EXPT. NO. 1.1 DEVELOPMENT AND EVALUATION OF FOUR-WHEEL TRACTOR OPERATED SEEDER

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Abstract

Power tiller (two-wheeled tractor) is the most prevalent tillage machine in Bangladesh, as well as a prime mover for various seeding machines in agriculture. Sowing is one of the most important components for the establishment and productivity of any crop. Due to the vibration of the power tiller, it is difficult to maintain a consistent seed to seed spacing, depth of seeding, straight line, and so on. Another issue is that the operator feels tired of walking behind the machine. However, recent day's 4WT (four-wheel tractor) are being introduced in farming works, they are also a suitable option to resolve all of the issues described herein. Therefore, this research has been under taken to develop four-wheel tractor operated seeder. A four-wheel tractor operated seeder was designed and fabricated during 2020-21 at FMP Engineering division, BARI, Gazipur. This seeder can sow maximum 09-lines seed at a time, and tilling width was 180 cm. The effective field capacity of the 4WT operated seeder for maize and chickpea were found to be 0.248 and 0.231ha/h, respectively. The field efficiency of the 4WT operated seeder for maize and chickpea were estimated as 78.73 and 77.77%, respectively. The uniformity of seed distribution was found 97.33%. The mean emergence time of the maize and chickpea were 6.03 and 11.46 days, respectively. The emergence rate index of maize and chickpea were 0.83 and 0.98, respectively. Seed emergence of maize and chickpea were 95 and 93.89 % when the seed were planted with the 4WT seeder The experiment will be carried out in the coming year in order to improve and evaluate the performance of the four-wheel tractor operated seeder.

Introduction

Sowing is one of the key factors that influence the success of any crop establishment and productivity. Power tiller (two-wheeled tractor or 2WT) is the common tillage tool in Bangladesh agriculture but recent days 4W tractors are being introduced in farming works along with its transportation works. At present, power tiller operated seeding implements are common for its easy access to small land. Two wheel tractor operated seeding machinery has been developed by different organizations and promotional activities are being conducted in the farmer's field of Bangladesh for yield gap minimization, water saving, efficient input utilization, soil health improvement and sustainable crop production and crops diversification (Hossain *et al.*, 2014). But, power tiller has limitation to work in high moisture and hard soil to perform works due to its limited horse power (12 HP) whereas 4W tractor power ranges 35-55 Hp. Now a day, we see that number of 4W tractors is increasing and will be increased coming days and more engaged in farming activities. Maximum crop production and seeding operation need to complete within the recommended period avoiding slowness, time consume, costly operation and decreasing turnaround time. These tractor units can be used for seeding purposes addition to its transportation and soil tilling works. Mechanical seeder saves time, fuel and considerable cost as compared to conventional practices (Hossen *et al.*, 2013). Conservation agriculture (CA) based tillage technology permits direct seeding in untilled soil with moderate level of crop residues. CA is combines three major farming principles for successful crop production with the latest technologies - less soil disturbance, crop residue management, and following beneficial crops rotation (Hobbs *et al.*, 2008). A good seeder could be usable as CA Seeder when it will effectively penetrate its furrow opener in untilled soil and place the seed at the optimum depth for rapid plant emergence (Ozmerzi *et al.*, 2002). Most prominent problems of CA adoption in South Asia is lack of suitable machinery which could be reduced developing and adopting small 4WT based seeding devices such as zero, strip till planter considering its higher power range and performances (Jin *et al.* 2014). Farmers are also showing interest using tractor operated seeding devices considering its higher power range and performances. Therefore, this research work has been taken to design, develop and evaluate a suitable four-wheel tractor operated seeder for completing seeding operation in a single pass.

Material and Methods

A tractor operated seeder was designed using SolidWorks 2016 and fabricated as per design during 2020-21. Some design considerations were as i) the seeder will be able to operate most available 4WT, ii) the seeder could also be used in full tillage, and CA tillage mode, and iii) the seeder will be able to plant different types of seed. The different views of 4WT seeder were shown in Fig 1 and Fig 2. The designed seeder was fabricated at FMP Engineering division of Bangladesh Agricultural Research Institute, Gazipur during 2020-21. The 4WT seeder was fabricated and settle on the top of the rotavator of tractor. The seeder is composed of a frame, seed box with inclined plate seed metering mechanism, T-inverted furrow opener, seed tube, and a drive wheel based power transmission system (Fig 3). The machine was supported with depth control skids of the rotavator.

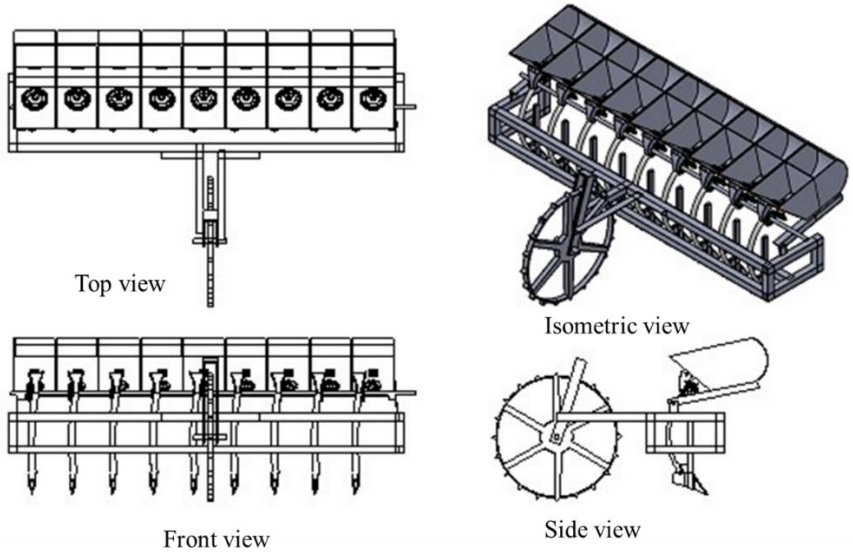

Fig. 1. Two dimensional orthographic views of the 4WT Seeder.

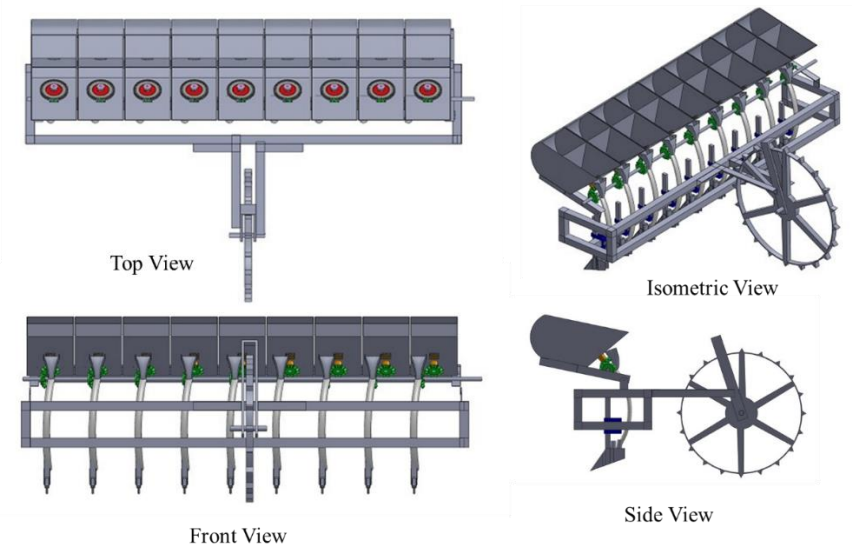

Fig. 2. Three dimensional orthographic views of the 4WT Seeder.

Fig. 3. Major functional components of the fabricated 4WT operated seeder.

A four-wheel tractor (4WT) operated seeder was design and fabricated at FMPE (Farm Machinery and Postharvest Process Engineering) Division, BARI (Bangladesh Agricultural Research Institute), Gazipur during 2020-21. Specification of the 4WT seeder is shown in Table 1. Maximum 09-lines seed can be sown with this seeder for which 09 seed box were attached. The power to rotate the inclined seed plate was transferred from the drive wheel and it located on the rare of the seeder. The diameter of the drive wheel was 600mm.

Table 1. Specification of the 4WT seeder

Sl. No.	Parameter	Dimension
01	Overall dimension	2000 × 850 ×650 mm
02	Dimension of the seed box	385 x 200 x 255 mm
03	No of seed box	09
04	Type of furrow opener	T-inverted
05	No of furrow opener	09
06	Diameter of the drive wheel	Ø 600 mm

Experimental procedure

During 2020-21, the 4WT operated seeder was used to evaluate the field performance at research field of FMP Engineering division, BARI, Gazipur. The performance evaluation was done for testing the performance in tilled soil during 2020-21 with maize and chickpea. The sowing date of maize and chickpea in the tilled plots were 23 February 2021 and 01 February 2021. All agronomic adjustments such as seed rate control, depth of seeding, line to line distance adjustment, multiple crops seeding were adjusted in the tractor driven seeder.

Field capacity, field efficiency, and fuel consumption were taken as the dependent variable for the present study. The effective field capacity, theoretical field capacity, and field efficiency were calculated by recording the time consumed for actual work and the time lots of other miscellaneous activity such as turning adjustment under field operating conditions.

Theoretical field capacity is rate coverage of the implements based on 100 percent of the rated speed & covering 100 per cent of its rated width.

$$Tfc = ws/10 \quad (1)$$

The effective field capacity is calculated by recording the actual area covered by the implement, based on its total time consumed and non-productive time.

$$Efc = A/(Tp+T1) \quad (2)$$

It is the ratio of effective field capacity and theoretical field capacity expressed in percent.

$$Ef = Efc/Tfc \quad (3)$$

Where,

Efc = Effective field capacity (ha/h), Tfc= theoretical field capacity (ha/h), Ef = field efficiencies (%), A = total area covered (ha), Tp= productive time (h), T_1 = non-productive time (h), W = effective working width (m), S = effective speed of operation (km/h).

Coefficient of seed distribution uniformity

To calculate the coefficient of uniformity of seed distribution, prepared land strip with measurements of 20 ×1.8 m was filled with a layer of fine soil of 50 mm thickness. An area of two rows with a length of one meter was randomly selected using a wooden frame in each replication. The planted seeds in this area were separated from the soil using a sieve. The coefficient of uniformity of seed distribution was computed using the following equation 4 (Afzalinia *et al.*, 2012; Senapati *et al.*, 1992).

$$S_e = 100(1 - \frac{Y}{D}) \quad (4)$$

Where,
S_e = coefficient of seed distribution uniformity, %;
Y = average numerical deviation of average number of plants per meter length of row from average desired number of plants per meter run, and
D = average number of plants per meter length of row.

Maize emergence was counted daily from three to 15 days after sowing at four randomly selected 3 m long row lengths. The values of mean emergence time (*MET*) was calculated following (Celik and Altikat , 2010) as in Equation 5,

$$\mathrm{MET} = \frac{(\mathrm{N_1T_1 + N_2T_2 + \text{-----} + N_nT_n})}{(\mathrm{N_1 + N_2 + \text{----} + N_n})} \quad (5)$$

where $N_1 \ldots n$ is number of seedlings emerging since the time of previous count and $T_1 \ldots n$ is the number of days after the sowing. The emergence rate index (*ERI*) and plant emergence degree (PE) were also following Equation 6,

$$\mathrm{ERI} = \frac{\mathrm{STE}}{\mathrm{MET}} \quad (6)$$

and Equation 7, respectively,

$$\mathrm{PE} = \frac{\mathrm{STE}}{\mathrm{sn}} \times 100 \quad (7)$$

Where *STE* is number of total emerged plants (seedlings) per meter, *sn* is number of seeds sown per meter.

All plots were harvested for yield estimation and randomly 1m^2 area was harvested for yield contributing characters. Before selecting the yield estimation area, border effects were avoided. All the wheat straw and grain from the harvest area were collected. The harvested crops threshed. Then the grains were thoroughly dried upto safe moisture content and weighted to measure yield. Randomly 1 m^2 area was selected from the main plot for crop biomass, plant height, spike length, spike/m^2, grain/spike, and 100 grain weight.

Results and Discussion

Performance of the developed 4WT seeder for planting of rabi crops is shown in Table 2. The width of tilling was 180 cm. The average tilling depths from soil surface for maize and chickpea were 5.75 and 4.25 cm, respectively. The average effective field capacity of the 4WT operated seeder for maize and chickpea were found to be 0.248 and 0.231ha/h, respectively. The field efficiency of the 4WT operated seeder for maize and chickpea were estimated as 78.73 and 77.77%, respectively.

Table 2. Performance of 4WT operated seeder for different crops during 2020-21

Crop	No of passes	Forward speed (km/h)	Tilling width (cm)	Tilling depth (cm)	Theoretical field capacity (ha/h)	Effective field capacity (ha/h)	Field efficiency (%)
Maize	Single	1.75	180	5.75	0.315	0.248	78.73
Chickpea	Single	1.65	180	4.25	0.297	0.231	77.77

The performance of the 4WT seeder for spacing uniformity of maize seeds is shown in Table 3. There were 10 observations total, each observation was replicated three times. It is observed from the table that means seed to seed distances were 4.83 cm for the 4 WT seeder, compared to the expected spacing of 5.0 cm. The standard deviation of seed spacing was 0.36 cm. The seed distribution uniformity was 97.33% which was near to expected distribution uniformity (100.0%). So, the seed spacing of maize was found satisfactory for the 4WT seeder (Fig 4).

Table 3. Performance of the 4WT seeder for spacing uniformity of maize seeds

	Numbers of maize seed in 1.0 running meter			
Observation No.	Rep 1	Rep 2	Rep 3	Mean
1	5	5	5	5.00
2	5	5	4	4.67
3	5	5	5	5.00
4	6	5	5	5.33
5	5	5	6	5.33
6	4	5	5	4.67
7	5	4	4	4.33
8	4	4	5	4.33
9	5	5	5	5.00
10	5	4	5	4.67
Mean of spacing (5.0)	4.90	4.70	4.90	4.83
Stand dev.	0.57	0.48	0.57	0.36
Se, %	98	96	98	97.33

Se= Seed distribution uniformity

Chickpea Maize

Fig. 4. Field views of chickpea and maize field.

The mean emergence time of the maize and chickpea were 6.03 and 11.46 days, respectively (Table 4). The emergence rate index of maize and chickpea were 0.83 and 0.98, respectively. Seed emergence of maize and chickpea were 95 and 93.89 % when the seed were planted with the 4WT seeder.

Table 4. The mean emergence time (MET), emergence rate index (ERI) and emergence (PE) for different crops sown by 4 WT seeder

Crop	MET, Day	ERI	PE (%)
Maize	6.03	0.83	95
Chickpea	11.46	0.98	93.89

Conclusion

A four-wheel tractor operated seeder was designed and fabricated. With this seeder, maximum of 09-line seed can be sown, and the tilling width was 180 cm. The effective field capacity of the 4WT operated seeder for maize and chickpea were found to be 0.248 and 0.231ha/h, respectively. The field efficiency of the 4WT operated seeder for maize and chickpea were estimated as 78.73 and 77.77%, respectively. The seed distribution uniformity was 97.33%. The mean emergence time of the maize and chickpea were 6.03 and 11.46 days, respectively. The emergence rate index of maize and chickpea were 0.83 and 0.98, respectively. Seed emergence of maize and chickpea were 95 and 93.89 % when the seed were planted with the 4WT seeder. The experiment will be conducted in the coming year in order to improve and evaluate the performance of four-wheel tractor operated seeder for different crops.

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EXPT. NO. 1.2: DESIGN AND DEVELOPMENT OF A POWER TILLER OPERATED VEGETABLE SEEDLING TRANSPLANTER

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Abstract

The current method for transplanting vegetable seedlings is manual, which requires digging a hole in the soil, placing the seedling at the proper depth, and lastly filling the hole with press. All of these works are time-consuming, labour intensive, and expensive. This experiment was undertaken in context of the present agricultural system for seedling transplantation of vegetable seedling in the field. A three-dimensional projection of dibbler type and furrow opener type transplanter were drawn with SolidWorks 2018. A power tiller operated vegetable seedling transplanter was designed and fabricated with locally available iron materials at Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute, Gazipur during 2019-20. After the entire removal of the rotavator tillage assembly, a 2-row semi-automatic vegetable transplanter was developed, taking into consideration the power availability and space availability in the tiller. The dibbler, dibbler pressing sprocket, chain, press wheel, seat, depth adjusting wheel, furrow opener, soil covering device, and hitching arrangement were all part of the transplanter. The machine can transplant seedling two rows at a time. For dibbler type and furrow opener type, the spacing between the rows and seedling to seedling could be adjusted to 50-81 cm, 20-80 cm, and 25.80-62 cm, 12.50 cm - any distance, respectively. During lab test, there were no missing of placement of seedling for both types. Furrow opener type machine planted seedlings had a lower degree of vertical axis inclination following transplanting than dibbler type seedlings. It contains an irrigation system that provides water in the row to help transplanted seedlings recover from their initial stress. The dibbler type machine was tested for the evaluation of field performance with brinjal during 2020-21, there was no problem in growth and found the same yield as transplanted by hand. The performance of the vegetable transplanter was evaluated for transplanting brinjal at 70 × 60 cm spacing in the field at a forward speed of 1.2 km h^{-1}. Field capacity of the transplanter was found to be 0.050 ha h^{-1}. The furrow opener type transplanter was not used this year due to time constraints. The experiment will be carried out again next year in order to improve field performance.

Introduction

Bangladesh is a predominantly agricultural country, with agriculture playing a significant part in the national economy. Agricultural production systems have been enhanced through mechanized methods in recent decades, and great progress has been made in vegetable production and export. In the country, more than 60 different species of indigenous and exotic vegetables are grown (Anon, 2016a). Only 1.8 percent of total cultivable land is used to grow vegetables. Currently, 31.3 million metric tons of vegetables are grown on 3.74 million hectares (Anon., 2016b). In the country, 162 thousand farmers work in the vegetable industry. Vegetable production has expanded fivefold in the last 40 years, according to the FAO. Bangladesh is ranked third in the world for vegetable production, behind China and India. In the last decade, the amount of land under vegetable cultivation in the country has increased by 5%. In the last three years, vegetable production has increased at a rate of 6.0 percent. During the current Rabi season, 528 thousand hectares of land will be used for vegetable cultivation (Anon, 2016c).

Cucurbit, bean, okra, and leafy vegetables are seeded directly in the field for the most part. Tomatoes, eggplant, and peppers (Capsicum spp.) are sown in nursery beds and then manually transplanted onto ridges or a well-prepared seedbed (Ghai and Arora, 2007). Manual seedling transplantation is time consuming, labor intensive, and sometimes results in non-uniform plant distribution (Kumar and Raheman, 2008; Manes *et al.*, 2010; Parish, 2005). Winter is when 60% of these vegetables are grown (Anonymous, 2016), which makes it more difficult owing to labor shortages. Furthermore, bending down for each seedling for an extended period of time is harmful to human health.

In Bangladesh, there are 0.7 million active power tillers, with around 50000 tillers imported each year. We don't need power to operate the transplanter if a transplanter that can be attached to a power tiller. After removing the rotavator tillage attachment, hitch the transplanter to the same position of the power tiller. As a result, a power tiller-operated vegetable transplanter for small plots and medium land holdings is urgently needed. The power tiller operated vegetable transplanter has to be semi automatic machine as an operator could not simultaneously control and feed the seedlings to the metering unit, another two person needed to feed the seedling.

The goal of this work was to develop a walk-behind type power tiller operated semi automatic vegetable transplanter for any kind of vegetable seedlings and evaluate its performance under actual field conditions. The specific objectives of this research are given below

Objectives

a) To design and develop a power tiller operated vegetable seedling transplanter
b) To test and evaluate the performance of vegetable transplanter

Materials and Methods

A power tiller operated dibbler type vegetable seedling transplanter was designed and fabricated at Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute during 2019-20. Three-dimensional projection of the transplanter was drowned by Solid works 2018. Fabrication was carried out in accordance with the design, using locally available materials. The schematic views of the transplanter are shown in Fig.1 and 2. During 2020-21, many sections of the machine were modified, particularly the furrow opener type; we will go through the details later. A weight adjusting wheel is also included to keep the machine's weight and balance in line. The larger sprocket was moved to the backside for precise hole making where seedlings will be transplanted, as shown in Fig.1.

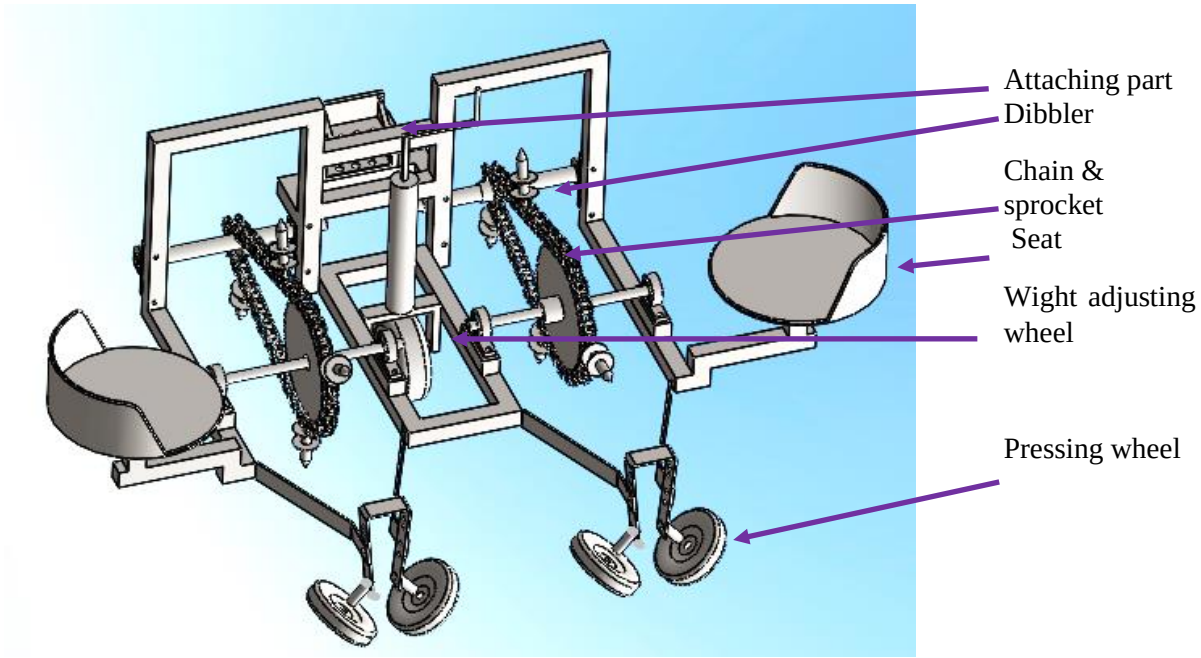

Fig. 1. Isometric view of dibbler type vegetable transplanter.

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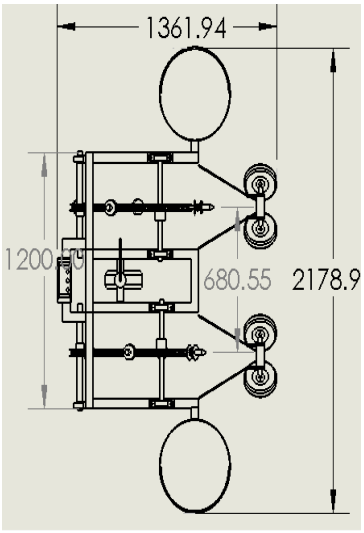
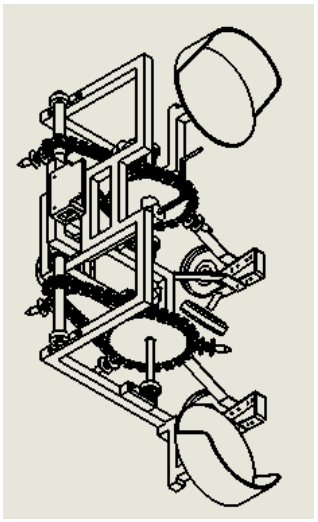
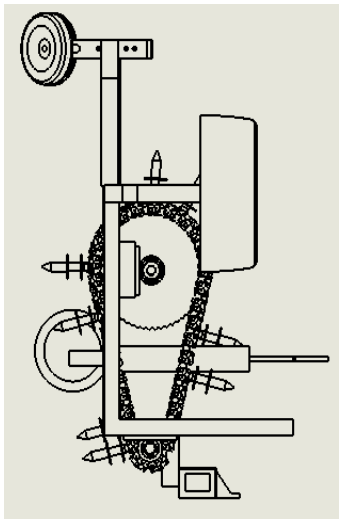


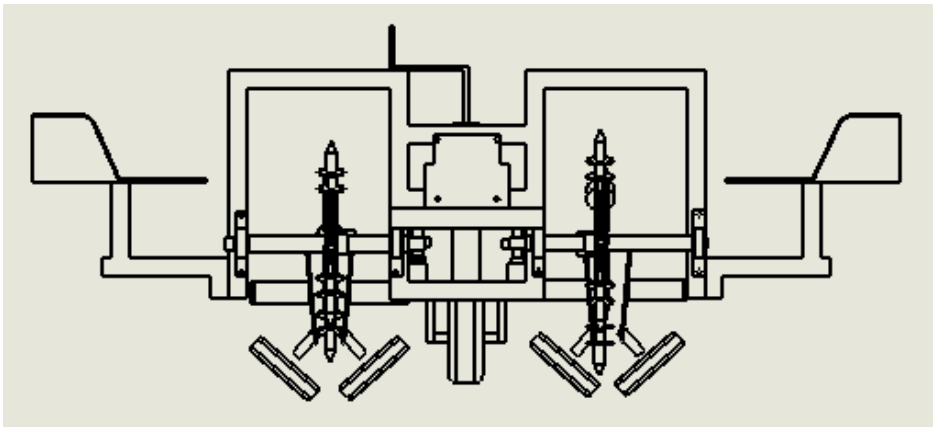
Top view (all dimension in mm)



Isometric view



Side view



Front view

Fig. 2. Schematic view of the vegetable seedling transplanter.

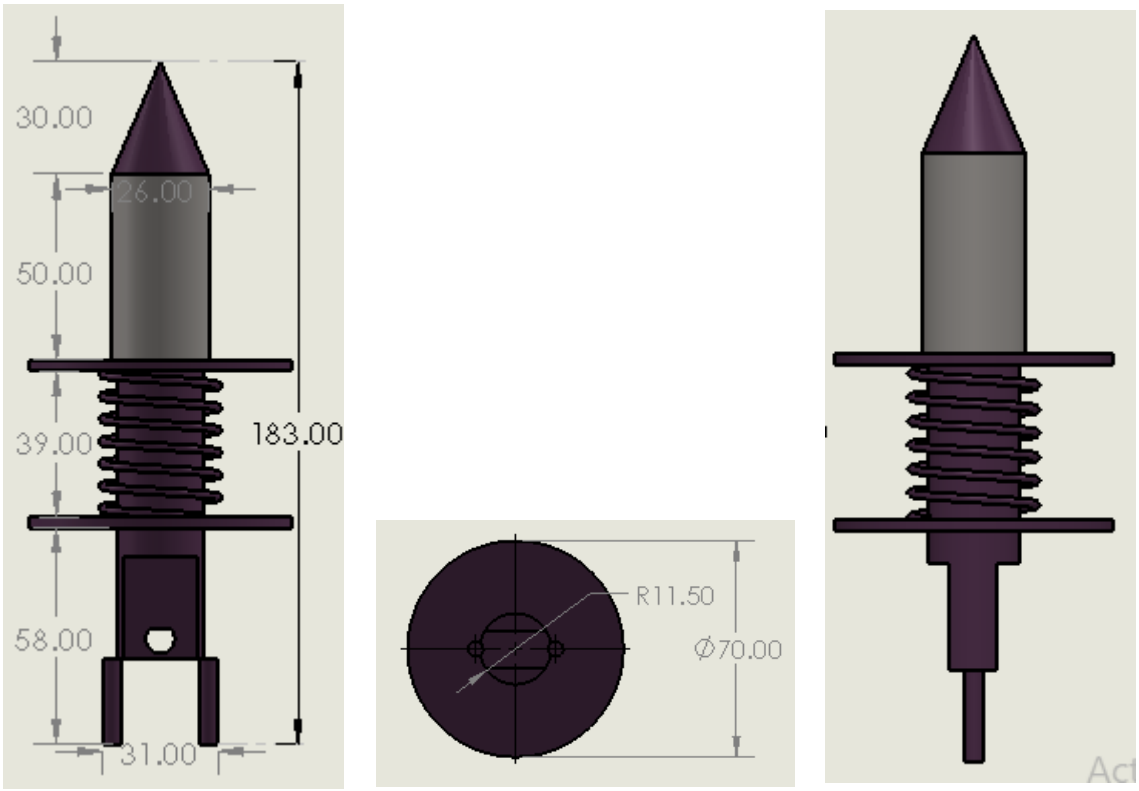
Working principle

The transplanter was attached with a power tiller. When power tiller moved forward, chain and sprocket of transplanter should be moved in the same direction because it was connected with a wheel shaft of power tiller. This chain and sprocket transfer power from the power tiller wheel shaft to the transplanter larger sprocket shaft, while increasing the speed in the larger sprocket 1.81 times due to a change in teeth number because there was another small sprocket, resulting in the forward speed of the power tiller wheel and sprocket being the same. The diameter of the sprocket was 34.5cm to press the dibbler and make a hole in the soil. To plant the seedling at the proper depth in the hole, two people are required (one for each row). The press wheels were used to cover the hole with soil once the seedling has been placed.

Major parts of dibbler type vegetable transplanter

Dibbler

Dibbler is an important part of vegetable transplanter is shown in Fig. 3. It is attached to the chain and is used to dig a hole in the ground. It has a flange, a spring, a beat point, and other features. There are two sprockets attached to the chain, one large and the other small in size. The large sprocket presses down on the dibbler, causing the beat point to come into touch with the soil and enter it. The dibbler's flange is employed to keep the hole's depth constant. After digging a hole in the ground, a spring is utilized to relieve pressure.

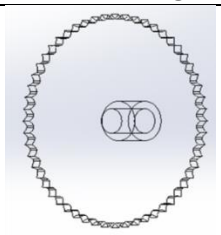
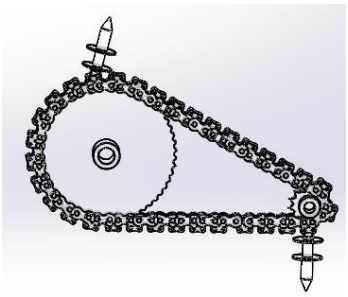


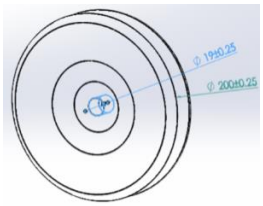
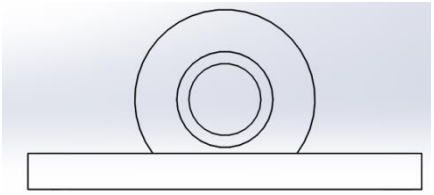
Front view(all dimension mm) Top view Side view

Fig. 3 Schematic view of dibbler of vegetable seedling transplanter.

The different important parts of the vegetable seedling transplanter is presented in Table.1

Table 1. Specifications of important parts of vegetable seedling transplanter

Name	Schematic diagram	Dimension and works
Pressing sprocket		Diameter- 334 mm Number of teeth-54 Thickness- 13 mm Press the dibbler for making hole Power transfer
Small sprocket		Diameter- 95 mm Number of teeth-14 Thickness-13 mm Help to remove the dibbler from soil Power transfer
Chain and Sprocket		Used to transfer the power Dibbler set in chain Maintain seedling to seedling distance

Press wheel		Diameter-200mm Thickness-50 mm Inner diameter-20mm After putting the seedling then cover the soil and compact
Bearing		UCB Bearing- P 206 & P 205 supporting the shaft Power transfer

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Furrow opener type vegetable transplanter

Furrow opener type vegetable transplanter was developed (Fig. 4) with various viewpoints (Fig. 5). It's almost similar to a dibbler-style vegetable transplanter, but the seedling planting method is different. In the dibbler type, the seedling was planted in a hole dug in the earth by the dibbler. However, in the case of a furrow opener, the furrow opener will continue to generate furrow, and the seedling must be placed in the furrow at a distance of 2 inches from the furrow opener wall. So that some soil fills in the furrow while also covering the seedling's root. The soil will again be filled into the furrow and root length of the seedling using a ring type wheel. It will give a little compaction in soil.

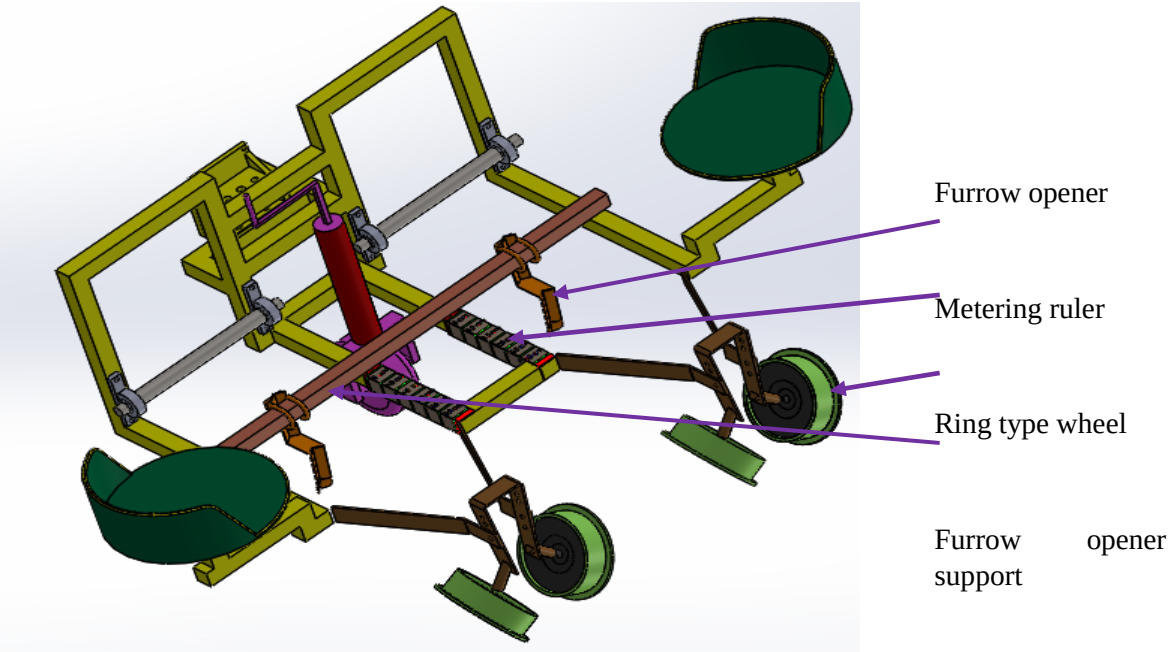


Fig. 4. Furrow opener type vegetable transplanter.

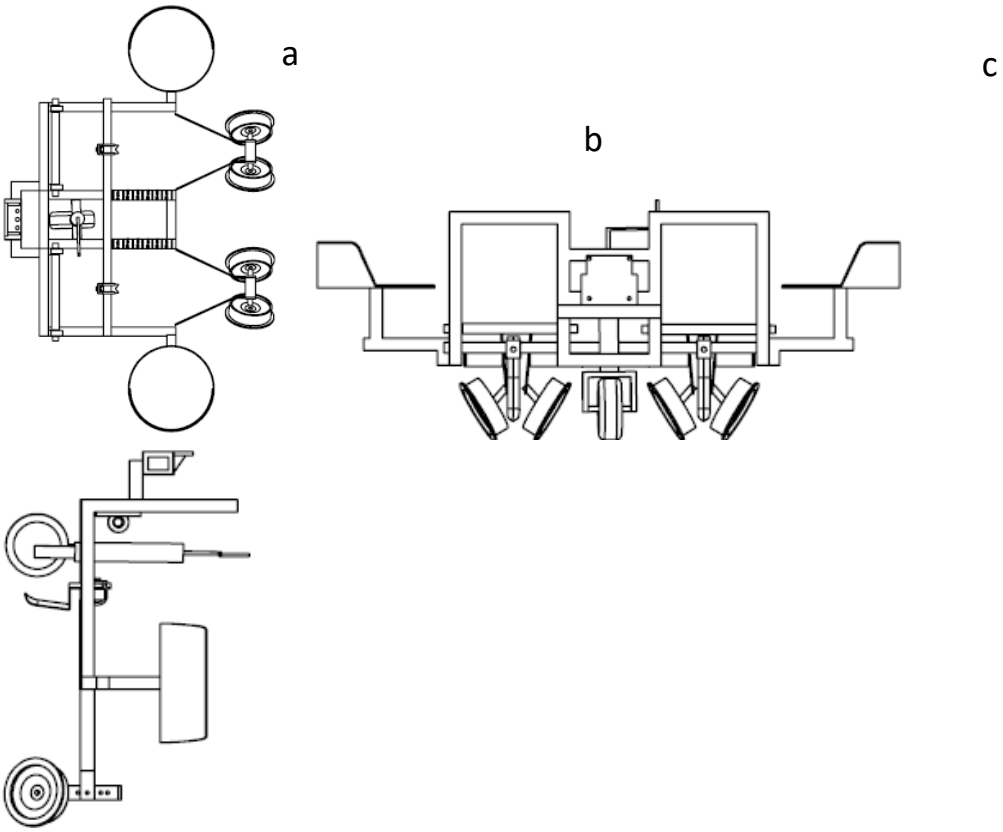
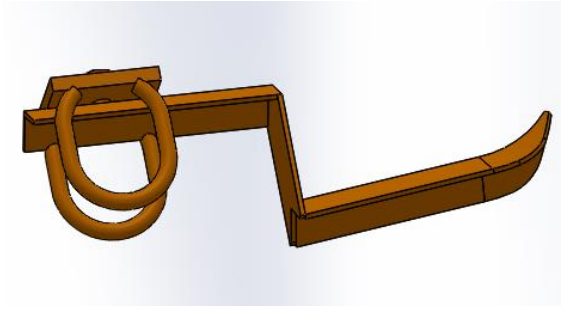


Fig. 5 a) Top view, b) Front view, c) Side view.

Major parts of furrow opener type vegetable transplanter

Furrow opener

It's made of iron that is readily available in the area. To build this furrow opener, we took into consideration all the factors. a) Distance between soil surface and machine lower body surface height, b) Lower portion of furrow opener is 10^{o} inclined with vertical axis for simple seedling placement, c) seedling depth, d) seedling to seedling distance, and so on. Three-dimensional projection of the transplanter was drowned by Solid works 2018. Then fabrication was done according to design and locally available materials were used to fabricate the furrow opener. The schematic views of the furrow opener is shown in Fig .6.



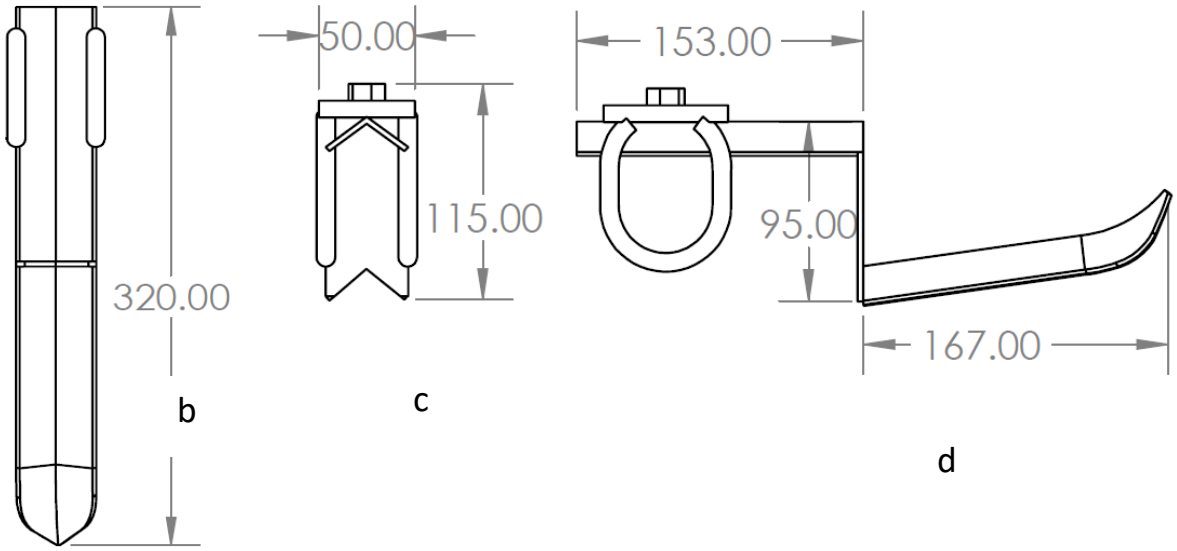


Fig. 6 Furrow opener a) Isometric view, b) Top view, c) Front view, and d) Side view.

Ring type press wheel and metering ruler

Ring-type press wheel was included in the transplanter to apply little pressure to the soil is shown in Fig.7a. The distance between seedlings varies with crop. Metering ruler is very useful for accurately placing of seedling in the furrow opener. Isometric view of metering roller shown in Fig. 7b.

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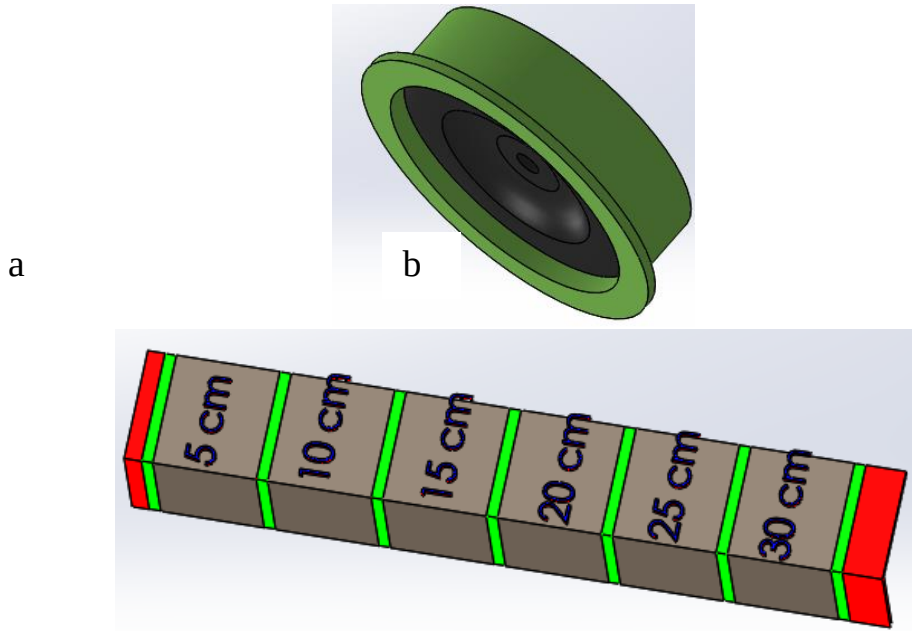

Fig.7a) Ring type press wheel, b) metering roller

Laboratory test

Both types of vegetable transplanters were subjected to laboratory testing. The machine was tested for seeding depth, seedling to seedling distance, percent hole or furrow coverage with soil, missing seedlings%, soil compaction, seedling inclination with vertical axis, and other factors.

Field experiments

Experiments were conducted at the Farm Machinery & Postharvest Process Engineering Divisional research farm of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the rabi season (winter) of 2020-21. The machine was tested at brinjal field. The treatments were T1- Manual transplanting & T2- Transplanting by vegetable transplanter. This is very common method to apply the fertilizer by broadcasting at 10 DAT and 50 DAT for brinjal. Details of the experiment is shown in Table 2, and experimental field view in Fig.8.

Table 2. Details of the experiment for different crops

SL.No.	Parameters	
1	Variety	BARI Begon-8
2	Plot size,m^2	1.5×20
3	Line to line, cm	70
4	Plant to plant, cm	60
5	Date of transplanting	25.11.21

Fig. 8. Pictorial view of experiment field at Gazipur.

Results and Discussion

A power tiller-operated vegetable seedling transplanter was designed, constructed, and tested for two different seedling planting styles (Fig 9). In the lab, we tested the furrow opener type, but not in the experiment field. Both types have an overall dimension of 3350×2000×1500 mm. The field capacity and forward speed of both transplanter were 0.05 ha/h (depending on operator and the crop) and 1.2 km/h respectively Finally, it contains an irrigation system for watering the soil where the seedlings have been planted. This machine is suitable for cup type and non-cup type.

Fig 9. Pictorial view of developed vegetable seedling transplanter.

Laboratory performance for dibbler type

The average depth of placement and distance between seedling to seedling were 3.25 cm and 25.80-62 cm (Table 3). Following the placement of the seedling in the hole, the hole must be completely covered with soil (about 100 percent); otherwise, the seedling may die due to high water loss. According to our findings, the average hole coverage was 115 percent. Additional soil is given for earthing-up after the hole has been covered. During the transplanting process, no seedlings were misplaced. Maintaining row to row distance is a challenge. The minimum and maximum distance can be maintained 50 cm and 81 cm respectively. Another issue is backfilling the hole; seedlings are not always placed at the proper depth. If the dibbler is replaced with a larger one.

Table 3. Performance of dibbler type vegetable transplanter at laboratory

Parameters		Observations										
		1	2	3	4	5	6	7	8	9	10	Mean
Depth of placement, cm		3.10	3.24	3.46	2.85	3.66	3.50	3.41	3.00	3.00	3.32	3.25
Distance between seedling to seedling, cm	Max.	25	23	29	28	26	25	28	24	26	24	25.80
	Max.	61	63	60	62	62	63	62	62	61	63	62
Row to row distance, cm	Min	50	50	50	50	50	50	50	50	50	50	50
	Max.	81	81	81	81	81	81	81	81	81	81	81
% of hole covering		120	115	108	125	121	109	110	117	115	115	115.50
Missing of placement		0	0	0	0	0	0	0	0	0	0	0
Seedling inclination ^{o}		23	12	15	24	19	25	26	18	12	22	19.50

Laboratory performance for furrow opener type

We tested a furrow opener type vegetable seedling transplanter in the lab. It can keep seedling roots at a depth of 2-8 cm. As a result, it can cover a wide variety of crops within this range. The average minimum distance between seedlings was determined to be 12.90 cm, with no issues for maximum distances (Table 4). It is critical to completely fill the furrow after planting the seedling; otherwise, the seedling may die owing to excessive water loss. The average hole coverage was 118.20 percent, according to our findings. Additional soil is given for earthing-up after the hole has been covered. There was no missed placing of seedling during lab test.

There is no problem to maintain row to row distance for different kind of crops. The minimum and maximum distance can be maintained 20 cm and 80 cm respectively. Back fill is a significant issue with dibbler transplanters, however it is not an issue here. Because the seedling was planted about 2 inches from the furrow opener's wall. So that some soil fills in the furrow while also covering the seedling's root. The average seedling inclination was 12.80^{o} angle with vertical axis.

Table 4. Performance of opener type vegetable seedling transplanter at laboratory

Parameters		Observations										
		1	2	3	4	5	6	7	8	9	10	Mean
Depth of placement, cm		It can maintain 2- 8 cm depth of seedling root										
Distance between seedling to seedling, cm	Min.	11	13	14	15	12	13	11	13	13	14	12.90
	Max.	Any distance can maintain										any
Row to row distance, cm	Min.	20	20	20	20	20	20	20	20	20	20	20
	Max.	80	80	80	80	80	80	80	80	80	80	80
% of Hole covering		119	118	118	119	121	117	118	117	116	119	118.20
Missing of placement		0	0	0	0	0	0	0	0	0	0	0
Seedling inclination, ^{o}		8	12	11	14	12	11	16	14	11	19	12.80

Field experiment

Due to time constraints, the furrow opener type of vegetable transplanter was not tested in the field, only the dibbler type was. Table 5 shows that there were no statistical differences in yield and yield contribution parameters of Brinjal. In Bangladesh, the average yield of brinjal was 20-24 t/ha (Chowdhuri *et al.*, 2014). Machine performance data is nearly identical to average yield data. The system will be put to the test for various crops such as tomato, cabbage, cauliflower, and others during the upcoming Rabi season.

Table 5. Yield and yield contribution parameters of Brinjal

Treatment	Plant height, cm	No. of fruit/plant	Fruit length, cm	Fruit wt. g (avg 5 fruit)	Yield, t/h
1. Manual transplanting	98	13.7	29.7	377.5	25.28
2.Vegetable transplanter	101.13	13.9	29.3	367.3	25.95

Conclusion

A power tiller-operated vegetable seedling transplanter has been designed and developed for farmers to reduce labor, cost, and drudgery in the transplanting of vegetable seedlings. For dibbler type and furrow opener type, the spacing between the row to row may be adjusted to 50-81 cm, 20-80 cm, respectively and seedling to seedling may be adjusted to 25.80-62 cm, 12.50 cm - any distance respectively. For both types of transplanter, there were no missing seedling placement during lab test. Furrow opener type seedlings had a lower degree of vertical axis inclination following transplanting than dibbler type seedlings. For dibblers, the average depth of place can be maintained at 3.25 cm, whereas for furrow openers, it can be maintained at 2-8 cm. The average forward speed and field capacity are 1.2 kilometers per hour and 0.050 hectares per hour, respectively. We did not use the furrow opener type transplanter this year due to time constraints. In both treatments, there were no statistical changes in Brinjal yield and yield contribution parameters. The experiment will be carried out again next year in order to improve field performance.

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EXP NO. 1.3 ENERGY USE ANALYSIS OF CONSERVATION TILLAGE SYSTEMS FOR THE RICE-MAIZE CROPPING PATTERN

M A HOQUE AND M I HOSSAIN

Abstract

An improved agricultural production system requires the proper amount of energy, as well as its effective and efficient usage. Conservation agriculture (CA) based crop management can considerably cut cost and improve soil health, and so contribute significantly to smallholder farmer's income and food security. System-based evaluation of the conservation tillage with respect to energy and economics is important. Therefore, this programme was undertaken for Rice-Maize cropping pattern in order to estimate productivity, quantify energy flow and determine financial profitability of conservation tillage methods of Rice-Maize pattern. the experiment was conducted with eight treatments at the research field of Farm Machinery and Postharvest Process Engineering (FMPE) Division, BARI during 2018-21. Treatments were: Conventional Tillage (CT) T. Aman-CT Maize, CT Machine transplanted T. Aman-CT Maize, CT T. Aman-Strip Tillage (ST) Maize, CT T. Aman-Zero Tillage (ZT) Maize, STMT T. Aman-ST Maize, Strip till followed by manual transplanting (STMT) T. Aman-ZT Maize, Unpuddled Tillage (UPT) T. Aman-ST Maize, UPT T. Aman-ZT Maize. During 2020-21, the yield of T. aman and maize for different treatments were not significantly varied. Indirect energy of maize shared lower amount in CT than ST and ZT. The highest energy output-input ratio was found for strip tillage followed by manual planted T.aman-ST maize cropping systems. The highest BCR was found in STMT T.aman-ST Maize cropping pattern. As a result, due to its energy efficiency and economic success, conservation tillage-based agricultural systems could be advocated to farmers.

