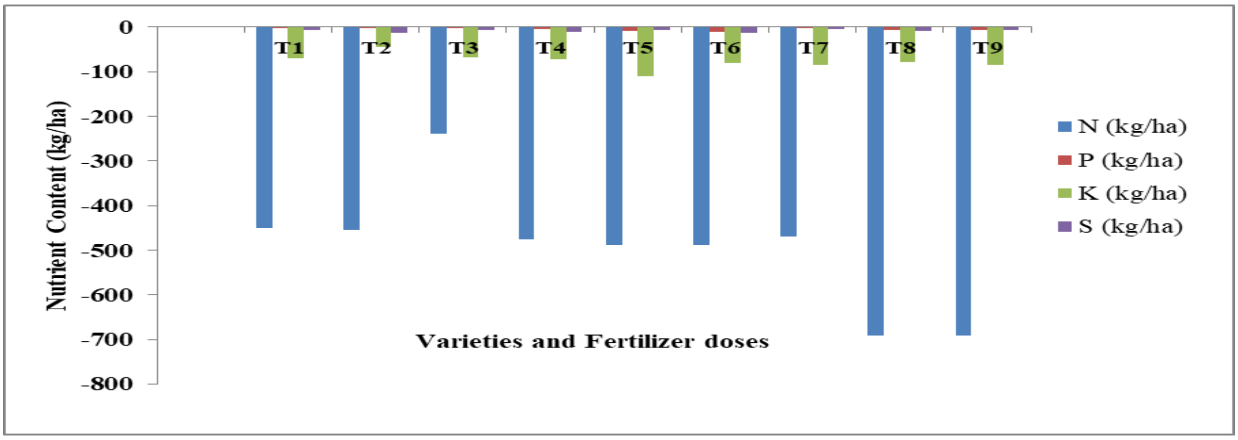
Table 2d. Effect of varieties and fertilizer doses on nutrient uptake of khesari at Gazipur during 2021-2022

Treatment combinations	N kg ha^{-1}		P kg ha^{-1}		K kg ha^{-1}		S kg ha^{-1}	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
T_1	17.35	9.03	5.13	5.27	9.92	23.78	3.54	3.01
T_2	20.02	9.82	6.18	5.23	12.78	28.51	3.19	4.44
T_3	19.12	11.65	5.62	5.83	12.22	36.19	3.65	5.12
T_4	30.31	21.07	8.51	9.94	18.18	43.08	3.03	7.81
T_5	35.82	28.03	9.61	11.73	22.14	50.34	2.93	11.15
T_6	33.73	29.11	8.93	11.64	19.71	48.95	4.00	9.79
T_7	29.38	23.57	7.98	10.31	17.91	46.65	2.94	8.59
T_8	33.23	26.18	9.03	13.49	18.99	47.07	5.67	10.05
T_9	31.01	28.20	8.52	10.87	19.40	45.79	3.67	9.83

T_1: 100% PKSZnB + BARI Khesari-3, T_2: 100% PKSZnB + BARI Khesari-5, T_3: 100% PKSZnB + BARI Khesari-6, T_4: 100% PKSZnB + *Rhizobium* with BARI Khesari-3, T_5: 100% PKSZnB + *Rhizobium* with BARI Khesari-5, T_6: 100% PKSZnB + *Rhizobium* with BARI Khesari-6, T_7: 100% NPKSZnB + BARI Khesari-3, T_8: 100% NPKSZnB + BARI Khesari-5 and T_9: 100% NPKSZnB + BARI Khesari-6

Effect of varieties and fertilizer doses of grasspea on apparent nutrient balance study

In our conducted research study, we determined the apparent nutrient balances of different treatment combinations. In nutrient balance calculation, nutrient output was subtracted from the nutrient input. In respect of input items, we only use initial soil and the added fertilizer nutrient content. But in output items, we were calculated the seed and stover nutrient content and post-harvest soil of grasspea study. In the apparent nutrient balance graph, we observed that N, P, K, and S showed the negative balances in all combinations.



T_1: 100% PKSZnB + BARI Khesari-3, T_2: 100% PKSZnB + BARI Khesari-5, T_3: 100% PKSZnB + BARI Khesari-6, T_4: 100% PKSZnB + *Rhizobium* with BARI Khesari-3, T_5: 100% PKSZnB + *Rhizobium* with BARI Khesari-5, T_6: 100% PKSZnB + *Rhizobium* with BARI Khesari-6, T_7: 100% NPKSZnB + BARI Khesari-3, T_8: 100% NPKSZnB + BARI Khesari-5 and T_9: 100% NPKSZnB + BARI Khesari-6

Figure 1d: Effect of varieties and fertilizer doses on apparent nutrient balance of khesari at Gazipur during 2021-2022

From the study we explained that the plant can uptake more nutrient than applied in the field. Because what amount of fertilizer we applied in the field, most of the amount of those fertilizers was lost in many ways such as volatilization, runoff, leaching etc. Besides, there are so many sources from where nutrient could add to the soil like irrigation water, rainfall, biological fixation, thunderstorm, organic amendment and so on (Figure 1d). So, we were easily explained that nutrient losses from soil were higher from our applied nutrient that's why plant took vast amount of nutrient from the inherent soil.

Physicochemical and microbiological status of soil

The texture of the experimental field soil was clay loam in nature. Initial soil pH was 6.44 but after application of different treatment on that soil, the pH was slightly increased up to 6.85. Organic matter content was improved up to 1.32% to 1.39% after completion of the experiment. Ca and Mg content were decreased from the existing soil condition except T_7, T_8 and T_9 treatment. But N and K content increased in post-harvest soil. Soil P content was decreased in post-harvest soil because plant takes luxurious amount P content from soil. S, Cu, Mn and B content was increased but Fe and Zn content were decreased in post-harvest soil of the experimental field. Microbial population status revealed that enormous amount of rhizobial population was observed in post-harvest soil. The maximum number of rhizobial population was found at T_5 treatment which was 4.0 x 10^5 g^{-1} soil and the lowest number was observed at T_1 and T_2 treatment. These results may be attributed to production of more crop biomass due to inoculation and consequently higher return of organic residues and exudates into the soil enhancing microbial biomass and activities (Babu *et al*, 2015). The pulse crops residues have lower C:N ratio, as a result of which immobilization after incorporation in the soil is low, which consequently enhances N availability to subsequent crops (Table 1a, 1b and 1c).

Discussion

Biological Nitrogen fixation (BNF) is the biochemical mechanism where rhizobia bacterial symbiont of legumes fixes inert atmospheric nitrogen into a plant usable form under the presence of enzyme nitrogenase (Mohammadi and Sohrabi., 2012). The nitrogenase enzyme is a biological catalyst which is present in the bacteroid and mediates the reaction. BNF is an economically attractive and ecologically sound source of nitrogen and helps in decreasing the dependence on external inputs. The inoculation of *Rhizobium* with chemical fertilizer significantly increases the all-growth parameters of grasspea plants. In our tested three grasspea varieties (BARI khesari-3, BARI khesari-5 and BARI khesari-6) with *Rhizobium* inoculation and chemical fertilizer application enhance the nodule number per plant, nodule weight (mg), plant height (cm), root length (cm), root weight (mg), shoot weight (g), number of pods per plant by competing rest of two fertilizer doses significantly but 1000-seed weight (g), seed yield (t/ha) and stover yield (t/ha) of grasspea plants. Rokhzadi *et al*., (2008) reported that *Rhizobium* inoculation with chemical fertilizer promote the vegetative growth as well as yield contributing traits of grasspea plants. Many researchers proclaimed that *Rhizobium* inoculation with fertilizer is an effective measure to increase N_2 fixation, promote N nutrition in legumes and increase yield (Mirza *et al*., 2007; Thomashow and Bakker., 2015). Singh *et al*., (2011) explained that inoculation with chemical fertilizer increase the number of primary and secondary branches of grasspea plants. Giri and Joshi., (2010) also reported that *Rhizobium* inoculation with fertilizer in grasspea plants enhance the plant height as well as chlorophyll content. Khan *et al*., (2003) declared that *Rhizobium* inoculant with fertilizer increase the number of pods per plant, number of seeds per plant and 1000-seed weight. These observations are unity with Akhtar and Siddiqui (2009) and Meena *et al*., (2013). El Hadi and Elsheikh (1999); Maleki *et al.* (2009); Ogola (2015) reported that inoculation of grasspea seed with *Rhizobium* and chemical fertilizer application in the field improve the yield of grasspea plants. The increase in the yield components through seed inoculation might be due to higher nodulation and more nutrient availability, resulting in vigorous plant growth and dry matter accumulation, which in turn resulted in higher seed yield (Namvar *et al*, 2013; Uddin *et al,* 2014).

The nodule number was increased significantly in three different varieties of grasspea plants. The nodulation capacity was also increased in three different fertilizer doses where *Rhizobium* inoculants were used simultaneously. The root nodules are degree of infection leading to nodule development after *Rhizobium* inoculation (Bhattacharjay *et al*., 2009). The positive effect of *Rhizobium* inoculation with chemical fertilizer on number and dry weight of nodules per plant in grasspea is very well documented by various researchers (Eusuf Zai *et al.*, 1999; Bhuiyaan *et al*., 2008a). *Rhizobium* inoculation resulted in excellent nodulation in contrast to poor nodulation in without inoculation (Khattak *et al.*, 2006). Suryawanshi *et al.*, 2007 observed significant effect of inoculation on nodule number and nodule dry weight. Inoculation studies have been shown to increase nodule number and nodule dry and fresh weight per plant in grasspea (Verma *et al.*, 2010; Sahai and Chandra, 2010).