Introduction

Conservation agriculture (CA) based crop management on under-utilized lands could substantially benefit smallholder farmers and make considerable contributions to regional food security. Declining of the natural resources leads the farmers to seek ways for sustainable intensification of the existing cropping systems. The conservation agriculture (CA) based production systems may achieve these with less labor and energy and higher economical profit margins. Conservation agriculture can facilitate improved crop establishment and timely sowing, maintain or increase yield, lower production costs and energy use, and increase income, while improving system resilience (Gathala *et al.,* 2016; Jat *et al.,* 2013; Kumar *et al.,* 2013; Timsina and Connor, 2001). For enhancing the energy efficiency, it must be attempted either to increase the crop yield without increasing energy input or to conserve energy without affecting the output (Singh *et al.,* 2004). Crop rotation with CA suffers due to puddling during rice cultivation when rotated with strip- or zero-till maize or wheat and puddling is done in T.aman cultivation (Erenstein and Laxmi, 2008). Thus, system-based evaluation of the CA research is important as it can have described real effect in soil, crop and energy. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction. The amount of energy used in agricultural production, processing and distribution is significantly high (Hoque, 2017). Supply of the right amount of energy and its effective and efficient use are necessary for an improved agricultural production. Tillage implement energy requirement is directly related to working depth, tool geometry, travel speed, width of the implement and soil properties (Islam, 2012).

Objectives

a) To assess the productivity of CA tillage practices
b) To quantify the input- output energy flow in Rice-Maize cropping pattern
c) To evaluate the energy efficiency and financial profitability of the systems

Materials and Method

An experiment was established at the research field of Farm Machinery and Postharvest Process Engineering (FMPE) Division, BARI during 2018-19 and continued upto 2020-21. During the rabi season, strip tillage (ST) and Zero Tillage (ZT) were used as CA practices. In comparison to conventional tillage, strip till followed by manual transplanting (STMT) and unpuddled

transplanting by transplanter (UPT) were used as CA practices during the T. aman season. Thus, the following treatments were investigated with 03 (three) replications

T_1=CT T. Aman-CT Maize
T_2=CT Machine transplanted T. Aman-CT Maize
T_3=CT T. Aman-ST Maize
T_4=CT T. Aman-ZT Maize
T_5=STMT T. Aman-ST Maize
T_6=STMT T. Aman-ZT Maize
T_7=UPT T. Aman-ST Maize
T_8=UPT T. Aman-ZT Maize

Residue management

After the aman crop, 250mm of anchored rice residues were retained in the experiment plots. After maize, 250 mm residue was retained in the plots where rice with strip till was manually transplanted and unpuddle mechanically transplanted, as well as maize with strip and zero tillage. In conventional tillage, each rice and maize crop was harvested by cutting at a height of 5 cm from the ground. All harvested straw was removed and the 5 cm height of anchored residue was mixed with soil during puddling in rice field.

Crop management

During T. amn season BINA Dhan-7 was transplanted on 25-07-2020 and harvested on 15-11-2020. The plot size was 6 x5 sq. m(square meters). Standard fertilizer dose (68-10-35-6 kg/ha NPKS), weed management practice and irrigation schedule were followed. All plots were harvested for yield estimation and randomly $1m^2$ area was harvested for yield contributing characters. Variety of maize was BARI Hybrid maize-9. The date of sowing was December 1,2020. The plot size was same as T. aman. Different views of the experimental field are shown in Fig 1. The harvest held on April 26, 2021. Standard fertilizer dose (230-48-90-43-10 kg/ha NPKSZn), weed management practice and irrigation schedule were followed. Before selecting the yield estimation area, border effects were avoided. All the ears from the harvest area were collected. The ear cover was removed. When the ears (with grain) of the area were thoroughly dried. Then the maize was shelled with the help of a maize sheller. All the maize grains were collected and weighed. A representative cob sub-sample of five representative cobs for moisture determination were collected and being weighed. Randomly 1 m^2 area was selected from the main plot for crop biomass, plant height, ear length, ear girth, number of grains and 100 grain weight. There were 10 plants in each of these areas. The energy conversion was carried out with standard energy equivalent as mentioned in Table 1.

Weed management

In CA plots, at least two days before planting, 1 kg active ingredient (a. i.) glyphosate ha^{-1} was applied by mixing in 320–400 L ha^{-1} of water and 0.15–0.2 kg urea ha^{-1} with a three-nozzle flat-fan spray boom. A pre-emergence herbicide Pretilachor @ 500 g a. i. in 400 L of water ha^{-1} was applied 1-3 days after transplanting. If any weeds were stillvisible, they were uprooted and removed. The soil was not turned over during manual weeding. In CT plots, weeds were generally controlled by pudling and then if any weeds survived, they were uprooted and removed.

Fig. 1. Field views of maize (top three) and rice (below three) cultivations with different treatments.

Table 1. Energy equivalent of energy input and energy output indicators

Parameter	Energy equivalent (MJ/unit)	Unit	References
Human Labour	1.96	h	Shahin *et al.* (2008)
Machine	62.7	h	Shahin *et al.*, (2008), Erdal *et al.* (2007)
Diesel	56.31	l	Islam *et al.*, (2012), Erdal *et al.* (2007)
N	64.4	kg	Ozkan *et al.* (2004)
P	11.96	kg	Ozkan *et al.* (2004)
K	6.7	kg	Ozkan *et al.* (2004)
Zn	5	kg	Khosruzzaman *et al.* (2010)
S	1.12	kg	Khosruzzaman *et al.* (2010)
Irrigation water	1.02	m^3	Shahin *et al.* (2008)
Herbicide	200	kg	Khosruzzaman *et al.* (2010)
Fungicide	145	kg	Khosruzzaman *et al.* (2010)
Maize	15.1	Kg	Chaudhary *et al.* (2006)
Maize straw	19.4	kg	Khosruzzaman *et al.* (2010)
Rice	14.7	kg	Shahin *et al.* (2008); Hoque (2017)
Rice straw	12.5	kg	Shahin *et al.* (2008); Hoque (2017)

All energy input from spraying of herbicide followed by tillage, planting, weeding, intercultural operation, harvesting, threshing and upto cleaning was calculated along with all energy output with the following equations

Total energy input

Total energy input, MJ/ha = $E_{de} + Ei_e$ (1)

Where,

E_{de} = Direct energy input, MJ/ha

E_{ie} = Indirect energy input, MJ/ha

Direct energy input, MJ/ha = $E_h + E_f$ (2)

Where,

E_h = Human energy input, MJ/ha

E_f = Fuel energy input, MJ/ha

Human energy input, MJ/ha = $\frac{L \times wdlf \times whl \times L_{eqv}}{A_a}$ (3)

Where,
L = Number of labor for all activities, person
wdlf = Number of working days for labor, day
whl = Working hour, h/day
L_{eqv} = Energy equivalent of labour, MJ/h
A_a = Cultivated area, ha

Mechanical energy input, MJ/ha = $\frac{MF_f \times wh_{mf} \times F_{eqv}}{A_a}$ (4)

Where,
MF_f = Fuel consumption of power source machine, L/h
wh_{mf} = Working hour for farm machine, h
Feq = Energy equivalent of fuel, MJ/L
A_a = Cultivated area, ha

Indirect energy input, MJ/ha = $E_s + E_m + E_{fr} + E_{pp} + E_i$ (5)

Where,
E_s = Seed or biological energy input, MJ/ha
E_m = Machinery energy input, MJ/ha
E_{fr} = Fertilizer energy input, MJ/ha
E_{pp} = Plant protection energy input, MJ/ha
E_i = Irrigation energy input, MJ/ha

Seed was considered as biological energy resources input. Therefore, only seeds were considered to calculate biological energy input.

Total seed input, MJ/ha = Seed x S_{eqv} (6)

Where,
Seed = Amount of seed applied, kg/ha and S_{eqv} = Energy equivalent of seed, MJ/kg

Energy sequestered in machinery was calculated as following formula.
Total energy sequestered, MJ/ha = M×h (7)

Where,
M = Energy sequestered in manufacturing for machinery, MJ/h
h = Machine working hour, h/ha

Total fertilizer input, MJ/ha =((Urea x $U_{eqv)}$ + (TSP x T_{eqv}) + (MoP x K_{eqv}))A (8)

Where,
U_{eqv} = Energy equivalent values of urea, MJ/kg
T_{eqv} = Energy equivalent values of triple super phosphate, MJ/kg
K_{eqv} = Energy equivalent values of muriate of potash, MJ/kg
Urea = Urea fertilizer rate applied, kg/ha
TSP = TSP fertilizer rate applied, kg/ha
MoP = MoP fertilizer rate applied, kg/ha
A_a = Cultivated area, ha

Plant protection energy input, MJ/ha= $E_{pp\text{-}h} + E_{pp\text{-}p}$ (9)

Where,

$E_{pp\text{-}h}$ = Herbicide energy input, MJ/ha

$E_{pp\text{-}p}$ = Pesticide energy input, MJ/ha

Total herbicide input, MJ/ha =Her × H_{eqv} (10)

Where,

Her = Applied rate of herbicide, kg or lit/ha

H_{eqv} = Energy equivalent MJ of herbicide, MJ/kg or MJ/lit

Total pesticide input, MJ/ha = Pes × P_{eqv} (11)

Where,

Pes = Application rate of pesticide, kg/ha or lit/ha

P_{eqv} = Energy equivalent MJof pesticide, MJ/kg or MJ/lit

Irrigation energy input, MJ/ha = $I_w \times I_{eqv}$ (12)

Where,

I_w = Volume of irrigation water, m^3

I_{eqv} = Energy equivalent MJ of irrigation, MJ/m

Energy output

Energy output was considered of main product and by-product.

Total energy output, MJ/ha = (Yield x E_{eqp}) + (By-product x E_{eqb}) (13)

Where, E_{eqp} = Energy equivalent value of main product (grain yield of rice and maize) and

E_{eqb} = Energy equivalent value of by-product (Biomass of rice and maize)

Energy ratio (energy use efficiency), energy productivity, net energy gain and specific energy were calculated using the following relationships (Singh, 2002; Sartori *et al.,* 2005):

$$\text{Output- input energy ratio} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}} \quad (14)$$

$$\text{Energy productivity} = \frac{\text{Product Output (kg/ha)}}{\text{Input energy (MJ/ha)}} \quad (15)$$

Net energy gain= Output energy (MJ/ha) - Input energy (MJ/ha) (16)

$$\text{Specific energy} = \frac{\text{Input energy (MJ/ha)}}{\text{Product output (Biomass) (kg/ha)}} \quad (17)$$

Operating cost calculation

The operating cost was calculated to determine its economic performance and production cost. Costs were calculated for both fixed and variable costs. The following formulae were used to calculate fixed cost: depreciation, interest on investment, tax, insurance and shelter costs (Hunt, 2001).

Annual depreciation (Tk/yr), D= (P-S)/L (18)

Where, P = Purchase price, Tk

S =Salvage value, Tk

L= Working life of the machine, yr

Interest on investment (Tk) , I=(P+S)/2*i (19)

Where, i= rate of interest

P=Purchase price, Tk

S =Salvage value, Tk

Tax, insurance and shelter cost T=3% of P (20)

Total fixed cost per year, FC= (a+b+c)

The cost of fuel, lubrication, and labour were all taken into calculating variable cost. These cost increase with increase of machine use and vary to a large extent in direct proportion to number of days used per year.

Labour cost per hour, L= Tk/man/h (21)
Fuel cost per hour, F= l/h × Tk/l (22)
Lubrication oil cost per hour, O= 3% of fuel cost (23)
Repair and maintenance cost per year=3.5% of purchase price (24)
Total variable cost= (d+e+f+g) (25)

A simple partial economic analysis was done based on total production. The following formulas were used to compute total production cost, gross return, gross margin and benefit-cost ratio (BCR) using produce prices from local market

Total product value= Yield (kg/ha) x Price (Tk/kg) (26)

Gross return (Tk/ha) = Total product value – Variable production cost (27)

Net return = Total Product value (Tk/ha) – Total production cost (Tk/ha) (28)

$$\text{Benefit –cost ratio} = \frac{TPV}{TPC} \quad (29)$$

Where, TPV= Total Production value (Tk/ha), TPC= Total production cost (Tk/ha).

Results and Discussion

Yield and yield contributing character of T. aman rice at Gazipur for different treatments combination during 2020-21 were presented in Table 2. Grain at storage moisture content of 12% and straw yield of rice for different treatments were not significantly varied. Plant height, number of tillers per hill, number of fill grains per panicle were all found to be non-significant. When the treatments were merged to basic three treatments (CT, ST and ZT) for aman rice, yield and yield contributing characters were significantly varied. The highest rice yield was found in strip till manual transplanted rice which was similar with that in conventional. This higher rice yield was found for higher numbers of fill grain and lower number of unfill grain of rice. Yield and yield contributing character of maize at Gazipur for different treatments combination during 2020-21 were presented in Table 3. Grain at storage moisture content of 14% and straw yield of maize for different treatments were not significantly varied. Plant population, plant height, cob length, no of grain per cob and thousand grain weights were also non-significant. When the treatments were merged to basic three treatments (CT, ST and ZT) for rabi crops, significant variation in yield and yield contributing characters of maize were found. The highest maize grain yield was found in strip tillage which was similar with that found in zero tillage due to higher cob dia. The lower maize yield was found in conventional tillage.

Direct energy consumption for T.aman rice cultivation was 47% in CT, 29% in STMT and 29% in UPT during rice cultivation (Table 4). Direct energy was the highest in CT and the lower STMT and UPT due to difference in labour and fuel use. Indirect energy shared 53% in CT, 71% in STMT and 71% in UPT. Machinery energy was the highest in CT (16%). Irrigation energy consumption in rice cultivation was 7 to 11% of the total. Energy for plant protection was more in UPT and STMT than that in CT because of application of herbicide prior transplanting.

Direct energy consumption for maize was accounted for only a small proportion of the total energy consumption. Direct energy was 16% in CT, 10% in ST and 10% in ZT during maize cultivation (Table 4). Direct energy was the highest in CT and the lower ST and ZT due to difference in fuel use. Indirect energy shared 84% in CT, 90% in ST and 90 % in ZT. The largest source of indirect energy consumption was from fertilizer (61-65% of the total energy consumption). Machinery energy was the highest in CT (8%). Irrigation energy consumption in maize cultivation was 10 to 13% of the total. Energy for plant protection was more in ST (7%) and ZT (7%) than that in CT because of application of herbicide prior strip tillage.

Table 2. Yield and yield contributing character of rice at Gazipur for different treatments combination during 2020-21

Treat	Hill popul /m^2	Plant height, cm	No. of Tiller /Hill	Panicle length, Cm	No. of filled grains/ panicle, g	No. of unfilled grains/ panicle, g	Grain yield, (t/ha)	Straw yield, (t/ha)
T_1	25.33	97.81	17.57	26.82	64.73	28.80	5.21	5.79
T_2	25.00	92.65	21.13	23.57	59.47	33.47	5.93	6.94
T_3	25.00	97.18	17.45	22.74	67.83	27.53	5.60	6.21
T_4	25.00	97.39	18.80	23.45	67.40	33.93	5.90	6.91
T_5	25.33	89.83	17.93	21.84	67.47	25.20	6.22	7.28
T_6	25.33	92.45	18.80	21.88	69.60	25.20	6.14	6.82
T_7	24.67	91.99	19.07	23.23	57.67	29.73	5.12	5.99
T_8	25.33	94.34	17.40	23.01	58.53	34.20	4.80	5.33
HSD	NS	NS	NS	NS	NS	NS	NS	NS
CV	1.87	4.04	10.40	10.20	11.08	19.15	12.85	13.00
CT	25.08	96.26 a	18.74	24.15	64.86 ab	30.93 ab	5.66 a	77.53 ab
STMT	25.33	91.14 b	18.37	21.86	68.53 a	25.20 b	6.18 a	42.29 a
UPT	25.00	93.17 ab	18.23	23.12	58.10 b	31.97 a	4.96 b	33.95 b
HSD	NS	3.98	NS	NS	6.99	5.78	0.69	0.88
CV	1.83	4.06	11.37	10.40	10.46	18.80	11.90	13.20

T_1=CT T. Aman-CT Maize; T_2=CT Machine transplanted T. Aman-CT Maize; T_3=CT T. Aman-ST Maize; T_4=CT T. Aman-ZT Maize; T_5=STMT T. Aman-ST Maize; T_6=STMT T. Aman-ZT Maize; T_7=UPT T. Aman-ST Maize; T_8=UPT T. Aman-ZT Maize

Table 3. Yield and yield contributing character of maize at Gazipur for different treatments combination during 2020-21

Treatment	Plant population /m^2	Plant height, cm	Cob length, cm	Cob dia, cm	Number of grain/cob	TGW, g	Grain yield, (t/ha)	Straw yield, (t/ha)
T_1	5.33	265.67	17.53	4.13	21.65	245.33	6.38	6.95
T_2	6.04	264.67	18.19	4.13	22.31	222.42	6.76	7.37
T_3	6.31	266.67	18.21	4.21	22.42	244.42	7.58	8.26
T_4	6.22	270.33	19.44	4.26	23.70	241.17	7.52	8.19
T_5	5.95	275.67	19.07	4.13	23.21	226.73	7.71	8.40
T_6	5.60	268.00	18.30	4.26	22.56	236.35	7.09	7.72
T_7	6.67	265.33	19.10	4.33	23.43	248.50	7.14	7.78
T_8	6.31	269.33	18.84	4.24	23.08	246.93	7.59	8.27
HSD	NS	NS	NS	NS	NS	NS	NS	NS
CV	13.07	2.82	6.34	2.85	5.43	7.48	9.86	9.85
CT	5.69	265.17	17.86	4.13 b	21.98	233.87	6.57 b	7.16 b
ST	6.31	269.22	18.80	4.22 ab	23.02	239.88	7.48 a	8.15 a
ZT	6.04	269.22	18.86	4.25 a	23.11	241.48	7.40 a	8.06 a
HSD	NS	NS	NS	0.11	NS	NS	0.53	0.57
CV	13.64	2.31	4.30	3.20	7.18	7.08	9.84	9.92

T_1=CT T. Aman-CT maize; T_2=CT Machine transplanted T. Aman-CT maize; T_3=CT T. Aman-ST maize; T_4=CT T. Aman-ZT maize; T_5=STMT T. Aman-ST maize; T_6=STMT T. Aman-ZT maize; T_7=UPT T. Aman-ST maize; T_8=UPT T. Aman-ZT maize.

Table 4 Source wise energy consumption (GJ/ha) under different tillage options in maize cultivation

Source	T. aman			Maize		
	CT	STMT	UPT	CT	ST	ZT
Direct Energy						
Human	4.37 (24)	2.04 (18)	2.04 (18)	1.25 (5)	1.01 (4)	1.02 (4)
Fuel	3.99 (22)	1.29 (11)	1.27 (11)	2.95 (11)	1.44 (6)	1.43 (6)
Subtotal	8.36 (47)	3.34 (29)	3.32 (29)	4.19 (16)	2.45 (10)	2.45 (10)
Indirect Energy						
Seed	0.59 (3)	0.59 (5)	0.59 (5)	0.34 (1)	0.34 (1)	0.34 (1)
Machinery	2.84 (16)	0.83 (7)	0.84 (7)	2.09 (8)	0.97 (4)	0.96 (4)
Fertilizer	4.74 (26)	4.74 (41)	4.74 (41)	16.08 (61)	16.08 (65)	16.08 (65)
Plant. Prot	0.15 (1)	0.89 (8)	0.89 (8)	1.09 (4)	1.75 (7)	1.75 (7)
Irrigation	1.24 (7)	1.29 (11)	1.21 (10)	2.50 (10)	3.04 (12)	3.10 (13)
Subtotal	9.57 (53)	8.34 (71)	8.27 (71)	22.11 (84)	22.19 (90)	22.24 (90)
Grand Total	17.93(100)	11.68(100)	11.59 (100)	26.30 (100)	24.64 (100)	24.69 (100)

Figure in the bracket indicate the % of the total energy

Energy output-input relationship under different tillage methods in maize and T. aman rice cultivation is shown in Table 5. Input energy of rice cultivation was significantly varied under different tillage method. The highest input energy of rice cultivation was found for CT. Output-input ratio and energy productivity were significantly higher in STMT transplanted rice.

Input energy of maize cultivation was significantly varied under different tillage method. The highest input energy was found for CT. Output energy, output-input ration, net energy and energy productivity were higher in strip tillage methods of maize cultivation.

Table 5 Energy output-input relationship under different tillage methods in T. aman and maize cultivation

Method	Input Energy GJ/ha	Output energy GJ/ha	Output-Input Energy Ratio	Net Energy gain, GJ/ha	Energy Productivity, kg/GJ	Specific Energy, GJ/kg
T. aman rice cultivation						
CT	15.47 a	163.98 ab	10.58 c	148.51 ab	0.37 c	1.30 a
STMT	11.23 b	178.97 a	15.92 a	167.74 a	0.55 a	0.85 c
UPT	11.03 b	143.65 b	13.01 b	132.62 b	0.45 b	1.05 b
LSD	0.41	21.16	1.26	20.89	0.04	0.13
CV	3.12	12.47	9.12	13.34	8.65	14.02
Maize cultivation						
CT	26.30 a	238.14 b	9.05 b	211.84 b	0.25 b	1.93 a
ST	24.45 b	270.94 a	11.08 a	246.48 a	0.31 a	1.57 b
ZT	24.51 b	268.10 a	10.93 a	243.59 a	0.30 a	1.60 b
LSD	0.34	23.61	0.95	23.56	0.03	0.15
CV	1.36	9.24	9.26	10.21	9.26	8.92

Input energy for different cropping systems was not varied but the energy output was varied (Fig 2). The highest energy output-input ratio was found for STMT T.aman-ST maize cropping systems. The lowest energy ratio was found in CT manual transplanted T. Aman-CT Maize cropping systems.

The highest BCR was found in STMT T.aman-ST Maize cropping pattern followed by CT T. aman -ST Maize cropping pattern (Fig 4).

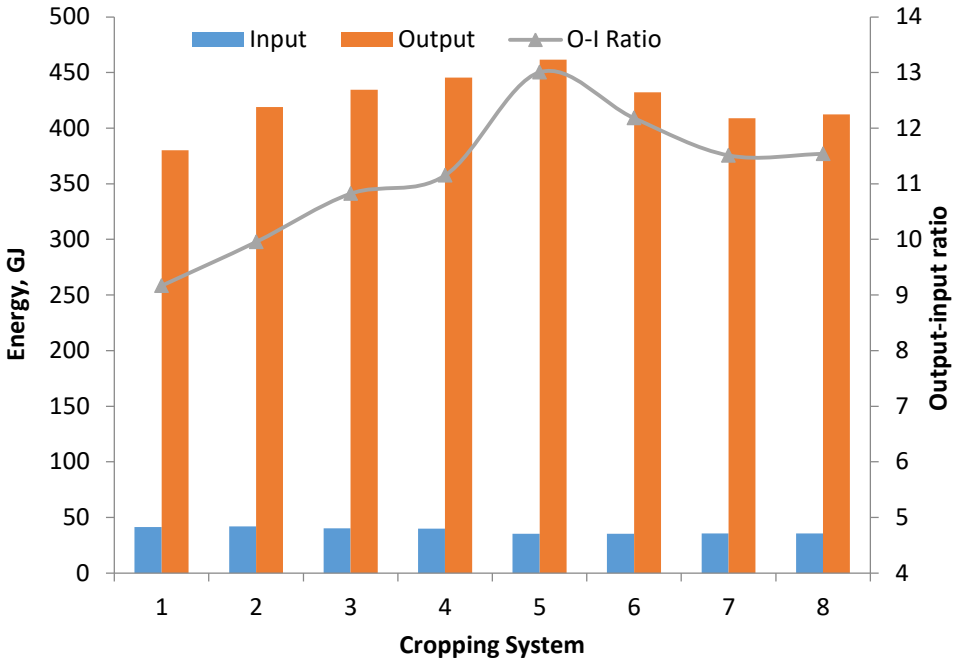

Fig. 2 Energy input, output and energy ratio for different cropping systems.

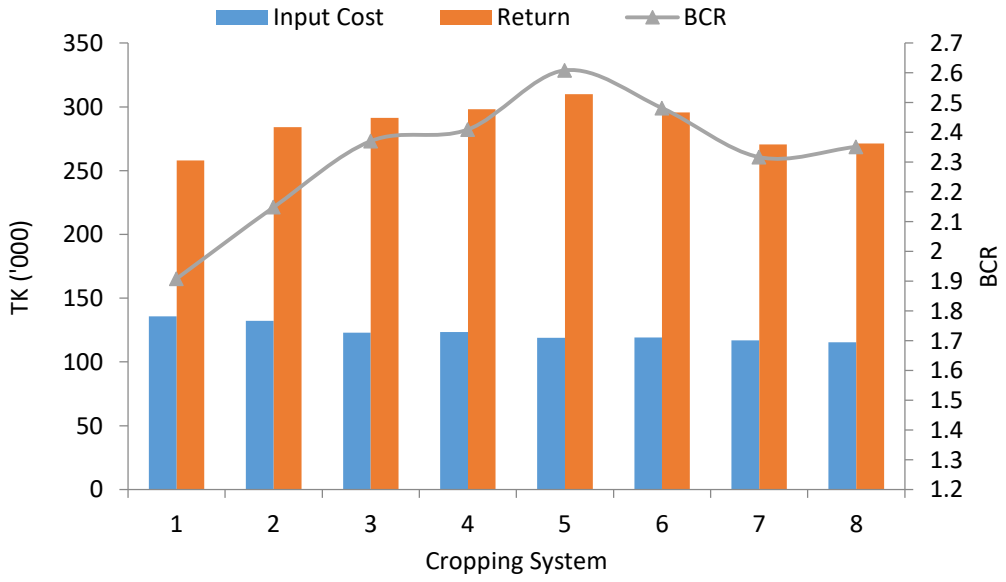

Fig. 3 Input-output cost and BCR for different cropping systems.

Conclusion

Yield of T aman and maize for different treatments were not significantly varied. Direct energy of T. aman rice cultivation was the highest in CT and the lowest ST and ZT due to differences in labour and fuel use. When compared to total energy consumption during maize cultivation, direct energy usage was the lowest. Indirect energy of maize shared lower amount in CT than ST and ZT. The highest energy output-input ratio was found for strip tillage followed by manual planted T.aman-ST maize cropping systems. The highest BCR was found in STMT T.aman-ST Maize cropping pattern. As a result, due to its energy efficiency and economic success, conservation tillage-based agricultural systems could be advocated to farmers.

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EXPT. NO. 1.4 DESIGN AND DEVELOPMENT OF ONION AND GARLIC DETOPPER

M A HOQUE, M A HOSSAIN, M A MOTTALIB AND S BRAHMA

Abstract

Onion and garlic are important spice crops in Bangladesh. After harvesting, the edible bulb portion is separated from the inedible stem by cutting or detopping by manually leaving only 15–30 mm stem with the bulb, one by one, mostly using a sharp kitchen knife (boty) which is laborious, time consuming and costly. Therefore, an onion and garlic detopper machine was designed and fabricated at the workshop of the Farm Machinery and Postharvest Process Engineering(FMPE) Division of Bangladesh Agricultural Research Institute(BARI), Joydebpur, Gazipur during 2019-20. It was then improved during the period of 2020–21. Both the detoppers were made with locally available materials with a 0.37 kW electric motor. The detopper was improved by adding tray and wheel. Average capacity of the detopper for onion with previous model and the improved model were found to be 62.70 and 64.92 kg/h, respectively, whereas only 49.96 kg/h could be trimmed by two persons manually. Average capacity of the detopper for garlic with previous model and the improved model were found to be 43.32 and 48.92 kg/h, respectively, whereas only 30.72 kg/h could be trimmed by two persons manually. Stem length of onion and garlic after detopping by the improved machine were near to manual method. However, the capacity of the machine was not as high to attract a user to purchase the machine. Therefore, attempts have been started to develope an alternative design of detopper which will be fabricated in the next year.

Introduction

Onion (*Allium cepa*) is an important spice crop in Bangladesh. It ranks first in production (1.80 M tons) and in acreage (172533 ha) among the spices during 2018–19 (BBS, 2019). Garlic (*Allium sativum*) is an another important spice crop. The area and production of garlic were 71443 ha and 461970 M tons, respectively during 2018–19 (BBS, 2019).

During winter, onion and garlic are widely cultivated all over Bangladesh. Farmers generally follow traditional method for cultivating onion in Bangladesh. On the other hand, the productivity of the onion crop in the country is very low (5.36 tha^{-1}) against the world's productivity, being (17.45 tha^{-1}) (FAO, 2015). To meet up the demand of increased population, onion production should be increased with lower production cost. After onions have dried for 3-5 days in field under sunny dry conditions, remove the roots and tops of the onions. Tops are cut at approximately 38-50 mm above the bulb and roots cut off completely. Extra short necks increase the likelihood of disease infection. During clipping, take care to prevent injury to the bulbs with the shears and by dropping the bulbs onto hard surfaces such as the bottom of buckets and other onions. The roots and stems of onion and garlic are usually required to be removed before sold or store. This operation conventionally has done manually using traditional sickle, knives, pruners, axe and scissors which is tedious and time consuming (George and Kelley, 2008).

The production cost increases for this manual detopping since labour cost is high during harvesting. Moreover, sometimes labour is not available which leads to postharvest loss during unfavorable weather during harvesting season. Qi *et al.* (2011) stated that the factor affects the cutting process is the cutting tools. The knife sharpness can significantly affect storage life, whereas dull knives cause bruises and damage to the tissue layers (Gil and Allende 2012. Mishra *et al.*, 2012). Habib *et al.* (2001) reported that the cutting process of agricultural plants is more complicated than the cutting of engineering materials. This may be due to plants are not homogeneous. Rani and Srivastava (2012) designed and developed a detopper consisted of a chute type feeding unit, a belt conveyor, an oscillating conveyor, rotating fingers and a rotating cutter. An electric powered transmission system drove all moving components. The onion bulbs were fed through a chute type feeding unit to the belt conveyor that ensured uniform transport of the bulbs to an oscillating conveyor. The belt conveyor had two rollers and an endless conveyor belt moving at a speed of 0.53 m/s. The oscillating conveyor had a frame, round rods and a crank mechanism to facilitate downward orientation of onion leaves. The bulbs with leaves in downward orientation passed through rotating cutters. The cutter was provided at the downward side of the oscillating

conveyor so that the cutting could be done from beneath without damaging the bulbs. Output capacity was 300 kgh^{-1} and the detopping efficiency was 79% (Rani and Srivastava, 2012) but the machine was developed for commercial use. There is very little information in the literature on the design and development of small scale onion and garlic detopper for cutting roots and stems of onion and garlic. Therefore, this program was under to design and develop a small scale onion and garlic detopper machine.

Objectives

a) To design, develop and fabricate a small scale onion and garlic detopper machine
b) To evaluate the performance of the developed machines for detopping onion and garlic.

Materials and Method

An onion and garlic detopper machine was designed and fabricated at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during the period of 2019-20 for lot feeds with two operators and 2–3 helpers. The detopper was improved during 2020-21. The cutter blades shearing action were used for the detopper. The materials used for the fabrication of different parts of the machine were MS angle bar, MS flat bar, MS rod, MS sheet, MS shaft, rubber sheet, ball-bearing, and miscellaneous small spares. The functional parts of the machine are (1) Power source; (2) Power transmission; (3) Feeding fingers; (4) Cutter bar; (6) Outlet chutes.The photographic views of the onion stem cutter are shown in Fig. 1. The previous detopper was improved by adding a tray to store the raw materials on it. Four wheels were used for easy movement.

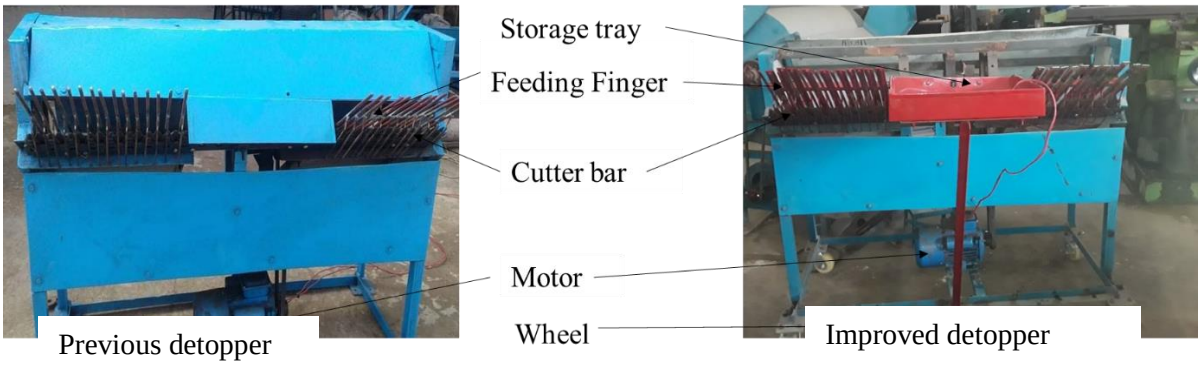

Fig. 1. Pictorial view of both the detoppers.

The functional parts of the detoppers are described briefly as follows:

(1) Power source: A 0.37 kW single phase electric motor was used as the source of power.
(2) Power transmission: The power transmission system is shown in Fig. 4. In the first step, rpm of motor was stepped down from 1400 to 756 in the main shaft of the reducer gear box. A reducer gear box was used to reduce the rpm from 756 to 175 on the cutting blade bar.
(3) Feeding finger: The feeding fingers were made of MS rod maintaining a uniform spacing of 15mm. The feeding fingers were located in both side maintaining a 500 mm space in middle of the machine. In each side the width of the feeding finger was 360 mm.
(4) Cutter bar: The main part of the detopper is in the cutting system. The cutting mechanism was followed with principles of share cutting as same as used in rice reaper. The width of the cutter bar was 1200 mm but the effective width of the cutter bar was (360 + 360) 720 mm. Number of v-shaped cutter bar were 15 which were placed upon same numbers of base of the cutter. Clearance between the upper and lower shearing element was 0.5 mm
(5) Outlet Chutes: Two outlet chutes were fabricated with MS sheet to collect onion or garlic after detopping. The dimensions were 570 x 440 mm.

(6) Storage tray: A storage tray was fabricated with MS sheet to store onion or garlic before detopping.
(7) Wheels: Four wheels were added in the onion or garlic detopper to move anywhere.

The power comes from the motor shaft with belt pulley to the inlet shaft of the reducer gearbox (Fig 2). From the reducer gear box, power was transmitted to the cutter bar through a universal shaft joint. Detailed specification of the detopper is given in Table 1.

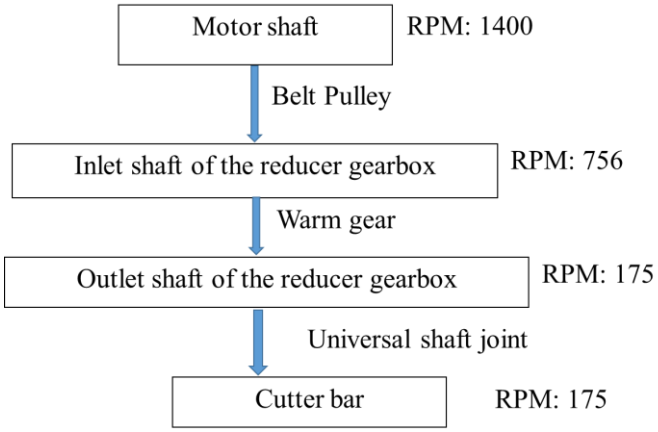

Fig. 2. Power transmission system of the detopper

Table 1. Specification of the improved onion and garlic detopper

Parameters	Improved detopper
Overall dimension	1390×690×1150 mm
Feeding tray/ Finger	400×360 mm
Diameter of cutting disk	Not applicable
Length of conveyor chain	Not applicable
Dimension of Cutter bar	1250 mm
Dimension of each cutter blade	80×50×10 mm
Width of each chain	Not applicable
Width of chain conveyor	Not applicable
Cutting disk rotation	Not applicable
Cutter blade speed	250 rpm

Performance Evaluation of the detopper:
The improved detopper was tested with onion and garlic collected from Sujanagar, Pabna during 2020-21. The improved detopper was compared with the manual method and the previous detopper use. The machines were operated with two operators and the manual method was calculated for single operator. The capacity of the machine was evaluated as the quantity of the onion/garlic could be feed within a recorded time. In this case, 10 kg of row materials were fed into the machine while the time to complete the cutting operation was recorded.

The capacity of the machine was calculated using following equation

$$C = \frac{Q}{T}$$

Where, C = Capacity of the machine, Q = Mass of the input materials, T = Time taken for processed.

Results and Discussion

Performance of the detopper for onion compared with the previous model of detopper and manual method is shown in Table 2. Average capacity of the detopper for onion with previous model and the improved model were found to be 62.70 and 64.92kg/h whereas only 49.96 kg/h could be trimmed by two persons manually. The capacity of the manual method was calculated for two persons since the machine was operated with two persons. Stem length of onion after detopping by the improved machine was near to manual method.

Performance of the detopper for garlic compared with manual method is shown in Table 3. Average capacity of the detopper for garlic with previous model and the improved model were found to be 43.32 and 48.92 kg/h whereas only 30.72 kg/h could be trimmed by two persons manually. The capacity of the manual method was calculated for two persons since the machine was operated with two persons. Stem length of garlic after detopping by the improved machine was near to manual method. However, the capacity of the machine was not as high to attract a user to invest for machine purchasing.

Table 2. Performance of detopper for onion during 2020-21

Trial	Capacity, kgh^{-1}			Stem length after cutting, mm		
	Previous detopper	Improved detopper	Manual/ 2 persons	Previous detopper	Improved detopper	Manual/ 2 person
1	61.76	67.76	51.8	24	20	15
2	64.64	65.36	49	20	16	17
3	61.49	69.36	54	22	18	16
4	61.61	59.9	57	26	22	17
5	63.98	62.2	38	23	19	15
Average	62.70	64.92	49.96	23	19	16

Table 3. Performance of detopper for garlic during 2020-21

Trial	Capacity, kgh^{-1}			Stem length after cutting, mm		
	Previous detopper	Improved detopper	Manual/ 2 persons	Machine	Machine	Manual
1	42.76	47.76	27.8	21	18	15
2	42.36	45.36	33	20	14	17
3	43.36	49.36	30	22	16	16
4	45.9	59.9	35	22	20	17
5	42.2	42.2	27.8	23	17	15
Average	43.32	48.92	30.72	21.60	17.00	16.00

To improve the capacity of the machine and to feed onion or garlic continuously for detopping, further design is needed. Thus, attempts were started to developed an alternative design of detopper (Fig 3). The fabrication (Fig 4) was started but could not be completed due to COVID pandemic and lockdown situations.

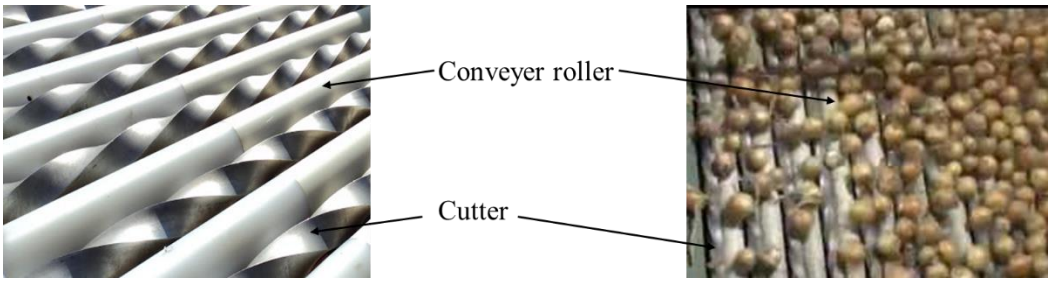

Fig 3. Conceptual design of the new detopper

Arrangement of the roller and cutter

Fig 4. Fabrication and arrangement of roller and cutter of new detopper

Conclusion

The detopper for onion and garlic was improved by adding tray and wheel. Average capacity of the detopper for onion with previous model and the improved model were found to be 62.70 and 64.92 kg/h respectively, whereas only 49.96 kg/h could be trimmed by two persons manually. Average capacity of the detopper for garlic with previous model and the improved model were found to be 43.32 and 48.92 kg/h respectively, whereas only 30.72 kg/h could be trimmed by two persons manually. Stem length of onion and garlic after detopping by the improved machine were near to manual method. However, the capacity of the machine was not as high to attract a user to invest for the machine purchasing. Thus attempts have been started to develop an alternative design of detopper which will be fabricated in the next year.

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EXPT. NO. 1.5 INVESTIGATION OF LONG TERM CONSERVATION AGRICULTURE AT BARI AND ADAPTIVE TRIALS OF CONSERVATION MACHINERY AND WATER MANAGEMENT SYSTEMS IN THE SOUTHERN DELTA OF BANGLADESH

M A HOSSAIN, M A HOQUE, M J ALAM, M M ALAM AND C K SAHA

Abstract

Conservation agriculture (CA) is a tool of sustainable agriculture utilized in many countries. Sustainable agriculture has different dimensions among which the most important ones are environmental, social, economic, and institutional. Long-term tillage system and site-specific crop management can affect changes in soil properties and processes, so there is a critical need for a better and comprehensive process-level understanding of differential effects of tillage systems and crop management on the direction and magnitude of changes in crop yield, soil carbon storage, and other soil properties. Therefore, the study has been undertaken to evaluate the long term effect of conservation agriculture and conventional tillage on crop yield and soil properties for different cropping system and tillage method. The long term conservation agriculture trials were conducted at CA park established at Bangladesh Agricultural Research Institute (BARI), Gazipur during 2020-21. The maize and mungbean experiments were conducted with four tillage methods such as T_1= Conventional; T_2= Strip tillage; T_3= Zero tillage and T_4= Bed planting. Rice experiment was conducted with the tillage methods as T_1= Manual transplanted in conventional tilled soil; T_2= Mechanical transplanted in conventional tilled soil; T_3= Manual transplanted in unpuddled soil and T_4= Mechanical transplanted in unpuddled soil. The long term CA trials were initiated. Different facilities were created in CA park for long term experiments. The yield of maize, mungbean and Aus rice were not varied with the treatments since advantage of CA could not achieved in absence of residue. About 0.65 ha of mungbean was planted by BARI seeder at Mundopasha, Wazipur, Barishal and 4.70 ha mungbean was planted at Holdibaria, Kolapara, Patuakhali. Significantly the highest yield of mungbean was obtained from strip, zero and conventional tillage methods both in Barishal and Patuakhali. About 2.60 ha of jute was planted by BARI seeder at Dumuria, Khulna and Jute is now in growing stage. The experiments will be continued in the next year to impose the residue treatments and to observe the impact in the long run.

Introduction

The conventional crop production has been considered unsustainable, as it is less energy efficient, consumes more water with lesser productivity, employs improper inputs usage, and obsolete crop establishment methods (Jat *et al.*, 2011 and Parihar *et al.*, 2016). Consequently, poor residue management under conventional tillage (CT) practices forced the farmers either to burn them in-situ or feed to the cattle (Jat *et al.*, 2017). Repetitive tillage can require significant amounts of fuel and energy and can result in increased production cost and reduced profit (Gathala et al., 2011). Conservation agriculture is a concept of crop production that aims to achieve high and sustained production levels while conserving the environment (Edralin *et al.* 2016). Moreover, intensive tillage not only degrades the soil organic matter due to the enhanced oxidation but also disturbs the organic carbon (SOC), hence damages the soil properties (Gathala *et al.*, 2011). The mismanagement and the intensifying environment through conventional tillage practices could be reoriented by following to the CA-based practices i.e., no- or minimum tillage, residue retention, and diversifying the crops, thereby, enhancing the soil health and yields (Ladha *et al.*, 2009; Corsi and Mumunjanov, 2019). Also, adoption of the CA-based crop establishment practices (CEP) in different rotations significantly improves the water use efficiency (Balwinder *et al.*, 2015), system yields (Pooniya *et al.*, 2021), and net returns (Gathala *et al.*, 2011). Besides, it improved the soil physical properties (Gathala *et al.*, 2011). Yield improvements have been reported on several crops grown under conservation agriculture in several parts of the world. there is little scope to extend the agricultural land frontier: crop land availability in Bangladesh has declined by 68,760 ha year^{-1} (0.73%) since 1976 (Hasan*et al.*, 2013). In other words, Bangladesh needs to produce more food from the same land, while at the same time easing farm labor requirements resulting from the country's increasingly profitable alternative forms of employment (Zhang *et al.*, 2014).

Long-term tillage system and site-specific crop management can affect changes in soil properties and processes, so there is a critical need for a better and comprehensive process-level understanding of differential effects of tillage systems and crop management on the direction and magnitude of changes in crop yield, soil carbon storage, and other soil properties. Therefore, the study has been undertaken to evaluate the long term effect of conservation agriculture and conventional tillage on crop yield and soil properties for different cropping system and tillage method.

Objectives

a) Establishment of CA platform to visualize the benefits of conservation agriculture in yield and soil properties with long term experiment
b) Testing and demonstration and adoption of selected conservation agriculture and irrigation machinery and methods in the selected areas

Materials and Methods

The long term conservation agriculture trials were conducted at CA park was established at Bangladesh Agricultural Research Institute (BARI), Gazipur ($23^0$59′05.0″N $90^0$24′50.9″E) during 2020-21. Total area of the park was 0.7 ha land. Southern part of the block was higher in elevation which was being prepared for CA trials. Northern part of the block was lower in elevation which was developed filling the soil. A submersible solar pump with 4020 Wp solar panel was installed for green energy irrigation in the CA Park (Fig. 1).

Fig 1. Solar pump installed at CA Park.

A field lab cum pump house was also built (partially) along with the solar pump systems. The buried pipe irrigation systems with eight risers were established for efficient water management in the CA experiments (Fig. 2).

Fig. 2. Riser of the buried pipe system.

The total area was divided into four for different experiments. Initial soil sample of every parts were collected (Fig. 3) for analysis of physical and chemical properties. Soil samples have sent to BARI Soil Science laboratory, BARI for analysis.

Fig. 3. Soil sample collection for physical and chemical analysis.

The southern part was for Experiment 1 (Tillage and residue effect on crop productivity, soil health and profitability in Maize- Rice cropping pattern), Experiment 2 (Tillage and residue effect on crop productivity, soil health and profitability in Mungbean- Rice cropping pattern) and in northern part Experiment 3 (Unpuddled rice planting improve soil health and profitability in long term Rice-Rice cropping pattern).

Tillage and residue effect on crop productivity, soil health and profitability in Maize- Rice cropping pattern

The factorial experiment was conducted with four tillage methods and two residue levels. The tillage methods were T_1= Conventional; T_2= Strip tillage (Fig. 4); T_3= Zero tillage and T_4= Bed planting (Fig. 5). The residue Level will be L_1= No residue and L_2= Residue (25cm). Since this was first crop, there was no residue at this time. The overall plot size of the experiment was 36 x 55 m. The individual plot size was 30 x 3.6 m. The planting date of the maize crop was 28 December 2020. The harvesting date of the maize was 13 June 2021.

Fig. 4. Pictorial view of strip tillage.

Fig. 5. Pictorial view of bed planting.

Tillage and residue effect on crop productivity, soil health and profitability in Mungbean-Rice cropping pattern

The factorial experiment was conducted with four tillage methods of mungbean. The tillage methods were T_1= Conventional; T_2= Strip tillage (Fig. 4); T_3= Zero tillage and T_4= Bed planting (Fig. 5). The individual plot size was 30 × 3.6 m. The sowing date of the mungbean was 03 March 2021 and The harvesting date of mungbean was 01 May 2021.

Unpuddled rice planting improve soil health and profitability in long term Rice-Rice cropping pattern

The factorial experiment was conducted with four tillage methods. The variety of rice was BRRI dhan48. The tillage methods were T_1= Manual transplanted in conventional tilled soil; T_2= Mechanical transplanted in conventional tilled soil; T_3= Manual transplanted in unpuddled soil and

T_4= Mechanical transplanted in unpuddled soil. The individual plot size was 28 x 3.25 m. The transplanting date of the rice was 01 April 2021. The harvesting date of rice was 08 July 2021.

Table 1. Initial soil physical properties of the different experimental fields

Exp No	Bulk density (g/cm^3)	Field capacity (%)	Penetration resistance (N/cm^2)	Particle size distribution (%)			Textural class
				Sand	Clay	Silt	
1	1.67	29.95	250	49	28	23	Sandy clay loam
2	1.66	29.96	215	54	22	24	Sandy clay loam
3	*	31.03	*	52	21	27	Loam

Table 1. Initial soil chemical properties of the different experimental fields

Experiment No	pH	OM	N	P (µg g^{-1})	K	Mg	S	Zn	B
		%			meq 100 g^{-1}		µg g^{-1}		
1	6.35	1.15	0.06	3.5	0.20	1.86	17.0	2.90	0.57
2	5.9	1.3	0.07	4.0	0.15	1.49	14.5	3.16	0.52
3	6.25	1.2	0.065	3.0	0.135	1.30	16.0	2.86	0.59
Critical level		-	-	7.0	0.12	0.50	10.0	0.60	0.20

Field trial/demonstration/adaptation of selected CA and irrigation machinery/method

The project locations are Wazipur, Barishal; Kolapara, Patuakhali and Dumuria, Khulna. In the Rabi season (Mid October-Mid April) 2020-21, 0.65 ha of mungbean was planted by BARI seeder at Mundopasha, Wazipur, Barishal, 4.70 ha mungbean was planted at Holdibaria, Kolapara, Patuakhali (Fig. 6).

Fig. 6. Mungbean seed sowing in Patuakhali and Barishal.

About 0.47 ha maize and 0.35 ha sunflower were planted by seeder machine at Noiltola, Boithaghata upazila of Khulna which is located in Polder 30 (Fig. 7). In the Kharif season (May-August), 2.60 ha of jute was planted in Dumuria, Khulna by CA machines (PTOS, strip tillage and conventional tillage) as shown in Fig. 8.

Fig. 7. Crop planting by BARI seeder at Noiltola, Boithaghata, Khulna.

Fig. 8. Jute planting by BARI seeder at Baratia, Dumuria, Khulna.

Water logging is a problem for early planting of *Boro* rice in *Gher* (ditch: in dry season cultivated rice and other season cultured fish). About 1.35 ha of *Gher* was drained out with axial flow pump and cultivated *Boro* rice in Dumuria, Khulna (Fig. 9).

Fig 9. Draining out of Gher water by axial flow pump in Dumuria, Khulna.

Results and Discussion

Yield and yield contributing characters at CA Park, BARI, Gazipur

The yield and yield contributing characters of maize for different tillage methods during 2020-21 are shown in Table 3. The maize yield was not varied with the tillage and sowing treatments during 2020-21 though cob diameter and thousand grain weight were varied. The highest cob diameter was found in bed planted field which was similar with that of strip and zero tillage. The lower cob diameter was in conventional tillage and manually planted maize which was similar

with that of strip and zero tillage. The thousand grain weight of maize of conventional and zero tilled field was similar but higher than others.

Table 3. Yield and yield contributing characters of maize for different tillage methods

Treatment	Plant height, cm	No. of cob/m^2	Cob length, cm	Cob dia, cm	No of fill grain	TGW, gm	Yield, t/ha
T_1	200.40	4.75	15.68	4.11 b	443.67	323.67 a	6.91
T_2	201.93	4.74	15.85	4.23 ab	438.27	291.33 b	6.52
T_3	198.53	4.29	16.71	4.23 ab	467.53	309.00 ab	6.90
T_4	208.07	4.84	17.25	4.42 a	506.67	290.33 b	8.48
CV	8.98	9.50	8.67	3.31	12.77	5.05	18.15
LSD	NS	NS	NS	0.28	NS	30.64	NS

T_1= Conventional; T_2= Strip tillage; T_3= Zero tillage and T_4= Bed planting

The yield and yield contributing characters of mungbean for different tillage methods during 2020-21 are shown in Table 4. The mungbean yield and yield contributing characters were not varied with the tillage and sowing treatments during 2020-21.

Table 4. Yield and yield contributing characters of mungbean for different tillage methods

Treatments	Plant height, cm	Plant population/m^2	Pod length, cm	No of pod	No of fill grain	No of unfill grain	TGW, g	Yield, kg/ha
T_1	25.82	28.37	7.56	6.07	8.87	1.07	28.20	642.63
T_2	25.97	34.66	7.42	5.07	6.20	1.73	28.37	508.47
T_3	26.19	29.78	7.31	5.20	9.13	1.13	26.83	488.60
T_4	25.17	31.89	7.33	5.80	8.73	0.67	28.83	541.33
CV	11.67	15.93	2.83	11.35	21.16	47.72	9.86	20.08
LSD	NS	NS	NS	NS	NS	NS	NS	NS

T_1= Conventional; T_2= Strip tillage; T_3= Zero tillage and T_4= Bed planting

The yield and yield contributing characters of Aus rice for different tillage methods during 2020-21 are shown in Table 5. The rice yield was not varied with the tillage and sowing treatments during 2020-21 though unfilled grain numbers were varied. The highest unfilled grain was found in unpuddled field which indicate possibility of increasing yield in unpuddled field by reducing numbers of unfilled grain in the coming years.

Table 5. Yield and yield contributing characters of Aus rice for different tillage methods

Treatments	No of hill/m^2	No of tiller/hill	Effective tiller/hill	Panicle length, cm	No of fill grain	No of unfill grain	TGW, gm	Yield, t/ha
T_1	36.33	18.40	17.07	21.61	67.33	20.07 b	28.20	4.09
T_2	35.33	20.93	19.60	19.93	58.60	19.73 b	28.37	4.19
T_3	39.67	19.87	19.13	20.86	58.80	36.53 a	26.83	4.11
T_4	34.00	19.00	16.67	21.25	72.87	26.73 ab	28.83	4.18
CV	9.62	11.98	12.37	5.82	22.78	21.74	9.86	5.61
LSD	NS	NS	NS	NS	NS	11.19	NS	NS

T_1= Manual transplanted in conventional tilled soil; T_2= Mechanical transplanted in conventional tilled soil; T_3= Manual transplanted in unpuddled soil and T_4= Mechanical transplanted in unpuddled soil.

Yield and yield parameters of mungbean in Barishal

Yield and yield contributing parameters of mungbean at Dhamshar, Wazirpur, Barishal is given in Table 6. Significantly the highest grain yield of mungbean was found from PTOS planted plots than ST and ZT but there was significantly different with CT. The pod length, number of pods per plant, 100 grain weight, pod yield of PTOS and CT were statistically similar. But the plant population PTOS was significantly higher than CT. Hence, the grain yield of PTOS (1247.52 kg/ha) was higher than CT (1081.07 kg/ha) but their difference was statistically insignificant. Higher grain yield was obtained from ST than ZT but their difference was not statistically significant. There were no significant differences of plant population, plant height, pod length, number of pods per plant, 100 grain weight, pod yield between ST and ZT. The higher grain yields from PTOS and CT were found because in PTOS and CT methods full tillage was practiced and fertilizers were mixed with soil. But, in ZT and ST methods fertilizer were not mixed properly with the soil (some remained on the soil surface).

Table 6. Yield and yield contributing parameters of mungbean at Dhamshar, Wazirpur, Barishal

Treatments	Plant population (m^2)	Plant height (cm)	Pod length (cm)	No of pod/plant	100 grain weight (g)	Pod yield kg/ha	Grain yield kg/ha
ZT	19.60b	28.37b	5.74b	9.41b	4.46b	922.47b	688.27b
ST	27.02b	34.79b	5.50b	9.63b	4.55ab	1023.61b	764.02b
PTOS	43.17a	57.07a	6.47a	15.03a	4.87a	1678.63a	1247.52a
CT	27.96b	35.03b	6.40a	13.23ab	4.65ab	1498.95a	1081.07a
CV (%)	14.81	10.70	5.50	17.57	3.47	11.66	13.90

Yield and yield parameters of mungbean in Patuakhali

Yield and yield contributing parameters of mungbean at Holdibari, Kolapara, Patuakhali is given in Table 7. It is revealed from the table that differences of yield parameters of mungbean except 100 grain weight among the treatments in Holdibari were found statistically significant. The highest pod yield and grain yield were obtained from PTOS than other treatments. The highest plant population and pod yield enhanced the highest grain yield. The yield obtained from CT was statistically higher than those of ZT and ST by signifantly lower than PTOS. The grain yields and other parameters of ZT and ST planted mungbean were statistically similar. During the cropping season, there was no rain occurred in Patuakhali and there was no available water for irrigation. Crop growth was stagnated due to moisture stress especially in ZT and ST planted plots.

Table 7. Yield and yield contributing parameters of mungbean at Holdibari, Kolapara, Patuakhali

Treatment	Plant population (m^2)	Plant height (cm)	Pod length (cm)	No. of pod /plant	100 grain weight (g)	Pod yield kg/ha	Grain yield kg/ha
ZT	23.77c	29.50b	5.84b	7.30b	4.55	853.35c	569.57c
ST	24.50c	28.67b	5.33b	8.17b	4.60	908.14c	613.61c
PTOS	35.73a	54.34a	6.30a	15.13a	4.65	1779.48a	1227.23a
CT	27.96b	57.39a	7.20a	13.27a	4.72	1397.89b	950.95b
CV (%)	17.87	17.37	5.88	17.90	2.42	7.30	6.80

Jute in Dumuria, Khulna

About 2.60 ha of jute was planted by PTOS and strip tillage methods at Baratia and Kulbaria villages of Dumuria Upazila, Khulna district. Zero tillage could not be practiced here due to clay soil. When this clay soil dries, it crakes deeply. Jute was sown in May 2021, now in growing stage as shown in Fig. 10.

Fig. 10. Jute is in growing stage at Baratia, Dumuria, Khulna.

Conclusion

The long term CA trials were initiated this year (2020-21). Different facilities for CA experiment were created. The yield of maize, mungbean and Aus rice were not varied with the treatments since advantage of CA could not achieved first few years and in absence of residue. Significantly the highest yield of mungbean was obtained from strip, zero and conventional tillage methods both in Barishal and Patuakhali. About 2.60 ha of jute was planted by BARI seeder at Dumuria, Khulna and Jute is now in growing stage. The experiments will be continued in the next year to impose the residue treatments and to observe the impact in the long run.

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EXPT. 1.6 DEVELOPMENT OF A RESIDUE CLEARING DEVICE FOR CONSERVATION TILLAGE BY PRECISION SEEDER TO PREVENT BLOCKAGE OF FURROW OPENERS AND IMPROVE SEEDING UNIFORMITY

M R KARIM, M Z HASAN AND M A HOSSAIN

Abstract

Crop residue retention in the field after harvesting is an important concept in conservation agriculture for incorporating organic matter, and maintain soil moisture. But crop residues often get entangled with the furrow openers, blades and rotary shaft of conservation tillage and seeding machineries. As a result, they obstruct furrow openers, causing seed dragging, shallow/surface placement of seeds, etc. and reduce rotary blades performance (soil cutting ability, residue hair-pinning, poor seed-soil contact, etc.). It was found to blockage of barley residue (average height of 237 mm) in furrow openers without attachment of residue clearing device for sowing seeds at 20 cm, 30 cm and 60 cm row to row distance 1200 kg/ha, 800 kg/ha and 400 kg/ha respectively. Therefore, this study was undertaken to develop residue clearing device (RCD) consists of a cutting unit connected to the front side of the blades/furrow openers to cut residues in the path of the device. Three-dimensional projection of this device has been drawn and fabricated with locally accessible iron materials in engineering workshop of FMPE Division of BARI in 2020-2021. In this experiment, First-time, three model of residue clearing devices were fabricated and tested with dry run-in presence of barley residue. During the preliminary test of first three models of residue clearing device did not show good performance and several problems were observed. Based on the problems observed, the residue clearing device (model 4) was designed and set up after fabrication. The complete performance evaluation of RCD (model 4) could not be done in 2021 due to the unavailability of residue after completion of its fabrication. The performance of the device will be tested and evaluated in next year and fine-tuned.

Introduction

Crop residues on the soil surface makes uniform seedling establishment difficult in conservation tillage systems, in addition high levels of crop residues present a constraint to the adoption of conservation tillage because residues mechanically interfere with seeding operations. Improved seeding equipment or residue removal may be necessary for successful direct drilling practices (Carter, 1994; Manjeet and Shukla, 2006; Siemens and Wilkins, 2006). Several types of residue management units or components attached to no-tillage sowing equipment have been developed. Broadly, these units are designed to: (1) cut the residue ahead and along planting paths, (2) push residues sideways (in-between furrow openers) ahead of furrow opening, (3) lift the residue and throw it back on the soil after the seed has been placed and covered, and (4) bury the residue in a strip ahead of furrow opening, or a combination of any two of the above (Sidhu *et al.,* 2007; Grisso *et al.,* 2009; Dadi and Raoufat, 2012; Brandelero *et al.,* 2015).

Many scientists noted that post-harvest plant residues left on the soil surface represent one of the main sources of interference in ensuring the proper technological process of strip-tillage and direct drilling (Korucu and Arslan, 2009; Siemens *et al.,* 2004; Tourn *et al.,* 2003; Vaitauskien & *et al.,* 2015). The row cleaner design is important in ensuring that all plant residues are removed from soil strips and that planted seeds are not incorporated into those residues, which would prevent good interaction between the seeds and soil, and germination would be negatively affected (Siemens *et al.,* 2004; Sprague and Triplett, 1986). Siemens *et al.* (2004), Skeeles and Brandt (1993) and Tourn *et al.* (2003).

Disc row cleaners of different designs can be used for strip-tillage or direct drilling. Disc row cleaners can be manufactured with straight or hooked teeth or pins. In certain cases, a disc knife can be fixed in front of row cleaners or between cleaner discs, which cuts plant residues and soil surface before removing residues to the sides (Fallahi and Raoufat, 2008; Linke, 1998).

Siemens *et al.* (2004), Skeeles and Brandt (1993) and Tourn *et al.* (2003) proposed that the removal of plant residues from the soil section for seed incorporation results in a higher yield compared with other soil sections, where row cleaners have not been used in front of the drill. (Linke, 1998; ASAE, 1995).Fallahi and Raoufat (2008) evaluated the residue handling performance of a smooth disc coulter and showed that this unit retained approximately five times

the minimum required cover (MRC) of 30% for effective soil conservation (Kassam *et al.*, 2012; FAO, 2015) and about 15% more subsurface residue than when no disc coulter was used. Smooth disc coulters also allow for deeper and more uniform seeding depth (Fallahi and Raoufat, 2008).

The Turbo Happy Seeder version 1 was initially developed for wheat-rice cropping systems in the Indo-Gangetic Plain to sow wheat into heavy and anchored rice stubble (Saunders *et al.*, 2012; Sidhu *et al.*, 2015; Zhang *et al.*, 2017). This machine is equipped with J-shaped flails (Fig 1) mounted on a PTO-driven rotating shaft (rotational speed: 1000–1300 rpm) that cut residues in front of furrow openers, and feed the residues past and in-between the furrow openers. This configuration ensures an obstruction-free furrow opening (Naveen Guptaa *et al.*, 2016). The system is also able to sow effectively into residue's mass up to about 9000 kg ha^{-1} without blockage (Saunders *et al.*, 2012; Sidhu *et al.*, 2015).

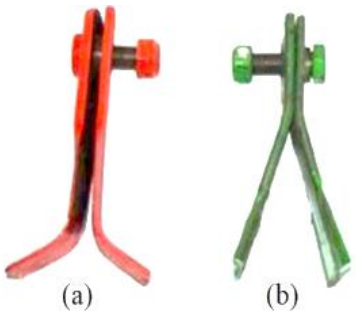

Fig 1. J-shaped flail of the Turbo Happy Seeder version 1 and (b): inverted gamma-shaped flails of the Turbo Happy Seeder version 2. Retrieved from: Sidhu *et al.* (2015), with permission from Prof. J. Blackwell (Charles Sturt University, Australia).

Brandelero *et al.* (2015) found that with about 11000 kg ha^{-1} of sorghum residue, the quantity of hairpinned residue under the smooth disc coulter treatment was about four times compared to that of a row cleaner. Quantities of hairpinned residue, required draft and vertical forces, and torque were assessed by Bianchini and Magallanes (2008) for smooth, notched and toothed disc coulters in a soil bin. The quantity of hairpinned residue with the toothed coulter averaged between 98% and 99% less than with the notched and plain coulters, respectively. By contrast, Kushwaha *et al.* (1986b) found that the draft and vertical forces required for cutting crop residue were greater when power-assisted notched disc coulters were used, and therefore consumed more energy.

Francetto *et al.* (2016) found no significant difference in seeding depth among treatments with plain, fluted and no coulter attachments. However, Iqbal *et al.* (1998) found that using a planter with fluted disc coulters resulted in deeper, but less accurate, seeding depths compared to when a conventional planter was used. The types of disc coulter soil and residue cutting devices.

Disc coulter types can be broadly classified on seven types of discs classified on the basis of the profile of the cutting edge, have been identified: ‘plain’, ‘notched’, ‘bubble’, ‘ripple’, ‘fluted’, ‘wavee’ and ‘turbo’ (Fig. 2) (Murray, *et al.*, 2006)

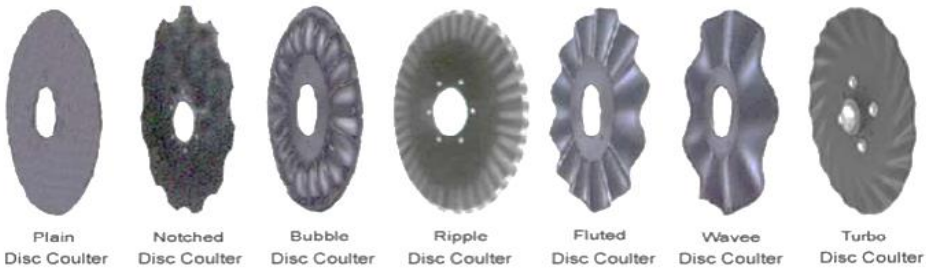

Fig 2. Types of disc coulter soil and residue cutting devices.

The sinusoidal cutting edge of the remaining four, i.e., the ripple, fluted, wavee and the turbo types, provides greater disturbance.

Fig 3. Typical cutting-edge profiles for each general disc coulter type.

The major distinction between the four is the number and overall width of the convolutions. Ripple disc coulters have numerous, narrow convolutions and wavee disc coulters have few, wide convolutions. While the cutting edge of the turbo type is fluted, it differs from conventional fluted types in that the grooves are spiraled, not radial. Fig. 3 shows the typical profile of the cutting edge on each general type (Murray, *et al.*,2006). Morrison *et al.*, 1988; Murray *et al.*, 2006; Fallahi and Raoufat, 2008; Taylor and Schrock, 2013) to allow for free movement of furrow openers placed behind them; hence, minimizing blockage caused by accumulation of residues (Kushwaha *et al.*, 1986a; Baker *et al*,.2007).

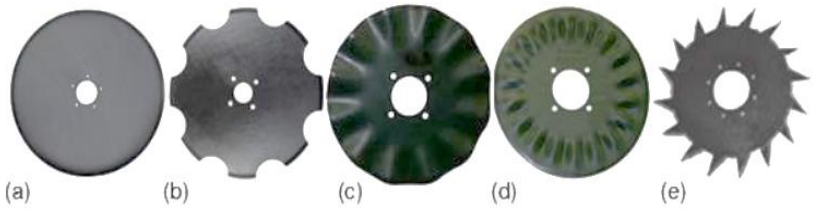

Fig 4. Several types of residues cutting units.

Several types of residues cutting units (Fig 4) are available, including those reviewed within this work: (1) smooth or plain, (2) notched, (3) toothed, (4) fluted and (5) bubble disc coulters (6) power-assisted strip-chopping rotary coulter and (7) the residue cutting unit of the Happy Seeder.

Two types of row cleaners are reviewed in a article; namely: the finger row cleaner (Fig. 5) and a more recent device developed by Yang *et al.* (2015), which is shown in Fig. 6. The finger-type cleaner sweeps residues aside by rotating as it touches the ground [Murray *et al.* (2006) and Baker *et al.* (2007)]. For improved performance, attachments such as treaders can be mounted on the row cleaner (Dadi and Raoufat, 2012).

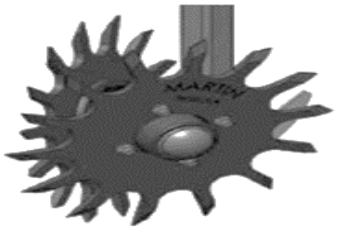

Fig 5. Finger row cleaner.

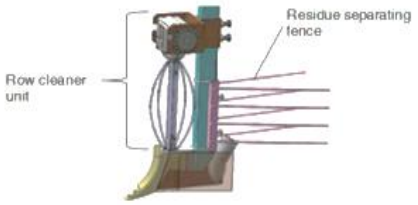

Fig 6. Row cleaner developed by Yang *et al.* (2015).

The amount of subsurface residue retained was 9% less and 3% more compared, respectively, to when plain disc coulters and no residue management devices were used (Fallahi and Raoufat, 2008). Despite this, no significant effect on cottonseed yield was observed, probably due to the compensatory growth capacity of cotton (Sadras, 1996). Brandelero *et al.* (2015) compared the residue handling performance of a row cleaner with a treader attachment (Fig. 7) and a plain disc coulter operated in a 11000 kg ha^{-1}-sorghum residue. The study showed that the row cleaner with treader attachment retained approximately a quarter of hairpinned residue compared to the disc coulter (Brandelero *et al.*, 2015).

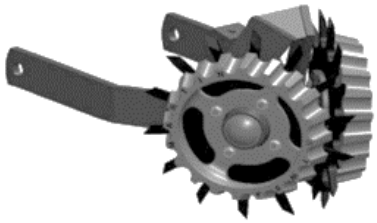

Fig. 7. Row cleaner with treader attachment.

Crop residues often get entangled with the furrow openers, blades and rotary shaft. Thus, they block furrow openers causing seed dragging, shallow/surface placement of seeds, etc. and reduce performance of the rotary blades (soil cutting ability, residue hair-pinning, poor seed-soil contact, etc.). In large scale conservation tillage machinery, this residue accumulation and seed blockage is prevented by clearing or cutting the residues in the path of the blades/furrow opener by a separate cutting unit connected to the front part of the blades/furrow openers. At present there is no such residue clearing device in BARI strip-till and zero-till planters to prevent blockage of the furrow openers from crop residues. Thus, their tillage and seeding performances are often poor. Therefore, to enhance the tillage and seeding performance there is a need to attach a clearing device in front of the rotary tiller to clear the residues and from this view this research program has been undertaken.

Objectives

a) To develop a residue clearing device to reduce seed blockage of furrow openers under conservation tillage seeding

b) To evaluate field performance of the device under different soil and crop residue conditions.

Materials and Methods

The seeder was dry run for 560 cm linear distance of pass without attachment of furrow opener and the weight of blocked residue in front of furrow opener was recorded. It was reapeted for 6 times of observation and mean data were recorded. Same time height of residue were collected from six hills and mean data were also recorded. Three type of residue clearing device (RCD) - Model 1, 2 & 3 were fabricated gradually in the engineering workshop of FMPE Division, BARI and attached in front of furrow opener of precision seeder and conducted dry run in experimental field where remain barley residue (average height of 27 cm) and blockage of residue was observed with eye estimation. When the first three residue clearing devices failed to show good performance, the model 4 residue clearing device was developed with the following design criteria (1) Plain Disc type coulter (2) Diameter of the disc coulter (3) Location of the disc coulter (4) Powered type (5) Gap between coulter and the shank of the furrow opener (6) Ease of setup (7) Power transmission system, and so on. The final geometry of all models of residue clearing device (Model 1, 2 & 3) including plane disc coulter (Model 4) for cutting and removing residue designed using SolidWork 2020 (Fig 8).

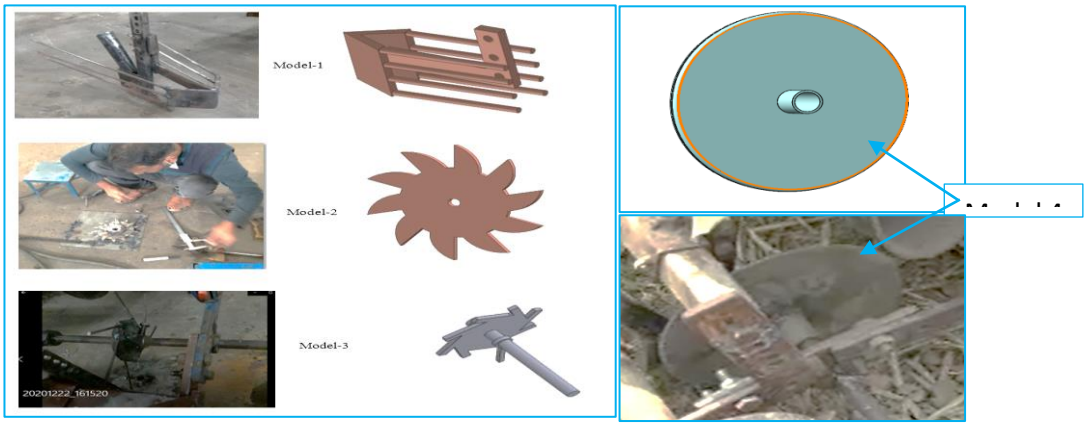

Fig 8. Pictorial view of pre-tested three types of residues clearing devices.

Theoretical substantiation of strip width of coulter

During designing of the plane disc coulter (model 4), the theoretical substantiation of strip width was also taken into consideration. By varying the rake angles of disc row cleaners and the gaps between discs, it is possible to change the width of the soil strip cleaned. For the removal of plant residue from the soil strip surface, row cleaner discs or their teeth must penetrate the soil, thus disturbing the soil surface in the strip inevitably. Let us consider that the row cleaner discs penetrating the soil down to point C (Fig. 9). According to Fig. 9, the radius of row cleaner disc R can be expressed as (K. Vaitauskienė *et al.*, 2017).

$$R=OC + CD \quad (1)$$

In the case where a disc tooth is in the deepest position and its central axis corresponds to the vertical axis of the entire disc, angle γ—which is between this vertical axis and the line joining the disc center with the soil—can be expressed from right triangle OCA (K. Vaitauskienė *et al.*, 2017).

$$\text{Sin } \gamma = \frac{CA}{OA} = \frac{CA}{R} \quad (2)$$

Distance CA from the disc center to the soil surface can be expressed from formula (2) (Vaitauskienė *et al.*, 2017).

$$CA = R.\ \sin \gamma. \quad (3)$$

or from Fig. 9 (Vaitauskienė *et al.*, 2017).

$$CA=\sqrt{R^2 - OC^2}. \quad (4)$$

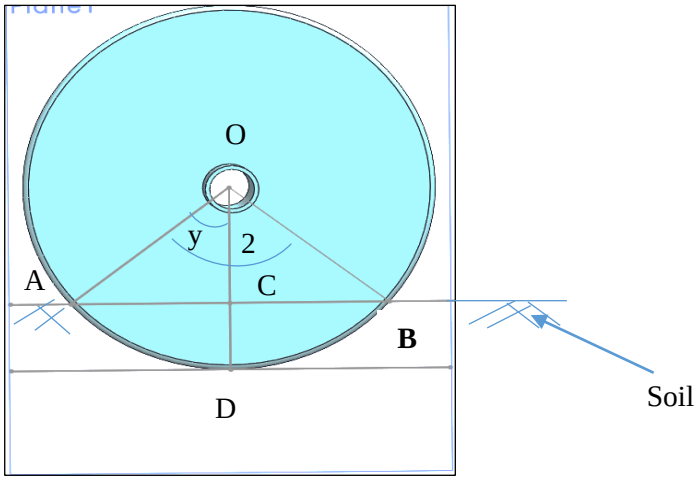

Fig 9. Scheme of interactions of disc row cleaner with soil: R—disc radius of row cleaner, CD—depth of disc penetration into soil; O—disc center; A and B—points at which disc ends meet soil surface.

Decreasing distance OC and increasing disc penetration depth increases the intersection area of the row cleaner disc edges with the soil surface, together increasing the width of the soil strip cleaned and disturbed by the disc teeth. The AB dependence of this width on the disc radius and penetration depth is expressed as follows (K. Vaitauskienė *et al.*, 2017):

$$AB= \sqrt[2]{R^2 - (R - CD)^2} \quad (5)$$

Working principle of residue clearing device

The residue clearing device (model 1) was sweep type (Fig 10) and when the seeder was moving forward, it started to sweep forward as it was attached with the shank of the furrow opener. When

the furrow opener entered into the soil, it was out of soil due to it's set up. It was set up such that it could sweep over the soil for protecting the furrow opener from blockage of residue directly in front of the shank of the furrow opener. It was set up in front of furrow opener shank to some extent as if it can accumulate or catch the residue before reached to the shank of furrow opener. The residue clearing device (Model 2 and 3) were mounted on a shaft which was driven by ground wheel (Fig. 10).

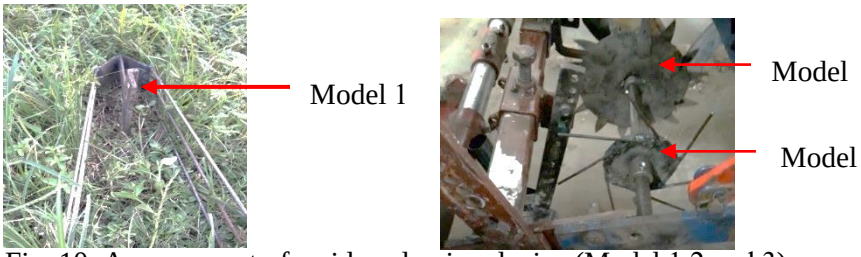

Fig. 10. Arrangement of residue clearing device (Model 1,2 and 3).

When the ground wheel came in contact with the plain soil, both the devices started to rotate and griped the residue with its teeth or fingers. They could release some residue from the front side of the furrow opener and some residues were stacked with the devices. But, when it reached on topographic land, it was gone out of contact with the soil and stopped rotation. At that time, it could not clear any residues and accumulated all residues in front of the shank of furrow opener. When ground wheel got soil contact again, the finger or teeth of the row clearing devices (model 2 & 3) rotated but could not clear residue in appropriate manner due to the earlier stuck or blockage of residue in front of the furrow openers as well as with its fingers.

Result and Discussion

Manufacturing and setting of Residue Clearing Device (RCD) Model 4: The residue clearing device was fabricated in FMPE division Engineering workshop according to the design, which was done using SolidWorks 2020. The device was developed using locally available materials collected from local hardware shop/supplier. The RCD was consisted of six parts; each of which included one powered wheel or disk coulter for cutting and removing residue. The outside diameter of the disk coulter was231 mm. The RCD was made of mild steel with a thickness of 3 mm. The gap between RCD and Shank of the furrow opener was adjusted (25-37 mm) to avoid accumulation of residue. All of the components were mounted on a single shaft that was designed to attach with the existing frame of precision seeder to carry the RCD (Model 4) in Fig 11 and 12.

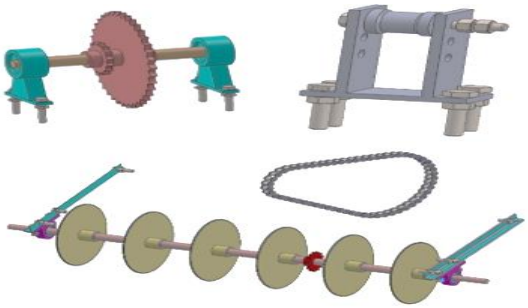
Fig. 11. Arrangement of different parts associated with the residue clearing device (Model 4) on its shaft and brackets.

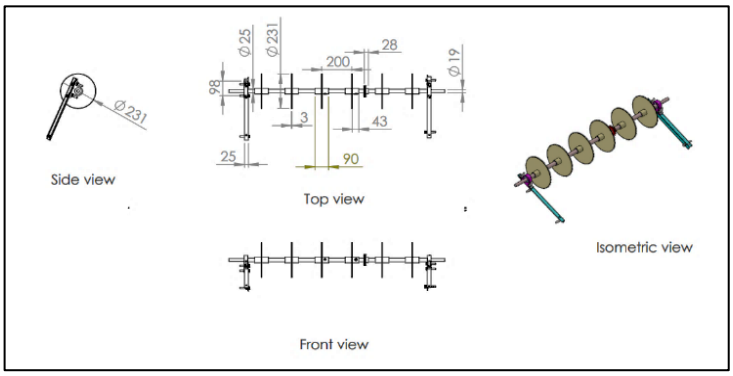

Fig 12. Schematic view of residue clearing device (Model 4).

The shaft was selected considering the load endurance capacity, as if it would not be bend under load or over load once it was entered into the soil. It was made of high carbon steel with 25 mm outer diameter. The residue clearing devices (Fig 12) were evenly placed on the shaft, with 200 mm between each part (recommended row spacing of 200 mm), although they could be adjusted to maintain 300 mm and 600 mm row spacing, respectively for pulse/oilseed crops and maize. The precision seeder was used to attach the residue clearing device (Model 4) as shown in Fig 13.

Fig. 13. Residue clearing device (Model 4) attached with precision seeder.

Design and development of power transmission system

The power transmission system was designed with SolidWorks 2020 (Fig 14) and fabricated accordingly. In fact, the power transmission system was designed to transmit power from front wheel axle of the precision seeder. The chain and sprocke were used to transfer power from one shaft to other. It was divided into three steps. First step: Power was carried from front wheel main axle to the first line shaft, which was then turn to the second line shaft, finally to the shaft where the disc coulter was attached (Fig.15).

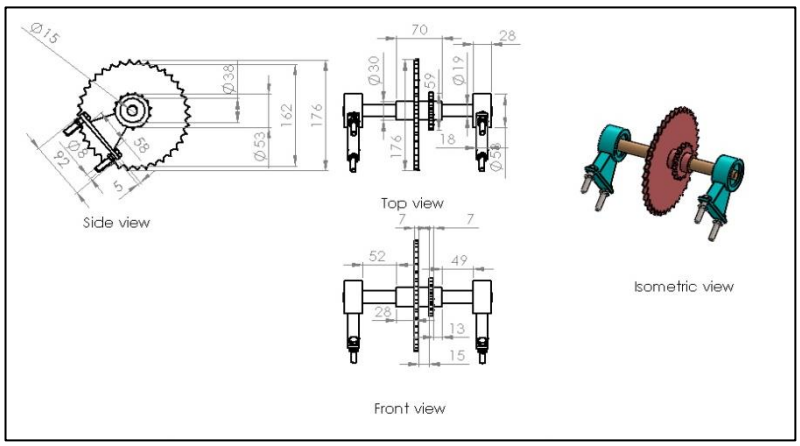

Fig 14. Schematic view of Power transmission components of residue clearing device.

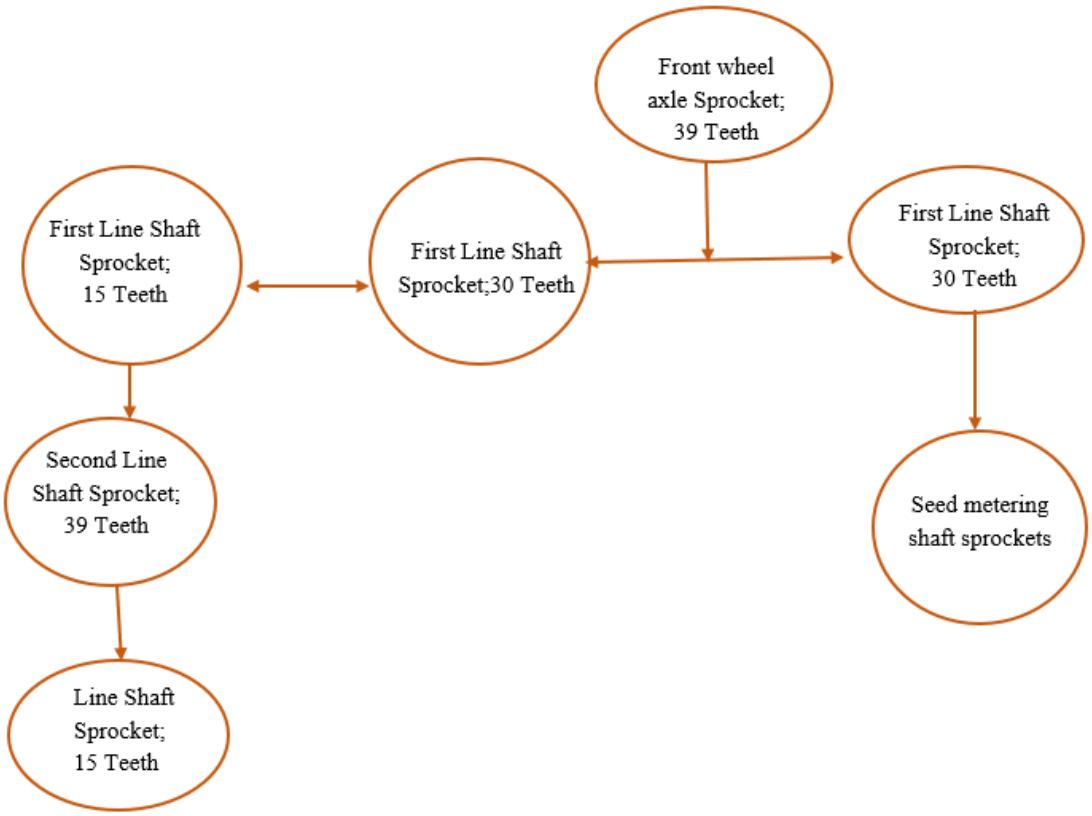

Fig 15. Diagram of power transmission system from front wheel axle to residue clearing shaft.

Chain carrying rake

When the chain (428 grade) was aligned to transmit power from second line shaft to the shaft of residue clearing plain disc coulter, some troubles were found like disengagement of chain from sprocket due to its improper adjustment (alignment and tension). To overcome those problem a re-adjustable chain carrying rake made with roller and MS plate was developed (Fig 16).

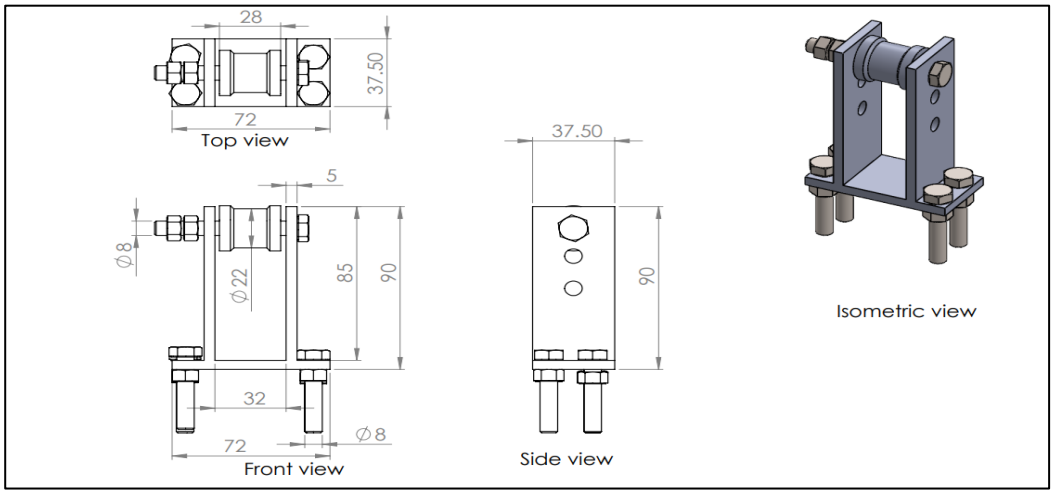

Fig 16. Schematic view of power transmission chain alignment components.

Result and Discussions

The seeder was tested for 560 cm liner distance of run into the field remaining barley residue of average height of 237 mm without attachment of residue clearing device to see the stuck of residue in furrow opener. It was found to stuck the residue on an average 134.33 gm in one furrow opener (Table 1. and Fig 17) for passing of 560 cm liner distance.

Table 1. Height and weight of residue stuck in one furrow opener for passing of 560 cm linear distance

Obs. No.	Height of residue, mm	Weight of residue stuck, gm/furrow opener
1	254	215.6
2	254	99.6
3	304.8	206.8
4	254	64.7
5	152.4	135.5
6	203.2	83.8
Mean	237.07	134.33

Fig 17. Residue stuck in furrow opener without attachment of residue clearing device.

From the above sampling data, it can be concluded that when the seeds will be sown in 20 cm row to row spacing without using residue clearing device, there will be attached six furrow openers with the precision seeder for sowing seeds in six rows at a time. There will be found to be blockage of residues in furrow openers 1200 kg/ha. Similarly, for sowing seeds like maize in two

rows (60 cm row to row spacing) and four rows like pulses, oil seeds, barley seeds, etc. (30 cm row to row spacing) the blockage of residue may be 400 kg/ha and 800 kg/ha respectively. Three models of residue clearing device (model 1,2 and 3) were gradually attached with the precision seeder and tested in the field. According to eye estimation, the blockage of residue in furrow openers were almost similar to the absence of residue clearing device (Fig 18). Based on the result, then residue clearing device (model 4) was developed.

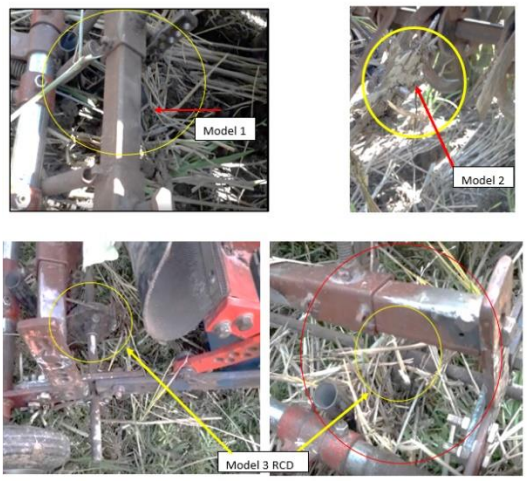

Fig. 18. Residue stuck in furrow opener with attachment of residue clearing device (model 1, 2 and 3).

Preliminary set up, dry run in field and fine tuning of residue clearing device (model 4)
The device (model 4) was dry run-in field and a problem was found during dry run. It was found because at first the device was attached with a shaft of 12 mm diameter and bushes were used in both sides for attachment of the shaft with main bracket instead of bearing. When the machine was dry run, the power distribution chain was being displaced or disengaged from/with the sprocket due to be over loaded. The identified problem was then resolved by setting stronger (19 mm diameter) shaft and using UCP bearing in both sides (Fig. 19).

Fig 19. Preliminary set up, dry run in field and fine tuning of residue clearing device (model 4).
The strip width of coulter was determined during dry run-in field and it was found to be 187.45 mm (Fig 20).

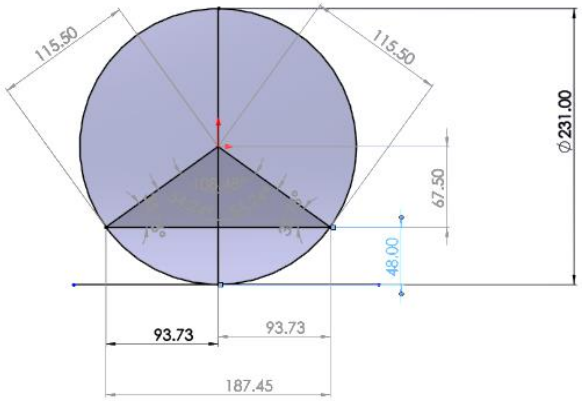

Fig 20. The strip width of coulter during penetrating in soil.

But, the complete test of the residue clearing device (model 4) could not be done due to the lack of residue in field after completion of the fabrication in 2020-2021. The device will be tested in detail on next Robi season when the crop residue will be available.

Conclusion

Four different types of residue clearing devices were designed, fabricated, and tested with dry run doing set up with the precision seeder. The field performance evaluation could not be done in this year due to unavailability of residue in field after fabrication completed. The performance of residue clearing device will be tested and evaluate in different types and height of residue condition in the next year.

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EXPT. NO. 2.1 DEVELOPMENT OF ORCHARD WEEDER CUM MINI TILLER

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Abstract

Number of fruit orchards have been increasing and the farmers are searching a suitable power weeder for those orchards to not only till inter row space for weeding but also cultivating vegetables on those space. A diesel engine operated power weeder was developed during 2010 and a battery-operated weeder was developed for row crops during 2016-19 which were less capable to use in the orchard. Thus, this research programme was undertaken as continuation of the previous study to improve the power weeder suitable for both orchard and kitchen yard. The weeder was improved and redesigned at the workshop of the FMPE Division of BARI, Gazipur during 2020-21. Then the weeder was fabricated according to the design with locally available materials and spare parts with 4hp diesel engine. The weight of the weeder was 100 kg and the width of weeding/tilling was 380mm. The power weeder could be an effective means for fast and low cost weeding of fruit orchard. This machine could be used in all the year round. The effective field capacity of the improved weeder in the orchard and kitchen garden as mini tiller were 0.048 and 0.049 ha/h and field efficiency were 76.19 and 77.78%, respectively. Further field test is required for fine tuning of the machine.

Introduction

Weeds have always been problems in the crop cultivation as they lower yields and quality of yields. Weeds reduce yields by competing with crops for water, nutrient and sunlight. Weeds may also reduce profits directly by hindering harvest operations and producing chemicals that are harmful to crop plants (allelopathy). They harbour insects, compete with the crops for water, light, and plant nutrients, reducing the quality and yield of crops and farmers' income (RNAM, 1983; Frayer, 1970). This competition generally occurs quite early in the life of a crop and the damage caused by weeds is irreversible. More than 3,000 weed species have been identified all over the world (Olukunle and Oguntunde, 2006). The cost of weed management is enormous; however, the opportunity cost of weed management is higher. Oni (1990) reported that 50-70% of yield reduction is caused by poor weed control. Therefore, timely removal of weeds is essential to achieve increased agricultural production.

Mganilwa *et al.*, (2003) identified four methods of weed control - cultural, mechanical, biological and chemical. The decision on which weed control method is to adopt depends on several factors such as specificity of weed problems, farm size, type of growing crops, availability of working labours and tools, used. Mechanical weeding is an environmentally friendly method for controlling weeds. Mechanical weeding using improved hand tools or power operated machines appear to be the most practical and efficient method for the country. Agricultural labour is becoming scarce day by day. Wage is also increasing. On the contrary, engine is becoming popular as a source of power and engine operated machines are replacing costly and drudgerious manual operations (land preparation, threshing, winnowing, etc). Therefore, to reduce the cost of weeding, maintain timeliness, and to meet-up the scarcity of agricultural labour, use of power weeder should get high preference.

Mechanical weeders range from basic hand tools to sophisticated tractor driven or self-propelled machines. Such weeders include cultivation tools such as hoes, harrows, tined implements, brush weeders, cutting tools like mowers and strimmers, as well as implements like thistle-bars that may do both (Bond and Turner, 2005). The term mechanical weed control is restricted to methods implying shallow (0-50 mm) soil tillage (Kurstiens, 2002). If the working depth of cutting tools is adequately shallow and precisely controlled, they may be operated as close as 20-30 mm from plants (Ascard and Mattsson, 1991; Melander and Hartvig, 1997; Northway and Tullberg, 2000; Home *et al.*, 2001). So, inter-row weed control is generally not a problem if this strip can be tilled (Kurstiens, 2002).

In Bangladesh, though many researches of BARI and BRRI worked on manual weeder, a good initiation was done on development of power weeder by Hoque *et al.*, (2010). The weeder was mainly developed for row crops and tested for weeding in mango orchard. Gulandaz *et al.*,

(2019) has developed a battery operated weeder for row crops during 2016-19. Recently number of fruit orchard have increased and the farmers are searching a suitable power weeder for those orchard to not only till inter row space for weeding but also cultivating vegetables on those space. Battery operated weeder was not capable to operate in the orchard weeder. Hoque et al, (2010) was also suggested for further detail study to adopt the power weeder in the orchard. However, this research programme was undertaken as continuation of the previous study to improve the power weeder suitable for both orchard and kitchen yard.

Materials and Methods

A power operated weeder has been developed at Farm Machinery & Postharvest Process Engineering Division of BARI, Gazipur during 2020-21. The weeder was designed to improve the previous model of the weeder (Fig. 1) and was fabricated with locally available materials (Fig 2) at Janata Engineering, Sarojganj Bazar, Chuadanga. The main components of the improved weeder are drive wheel, depth wheel, mainframe, handle, power transmission system and engine. The materials of the improved power weeder are MS sheet, MS angle, SS rod, belt, pulley, chain and sprocket. The specification of both models are shown in Table 1.

Fig 1. Previous model.

Fig 2. Improved model.

Table 1. Comparative specifications of both the previous and the improved weeder models

Sl.No.	Items	Previous model	Improved model
1	Power	6 hp	4 hp
2	Drive wheel type	Rubber	Mild steel
3	Drive wheel size	457 mm	330 mm
4	Drive wheel lugs height	12 mm	10 mm
5	Depth wheel diameter	254 mm	150 mm
6	Power transmission	Gearbox, V-belt, chain sprocket	V belt; chain sprocket
7	Rotary shaft width	400 mm	380 mm
8	Weight	145 kg	100 kg

Performance test evaluation

To ascertain various design parameter of the weeder, laboratory test was carried out to determine the engine speed, rotary speed and fuel consumption. Fuel consumption was determined from operating the power weeder at field speed in tilled soil and measuring the time and volume of fuel required. The field experiment was conducted at a guava orchard at Chuadanga and a kitchen garden at BARI, Gazipur during Rabi season of 2020-21.

Fig 2. Field performance evaluation of orchard weeder in a guava orchard.

The engine was started and clutch of rotary shaft was engaged. The depth was measured with a steel scale and set at 25-30 cm by adjusting rear wheel, depending on soil moisture, depth of weed root, and soil condition (hard or soft). The wheel clutch was released and the machine traveled forward cutting the weeds and soil. Time to cover the length of the field was recorded. Seven to ten centimeter margins on both sides of plants were left to protect the plant from injury.

The effective width and depth of weeding were randomly measured by a steel tape. Lost time due to adjustments and interruptions were recorded. Three quadrants of 50x75 cm were previously marked on the soil and the weed species and number were recorded. Weed counts (uncut) were done in these three quadrates after one pass of the weeder. Weeds not uprooted or cut partially were counted as uncut, as it could survive. Weeding index (e) was calculated using the following equation (RNAM, 1993):

$$e = \frac{W_1 - W_2}{W_1}$$

Where, W_1 = Weed count before weeding
W_2 = Weed count after weeding

Effective field capacity (EFC) was calculated from the recorded total time required to cover one plot including turning time and the time required for break downs or adjustments. Theoretical field capacity (TFC) was calculated from the mean values of working width and speed. Field efficiency was calculated from the ratio of EFC and TFC. Average forward speed was calculated for each plot from the recorded time required to travel one line (6 m).

Results and Discussion

Laboratory Test

The laboratory test results are summarized in Table 2. The average rotary blade speed was 1200 rpm in the laboratory trial without load but the speed was reduced to 1000rpm when the weeder was used in the field. The theoretical field capacity of the improved power weeder was 0.063 ha/h. The fuel consumption was very minimum (0.65 l/h) since the engine was only 4hp.

Table 2. Laboratory test of power weeder

Parameter	Average values
Rated engine speed, rpm	2000
Rotary blade speed, rpm	1200*
Fuel consumption, l/h	0.65
Theoretical field capacity, ha/h	0.063

* Field speed was 1000 rpm

Field Test

The forward speed, depth of weeding, and the field capacity were found good for the machine (Table 3). The soil was in free able condition and weeder was operated to the desired depth. Plant damages in these mechanical methods were negligible. A chain-cover was also used to protect the

chain-sprockets from dust. The field test results showed that the weeds in the guava orchard were effectively removed or uprooted in this method. The effective field capacity of the improved weeder in the guava orchard was 0.048 ha/h and the field efficiency was 76.19%. The Weeding index (WI) for power weeder was 0.81. The WI was calculated for the tilled strips (38 cm) by the power weeder between rows. About 5 cm margin on both sides of plants were left unweed in mechanical method. The improved weeder was also tested in the kitchen garden to plough the soil in small plot at BARI campus. The effective field capacity and field efficiency of the improved weeder in the kitchen garden as mini tiller was 0.049 ha/h and was 77.78%. When the machine was used as weeder in the kitchen garden, the weeding index was 0.88.

Table 3. Field performance of improved weeder during 2020-21

Crop	Forward speed (km/h)	weeding width (mm)	Weeding depth (mm)	Effective field capacity (ha/h)	Field efficiency (%)	Weeding index, %
Orchard	1.65	380	40	0.048	76.19	0.81
Kitchen garden	1.65	380	45	0.049	77.78	0.88

Conclusion

Recent trend of labour shortage and seasonal price hike has led the farmers to use efficient farm machineries. An improved power weeder was designed and fabricated to operate with 4hp diesel engine. The weight of the weeder was 100 kg. The width of weeding/tilling was 380 mm. The power weeder could be an effective means for fast and low cost weeding of fruit orchards. This machine could be used in all the year round. The effective field capacity of the improved weeder in the orchard and kitchen garden as mini tiller were 0.048 and 0.049 ha/h and field efficiency were 76.19 and 77.78%, respectively. Further field test is required for fine tuning of the machine.