Grasspea is valued for its high protein content. Usually grasspea contains near about 28.2% protein in grain. Since protein content in grain directly associated with N content in grain. Qureshi *et al*., (2009) reported that inoculation with *Rhizobium* of grasspea increase the N and P content in grain. It also increases the N and P content in shoot of grasspea plants (Erman *et al*., (2011). Sahai and Chandra (2011), Rokhzadi and Taoshih (2011) and Das *et al*., (2012) reported that *Rhizobium* inoculation with chemical fertilizer in grasspea improve the nutrient uptake from soil. Use of *Rhizobium* inoculants helps in improving available N and P in the soil after crop harvest which can be utilized by the next crop (Abdalla *et al*, 2013). Similarly, Chandra and Pareek (2015) recorded 0.6%, 6.5% and 4.3% higher organic carbon, available N and available P, respectively, in a *Rhizobium* inoculated grasspea. These findings are in line with those of Zaidi *et al.*, (2003) and Tagore *et al.*, (2013).

Conclusions

In conclusion, the present study showed that among three fertilizer doses, *Rhizobium* + 100% PKSZnB and 100% NPKSZnB performed better than rest of the fertilizer doses and exhibits the maximum nodulation. Regarding the three grasspea varieties, BARI khesari-5 unveiled the maximal nodulation compare to other varieties of grasspea. On the other hand, integrated effects of fertilizer doses and varieties exhibited that *Rhizobium* + 100% PKSZnB with BARI khesari-5 executed better than rest of the combinations. Beside these, yield and yield contributing attributes of grasspea varieties, same dose, same variety and same combinations which were described earlier performed better than others at Gazipur. According to the findings of experiment it may be declared that grasspea required 16-17 days for their first nodule initiation. Considering the microbial population status, *Rhizobium* + 100% PKSZnB with BARI khesari-5 exhibited the higher number of populations than others. Among nine different treatment combinations, it was observed that *Rhizobium* + 100% PKSZnB with BARI khesari-5 and BARI khesari-6 showed the maximum nutrient uptake in case of N, P, K, and S, respectively which was followed by 100% NPKSZnB with BARI khesari-5 and BARI khesari-6 at Gazipur. In apparent nutrient balance study, the entire nutrient showed the negative balance. Further assessment in needed to validate the findings.

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ISOLATION OF PHOSPHATE SOLUBILIZING BACTERIA (PSB) AND THEIR EFFICACY ON THE GROWTH OF BARLEY

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Abstract

A pot experiment was conducted during rabi season 2021-2022 at the net house of Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur to isolate the phosphate solubilizing bacteria (PSB) and their performance on the growth of barley laid out in RCBD with three replications. There were five treatments viz. T_1= Control, T_2= PSB isolate I (AEZ-29), T_3= PSB isolate II (AEZ-03), T_4= PSB isolate III (AEZ-11) and T_5= PSB isolate IV (AEZ-09). The four isolated PSB strains containing about 10^8cells g^{-1} inoculum. Among five different treatment combinations, T_4 (PSB isolate III, AEZ-11) performed better than others. The germination percentage (97.16%) and seedling vigor index (3588) exhibited the better results significantly in T_4 treatment. In different growth parameters of barley like plant height (75.94 cm), root length (21.53 cm), root weight (397.52 mg), no. of tiller per hill (2.30), no. of spikes per hill (2.13), no. of kernel per spike (45.83), spike length (15.40 cm) and no. of filled kernel per spike (41.03) also showed the superior results in the same treatment. The PSB isolate III, AEZ-11 (T_4) revealed the maximum 1000-kernel weight (33.75 gm), seed yield per 10 plants (33.88 gm) and straw yield per 10 plants (54.99 gm), respectively. In respect of nutrient content, the seed and straw of barley showed the maximum amount of N (2.43 and 1.42%), P (0.69 and 0.51%), K (0.91 and 2.48%) content in the T_4 treatment. The better performing PSB isolate (PSB isolate III) increased the P availability in the soil than rest of the three isolates. The enormous amount of PSB population (3.0 x 10^5 per gm soil) was also produced in the T_4 treatment. The worst performance was recorded in the T_1 (Control) treatment in case of all parameters of barley production.

Introduction

Barley is a minor cereal in Bangladesh. It is known as "Zob″. It is cultivated in Bangladesh from long days ago. It can be grown in unfertile char land of Bangladesh. Nutritional value of barley is higher than wheat. In Bangladesh, total cultivable land is about 330 hectares and total production is near about 287 metric tons (BBS, 2015). Phosphorus is one the most essential elements for plant growth after nitrogen. However, the availability of this nutrient for plant is limited by different chemical reactions especially in arid and semi-arid soils. Phosphorus plays a significant role in several physiological and biochemical plant activities like photosynthesis, transformation of sugar to starch, and transporting of the genetic traits. Sharma (2002) reported that the advantages of feeding the plants with phosphorus are to create deeper and more abundant roots. Phosphorus causes early ripening in plants, decreasing grain moisture, improving crop quality and is the most sensitive nutrient to soil pH (Malakooti, 2000). Malakooti and Nafisi, (1995) declare that the best pH for P uptake is 6.5. Arpana *et al*. (2002) reported that a great proportion of phosphorus in chemical fertilizer becomes unavailable to the plants after its application in the soil. They referred this information of strong bonds between phosphorus with calcium and magnesium in alkaline pH and the same bonds with iron and aluminum in acidic soil. Therefore, the plants need an assisting system which could extend beyond the depletion zones and help to absorb the phosphorus from a wider area by developing an extended network around root system (Salehrastin, 1999). Bio-fertilizers (Phosphate Solubilizing Bacteria) are considered among the most effective plant assistants to supply phosphorus at a favorable level. These fertilizers are produced on the basis of selection of beneficial soil microorganisms which have the highest efficiency to enhance plant growth by providing nutrients in a readily absorbable form. Application of inoculants provided from these microorganisms enhances an abundant population of active and effective microorganisms to the root activity zone which increases plant ability to uptake more nutrients. Phosphate solubilizing microorganisms refer to a group of soil microorganisms that as components of phosphorus cycle, can release it from insoluble sources by different mechanisms (Salehrastin, 1999). Phosphate solubilizing fungi and bacteria are known as effective organisms in this process (Reyes *et al.* 1999). Among the soil bacteria communities, *Pseudomonas strata* S., *Bacillus sircalmous* and intrubacters could be referred to as the most important strains (Subbarao, 1988). In particular, *Pseudomonas flourcents* is considered as an important member of rhizosphere organism community. The positive effect of *Pseudomonas* inoculation on plant growth has been reported in many research trials. Phosphate solubilizing bacteria like *Z-ketuaxelalic sp.*, *Malic* sp. and *Socsinic sp.* are able to affect the solubility of low dissolvable inorganic phosphorus compounds, by secreting different organic acids. The other bacteria of the same group are able to release phosphorus from phosphorus organic compounds, by producing phosphate enzymes. Regarding to conducted researches, the role of Phosphate solubilizing bacteria and their potential capacity to influence phosphorus cycle processes in plant-soil system, cannot be ignored. Phosphate solubilizing bacteria not only release phosphorus but also produce other biological compounds like hormones such as auxin and gibberellic acid as well as vitamins. The increase in number and diversity of microorganisms and their interaction lead to increase in number and diversity of effective organic acids through the solubility process of insoluble phosphorus (Arpana *et al.* 2002). Yahya and Azawi, (1998) reported the highest population of Phosphate solubilizing bacteria in agricultural and rangeland soils. Kim *et al*. (1989) indicated that the population of Phosphate solubilizing bacteria depends on cultural activities and different soil properties (physical and chemical properties, organic matter, and soil phosphorus content). The Bacteria species *Pseudomonas sp*. has a considerable potential in phosphorus uptake efficiency. Due to the ecotype diversity of this species and its tolerance in some environmental stresses, this bacterium is of special importance as a biological fertilizer (Kim *et al.* 1989 and tilak *et al.* 1995).

One of the most important means to achieve the goals of sustainable agriculture is to extent the application of biofertilizers. To reach this goal, it is necessary to moderate the use of chemical fertilizers and pesticides through the time and in the meantime increase the soil organic matter. By considering the above discussion following objectives were undertaken such as

I) To isolate the phosphate solubilizing bacteria (PSB) from rhizospheric soil from four different AEZs soils of Bangladesh

II) To evaluate the ability of PSB on the growth of barley

III) To monitor the soil fertility status

Materials and Methods

Location and treatments of the experiment

A pot experiment was conducted at the Net house of Soil Science Division, BARI, Joydebpur, Gazipur. The tested crop was Barley (cv. BARI barley-6). The experiment was laid out in RCBD with five treatment combinations viz. T_1= Control, T_2= PSB isolate I (AEZ-29), T_3= PSB isolate II (AEZ-03), T_4= PSB isolate III (AEZ-11) and T_5= PSB isolate IV (AEZ-09), respectively. Each treatment was replicated three times. Before filling up the pot, all the potting media (soil) were autoclaved by maintained a standard protocol. After filling up the pot, all the potting media was fertilized by 0.51, 0.42, 0.40, 0.18 gm and 25gm Urea, TSP, MoP, Gypsum and cowdung, respectively. Barley seeds were sown on 27 November 2021 and harvested on 10 March 2022, respectively. Intercultural operations like watering, weeding, insect pest managements etc, were done as and when necessary. Initial soil sample was collected and analyzed. After harvest of the test crop, we also collected the post-harvest soil and plant samples to analyze the different nutrient content and microbial population status.

Isolation and selection of PSB bacterial isolates

To isolate Phosphate Solubilizing Bacteria (PSB) bacteria, soil samples were collected from four different AEZs soils of Bangladesh from the root zone of barley crop field. Phosphate-solubilizing bacteria were isolated from rhizospheric soil samples by plating serial dilutions of rhizospheric soil extracts in Pikovskaya's solid medium (Pikovskaya, 1948). That medium contains insoluble tri- or bi-calcium phosphate, allowing the detection of phosphate-solubilizer microorganisms by the formation of "halos" around their colonies. The addition of bromophenol blue, which produces yellow-colored halos around the colonies in response to the pH drop by the release of organic acids, or proton release in exchange for cation uptake, generates more reproducible results than with the simple halo method (Gupta *et al*., 1994). Although phosphate-solubilizing capability remains stable in most isolates, some strains show instability of this trait after several cycles of inoculation (Halder et al., 1990 and Illmer *et al*., 1992). Thus, the persistence of phosphate-solubilizing capacity after five or more subcultures should be the first criterion in selecting bacterial strains as microbial inoculants. Last of all, the identification of the most efficient phosphate solubilizers in vitro has to be done by quantifying their phosphate-solubilizing capacities in liquid cultures since, in some cases, there have been contradictory results between plate halo detection and phosphate solubilization in liquid cultures (Rodriguez *et al*., 1999). In this regard, a novel defined microbiological growth medium (NBRIP), which demonstrated about 3-fold higher efficiency compared to Pikovskaya's medium, has been formulated by Nautiyal, (1999). After in vitro selection of the most efficient phosphate solubilizers, experiments should be carried out in order to know the effectiveness of the selected PSB strain(s) in association with the crop to be inoculated. The response of plant species or genotypes to inoculation often varies according to the bacterial strain used. Differential rhizosphere effect of crops in harboring a target PSB strain (Gaind *et al*., 1991 and Pal, 1998) or even the modulation of the bacterial phosphate-solubilizing capacity by specific root exudates (Goldstein *et al*., 1999) may account for the observed differences. Finally, field trials to test the performance of the inoculum under real conditions are advisable since the efficiency of the inoculation varies with the soil type, P content of the soil, and other parameters (Rodriguez *et al*., 1999). By maintaining all the criteria, we selected four isolates (isolate I, Isolate II, Isolate III and Isolate IV) to conduct our experiment.

Soil and plant analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Soil texture was determined by hydrometer method (Beverwijk, 1967). Organic carbon was determined by wet oxidation method (Walkley and Black). Total N was determined by modified Kjeldahl method. Calcium, K and Mg were determined by NH_4OAc extraction method. Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Modified Olsen method (Neutral + Calcareous soils). Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$. PSB population status was determined by plate counting method.

Table 1a. Physical, chemical and microbiological population (PSB) status of initial soil during 2021-2022

Location	Soil texture	pH	OM (%)	Ca	Mg	K	Total N (%)	Available P ppm	P	S	Cu	Fe	Mn	Zn	B	PSB population g^{-1} soil
				meq $100g^{-1}$ soil					ppm							
Kodda soil, Gazipur	Sandy loam	8.32	0.88	9.54	1.71	0.25	0.06	27	17	40	1.79	47.89	6.22	3.53	0.80	1.5×10^4
Critical level	-	-	-	2.0	0.5	0.12	-	-	10	10	0.2	04	1.0	0.60	0.2	-

Table 1b. Chemical and microbial population (PSB) status of post-harvest soil during 2021-2022

Treatments	pH	OM (%)	Ca	Mg	K	Total N (%)	Available P ppm	P	S	Cu	Fe	Mn	Zn	B	PSB population g^{-1} soil
			meq $100g^{-1}$ soil					ppm							
T_1	8.4	1.21	5.6	1.72	0.12	0.06	35	12	33	1.61	22.7	3.01	3.41	0.82	1.0×10^5
T_2	7.21	1.21	5.9	1.81	0.15	0.07	38	13	34	1.63	21.0	2.82	3.43	0.32	2.5×10^5
T_3	7.11	1.22	5.8	1.81	0.15	0.07	39	14	33	1.72	22.9	3.12	3.72	0.36	2.5×10^5
T_4	7.10	1.55	5.5	1.74	0.17	0.08	39	15	33	1.91	23.1	3.13	3.43	0.22	3.0×10^5
T_5	7.13	1.38	6.2	1.79	0.16	0.08	38	14	33	1.91	22.2	3.10	3.44	0.54	2.0×10^5
Critical level	-	-	2.0	0.5	0.12	-	-	10	10	0.2	04	1.0	0.60	0.2	-

T_1= Control, T_2= PSB isolate I (AEZ-29), T_3= PSB isolate II (AEZ-03), T_4= PSB isolate III (AEZ-11) and T_5= PSB isolate IV (AEZ-09)

Germination percentage (%)

During the course of the experiment growth and development of plants in the pot were carefully observed. Seed germination tests were carried out according to ISTA (1993) methods and performed with four replications of 25 seeds each. The germination test was conducted using sand method of germination and 25 seeds per replication were sown on sterilized sand. Distilled water was added to each beaker every alternate day while inside the germinator to keep uniform moisture content of paper towels. No light was provided during germination, as light is not necessary for germination of barley seeds (I.S.T.A., 1985). Seeds were considered germinated when the emerging radical was at least 2 mm long (Murillo Amador *et al.*, 2002). Final count was made on eighth (8th) day. The germination percentage was calculated by counting the total number of seeds germinated from each replication at final count.

Seedling vigor index

The germination percentage obtained in the germination test was used to calculate vigor index. The vigor index was calculated adopting the method of Abdul Baki and Anderson (1973).
Vigor Index I = Germination percentage x average seedling length

Vigor Index II = Germination percentage x seedling dry weight in milligrams. But here we calculated the vigor index II only.

Growth analysis

All the yield and yield contributing characters such as plant height (cm), root length (cm), root weight (mg), number of tillers per hill, number of spikes per hill, number of kernels per spike, spike length (cm), number of filled kernel per spike, number of unfilled kernels per spike, 1000-kernel weight, seed yield and straw yield data were recorded. Ten (10) randomly plants were selected and uprooted to take the data of above mention parameters.

Statistical analysis

Data were statistically analyzed using Analysis of Variance (ANOVA) following Crop Stat package while the all-pair comparisons were done by Statistix-10 software (Gomez and Gomez, 1984).

Results and Discussion

Results

Germination percentage (%) of barley

Phosphate Solubilizing Bacteria (PSB) has the greatest influence on the germination percentage (%) of barley. Among five different treatment combinations we remarked that T_4 (PSB isolate III) treatment exhibited the highest germination percentage (%) compare to other treatments significantly. The maximum germination percentage was 97.16% in at T_4 treatment and the lowest percentage was at T_1 (control) treatment which was 90.66%. The other three treatments (T_2, T_3 and T_5) had the good impact on germination percentage of barley over control (Table 2a).

Seedling vigor index

A seedling vigor index determines how well it performs, its ability to yield strong seedlings that become robust and uniform plants. On the other hand, seedlings seen to be low in vigor will produce weaker seedlings that will be more susceptible to attack, contamination, and other environmental issues. Phosphate Solubilizing Bacteria (PSB) was performed better in seedling vigor index over control. In five different treatment combinations we noticed that T_4 treatment revealed the highest seedling vigor index compare to remaining treatments significantly. Besides, T_3 and T_5 treatment statistically identical with T_4 treatment. The highest seedling vigor index was 3588 which was higher than rest of others (Table 2a). The least seedling vigor index was at T_1 treatment (control) which was 1777 (Table 2a). So, our study focused that PSB isolates had the ability to produce stronger seedlings for crop production of barley.

Effect of PSB on the growth of barley

PSB isolates have the significant effects on different growth parameters of barley. In our investigated research study, we used four PSB isolates from four different AEZs soils of Bangladesh with one control treatment. Among five different treatments, we observed that only T_4 treatments had the superiority compare to others in respect of plant height (cm), root length (cm), root weight (mg), number of tillers per hill and number of spikes per hill, respectively. The highest plant height was recorded at T_4 treatment which was 75.94 cm compare to rest of the others significantly but T_5

treatment identical with T_4 treatment statistically (Table 2a). The same treatment revealed the supremacy in case of root length (cm), root weight (mg), number of tillers per hill, number of spikes per hill which were 21.53 cm, 397.52 mg, 2.30 and 2.13, respectively (Table 2a). On the contrary, T_1 treatment exhibited the lower value in case of all growth parameters (Table 2a). Besides these, number of tillers per hill and number of spikes per hill, we noticed that T_2 and T_5 treatments were identical with T_4 treatment statistically (Table 2a).