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EXPT. NO. 2.2 DESIGN AND FABRICATION OF PETROL ENGINE OPERATED BOOM SPRAYER FOR FIELD CROPS

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Abstract

A petrol engine operated boom sprayer was designed and fabricated at the workshop of Regional Agricultural Research Station (RARS), Jashore during 2019-20. It was improved in 2020-21 at the workshop of Farm Machinery and Postharvest Process Engineering (FMPE) Division of Bangladesh Agricultural Research Institute (BARI), Gazipur. A spray pump was incorporated with this improved machine with the replacement of front wheel-based pumping system which was followed by reciprocating action. The machine was tested at the laboratory. The improved sprayer consists of a light weight power unit (6.5 hp, 4 Stroke petrol engine) and a spraying unit. It consists of two narrow rubber wheels in front side and one mild steel (MS) made rear wheel in rear side which is powered from engine through belt, pulley, chains and sprockets. The ground clearance of the machine was 900 mm. The rear wheel which acts as not only a support but also as power wheel. The spray unit consists of one tank made of MS sheet which contains 100-liter (Maximum) spray liquid, an engine operated spray pump, two booms of 3 nozzles in every boom (totally 6 nozzles) and mounting frame to adjust boom height from 500 mm to 900 mm to suit different crops as per plants height. The nozzle spacing was set at 500 mm in the boom. For lab test, two lines of 12 m apart were marked on the floor and the machine was dry run for 12 m. The forward speed of boom sprayer was 2.6 km/h. Effective width of coverage, theoretical field capacity, effective field capacity and the efficiency were found to be 2.9 m, 0.8 ha/h, 0.7 ha/h and 93 % respectively which were remarkably higher than manually operated electric rechargeable knapsack and manual knapsack sprayer. Detail evaluation, field test and economic analysis could not be completed this year. The experiment will be continued next year.

Introduction

Bangladesh is an agricultural country with the gross cropped area is about 15.595 M ha and net cropped area is 8.02 M ha (BBS 2019). Out of this cultivable area, 2.231 million hectares are single cropped, 3.966-million-hectare double-cropped and 1.788 million hectare is triple cropped. In our country, about 40.2% people are involved in agricultural sector presently. But, during the last few decades the agricultural laborers have been migrating to industrial or other sectors of economy. Therefore, the scarcity of agricultural labor is increasing gradually. It is estimated that, if this trend continues, the agricultural laborers will be reduced to 30% by 2025 and to 20% by 2030 (BBS 2017). But, it should be noted that agricultural sector is the backbone of Bangladesh economy. Crop production started to gear up dramatically when our agriculture combined to modern technology involvement, mechanization for time and cost saving, application of chemicals (pesticides and fertilizers), government strategies and specialization to favor boosting the production (ASR, 2006). These changes helped farmers to overcome the labor scarcity gradually facing for crop production. But, with the enhancing scenario of production, crop protection as well as management has become more challenging in compared with early ages. Crop protection always attempts to avoid or prevent crop losses or to reduce them to an economically acceptable level but losses due to pests is subjected to increase enormously. In agricultural sector farmers have to serve many fieldworks like weeding, reaping, sowing, spraying, etc. Out of these fieldworks, spraying is the most important operation normally performed by the farmer to protect their cultivated crops from pests, insects, funguses, and diseases for which various insecticides, pesticides, fungicides, and nutrients are sprayed on crops for protection (Krishna M.B, 2017).

Spray machine is a very much important equipment to ensure proper application of pesticides as well as to save the crops from damage due to pest infestation. It can contribute remarkably in pest management and substantially increase food production along with saving huge crops worth. Crop yield is hampered not only by attack of pests and diseases but also by weed. Chemical control is the popular method adopted for controlling most insects, weed and diseases though there are different types of methods to control the attack of pests, diseases and weed (Rabbani et al, 2020). Spraying is one of the most effective and efficient techniques for applying small volume of spray liquid to protect crops from attack of pests, diseases and weed. It was

estimated that about 50-80% of applied pesticide is wasted due to poor spray machinery and inappropriate application methods (Khan *et al.,,* 1997). The battery-operated sprayers have operational constraints such as choking of a nozzle, poor quality of spray, high human effort, low field capacity, the uncertainty of grid power availability and deep discharge of the battery, etc. During spraying, farmers swing the spray nozzle head. It results in uneven application of pesticides making the operation less efficient and uneconomical (Rahul V.K, 2018).

The non-uniform pesticide distribution results in phyto-toxicity (due to over dosing) and resistance (due to under dosing) of pests. The man-machine interaction is of utmost importance for performance of manual operations (Khan *et al.,* 1997). However, upholding a constant walking speed and maintenance of optimum distance between nozzle and plant tops can ensure uniform distribution of spray material. Fluctuation in walking speed or height of sprayer nozzle from plant tops results in uneven distribution of spray material. Spencer and Dent (1991), in their study said that walking speed of the operator regulates spray application quality in a big extent. Garman and Navasero (1984), Alam *et al.,* (2000), and Piggin *et al.,* (2001) reported that overlap or unsprayed areas can be occurred during swing operation of LOK's lance and the nozzle height was changed by 10% in each swing of lance and it is quite impossible to maintain a constant nozzle height during swing of the lance (Rahman, 2010).

Wang *et al.,* (1995) carried out a laboratory experiment on spray distribution pattern uniformity for agricultural nozzles and showed that nozzle height had a strong effect on spray distribution uniformity, but spray pressure had no significant effect on the uniformity. Joshi Dhruv Bharatbhai (2017) stated that spraying of pesticides is done to control pest and diseases for that purpose sprayer are used. Sprayer must break liquid into droplet of effective size, also distribute them uniformly over the plants and regulate the amount of liquid to avoid excessive application controlling pest, diseases is one serious problem facing the farmers everywhere.

In conventional methods, manually operated low and high-volume hydraulic sprayer and power operated hydraulic sprayer with long boom, long lances or spray gun are used to carry fluid at different targets. Recently, different types of battery powered manually operated knapsack sprayers are found in the markets which are also used in crop fields for plant protection. But, in this method, the time and labor required is also more. It is difficult to spray the pesticide uniformly and effectively throughout the plants by conventional method of spraying too (Mittal *et al.,* 1996). Though this method gives good pest control, it consumes large volume of liquid per plant, great amount of time and labor are required. Also drip losses are more. Owing to concern towards protecting environment from pollution by excessive use of pesticide and to economies the spraying method suitable alternative should be identified. Though there are different types of spray machines used in field but most of those are not completely user friendly, cheap in price and are hazardous to carry in knapsack including 16–20-liter spray liquid. That is why, the recommended quantity of spray liquid is not applied during spray and desired result is not come in most of the cases.

Engine operated like petrol engine operated sprayer is better option due to its medium cost and small size implying better maneuverability in the small land holding. Self-propelled walking type sprayers can full fill the mechanization gap to do spraying operation at the faster rate. This shows, there is an urgent need to introduce mechanical sprayer in Bangladesh. The engine operated self-propelled sprayer should be easily maneuverable and less expensive for farmers or best source of power spraying operation. Present pattern of row cropping concept being gradually adopted by Bangladeshi farmers. Development of self-propelled vehicle type light weight engine (petrol) operated sprayer is the need of today. Considering this, a user friendly and easy operating spray machine is needed through which effective way of using pesticides could be adopted. To achieve the target of appropriate spray, it is important to design and fabricate a user-friendly petrol engine operated boom sprayer for upland field crops and therefore, this research project was under taken.

Objectives

a) Design and fabrication of a petrol engine operated boom sprayer for upland field crops
b) Increase the spray efficiency of boom sprayer over the knapsack sprayers
c) Ensure proper application (spray) of herbicide and insecticide as well as reduce spray time consumption.

Materials and Methods

A boom sprayer was designed considering some basics of row crops cultivation. The major considerations were: the wheels should be adjustable with the row distance, sprayer should be light in weight, sprayer capacity should be more than the manual sprayer, sprayer nozzle height should be adjustable and sprayer should be replicable by the local manufacturer. A boom sprayer (Fig 1) was fabricated according to design in Engineering Workshop of Regional Agricultural Research Station (RARS) Jashore during 2019-20 which was improved in year 2020-2021 (Fig 2) at engineering workshop of FMPE Engineering Division. Different types of materials were used to fabricate the machine collected from local market. The improved machine was fabricated using MS box, MS angles, MS pipes and MS Sheet, rubber made spray liquid inlet and delivery pipe as well as spray pump, etc. Two types of spray nozzles (hollow cone and flat fan) were collected to make the boom of the machine (improved in 2020-2021).

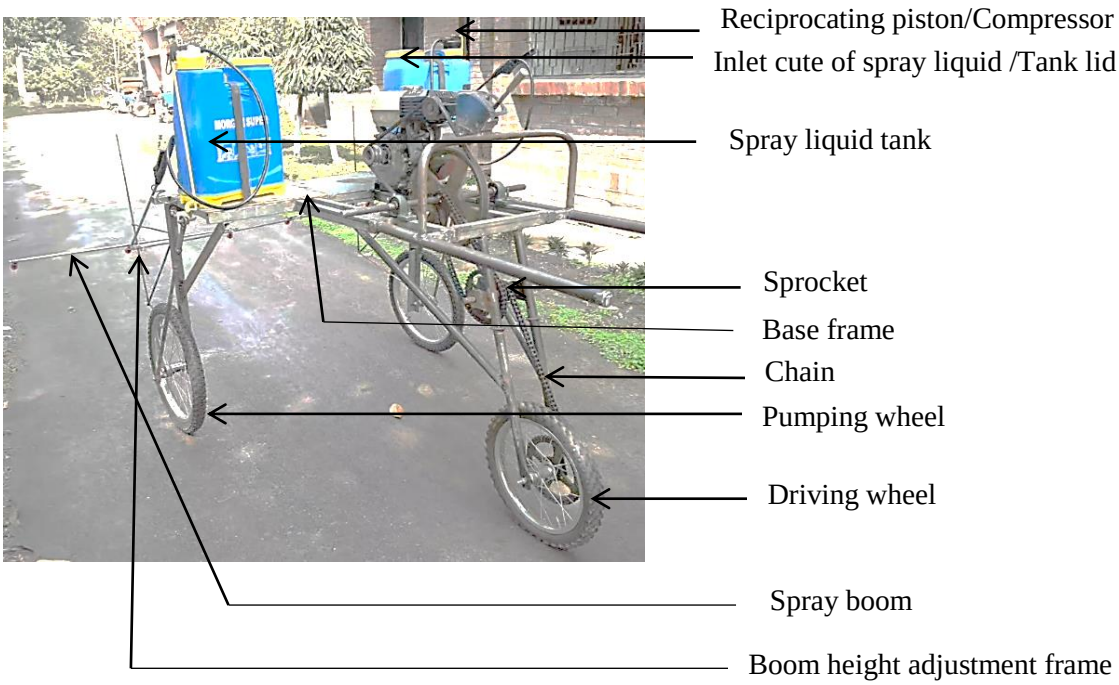


Fig. 1. The major parts and functional components of boom sprayer (First Prototype developed in 2020).

Fig 2. The major parts and functional components of boom sprayer (improved in 2020-2021).

Major parts and functional components with function

Major parts and functional components of the boom sprayer and their function have been illustrated in below:

Base frame/Chassis

The base frame was fabricated with different materials like MS angle, MS Sheet, MS pipe, MS Box on which the engine and knapsack sprayers has been set up. The size of the base frame was 1200 mm x 1510 mm.

Driving wheel

The rear wheel of the machine acts as driving/power/draft wheel. When the engine starts, the power transmitted to this wheel. When allow the power on it, starts rotating. With its' rotation, the machine starts to move forward. The dimension of the wheel was 350 mm diameter and 50 mm width.

Spray Pump

There is a spray pump attached on the base frame which can maintain the standard spray nozzle pressure. The pressure pump is operated by petrol engine through power transmission bet and pulley. The size of the pulley attached with the spray pump is 254 mm diameter. There are three pipe among which first one is spray liquid inlet pipe, second pipe is for spray liquid delivery and third one is to over flow the excessive spray liquid to the spray liquid tank. There is a pressure control knob to adjust the pressure of the pump.

Fig 3. Spray pump.

Inlet chute of spray liquid/Tank lid

This is the opening of spray tank through which the spray liquid is filled in the tank.

Nozzle

Nozzle comprises of the outlet of reservoir system. It is the main part of a mechanism which sprays the spray chemicals or pesticide. This machine has opportunity to use two types of nozzles- (i) Hollow cone nozzle and (ii) Flat fan nozzle. For the lab test the hollow cone nozzles were used.

Spray liquid tank

Spray liquid tanks are containers that hold spray liquids/chemicals. There was one 100 liters chemicals holding capacity tank in this machine which is made of Mild Steel sheet of 1.29 mm (16 gauge) thickness.

Spray Boom

There are multiple nozzles in a boom (Fig 3). This is the basic difference from the single nozzle sprayer. The boom is fabricated using Stainless Steel pipes and the nozzle connecter welded with the pipe maintaining 50 cm spacing. Thus, the width of boom is obtained 100 cm and it covered 150 cm spray width. So, there were two booms to spray chemicals in 300 cm spray width. The spray liquid outlet port is divided into two small ports attached with two liquid delivery pipes to deliver spray liquid to two booms.

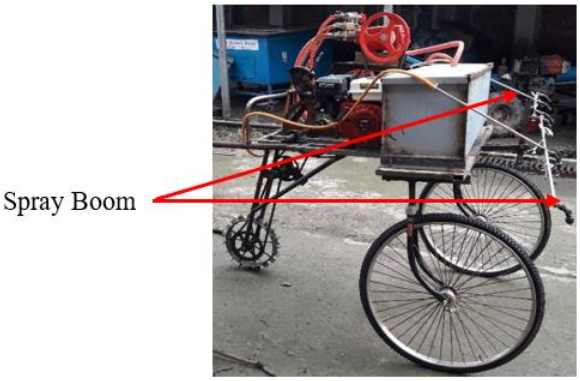


Fig 4. Spray boom.

Boom height adjustment frame

Nozzle height had a strong effect on spray distribution uniformity and it is found that spray deposition decreased as the height of nozzle is increased. To adjust the nozzle or boom height, a boom height adjustment bracket was fabricated. Due to this bracket, the spray height could be adjusted in a constant height (500 mm to 900 mm) based on plant height.

Power transmission system

A 6.5 hp. petrol engine was used as power source of this machine. It transmits power from PTO shaft to driving wheel following the specific power transmission system mentioned in following Fig 4. The power transmitted from engine to rear wheel through belt, pulley, chain and sprocket. When the rear wheel rotates, it helps to rotate the front wheels and the machine moves forward. Same time, the front wheels transmit power to reciprocate the piston or compressor through reciprocating rod and discharges the spray chemicals through the nozzles.

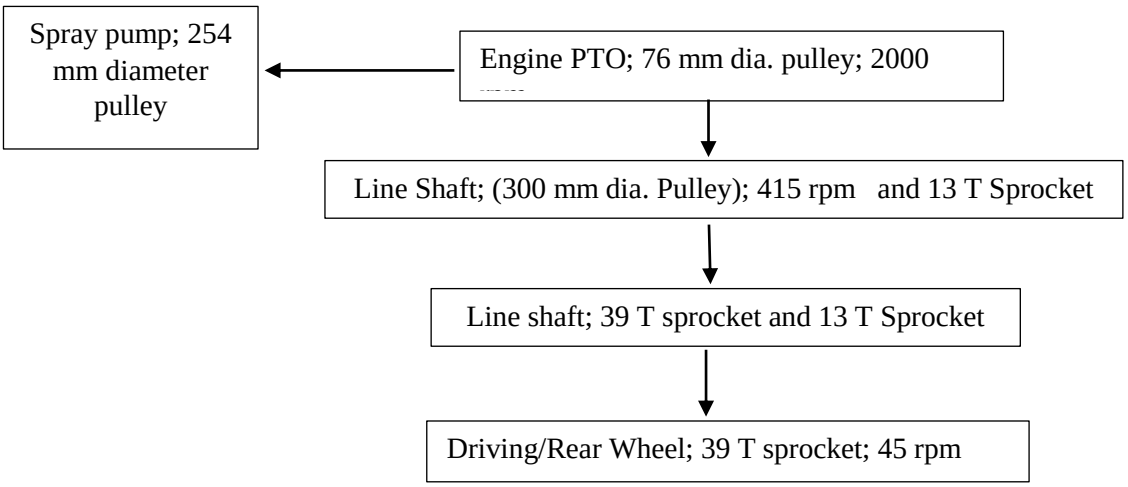


Fig 5. Power transmission system of the boom sprayer.

The technical specification of the boom sprayer developed in 2019-2020 and improved in 2020-2021 have been mentioned in table 1.

Table1. Technical specifications of the boom sprayer in (2019-2020) and (2020-2021)

Sl.No.	Particulars	Specifications (2019-2020)	Specifications (2020-2021)
1.	Engine	Petrol; 4 hp.; 4 strokes	Petrol; 6.5 hp.; 4 strokes
2.	Length x Width	135 cm x 142 cm	120 cm × 151cm
3.	Ground clearance	90 cm	90 cm
4.	PTO rpm (Avg.)	2000	2000
5.	Line shaft rpm	416	415
6.	Power wheel (Rear wheel) rpm	46	46
7.	Power wheel (Rear wheel) perimeter	103 cm	110 cm
8.	Forward Speed	2.8 km/h (without slip)	2.9 km/h (without sleep); 2.56-2.67 km/h (with sleep)
9.	Nozzle types	Hollow cone and flat fan	Hollow cone and flat fan
10.	Discharge of one hollow cone nozzle	911 ml/min	764 ml/min
11.	Discharge of one flat fan nozzle	760 ml/min	Was not tested
12.	Width of one boom (3 nozzle boom)	100 cm	100 cm
13.	Nozzle spacing in boom	50 cm apart	50 cm apart
14.	No. of Boom	2 Nos. in 2 parts	2 Nos. in 2 parts
15.	No. of nozzles	3 Nozzles in every boom; totally 3 +3 = 6 nozzles in 2 individual booms which attached in one frame	3 Nozzles in every boom; totally 3 +3 = 6 nozzles in 2 individual booms which attached in two adjustable frame
16.	Type of pumping/compressing device	Reciprocating piston/compressor	Engine operated spray pump
17.	Strokes of reciprocating piston	33 Nos./min	N/A
18.	Type of the machine	self-propelled & walking type	self-propelled & walking type
19.	Theoretical width of coverage	300 cm	300 cm
20.	Fuel consumption	650-700 ml/h	700-750 ml/h
21.	Tank capacity	16 + 16 = 32 liters (2 Nos. of 16 liters volume tank attached with 2 knapsack sprayer of the machine)	100 liters
22.	Boom height adjustment system	Re-adjustable	Re-adjustable
23.	Line/row spacing adjustment system	Re-adjustable for 20 cm, 30 cm and 60 cm line to line distance of crops	Re-adjustable for 20 cm, 30 cm and 60 cm line to line distance of crops

Working principle of the boom sprayer

At first the engine has to start keeping the main class lever in disengaged (Off) position. When the engine started, the main class lever has to be shifted to engaged (On) position. After doing that power started to transmit and the machine starts to forward. Simultaneously, the spray liquid or chemical started to enter into the spray pump through inlet pipe from spray liquid tank. Meanwhile, the gate valve of the spray liquid delivery pipe has to open and instantly discharge

starts through delivery pipe to spray lance. Sametime, the spray is started through 6 nozzles attached with the boom in the form of spray mist.

Laboratory test, data collection and processing

After completing the improvement, the sprayer was tested in the lab condition. Data were recorded during test and processed for manual knapsack sprayer, electric knapsack sprayer and boom sprayer. For lab test, two lines 12 m apart were marked on the floor and the machine was dry run for 12 m. The forward speed was calculated from the time required to pass the distance of 12 m by the machine and average forward speed was calculated. Effective width of coverage, theoretical field capacity, effective field capacity and efficiency were also calculated accordingly. The major parts and functional components of the sprayer are described in the following sections.

Travelling speed

As it was a petrol engine operated sprayer, so the speed was varied with the engine speed (rpm). The average of such 3 readings was taken to calculate the travelling speed of machine in km/h. The speed of the machine was determined by using equation (1).

$$S = \frac{d}{t} \qquad (1)$$

Where S= Speed (km/h), d= Distance travelled (km) and t=Time (h)

Width of operation

Width of spraying operation was taken randomly at the different locations and measured from mean value.

Theoretical field capacity

Theoretical field capacity was estimated by equation 2. (Kepner *et al.*, 1978, Hunt, 1979 & Sahay, 2008).

$$Ct = \frac{WxS}{C} \qquad (2)$$

Where, Ct = Theoretical field capacity (ha/h), w = Spraying width of the boom (m), S= Speed (km/h) and C = Constant, 10.

Effective field capacity

The time consumed for real work and that lost for other activities such as turning, filling of spray liquid in tank were taken into consideration for calculating effective field capacity. The time required for effective operation and time lost measured by stopwatch. The time lost for refueling was not considered because usually filling up before starting test can make refueling unnecessary for especially large field, also time for rectifying machine trouble and nozzle was not taken into consideration as it varies widely to varies factors and its inclusion in time factor sometime unreasonably lower the effective field capacity. Effective field capacity of the sprayer was calculated using equation (3) (Kepner *et al.*, 1978, Hunt, 1979 & Sahay, 2008). It is the effective field capacity that indicates the effective area coverage in unit time.

$$C = \frac{A}{T} \qquad (3)$$

Where, C=Field capacity (ha/h), A=Total area covered by the sprayer (ha) and T=Total time (h).

Field efficiency

It is the ratio of the effective field capacity to theoretical field capacity (Kepner *et al.*, 1978, Hunt, 1979 & Sahay, 2008). Field efficiency of the sprayer was calculated using the following equation;

$$e = \frac{C}{Ct} X\ 100 \qquad (4)$$

Where, e = Field efficiency (%), C= Effective field capacity (ha/h) and C_t= theoretical field capacity (ha/h)

Application rate

Application rate was determined by following equation (Issa, W.A. *et al.*, 2020)

$$\text{Application rate } \left(\frac{L}{m2}\right) = \frac{Volume\ collected\ (L) \times Time\ (min)}{Time\ (\text{min}) \times Area\ of\ test\ (m2)} \qquad (5)$$

Measurement of missing and overlapped spraying area

The spraying area coverage data were recorded. A white sheet was used for spraying on it. To identify the sprayed area blue color was mixed with water and sprayed on the paper by one walk. Then the colored area was calculated for power boom sprayer. The colored area represents the sprayed area and the white area represents the missing or void area where the dark colored area represents the overlapping area. The working procedure is shown in Fig 05.

Fig 6. Spraying on white paper.

Measurement of missing area percentage

After measuring blue colored and dark blue colored space, the remaining white space was considered as missing area. Missing area was calculated by the following formula:(Rabbani, M. A. *et al.*, 2020)

$$\text{Missing area (\%)} = \frac{White\ area\ (cm2)}{Total\ area\ (cm2)} \times 100 \qquad (6)$$

$$\text{Overlapping area (\%)} = \frac{Dark\ blue\ area\ (cm2)}{Total\ area\ (cm2)} \times 100 \qquad (7)$$

Image analysis of spray drift/pattern

The measurement of the droplet diameter was conducted by mixing the water and ink liquid with a ratio of 30 ml of ink and 1000 ml of water which is sprayed onto water sensitive paper (WSP) (Fig 7 (a) then image was collected just passing after the sprayer over the water sensitive paper. The water sensitive paper was collected from Syngenta, a globally renowned pesticide supplying company also working in Bangladesh. To see the droplets attributes the image were collected using this paper maintaining same focal length: 3.70 mm, ISO: 40, resulation:4128×3096 and aperture: F1.9. To keep these two criteria constants, an image collecting small size device (Fig 7(c)) was developed as per design where a camera (Fig 6 (b)) was fixed. After taking the image, it was processed for analysis and the spray drip results were analyzed with an image analytical software “ImageJ software” to determine the spray drift pattern.

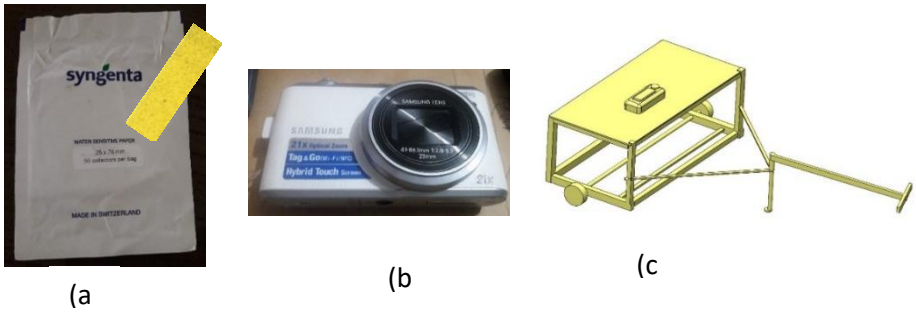


Fig 7. (a) Water Sensitive Paper (b) Camera (c) Image collection device.

Results and Discussion

The effective width of coverage, forward speed, theoretical field capacity and effective field capacity of three types of sprayers was determined Fig 8 (a). From Fig, the highest effective width of coverage (2.9 m) was found for improved boom sprayer where as it was found similar result (1.8 m) for electric and manual knapsack sprayer. The forward speed (2.6 km/h), theoretical field capacity (0.8 ha/h) and effective field capacity (0.7ha/h) was also comparatively higher than electric and manual knapsack sprayer.

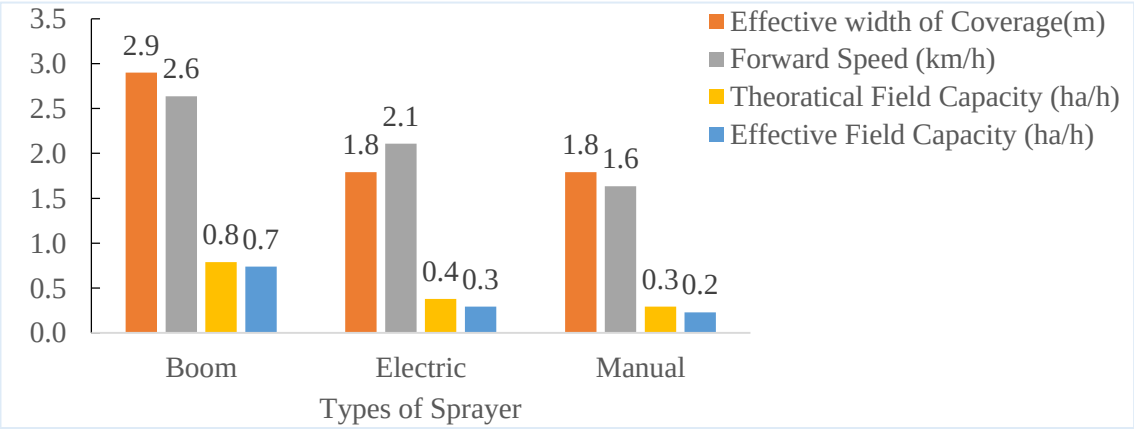


Fig 8 (a). The effective width of coverage, forward speed, theoretical field capacity and effective field capacity of three types of sprayers.

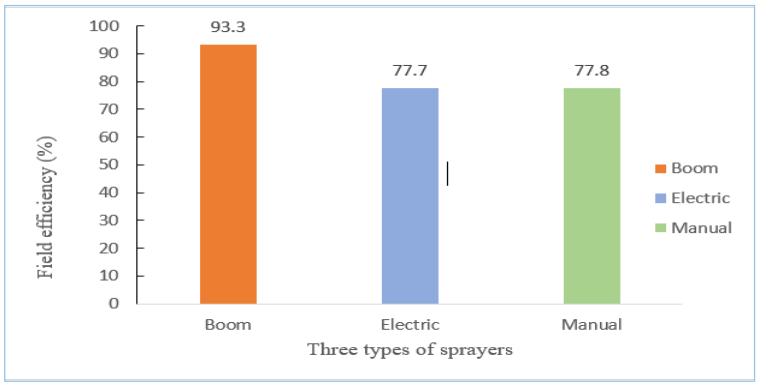


Fig 8 (b). The field efficiency of three types of sprayers.

From Fig 8(b) it was found that the field efficiency was highest (93%) for power boom sprayer where the efficiency of manual knapsack and electric knapsack sprayer was 78% respectively.

Measurement of missing and overlapped spraying area

The missing and overlapped spraying area percentage was calculated and found that the Over lapping percentage of boom sprayer was 0.97% whereas the missing area percentage was 1.3%.

Fig 9. Measurement of missing and overlapped spraying area percentage.

Application rate

The application rate was determined by collecting the spray liquid into plastic bottle for three types of sprayers with the attachment of hollow cone nozzle into the spray lance or spray boom. It was measured after collection with measuring cylinder and the result shown in Fig 9. The highest application rate was found to be 820 l/ha for boom sprayer when the lowest rate was found to be 694 l/ha for manual knapsack sprayer. It was found to be 716 l/ha for electric sprayer (Fig 10).

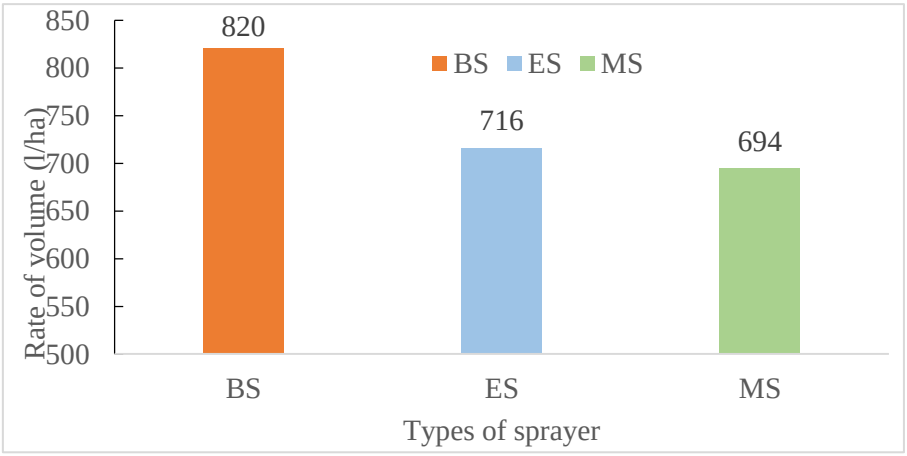
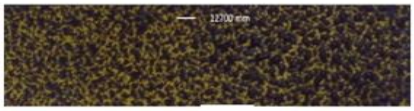


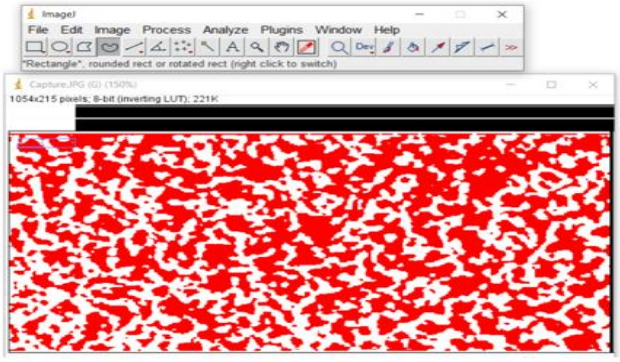
Fig 10. Application rate of spray liquid volume of three types of sprayers. (BS-Boom spryer, ES-Electric sprayer; MS- Manual knapsack sprayer).

Spray drift pattern

The spray drift distribution pattern was of boom sprayer, electric sprayer and manual knapsack sprayer was shown in Fig [11 (a), (b) & (c)], [11(a), (b) & (c)] and [12(a), (b) & (c)] respectively ere sample counts were 20 droplets for every type of sprayer.



11(b)



11 (c)

Figure 11 (a) Boom Sprayer droplets distribution pattern (b) Image in WSP and (c) Processed image.

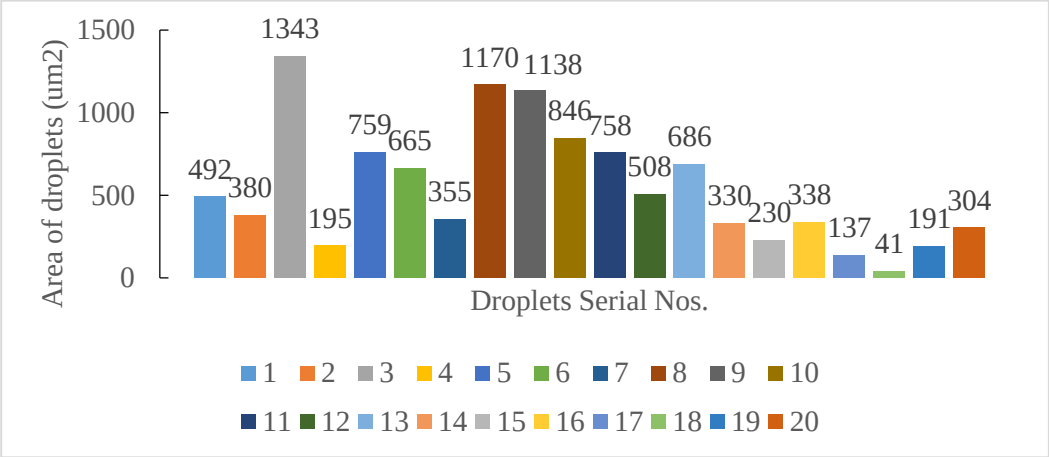
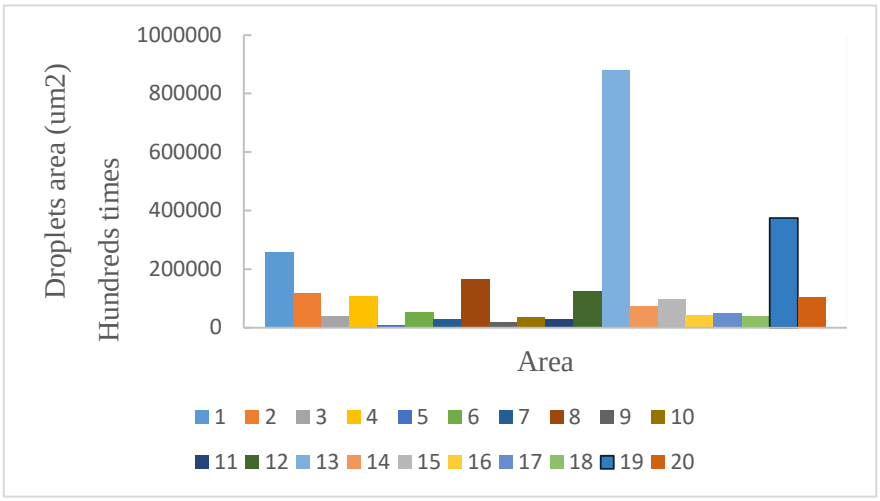
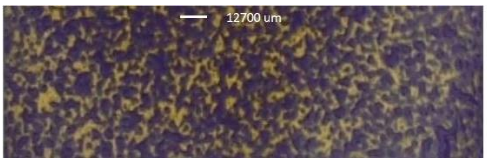


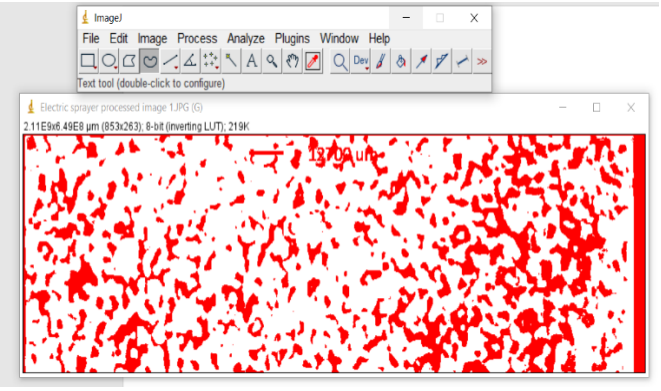
Fig 11. (a) Boom Sprayer droplets distribution pattern (b) image in WSP and (c) processed image.



12 (a)

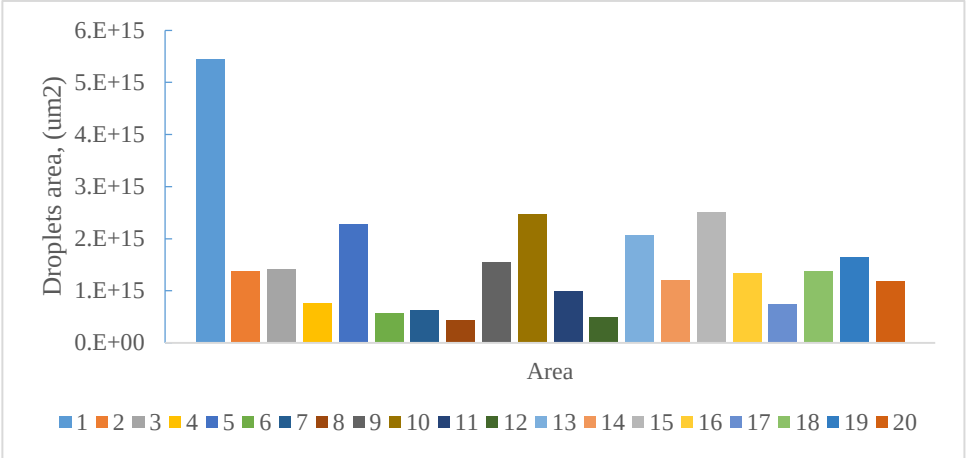


12 (b)

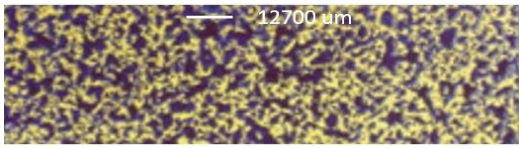


12 (c)

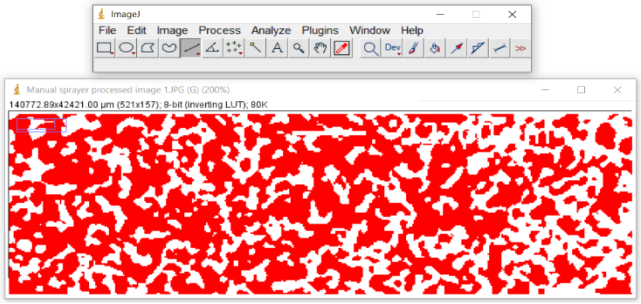
Fig. 12. (a) Electric Sprayer droplets distribution pattern (b) Image in WSP and (c) Processed image.



13 (a)



13 (b)



13 (c)

Fig 13. (a) Manual knapsack sprayer droplets distribution pattern (b) Image in WSP and (c) Processed image.

Conclusion

The spray unit consists of one tank made of mild steel (MS) sheet which contains 100-liter (maximum) spray liquid, an engine operated spray pump, two booms of 3 nozzles in every boom (totally 6 nozzles) and mounting frame to adjust boom height from 500 mm to 900 mm to suit different crops as per plants height. The nozzle spacing was set at 500 mm in the boom. After improvement, the boom sprayer was tested by dry run where the forward speed was 2.6 km/h. Effective width of coverage, theoretical field capacity, effective field capacity and the efficiency of boom sprayer were found to be 2.9 m, 0.8 ha/h, 0.7 ha/h and 93% respectively which were remarkably higher than manually operated electric rechargeable knapsack and manual knapsack sprayer. The field performance evaluation of the boom sprayer will be done in the next year.

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EXPT. NO. 2.3: DEVELOPMENT OF AN AUTOMATIC IRRIGATION DEVICE

M. Z. HASAN, M. R. KARIM and M. S. MIAH

Abstract

During winter and pre-monsoon (December-May) which coincide with Rabi cropping season, water scarcity poses a big challenge to Bangladesh agriculture. However, water is still regarded as a free commodity to the rural farmers and therefore wastage of irrigation water is a very common practice throughout the country. Use of sensors and automatic devices in agriculture helps prevent wastage of natural resources and benefits farmers in numerous ways. An automatic irrigation device was fabricated in FMPE Division, BARI to initiate precision agriculture practices among Bangladeshi farmers. The device consisted of soil moisture sensors, a control unit and a solenoid valve. The working principle of the device was formulated as that the sensors would measure soil moisture (db) at a given time, control unit would compare the soil moisture content with a predetermined threshold value. If moisture level (db) went below the threshold, the solenoid valve would be switched on to supply water to the plants. When soil would be soaked beyond the threshold value, the control unit would get moisture content from the sensors, compare and switch off the valve to stop irrigation. In the initial stage the sensors were calibrated against soil samples of different soil moisture contents. The graph exhibited a descending trend from high to low moisture contents (db) against increasing sensor ADC values. Higher sensor value on the display indicated lower moisture content and vice versa. The values of the sensors were found almost similar for respective moisture contents, which is satisfactory. However, there are still some parameters to test. Afterwards, this device will be set up in the field during Rabi season to evaluate its field performance.

Introduction

Food security is one of the major targets of Sustainable Development Goals (SDGs) which depends on modern agriculture. Due to population growth, urbanization and industrialization, agricultural land in Bangladesh is decreasing. Therefore, food production has to be increased either vertically or horizontally to feed the future generation. But there is no alternative of adaption of modern technology to increase the productivity of the land. In terms of pumping irrigation water from surface water or groundwater sources, Bangladesh is fully mechanized. However, the country still lags in the adoption of modern technologies when it comes to distribution of this water. The most prevalent method among farmers is flood irrigation in which wastage of water does not count. Furrow irrigation method is applied when crops are planted on beds. No estimation or measurement of irrigation water is done in this method either. The advancement in the technologies has enabled the use of state-of-art technology at a reasonably low cost. In automation system water availability to crop is monitored through sensors and as per need, watering is done through the controlled irrigation.

Automated irrigation system is a familiar technology throughout the world. Plenty of projects and research activities have been conducted worldwide on this topic which is apparent from overwhelming number of literatures available online. In Bangladesh there are some instances of adoption, research and development of automated irrigation or relevant technologies. Bangladesh Agricultural Development Corporation (BADC) and Barind Multipurpose Development Authority (BMDA) commissioned prepaid cards with their deep tube wells. In this system prepaid card is inserted for starting pump and the pump runs based on amount of recharge of the card. Time and soil moisture availability of irrigation are ignored in this system. Haque *et al.* (2021) proposed a smart irrigation system (sprinkler irrigation) where real-time weather data and real-time soil moisture sensor data could be collected and transmitted to servers using LoRaWAN gateway. Soil moisture sensors would collect the moisture level of soil, and the weather sensor would forecast the weather condition. When the soil moisture level goes below a predefined threshold level, and the weather forecast does not show any probability of rain, then AI makes a decision, and the sprinkler is turned on. They proposed to create an IoT network consisting of sensors (weather sensor and soil moisture sensor), LoRaWAN gateway, network server, and application server. Using the collected real-time data, an AI based algorithm could be used to make the optimal decision for controlling the automatic sprinkler.

Shufian *et al.* (2021) developed an automated AWD irrigation system for *Boro* rice. The authors used a microcontroller and ultrasonic sensors to detect and measure water levels in an AWD device installed in the rice field. The microcontroller gave signal to start the pump when water level inside the pipe was at 15 cm below the ground surface, and stopped the pump when water level reached 7 cm above the ground surface. The whole system was operated with lead-acid battery using fast charging and solar charge controller. Akter *et al.* (2018) developed a smart irrigation system in Hajee Mohammad Danesh Science and Technology University, Dinajpur. The system consisted of a soil moisture sensor, a microcontroller, a single channel relay module and a 12V DC motor pump. The authors showed sensor readings recorded at one minute interval after application of water in a pot filled with soil. Ahmed and Akash (2020) also developed a similar smart irrigation system in University of Chittagong. The authors tabulated sensor readings from four locations of the university. However, they did not correlate sensor readings with actual volumetric soil moisture contents. It was mentioned that the system was suitable for gardeners.

Rahman *et al.* (2016) proposed a concept of solar PV driven automated irrigation system using microcontroller, soil moisture sensor, relay, solenoid valve, LCD display, solar panel and battery. The authors did not show fabrication and performance of the system. Proper irrigation water management means that water should reach at the right place, at the right time, with the required volume and with minimum loss. Proper irrigation water management may allow irrigation of additional land with the same volume of water and provide a remarkable increase in crop yield. The increased crop yields may contribute to the reduction in hunger and poverty in rural Bangladesh (Dey *et al.* 2006). Therefore this experiment has been undertaken to fulfill the following

Objectives

a) Develop an automated irrigation device from locally available materials
b) Calibrating the device to determine exact soil moisture content
c) On-farm evaluation and fine tune the device based on field performance

Materials and Methods

Background

During 2019-2020 an automatic irrigation device was fabricated at FMPE Division, BARI. It comprised of three components namely, wireless sensor unit, wireless control unit and a solenoid valve (Fig 1). But the device was inefficient because the sensor unit did not provide stable service. The procured solenoid valve required a minimum pressure difference from 0.3 to 0.5 bar (30 to 50 kPa) to operate, therefore, it mismatched with the system. Besides, the device required AC current to power up and had no provision to use solar energy as its power source. During test run the device failed to supply proper amount of water to the pipeline because discharge was very low (2.3 l/h) (Hossain *et al.*, 2020).

(a) (b) (c)

Fig. 1. (a) wireless sensor unit, (b) control unit, and (c) solenoid valve of the device made in 2020.

Design and working principle of the device

Based on the test results of last year of this device, a new design was made addressing its limitations during 2020-21. Fig 3 shows flow chart of the operation of the new device. The core element of the automatic irrigation device is the soil moisture sensor. These sensors transform soil's physical values into electronic signal convenient for measuring, transmitting, converting and recording information about the state of the soil moisture. The circuit board consists of an *Arduino Mega* microcontroller, a GSM module, a LCD display, a 4-channel relay (12V), a buck converter (24V to 12V), an inverter (300W, DC 12V to AC 230V), a battery (12V 7.5A), a solar panel (18V) and a solenoid valve (gravity flow, 0.75 inch diameter) (Fig 4 and 5).

The sensor consists of two open electrodes. Mineral substances of the soil act as insulators. Dry soils have very high electrical resistance, and the more water is contained in the soil, the lower the resistance between the two electrodes. When the moisture content in the soil is lower than the set value, the relay is activated. It turns the solenoid valve on which is attached to the outlet of the water tank. After supply of irrigation water when the optimum moisture level is reached, the relay switches off the valve. The device is best suited for drip irrigation system. However, it can be used in any irrigation system after making appropriate modifications to the device.

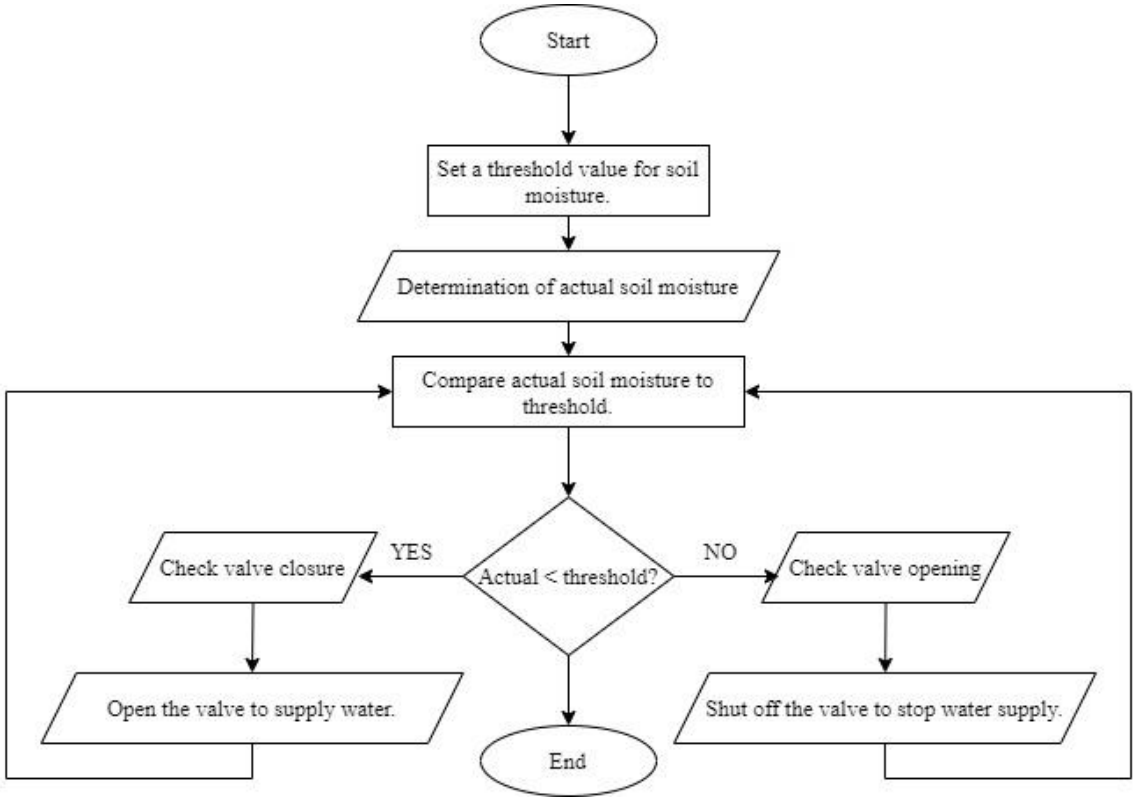


Fig. 3. Flow chart of the operation of the device.

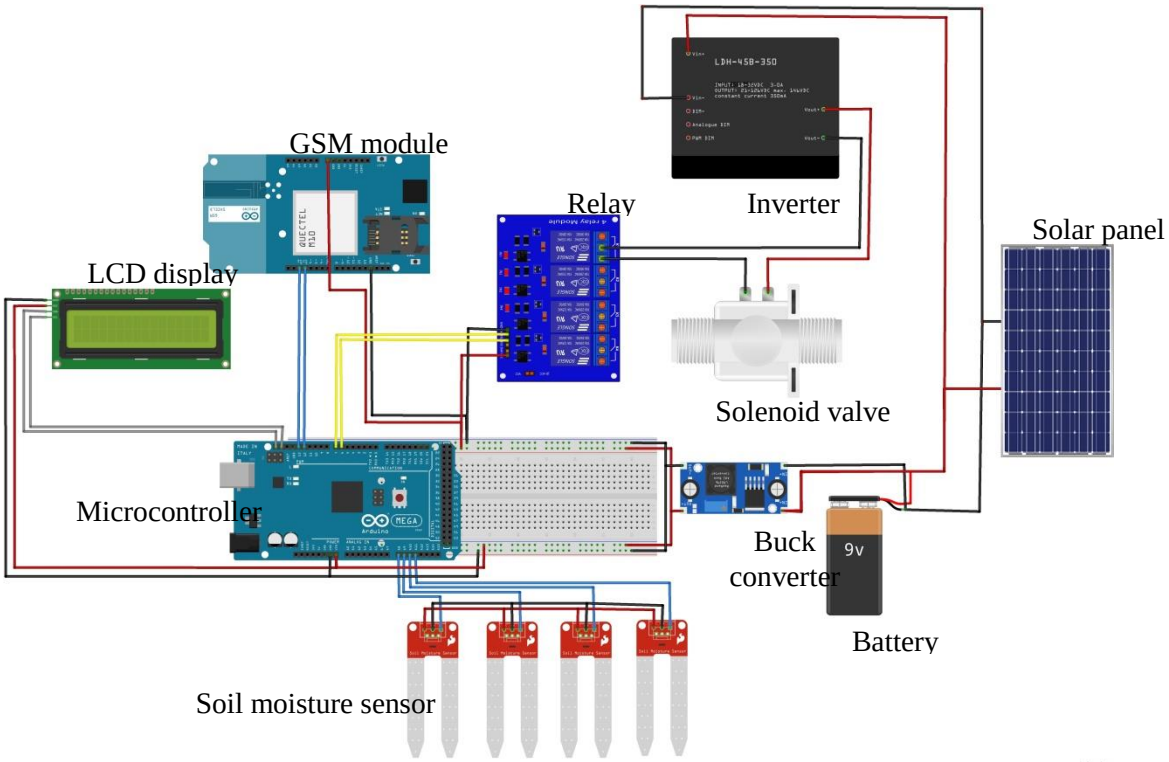


Fig 4. Block diagram of the automatic irrigation device.