Table 2a. Phosphate Solubilizing Bacteria (PSB) effects on growth parameters of barley at pot study during 2021-2022 at Gazipur

Treatments	Germination (%)	Seedling vigor index (%)	Plant height (cm)	Root length (cm)	Root weight (mg)	No. of tillers per hill	No. of spikes per hill
T_1	90.66b	1777c	65.49c	15.41d	235.3c	1.66b	1.46c
T_2	94.83a	2776b	71.77b	17.40c	282.3bc	2.10a	2.06a
T_3	95.50a	3145ab	70.35b	19.04bc	289.0bc	1.80b	1.73bc
T_4	95.83a	3588a	75.94a	21.53a	397.52a	2.30a	2.13a
T_5	97.16a	3135ab	73.14ab	19.74b	322.1b	2.13a	1.96ab
SE (±)	1.25	283.2	1.71	0.72	28.63	0.11	0.13
F test	**	**	**	**	**	**	**
CV (%)	1.62	12.03	2.94	4.76	11.49	7.27	8.61

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significance.

T_1= Control, T_2= PSB isolate I (AEZ-29), T_3= PSB isolate II (AEZ-03), T_4= PSB isolate III (AEZ-11) and T_5= PSB isolate IV (AEZ-09)

Effect of PSB on yield and yield contributing attributes of barley

In between five different treatments, we really point out that T_4 (PSB isolate III) treatment showed the dominancy in case of all yield and yielding parameters of barley. Statistically the number of kernels per spike, spike length (cm), number of filled kernels per spike, number of unfilled kernels per spike, 1000-kernel weight (gm), seed yield per 10 plants (gm) and straw yield per 10 plants (gm) recorded the highest value in T_4 treatment compare to all others significantly. The uppermost value of number of kernels per spike, spike length (cm), number of filled kernels per spike, number of unfilled kernels per spike, 1000-kernel weight (gm), seed yield per 10 plants (gm) and straw yield per 10 plants (gm) were 45.83, 15.40 cm, 41.03, 4.80, 33.75 gm, 33.88 gm and 54.99 gm, respectively (Table 2b). The lowest value was recorded at T_1 (control) treatment in our conducted research study (Table 2b).

Table 2b. Phosphate Solubilizing Bacteria (PSB) effects on yield and yield contributing characters of barley at pot study during 2021-2022 at Gazipur

Treatments	No. of kernel per spike	Spike length (cm)	No. of filled kernel per spike	No. of unfilled kernel per spike	1000-kernel weight (gm)	Seed yield/10 plants (gm)	Straw yield/10 plants (gm)
T_1	41.03b	13.00d	31.90d	9.13a	28.51d	24.60d	43.30c
T_2	42.63b	14.30c	36.33c	6.30b	29.80c	29.29c	50.66b
T_3	41.03b	14.91ab	36.23c	4.80c	31.88b	30.47bc	50.85b
T_4	45.83a	15.40a	41.03a	4.80c	33.75a	33.88a	54.99a
T_5	45.00a	14.65bc	39.46b	5.53bc	32.57b	31.22b	51.55ab
SE (±)	0.84	0.22	0.60	0.45	0.45	0.62	1.61
F test	**	**	**	**	**	**	**
CV (%)	2.40	2.00	2.02	9.20	1.78	2.54	3.94

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significance.
T_1= Control, T_2= PSB isolate I (AEZ-29), T_3= PSB isolate II (AEZ-03), T_4= PSB isolate III (AEZ-11) and T_5= PSB isolate IV (AEZ-09)

Nutrient content in seed and straw of barley

The nutrient content in seed and straw of barley plant varied from one treatment to others significantly. Among five different treatment combinations, the analytical data represented that N content was recorded higher in seed rather than straw. The barley seed and straw displayed the maximum N (2.43% and 1.42%) content in T_4 treatment which was higher than others. The P (0.69% and 0.51%) content was also found higher at T_4 treatment in respect of seed and straw compare to rest of the treatments. The seed and straw of barley plant exhibited the maximum amount of K, S and Ca content at T_4 treatment. The highest K content was 0.91%, 2.48% in seed and straw of barley plant, respectively. The S and Ca content was followed the above trend. The highest S content was found at 0.16%, 0.22% in seed and straw of barley plant. The topmost amount of Ca content was observed at 0.87%, 0.81% in seed and straw. In Mg content study, we noticed that the high level of Mg content was noted at T_4 treatment in seed and straw of barley. The highest Mg content was found at 0.56% in seed and 0.54% was also in straw of barley plant. The lowest amount of N, P, K, S, Ca and Mg content was recorded at T_1 treatment in our investigated study. According to the above findings we were clearly stated that the PSB application in barley cultivation helps to uptake the all nutrients which were essential for the growth and development (Table 2c).

Table 2c. Phosphate Solubilizing Bacteria (PSB) effects on percent nutrient content in seed and straw of barley at Gazipur during 2021-2022

Treatments	**N**		**P**		**K**		**S**		**Ca**		**Mg**	
	%											
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
T_1	1.91c	1.22d	0.51c	0.34c	0.81c	1.92d	0.10b	0.14d	0.45e	0.51c	0.31d	0.26d
T_2	2.19b	1.33c	0.63b	0.43b	0.86b	2.13c	0.14a	0.17c	0.58d	0.57c	0.42c	0.33c
T_3	2.28ab	1.38ab	0.65ab	0.44b	0.86b	2.33b	0.13a	0.18bc	0.69c	0.65b	0.46b	0.37c
T_4	2.43a	1.42a	0.69a	0.51a	0.91a	2.48a	0.16a	0.22a	0.87a	0.81a	0.56a	0.54a
T_5	2.33ab	1.37bc	0.64ab	0.49ab	0.88b	2.34b	0.15a	0.20ab	0.74b	0.76a	0.47b	0.43b
SE (±)	0.08	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.006	0.03	0.008	0.02
F test	*	**	**	**	**	**	*	**	**	**	**	**
CV (%)	4.79	1.89	4.16	6.67	1.80	1.58	10.06	8.39	1.26	6.28	2.21	6.87

Different letters indicated significant difference within columns at 0.05 probability level, (**) indicates that significant at 1% level of significance.
T_1= Control, T_2= PSB isolate I (AEZ-29), T_3= PSB isolate II (AEZ-03), T_4= PSB isolate III (AEZ-11) and T_5= PSB isolate IV (AEZ-09)

Physicochemical and microbiological status of soil

The texture of the soil was sandy loam in nature which was used in experiment as a media. Initial soil pH was 8.32 but after application of PSB on that soil, the pH was slightly reduced up to 7.10 because PSB inoculation in soil released some organic acids which was reduced the pH of soil. Organic matter content was improved up to 0.88% to 1.55% after completion of the experiment. Ca and K content was decreased from the existing soil condition but Mg content increased in post-harvest soil. The N content of the soil was increased up to 0.06 to 0.08%. Soil P content was decreased in post-harvest soil because plant take luxurious amount P content from soil but available P content was increased in PSB inoculated treatment. S, Cu, Fe, Mn, Zn and B content was decreased in post-harvest soil of the experimental pot. Microbial population status revealed that enormous amount of PSB population was observed in post-harvest soil. The maximum number of PSB population was found at T_4 treatment which was 3.0 x 10^5 g^{-1} soil and the lowest number was observed at T_1 treatment (Table 1a and 1b). These results may be attributed to production of more crop biomass due to inoculation and consequently higher return of organic residues and exudates into the soil enhancing microbial biomass and activities (Babu *et al.* 2015).

Discussion

Phosphorus is one of the vital elements for the growth and development of barley (Tigre *et al.* 2014). On the basis of essentiality, its position just after nitrogen. However, its availability for plants in soil for uptake is retarded due to different chemical reactions. When it's applied in the soil, its fixed with soil particles in between high and low pH. For this nature of P fertilizer, we have to apply huge amount of P containing fertilizer in the soil. To alter the nature of P fertilizer in the soil, Phosphate Solubilizing Bacteria (PSB) is an immediate solution for this problem. PSB is usually effective on phosphate solubility. Inoculation of PSB with barley seeds increased the seed germination percentage as well as seedling vigor. The findings of our research study which is comparable with the results of Gholami *et al*. (2009) who reported that inoculation of PSB with seeds enhance the seed germination percentage. Because PSB inoculants synthesis the seed germination hormone like gibberellins which triggered the activity of specific enzymes that promoted early seed germination, such as α amylase that increase the availability of starch assimilation. Sharma *et al.* (2007)., Aipova *et al*. (2010) and Egamberdiyeva, (2007) agreed with our findings who declared that PSB inoculations with seeds rise the seed germination percentage and seedling vigor index of plants. Phosphate solubilizing microorganisms enhanced plant growth and increase crop yields by one or more mechanisms such as phosphate solubilization and mineralization, production phytohormones, bioactive ingredients and organic growth promoting substances (Khan *et al.* 2009). Also, Phosphate solubilizing microorganisms enhancing phosphorus availability to plants by lowering the soil pH due to its organic acids production and can mineralized organic P by acid phosphatases. These bacteria have been shown to enhance the growth parameters and yield of barley. Gaind and Gaur, (1991)., Abd-Alla, (1994)., Tomar *et al.*, (1998)., Khalid *et al.*, (2004) and Pandey *et al*., (2006) agreed with the above findings. Mehrvarz and Chaichi, (2008)., Suri and Choudhary, (2010)., Awasthi *et al*. (2011) and Lone *et al*. (2011) declared that PSB inoculation increase the plant height (cm), root length (cm), tillers number, spike length (cm), number of grains per spike, 1000-kernel weight and yield of barley to reducing soil pH by organic acids realization and mineralized organic phosphorus by phosphate fertilizer. In our investigated study, we observed that PSB application in barley production enhance the nutrient content in grain and straw. Gaur, (1990)., Gaind and Gaur, (1991)., Dubey, (1996)., Anthoniraj et al. (1994) and Pal, (1998) reported that PSB inoculation in crop plants increase the nutrient contents in grain and straw of barley.