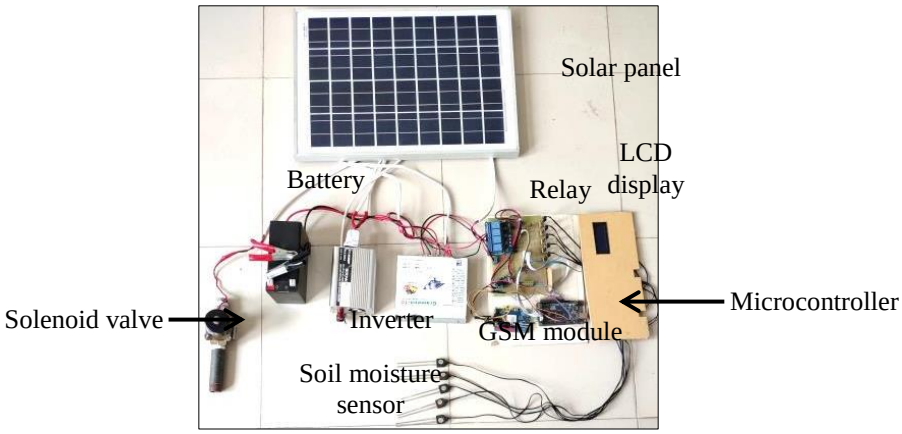


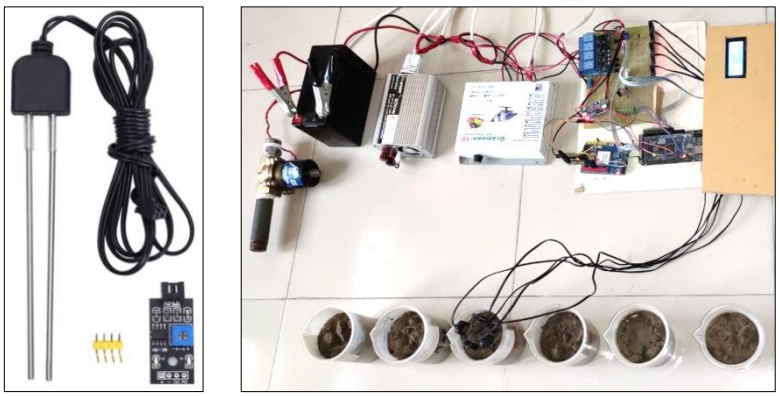
Fig 5. The automatic irrigation device after fabrication.

Calibration

Soil samples were air dried by laying them on a paper substrate in the laboratory. Stones, roots, or other unwanted materials were removed, and big clumps of soil were broken. After the soil became dry enough, it was put in plastic containers that were deep enough to accommodate the entire length of the soil moisture sensor (Fig 6a).

After filling the plastic containers with soil, a moisture spectrum was in all containers. From the first container moisture content gradually increased in other containers until saturated. The corresponding values of the soil moisture sensors for various moisture levels were recorded from the display (Fig 6b). Afterwards, gravimetric method of moisture estimation was used to measure actual soil moisture. The soil sample was placed in an oven at 105 °C and dried to a constant weight for 24 hours. The percentage of moisture was calculated as (Motsara and Roy, 2008):

$$\text{Moisture percent} = \frac{\text{Loss in weight}}{\text{Oven dry weight of soil}} \times 100$$



(a) (b)

Fig 6. (a) Soil moisture sensor used in the device, (b) calibration of the device under different moisture contents.

Results and Discussion

Fig 7 shows the relationship between actual moisture contents (db) and corresponding values recorded from three sensors. The graphs show a descending trend from high to low moisture content against increasing values along x-axis. It can be inferred that higher sensor value on the display indicates lower moisture content and vice versa. The sensors did not exhibit identical value in the same soil. However, the combined graph shows that from 30.8% moisture content (db) the three lines maintained almost similar distance while descending till 24.4% moisture content (db). Then from 24.4% to 20.4% moisture content (db) the lines intersected each other. This indicates that the sensors exhibited uniformity when moisture content was below 24.4%. This is a good indicator because accurate detection of soil moistures is important when the moisture content reaches near the wilting point.

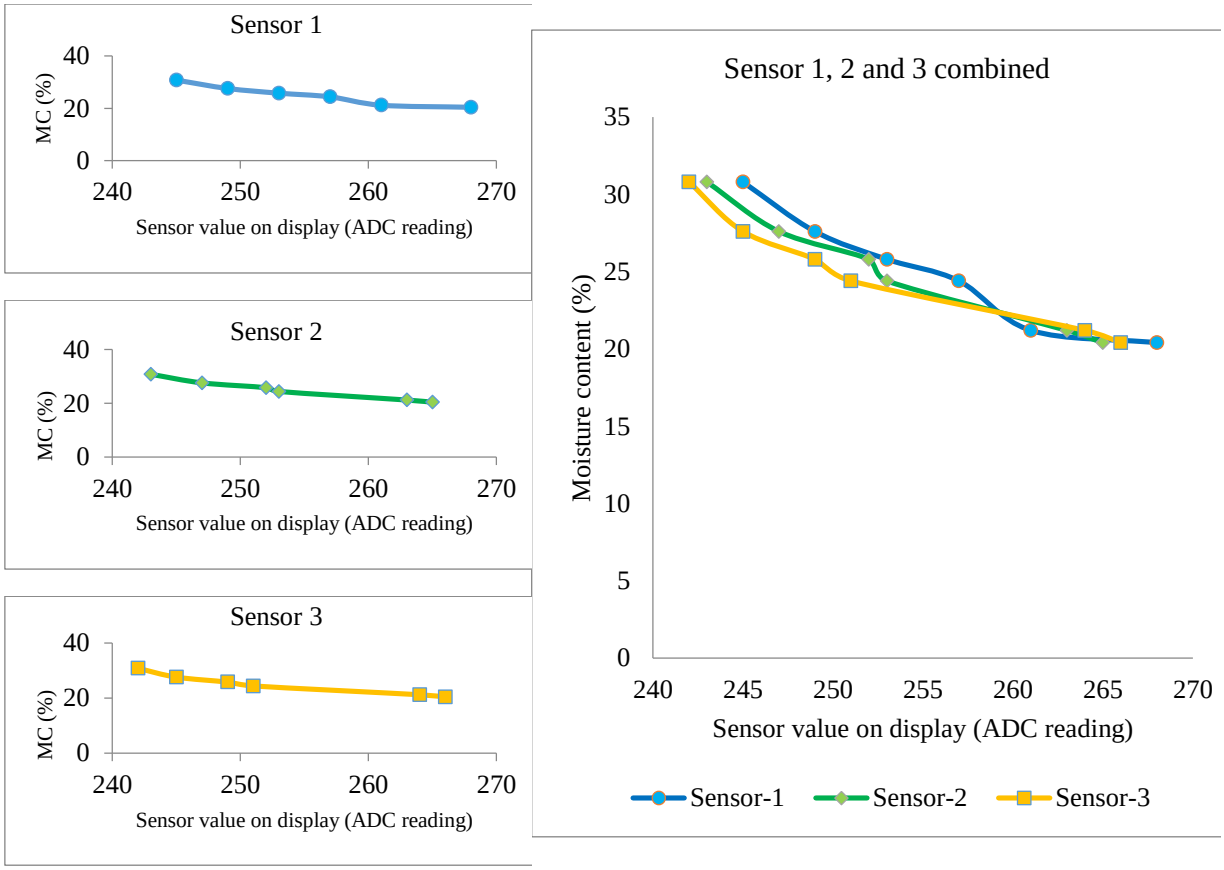


Fig. 7. Relationship between actual soil moisture content (db) and sensor value (ADC reading).

The sensor used in the device was resistive soil moisture sensor. It sends analog signals i.e. voltage to the microcontroller. Nearly all microcontrollers have a device built into them that converts these voltages into values to enable the user understand it. When a microcontroller is powered from five volts, it takes zero volts (0V) as a binary 0 and five volts (5V) as a binary 1. In order to convert different voltages a feature is used called Analog to Digital Converter (ADC) that converts an analog voltage on a microcontroller's pin to a digital number. The ADC on the *Arduino* microcontroller which is used in this device, is a 10-bit ADC, meaning it has the ability to detect 1024 (2^{10}) discrete analog levels. The ADC reports a ratio metric value. This means that the ADC assumes 5V is 1023 and anything less than 5V will be a ratio between 5V and 1023. For this reason, resistive sensor values do not have any unit. Therefore, further tests should be done to measure voltages between sensor probes after inserting them in soils with different moisture contents. These measurements will be helpful to observe the variation of voltages against different moisture contents.

Conclusion

Water resources in Bangladesh are depleting at an alarming rate. Precise application of irrigation water is a crucial step to alleviate this situation. Modern technologies have allowed us to reduce drudgery in agricultural activities as well as conserve natural resources. An automatic irrigation device was fabricated at FMPE Division, BARI to help Bangladeshi farmers get acquainted with and adopt precision agriculture practices. The working principle of the device was formulated that the soil moisture sensors would measure soil moisture content of the field. A microcontroller would compare this value with a predetermined threshold value. If the value was found smaller than the threshold value it would switch on a relay module. The relay would turn on a solenoid valve attached to the water tank. After applying irrigation water when the soil moisture content would reach beyond the threshold value, the relay would switch off the valve to stop irrigation. The sensors were calibrated for different moisture contents. Higher sensor value on the display

indicated lower moisture content and similarity was found among sensor readings, which was proven satisfactory. However, further tests should be carried out to find more characteristics of the sensors. The device will be set up in the field in the next *Rabi* season to evaluate its field performance.

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EXPT. NO. 3.1 DEVELOPMENT OF A BARLEY THRESHER

M. Z. HASAN and M. R. KARIM

Abstract

Barley is becoming an important health food and a functional food product for a large portion of people because of the recognized benefits. It can be profitably grown in the coastal fallows of Bangladesh where soil salinity and water-stress prohibit growing most of the crops during the dry season. However, threshing of barley is a tedious job which is done manually by the farmers. In the Plant Breeding Division of BARI two threshers were used to thresh barley in six steps which is laborious. The present experiment aimed to develop a thresher that would make barley threshing process concise and efficient. In this endeavour, threshing part of the BARI Rice-wheat thresher was modified by attaching two types of rasp bars on the threshing cylinder and adding a perforated MS sheet on the concave. The thresher did not perform satisfactorily as threshing recovery (38%), threshing efficiency (39.8%) and cleaning efficiency (56%) were low. However, percentage of blown grain (3.29%) and damaged grain (1.46%) were found negligible. Further modification and testing of the thresher would be done during the next years.

Introduction

Barley is a minor crop in Bangladesh which is grown mainly in some pockets of northern region. In 1971–1972, the coverage and total productions were only 28,700 ha and 21,300 t, respectively which decreased to 297 ha and produced 244 t in 2018 (Fig. 1). The only barley-based cropping pattern in Bangladesh was Barley−Fallow−Fallow, which occupied 0.0002% of the net cropped area (Nasim *et al.*, 2017). Barley is cultivated in highly diverse regions around the globe and is widely recognized as the crop of the poor since it requires very low inputs and can acclimatize to drought and problem soils, i.e. saline, acidic and alkaline soils (Kumar *et al.*, 2014). Bangladesh needs to increase cropping intensity in order to cope with ever increasing population and dwindling cultivable lands. Vast saline areas in the central and southern coastal regions of Bangladesh remain fallow after harvesting of *T. aman* (monsoon rice) where crop intensifying is a major challenge. Cultivation of salt-tolerant crop cultivars of wheat, barley and pulses with careful management practices can bring substantial change in the agricultural practice to increase cropping intensity in these areas. With the aim to increase cropping intensity in the fallow lands, barley can be profitably grown in the coastal districts where soil salinity and water-stress prohibit growing most crops during the dry winter season.

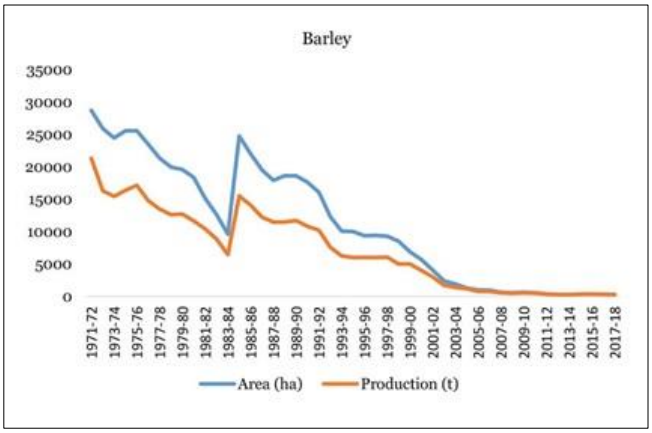


Fig. 1. Area coverage and production trend of barley in Bangladesh (Sarwar and Biswas, 2021).

BARI has released 9 barley cultivars, and 54 accessions of barley germplasm are also conserved at the PGRC (Sarwar and Biswas, 2021). However, there is no commercial machine available in the country for threshing of barley. Barley genotypes have been classified in two based on presence of hull around the kernels i.e. hull-less and hulled (Jood and Kalra, 2001). This variation in the same crop makes threshing of barley a complex operation. Because, hull-less barley can be threshed using the available rice-wheat threshers. But, the hulled varieties are difficult to thresh with these

threshers. Therefore, it is important to develop a thresher that can efficiently thresh both the hulled and hull-less barley varieties.

Objectives

d) Develop a barley thresher that can efficiently thresh hulled and hull-less barley varieties
e) Evaluate performance of the barley thresher
f) On-farm evaluation and fine tune the thresher based on early users' feedback

Materials and Methods

Existing process of barley threshing

The Plant Breeding Division of BARI uses two threshers for threshing barley- BARI rice-wheat thresher and a hold-on type small thresher. The whole process can be described in six steps as follows:

i. Feeding the crop bundles into BARI rice-wheat thresher
ii. Threshed grains fed into the small thresher
iii. Manual winnowing
iv. Grains fed into the small thresher for hull removal
v. Sun drying
vi. Dried grains fed into the small thresher for cleaning

Fabrication of the thresher

Following the design of a European model obtained from the Plant Breeding Division of BARI, FMPE Division developed a small scale barley thresher by reverse engineering (Hossain *et al.*, 2020) (Fig 3). The model was laboratory scale hold-on type and had pegs on its cylinder. It was suitable for hull-less barley varieties. However, the thresher did not perform satisfactorily as its feed rate, threshing and cleaning efficiencies were low.

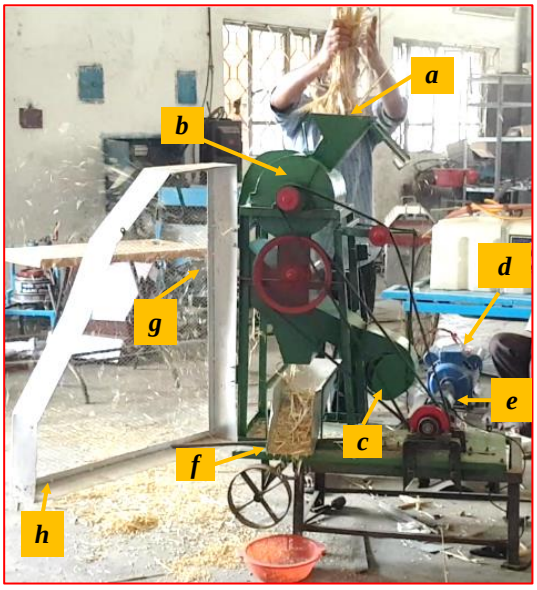


Fig. 3. Functional components of the barley thresher: a - feeding chute, b - threshing cylinder and rotor, c - blower, d - driving motor (0.75 kW), e - torque transducer assembly, f - grain outlet, g - straw outlet (not seen in the Fig), h - safety guard (Hossain *et al.*, 2020).

In order to overcome these shortcomings, the existing BARI Rice-wheat thresher was modified. The existing pegs and concave were not proven sufficient for threshing barley. Therefore, the following components were fabricated and attached with the threshing part of BARI thresher (Fig 4), keeping rest of the thresher intact. These additional components would be used as attachments and could be attached or removed easily.

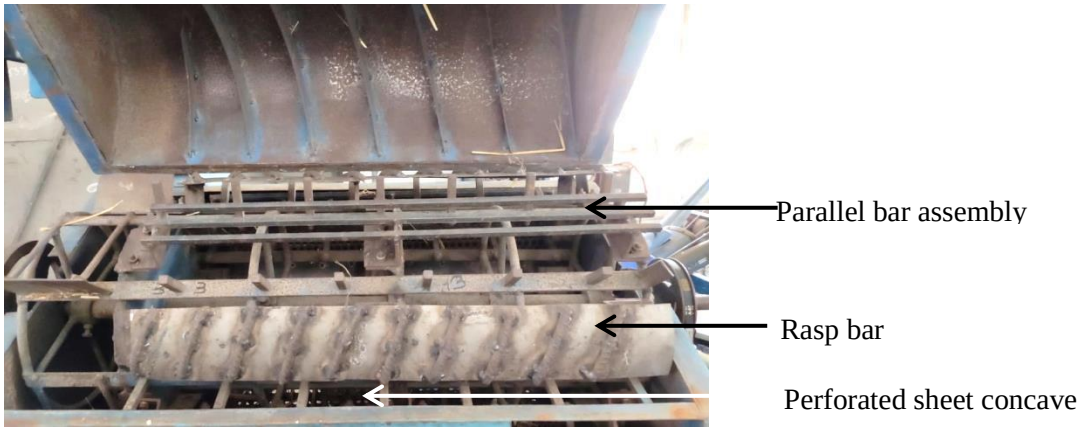
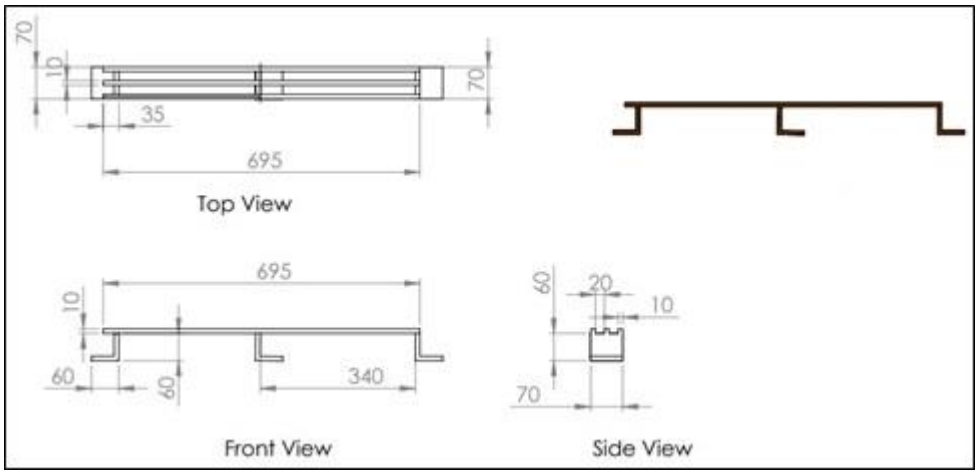


Fig. 4. Modified threshing part of the BARI Rice-wheat thresher.

Parallel bar assembly: Three MS square bars, each 1cm in cross sectional length and width, were welded in parallel 2 cm apart from each other on three 7 cm long angle bars (Fig 5). Each square bar was 69.5 cm long. The assembly was bolted to the cylinder's circular surface. Four units of such assembly were made and bolted around the threshing cylinder at equal interval. It was made to push the incoming straw and grains outward so that the rotating cylinder can rub them against the perforated concave.

(a)

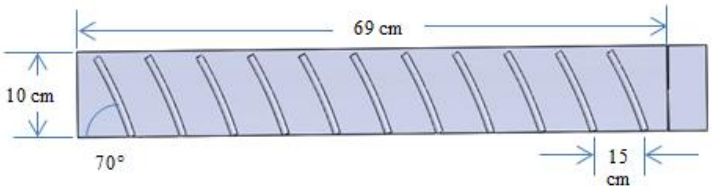


(b)

Fig. 5. (a) Photograph and (b) CAD drawing of the parallel bar assembly

Rasp bar: A MS sheet (1.5 mm thickness) was rolled into a hollow cylinder having radius and height of 22 cm and 69 cm, respectively. The cylinder was cut along its axis into four 10 cm wide strips. A deformed circular MS bar (8 mm diameter) was cut into 10 cm long pieces, bent according to the curve of the strips. Afterwards, the deformed bar pieces were welded on the outer surface of the strips in a way that each bar remained 15 cm apart at 70° angle with strip length (Fig 6). Three 7 cm long angle bars were welded on the inner side of the strips and bolted to the cylinder's circular surface.

(a)



(b)

(c)

Fig 6. (a) Photograph and CAD drawing (b) top view, (c) front view of the rasp bar

Additional concave: A 1.5 mm thick perforated MS sheet (hole diameter: 1 cm, centre to centre distance: 1.5 cm) was cut and bent according to the upper dimensions of the existing concave of the BARI rice-wheat thresher. It was fitted above the concave using nuts and bolts.

Testing of the thresher

Barley was harvested from FMPE Division research field, bundled and dried to 16% moisture content. The bundles were weighed before feeding using an electronic scale. Threshing time was recorded using a stopwatch. Test run was replicated three times and average values were calculated. After each test run the thresher was stopped, grains and straws were collected from the grain outlet and straw outlet. The grains were separated from straws. Unthreshed grains, broken grains and whole grains were separated manually before weighing.

Grain-straw ratio

Grains and straw were separated from a known weight of harvested bundle. Collected grain and straw were weighed separately and grain-straw ratio was determined as follows (Ajmal *et al.*, 2017):

$$\text{Grain-straw ratio} = \frac{\text{Weight of the grains}}{\text{Weight of straw}} \quad (1)$$

Feed rate

Bundles of known weight were fed into the threshing unit and time required to feed was measured. Feed rate was measured as follows (Ajmal *et al.*, 2017):

$$\text{Feed rate} = \frac{\text{Amount of materials fed into the threshing unit (kg)}}{\text{Feeding time (h)}} \quad (2)$$

Threshing performance

Threshing performance was calculated as per RNAM test code as follows (RNAM, 1995):

(a) *Total grain input*

$$A = B + C + D \quad (3)$$

Where, A = Total grain input (g), B = Mass of threshed grains (whole and damaged grains) obtained at the grain outlet (g), C = Mass of threshed grains (whole and damaged grains) obtained at the straw outlet (g), D = Mass of unthreshed grains obtained at both the outlets (g)

(b) *Threshing recovery*

$$\text{Threshing recovery (\%)} = \frac{B}{A} \times 100 \quad (4)$$

(c) *Damaged grains*

$$\text{Damaged grains (\%)} = \frac{E}{A} \times 100 \quad (5)$$

Where, E = Mass of damaged grains collected at both the outlets, g

(d) *Whole grains*

$$\text{Whole grains (\%)} = \frac{W}{A} \times 100 \quad (6)$$

Where, W = Mass of whole grains collected at both the outlets, g

(e) *Blown grains*

$$\text{Blown grains (\%)} = \frac{F}{A} \times 100 \quad (7)$$

Where, F = Mass of whole grains obtained at the straw outlet, g

(f) *Unthreshed grains*

$$\text{Unthreshed grains (\%)} = \frac{H}{A} \times 100 \quad (8)$$

Where, H = Mass of unthreshed grains obtained at both the outlets, g

(g) *Threshing efficiency*

$$\text{Threshing efficiency (\%)} = 100 - \text{Unthreshed grains (\%)} \quad (9)$$

(h) *Cleaning efficiency*

$$\text{Cleaning efficiency (\%)} = \frac{I}{J} \times 100 \quad (10)$$

Where, I = Mass of whole grains obtained at the grain outlet (g), J = Mass of all the materials obtained at the grain outlet (g).

Results and Discussion

The thresher was tested with bundles of barley (grain-straw ratio: 0.57) at 296.88 kg/h feed rate. The operator allowed sufficient time to feed and complete threshing. Therefore, there was no limitation of threshing time. Table 1 shows threshing parameters related to the thresher's performance.

Table 1. Threshing performance of the thresher

Test no.	Total grain input, g	Threshed grains at grain outlet, g	Threshing recovery, %	Unthreshed grains at both outlets, g	Threshing efficiency, %	Cleaning efficiency, %	Grains at straw outlet, g	Blown grain, %
1	511.53	205.69	40.21	310.70	39.26	56.31	17.24	3.37
2	403.72	148.29	36.73	236.38	41.45	61.68	12.05	3.68
3	427.31	158.75	37.15	261.56	38.79	50.49	14.86	2.82
Mean	447.52	170.91	38.03	269.36	39.83	56.16	14.72	3.29

Threshing recovery (38.03%) was found low because the barley was a hulled variety; therefore, rubbing action of the rasp bars succeeded in separating spikelets from the spikes (Fig 7a) but could not remove the hulls. The same reason explains low threshing efficiency (39.83%). This outcome can be improved by adjusting engine rpm or adding a dehulling mechanism with the thresher.

Cleaning efficiency (56.16%) was not also found satisfactory. This was because straw of the barley became weak and brittle due to delay in threshing after harvesting. Therefore the straw broke into small parts and passed with the grains to the grain outlet. Low cleaning efficiency may also happen by high clearance between the rasp bar and the concave which can be adjusted to improve cleaning efficiency. In contrast to poor performance in these parameters, percentage of blown grains (3.29%) was found satisfactorily low.

Against average total grain input of 447.52 g, percentage of whole grains was found around 38% which is unacceptably low (Fig 8). The reasons have already been discussed above. However, percentage of damaged grains was negligible and damage was mainly caused by granary weevil infestation (Fig 7b).

Fig 7. (a) Unthreshed grains (spikelets) from the grain outlet (b) whole grains damaged by granary weevil.

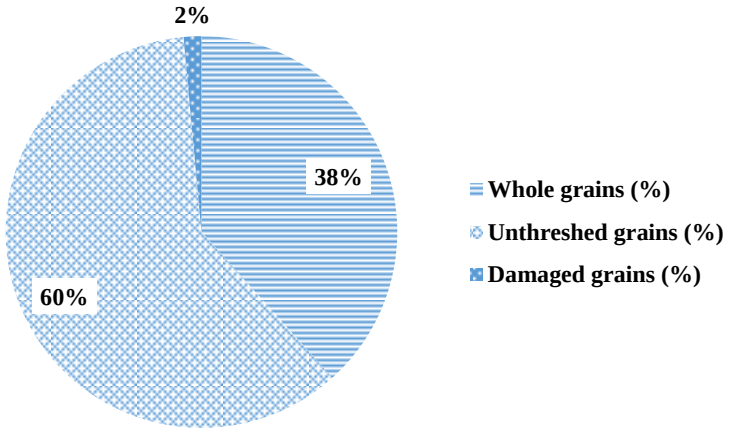


Fig 8. Threshed grain quality assessed from the samples.

Conclusion

Threshing of barley is a tedious job which is usually done manually by the farmers as suitable threshing machine is not available in the market. The Plant Breeding Division of BARI uses two threshers and threshing is accomplished in six steps. In the present experiment, preliminary

laboratory testing of the hulled barley variety at 296.88 kg/h feed rate suggests that the performance of the thresher was not up to the mark as threshing recovery (38.03%), threshing efficiency (39.81%) and cleaning efficiency (56.16%) were low. However, the thresher could separate the spikelets leaving no spike intact; besides, percentage of blown grains and damaged grains was very low. To improve performance of the thresher, fine tuning its design and setting followed by wide laboratory and on-farm testing will be continued.

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EXPT NO. 3.2 DEVELOPMENT OF A POWER OPERATED SUNFLOWER THRESHER

M A HOQUE, M A HOSSAIN, M S MIAH AND M M ALI

Abstract

A study was conducted for solving the problem faced by farmers in separating seeds from the sunflower head. Sunflowers are manually threshed by beating the sunflower heads with stick. The aim of the experiment is to design and fabricate a power operated machine which will separate the seeds from the sunflower. The capacity of the previous model of sunflower thresher was 100 kg/h which could not satisfy the farmers' demand. Threrefore a power sunflower thresher was develpoed with beating action. The thresher was designed and fabricated in FMPE Divisional workshop with available local materials during 2020–21. The main components of the improved model are hopper, threshing cylinder, axial shaft with peg, output hopper, separation sieve, seed output hopper, wheel, engine etc. The threshing was done by beating with the pegs of the rotating cylinder. The thresher was operated with a diesel engine of 2.98 kW (4 Hp). The weight of the thresher was 125 kg (without engine). The capacity of the machine was 600 to 1000 kg/h depending on the moisture contents of the head at Gazipur. A special criterion of this machine is that the machine could be used for both harvested head at maturity and dry head. There was no breakage seed due to use of the machine. The machine was used to operate at 375 to 400 rpm speed of the threshing cylinder to avoid the unshelled seeds. The threshing cost of the sunflower thresher was 494 Tk/ton. The benefit cost ratio for custom hire service of the machine was 3.45 :1. The sunflower thresher was evaluated at farmer's field of Noakhali and found similar capacity found at Gazipur. Farmers expressed their satisfaction. The machine could be recommended for the sunflower growers.

Introduction

Sunflower is one of the principal oilseeds crops of Bangladesh. The present total area under sunflower and other minor oilseed cultivation in Bangladesh is 1290 ha with a production of 1975 metric tons durin 2018-19 (BBS, 2020). The area under oilseeds cultivation is decreasing over the years due to various technical reasons like lake of appropriate machinery (Miah *et al.*, 2014). Farm machinery is an important and fundamental element for agricultural development and crop production in Bangladesh. Farm machinery significantly decreases the time required for farmers to accomplish farm tasks. Sunflower is one of the important oilseed crops in Bangladesh. The area under sunflower crop is now increasing especially in the Southern region. It is expected to increase its production in coming decade to meet the growing demand of vegetable oil of the country. A research work is needed to formulate based on problems faced by the farmers in and around Erode in removing the seeds from sunflower. It takes a lot of time and requires a large man power labour for removing the seeds. Either farmers follow manual method of removing or they have to depend upon the industries which lend them large machines to remove the seeds (Kazi *et al.*, 2016). In the manual method they remove seeds by sliding the sunflower over a wire mesh or thrash it with a metal weld which is really problematic and involves a lot of labours which will land them in wastage of time and energy. The output of the traditional manual threshing is very low and depends upon the efficiency and experience of the workers. Earlier BARI (1993) developed a manual single head sunflower thresher which was again laborious to operate. Due to unavailability of suitable sunflower thresher, farmers are following the traditional methods. Considering the above facts and socio-economic condition of the farmers of the country, a study has been taken.

Objectives

a) To design and fabricate a power operated sunflower thresher
b) To test performance of the sunflower thresher

Materials and Method

A sunflower thresher was designed and fabricated during 2017-2020. Some factors were taken into consideration in order to design the power operated sunflower thresher. An orthographic projection

was drawn with SolidWorks 2016. The schematic views of the improved model of the sunflower thresher are shown in Fig. 1. The dimensions were scale down to reduce the price maintaining same capacity. The space between the pressing rollers (38mm to 35mm) were reduced. A threshing fan was incorporated in the improved version to separate the dust part from the seeds.

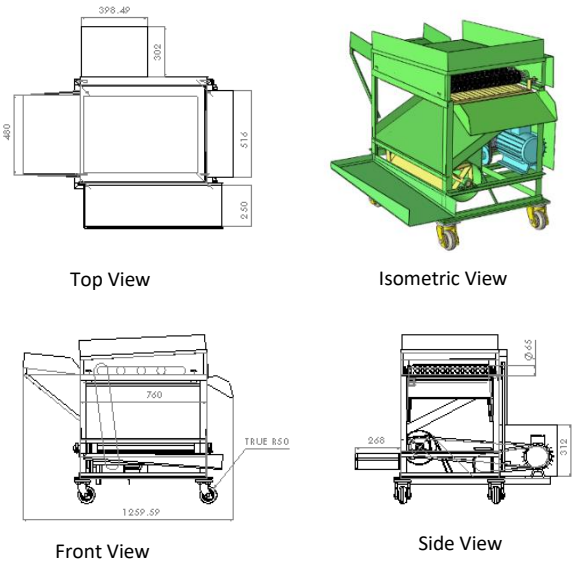

Fig. 1. Schematic views of the improved model fabricated during 2019-20.

The feeding system was slow and have to feed one by one. Thus the user was asking for a higher capacity machine. Thus further attempts were done to develop an improved sunflower thresher to meet farmer's demand during 2020-21. The design parameters considered were feed rate, power requirement, axial flow shaft speed, seed separation capacity and hopper capacity etc. The main components of the improved model were hopper, threshing cylinder, axial shaft with peg, output hopper, separation sieve seed output hopper, wheel, engine etc. Description of different parts are below

Storage hopper: The storage hopper was made of MS angle, MS flat bar and MS Sheet. It is placed on the top of the threshing chamber. The assistant operator initially put the sunflower heads on this hopper. The outlet of this hopper was to the inlet hopper. It was also inclined to the inlet hopper for easy feeding.

Inlet hopper: The inlet hopper was made of MS angle, MS flat bar and MS Sheet. It is placed on the top of the threshing chamber. The operator inserts the sunflower heads to the threshing chamber through it. It was also inclined to the inlet hopper for easy feeding.

Threshing chamber: This is the main working part of this machine. There is one rotating cylinder which was placed centrally. The rotating cylinder was attached on two self-centered bearings. The diameter of the rotating cylinder was 250 mm and length was 600 mm. Total 20 number of beating pegs were placed on five strips uniformly with a screw shape. The peg diameter was selected to avoid seed injury. The diameter of the pegs were 60 mm and length were 50 mm. The inner cylinder was covered with an outer cover. Diameter of the cover was 780 mm. Number of threats in screw conveyer were 4.5.

Storage hopper

Fig 2. Pictorial view of the sunflower thresher

Head output hopper: This hopper allows the heads to discharge after separating the seeds. The hopper was made of MS sheet with a curve shape to place the head in a fixed distance from the machine.

Separation sieve: After action of the threshing chamber, heads were thrown out and seed along with broken parts of heads were drop down of the machine. A separation sieve was placed here to separate the garbage from the seed. The sieve was powered from the axle of the rotating cylinder. The cam connection created a forward motion to the larger particle on top of the sieve allowing the seed to dispense through the hole.

Wheel: Three wheels were used to facilitate the easy movement of the machine. The front wheel was attached with a handle which allow to turn or rotate.

Engine: A small (4hp) single cylinder diesel engine was used as a prime mover of this machine. This type diesel engine is the smallest engine available in Bangladesh to operate a small agricultural equipment.

A pictorial view of the improved sunflower thresher is shown in Fig 3. Different parameters of the sunflower thresher are shown in Table 1. The threshing was done by beating with the pegs of the rotating cylinder. The thresher was operated with a diesel engine of 2.98 kW (04 Hp). The weight of the thresher was 125 kg (without engine).

Fig 3. Operational view of the power sunflower thresher.

Table 1. Different parameters of the power sunflower thresher

Parameters	Sunflower thresher
Overall dimension (mm)	1500 x 1300 x 1500
Dimension of feeding hopper (mm)	360 x 360 x 90
Dimension of Sieve (mm)	600 x 600
Rotating cylinder dimension (mm)	600 x Ø 250 dia.
No of Peg	20
Peg dimension (mm)	50 x Ø 60 dia.
Speed of rotating cylinder (rpm)	375-400
Wheel diameter (mm)	100
Engine capacity	2.98 kW (4 Hp)
Weight of the machine	125 kg

Capacity of sunflower thresher

The capacity of the machine was evaluated as the quantity of the sunflower head could be threshed to get seed within a recorded time. In this case, 10 kg of sunflower was feed into the machine while the time for the threshing operation to complete was recorded. This was calculated using following equation

$$C = \frac{Q}{T} \qquad (1)$$

Where
C = Capacity of the machine, ton/h
Q = Mass of processed sunflower head, ton
T = Time taken for processed, h

Injured seed

The percentage injured seed was determined during the threshing process. The injured seed was separated from the whole seed by hand picking immediately after the threshing process was completed. This was computed using the equation

$$P_2 = \frac{M_2}{M_a} \times 100 \qquad (2)$$

Where
P_2 = Percentage of injured seed, %
M_2 = Mass of injured seed, ton
Ma = Actual mass of seed fed into the machine, ton

Unshelled seeds
The percentage of unshelled seeds during the threshing process was calculated. This was computed using the following equation

$$P_3 = \frac{M_3}{M_0} \times 100 \qquad (3)$$

Where
P_3 = Percentage of unshelled seeds, %
M_3 = mass of seed unshelled, ton
M_o = mass of seed unshelled + mass of seed shelled, ton

Separation efficiency
The percentage of separation during the threshing process was calculated. This was computed using the following equation

$$P_4 = \frac{M_4}{M_4 + M_5} \qquad (4)$$

Where
P_4 Percentage of separation, %
M_4 mass of separated seed, ton
M_5 mass dust mixed seed with separated see, ton

Economic analysis
Operation cost estimation of sunflower thresher
Economic analysis of the sunflower thresher was done. Cost analysis included the operating cost of the machine. Operating cost of the machine included the fixed cost and variable cost. Fixed of the machine included capital consumption and shelter. Variable costs included labour, electricity, repair &maintenance. One labour was required for operating the machine.

Fixed cost
Fixed cost of the machine included annual depreciation, interest on investment, and shelter. Capital consumption included depreciation and interest.
i) Capital consumption (CC)

$$CC = (P - S)CRF + S \times i \qquad (5)$$

Where,
P=Purchase price, Tk
S=Salvage value, Tk
CRF= Capital recovery factor

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \qquad (6)$$

Where,
i= Rate of interest
L=Life of machine, yr

ii) Shelter, T=3.0% of purchase price of the machine, Tk

Total fixed cost per year

$$FC = CC + T \quad (7)$$

Variable Cost

In calculation of variable cost, the following relations were assumed

i) Labour cost per hour, L_b=Tk man-h^{-1}

ii) Electricity cost per hour, E=Lit h^{-1}

Total variable cost

$$VC = L_b + E \quad (8)$$

Annual cost/operating cost

$$AC = FC + VC \quad (9)$$

Field performance evaluation

The adaptive trial of the power sunflower thresher was done at different four locations of Subarnachar upzilla, Noakhali. Subarnachar is the important sunflower growing area of Noakhali district. Total 120 farmers were observed the performance of the machine for threshing sunflower. The machine performance was evaluated during adaptive trials.

Results and Discussion

A sunflower thresher was improved according to farmer's demand. The performance of the power sunflower thresher was varied with the speed of the rotating threshing cylinder (Table 2). When the speed was lowest (300rpm) the capacity was lowest and there was unshelled seed (7.94%) on the head. When the speed of the rotating cylinder was increasing, the capacity of the machine was increasing and unshelled grain was decreasing but the seed separation efficiency of the machine from the husk, broken heads and other garbage was decreasing. The unshelled seeds on the heads were found to be negligible for the speed from 375 to upward. The highest separation efficiency was found between the rotating speed 375 to 400rpm.The broken grain was not found in all tested speed since the higher diameter of pegs were used to beat on the heads. Considering all performance parameters, the suitable rotating speed of the threshing cylinder was found to be within 375 to 400 rpm.

Table 2. Effect of speed of the threshing cylinder on performance of the sunflower thresher

Speed (rpm)	Capacity, kg/h	Separation efficiency (%)	Injury (%)	Unshelled (%)
300	716	92	0.16	7.94
325	720	93	0.17	5.56
350	735	93	0.82	2.06
375	916	95	0.73	0.73
400	938	95	0.63	0.02
425	958	75	0.84	0
450	960	63	2.14	0
500	982	58	3.33	0
700	1004	55	3.91	0

Comparative capacity of the sunflower threshing at Gazipur is shown in Table 3. Capacities of the pedal thresher and manual threshing were 51 and 34 kg/h, respectively. Capacities of the power operated sunflower thresher of previous and improved model were 100 and 800 kg/h. The capacity of the improved power sunflower thresher was 8, 19 and 38 times higher compared with previous power thresher, pedal thresher and manual threshing, respectively.

Table 3. Comparative capacity of the sunflower threshing at Gazipur during 2020-21

Types of threshing	Capacity, kg/h
Improved thresher	800
Previous thresher	100
Pedal thresher	51
Manual	34

Performance of the improved power sunflower thresher at different moisture content is shown in Table 4. Capacity of the thresher varied with moisture content of the heads. The fresh harvested heads at their maturity usually contain higher moisture content. Capacity of the thresher was varied from 606 to 1013 kg/h within 35 to 65% moisture content (wb). Unshelled sunflower seed was higher (1%) in heads having higher moisture content.

Table 4. Performance of the improved power sunflower thresher at different moisture content at Gazipur during 2020-21

MC (%)	Capacity, kg/h	Separation efficiency (%)	Unshelled seed (%)
35	606	95	0.0
55	748	94	0.6
65	1013	80	1.0

Economic analysis of the power sunflower thresher is shown in Table 5. The operating cost of the power sunflower thresher is 297 Tk/ton, respectively. Net profit of the power sunflower thresher is 245632 Tk/year. The BCR of the machine is 3.45:1.

Table 5. Economic analysis of the sunflower thresher for different models

Sl. No.	**Cost Items**	**Power sunflower thresher**	**Manual**
1	Purchase Price, Tk	43000.00	
2	Working days per year, yr	30	
3	Working hours per year, h	240	
4	Machine life, yr	7	
5	Salvage value, Tk	4300.00	
6	Capital consumption cost (CC), Tk	8389.19	
7	Shelter cost, Tk	215.00	
8	Total fixed cost, Tk/year	8594.19	
9	**Total fixed cost, Tk/h**	**35.81**	
10	Labour cost per hour, Tk/h	187.50	62.5
11	Electric/ Diesel cost , Tk/h	65	
	Repairing cost, Tk/h	6.27	
	Lubricating cost, Tk/h	1.95	
12	**Total variable cost, Tk/h**	**260.72**	62.5
13	**Total operating cost, Tk/h**	**296.53**	62.5
14	Capacity, kg/h	600	25
15	Operating cost, Tk/kg	0.49	2.5
	Operating cost, Tk/ton	494	
16	**Operating cost, Tk/yr**	71167	**2500.00**
17	Custom hire based income (@2200Tk/ton), Tk/yr	316800	
18	Net Profit , Tk/yr	245632	
19	**BCR**	**3.45**	

The power sunflower thresher was send to Noakhali during 2020-21. The sunflower thresher was demonstrated in different four places of Subarnachar upazila of Noakhali district and used by the farmers (Fig 4). The capacity of the sunflower thresher was 625-750 kg/h (Table 6) which was similar to the capacity observed at Gazipur.

Fig 4. Field use of the sunflower thresher at Noakhali.

Table 6. Field Performance of the improved Sunflower thresher at different location of Noakhali district during 2020-21

Location	Amount, kg	Capacity, kg/h
Purba Badamtoli	1600	635
Alamin Bazar	1200	625
Uttar kocchopia	1200	625
Bhuiarhat	1000	750

Conclusion

The power operated sunflower thresher was designed and developed. The capacity of the machine was 600 to 1000 kg/h at Gazipur depending on different moisture content. The machine could be used for both the freshly harvested head at maturity and dry head. The sunflower seed was not break due to use of the machine. The unshelled seed on the head could be avoided and satisfactory seed separation could be achieved by operating the machine at 375 to 400 rpm. The cost of operation of the sunflower thresher was 494 Tk/ton. The benefit cost ration for custom hire service of the machine is 3.45 :1. The sunflower thresher was evaluated at farmer's field of Noakhali and found similar capacity found at laboratory. Farmers expressed their satisfaction. The machine could be recommended for the sunflower growers.

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EXPT NO. 3.3 IMPROVEMENT OF THE SITTING TYPE COCONUT TREE CLIMBER

MAHEDI HASAN, M N AMIN, M S MIAH AND M R KARIM

Abstract

Traditional method of coconut harvesting is climbing on a tree directly by hands and feet. BARI has already developed a manual coconut tree climber that was standing type. So, a sitting type coconut tree climber was designed and fabricated at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute, Gazipur during the period of 2019-20.The materials used for the fabrication of different parts of the previous climber were MS square pipe, nut-bolts, rubber, belts, fabrics etc. It was improved during 2020-21 with SS square pipe, nut-bolts, rubber, belts, fabrics, movable cross rail lock etc. The total weight of the previous climber and the improved climber are 15.8kg and 10.8kg respectively. During operation the height of the trees was taken from 6.9m to 9.7m . During operation the highest speed of the sitting type climber during climbing up a tree was 10.54 m/min and the highest speed of climber during climbing down from a tree was 7.46 m/min when the height of the tree was 9.7m. the average speed of the climber during climbing up was 8.19m/min whereas it was 6.81m/min during climbing down from the tree. During operation blood pressure data was varied from 10 to 20 mmHg of systolic and diastolic pressure. At the beginning it is time consuming but with continuous use and practice it will reduced the time required for the climbing. Though there are some problems in coconut climbing machine but it will be useful for both the residential growers and commercial cultivators. The prices of the previous climber and the improved climber were calculated about 6000 Taka and 12000 Taka, respectively. The weight of the climber can be reduced by the use of alloys or composite materials. The experiment will be continued next year to make it user friendly.

Introduction

Coconut is very popular and common fruits in Bangladesh. At present coconut are grown in an area of about 43000 ha with a production of 81400 tons (FAOSTAT, 2013) .The southern part of the country contributes about 80% of total production. (BBS, 2002). Unfortunately despite its mass distribution and wide spread around the world, coconut harvesting is still done without proper safety measures which can lead to serious injuries. It is very difficult to climb on coconut tree manually due to the constant cylindrical structure and single stem. If a person wants to climb a coconut tree manually climbing person has to put his hands close to each other on the back of the trunk, and pull one foot in front of the other one in front of the climbing person on the tree. By keeping pressure on the trunk with the balls of the climbing person's feet and toes, walk up alternating moving feet and hands. Technically it seems to be the easiest to learn but requires good balance and arm strength (Jeff Jepson, 2000). People who employed for coconut tree climbing suffer musculoskeletal disorders. It is very hard to learn the necessary skills to climb coconut trees. A professional climber with proper training only could able to climb coconut tree. In Bangladesh traditional method of coconut harvesting is climbing on a tree which is very risky. As the coconut trees are very tall so injuries associated with coconut tree climbing, particularly falling from coconut trees is common in Bangladesh.

Now a days, different types of coconut harvesting methods are held with the human in other countries of the world like India, Malaysia, and Sri Lanka. Edacheri *et al.,* (2011) reported that at present there are mainly two types of coconut tree climbing devices are available in Indian market. The two types are sitting type climbing device and standing type climbing device. Mohankumar *et al.,* (2013) developed tree climbing device and evaluated based on ergonomical parameters and ergo refinements. The inclination of upper frame of climbing device is increased with respect to the horizontal, while moving towards the top of the tree. As a result, the centre of gravity of the user moves towards outside of the body making the operator feel insecure and unstable.

Morris (2002) developed a climbing tree stand having a first platform and a second platform having a base frame, a first arm and a second arm, a support arm, first and second illumination assemblies, and a blade attached to an upper bracket of the base frame. The first and second arms were pivotally attached to the base frame and were releasable engage able with the

support arm. The support arm had a curved portion at an opposed distal end of the first arm and second illumination assembly was attached to a distal end of the second arm of each platform. The second platform included a foot support lifting bracket attached to its base frame. The foot support lifting bracket was comprised of rigid non flexible structure. Graham *et al.,* (2003) developed an adjustable tree stand comprising of a seating section and a standing section, each having inclined attachment bars adjacent the section sides, and seating and standing section cables, each having first and second ends with handles at each of the ends. Each attachment bar had outer and inner faces with a plurality of spaced, aligned attachment holes extending between the faces, and a plurality of spaced, aligned latch holes alternating with the attachment holes. Each of the handles had a pair of flanged projections insert able into adjacent attachment holes in an attachment bar and a latch pin insert able into a latch hole between the adjacent holes. Each projection was moveable from an insertion position to a locked position within a hole when the cable was tensioned, and was prevented by the latch pin from moving back to the insertion position when the cable was relaxed.

Joseph (2006) developed a coconut-climbing device having two frames (left and right). Each frame was having flexible adjustable encircling iron rope mounted around a tree and tree gripping rubber pad. The two main frames were fitted on the tree side by side enabling the operator to lift the frames conveniently using the sliding member. Laborde (2006) developed a climbing tree stand apparatus with upper and lower platforms that were independently movable up the tree from under alternatively sitting and standing on one or the other of the platforms. There is no device available with safety features and easy climbing on coconut trees. Keeping the aforementioned facts in view, the simple device was fabricated with safe and easy to use device for climbing coconut palm, which could even be operated by an unskilled person.

Coconut tree climbing equipment helps to climb on coconut tree without much human efforts. In India robotic type of climber has also developed. Hariskrishna *et al.,* (2013) reported that most of these climbing robots are capable of climbing regular structures like poles, walls, domes etc. But a very few are capable of climbing trees, main reason being irregular surface and variation of diameter with length. It also requires greater agility and high maneuverability to be used as a product. Also the bark of some trees may not be strong enough to bear the weight of the climbing device, hence conventional climbing robots cannot be used for tree climbing applications. Jahan *et al.,* (2018) developed a standing type coconut tree climber at the Workshop of FMPE Division of BARI, Gazipur .Therefore, this study has been undertaken to develop a sitting type coconut tree climber which will help the user to climb coconut tree more comfortably and easily. So, it will be very useful for the peoples who have large coconut cultivation as well as the residents who have less coconut trees.