Conclusions

According to the findings of the experiment revealed that inoculation of PSB biofertilzer enhance the growth, yield and nutrient content of barley over control. The PSB biofertilizers are considered as the most favorable natural compounds to enhance the micro-organism activities in the soil. Among five different treatments, T_4 (Isolate III) treatment performed better than rest of the treatments. Microbial population status and P availability was also increased in the same treatment. It was a preliminary trial. So further investigation is needed to establish the above findings.

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Bangladesh Agricultural Research Institute
Soil Science Division
Joydebpur, Gazipur

Research Achievements 2021-2022

(Technology Developed)

Sl. No.	Technology Developed	How Country/Farmer/User will be benefited
Physical Aspects of Soil Management		
1.	Sweet pepper water requirement by Lysimeter study during crop cultivation Growth stage wise crop coefficient values (Kc) of Sweet pepper (cv. BARI Misti morich-1 at Initial, development, mid-season and late season stages was found 0.43, 0.82, 0.94 and 0.86)	Water requirement of sweet pepper could be estimated using Kc values, which would increase water use efficiency, crop yield and reduce production cost through saving irrigation water.
2.	Strip tillage and urea super granule application increase the crop productivity and improve soil fertility under Gardenpea-Aroid-T. aman cropping system Application of strip tillage and USG (urea super granule) $N_{40}P_{35}K_{110}$ $S_{40}Zn_1B_1$ kg ha^{-1} for Gardenpea, $N_{140}P_{30}K_{115}S_{15}$ kg ha^{-1} with 6 t cowdung ha^1 for aroids and $N_{100}P_5K_{45}S_{10}Zn_1$ kg ha^{-1} for T.aman) produced the highest yield for gardenpea-aroids-T. aman cropping at Gazipur district (AEZ-28).	Increase system productivity, improve soil fertility and decrease production cost, expected to be maintained by following the strip tillage and urea super granule application.
Chemical Aspects of Soil Management		
1.	Improved soil fertility and crop productivity using crop residues biochar at Gazipur Biochar is made from crop residues (i.e. groundnut straw, chickpea straw and mustard straw) and its effectiveness is compared to cow dung. The stability of soil carbon is compared.	Crop straw biochar enhanced the yield of BARI Khoi Bhutta up to 45% from RDCF and 25% from crop straw. The reduction of carbon content is slower in biochar applied soil and higher in CD and crop straws amending materials. The users will be benefitted by adopting this technology due to no cost of lime application to remove soil acidity as well as improve soil fertility and long-term carbon retention in the soil.
2.	Cabbage production by applying Rice Husk biochar to reduce the chemical fertilizers at Gazipur Biochar produced from rice husk and three rates (1.5, 3.0 and 4.5 t ha^{-1}) with 100% or 80% RDCF was applied to compare with control and 100% RDCF.	Compare to RDCF with 4.5 tha^{-1} RHB yield increased up to 43% and reduction of 20% RDCF from RDCF increased up to 35% from RDCF applied soil. The users will be benefitted by adopting this technology due to improve soil fertility and long-term carbon retention in the soil.

Sl. No.	Technology Developed	How Country/Farmer/User will be benefited
3.	Nutrient management for a rooftop garden Application of 80% Soil Test Based fertilizer doses along with 2 kg vermicompost for 6 kg soil as media was found optimum for maximizing the yield of different vegetables, fruits and flowers grown on the rooftop garden.	The crop yields were increased up to 75% in the rooftop garden by application of integrated nutrient management package (80% Soil Test Based fertilizer doses along with2 kg vermicompost for 6 kg soil). Rooftop gardens increase the amount of arable land to produce food which has an impact on GDP. The developed technology may help in increased crop production as well as income of the rooftop gardeners.
4.	Groundnut yield and soil fertility improvement by using vermicompost at charland, Jamalpur Among the treatments, 85% RDCF with vermicompost @ 3 t ha^{-1} produced the highest average groundnut yield 2.16 t ha^{-1} which was 19.33 % higher over 100% RDCF dose due to carbon accumulation in soil	Integrated use of chemical fertilizer with vermicompost could be a superior recommendation for higher groundnut yield. Farmers may be advised to cultivate groundnut in charland applying 85 % chemical fertilizer with vermicompost @ 3 t ha^{-1} application. This practice would enable farmers to increase productivity of groundnut by reducing at least 15% of chemical fertilizer.
5.	Increasing onion yield and improving soil health through organic fertilizers and biofertilizer at Jamalpur Among the treatments, Tricho compost (5t/ha.) + IPNS basis NPKSZnB +AM gave the highest bulb yield, root colonization and no of spore population. Macro and micronutrient uptake significantly increased over STB fertilizer.	Integrated use of tricho compost (5 t/ha), arbuscular mycorrhizal fungi along with IPNS based chemical fertilizers is found optimum for onion yield bulb yield (22.65 tha^{-1}) in Old Brahmaputra Floodplain Soil of Jamalpur (AEZ-9). It also helps to reduce the chemical fertilizer, carbon accumulation to the soil and sustain soil environment. This technology will be cost effective.
6.	Nutrient management through tricho-compost on the yield of garlic at Jamalpur Tricho compost @ 4 t ha^{-1} with IPNS basis chemical fertilizer produced highest yield (9.41 tha^{-1}).	Integrated use of tricho compost (4 t/ha) with IPNS based chemical fertilizers is the best treatment for garlic yield in Old Brahmaputra Floodplain Soil of Jamalpur (AEZ-9). Farmers will be benefited financially by increasing the garlic cultivation by reducing the cost as well as soil borne pathogen. This will also improve soil health due to addition of organic fertilizer.
7..	Production of foxtail millet through integrated nutrient management in Gazipur and Jamalpur regions IPNS with 1.5 t ha^{-1} vermicompost is superior to the other fertilizer management packages in respect of yield and nutrient uptake as well as economic return for cultivation of foxtail millet in the the Grey Terrace soil of Gazipur (AEZ-28) and Dark Grey Floodplain soil of Jamalpur (AEZ-9) districts of Bangladesh.	Integrated use of vermicompost (1.5 t/ha) with IPNS based chemical fertilizers technology provided the highest yield of foxtail millet at Gazipur (2.38 t ha^{-1}) and Jamalpur (2.26 t ha^{-1}) where economic return (BCR 2.26 and 2.19 at Gazipur and Jamalpur, respectively). It also increases the nutrient uptake and sustaining the soil fertility.

Sl. No.	Technology Developed	How Country/Farmer/User will be benefited
8.	Growth and quality improvement of brinjal by application of Vermiwash at Jamalpur Chemical fertilizer with foliar spray of 20% concentration of vermiwash boosts Brinjal yield by 10% to 15% over sole chemical fertilizer application.	Farmers will profit from an increase in brinjal production since vermiwash promotes successful and early flowering. Vermiwash treatment increases brinjal quality parameters because nutrients are more readily available in liquid form.
9.	Application of kitchen waste compost on soil carbon accumulation and tomato yield. Application of 100% chemical fertilizer with kitchen waste compost @ 5 t ha^{-1}can boost tomato yield and promote soil carbon buildup.	Application of Kitchen Waste Compost @ 5 tha^{-1} with 100% recommended dose of chemical fertilizer can be practiced for achieving higher yield of tomato as this combination enhanced the yield of tomato up to 22.4% from RDCF. It also brings economic benefits and environment's cleanliness.
Micronutrient Aspects of Soil Management		
1.	Yield and nutrient uptake of cauliflower increased by seed priming The combined use of micronutrients, seed soaked with 0.05% zinc and 0.01% boron gave the highest yield 59.2 t $ha^{-1}$of cauliflowers	Seed priming with a combination of micronutrients significantly improved yield and nutrient uptake which was cost effective and economically more viable than soil application.
2.	Boron application increased yield and nutrient uptake of mungbean BARI Mung 8 produced the highest (1.60 t ha^{-1}) yield by the application of 1.5 kg B ha^{-1} as compared to the other treatment at Tista Meander Floodplain Soil of Rangpur (AEZ-3) during kharif season	Production cost will be minimized and yield of BARI Mung-8 will be maximized through application of boron**.**
Microbiological Aspects of Soil Management		
1.	Biofertilizer application with legume crops increased yield in the farmer's field *Rhizobium* biofertilizer application with legume @ 1.5 kg ha^{-1} increased yield up to 30% in the field.	Application of biofertilizer (*Rhizobium*) with PKSZnB on legume crops increased the yield. It also motivates the farmers to use biofertilizer instead of N fertilizer.
2.	Bulb yield of onion increased after combined application of Azotobacter with reduced N fertilizer doses Azotobacter application in combination with reduced N fertilizer doses increased bulb yield of onion up to 70% over control in the field.	Application of Azotobacter with 80% N fertilizer increased the growth and onion bulb yield. It also reduced the 20% N fertilizer uses during onion production.
3.	Application of Arbuscular Mycorrhizal (AM) fungi and phosphorus on cauliflower Arbuscular Mycorrhizal (AM) fungi with 50% P fertilizer application increased curd yield of	The plant that received Arbuscular Mycorrhizal fungi in nursery bed produced higher curd yield than without AM in all phosphorus levels of cauliflower. The

Sl. No.	Technology Developed	How Country/Farmer/User will be benefited
	cauliflower up to 25% over control and also maintain the soil fertility.	application of AM with 50% P fertilizer increased the curd yield of cauliflower. It also saves 50% P fertilizer during cauliflower production.

Research Progress 2021-2022

Sl. No.	Research Progress	Expected Output
Programme area/Project: Physical Aspects of Soil Management		
1.	Synchronization of different aged compost to crop demand, nutrient release and their contribution to the production of red amaranth	75 days aged compost performed the best for red amaranth production under protected structure without affecting plant growth and yield. The nutritional status of the plants demonstrated that the nutrients were adequate and met the requirements for plant growth and yield of compost on plant growth and yield might vary depending on degree of mineralization of the organic matter. This is the first year experiment; further studies need to be required for final recommendation.
2.	Integrated nutrient management for cutting of Indian spinach under minimum tillage system	Cutting of Indian spinach was transplanted at 03 July, 2022. Now the crop is on field at harvesting stage and already 3 cut completed.
3.	Integrated nutrient management for cutting of kangkong under minimum tillage system	Cutting of kangkong was transplanted at 30 June, 2022. Now the crop is on field at harvesting stage and already 4 cut completed.
4.	Effect of crop establishment practices and IPNS based nutrient management on cabbage-Indian spinach- T. aman cropping system and soil physical health	Strip tillage gave better yield for cabbage and for T.aman but vice-versa for Indian spinach due to residual nutrient of subsequent crop. IPNS package gave the maximum yield for Indian spinach, and cabbage where 100% organic fertilizer gave the maximum yield for T.amanunder Cabbage- Indian spinach-T. aman cropping pattern. CO_2 emission was more in conventional tillage than strip tillage during cabbage growing period. 100% organic matter treatment emitted more CO_2 than IPNS and 100% chemical fertilizer and IPNS emitted less CO_2. Strip tillage gave more field capacity, soil moisture and less bulk density than conventional tillage. Organic based nutrient package gave more moisture, field capacity and less bulk density than chemical fertilizer.

Sl. No.	Research Progress	Expected Output
		Organic based nutrient package increased OM, N and Zn than chemical fertilizer treatment. In case of Organic based treatment pH, P, K and S increased but more or less remain same for chemical based fertilizer compare to initial soil. B decreased compare to initial soil. The 9th crop T. aman is on field at early tillering stage
5.	Requirement of nitrogen for mustard-okra-T.aman cropping system based on conservation agricultural practices	125% nitrogen dose performed the best than other doses for first crop mustard. The 3rd crop T. aman is on field at tillering stage
Programme area/Project: Chemical Aspects of Soil Management		
1.	Nutrient management for sustaining soil fertility and yield of Wheat-Mungbean-T.Aman cropping pattern	Incorporation of mungbean residue from the Wheat-Mungbean-T. Aman cropping pattern can improve soil fertility and crop productivity of the pattern and the soil nutrient status may be sustained in High Ganges River Floodplain Soils (AEZ-11) of Jashore.
2.	Nutrient management for sustaining soil fertility and yield of Mustard-Mungbean-T.Aman cropping pattern	Incorporation of mungbean residue from the Mustard-Mungbean-T.Aman cropping pattern can improve soil fertility and crop productivity of the pattern and the soil nutrient status may be sustained in High Ganges River Floodplain Soils (AEZ-11) of Jashore.
3.	Long-term integrated nutrient management for sustaining soil fertility and yield of Maize-Mungbean-T.Aman cropping pattern	Incorporation of organic manures in the Maize-Mungbean-T.Aman cropping pattern can improve soil fertility and crop productivity of the pattern and the soil nutrient status may be sustained and it could reduce chemical fertilizers to certain extent (15-20%) of the cropping pattern in Grey terrace Soil of Gazipur (AEZ-28).
4.	Efficacy of different form of urea on nitrogen availability and yield of maize	Among three form of urea, highest yield (10.75 t ha^{-1}) of maize was obtained from 200 kg N ha^{-1}as urea super granule (USG) which was very close to 205 kg N ha^{-1} as neem coated urea (10.69 t ha^{-1}). But highest gross margin (72153 Tk. ha^{-1}) as well as BCR (7.00) was obtained from 205 kg N ha^{-1} neem coated urea. Due to high application cost of USG in soil, benefit cost is lower in USG treated maize than that of neem coated urea.
5.	Effect of different form and doses of urea fertilizer on nitrous oxide emission, nitrogen use efficiency and yield of cauliflower	Application of 180 kg N ha^{-1} as Neem coated urea along with P_{60}, K_{90}, S_{20}, Zn_3 & $B_{1.5}$ kg ha^{-1} is found optimum and economically profitable for cauliflower yield (42.44 t $ha^{-1)}$. Highest gross margin (3,32,019/- Tk ha^{-1}) as well as BCR (4.76) was obtained from 180 kg N ha^{-1}as Neem coated urea. Among the three form of urea, use efficiency is higher in USG followed by neem coated urea and prilled urea.
6.	Effect of different organic manures on carbon accumulation in soil and yield of crops in mustard-mungbean-T.aman cropping	Application of Bioslurry @ 7.5 t ha^{-1} with IPNS basis chemical fertilizer produced the highest rice equivalent yield of the crops (12.74 t ha^{-1}) at Gazipur (AEZ-28). It also helps to increase soil fertility and reduce the use of chemical fertilizer which minimizes production cost.

Sl. No.	Research Progress	Expected Output
	pattern	
7.	Effect of kitchen waste compost on broccoli yield and carbon accumulation in soil	100% RDCF along with kitchen waste compost @ 5.0 t ha^{-1} is superior to the other fertilizer management packages in respect of yield (15.40 t ha^{-1}) as well as slightly increase carbon content where economic return (BCR 2.70) for cultivation of broccoli in the Gazipur (AEZ-28) district of Bangladesh. Further investigation will be required for the confirmation of the findings.
8.	Nutrient management of sesame in Barishal region.	Application of 125% RDCF of FRG'2018 (50:20:40:10:1:2 kg ha^{-1}NPKSZn& B) produced the highest seed yield (901.50 kg ha^{-1}) of sesame (cv. BARI Till-4) at non calcareous Grey Floodplain Soil of Barishal (AEZ-13). Use of 125% RDCF of FRG'2018 (50:20:40:10:1:2 kg ha^{-1}NPKSZn& B) produced the highest seed yield of sesame (cv. BARI Till-4) at non calcareous Grey Floodplain Soil of Barishal (AEZ-13).
9.	Effect of co-composting biochar on Cabbage-Indian spinach-T.aman productivity	Application of 80% RDCF with 5 t ha^{-1} co-composting biochar (COMBI) can produce the greater rice equvalant yield (REY) on Cabbage-Indian spinach-T.aman cropping pattern at Gazipur. Application of COMBI instead of easily degraded organic amendments seems to be a promising option to supply enough nutrients for the healthy growth and productivity of Cabbage-Indian spinach-T.aman pattern.
10.	Nutrient management of onion to reduce storage rots	Application of $N_{105}P_{45}K_{90}S_{30}Zn_{3}B_{1.4}OF_{3}$ kg ha^{-1} can produce the maximum bulb yield of onion. On the other hand, $N_{100}P_{70}K_{120}S_{40}Zn_{1.05}B_{0.51}Ca_{60}Mg_{50}$kg ha^{-1} application increased the storage duration of onion bulbs and there after decreased slowly.
11.	Development of fertilizer recommendation for chilli onion intercropping system	Application of 100% RDCF of chilli along with 40% RDCF of onion is most profitable (CEY 21.97 t ha^{-1} & BCR 4.69) for chilli with onion intercropping system in the study area (AEZ-28) and its extrapolation areas as well. Further investigation will be required for the confirmation of the findings.
12.	Integrated potash management for mustard	Integrated application of STB fertilizer dose with rice husk ash @ 2 t ha^{-1} appeared as best suited combination for boosting mustard yield and optimizing economic return. It also reported to have highest potassium uptake.
13.	Application of vermiwash on yield and nutritional quality of tomato	Treatment package consists of chemical fertilizer with 20 % concentration of vermiwash foliar application resulting in higher production of tomatoes with improved nutritional quality as compared to sole chemical fertilizer application
14	Development of fertilizer recommendation for linseed groundnut intercropping system	100 % RDCF of groundnut + 50 % RDCF of linseed treatment was the most profitable compared to other fertilizer packages inlinseed-groundnut intercropping system at Old Brahmaputra Floodplain Soils.
15.	Development of fertilizer recommendation for knolkhol maize intercropping system	From the present study, it may be concluded that treatment package consists of 100% RDCF of maize along with 50% RDCF of knolkhol is most profitable (MEY 30.13 t ha^{-1} & BCR 3.87) for maize with knolkhol intercropping system in the study area (AEZ-28). Further investigation will be required for the confirmation of the findings.