Objectives

a) To design, develop and fabricate a sitting type coconut tree climber
b) To evaluate the performance of the fabricated coconut tree climbers
c) To ensure the operators' safety

Materials and Methods

Description of the fabricated sitting type coconut tree climbers

A sitting type coconut tree climber was designed and fabricated at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during the period of 2019-20.The materials used for the fabrication of different parts of the previous climber were MS square pipe, nut-bolts, rubber, belts, fabrics etc. It was improved during 2020-21 with SS square pipe, nut-bolts, rubber, belts, fabrics, movable cross rail lock etc. Rubber grips were provided for operator's comfort. At the time of working, when the center of gravity of the user shifts outside of the body and the user feels insecure and unstable. In case of the developed device at any portion of the trunk makes 90° with the trunk so that operator feels safe. The total weight of the previous climber and the improved climber are 15.8kg and 10.8kg respectively. The photographic views of the sitting type coconut tree climbers

are shown in Figs below. Left side Figs are the parts of previous climber and the right side Figs are the parts of improved climber.

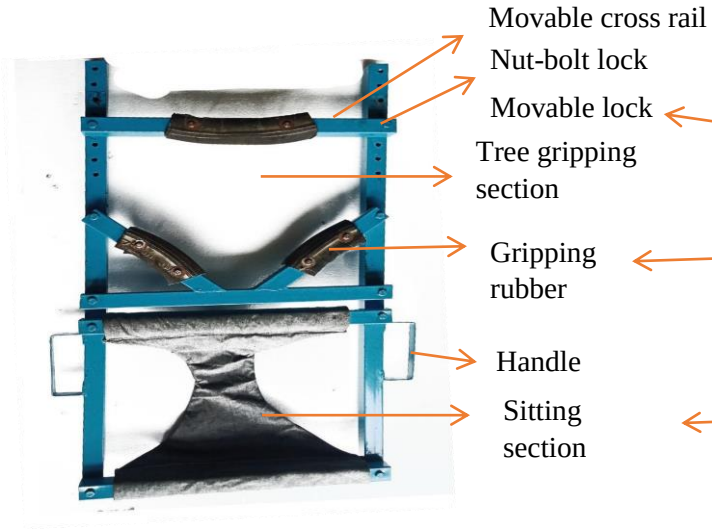

Fig. 1. Upper frame of the previous climber.

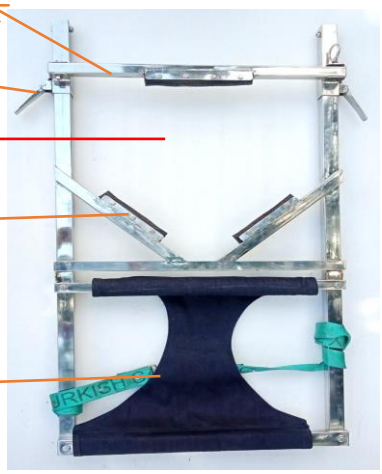

Fig. 2. Upper frame of the improved climber.

Fig. 3. Lower frame of the previous climber.

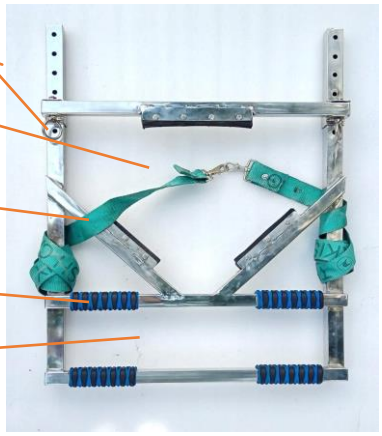

Fig. 4. Lower frame of the improved climber.

Working Principles of the sitting type coconut tree climber

The climber has two frames. An upper one for sitting purpose and another lower one used by leg. They are connected by a belt while the equipment is on the coconut tree. The user has to sit on the fabric seat which is provided on upper frame and has to insert his foot into the foot holder in the lower frame. The upper frame can be lifted by hands and the lower frame has to be lifted by leg. The process has to be repeated for the continuous climbing. In this type, there are two girth control provision by the movable cross rail in both of the frames of the climber that helps to adjust the machine as per the coconut tree diameter. Safety belt can be adjusted for safety purpose of the operator. Distance between the upper and lower frames can be adjusted by the connecting belt as per convenience. The fabricated coconut tree climbers with specifications are shown in Table 1.

Table 1. Specifications of different parts of sitting type coconut tree climber.

Sl. No	Name of the parts	Previous climber		Improved climber	
		Specification	Materials	Specification	Materials
1	Upper frame(L×W) mm	1100×560	MS Box pipe	1100×560	SS Box pipe
2	Lower frame(L×W) mm	710×560	MS Box pipe	710×560	SS Box pipe
3	Sitting section(L×W) mm	450×560	MS Box pipe & Fabrics	450×560	SS Box pipe
4	Foot section(L×W) mm	250×560	MS Box pipe& Belt	250×560	SS Box pipe
5	Tree gripping section(L×W) mm	470×560	MS Box pipe& Rubber	470×560	SS Box pipe
6	Inclined rail, mm	300	MS Box pipe	300	SS Box pipe
7	Cross rail, mm	480	MS Box pipe	480	SS Box pipe
8	Number of tree gripping rubber in both frame	6	-	6	-
9	Length of gripping rubber in inclined rail, mm	160	-	160	-
10	Length of gripping rubber in cross rail, mm	270	-	270	-
11	Diameter of knob hole in both frame(Ø)mm	9	-	9	-
12	Spacing of knob hole, mm	40	-	40	-
13	Weight of upper frame ,kg	8.8	-	6.3	-
14	Weight of lower frame ,kg	7	-	4.5	-
15	Number of movable cross rail lock in upper frame	-	-	2	-
16	Overall dimension of the climber(L×W)mm	1100×680		1100×680	

**L=length and W=Width, SS= Stainless steel and MS=Mild steel*

Performance Evaluation of the climber:

Both of the coconut tree climbers were tested for climbing on coconut trees beside the Land and Construction Section of BARI campus. Before and after the climbing operation on trees using the fabricated climbers, the operators' blood pressures data were taken. The blood pressures data were recorded using sphygmomanometer and stethoscope. The speed of the operators for climbing on trees by the fabricated climbers were calculated using following equation

$$S = \frac{D}{T}$$

Where

S = Speed
D = Distance covered
T = Time required

Fig. 5. The operational view of the previous climber.

Fig. 6. The operational view of the improved climber.

Fig. 7. Coconut harvesting by the previous climber.

Fig. 8. Coconut harvesting by the improved climber.

Results and Discussion

Performances of the operators for climbing on trees by the previous climber and the improved climber are shown in the Table 2. and Table 3. It was observed that most of the cases before climbing on a tree and after climbing down from a tree, the operator's blood pressures data were varied from 10-20 mmHg of systolic and diastolic pressures. It is quite normal for every person because blood pressure of every people literally increased after hard physical work. Sometimes blood pressures data may show little bit high value due to the fear of height and the use of new machine for the first time. During operation of the previous climber, the heights of the trees were taken from 6.9m to 9.7m. The highest speed of the operator during climbing on a tree was 10.54 m/min and the highest speed of the operator during climbing down from a tree was 7.46 m/min when the height of the tree was 9.7m. During operation of the previous climber some problems were observed. The weight of the climber was little bit more. So the operator felt sometimes inconvenient when climbing on a tree. This problem was solved by reducing the weight of the climber in the improved climber. It was also observed that by the more practicing, the speed of the operator climbing on the tree by the climber was increased. During operation of the improved climber, the heights of the trees were taken from 7.6m to 8.7m. The highest speed of climber during climbing on a tree was 7.91 m/min and the highest speed of climber during climbing down from a tree was 6.69 m/min when the height of the tree was 8.7m. Performance of the operator for climbing on trees by the improved climber is shown in Table 3. For both of the climbers while operators move towards top of the tree, operators felt insecure and unstable. To solve this problem, a safety belt was provided for avoiding the possibility of a fall which will increase the confident of operator to work without fear at any height of the trees. Performance of the operator for climbing on trees is mainly depends on the capability of person, slippage condition of trees, curving length of the tree trunk, weight of the climber, physical and mental condition of the operator, height of the tree etc. This experiment will be continued next year to make it user friendly and extent it different locations of through demonstration.

Table 2. Performance of the operator for climbing on trees by the previous climber

Blood pressure of the operator (mmHg)		Height of the tree (m)	Time (minute)		Speed (m/min)	
Before climbing up	After climbing down		Climbing up	Climbing down	Climbing up	Climbing down
110/70	120/80	6.9	1.35	1.20	5.11	5.75
120/80	130/90	8.3	0.93	1.15	8.92	7.22
130/90	130/80	9.7	0.92	1.30	10.54	7.46

Table 3. Performance of the operator for climbing on trees by the improved climber

Blood pressure of the operator (mmHg)		Height of the tree (m)	Time (minute)		Speed (m/min)	
Before climbing up	After climbing down		Climbing up	Climbing down	Climbing up	Climbing down
110/60	130/80	7.9	2.60	2.52	3.03	3.13
130/80	140/90	7.6	1.00	1.40	7.60	5.42
140/90	140/80	8.7	1.10	1.30	7.91	6.69

Conclusion

A sitting type coconut tree climber was designed and fabricated at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during the period of 2019-20. It was improved during 2020-21.The highest speed of the operator during climbing on a tree by the previous climber was 10.54 m/min and the highest speed of the operator during climbing down from a tree was 7.46 m/min when the height of the tree was 9.7m. The highest speed of the improved climber during climbing on a tree was 7.91 m/min and the highest speed of climber during climbing down from a tree was 6.69 m/min when the height of the tree was 8.7m.The total weights of the previous climber and the improved climber are 15.8kg and 10.8kg respectively. The prices of the previous climber and the improved climber were calculated about 6000Taka and 12000Taka, respectively. The weight of the climber can be reduced by the use of alloys or composite materials. Also better safety accessories can be thought of and included along with the equipment. This experiment will be continued next year to make it user friendly and extent it different locations of through demonstration.

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EXPT. 4.1 DEVELOPMENT OF SOYMILK MAKING MACHINERY

M A HOQUE, MD. AYUB HOSSAIN AND MD. MUBARAK ALI

Abstract

Soybean provides a cheaper and high protein that can be an alternative substitute to animal protein. In Bangladesh, uses of soybean for these food items are restricted due to unavailability of suitable machines. The design of the soymilk production and pasteurization plant would assist in increasing soybean for human consumption. The experiment was conducted to develop soymilk making machinery to increase consumption of soybean as human food during 2019-2021. A blender and a pasteurizing unit were designed and fabricated for making soymilk. A blender was improved during 2020-21 for making soymilk with increasing blade speed. Capacity of the blender and pasteurizing units were 2 liters and 6 liters, respectively. The operational time of the blender was reduced from 40 to 20 seconds which was selected with 83.68% blending efficiency to prepare soymilk for each batch. Time required for heating the interlayer water upto 100 ^{0}C was 37.67 minutes. Time for reaching milk temperature upto 100 ^{0}C was 5 minutes only. The soymilk was prepared with 20 minutes pasteurizing. The soya poneer was prepared and sensory evaluation was done. The panelists showed their satisfaction on soymilk and soya poneer. The experiment will be continued next year to improve the machine performance and financial analysis will be done.

Introduction

Soybean is a high value and profitable crop. Soybean provides a cheaper and high protein rich alternative substitute to animal protein. The costs and returns analysis revealed soybean production as a profitable enterprise with rate of return of 62% (Salam and Monayem, 2013). But the production of soybean is hampering due to lack of facility of oil production in Bangladesh. Alternate use of this nutritive soybean for human consumption could create greater market demand. Different soya foods like soya milk, soya biscuits, soya chapatti can be prepared from soybean. It has also diabetic, medical, industrial and agricultural importance (Hossain *et al.*, 1992). Soy protein directly lowers serum cholesterol levels. The soy cotyledon storage proteins are important for human nutrition. Soybean contains isoflavones, which are said to have potential anticancer effects. It contains two primary isoflavones called Genistein and Diadzein and a minor one called as Glycitein. They retard bone loss in premenstrual and postmenstrual women, soluble fiber in soy foods control blood sugar. Soy foods are quite important to us as they reduce the risk of heart disease. Regular consumption of soy food delays the process of aging and also improves mental and physical abilities, memory power, and hemoglobin levels of children (American Soybean Association, 2004). Owing to these qualities, soybean has long been used in supplementary foods. Soymilk is aqueous liquid obtained from extraction of milk from soybean. It involves grinding of soaked soybean with water to produce slurry, mixed of the slurry with water in order to separate the milk from chaff and sieving of the milk from the paste (Gbabo *et al.*, 2012). The consumer's enlightenment on health effects of dairy milk consumption has contributed in acceptability and popularity of soymilk (Gbabo *et al.*, 2012; Jinapong *et al.*, 2008). Dairy milk consumption was reported by McGee (2004) to increase the risk of suffering from certain health problems such as cow milk allergy, which is not found in grains drink. Most of these anti-nutritional factors can be destroyed through processing and boiling (Osho and Dashiell, 1998). The heating process during conventional soy milk making considerably destroys most of the anti-nutritional factors in soy milk and improves the digestibility of soy protein, as well. However, compounds, like phytic acid, which interferes with the availability of calcium, is not reduced effectively. At the same time, over-heating to eliminate trypsin inhibitor activity to a great extent can cause damage to amino acids, as well as loss in the overall nutritional value of soy milk. In additional, there is possibility of contamination of beverages as result of wearing of component parts of milling plate with time of use (Gana, 2011). Generally, there is a lack of studies on the evaluation of new methods of processing and preservation of soya **milk.** Soy paneer is known for its extraordinary nutritional benefits, as well as its versatility. Soy paneer is a soft cheese-like food made by curdling soymilk with a coagulant (Reja *et al.* 2014). The soy milk is coagulated either by salt or by acid followed by pressing to form soya poneer. Calcium chloride, magnesium chloride, citric acid and acetic acid are the commonly used coagulants. This product came into existence about three decades ago which can be stored up to one year (Banerjee *et al.*, 2019). Hence the design of the soymilk production and pasteurization plant would assist in increasing soyabean in human

consumption. In Bangladesh, uses of soybean for these food items are restricted due to unavailability of suitable machines. Thus, an experiment was conducted to develop soymilk making machinery to increase consumption of soybean as human foods.

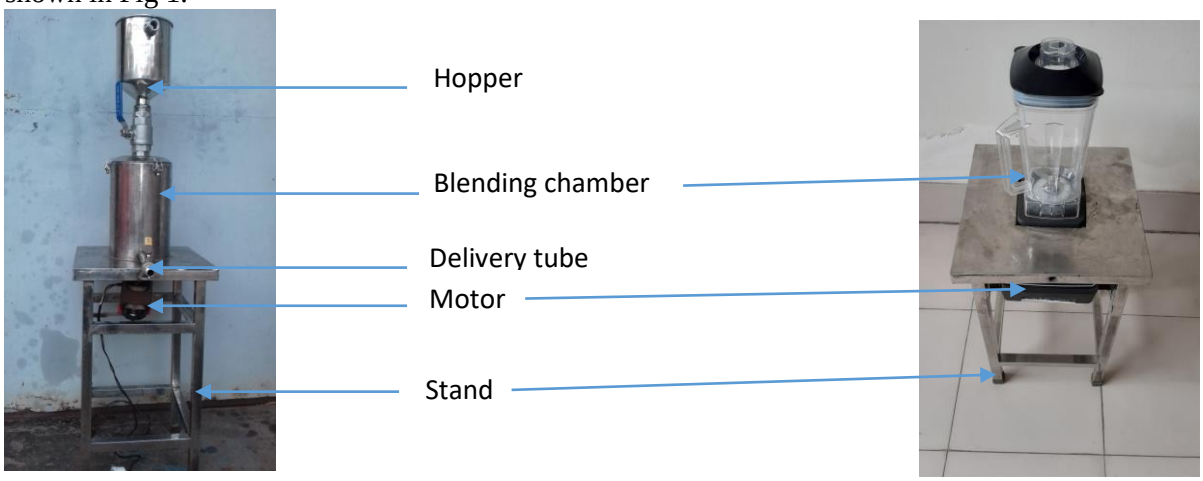
Materials and Methods

A set of soymilk machine was designed. Some factors were taken into consideration in order to design the machines. The design parameters considered were feed rate, power requirement, shaft speed of the blander and hopper capacity etc. Small type prototype of blender was targeted to develop with locally available stainless-steel material and single phase electric motor which will be easily functional by the progressive farmers and small entrepreneurs during 2018-19 which was improved during 2020-21. A pasteurizing heater is an important part which was design as well as blender part. The soya poneer press (Fig 3) was developed during 2019-20. The schematic views of the model of the blender and the pasteurizing heater are shown in Fig 1 and Fig 2.

Machine components

A mini plant was constructed using stainless steel materials and it is made of the following components:

i) Blending unit: This unit is made up of the following sub-component parts: outer casing, hopper, delivery tube, blending chamber, blending blade, shaft, pulley, V-belt and 2200 watt electric motor as shown in Fig 1.



Modified Blender base

Modified Blender base

Fig. 1. Blending unit for Soymilk making.

ii) Pasteurization unit: This unit is made up of the following sub-component parts: inner casing, outer casing (water jacket), milk inlet and outlet valves, water inlet and draining valves, external casing as shown in Figs 2.

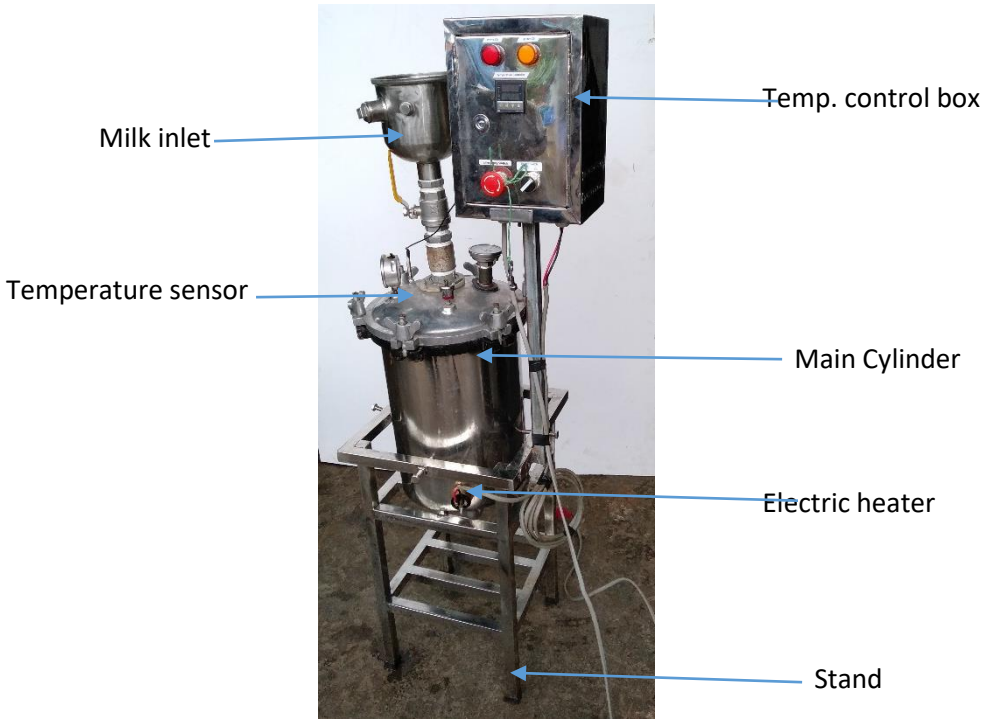


Fig. 2. Pasteurization unit for Soymilk making.

A blender and a pasteurizing unit was designed and developed for making soymilk during 2019-20. The blender unit was improved for blending soyabean during 2020-21. The specification of the previous and improved blender is shown in Table 1. The specification of pasteurizing unit of the previous and improved soymilk blender is shown in Table 2. The improved blender unit was operated with 0.22 kW electric motor having 48000 rpm speed whereas the previous blender was operated with 0.20 kW. The blender was designed for continuous feeding and operation. Two liters per batch were feed. The weight of the blender unit was reduced from 16.26 to 11 kg.

Table 1. Specification of the blender

Parameters	Previous model	Improved model
Overall dimension	1220 ×350 ×460 mm	900 ×350 ×350 mm
Dimension of the stand	600 ×350 ×350 mm	600 ×350 ×350 mm
Dimension of the blending chamber	162Ø ×260 mm	300 × 125 × 125 mm
Dimension of the hopper	150 Ø ×200 mm	nill
Dimension of the blending blade	135 ×80 ×3 mm	80×60 ×30 mm
Speed of the blade	6000 rpm	48000 rpm
Source of power	0.20 kW electric motor	0.22 kW electric motor
Capacity of blender	2 liter/batch	2 liter/batch
Weight of the blender	16.26 kg	11.00 kg

The pasteurizing unit prepared with two cylinders. The inner cylinder was to keep the soymilk and outer cylinder was to keep the hot water. Capacity of the inner cylinder is 6 liters. The space between the cylinders was filled with water which was heated with a 2000-watt heater. The temperature of the water was monitored with a sensor (200±1 ^{o}C) which was connected with a control box. The weight was 28 kg.

Table 2. Specification of the pasteurization unit

Parameters	Observation
Overall dimension	1440 ×540 ×440 mm
Dimension of the main cylinder	300 Ø ×390 mm
Dimension of the inner cylinder	200 Ø ×230 mm
Dimension of the hopper	140 Ø ×150 mm
Dimension of the stand	600 ×380 ×380 mm
Dimension of the control box	300 ×220 × 180 mm
Capacity of the unit	6 liters
Sensor range	200±1 ^{o}C
Heater load	2000 watt
Weight of the unit	28 kg

iii) **Soy poneer press:** This unit was design and developed during 2019-20 with Stainless Steel (Fig 3). Poneer press was made with round cylinder with 1.6 mm thick sheet with 5 mm SS Plate, 25 mm threaded shaft and other parts in SS. This will require less maintenance. Operation of the unit is easy to give more pressure upon soy poneer. This machine has the inbuilt container. It is amazing product and have capacity for making poneer in large quantity in the hygienic conditions along with retaining its quality.

Fig. 3. Soya poneer press.

Mode of operations of the machines for soya milk

The blending blade was fixed on the vertical shaft inside the blending chamber. Soaked and dehulled grain (200g each sample) of Soybean was feed inside the blending chamber. Water (1kg) was also feed with bean. The power source was then switched on for blending operation. The milk was poured to the pasteurization chamber from the blending machine. This is the raw soyamilk. The water tank was then mounted on the pasteurizing heating machine. The boiling tank was filled with water to the required level. The milk was fed into the machine through the hopper. The temperature of the water was monitored through the temperature gauge. The hot water was hold inside the pasteurizer for the required time. The pasteurizer outlet valve was open for outflow of the milk. The water jacket outlet valve was open for draining of the used water. Performance test of the soymilk was done at FMP Engineering Divisional workshop, Gazipur.

Preparation of Soybean Milk

The soymilk was as follow: the whole soybeans were washed and soaked in water (1:3) at room temperature (20±5 °C) for 10 hours in normal water and husk was separated from the bean by pressing the bean followed by washing with water. The beans were then ground in blender for various time. The ratio of beans to water was 1:5 (w/v). The resulted suspension was filtered. And then the suspension insert in pasteurization unit. The outer temperature was more than 100 ^{0}C and

inner temperature was 100 ^{0}C. The liquid was kept for 20 minutes. Hot suspension was come out by outlet. This suspension was cooled and become soymilk. The process of soymilk preparation is presented in Fig. 3.

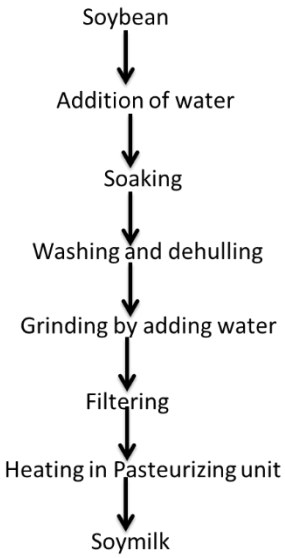


Fig 3. Flow chart for soymilk production

Determination of machine blending efficiency

This is the measure of the degree by which the grains are reduced in size and was determined by Equation as reported by Nwaigwe *et al.* (2012).

$$E_B = \frac{A}{MT} \times 100$$

where, EB is the blending efficiency (%); A is the amount of the material passed through the sieve (kg); MT is the total weight of the material feed into the machine (kg).

Preparation of Soya poneer

After preparing soyamilk, when the soybean milk's temperature come to 70-80 degree. Mix the citric water with soybean milk and stir 1-2 times. Stir the milk with limited break not continuously. Withing 15-20 minutes the milk started coagulate and water separated from it. If the milk has not yet been fully coagulated, then some more citric solution have to pour it. The coagulated milk was separetd instantly, else the tofu will not get soft. Once the milk and the water separate, a clean cloth spread over a strainer and pour the milk over it. Tofu were collected on the cloth and the water was strain down into the bowl when press with the soya poneer press device. Good quality soft tofu were found after press and waiting 30-40 minutes. The tofu inside the cloth was freeze inside the cloth that can be used to make various different dishes. Then prepared soya poneer was evaluated by sensory evaluation. Ten panelists were evaluated soya poneer.

Results and discussion

Performance of blender for soaked soybean sample during 2020-21 is shown in Table 3. Blending efficiency varied with the operating time. But the incensement of the blending efficiency was nearly static after 20 seconds operation in the improved blender though this time was 40 seconds for the previous model. Thus the operational time 20 seconds was selected with 83.68% blending efficiency to prepare soymilk for each batch.

Table 3. Performance of blender for soaked soybean during 2020-21

Previous Model		Improved Model	
Operating Time, Sec	Blending efficiency (%	Operating Time, Sec	Blending efficiency (%)
10	55.21	10	75.29
20	61.50	15	83.68
30	68.41	20	83.68
40	76.78	25	83.74
50	76.20	30	83.74
60	76.26	35	83.74

Performance of pasteurizing unit for soymilk making during 2020-21is shown in Table 4. Time for heating the interlayer water upto 100 ^{o}C was 37.67 minutes. Time for reaching milk temperature upto 100 ^{o}C was 05 minutes only. Water temperature was 5-10 ^{o}C more than the soymilk temperature. The soymilk was prepared with 20 minutes pasteurizing as shown in Fig 4.

Table 4. Performance of pasteurizing unit for soymilk making during 2020-21

Trial No.	Inter layer water volume, liter	Time for heating the interlayer water upto 100 ^{o}C, minutes	Amount of milk, liters	Time for getting milk temperature 100 ^{o}C, minutes	Pasteurizing time for each batch, minutes	Temperature, ^{o}C	
						Milk	Inter layer water
01	8	38	4.5	05	20	100	108
02	8	38	4.5	05	20	100	110
03	8	37	4.5	05	20	100	110
Average	8	37.67	4.5	05	20	100	109.33

Fig 4. Prepared Soymilk.

Soya poneer was prepared (Fig 5) and sensory evaluation was done. The sensory evaluation results during 2020-21 are shown in Table 5. The sensory evaluation showed that milk and soy poneer was accepted by the panelist.

Fig 5. Pictorial flow chart of preparing soya poneer during 2020-21

Table 5. Sensory evaluation of soymilk and soya poneer during 2020-21.

	Colour	Flavour	Tast	Texture	Hardness
Base Marks	10	10	10	10	10
Milk	8.14	7.43	7.86	8.71	-
Soy poneer	7.50	7.38	7.75	8.75	8.50

Conclusion

A blender was improved during 2020-21 for making soymilk. Capacity of the blender and pasteurizing unit was 2 liters and 6 liters, respectively. The operational time 20 seconds was selected with 83.68% blending efficiency to prepare soymilk for each batch. Time for heating the interlayer water upto 100 ^{o}C was 37.67 minutes. Time for reaching milk temperature upto 100 ^{o}C was 05 minutes only. The soymilk was prepared with 20 minutes pasteurizing. The soya poneer was prepared and sensory evaluation was done. The panelists showed their satisfaction on soymilk and soya poneer. The experiment will be continuing in the next year to improve the machine performance and financial analysis.

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EXPT. NO. 4.2 ADAPTIVE TRIAL OF BARI CREAM SEPARATOR

M S MIAH, M Z HOSSAIN, T N BARNA AND M A HOSSAIN

Abstract

To separate cream from whole milk, several methods have been devised. The present cream separation method is manual, which means that the milk must be boiled first, then allowed to cool so that the fat can form on the upper surface and be collected. All of these works are time-consuming, difficult, and expensive. In large-scale enterprises, a few imported large-scale cream separating machines are available. A multi-driven, portable, and user-friendly cream separator was designed and fabricated with locally accessible iron materials in the workshop of the FMPE Division of BARI, Gazipur during 2019-2020. It is made up of many components, including a feeding bucket, a uniform distributor, a cream collecting outlet, a skimmed milk collecting outlet, a spinning disc, and a power transmission system, among others. Several adaptive trails of the cream separator in various areas in Sirajganj and Gazipur were conducted to collect user feedback and incorporated it into the final product during 2020-21. The average feeding capacity and separation efficiency of the machine were 150 kg/h and 86%. The fat content of the whole milk was reduced from 3.30% to 0.47%. The operation of the machine has no influence on the protein content of milk. The benefit cost ratio of the machine was found 1.62 for the MS (Mild steel) model and 1.52 for the SS (Stainless Steel) type. The break-even points of the MS model and SS model were 140 days and 220 days respectively. All the users of Sirajgonj and Gazipur were highly satisfied with the performance of the machines. From the users, such as a larger feeding bowl and adjustable seat were incorporated in the machine. Furthermore, because milk is highly perishable, long-term storage is not viable. If there is no electricity or load shedding, then it can be operated by leg or hand without changing any setting. It is a machine that is suitable for women. Without any advanced technical skills, anyone can operate it. This machine is recommended for separating cream from fresh milk all over Bangladesh.

Introduction

Milk from the cattle contains a number of large and small butter-fat particles held in suspension. They are lighter in weight than the other parts of the whole milk. When milk is left standing, the milk portion low in fat (like skim milk) gradually settles at the bottom because it is heavier. On the other hand, butter-fat surfaces to the top through buoyancy. When the bulk of the fat globules find their way to the top, they constitute (like cream), which consists largely of the fat particles (Milk and Laval, 1877). All of the commercial separation of whole milk produce two kinds of fraction. The first fraction, which contains fat in highly concentrated form, is called cream while the other fraction, which is a non-fat fraction, is termed as skim milk. The fat content of cream can be varied, depending on the need, from 20 to as high as 80% fat (Qu *et al.*, 2019). Cream is used for making ice cream, butter, ghee and Anhydrous milk fat in the dairy plants. In the industrial production of cream, this process is accelerated by using centrifuges called "separators". In Bangladesh cream separation from milk is done at conventional method through stirring by wooden spoon by the small holder farmers. However, imported machine is used for large scale cream production in milk processing industry. There found no locally produced available machine for separating cream from milk in our country. Thus there need to develop a cream separator in this purpose (Kumar, 2013).

Bangladesh produces 1.90 million tons of milk each year where buffalo, cow, goat and sheep account as 0.03, 0.80, 1.04 and 0.03 respectively. However, milk processing statistics is very poor only 0.52 million tons (27%) where milk are processed as butter, cheese, ghee and skimmed as 0.002, 0.001, 0.03 and 0.48 respectively (FAOSTAT, 2018). However, this milk processing is mainly done in the big industries like Milk vita, Pran, Aarong etc. They collect milk from farmers at major milk producing area like Shirajganj, Pabna, Rajshahi at a cheaper rate (Hemme *et al.*, 2004). As milk is a highly perishable product, so farmers don't wait for a longer time to sell their item even though the price is low. If the farmers can process their milk as cream or butter they could be benefited in two ways. One, they could sell the cream to butter, ghee and cheese processing factory. Secondly, they can sell the skim milk to consumers who look for zero fat and higher calorie milk. Even the skim milk can be used in preparing sweetmeat through boiling with vinegar or lemon. However, a small amount of farmers in our country separate cream from milk following the conventional method by stirring with a wooden spoon. There are also a few amounts of people who use cream separator machine imported

from India. There is no locally available workshop or company who produce this machine though there is notably demand from the farmers. Imported machines are high in cost and the spare parts are not available. The program hence was taken to develop low cost cream separator machine by locally available materials concerning maximum efficiency.

Dairy farm normally located in village area of Bangladesh, a few of the regions still did not reached electricity and most of the area have long time load shedding in day time. It is impossible to store the milk in normal temperature for a long time, because the milk is perishable product. Thus the program was taken to develop a cream separator which could be operated by electric motor or manual leg or hand. Laval from Sweden is considered the first man who invented the mechanical cream separator in 1880, based on the principle of centrifugal force. Whole milk is conducted into a bowl, commonly through a central tubular shaft. A spindle rotates the bowl at a rate of from 6,000 to 9,000 rpm, and a series of identical conical disks separates the milk into vertical layers. The heavier skim milk collects on the outer circumference of the rapidly whirling bowl, and the lighter cream tends to remain in the center. The pressure of the whole-milk supply above the bowl then forces the cream and skim milk out of the machine and into separate collecting vessels. The cream separator makes it possible to control the amount of fat (called butterfat) remaining in the milk. The gravity method ordinarily leaves one fourth of the fat in the milk, while the cream separator leaves only 0.01% to 0.02% of the fat in the skim milk. Since the latter process is much faster than the gravity method, there is less chance for harmful bacterial action (Laval, 2016). The machine was developed a lot since then, especially in terms of performances and material selection. Apart from European, China and India alone produced huge number of cream separator to export all over the world. The farmers in Bangladesh use some cream separators imported from India and China. Therefore, this program was taken to develop cream separator in local workshop to make this technology cheaper and available in Bangladesh and several adaptive trials were implemented in different regions

Objectives

a) To evaluate the performance of the cream separator.
b) To study the economic analysis.

Materials and Methods

In the year 2019-20, the FMPE Division's workshop designed and built a cream separator. The machine was tested in the laboratory and found suitable for separating cream from the fresh milk. The Adapative trials of the machine were conducted in Gazipur and Sirajganj during 2020-21.

Site selection

Adaptive trials were done in March 2021 in a small entrepreneur house in Salna, Gazipur, and a dairy milk production area in Sirajgonj (Sadar and Ullapara) shown in Fig.1.

Fig. 1. Adaptive trial of cream separator at Sirajganj Sadar.

Data collection

We invited 15 dairy milk-related individuals into each adaptive to observe the machine's performance. We asked each participant a series of questions about the cream separating machine through a questionnaire.

Financial analysis

Operation cost estimation of cream separator

A cost-benefit analysis of the BARI cream separator was completed. The machine's operational costs were factored into the cost analysis. The machine's operating costs included both fixed and variable costs. The machine's fixed features included capital consumption and shelter. Labor and electricity were examples of variable expenses. The machine required one laborer to operate.

Fixed cost

Fixed cost of the machine included annual depreciation, interest on investment, and shelter. Capital consumption included depreciation and interest.

iii) Capital consumption (CC)

$$CC = (P - S)CRF + S \times i \quad (2)$$

Where,

P=Purchase price, USD
S=Salvage value, USD
CRF= Capital recovery factor

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \quad (1)$$

Where,

i= Rate of interest
L=Life of machine, yr

iv) Shelter, T=3.0% of purchase price of the machine, USD

Total fixed cost per year

$$FC = CC + T \quad (2)$$

Variable Cost

In calculation of variable cost, the following relations were assumed

iii) Labour cost per hour, L_b=USD man h^{-1}

iv) Electricity cost per hour, E=USD h^{-1}

Total variable cost

$$VC = L_b + E \quad (3)$$

Annual cost/operating cost

$$AC = FC + VC$$

Break-even use

Break-even machine use denotes a circumstance in which there is no profit and no loss, and the machine's use can be regarded a net gain (Gittinger, 1994). Revenue was calculated using the information gathered and expected values for various elements such as fixed and variable costs,

threshing capacity, and thresher usage. The following formula (Alam and Momin, 2009) was used to calculate the appropriate break-even use of the threshers:

$$\text{Break even use (ton)} = \frac{\text{FC for service life (Tk.)}}{\text{Revenue (Tk./ton)} - \text{VC (Tk./ton)}} \qquad (6)$$

Where, FC for entire economic life (USD) = Annual fixed cost (USD./yr) × economic life (yr); VC = variable cost, USD./ton

Results and Discussion

Feedback from user

The cream separator's performance has been deemed adequate, and it is an ideal cream separating equipment for farmers, small business owners, dairy sweet producers, and others. We asked a few questions, and the answers are shown in Fig.2. We have already included their suggestions into the cream separator, such as an adjustable seat, a larger wheel, sieving, and so on. However, lowering the machine's price is quite tough. We are now considering using aluminum instead of stainless steel to reduce the machine's cost. There is one feedback that can be used to boost the machine's capacity. It has the option of increasing the machine's capacity, but the price will be increased at the same time.

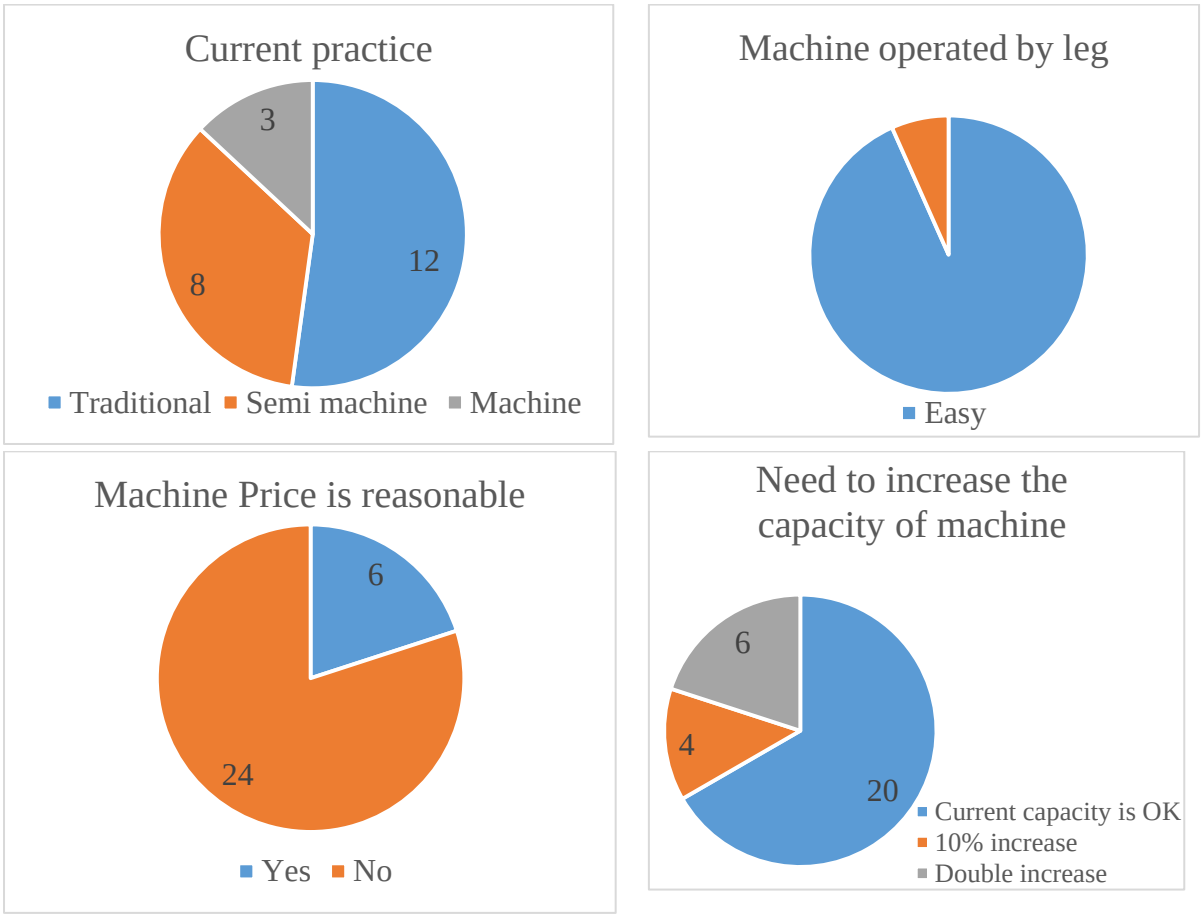

Fig. 2. Feedback come from adaptive trial.

Financial Analysis

Table 1 shows the cream separator's financial analysis. Fixed and variable costs were the two main cost categories. The cream separator was assumed to be used for 300 days per year. The machine requires only one operator, and the daily compensation was $6 USD (8 hours). The variable cost was the sum of the wage of the operators, the cost of repairs and maintenance, and the cost of power. The

MS model and SS model cream separators have benefit-to-cost ratios of 1.62 and 1.52, respectively. As a result, the cream separator is cost-effective for bespoke hiring businesses or industries.

Table 1. Financial analysis of Cream separator

Items	Mild steel model	Stainless steel model
Price, USD	660	960
Working days per year	300	300
Machine life, year	7	10
Salvage value	66	96
Capital consumption cost (CC)	163.29	237.52
Shelter	3.3	4.8
Total fixed cost, USD/year	166.59	242.32
Total fixed cost, USD/h	0.069	0.101
Labour cost per hour	0.75	0.75
Electric requirement ,USD/h	0.026	0.026
Electric cost, USD/h		
Repairing cost, USD/h(3.5% of purchase price)	0.0096	0.014
Lubricating cost, USD/h	0.0025	0.0025
Total variable cost, USD/h	0.787	0.792
Total operating cost, USD/h	0.857	0.893
Total operating cost of the Machine , USD/h		
Capacity of the machine,L/h	150	150
Operating cost, USD/L	0.0057	0.0059
Custom hire based income (@0.015USD/Litre), USD/yr	5400	5400
Machine operation cost, USD/yr	2057.14	2143.36
Net Profit , USD/yr	3342.85	3256.63
BCR	1.62	1.52

Break-even use

The break-even point for this sort of Cream separator (MS model) was 168000 L of whole milk, according to calculations. This sum was comparable to 140 days of service to separate the cream and skim milk from whole milk (Fig. 3). The break-even point for the SS model was 220 days, and the comparable whole milk was 264000 L. (Fig.4). It indicates that the MS and SS cream separators return their investment after 140 and 220 days of operation, respectively. The machine will be profitable for the rest of its life. Food quality and longevity are considerably superior in the SS model than in the MS model.

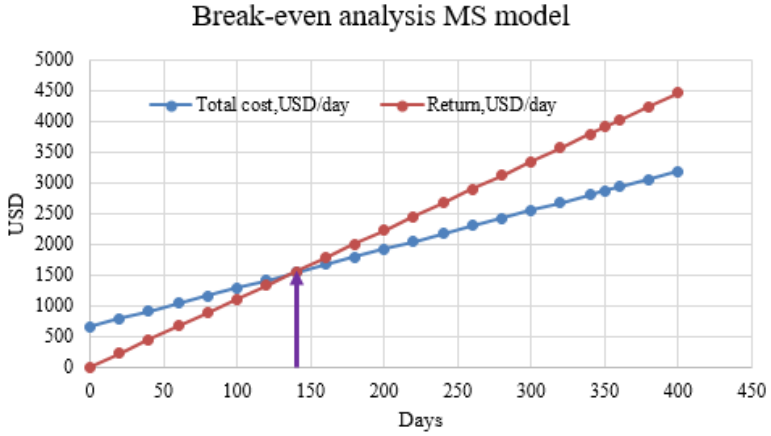

Fig. 3. Break-even analysis of MS model.

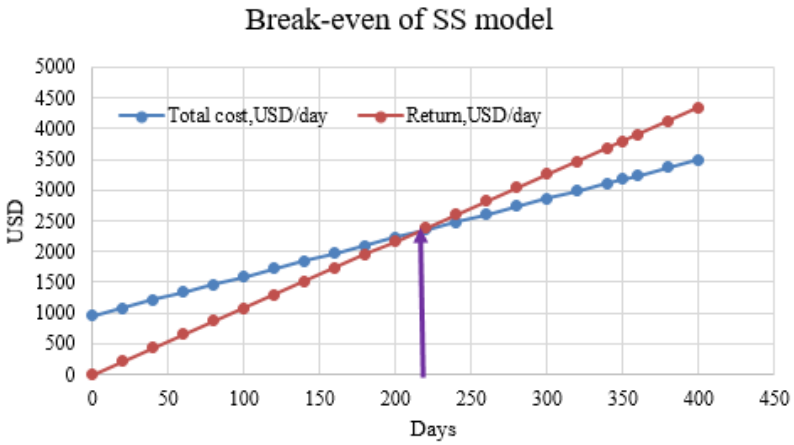

Fig.4. Break-even analysis of SS model.

Conclusion

Three adaptive trials were conducted in the districts of Sirajgonj (Sadar, Ullapara) and Gazipur. The performance of the cream separator has been deemed adequate, and it is an ideal cream separating machine for the farmers, small business owners, dairy sweet producers, and others. Their suggestions were incorporated into the machine. The average feeding capacity of the machine was roughly 150 kg/h. It can be controlled by both a motor and a pedal. The amount of ghee recovered from total milk was 2.65-2.90 %, and machine operation had no effect on milk protein changes. The cream separator's benefit-to-cost ratio was found to be 1.62 for the MS (Mild steel) model and 1.52 for the SS (Stainless steel) model. The cream separator's break-even point for MS model 140 days and SS model 220 days. It is a woman-friendly machine. Anyone can operate the machine and it does not necessitate a lot of technical knowledge.

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EXPT. NO. 4.3 DEVELOPMENT OF DRUM TYPE CARROT WASHING MACHINE

M. N. AMIN AND M. A. GULANDAZ

Abstract

Postharvest quality and safe food are important and prioritized issues of the government of Bangladesh. Proper postharvest handling is essential to reduce postharvest losses and improve overall quality of fruits and vegetables. The integration of improved technologies such as use of simple postharvest machinery and tools, use of plastic crate or innovative packaging system along with the use of sanitizer and best practices would be able to reduce the postharvest losses to minimum. Higher capacity self-propelled drum type carrot washing machine was designed and fabricated with locally available materials at Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur during year of 2020-2021. It was fabricated with MS flat bar, MS shaft, wood, bearing, chain-sprocket, wheel, self-starter diesel engine, motor, gear reducer etc. The main parts of it are - main frame, octagonal drum, power transmission system, water circulation system, delivery chute, self-propelled driving system and mechanical stirring system. Overall dimension of the carrot washing machine is 4750×1800×1980 mm. The rotating speed of the drum is 8 rpm. The capacity, washing efficiency and cleaning efficiency were 5.55 t/h, 97.90% and 99.33% respectively. The washing cost of carrot was 111 Tk./ton. BCR and payback period of the machine were 1.7 and 14 days respectively. The machines would be used by large farmers and traders of carrot for reduction of postharvest losses and drudgery, extension of shelf-life and fetch high price of fresh and safe carrots.

Introduction

The total production of vegetables of Bangladesh is 13.0 million tons. Total carrot production was 16306 tons in 1834 ha of cultivated land in 2017-18 (BBS, 2019). Islam (2004) reported that the postharvest losses of fruits and vegetables during all stages of postharvest operations were 43% of which handling and distribution accounted for 22.5%. After harvesting, vegetables are transported in the market without sorting, grading and washing. There are many micro-organisms, and dust on the surface of the vegetables. The products are infected by micro-organizams easily. Unhygienic products are sold in the markets. Some traders/retailers wash products with impure water of local ponds /canals. These washed products are harmful for human health that causes different diseases. Besides, a huge quantity and quality of products are lost. Sanitation is a great concern to produce handlers, not only to protect the produce against post-harvest diseases, but also to protect the consumers' food borne illnesses. E. coli 0157:H7, salmonella, Chryptosporidium, Hepatitis, and Cyclospera are among the disease-causing organisms that have been transferred via fresh fruits and vegetables (Burditt, 1982; Mitcham *et al.,* 1997). Washing is a standard postharvest handling operation for many fruits and vegetables to remove adherences, dirt, latex and external pathogenic structures. Unfortunately, in Bangladesh fruits and vegetables are hardly washed before entering into the marketing channel, and this contributes to poor quality and considerable losses of the produce.

Dawn and Annamalai (2013) developed a batch type root vegetable washer like carrot and radish. The holding capacity of the washer was 10 kg. It consisted of a detopper, a stainless steel washing drum, centre shaft with holes for water spraying etc. The washing drum was provided with different matting namely 5 mm thickness rubber, 1.5 and 3.5 mm thickness plastic, respectively for effective cleaning of the vegetables. The washing and cleaning efficiency were 97 and 91% for carrot and 96 and 90% for radish, respectively using 3.5 mm thickness plastic matting. Kenghe, *et al.,* (2015) was developed a prototype of fruit washer which consisted of cleaning unit, body and lid, rotor assembly, main frame and power transmission unit. The capacity of the washing the fruit varied from 340 kg/h to 892 kg/h and washing efficiency of the machine varied between 96.36 to 98.18% for all rotors used for potato washing. In Panjab, Sehgal and Arora (2006) designed and fabricated a stainless steel, portable, electric power (0.38 kW) operated vegetable washing machine. The inner rotary drum of the washer was made of stainless steel with 1.5 mm thickness, 760 mm length and 620 mm diameter. Washing efficiency ranged from 90.2 to 95.5% and capacity varied from 100-600 kg/h depending upon the types of vegetables washed. Capacity for the carrot was 350-400 kg/h and washing time was 8 minutes at speed of 40 rpm.

For this purpose, existing technologies need to be improved and new technologies should be intervened. Postharvest priorities across the globe have evolved considerably over the last decades from being exclusively technical in their outlook, to being more responsive to consumer demand. Growing populations across the world continue to create demand for fresh produce and processed horticultural products. Meeting these requirements as well as those of export markets necessitates assuring quality and safety in both domestic and export supply chains. Capacities must therefore be developed in order to respond to consumer and market demands.

The present project is designed on up-scaling and validation of potential postharvest technologies of the mentioned crops and dissemination of the technologies among the growers and other value chain actors to reduce postharvest losses. Thus, this proposed project ultimately aims in integrating improved tools for harvesting, handling, packaging and storage operations, cleaning and sanitization practices, and building capacity of stakeholders who directly involved in the value chain of selected crops and intensification of postharvest technologies and best practices through demonstration, hands on training and other associated intervention methodology.

Objectives

(a) To develop a higher capacity self-propelled drum type carrot washing machine
(b) To evaluate the performance of self-propelled drum type carrot washing machine

Materials and Methods

Developed of high-capacity drum type carrot washing machine

Brush type carrot washing machine was tested in laboratory and farmers' fields. Farmers opined that they need higher capacity low cost washing machine and movable to other places for serving of other carrot growers as custom hire basis. On basis of demand of farmers, a self-propelled diesel engine operated drum type carrot washing machine was developed.