Sl. No.	Research Progress	Expected Output
16.	Integrated Nutrient Management of year round four vine crops model for a intensive rooftop garden	Application of 80% of Soil Test Based fertilizer dose along with (1:3) vermicompost and soil was found optimum for maximizing growth and yield of vine crops on the rooftop garden.
17.	Utilization of banana peel on increasing tomato yield and improving soil fertility	Application of 20% Banana peel fertilizer with IPNS based recomended chemical fertilizers treated soil increase 22 tha^{-1} tomato yield where 10% Banana peel fertilizer with IPNS based chemical fertilizers soil increase 18 tha^{-1}. Banana peel fertilizer also enhance the nutrient uptake and sustaining the soil fertility.
18.	Sustainable substrate composition as influenced by organic amendment on dragon fruit in an extensive green roof	Treatment package consists of 30% biochar plus 30% vermicompost with farm soil produced a significantly higher substrate moisture content, plant canopy and plant dry matter content over the treatments
Programme area/Project: Micronutrient Aspects of Soil Management		
1.	Nanoscale zinc oxide particles for improving yield and quality of tomato	Tomato yield 94.5 and 94.2 t ha^{-1} was produced, when plants were treated (foliar application) with $ZnSO_4$. $7H_2O$ @ 150 ppm and ZnO nano particles @ 15 ppm, respectively.
2.	Effect of boron on yield and quality of bitter gourd	Application of 1.5 Kg B/ha + NPKSZn (STB) could be effective to increase bitter gourd yield (24.52 t ha^{-1}). Application of B also enhanced nutrient content, uptake, vit. C, TSS and decrease flower sheddings. Approximately 50% flower shedding decrease of bitter gourd due to a package application of 1.5 Kg B/ha + NPKSZn (STB).
3.	Foliar application of boron on reproductive growth of sunflower	Foliar application of 150 mg L^{-1} of B with the volume of 10 liters per plot (2.5 Lm^{-2}) produces highest seed yield (2.25 tha^{-1}) and decrease seed sterility of sunflower. Approximately 20% seed sterility decrease of sunflower due to 150 mg L^{-1} of B application.
4.	Foliar application of manganese on growth and yield of groundnut	Foliar spray of 0.04% Mn significantly influences on the growth, yield (2.59 t ha^{-1}) and yield parameters of groundnut. Foliar application of 0.04% manganese was found to be the most effective for groundnut cultivation. Crude oil and protein content and micronutrient content of groundnut increased by foliar application of Mn.
5.	Determination of critical limit of zinc for chickpea	The critical values of Zn for chickpea were found to be 0.63 mg kg^{-1} in soil and 25.3 mg kg^{-1} in plant tissue.
6.	Effect of foliar application of zinc in sweet orange	A higher sweet orange yield can be achieved by foliar application of Zn @ 1500 mg per liter. Production cost will be minimized and yield can be maximized by using Zn @ 1500 mg per liter as a foliar spray in the leaf.
7.	Effect of boron fertilization on lentil in Barishal region	According to studies conducted in the last two years, lentil yields (1459 kg - 1960 kg ha^{-1}) were improved by adding 1.5 to 2.5 kg ha^{-1} of boron in the Barishal region, (Non–calcareous Grey Floodplain Soils under AEZ 13). .
Programme area/Project: Microbiological Aspects of Soil Management		

Sl. No.	Research Progress	Expected Output
1.	Effect of different biofertilizer on the yield of Onion	Application of Azotobacter, PSB and Mycorrhiza reduced up to 20% chemical nitrogenous fertilizer and 50% chemical phosphatic fertilizer and increase bulb yield of onion.
2.	Effect of Azotobacter on the growth and yield of Chilli	Application of Azotobacter with 80% N fertilizer increased the growth and Chilli yield. It also reduced the 20% N fertilizer uses during chilli production.
3.	Effect of Arbuscular Mycorrhizal (AM) fungi and phosphorus on Broccoli	The plant that received Arbuscular Mycorrhizal fungi in nursery bed produced higher curd yield than without AM in all phosphorus levels of Broccoli. The application of AM with 50% P fertilizer increased the curd yield of Broccoli. It also saves 50% P fertilizer during Broccoli production.
4.	Effect of Arbuscular mycorrhizal inoculation on maize at different salinity levels	Application of Arbuscular mycorrhiza with 0 dS m^{-1} produced the highest seed yield and stover yield. It also clearly indicates that mycorrhizal inoculation could reduce the harmful effects of salinity to the host plants, thus increase plant survival allowing the plants growth under extreme condition.
5.	Effect of biofertilizer, biochar and chemical fertilizers on yield and qualitative properties of Maize	Application of Biochar @ 5 t ha^{-1}+*Rhizobium*+IPNS based PKS increased the seed yield and stover yield of Maize. So, we can able to reduce biochar and inorganic fertilizer without affecting the quality and productivity of groundnut.
6.	Isolation of Phosphate Solubilizing Bacteria (PSB) and their efficacy on the growth of barley	Inoculation of PSB biofertilzer enhanced the growth, yield and nutrient content of barley. The PSB biofertilizers are considered as the most favorable natural compounds to enhance the micro-organism activities in the soil. Isolation of PSB bacteria from AEZ-11 (Isolate-IV) increased the seed yield and straw yield of barley.

APPENDIX I. METEOROLOGICAL INFORMATION

Monthly average maximum and minimum temperature and total rainfall during the period from July 2021 to April 2022 at BARI, Gazipur

Month	Fortnight	Temperature (^{0}C)			Rainfall (mm)	No. of rainy days
		Maximum	Minimum	Mean		
July 2021	1st	36.5	28.1	64.6	257	8
	2nd	35.4	29.5	64.9	144	15
August 2021	1st	65	27.5	92.5	219	11
	2nd	34.5	28	62.5	259	13
September 2021	1st	37	28.1	65.1	45	8
	2nd	37.5	36.2	73.7	18	5
October 2021	1st	37.7	27.5	65.2	36	4
	2nd	36.5	32.2	68.7	57	3
November 2021	1st	32.3	31	63.3	17	3
	2nd	31.5	19.8	51.3	0	0
December 2021	1st	31.3	21.2	52.5	474	11
	2nd	27.5	16.4	43.9	253	5
January 2022	1st	28.5	17.5	46	0	
	2nd	26.8	24.3	51.1	10	2
February 2022	1st	27.6	21	48.6	28	2
	2nd	30.7	19	49.7	0	
March 2022	1st	35.4	21	56.4	0	0
	2nd	36.7	25.5	62.2	26	4
April 2022	1st	36	36.8	72.8	0	0
	2nd	36.2	27.6	63.8	10	1
Average		35.0	25.9	60.9	92.7	5.3

APPENDIX II. SCIENTISTS CURRENTLY WORKING IN THE SOIL SCIENCE DIVISION 2021-2022

Sl. No.	Name	Designation
01.	Dr. Habib Mohammad Naser	Chief Scientific Officer & Head
02.	Dr. A.T.M. Anwarul Islam Mondol	Principal Scientific Officer
03.	Dr. Mohammad Eyakub Ali	Senior Scientific Officer
04.	Dr. Md. Masuduzzaman Masud	Senior Scientific Officer
05.	Dr. Mst. Rokeya Khatun	Senior Scientific Officer
06.	Md. Harunur Rashid	Senior Scientific Officer (Deputation)
07.	Dr. Mst. Marufa Sultana	Senior Scientific Officer
08.	Dr. Most. Bilkis Banu	Senior Scientific Officer
09.	Sharmin Sultana	Senior Scientific Officer
10.	Ibne Saleh Md. Farhad	Scientific Officer
11.	Md. Jahangir Alam	Scientific Officer
12.	Mominur Rahman	Scientific Officer
13.	Alak Barman	Scientific Officer
14.	Md. Farid Ahammed Anik	Scientific Officer
15.	Mousumi Akter	Scientific Officer

APPENDIX III: SCIENTISTS OF SOIL SCIENCE DISCIPLINE AT BARI

Sl. No.	Name	Designation and Address
01	Dr. Sohela Akhter	Director (TCRC), BARI, Gazipur
02	Dr. Md. Ataur Rahman	CSO, SWM Section, HRC, Gazipur
03	Dr. Md. Monirul Islam	CSO, TCRC, Gazipur
04	Dr. Md. Mohi Uddin Chowdhury	CSO, OFRD, Noakhali
05	Dr. Md. Shahidul Islam Khan	PSO, OFRD, Patuakhali
06	Dr. Md. Alamgir Siddiky	PSO, RARS, Cumilla
07	Dr. Md. Abdus Salam	PSO, HARS, Ramgarh
08	Dr. Md. Rafiqul Islam	PSO, RARS, Rahmatpur, Barishal
09	Dr. Idris Ali Howladar	PSO, RHRC, Lebukhali, Patuakhali
10	Md. Mahbubul Hoque	PSO, Farm Division, Gazipur
11	Dr. Md. Jamal Hussain	PSO, RARS, Akbarpur,Moulvibazar
12	Dr. Shymol Brahma	SSO, RSRC, Gazipur
13	Dr. Nargis Akhter	SSO, OFRD, Mymensingh
14	Dr. Md. Arifur Rahman	SSO, RARS, Jamalpur
15	Dr. Md. Abdul Quddus	SSO, SWM Section, HRC, Gazipur
16	Dr. Md. Tohidur Rahman	SSO, TCRSS, Bogura
17	Md. Emdadul Hoque	SSO, OFRD, Manikganj
18	Dr. Md. Mokter Hossain Bhuiyan	SSO, RARS, Cumilla
19	Dr.Md. Nasir Uddin Mahmud	SSO, RARS, Jashore
20	Dr. Nazmus Salahin	SSO, RARS, Jashore
21	Dr. Md. Nure Yousuf	SSO, RSRC, Gazipur
22	Dr. Md. Jahangir Alam	SSO, OFRD, Gaibandha
23	Md. Razu Ahmed	SSO, SWM Section, HRC, Gazipur
24	Md. Tanvir Hasan	SSO, OFRD, Bogra (Deputation)
25	Shimul Mondal	SSO, RARS, Jashore (Deputation)
26	S.M. Mahabubul Alam	SSO, LRS, Chapainababganj (Deputation)
27	Shamima Akhter	SO, PRC, Gazipur (Deputation)
28	Ahmed Mostafa Kamal	SO, RARS, Burirhat, Rangpur (Deputation)
29	Muhammad Waliur Rahman	SO, BSPC, Debigonj, Panchagarh
30	Fouzia Sultana Shikha	SO, RARS, Jamalpur
31	Mst. Shamusun Nahar	SO, SRC, Bogura (Deputation)
32	Md. Atikur Rahman	SO, SRC, Bogura
33	Monira Yasmin	SO, RARS, Jamalpur
34	Umme Kulsum Laili	SO, OFRD, Bogura
35	Oli Ahmed Fakir	SO, ARS, Satkhira
36	Dr. Md. Ariful Islam	SO, PRC, Ishurdi
37	Md. Mainul Islam	SO, OFRD, Patuakhali
38	Jhuton Sarkar	SO, Citrus Research Centre, Jointapur, Sylhet
39	Fardus Ahamed Nasim	SO, Training & Communication, Gazipur
40	Abu Saleh Md. Eusuf Ali	SO, RHRC, Cumilla

APPENDIX IV: SCIENTIFIC/OFFICIAL STAFFS CURRENTLY WORKING IN THE SOIL SCIENCE DIVISION AT BARI

Sl. No.	Name	Designation
01.	Md. Shah Ali Talukder	Scientific Assistant
02.	Md. Monirul Islam	Scientific Assistant
03.	Md. Moniruzzaman	Steno Typist Cum Computer Operator
04.	Md. Wazed Ali	Steno Typist Cum Computer Operator
05.	Md. Nachar Uddin	Steno Typist Cum Computer Operator
06	Md. Kamal Hossain	Scientific Assistant
07.	Mrs. Nasima Akter	Scientific Assistant
08.	Farhana Yesmin	Scientific Assistant
09.	Md. Abdul Motaleb	Scientific Assistant
10.	Md. Amjad Hossain Akhond	Scientific Assistant
11.	Sadeka Akter	Office Asst. Cum Computer Operator
12.	Ammber Kowsary	Computer Operator
13.	Md. Enamul Haque	Scientific Assistant
14.	Mohammad Habibur Rahman	Scientific Assistant
15.	Md. Sohel Siraj	Scientific Assistant
16.	Tajrian Begum	Scientific Assistant
17.	Mohammad Nazrul Islam	Scientific Assistant
18.	Mahmuda Begum	Scientific Assistant
19.	Monira Begum	Office Asst. Cum Computer Operator
20.	Ruksana Parvin	Office Asst. Cum Computer Operator
21.	Sayma Jahan	Office Asst. Cum Computer Operator
22.	Md. Mobarak Hossain	Scientific Assistant
23.	Afroza Akter	Scientific Assistant
24.	Md. Mahadi Hasan	Scientific Assistant
25.	Mahfuza Begum	Office Asst. Cum Computer Operator
26.	Saifuddin Ahmed	Lab Technician
27.	Yesmin Akter	Laboratory Attendant
28.	Mrs. Nilufer Najrin	Laboratory Attendant
29.	Afsari Khanam	Laboratory Attendant
30.	Md. Mokbul Hassain	Laboratory Attendant
31.	Jasmin Akter	Laboratory Attendant
31.	Sudarshan Chakrabarty	Laboratory Attendant

33.	Nasrin Akter Sima	Laboratory Attendant
34.	Azharul Islam	Laboratory Attendant
35.	Kamrunnahar	Laboratory Attendant
36.	Mohammad Sirajul Islam	Preparer
37.	Aleya Begum	Office Sohayuk
38.	Md. Abuddus Sattar	Office Sohayuk
39.	Md. Nazrul Islam	Office Sohayuk
40.	Mst. Masuda Begum	Office Sohayuk
41.	Tuyaba Begum	Farm Attendant
42.	Ahmad Mostafa	Office Sohayuk

APPENDIX V: কর্মসম্পাদন সূচক, লক্ষ্যমাত্রা এবং অর্জন- ২০২১-২০২২

ক্রমিকনং	সূচক	একক	২০২১-২২	২০২১-২২
			লক্ষ্যমাত্রা	অর্জন (জুন ২০২২)
১.	উদ্ভাবিত প্রযুক্তি	সংখ্যা	৪	৪
২.	প্রশিক্ষিত কৃষক	সংখ্যা	৬০	৬০
৩.	প্রশিক্ষিত বিজ্ঞানী/ কর্মকর্তা/কর্মচারী	সংখ্যা	৩০	৬০
৪.	স্থাপিত প্রদর্শনী	সংখ্যা	-	-
৫.	আয়োজিত সেমিনার/ওয়ার্কশপ	সংখ্যা	১	১
৬.	বার্ষিক গবেষণা রিপোর্ট	সংখ্যা	১	১
৭.	মাঠ দিবস/র‍্যালী	সংখ্যা	১	১
৮.	হস্তান্তরিত জাত	সংখ্যা	-	-
৯.	হস্তান্তরিত প্রযুক্তি	সংখ্যা	-	-
১০.	লিফলেট, বুকলেট ,নিউজলেটার, জার্নাল, বুলেটিন, প্রকাশনা ইত্যাদি	সংখ্যা	১	১
১১.	উৎপাদিত ব্রিডারবীজ	মে. টন	-	-
১২.	উৎপাদিত চারা / কলম/কাটিং	সংখ্যা	-	-
১৩.	-	-	-	-
১৪.	-	-	-	-
১৫	-	-	-	-
১৬	-	-	-	-
১৭	-	-	-	-
১৮	-	-	-	-
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২৫	-	-	-	-

APPENDIX VI: LIST OF PUBLICATIONS (January 2021 to June 2022)

Total number of publications: 09 (Nine)

Abul Fazal Mohammed Shamim Ahsan, Al Harun Md. Motiur Rahman Talukder, Shamsun Nahar Mahfuza1,Faruque Ahmed, Mohammad Amdadul Haque, Mohammad Abdul Goffar, Mohammad Masuduzzaman Masud, Ahmed Khairul Hassan. Assessment and assortment of tomato genotypes against salinity at vegetative stage. Asian J Agric & Biol. Accepted: December 30, 2021, DOI: 10.35495/ajab.2021.08.321

Apu C. K., P. K. Biswas, T. S. Roy, S. Shome and A. Barman. Growth, grain development and yield performance of boro rice varieties under water stress condition. Bangladesh Agronomy Journal, 2021. 24(2): 105-113

Barman A., S. Shome, M.R. Khatun, M.M. Masud and S. Akther 2021. Increasing Cropping Intensity and Crop Productivity of Four Crops Based Mustard-Boro-T. Aus-T. Aman Cropping Pattern. Bangladesh Agronomy Journal 24(1):109-117

Khatun M. R., A. Barman., M. M. Masud., Marufa Sultana and S. Akhter, 2022. Effects of organic manures on sustainable cauliflower production in Grey Terrace soils of Bangladesh. Bangladesh Journal of Environmental Science, 42: 35-40

Liza M. M., A. Barman, S. Shome and M. E. Rahman and Polly. Influence of coupled application of potassium and boron on growth and yield of late sown mungbean. World Journal of Advanced Research and Reviews, 2021. 11(1): 256–264 https://doi.org/10.30574 /wjarr.2021.11.1.0343

Liza M. M., S. Shome, A. Barman, Polly and M. E. Rahman. Combined effect of potassium and boron on low-temperature tolerance in mungbean under late sowing condition. International Journal of Biosciences, 2021. 19(2): 108-117 http://dx.doi.org/10.126 92/ijb/19.2.108-117

Marufa Sultana, Islam Rafiqul M, Jahiruddin M, Rahman Mazibur M, Abedin Anwarul Md, Al Abdullah Mahmud. 2021. Nitrogen, phosphorus, and sulphur mineralization in soil treated with amended municipal solid waste compost under anaerobic and aerobic conditions. International Journal of Recycling of Organic Waste in Agriculture 10:245-256

Marufa Sultana, M. Jahiruddin, M. Rafiqul Islam, M. Mazibur Rahman, Md. Anwarul Abedin. 2021. Effects of nutrient enriched municipal solid waste compost on soil fertility, crop yield and nutrient content in brinjal. *Eurasian Journal of Soil Science* 10(3): 191-198.

Marufa Sultana, M. Jahiruddin, M. Rafiqul Islam, M. Mazibur Rahman, Md Anwarul Abedin and Zakaria M. Solaiman 2021. Nutrient Enriched Municipal Solid Waste Compost Increases Yield, Nutrient Content and Balance in Rice. *Sustainability*, *13*(3), 1047