Design of the self-propelled diesel operated drum type carrot washing machine

The carrot washing machine was designed with following consideration

i. The capacity of the machine should be 2.5-3.5 ton per batch for root crop or carrot
ii. It should be self- propelled
iii. Fabrication cost should be minimum as possible
iv. Water circulation should be controlled
v. Root vegetables should be clean and moved by friction force each other and rotation force
vi. Power transmission system should be easy
vii. Available prime mover should be used

Engineering drawing was done using AutoCAD and SolidWork 17 software showing different parts with dimensions.

Brief description of the self-propelled diesel operated drum type carrot washing machine

A root crops washing machine was designed and fabricated at Farm Machinery and Postharvest Process Engineering Division, BARI, Gazipur during June to September 2020. It was fabricated with MS flat bar, MS shaft, wood, FL bearing, chain-sprocket, wheel, self-starter diesel engine, motor, gear reducer etc. The main parts of it are: i) Main frame; ii) Octagonal drum; iii) Power transmission system; iv) water circulation system; v) delivery chute; vi) self-propelled system and vii) mechanical stirring system. An isometric view of the machine is shown in Fig.1. The top, front and side views of the root crop washing machine are presented in Fig.2. A photographic view of the machine is shown in Fig.3.

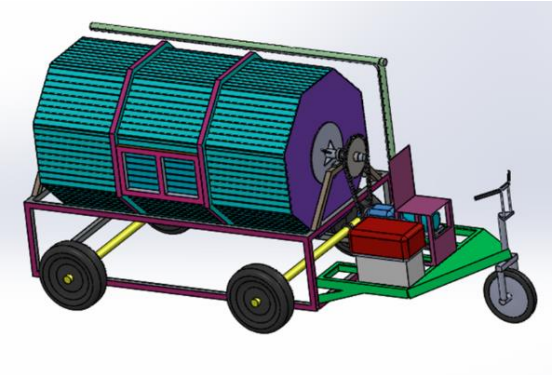
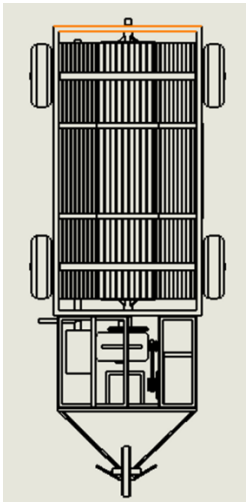
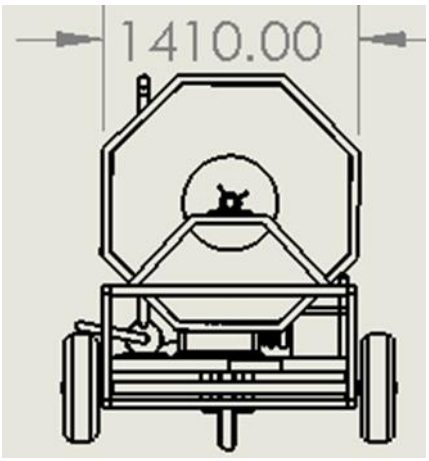


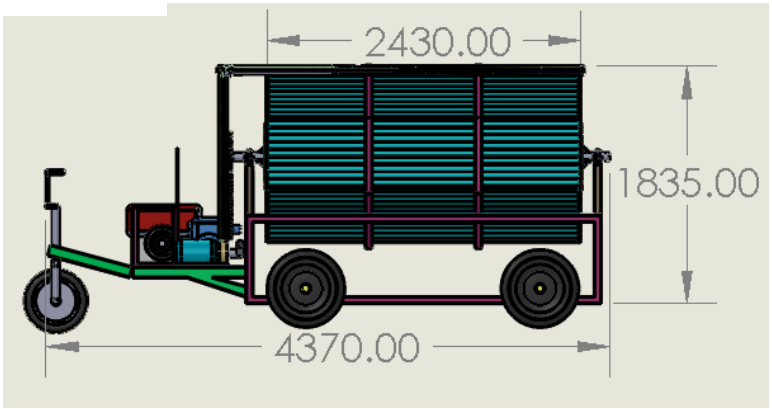
Fig. 1. Isometric view of drum type carrot washing machine.



Top View



Side View



Front View

Fig. 2. Top, front and side views of drum type carrot washing machine.

Fig. 3. Pictorial view of drum type carrot washing machine.

Description of main parts of the machine

Main frame

It was fabricated with 508× 508× 5 mm MS square box. It was an irregular pentagonal in shape and its overall dimension was 4115× 508× 4 mm. It has three wheels, and stirring system.

Octagonal drum

It was fabricated with MS plate, MS shaft, MS flat bar, MS box, MS shaft and wood etc. It is an octagonal in shape drum. Overall dimension of the drum was 2439× 1218× 457 mm. It consisted of 72 mild steel flat bar having 50 mm width and same size and number wood was incorporated with inner of the flat bar using nut bolts. Clearance between each flat bar was 2 mm. An opening at one side on circumference of the drum was done for feeding carrots and deliver of carrots (Fig.4). Drum was rotated clockwise. Drum hold the carrots and rotated the carrots to clean of mud from the root vegetables.

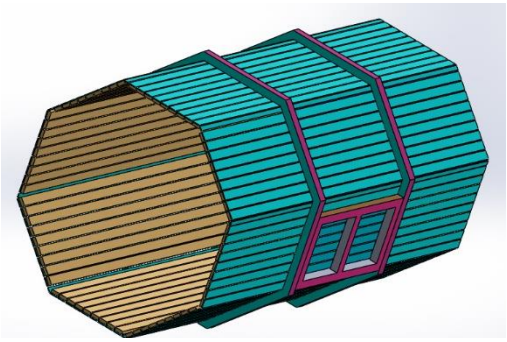


Fig. 4. Pictorial view of main frame of drum type carrot washing machine.

Power transmission system

Carrot washing machine was operated by self-propelled water cool 22 hp diesel engine. The engine is started by self-starter operated with a battery. The speed was reduced from 2200 rpm to 8 rpm by means of gear reducer and belt pulley.

Water circulation system

It was consisted of centrifugal pump, water tank, suction and delivery pipe and perforated pipe. It is one of the essential parts of the washing machine to supply water for cleaning vegetables. Electric water pump was used to supply water for washing of vegetables. A single perforated pipe (25.4 mm Ø and hole1.0 mm Ø) was placed horizontally that was fixed on the longitudinal sides over the machine. Water flow was maintained by a regulator valve.

Self-propelled system

The washing machine has three wheels and power transmitted from diesel engine to front wheels (185/65 R) axle. Mechanical stirring was attached the washing machine for controlling the machine.

Working Principle

First, the machine is placed on plane surface and shady place near water and electric source. The water tank is filled with fresh water. Then the diesel engine is started to run the drum and pump is started to supply water through perforated pipe. Harvested carrots are directly fed in the opening gate of the machine. About one to two minutes after operation, water supply is started for removing mud. They are rolling slowly among them by 5-7 minutes. Later on, water is sprayed for removing mud from the surface of the carrots. Then engine is stopped and the washed vegetables are collected in a plastic crate or jute sack through delivery opening gate. This process is continued. Finally, the washed vegetables are carried out to the drying place to get their surface dry.

Laboratory test

Carrot was collected from cold storage which were stored in cold storage, Genda, Saver on 20 March 2020 for determination of storage life of washed and unwashed carrots. Machine was tested with storage carrots at Farm Machinery and Postharvest Process Engineering Division, Joydebpur, Gazipur on August 2020 to conduct preliminary test of the machine for checking functional parts of the machine. Quantity of carrots, washing time, speed of drum, water use, and injury of vegetables after washing were recorded during operation of the machine.

Field test

The machine was tested with fresh harvested carrot 10 March 2021 at Musurikhola, Saver, Dhaka (Fig.5). Quantity of carrots, washing time, speed of drum, water use, and injury of vegetables after washing were recorded during operation of the machine.

Fig. 5. Testing the carrot washing machine at Musurikhola, Savar, Dhaka on 10 March 2021.

Performance parameters

The performance of the developed vegetable washing machine was evaluated regarding on the washing efficiency and cleaning efficiency as per equation mentioned below.

$$\text{Washing efficiency} = \frac{\text{Weight of the carrot after washing}}{\text{Weight of the carrot before washing}} \times 100 \qquad (1)$$

Cleaning efficiency is the removal of fibrous roots from the rootstalk. In a sample, the number of cleaned tubers free of the fiber refers to the extent of cleaning as given in equation (2).

$$\text{Cleaning efficiency} = \frac{\text{No of cleaned roots free of fibers}}{\text{Total number of roots}} \times 100 \qquad (2)$$

Financial analysis

Price estimation for fabrication of leafy & fruit vegetable and fruits washing machine

The fabrication cost of the machines was calculated including cost of materials, labour, overhead, incidental expenses.

Price estimation for fabrication of drum type carrot washing machine

The fabrication cost of the machines was calculated including cost of materials, labour, overhead, incidental expenses.

Washing cost estimation washing machine

Economic analysis of the vegetable washing machine was done as per standard procedure. Operating cost of the machine included the fixed cost and variable cost. Fixed of the machine included capital consumption and shelter. Variable costs included labour, electricity, oil fuel, water, materials, repair & maintenance.

The prices of the drum type carrot washing machine are BDT 3,00,000.00. Machine life of the machine is 7 years. Working duration is 175 days per year. Four labours are required for operating the machine. Labour wage is BDT 500 per day and water charge is 100 BDT/h and materials cost is 1.00 BDT/h. Interest rate of investment was 12%.

Fixed cost

Fixed cost of the machine included annual depreciation, interest on investment, and shelter. Capital consumption included depreciation and interest.

v) **Capital consumption (CC)**

$$CC = (P - S)CRF + S \times i \text{ (2)} \qquad (3)$$

Where, P=Purchase price, BDT
S=Salvage value, BDT
CRF= Capital recovery factor

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \qquad (4)$$

where, i= Rate of interest
L=Life of machine, yr

vi) **Shelter,** T=3.0% of purchase price of the machine, BDT

Total fixed cost per year

$$FC = CC + T \qquad (5)$$

Variable Cost

In calculation of variable cost, the following relations were assumed

v) Labour cost per hour, L_b=BDT man-h^{-1}
vi) Electricity cost per hour, E=Lit h^{-1}
vii) Repair and maintenance (R&M) cost per year =3.5% of purchase price of the machine
viii) Water charge, BDT/h (0.03 BDT/L × 3000l/h)
ix) Materials cost (plastic crate, bowl, triple, pipe, pedestal fan etc)

Total variable cost

$$VC = L_b + E + R\&M \qquad (6)$$

Annual cost/operating cost

$$AC = FC + VC \qquad (7)$$

Results and Discussion

Performance

Self-propelled drum type carrot washing machine was fabricated with local iron materials. Overall dimension was 4750×1800×1980 mm. Performance test was evaluated with carrot at FMPE divisional workshop (Table 1). The machine was operated by diesel engine and motor was operated electricity. The drum was rotated at 8 rpm. The capacity, washing efficiency and cleaning efficiency were 5.55 t/h, 97.90% and 99.33% respectively. The machine was tested with harvested carrot at Mosurikhola 10 March 2021 (Table 2). The capacity, washing efficiency and cleaning efficiency were 5.40 t/h, 98.50% and 98.75% respectively.

Table 1. Performance test of the machine at FMPE Division, BARI, Gazipur (Lab test)

Sl. No.	Amount of carrot, kg	Required washing time, sec	Speed of drum, rpm	Loading time, min	Unloading time, min	Capacity, kg/h	Washing efficiency, %	Cleaning efficiency, %	Injury, %
1	273	180	8	3	12	5460.00	97.07	99.5	Nil
2	290	190	8	3	12	5494.74	98.62	99.0	Nil
3	300	190	8	3.5	12	5684.21	98.00	99.5	Nil
Mean	287.67	186.67	8.00	3.17	12.00	5546.32	97.90	99.33	

Table 2. Performance test results of the washing machine at farmer's field

Sl. No.	Amount of carrot, kg	Required washing time, sec	Speed of drum, rpm	Loading time, min	Unloading time, min	Capacity, kg/h	Washing efficiency, %	Cleaning efficiency, %	Injury, %
1	400	300	8	4	2	4800	98.00	98.5	Nil
2	700	420	8	8	3	6000	99.00	99.0	Nil
Mean	550	360	8	6	2.5	5400	98.5	98.75	

Profitability analyses

Price of the machine was estimated about 300000.00 Tk. The washing cost, BCR, payback period of drum type carrot washing machines is shown in Table 3. Profitability analysis revealed that the method of vegetable washing incurred fixed and variable costs. The lion share of cost was estimated for variable cost for the method. Fixed cost included two cost items namely capital consumption and shelter, whereas variable cost included labour, electricity/fuel, R & M, materials and water charge. The washing cost of carrot was 111 Tk./t. BCR and payback period of the machine were 1.7 and 14 days respectively.

Table 3. Financial analysis of the drum type carrot washing machine

Cost item	Value
Machine price, Tk	300000.00
Fixed cost (FC)	
1. Capital consumption (CC), Tk./yr	62762.00
2. Shelter (T), Tk/yr	1500.00
Sub-total, Tk./yr	6426.00
Sub-total, Tk./h	64.00
Variable cost (VC)	
Labour, Tk./h	250.00
Electricity, Tk./h	9.0
Fuel cost, Tk./h	123.00
Lubricant, Tk.h	2.0
R&M, Tk./h	10.00
Materials, Tk./h	2
Water cost, Tk/h	100

Sub-total	
Total cost (FC+VC), Tk/h	558.00
Capacity of the machine, t/h	5
Washing cost (Total cost/capacity), Tk./t	111.00
Payback period, days	14
BCR	1.7

Conclusion

A large capacity self-propelled drum type carrot washing machine was developed. Capacity of the machine was 5.50 t/h. Washing efficiency and the cleaning efficiency of the machine were about 98% and 99.0% respectively. Washing cost by the machine was 0.12 Tk./kg and payback period and benefit cost ratio were 14 days and 1.7 respectively. The carrot washing machine is suitable for commercial purpose and economically viable. Traders showed interested and they are used for washing of carrot collected from cold storage.

Acknowledgement

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EXPT. NO. 4.4 UPSCALING AND FINE TUNING OF COFFEE POSTHARVEST PROCESSING MACHINERY

M N AMIN, M A HOSSAIN, AND M M HASAN

Abstract

The coffee growers of Hill Tracts process the green coffee at home the quality of which is very low. They consume it themselves but for commercial purpose the quality must be maintained. Like other processing steps, coffee pulping and dehulling need machines because it is a very labor intensive job. The coffee growers of Bangladesh usually pulp by hand in pestle and mortar. This practice is very costly, time consuming and laborious and produce low quality products. BARI has developed small scale coffee pulper, dehuller, roaster and grinder. The fresh coffee cherry was pulped by both the pulper and manual (hands) and dried by dryer and sun shine. Mechanical injury of parchment coffee was found to be on an average 0.82% in pulping machine and nil in manual practice for both the drying methods. In respect of colour and moisture content of parchment coffee, no significant difference were observed in both the drying methods. Hue angle of parchment coffee both in the sun drying and solar drying indicated the yellowish lime colour. The dehuller was tested with both dried parchment coffee and dried coffee cherry. The capacity of the dehuller for dried parchment coffee was double compared to dried coffee cherry. On the other hand, whole coffee bean was found to be 1.5 times higher in dried parchment coffee than that of dried coffee cherry and broken coffee bean was 86% lower than that of dried coffee cherry. The capacity of the roaster was 1.70 kg/h. Dark fried coffee bean was obtained by 94% from raw dried coffee bean and losses of bean was found to be 5.50 percent. The capacity of the grinder was 3.07 kg/h. Medium course coffee powder was obtained by 99.19% and losses of powder was found to be 0.81 percent. The study will be continued for better findings and economic analysis.

Introduction

The annual coffee production in Bandarban of Bangladesh are 2.6 tons and cultivated area is 70 ha (DAE, 2018). Coffee is cultivated in the hills of Chattogram Hill Tracts for last three decades in a very small scale but could not spread successfully all over the hilly region due to lack of suitable coffee processing technology and facilities (Bangladesh Today, 25 February 2010). The unavailability of the modern technologies and machineries for coffee processing are the barrier for export quality coffee production too. Coffee cherries are harvested when they become bright-red, glossy, and firm, either by selective hand-picking or non-selective stripping of whole branches or mechanical harvesting. The hand-picking method is very time consuming, but it gives a superior product quality. The coffee fruit (also called berry or cherry) consists of a smooth, tough outer skin or pericarp, usually green in unripe fruits, which turns to red-violet or deep red when ripe. The pericarp covers the soft yellowish, fibrous and sweet pulp or known as outer mesocarp. When the fruit is ripe a thin hydrated slimy layer will be formed know as mucilage (also called pectin layer). Then there will be a thin endocarp, yellowish in color known as parchment. Underneath the parchment, the beans are covered with another thinner membrane, the silver skin (the seed coat). The silver skin covers the coffee seed or bean. Each cherry generally contains two coffee beans. If there is only one it assumes a rounder shape and it is known as pea-berry (Belitz *et al.*, 2009).

Green coffee is produced either by dry processing or by wet processing. After harvesting, the coffee fruits are separated from the pulp, which is carried out by dry or wet processing (Illy & Viani 1995). The dry process is simple and inexpensive. The whole cherries are dried under the sun in open air, followed by the separation of the hull (dried pulp and parchment) for getting the green beans. On the contrary, the wet process requires more care and investment, but results in a superior coffee quality. In the wet process, the pulp of the coffee cherries, which is made up of exocarp and mesocarp, is removed mechanically, but the parchment remains attached to the beans. After drying either under the sun or in a dryer, the parchment is removed to produce the green coffee beans. The coffee cherries are dried immediately after harvest. This is usually sun drying on a clean dry floor or on mats. The bed depth should be less than 40mm and the cherries should be raked frequently to prevent fermentation or discoloration. However, there are problems associated with this method. The most serious problem is dust and dirt blown onto the produce. Another problem is rainstorms often appear (even in the dry season) with very little warning, this can soak the produce very quickly. Finally, labour has to be employed to prevent damage or theft. Sun drying is therefore not recommended.

The dried cherry is then hulled to remove the pericarp. This can be done by hand using a pestle and mortar or in a mechanical dehuller. The mechanical dehullers usually consist of a steel screw, the pitch of which increases as it approaches the outlet so removing the pericarp. The hulled coffee is cleaned by winnowing. Defective beans are also removed. Sorting takes place both in the producing and manufacturing countries to achieve high quality coffee beans, and is carried out by either mechanical or optical means. In the mechanical method, defective beans are hand-picked and fed into air classifiers (catadors) where they enter an adjustable rising current of air. Coffee is one of the most popular beverages in the world. One of the principle post-harvest technological processes is drying, giving rise to the formation of the characteristic colour, flavour and taste of coffee brew. Conventionally there are two types of drying techniques used in the coffee processing, (sun drying and mechanical drying). The initial moisture content of harvested coffee is about 55-60% and after drying lowers the moisture content to around 12% (wb) (Ghosh and Venkatachalapathy, 2014).

Modern processing technologies are available in the developed countries but the cost is very high, beyond the financial capacity of the coffee growers in Bangladesh. The coffee farmers need small scale coffee processing equipment, so that they can consume the quality coffee and sell it to the domestic market to get cash money. The coffee growers of Hill Tracts process the green coffee at home and the quality is very low. They consume it for their own purpose but for commercial purpose the quality must be maintained. Like other processing steps, coffee pulping is also a machine involve process because it is a very labor intensive work. The coffee growers of Bangladesh usually pulp by hand in a pestle and mortar. This practice is very costly, time consuming and laborious and produce low quality products. There is no coffee pulper and dehuller available to the cultivators for small scale production in Bangladesh. BARI has developed small scale coffee pulper cum grinder, pulper, dehuller, and coffee roaster. Production and consumption of coffee is increasing day to day. It is a great scope to conduct study to improve precision coffee postharvest machinery in the market channel for reducing the postharvest losses getting good quality and safe fresh products. The demand of foreign market and local super market are quality, safe and fresh product. Besides, in Bangladesh policy makers has given emphasis getting chemical free fresh and safe products. Most of the consumers are very conscious to take good quality, safety and fresh products at higher price of products. Now a day, it is a challenge to reduce the postharvest losses of fruits and getting good quality and safe fresh products.

Objective

a) To improve and fine tuning of postharvest coffee machinery
b) To evaluate the performance of the postharvest machinery in laboratory and farmers' fields

Material and Methods

Performance test of pulper

The performance of the pulper was evaluated with the fresh harvested coffee cherry (Arabica variety) collected from Lal Due Bowm of Ruma Bandarban and ARS, Chattragram. The experiment was conducted at FMPE Division, BARI, Gazipur during 2020- 2021 (Fig.1). Moisture content of cherry was determined by the oven method at 105 + 3ºC (BRASIL, 1992). The pulping time, amount of coffee cherry, unshelled parchment, whole parchment, and husk amount were recorded.

Performance test of dehuller

Performance test of dehuller was conducted with dry parchment coffee and dry coffee cherry at FMPE Division, BARI, Gazipur during 2020-2021. Weight of Parchment coffee, whole parchment coffee weight, broken or injury parchment coffee weight, moisture content and colour parameters were determined (Fig.2).

Performance test of roaster

Performance test of roaster was tested with the coffee bean at FMPE Division, BARI, Gazipur during 2020-2021(Fig.3). Roasting temperature, roasting time, weight of fried coffee bean etc were recorded.

Performance test of grinder

Performance test of grinder was tested with the fried coffee bean at FMPE Division, BARI, Gazipur during 2020-2021(Fig.4). Grinding time, weight of fried coffee bean etc were recorded.

Fig.1. Pulper test.

Fig. 2. Dehuller test.

Fig.3. Roaster test.

Fig. 4. Grinder test.

Results and Discussion

The fresh coffee cherry was pulped by both the pulper and manual (hands) and dried by dryer and sun shine. The mechanical injury, colour and moisture contents of parchment coffee was observed and compared to manual practice (Table1). Mechanical injury of parchment coffee was found to be on an average 0.82% in pulping machine and nil in manual practice for both the drying methods. It indicated that the pulper should be modified for reducing broken percentage. In respect of colour and moisture content of parchment coffee, no significant difference were observed for both the drying methods. Hue angle of parchment coffee both the sun and dryer indicated the yellowish lime colour.

Table 1. Comparison of quality of dried parchment coffee after pulping using pulper and manual method

Treatment	Weight of parchment coffee, g	Weight of good parchment, g	Injury/ broken parchment, g	Moisture content, % (wb)	Colour parameters	
					L*	h°
T1:Pulping by pulper and drying in dryer	596	592	4.0 (0.67%)	10.31	56.41	79.64
T2: Pulping by hand and drying in dryer	538	538	0.0 (0%)	11.11	56.61	78.90
T1: Pulping by pulper and drying in sun	207	205	2.0 (0.96%)	9.90	55.61	79.90
T1: Pulping by hand and drying in sun	460	460	0.0 (0%)	10.53	57.66	76.92

The dehuller was tested with dried parchment coffee and dried coffee cherry is shown in Table 2. The capacity of the dehuller for dried parchment coffee was double compared to dried coffee cherry. On the other hand, whole coffee bean was found to be 1.5 times higher in dried parchment coffee than that of dried coffee cherry and broken coffee bean was 86% lower than that of dried coffee cherry. Higher broken coffee bean was observed due to higher moisture content of dried coffee cherry.

Table 2. Performance test of dehuller with dried parchment coffee and dried coffee cherry

Type of dried coffee	Moisture content, %(wb)	Initial weight of coffee, g	Whole coffee bean, %	Broken coffee bean, %	Weight of dry coffee husk, g	Dehuller capacity, kg/h
Dried parchment coffee in dryer	10.71	2550	65	1.00	16	241.58
Dried coffee cherry in sun dry (Chattogram)	13.21	2000	42	7.00	50	122.03
Dried coffee cherry in sun dry(Gazipur)	17.42	3240	42	8.00	49	145.80

Performance test of roaster with raw dried coffee bean is shown in Table 3. It was observed that capacity of the roaster was 1.70 kg/h. Dark fried coffee bean was obtained by 94% from raw dried b coffee bean and losses of bean was found to be 5.50 percent. The capacity of the roaster was lower and loss of bean was higher. So, the roaster will be up scaled and fine-tuned for higher capacity and lower bean loss.

Table 3. Performance test of roaster with raw dried green bean

Raw dry coffee bean, g	Dark Fried coffee bean, %	Roasting time Dark Fried coffee bean, min	Roasting temperature, °C	Loss of bean, %	Capacity of the roaster, kg/h
970	93.00	25	180-220	6.00	2.328
398	94.00	20	180-220	6.00	1.194
524	95.00	20	180-220	4.50	1.572
Mean	**94.00**	**21.67**	**180-220**	**5.50**	**1.70**

Performance test of grinder with dark dried coffee bean is shown in Table 4. It was observed that capacity of the grinder was 3.07 kg/h. Medium course coffee powder was obtained by 99.19% and losses of powder was found to be 0.81 percent.

Table 4. Performance test of grinder with dark dried bean

Dark Fried coffee bean, g	Grinding time, sec	Coffee powder, g	Loss of fried coffee bean, g	Capacity of grinder, kg/h
710	840	703 (99.01%)	7 (0.99%)	3.04
650	760	645 (99.23%)	5 (0.77%)	3.08
600	700	596 (99.33%)	4 (0.67%)	3.09
Mean	766.67	99.19%	0.81%	3.07

Conclusion

BARI has developed small scale coffee pulper, dehuller, roaster and grinder. The fresh coffee cherry was pulped by both the pulper and manual (hands) and dried by both dryer and sun shine. Mechanical injury of parchment coffee was found to be 0.82% in pulping machine and nil in manual practice for both the drying methods. In respect of colour and moisture content of parchment coffee, no significant difference were observed for both the drying methods. Parchment coffee both the sun and dryer showed the yellowish lime colour. The capacity of the dehuller for dried parchment coffee was double compared to dried coffee cherry. Whole coffee bean was found to be 1.5 times higher in dried parchment coffee than that of dried coffee cherry and broken coffee bean was 86% lower than that of dried coffee cherry. The capacity of the roaster was 1.70 kg/h. Dark fried coffee bean was obtained by 94% from raw dried coffee bean whereas losses of bean was found to be 5.50 percent. The capacity of

the grinder was 3.07 kg/h. Medium course coffee powder was obtained by 99.19% and losses of powder was found to be 0.81 percent. Coffee cultivation is increased in hilly and plane areas day by day. So, the existing BARI developed coffee processing machine will be upscaled and fine-tuned for medium farmers and commercial purpose.

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EXPT. NO. 4.5 DESIGN AND DEVELOPMENT OF A JUTE DECORTICATOR

M R KARIM, M Z HASAN AND M.A HOSSAIN

Abstract

Jute is called the 'Golden Fiber' of Bangladesh. The global demand for jute and related products is being increased because the people are now looking for biodegradable fiber as well as eco-friendly products for replacing synthetics. However, jute cultivation and processing are labor and cost intensive operations. Jute fiber extraction accounts for around 17–20% of total production cost and involves lots of drudgery. With the aim to reduce the drudgery and fiber extraction cost, a small-scale jute decorticator was developed and tested at the FMPE (Farm Machinery and Post-harvest process Engineering) division, BARI, Gazipur during 2019-20. The decorticator machine was used to test three samples of jute plants ('deshi' variety) harvested from an area of 20 sq m in 2019-2020. The average fresh jute plants input capacity and the fresh fiber output capacity of the prototype jute decorticator were found to be 0.40 ton/h and 0.19 ton/h, respectively. Some problems were identified during performance test of the prototype machine in 2019-20. It was found that thinner plants (bottom diameter < 7.2 mm) tended to wrap around the rollers and recommended to be avoided. The machine could not be tested as per design in 2020-2021 because jute is in pre-maturity stage during the reporting time and will be harvested in the first week of August 2021. The machine has been modified to get unbroken jute sticks fied.The decorticator will be widely tested in 2020-2021 and 2021-2022.

Introduction

Jute is the most popular cash crop to Bangladeshi farmers. Jute covers about 4.8 % of gross cropped area where as the gross cropped was 15.595 M ha (BBS, 2019). Total demand of jute goods in the international market is 0.75 Mt (Uddin *et al.*, 2014). In 2018-19, total production of jute in Bangladesh was 85,76,087 bales from 7,49,658 hectares land (BBS, 2019; P-182).

Bangladesh has a golden history of jute which is also known as 'Golden Fiber'. People are now looking for replacing synthetics with increasing the use of ecofriendly biodegradable fresh fiber products. From jute sector about 5% of total foreign exchange earnings and 4% of country's GDP is earned (Peu. *et al.*,2019). There are 148 jute mills in Bangladesh and about 1,60,000 employees of the country are directly in the jute mills (Uddin. *et al.*,2014). The livelihood of about 25 million people (almost one - fifth of the total population) is dependent on jute - related activities in agriculture, domestic marketing, manufacturing and trade (BBS 2019). About 90% of jute products produced in Bangladesh is exported (Rahman, 2001). Jute is a good source of revenue for the governments in the form of taxes, levies, sales tax, and custom duties on jute goods (Sikdar and Banerjee, 1990).

Bangladesh is famous for jute production and earned a big amount of foreign currency by exporting jute and jute products to different countries. At one stage, Jute was only the vital sector in Bangladesh from which major portion of foreign currency is to come and help Bangladesh's economy and a large number of manpower were employed there. Bangladesh was recognized as one of the best jutes producing and exporting countries of the world (Islam *et al.,* 2013).

Over the last 20–25 years it did slide down to the seventh position. Now it regained to come to the fourth position (Abdullah, 2013). Bangladesh is currently the second largest producer of jute fiber (Stephen and Abir, 2014). Bangladesh falls behind its other competitors in developing and applying technologies in cultivation and processing of jute. In terms of world export of jute fiber, Bangladesh's share is more than 70%, which makes Bangladesh the largest exporter of jute fiber in the world (M.M Hossain *et al.*, 2015).

Jute is the second most important bast fiber after cotton, in terms of usage, global consumption, production and availability. It is an important cash crop in Bangladesh and India, which together accounts for about 84% of world production of jute fiber (Islam, 2009). In Bangladesh around 4 to 5 million small and subsistence farmers derive their livelihood from Jute and Allied Fiber (JAF) crop production while thousands of other workers and employed in its processing, handling, manufacturing (Saah, 2011). Global awareness on 'save the environment` increases the demand of jute. Jute and jute products not only retard ecological degradation but also conserve green environment and atmosphere as a whole. Thus, jute is a crop having a lot of positive benefits in establishment of green economy, soil health and environment. The climate and soil of our country is highly congenial for jute cultivation. The Bangladesh jute industry contributes about 5% to foreign

exchange earnings and 4% to GDP while 3 million farmers are dependent on jute cultivation (Article: Jute and jute goods, official website of EMBASSY OF BANGLADESH, In the Republic of Uzbekistan).

Adaptation of UN sustainable development goals worldwide and concerns over the use of manmade (synthetic) fibers, demand for eco-friendly natural fibers has been increasing which has created a wide market opportunity of jute and allied products. However, due to competition with other crops, shortage of laborers and scarcity of suitable open water bodies for retting jute, its cultivation area has decreased compared to 1970s. In recent years' jute production are competitively low and it was found that total jute production in the year 2018-2019 has been estimated 3.58% lower than that of last year 2017-2018 (BBS 2019). There is a massive problem in retting process (traditional retting) due to water scarcity and low fiber quality. It indicates the increasing trend of production but benefit is very low for poor quality fiber (Ali *et al*, 2015).

Ribbon retting is a particular method of retting based on a mechanical pre-treatment of plant stalks that allowed reducing the requirement of water, the length of retting time and the level of environmental pollution to almost one-fourth in comparison to other method that processed the whole plant. But the manual ribbon retting process requires more labour for disintegrate the fibre from the stem and forming the process (BJRI, 2017). In Bangladesh, fibre quality improvement division of Bangladesh Jute Research Institute (BJRI) invented a power operated jute auto ribboner and demonstrate the machine in separating jute fibre in 2016 (BJRI, 2017). It was bigger in size, higher in price and was not handy as well as easily portable.

It was also found that the maximum production cost has involved in fibre extraction (16.9 to 20%) and weeding (16.33 to 20%) (Ghimire and Thakur, 2013; Seheli and Roy, 2014). Thus, a cost-effective technology has to develop in jute production and processing aspect for lowering the production cost and increasing the profit margin (Seheli and Roy, 2014). So, there is an urgent need to develop a technology of mechanization in the process of extraction of fibre. The improved technology (retting of only the extracted green fiber) involves mechanical extraction of ribbon from jute stems immediately after harvest with the help of machine followed by retting of ribbon in water. Fibre yield and its quality depend on proper retting of jute. Conventional method of retting and extraction of jute fibre is a laborious and costly. The traditional method of extraction of fibre from jute plants has three disadvantages in terms of time (2-3 weeks), cost of labourers and production of poor quality of fibre due to lack of fresh water (Borkar and Das, 2006). But in mechanized way of jute fiber extraction using jute decorticator, the green bark/ribbon peeled off from the whole jute plants and can be conveniently retted in much less volume of water to yield quality fibre of high grade compared to the conventional method. Mechanization of the jute fiber extraction and improved retting process can reduce labour, drudgery, time, cost and volume of water requirement. Therefore, to develop a suitable, portable and handy jute decorticator this research project has been undertaken to design and develop an economically viable, portable, and handy jute fibre extraction machine.

Objectives

a) Design and development of a suitable, portable and handy jute decorticator
b) Evaluate performances of the jute decorticator in laboratory and on-farm.

Materials and Methods

The jute decorticator was fabricated at workshop of FMPE division, BARI, Gazipur during 2019-20. The machine was designed having concentrated on (i) fiber extraction quality, (ii) Machine should be small in size, (iii) farmer friendly Price and, (iv) machine Portability. There are two rollers in grabbing zone of the machine. After grabbing zone there is primary extraction zone where remains a primary extraction roller. After that, there is delivery zone where two Nos. of extraction rollers (upper and lower position) in front side of the machine for final separation of green jute fiber and jute sticks. The machine works on the principle of stripping of green ribbon/barks from the harvested stem. The machine was developed using the locally available materials. The technical specification of the machine is shown in Table 1.

Design and drawing

The design and drawing of the jute decorticator were done using the computer aided design software SolidWorks 2020.

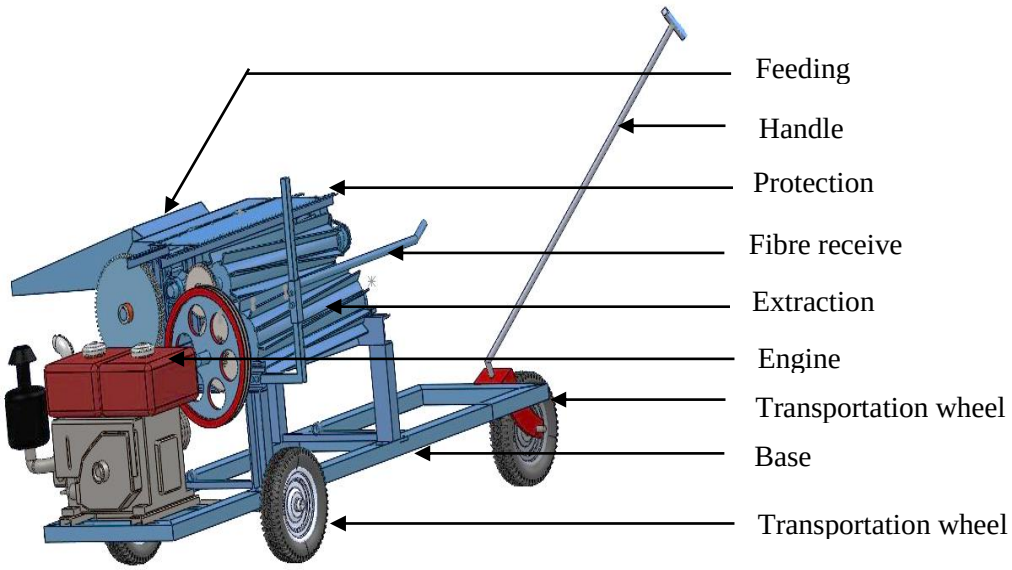

Fig. 1. Isometric view jute decorticator prototype developed in 2019-2020 and major functional parts.

Table 1. Technical parameters of the jute decorticator

Feeding system	Direct feeding
Dimension	131 mm x 135 mm x 116 mm
Weight	204 kg
Motor	8 PH (output) & 7 hp (Rated Output); 2600 rpm; diesel engine
Capacity	400 kg per hour for fresh Jute
Price (Approx)	70000-80000 (BDT)

The major parts and functional components

The major and functional components of the jute decorticator are one Primary extraction roller, one secondary extraction roller, two Nos. of grabbing rollers, one fiber receiving stand, one base frame, protection cover and a spring-loaded tray. The machine is smaller in size and it was 1310 mm x 1350 mm x 1160 mm. There are two grabbing rollers in grab zone of the machine. There is a primary extraction zone after the grabbing zone where a primary extraction roller remains. After that, there is delivery zone in front of the machine with two extraction rollers (upper and lower position) for final separation of green jute fiber and jute sticks. The machine is easily portable due to have transportation wheels for moving one place to another place The machine was driven by a diesel engine of 5 kW and during performance test the machine was ran at 1620 rpm that provided an extraction roller rpm of 421 (under no load) and 416 (under load). The major parts and functional components of the jute decorticator are described in the following sections

Feeding tray: A feeding tray is made of MS sheet. It is to feed the green jute plants into the grabbing zone of the machine (Fig. 2). The dimension of the feeding tray was 555 mm x 500 mm x200 mm.

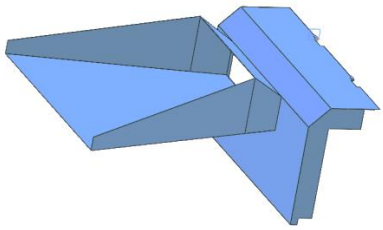

Fig. 2. Isometric view of feeding tray.

Primary extraction roller: One primary extraction roller having 425 mm length shown in Fig 3 was made of four external blockade of mild steel (MS) angle bar with 30 mm height and 4mm thickness. The diameter of roller was 40 mm. The function of this roller was to loosen the broken jute sticks inside the ribbon and primary extraction. It also moved the broken jute sticks into the ribbon, ensuring that the ribbon and jute sticks were completely separated in next step or completely secondary extraction.

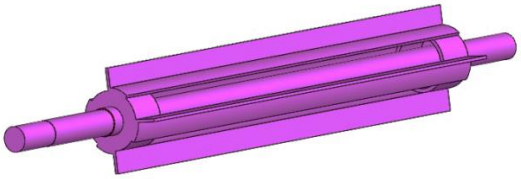

Fig. 3. Isometric view of primary extraction roller.

Secondary extraction roller: There were two secondary extraction rollers (Fig 4) having a length of 425 mm and a diameter of 114 mm. The diameter of lower secondary extraction roller was 65 mm greater than upper secondary extraction roller. There were eight cross bars with 38 mm height in upper secondary extraction bar where as twelve cross bars of same height in lower secondary extraction roller. The function of these two rollers was complete separation of broken jute sticks and ribbon after primary separation with primary extraction roller.

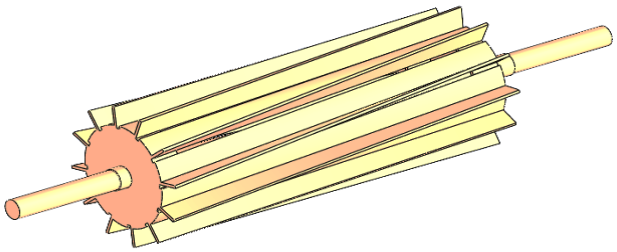

Fig 4. Isometric view of secondary extraction roller.

Grabbing rollers: There were two grabbing rollers having same working dimension of 425 mm length (Fig 5). The roller diameter was 88 mm. There were eight external blockades made of mild steel (MS) rod with 10 mm diameter and 425 mm length.

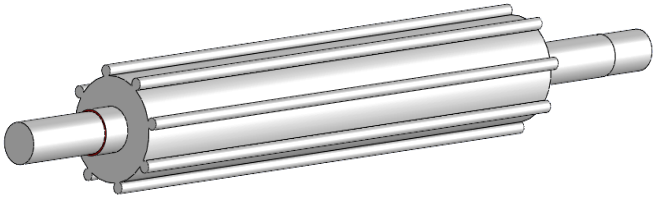

Fig. 5. Isometric view of grabbing roller.

Fiber receive stand: There was a fiber receiving stand in the out let side of the jute decorticator. There was provision of adjusting the height and distance of the stand form the extraction rollers (Fig 6).

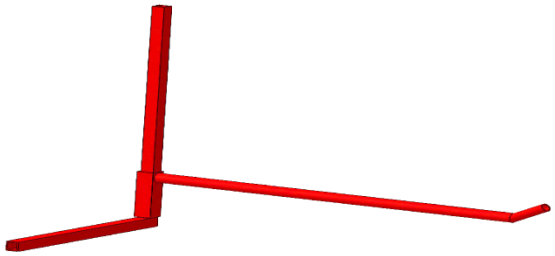

Fig. 6. Isometric view of fiber receive stand.

Base frame: It was the main load bearing part of the machine. For easy transportation between and within working villages, three wheels were attached with this frame. This frame (Fig 7) was made of MS angle bar. The dimension of base frame was 118 cm x 64 cm x 55 cm and was made of 38 mm x 38 mm as well as thickness of 4 mm.

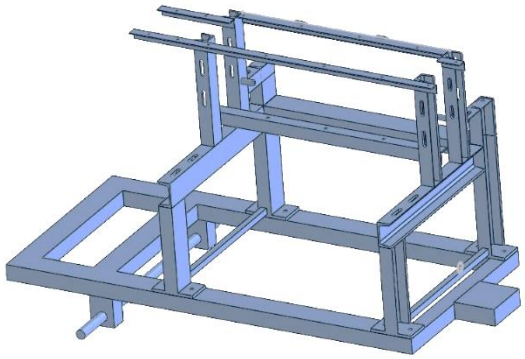

Fig. 7. Isometric view of base frame.

Protection cover: Whole moving parts of jute extraction machine was covered with protection cover (Fig 8). The protection covers were made of MS sheet and attached with nut and bolt. It prevents accident and ensures safety of the operators. For the protection cover of upper part of the machine, the broken jute sticks thrown only forward direction. It helps to collect the separated broken jute sticks easily from front side of the machine during extraction.

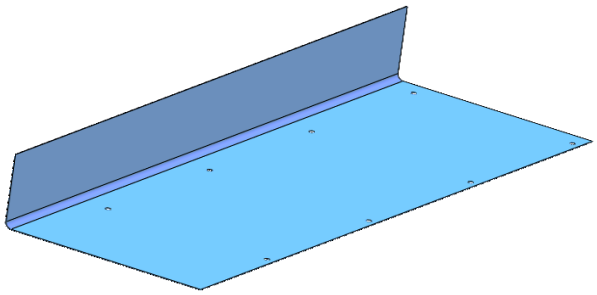

Fig. 8. Isometric view of protection cover.

Power source: The machine was powered by an 8-hp. diesel engine (Fig 9).

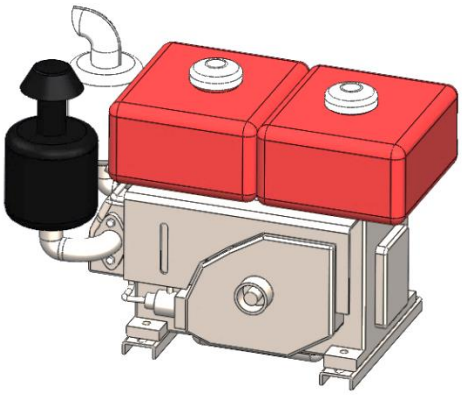

Fig. 9. Isometric view of power source (diesel engine).

Spring loaded tray: There was a spring-loaded tray (Fig 10) under primary extraction roller for adjustment or keeping jute plants of different diameter passes through grabbing roller after breakdown of jute sticks. It helps the primary roller to strike each and every plant for primary extraction with primary extraction roller.

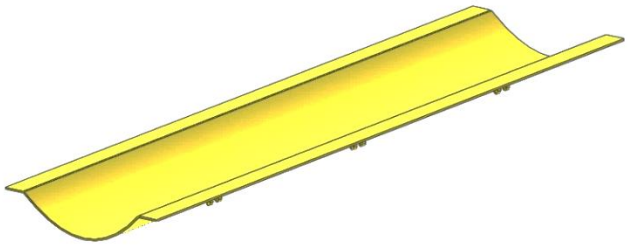

Fig. 10. Isometric view of spring-loaded tray.

Power transmission system: The power of engine was transmitted to extraction part of the machine through Belt, pulley, gear pinion, chain and sprocket (Fig 11).

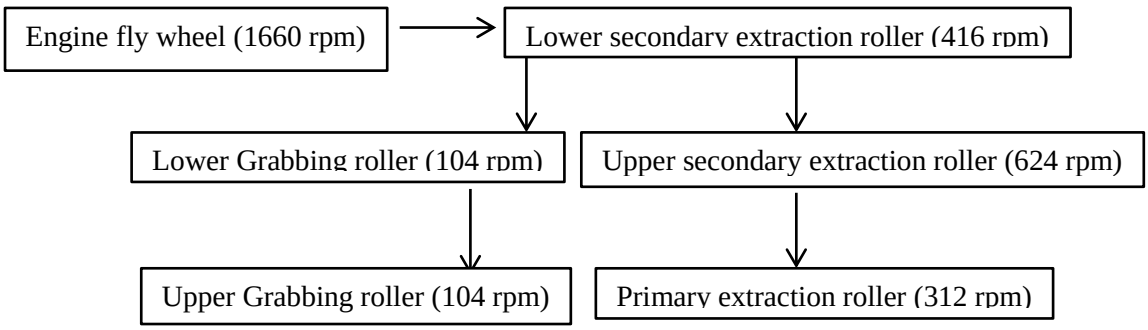

Fig. 11. Power transmission system of jute decorticator.

orking principle of the jute decorticator

The jute fiber extraction from fresh jute plants by jute decorticator is completed by following four steps illustrated in Fig 12.

Fig. 12. Flow diagram of working principle of jute decorticator.

Operating system of the jute decorticator

At first one of the assistants (out of three assistant of machine operator) of machine operator will take 8-10 plants from bundle of fresh jute plants and will give the operator who will feed those to grabbing zone of the machine through feeding tray. After fed the grabbing roller will grabbing those and give delivery to primary roller. After primary extracted the plants with broken jute sticks partially separated will be delivered to secondary extraction roller and finally be separated of green fibre as well as jute sticks broken down. The separated fibre will be received in the fibre receive stand and the second assistant of the machine operator will take the fibre from receive stand and try to align the fibre keeping the bottom portion equal until the next fibre received in the stand again and he will give the fibre unequal in bottom part to the next man (third assistant out of three) who will align finally and make bundle for retting (Fig 13).

Fig. 13. Operating system of the jute decorticator.

Performance evaluation of the Jute decorticator

For evaluating the performance, the following activities (table 2) were done.

Table 2. List of activities were done to evaluate the performance of jute decorticator

SL.No.	Activities	Description
1	Performance evaluation of developed machine	30 July 2020
2	Tested jute variety	Deshi variety of Jute
3	Location of jute cultivation for testing	Experimental field of FMPE division, BARI, Gazipur
4	Seed rate and fertilizer dose	Standard seed rate and fertilizer dose
5	The sowing date of seed in the experiment field	16 April 2020
6	Harvesting date	30 July 2020
7	Number of samples collected for testing	Three
8	Plot size of collected unit sample	4 m x 5 m
9	Number of replications during evaluation of machine performance	Three

After fabrication, the machine performance was evaluated in office premises of FMPE division. For field performance evaluation, three jute plant's samples were collected randomly from three representative area of 20 square meter. For measuring the extraction capacity of the machine, jute plants of 20 square meter area were fed into the machine and time required to extract the fresh jute plants was recorded by using stop watch. The feeding was replicated for three samples and time taken respectively. The engine (5 kW) was operated at 1620 rpm that provided an extraction roller rpm of 421 (under no load) and 416 (under load) during field performance evaluation. The fresh jute plants input capacity and the fresh fiber output capacity was determined using the following equation (equation No, 1 and 2).

Data recorded

Different types of data like MC (%, Wb) of whole jute plant, fresh jute fibre and byproducts, yield of jute, extraction capacity of jute decorticator, fresh jute plants input capacity, fresh fiber output capacity, diameter of green jute plants, different problems in decorticator observed during operation were recorded and

Moisture content (%)

MC (%, Wb) of whole jute plant, fresh jute fibre and byproducts was also measured following oven drying methods (minimum 72 h at 105 ℃) and using the following equation (equation No.3). Some problems of jute decorticator were also observed during performance evaluation and listed down in a tabular form for further improvement and fine tuning.

Yield contributing parameters

Yield of jute was also determined by collecting data of yield and yield contributing parameters from 20 square meter area (total 3 samples plot) like - plant population, plant height of 20 jute plants, Diameter in bottom and middle part of 20 jute plants and weight of jute plants. From the collected data the mean value was determined and then converted into determine the yield of jute in ton/ha.

Extraction capacity (C) of Jute decorticator
Fresh jute plants of 20 m^2 was fed into the machine at different feeding rate as 8-10 plants of medium diameter (10-12 mm) at a time. The diameter of green jute plant was (5.46 mm – 17.80 mm) and plants height was (1610 mm to 2920 mm) during extraction. Time required to complete the decortication of three samples was taken by stop watch and recorded in tabular form.

Fresh jute plants input capacity (C_i)
The fresh jute plants input capacity of the machine was determined by using the following equation (1) (Ukatua, 2006):

$$Ci = \frac{Wfp}{T_t} \qquad (1)$$

Where, C_i = Fresh Jute plants input capacity of the jute decorticator (kg h^{-1})
W_{fp} = Weight of fresh jute plants fed (kg)
Tt = Time required to feed (h)

Fresh fibre output capacity (C_o)
The fresh jute plants output capacity of the decorticator was determined by using the following equation (2) (Ukatua, 2006):

$$Co = \frac{Wff}{T_t} \qquad (2)$$

Where, Co = Fresh fiber output capacity of jute decorticator (kg h^{-1})
W_{ff} = Weight of fresh fibre (kg)
Tt = Time taken (h)

Moisture content, MC (%, wb)
When the test is done, we use the following equation to calculate moisture content (Mostara and roy (2008)

$$\text{MC (\%)} = \frac{(Wm-Wd)}{Wm} x100 \qquad (3)$$

Where, MC = Moisture content, (%)
W_m = Net weight of moist sample (kg)
W_d = Weight of dry matter (kg)

Results and Discussion
The results of performance test in 2019-2020 as well as machine capacity has been shown in table 3. The average fresh jute plants input capacity, the fresh fiber output capacity and fresh byproducts (fresh leaves and broken jute sticks) output capacity of prototype jute decorticator was found to be 0.40 ton/h, 0.19 ton/h and 0.17. The capacity of the machine was varying depending on speed of feeding and feeding continuity of fresh jute plants into the machine by the operator and his assistants. The capacity may increase with the skill of the operator (One) as well as the assistants (three) of machine operator.

Fig. 14. Actual picture of jute decorticator machine.

Table 3. Fiber extraction capacity of BARI jute decorticator (2019-2020)

Replication	Fresh Jute plants input capacity, ton/h	Fresh fiber output capacity, ton/h	Fresh byproducts output capacity, ton/h
1	0.4	0.19	0.16
2	0.39	0.18	0.16
3	0.4	0.21	0.18
Mean	0.4	0.19	0.17

The average moisture content percentage (table 4) in wet basis of whole jute plants, fresh jute fiber and byproducts (leaves and broken jute sticks, etc.) was found to be 79.80%, 83.52% and 78.90% respectively.

Table 4. Measuring the moisture content of whole jute plant, jute fiber and byproducts (2019-2020)

Sample	Rep	Pot No.	Tare wt., g (Pot)	Pot + Moist sample,g	net wt of moist sample, g	Pot+ Dried sample, g	Dry matter wt., g	MC (%)	Mean of MC (%)
Whole Jute Plants	1	2	220.1	465.2	245.1	269.3	49.2	79.93	79.80
	2	13	223	432.9	209.9	265.5	42.5	79.75	
	3	5	276.9	537.9	261	329.8	52.9	79.73	
Jute Fiber	1	17	100.6	266.3	165.7	128.4	27.8	83.22	
	2	8	282.9	539.4	256.5	325.1	42.2	83.55	83.52
	3	11	103.5	294.1	190.6	134.4	30.9	83.79	
Byproducts	1	19	286.6	560.5	273.9	344.7	58.1	78.79	
	2	3	282.5	523.3	240.8	334.6	52.1	78.36	78.90
	3	15	285.3	557.2	271.9	340.9	55.6	79.55	

Yield and yield contributing parameters

Yield and yield contributing parameters of the deshi jute variety determined from three average value of three samples area each sample size of 20 square meter were shown in table 5. The average plant population was found 61000 Nos./ha. The average plant height, diameter in bottom and middle part of the plants was 2211 mm, 11.45 mm and 6.73 mm respectively. The average yield of fresh jute was found to be 35.73 ton/ha in 20219-2020.

Table 5. Yield and yield contributing parameters of deshi jute variety used for machine performance evaluation (2019-2020)

Replication	Plant population (Nos./ha)	Plant height (20 plants), (mm)	Plant diameter (20 plants), (mm)		Yield of fresh plants (ton/ha)
			Bottom	Middle	
1	70000	2133.5	10.93	6.51	36.20
2	62000	2228.5	11.28	6.58	36.00
3	51000	2273.0	12.15	7.02	35.00
Mean	61000	2211.7	11.45	6.70	35.73

Size of ribbon and broken jute sticks

It was also found that the machine extracted ribbons in full length while the jute sticks were broken down into smaller pieces of 2-6 cm.

Fig. 15. Jute ribbons in full length and broken jute sticks extracted by jute decorticator.

Observed problems and effects

For further improvement and fine tuning the following problems were observed and identified their effects during performance evaluation of the machine (table 6). It was also found that plant diameter was an important factor for smooth operation of the jute decorticator. The plants diameter in bottom part of the plant should be at least greater than 7.2 mm to decorticate by the Jute decorticator.

Modification and improvement

The machine was modified a little bit with shifting the power transmission components i.e., four pinions attached with Grab rollers and extraction rollers (Primary and secondary) in improved version in 2020-2021 which were in Engine side earlier (developed version in 2019-2020). It was done for balancing in power transmission. The design and drawing of the machine before and after modification has been shown in Fig 16 and 17 respectively.

Table 6. Problems of jute decorticator observed during performance evaluation and their effect (2019-2020)

Sl.No.	Problems observed	Effect
1.	The fresh jute plants diameter less than 3.6 mm can't pass through the grabbing roller	Twisted with the rollers
2.	The fresh jute plants diameter greater than 3.6 mm and less than 7.2 mm can pass through the grabbing roller but the sticks are not completely separated and jute sticks were being broken down to the length not to the diameter	The stem or sticks inside the plants is not hard/strong enough due to its being smaller in diameter

3.	Could not be fed more 5 plants at a time When plants diameter was greater than 22.89 mm in bottom part of the plant (though normal feeding rate 8-10 plants of average diameter of 10-15 mm)	The power transmission belt attached between grabbing roller and secondary extraction roller found to slip. As a result, grabbing rollers were not rotating, plants were not entering into the feeding zone and extraction of fiber was stopped
4.	When the plant diameter was greater than 3.6 mm and less than 7.2 mm could not pass through the roller firmly	Found to be twisted with primary extraction roller

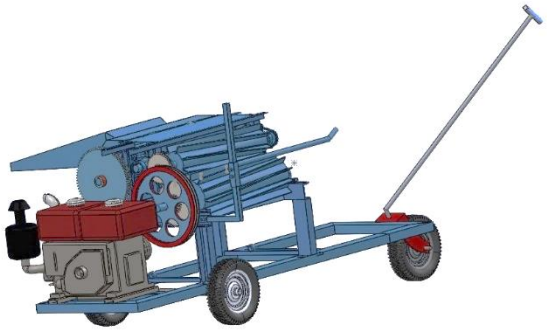

Fig. 16. Isometric view jute decorticator prototype developed in 2019-2020 (maximum number of power transmission components -all pinions and dual grooves sprockets in engine side).

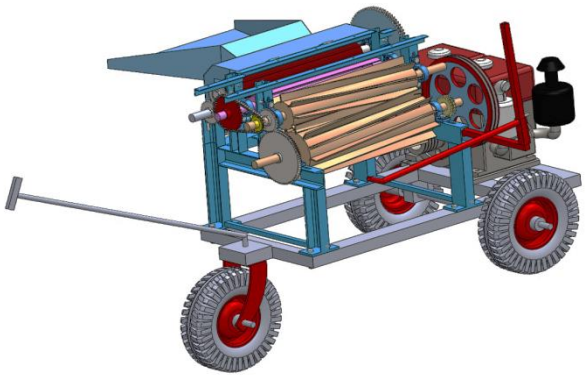

Fig. 17. Isometric view of jute decorticator prototype improved in 2020-2021 (maximum number of power transmission components -all pinions and single groove sprockets in opposite side of engine).

To meet the popular demand for unbroken jute sticks, the feeding part of the machine is under modification in order to prevent breaking of the sticks. In this modification process two extra parts will be added in front of the grabbing roller which will slit the fresh ribbon to the direction of length/height of plants. It will happen when the upper slitting roller will come in contacts with the plants had been fed into the grabbing zone before entered into the grabbing rollers. As soon as the thicker portion of the stem will come in contact with these rollers the upper roller will be disengaged slitting the ribbon and get upward movement with a spring-loaded clutch. Another one part will exert a twisting pressure on the slitted plants to move forward the sticks remain unbroken. The design and drawing of these two functional parts have been shown in Fig 18 (a) and 18 (b).

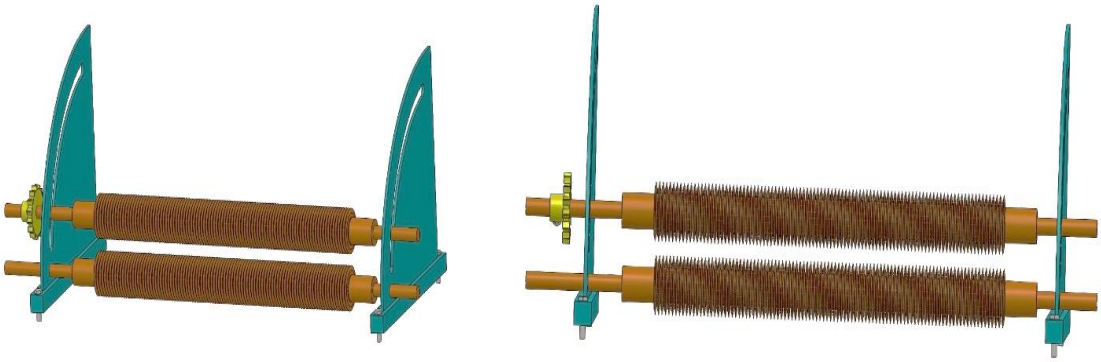

Fig. 18 (a). Ribbon cracking parts

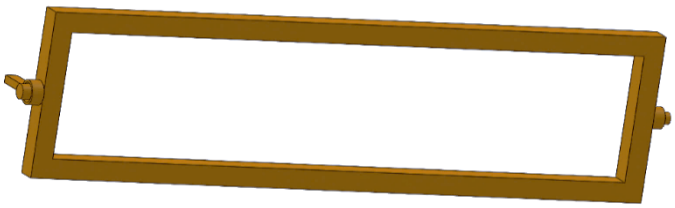

Fig. 18 (b). Twisting pressure applicating parts

In 2020-2021 the performance evaluation could not be done till now because the jute is in pre-maturity stage. It will be done after harvesting jute in first week of August 2020-2021.

Conclusion

The mechanical jute decorticator prototype was developed to mechanize the process of decorticating the fresh jute after it was harvested fresh jute plants from the field. The fresh jute plants input capacity and the fresh fiber output capacity of prototype jute decorticator were found to be 0.40 ton/h and 0.19 ton/h, respectively. During the performance test of this machine, it was found that thinner plants (bottom diameter < 7.2 mm) had a tendency to wrap around the rollers. Hence thinner plants should be avoided. The capacity of the decorticator was not up to the satisfactory level and need to be upgraded. The modification of the machine to get unbroken jute sticks is going on. The decorticator must be fine-tuned and thoroughly tested in the coming season when jute will be harvested and the modification will also be completed.

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EXPT. NO. 4.6 DEVELOPMENT AND ADOPTION OF SUITABLE TECHNOLOGY FOR HYGIENIC POTATO CHIPS PRODUCTION

M A HOQUE, T N BARNA, M HASAN, M A GULANDAZ, M M ALAM, M G F CHOUDHURY AND M A HOSSAIN

Abstract

Huge production of potato in Bangladesh needs alternate uses and suitable relevant technology. Sun drying is the most commonly used method to dry the agricultural products. The excess moisture in fresh produce causes spoilage and reduced the shelf life of the product. A study was conducted during 2020-21 to design and develop a low cost solar tunnel dryer for efficient and hygienic drying of potato slices, power operated potato slicer and a spiral potato slicer for value addition of potato chips. The development works were done at FMPE workshop and the adaptive trials were done at Magura. The febrication material was stainless steel. The modified slicer (SS model) was capable to slice variable thickness of slices. Capacity of the power operated slicer was almost double than the manual slicer. The developed dryer took 6.5 hours to dry the potato sliced from initial moisture content of 85%(wb) to final moisture content of 5% (wb), which is suitable for long term storage and marketing. The developed dryer took only 13 hours to dry the mushroom from initial moisture content of 93%(wb) to final moisture content 5% (wb). The dryer temperature was higher than the ambient temparature. The relative humidity in the dryer was decreased with drying time. A spiral potato slicer was developed which produced instaneous fresh potato chips for frying that may create income of an entreprenuer . The capacity of the spiral potato slicer was 10 kg/h with 2mm thick slices. The economic analysis and other studies will be done in the next year.

Introduction

The suffering of potato growers is increasing day by day even though their yield is high, as they are stuck with surplus stocks and low exports. Bangladesh is the seventh largest producer of the tuber crop. It produced a record high of 1.09 crore tonnes last year, according to the Department of Agricultural Extension (DAE). With an annual average demand of around 70 lakh tonnes, the country witnessed a surplus of about 40 lakh tonnes, most of which is wasted. Potato chips are made in some remote rural regions of Bangladesh maintaining minimal hygiene. In response to the current scenario, Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute has taken ample effort to successfully utilize the surplus yield in valuable by products. BARI potato slicer can slice 60 kg variable sized potato per hour (Hoque and Saha, 2017). Sun drying is the most commonly used method to dry the agricultural products. The moisture content in fresh produce is the basic cause for spoilage and if water is removed then the shelf life of production increases. Removal of water results in a reduction of weight and volume of the product, thereby reducing the cost and facilitating easy transportation. Drying is a unit operation widely followed under value addition (Rathore and Panwar, 2010). Since drying is a cost-intensive operation, use of solar energy is preferable as it is a non-exhaustive and eco-friendly practice. In sun drying, the product is exposed directly to the solar radiation, ambient temperature, wind velocity, relative humidity, etc. Traditional sun drying is the oldest method often resulting in poor quality produce, as the product is not protected against wind, rodents, dust, rain, bird etc. also drying process is not controllable requiring more drying space and labor (Hossain and Bala, 2007). Direct sunlight results in loss of color as well as the flavor of the product and it becomes undesirable. Solar dryers are the best alternatives to traditional drying because mechanical drying is not affordable by small farmers. The solar tunnel dryer is a polyhouse dryer suitable for drying of most of the food crops. It consists of a tunnel type triangular or semi-cylindrical drying chamber provided with windows to allow the ambient air to enter the dryer. An exhaust fan is provided to evacuate the moist air from the dryer. A sliding opening is also provided to facilitate easy handling of the produce. The low cost solar tunnel dryer can dry the slices quickly even during rainfall and low temperature. Keeping in view of the above-mentioned aspects, a solar tunnel dryer was developed and this study was done to evaluate the performance of solar tunnel dryer. Initiatives were also taken to develop a spiral potato slicer for high value marketing. Thus, a study was taken to improve and adopt BARI slicer for rural region to enhance healthy and quality

potato slices, to design and develop a low cost solar tunnel dryer for efficient and hygienic drying of potato slices and to design and develop a spiral potato slicer for value addition of potato chips

Materials and Method

The experiment was undertaken to increase the hygiene level of the traditional use of the potato chips. BARI slicer was modified to increase the hygienic condition in the long run. BARI Slicer was modified during 2019-20 but farmers opined high capacity and power slicer. Thus the attempts were taken to develop a power slicer. The power operated slicer was designed and was fabricated according to design from Expert Engineering Workshop, Tongi, Dhaka during 2020-21. The basic design criteria for developing the power slicer were: it will be capable to produce slice of variable thickness, to use for different fruits and vegetables, to produce different types of slice (i.e. round slice and slice for french fry) and the slicer will be operated with single phase electric motor. The specification of the power slicer is given in Table 1. Also the pictorial views of traditional slicing, existing BARI slicer and power slicer are shown in Fig. 1, Fig.2 and Fig.3, respectively. The fabricated power slicer was tested at FMPE divisional laboratory to evaluate the performance during 2020-21.

Table 1. Specification of the power operated slicer

Sl. No.	Parameter	Dimension
01	Overall dimension	740 × 460 ×420 mm
02	Diameter of the blade base disk	250 mm
03	Diameter of the cover of the blade	280 mm
04	Blade dimension	56 x 46 mm
05	French fry blade dimension	100 x 100 mm
06	Feeding cylinder diameter	Ø 65 mm
07	Rectangular feeding hopper diameter	135 mm × Ø 65 mm
08	Blade speed, rpm	1075
09	Motor capacity, hp	0.5

Fig. 1. Traditional unhygienic slicing.

Fig. 2. BARI slicer (SS model).

Fig 3. Power operated slicer.

An automatic blanching machine was designed and fabricated during 2020-21 at FMPE divisional workshop to maintain 80 ^{0}C water temperature during blanching of the potato slices. One magnetic controller, temperature controller and temperature sensor were used. The specification of the automatic blanching machine is given in Table 2. The fabricated blanching machine was tested at FMPE divisional laboratory to evaluate the performance during 2020-21. The pictorial view of automatic blanching machine is shown in Fig. 3.

Fig. 3. Automatic blanching machine

Table 2. Specification of the automatic blanching machine

Sl. No.	Parameter	Dimension
01	Overall dimension	740 × 460 ×460 mm
02	Water box	356 × 460 ×460 mm
03	Maximum capacity of water tank, liter	40
04	Maximum working water limit, liter	25
05	Time to heat water at 80 ^{o}C, minutes	30
06	Heater capacity, Watt	2000
07	Weight, kg	57.5

A low cost solar tunnel dryer as per farmer's need was designed to maintain hygienic and healthy potato food products since unhygienic drying is found in the field (Fig 4). The designed solar tunnel dryer was fabricated at FMPE divisional workshop during 2019-20 and was modified during 2020-21. Manual rotation system of the solar panel was incorporated to developed manual solar tracker to increase the efficiency of the solar panel. Additional electric heating system was incorporated for using the dryer during uncertain rain or rough weather to finish the drying batch (Fig 5). The specification of the solar tunnel dryer in shown in Table 3. The performance of the developed dryer

was evaluated at divisional workshop during 2020-21. The tunnel dryers were loaded with 10 kg potato slices (Fig 6). The performance study was done during 202-21. One solar tunnel dryer was fabricated and distributed to a mushroom producer at Magura. That solar tunnel dryer was tested for drying mushroom with 10 kg in a batch (Fig 7).

Fig 4. Unhygienic sun drying.

Fig 5. Solar tunnel dryer with heating system.

Fig. 6. Solar tunnel dryer feeding with slices.

Fig. 7. Solar tunnel dryer operation.

Table 3. Specification of the solar tunnel dryer

Sl. No.	Parameter	Dimension
01	Overall dimension	3200 × 1250 ×720 mm
02	Length of the tray	3050 mm
03	Width of the tray	1218 mm
04	Tray material	03 mesh plastic coated net
05	Dryer cover material	Polythene
06	Dimension of cover	3050 × 2000 mm
07	Cover holder with plastic pipe	3050 mm × Ø 19.10 mm
08	Solar heat collector material	Corrugated iron sheet
09	Solar panel size	576 × 355 mm
10	Solar panel capacity	10 Watt
11	Number of fan	01
12	Fan size	120 × 120 mm
13	Fan description	12 V and 1.00 A; 7
14	Heater	2000 Watt

A spiral potato slicer was designed and fabricated at FMPE divisional workshop during 2019-20. The spiral slicer was developed and refabricated during 2020-21. Specification of developed spiral potato slicer is shown in Table 4. The spiral slicer was fabricated with stainless steel to increase the hygiene level and to avoid rust (Fig 8 and 9). The performance of the developed spiral potato slicer was evaluated at divisional laboratory during 2020-21(Fig 9). After slicing the spiral, slices were deep fried in hot oil.

Fig. 8. Spiral potato slicer (previous model).

Fig. 9. Modified spiral slicer.

Table 4. Specification of Spiral potato slicer

Sl. No.	Parameter	Dimension of Previous model	Dimension of modified
01	Overall dimension	420 × 130 ×250 mm	440 × 127 ×156 mm
02	Length of the spiral shaft	300 mm	286 mm
03	Dia. of the spiral shaft	24 mm	20 mm
04	Dimension of handle	180 × 12 mm	102 × 27 mm
05	Dimension of base frame	420 × 140 × 45 mm	314 × 50 × 25 mm
06	Dimension of the blade holder	202 × 118 × 3 mm	76 × 50 × 3 mm
07	Dimension of the blade	103 × 43 × 2 mm	55 × 40 × 1 mm
08	Angle of the blade	5^0	5^0
09	Number of the spine	03	03
10	Weight	3 Kg	1.93 Kg

Results and Discussion

The BARI slicer was modified to increase the capacity and to avoid manual rotation. The comparative performance of both the slicer is shown in Table 5. The modified slicer was made of stainless steel and operated with 0.5 hp single phase electric motor. There was provision to change the thickness of the slices depending on demand. The modified slicer is a combined machine which can also produce lengthwise slices of mango, banana etc. A manual presses French fry slicer was also incorporated in left side of the slicer to make multiple use of the slicer. Capacity of the power operated slicer and manual slicer were 120 kg/h and 60 kg/h, respectively. The capacity could be increased by increasing the feeding chute which will be done in the next year.

Table 5. Performance of the power slicer compared with the previous model during 2020-21

Parameters	Previous model	Modified model
Materials	Stainless steel	Stainless steel
Operated	Manually	Electric motor (0.5 hp)
Weight	17.5 kg	57.50 kg
Slice thickness	Variable (1 to 3 mm)	Variable (1 to 5 mm)
Types of slices	Round slice	Round slices, lengthwise slice and french fry
Capacity	60 kg/h	120 kg/h

The drying performance of the solar tunnel dryer was satifactory. The time required for drying potato slices with the solar tunnel dryer at Gazipur at 30 November 2020 was 6.5 hours (Fig 10). The initial moisture content of the slices was 84.81%(wb) which was reduced to 4-5% (wb) with the tunnel dryer (Fig 10). The initial moisture content of the potato slices at 03 May 2021 was 84.81 (wb) which were also reduced to 4%(wb) with the dryer. The solar intensity, ambinet temparature, dryer temperature and relative humadity of the corresponding drying time are shown in Fig 11 and Fig 13. The dryer temperature was 10-15 ^{0}C higher than the ambient temparature. The relative humidity in the dryer were decreased with the drying time. The temparatures were varied with the solar intensity.

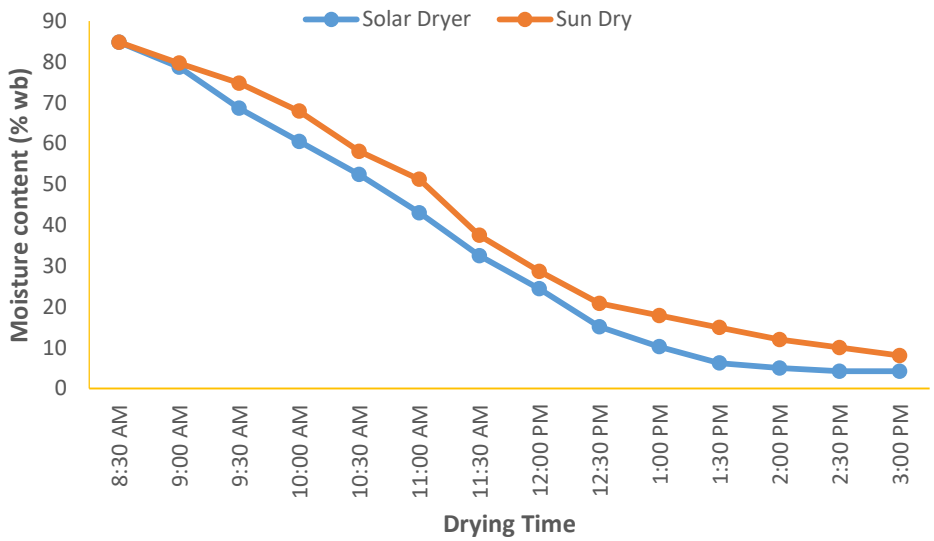

Fig. 10. Drying curve of potato slices in the solar tunnel dryer on 30 November 2020

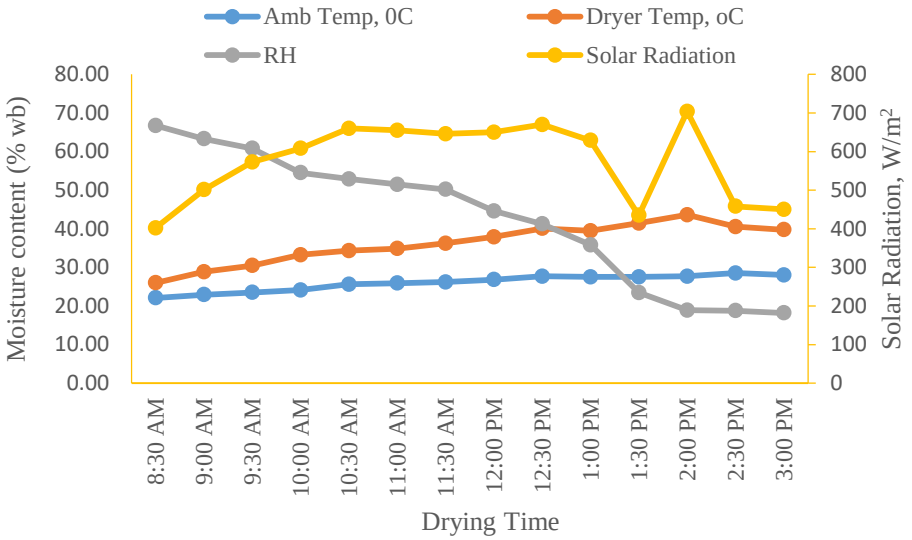

Fig. 11. Temp., RH, air velocity and solar intensity in the solar tunnel dryer on 30 November 2020.

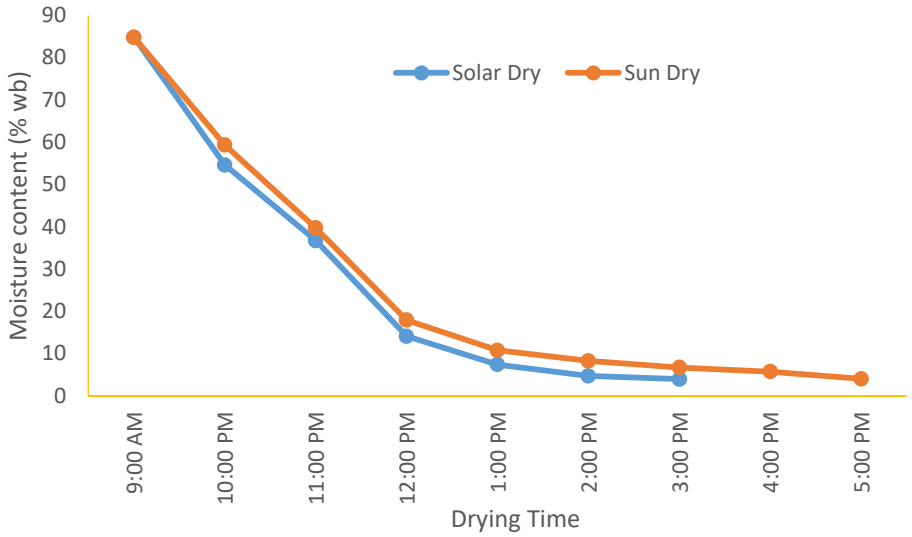

Fig. 12. Drying curve of potato slices in the solar tunnel dryer on 03 May 2021

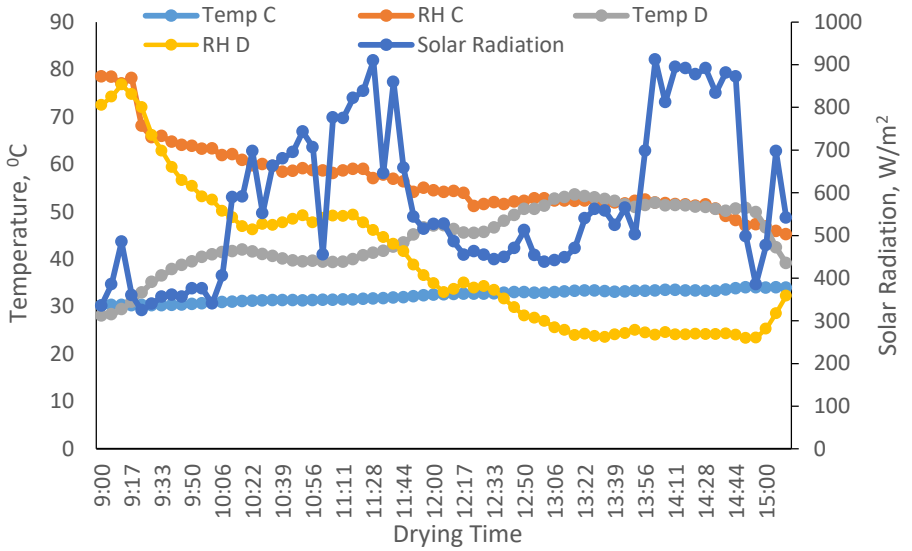

Fig 13. Temp., RH, air velocity and solar intensity in the solar tunnel dryer on 03 May 2021.

The drying performance of the solar tunnel dryer for mushroom drying was satifactory. The time required for drying mushroom with the solar tunnel dryer at Magura at 22 February 2021 was 10 hours (Fig 14). The initial moisture content of the mushroom was 92.83%(wb) which was reduced to arround 5% (wb) with the tunnel dryer (Fig 14). But after 13 hours drying under sun on tray and on ground, the moisture content were 6% and 9%. The solar intensity, ambinet temparature, dryer temperature and relative humadity (RH) of the corresponding drying time are shown in Fig 15. The dryer temperature was 09-12 ^{0}C higher than the ambient temparature.

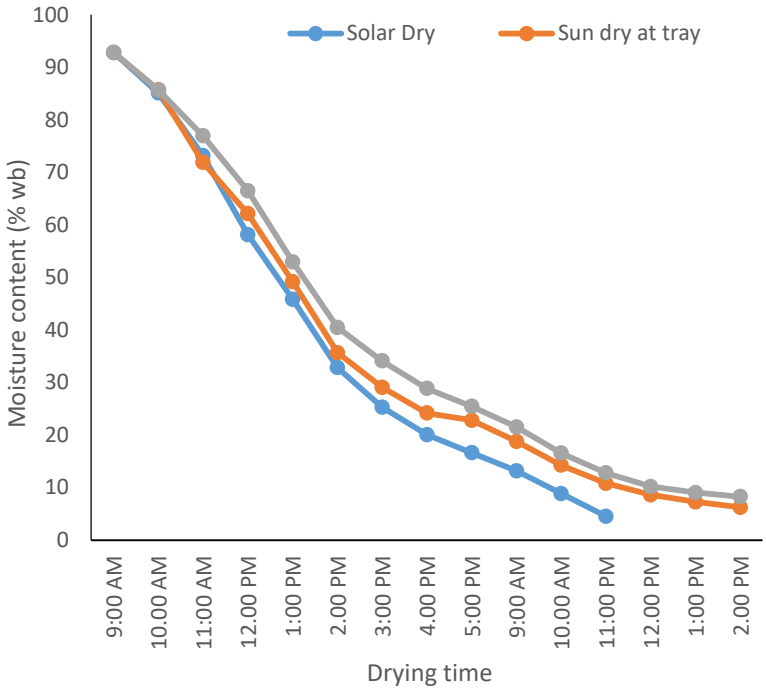

Fig. 14. Drying curve of mushroom in the solar tunnel dryer on 22 February 2021.

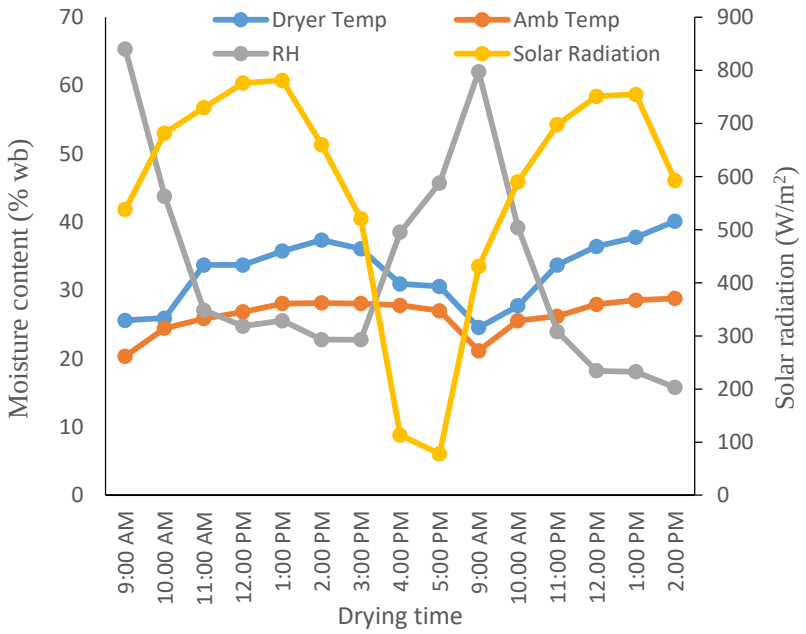

Fig. 15. Temp., RH, air velocity and solar intensity in the solar tunnel dryer for drying mushroom on 22 February 2021.

The developed spiral potato slicer was evaluated in FMPE laboratory during 2020-21. Performance of the spiral potato slicer during 2020-21 is shown in Table 6. The thickness of the slices was 2.00 mm. The capacity of the spiral potato slicer was 10.05 kg/h.

Table 6. Performance of the spiral potato slicer during 2020-21

Trial No.	Previous Model		Improved model	
	Thickness of the slices, mm	Capacity, kg/h	Thickness of the slices, mm	Capacity, kg/h
01	2.00	8.77	2. 00	10.50
02	2.25	8.40	2.00	9.45
03	2.25	8.49	2.00	10.20
Average	2.17	8.55	2.00	10.05

Conclusion

The BARI slicer was developed to increase the hygiene level and user acceptability. The construction material was stainless steel. The modified slicer (SS model) was capable to slice variable thickness slices. Capacity of the power operated slicer is almost double than the manual slicer. The developed dryer took only 6.5 hours to dry the potato sliced from primary moisture content 85%(wb) to final moisture content 5% (wb), which is very suitable for long term storage and marketing. The developed dryer took 13 hours to dry the mushroom from primary moisture content 93%(wb) to final moisture content 5% (wb). The dryer temperature was higher than the ambient temparature. The reletive humidity in the dryer were decreased with the drying time. A spiral potato slicer was developed which provides high value addition to processed potato products providing the entreprenuer an extra income . The capacity of the spiral potato slicer was 10 kg/h with 2.00 mm thick slices. The economic analysis and further study will be done in the next year.

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EXPT. NO. 4.7 UP-SCALING AND FINE TUNING OF CASHEW NUT POSTHARVEST PROCESSING MACHINE AND OIL EXTRACTING MACHINE

M N AMIN, M A HOSSAIN AND M M HASAN

Abstract

Cashew (*Anacardium occidentale* L.) is one of the high value crops of Bangladesh. It is cultivated in limited areas of Chattogram and Chattogram Hill Tracts. The cashew fruit is unusual in comparison with other tree nuts since the nut is outside the fruit. Removal of cashew kernel from its shell is a labour intensive operation. Therefore, The shape of the cashew nut, the toxic cashew nut shell liquid in its mesocarp and brittleness of the kernel make the shelling of the cashew nut difficult. In the processing of the nut, the greatest difficulty is the removal of the shell without damaging the encased kernel. The performance of the jacket vessel, semi-auto cashew nut sheller and oil expeller were evaluated at FMPE Division, BARI, Gazipur during 2020-2021. Raw cashew nuts was boiled at temperature of 105 °C and pressure of vessel of 0.59 kgf/cm^2 for 30 minutes. The raw cashew nut and water mixture ratio was 1:1. The boiled cashew nut was dried at 60°C for 6 hours using BARI solar cabinet dryer during June 2021. Shelling rate, shelling efficiency and whole kernel recovery of semi auto sheller were 2.84 kg/h, 74% and 82.70% respectively. Shelling rate and shelling efficiency of the sheller were higher in the results of 2019-2020 compared to results of 2020-2021. On the other hand, whole kernel recovery was higher in 2020-21 compared to 2019-20. Kernels were kept in an average for 10 hours at 60°C. Dried kernel were then brought out and the thin layers were manually cleaned. Finally, washed kernel were air dried at 6% moisture content by drier and packed. The expelling capacity of the oil expeller for cashew nut was 18.63 kg/h. Average oil recovery of cashew nut shell was 29.30% and oil cake was found to be 65%.

Introduction

Cashew (*Anacardium occidentale* L.) is a native fruit of North East Brazil. Later it would have spread spontaneously over a wide area of Central and South America, from Mexico to Rio de Janeiro. During the early 16th century, Portugal, who found the tree to be ideal in preventing soil erosion in light soiled arid areas, brought cashew in to Asia and Africa. Cashew was introduced to India by certain missionaries of Goa region in 1950 and later it spread rapidly along the entire west and south east coasts of Indian sub-continent as well as reaching the islands of Sri Lanka, Andaman, Nicobar and the countries like Malaysia, Indonesia, the Philippines, and recently Bangladesh. Cashew nut is cultivated in limited areas of Chittagong and Chittagong hill tracts area (www.megagroupbd.com/cashewNUT). The annual cashew nut production in Bandarban of Bangladesh are 708 tons and cultivated area is 611 ha (DAE, 2018). Cashew nut processing industry is quite new in Bangladesh. There is no accurate census on the number, type and size of the existing factories processing cashew. Cashew nut has great potentiality to be established as economic crop (KGF, 2011).

The edible portion of cashew nut is seed (kernel), obtained from shelling of roasted fruits (Amar Singh, 1992). Cashew kernels are used in snacks, as roasted and salted nuts alone or in mixture with other nuts. Cashew kernel is a good source of protein (21%), fat (47%), carbohydrate (22%) and minerals. Cashew nut differs in their size (weight, length, breadth and thickness), shape, colour and kernel characters. Broadly raw nuts can be grouped in to three catogories viz. small, medium and large, based on nut weight. Generally nut weight varies from 3 to 15 g. The nut length may vary from 3 to 6 cm whereas the nut width varies from 3 to 4 cm. The nut thickness varies from 2.5 to 3.0 cm. The length, width, thickness and weight of a random sample of cashew nuts of different size groups (small, medium and large) recorded at Cashew Research Station, Kerala Agricultural University, Madakkathara (Gaikwad, 2017). Artificial drying is more reliable and is required in medium or large-scale operations. Drying usually takes six hours, at a temperature of around 70°C (Gaikwad, 2017).

The moisture content is approximately 6% before drying and 3% after. It is important that the drying capacity is higher than the shelling capacity in case of periods of heavy rainfall because the drying operation will be lengthened since the kernels will absorb the moisture very quickly. Sun drying, where the kernels are spread out in thin layers under strong sunshine is possible, however artificial drying becomes necessary for medium or larger scale producers. Drying usually takes six hours, at a temperature of around 70°C. A uniform temperature throughout the drier is essential to avoid under drying or scorching (Ohler, 2001). Shelling is the removal of dry roasted shell and has an objective of producing clean, whole kernels free of cracks, as whole kernels have a better market

value than broken kernels (ITDG, 2002; Naturland, 2000). The manual shelling process involves placing the roasted nuts on a flat stone and cracking with a wooden mallet or batten (ITDG, 2002;Azam-Ali and Judge, 2004; Nazneen, 2004; Davis, 1999; Naturland, 2000). An average sheller can open ten nuts per minute which amounts to 4,800 nuts or about 5 kg of kernels. Experienced shellers can produce only half as much, with a quality of 90 per cent whole kernels (ITDG, 2002). The manual traditional method of shelling cashew nut using hammer is a labour intensive, slow and tedious process. It also has some health implications due to the corrosive action of CNSL on human skin (Ojolo and Ogunsina, 2007;Derm Net, 2007). Recently, roasted nuts have been cut by semi-mechanised shelling such as the impact-shelling machine (Nazneen, 2004). The pedal-operated knife cutter (Ajav, 1996) has been developed.Asemi-mechanised process that has been used in Brazil, uses a pair of knives, each shaped in the contour of half a nut had a daily production of about 15 kg of kernels (ITDG, 2002). A motorized cashew nut sheller developed by Jain and Kumar (1997) has a capacity of 18 kg/h and a shelling efficiency of 70% and whole kernel recovery of 50%. Ojolo and Ogunsina (2007) developed a cashew nut cracking device with a capacity of 21 kg of kernels per day and whole kernel recovery of 67 per cent.

Postharvest losses of fruit occurred for lacking of improved postharvest handling technology. Major portion of the postharvest loss occurred due to lack of improved packaging and handling machinery such as machine of harvesting, washing, sorting, grading, processing, treatment of cashew nut. BARI has developed small scale cashew nut sheller and dryer. But there is no good shelling machine available in this region. It is a great scope to conduct study to improve precision cashew nut postharvest machinery in the market channel for reducing the postharvest losses getting good quality and safe fresh products. The demand of foreign market and local super market are quality, safe and fresh fruits. Besides, in Bangladesh policy makers has given emphasis getting chemical free fresh and safe products. Most of the consumers are very conscious to take good quality, safety and fresh products at higher price of fruits. Now a day, it is a challenge to reduce the postharvest losses of fruits and getting good quality and safety fresh products.

Manually operated cashew nut sheller was modified into both the hand and pedal operated sheller instead of hand operated sheller during last year (2018-19). All sizes (large, medium and small) of raw cashew nut were boiled at 35 minutes, 40 minutes and 30-35 minutes respectively. The boiled cahew nut were dried by BARI developed solar dryer at 60 °C for 7 hours and sun drying during 2-3 days. The sheller was tested with raw boiled and dried cashew nut. The shelling rate of the cashew nut sheller was 0.60 kg/h. The highest shelling rate of the sheller (0.70 kg/h) was found in sun drying at boiling of 40 minutes. There was no observed whole nuts from cashew nut and maximum nut were split and broken. It may be due to cashew nut was not boiled properly and two blades of sheller were not properly adjusted. Sheller is new machine and need skilled operator and steam boiling process is one of the major activity for separation of nut from shell. The experiment will be conducted to mitigated the above this problem.

Traditionally, oil is extracted from oil seeds, nuts and pulse by roasting and grinding to fine particles or paste. This method of oil extraction is termed as solvent extraction method. Oil from rice bran is extracted by mixing the bran in normal hexane. Oil extraction process, when carried out traditionally, is energy and time consuming, tedious and of low oil recovery. Also the cooking process or handling of hot mixture can be hazardous and discouraging to processors (Aviara *et al.*, 2013). Khan and Hanna (1983) and Ibrahim and Onwualu (2005) extensively reviewed the technologies involved in the extraction of oil from oil-bearing agricultural products and confirmed the above short comings of the traditional methods. Thus, there is the need to mechanize oil extraction to reduce the drudgery involved in the traditional means of extracting the commodity.

There are a number of mechanical extractors with good oil recovery (Oluwole *et al.*, 2003; Oluwole *et al.*, 2007) but the majority of these extractors are medium to large scale equipment. These equipment are normally complex and present the problem of maintenance, accessibility of spare parts and availability of power source inputs (Ibrahim and Onwualu, 2005) making them uneconomical to small-scale farmers. Therefore, small-scale manually operated hydraulic oil press will no doubt be a suitable substitute to traditional means of extracting vegetable oil, because of its lower initial and operating costs and ease of handling and maintenance (Reddy and Bohle, 1993). So, there is a demand of mini oil expeller as small rice hauler exits in the rural areas. The main aim of this study is to design and fabricate a multi seed oil pressing machine. Other specific objectives are to evaluate the

performance of the machine in terms of oil yield, extraction rate, extraction efficiency and machine throughput capacity.

Objectives

a) To improve and fine tuning of postharvest cashew nut machinery
b) ii) To evaluate the performance of the postharvest machinery in laboratory

Materials and Method

Description of the jacket vessel

Jacket vessel is used for boiling of raw cashew nut for easy shelling of nuts. Main parts of the jacket vessel such as vessel, jacket, heaters, panel board, container, covered, pressure gauge, thermometer etc. It was made of SS sheet, u-channel, clamp, etc. Photographic view of the jacket vessel is shown in Fig. 1.

Fig. 1. Photographic view of the jacket vessel.

Performance test of the jacket vessel

The jacket vessel is placed on plane space and near the electrical board for electrical connection. About 35 litre of thermo-oil is purred into the vessel as heating media instead of water. Oil is heated by electric heaters of 6 kW. Raw cashew nuts and water are kept into the container. When heaters is on, oil is boiled and container water is heated through convention process by boiled oil. Raw cashew nut is boiled through hot water at 100°C for 0.5 kgf/cm^2 pressure within 20-25 minutes. Later, boiled raw cashew nut is delivered from the container.

Description of the semi auto sheller

The main parts of the semi auto cashew nut sheller are mainframe, hopper, crank shaft, cutting unit, scraper, blades, spring, picking bar, and adjusting levers etc. The pictorial view of semi auto cashew nut sheller is given in Fig.2

Fig.2. Pictorial view of two blades semi auto cashew nut sheller.

Performance evaluation semi auto sheller

The boiled cashew nut was dried at 60°C for 6 hours using BARI solar cabinet dryer during June 2021.The dried cashew nut differs in their sizes and weights. Broadly raw nuts can be grouped in to three categories viz. small (3.40-3.60g), medium (3.61-4.50g) and large (4.51-5.60g). Medium cashew nuts were shelled using semi auto cashew nut sheller (Fig.3). The shelling time, amount of cashew nut, unshelled nut, whole kernel, half kernel, split/broken kernel and clearance between the bladed edges etc were recorded.

Shelling rate, Shelling efficiency, and whole kernel recovery are calculated following the formula:

$$\text{Shelling rate} = \text{Weight } (kg) \text{ of kernel obtained per hour}$$

$$\text{Shelling Efficiency (\%)} = \frac{\text{Weight (kg)of cashew nut shelled per hour}}{\text{Total weight (kg)of cashew nut usedshelled}} \text{ x } 100$$

$$\text{Whole kernel recovery (\%)} = \frac{\text{Weight (kg of whole kernel obtained}}{Total\ weight\ (kg) of\ kernel\ obtained} \text{x}100$$

Oil expeller description

A mini oil expeller was redesigned and fabricated at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. It was made of locally available materials. The materials used for fabrication of different parts of the machine were MS plate, MS angle bar, MS flat bar, MS rod, MS sheet, cast iron, ball bearing, pulley, flat belt etc. The functional parts of the machine are feeding tray, rotor casing, spiral screw, shaft, cone, pulley and flat belt. Overall dimension of the expeller was 1200×570×1280 mm and power required to operate the machine was 3 kW electric motor. The average speeds expeller was 16 rpm. Different types of oilseeds such as mustard, sesame, sunflower and cashew shell are crushed in this machine.

Performance evaluation of oil expeller

At first the oil expeller is placed on a level place. The motor was started and then 2.0 kg of cashew nut shell is fed into the feeding hopper and delivered to the rotor casing to be crushed. Inside the rotor casing there was a spiral screw which moved the seed forward for pressing and oil was extracted from the seeds. Oil was collected below the rotor casing. When seeds were transformed into cake, it came out through the outer surface of the cone. The starting and ending time was recorded. The weight of shell, oilcake and oil (after 24 hours sedimentation) was also measured. The operation of the mini oil expeller is shown in Fig. 3.

Fig. 3. Performance test of the oil expeller with cashew nut shell.

Results and Discussion

A jacket vessel was used for boiling the raw cashew nut for easily separation of kernels from shell of nut. Raw cashew nut having 10.92% moisture content was boiled using the jacket vessel (Table 1). It was observed that raw cashew nuts were boiled at temperature of 105 °C and pressure of vessel of 0.59 kgf/cm^2 for 30 minutes. The raw cashew nut and water mixture ratio was 1:1. On the other hand, weight of boiled raw cashew nuts increased by 15% than that of raw cashew nuts.

Table 1. Performance test of jacket vessel with raw cashew nut at moisture content of 10.92% (wb) during 2020- 2021

Trial No.	Initial weight of raw cashew nut, kg	Weight of mixed water nut, kg	Temperature, °C		Pressure, kgf/cm^2	Boiling time, min	Final weight of raw cashew nut, kg
			Controller Display (Thermo -oil)	Thermometer (Inside of Vessel)			
1	20	19	125	105	0.60	30	23
2	10	10	127	100	0.56	35	11
3	20	19	130	110	0.60	25	23
Mean			127	105	0.59	30	

Performance of the semi auto sheller

The boiled cashew nut was dried at 60°C for 6 hours using BARI solar cabinet dryer during June 2021. Performance test of cashew nut sheller with boiled dried nut at moisture content 10.0% (wb) during 2020- 2021 (Table 2). It was observed that the shelling rate, shelling efficiency and whole kernel recovery of semi auto sheller 2.84 kg/h, 74% and 82.70% respectively. It was revealed that the shelling rate and shelling efficiency of the sheller were higher in the results of 2019-2020 (Table 3) compared to 2020-2021 results. On the other hand, whole kernel recovery was higher in 2020-21 compared to 2019-20. It might be due to single nut dropped in each cutter instead of multi nuts dropped. A motorized cashew nut sheller developed by Jain and Kumar (1997) has a capacity of 18 kg/h and a shelling of 70% and whole kernel yield of 50%. Ojolo and Ogunsina (2007) developed a cashew nut cracking device with a capacity of 21 kg of kernels per day and whole kernel recovery of 67%. It is concluded that shelling rate, efficiency and whole kernel recovery of the shellers depended on properly boiled and dried of nuts, number nuts dropping each time, clearance of between two blades and skillness of operator. Furthermore, raw cashew nuts should be dropped single in each time, maintained uniform size of each adjustment of two blades, and rate of delivery.

Table 2. Performance test of cashew nut sheller with boiled dried nut at moisture content 10.0% (wb) during 2020- 2021

Blade No.	Shelling rate (kg/h)	Shelling efficiency, %	Whole kernel recovery, %	Clearance between blades, mm
1	2.81	60.71	82.94	7.5
2	2.87	87.67	82.45	7.5
Mean	**2.84**	**74.00**	**82.70**	**7.5**

Table 3. Performance test of cashew nut sheller with boiled dried nut at moisture content 11.72% (wb) during 2019- 2020

Blade No.	Shelling rate (kg/h)	Shelling efficiency, %	Whole kernel recovery,%	Clearance between blades, mm
1 and 2	4.47	84.00	61.46	9.4

All types of shelled kernel (whole, half, broken kernel) were then put into an electrical dryer to dry the kernel and make the thin radish layer surrounding it crisp and brittle. Kernels were kept in an average for 10 hours at 60°C. Dried kernel were then brought out and the thin layers were manually cleaned. After that the kernels were washed in distilled water to clean outer surface as well as make its colour attractive. Finally, washed kernel were air dried at 6% moisture content by drier and packed them.

Performance evaluation of oil expeller

Performance test of oil expeller with cashew nut shell on 31 May 2021 is shown in Table 4. Overall dimension of the oil expeller was 1200×570×1280 mm and power required to operate the machine was 3 kW electric motor. The motor speed was reduced to machine using a gear box of 100:1. The average motor speeds was 16 rpm. The expelling capacity of the oil expeller for cashew nut was 18.63 kg/h. Average oil recovery of cashew nut shell was 29.30% and oil cake was found to be 65%.

Table 4. Performance test of oil expeller with cashew nut shell on 31 May 2021

Trails	Initial weight of cashew nut shell (g)	Expelling period (min)	Amount of extracting oil (g)	Weight of oil cake (g)	Oil recovery (%)	Capacity (kg/h)	Cake percentage	Loss of raw materials (%)
1	5000	16.18	1550	3105	31.00	18.54	62.10	6.90
2	5000	16.09	1455	3300	29.10	18.65	66.00	4.90
3	5000	16.05	1390	3340	27.80	18.69	66.80	5.40
Mean	5000.00	16.11	1465.00	3248.33	29.30	18.63	64.97	5.73

Conclusion

Raw cashew nuts were boiled at temperature of 105 °C and pressure of vessel of 0.59 kgf/cm^2 for 30 minutes. The boiled cashew nut was dried at 60°C for 6 hours using BARI solar cabinet dryer. Shelling rate, shelling efficiency and whole kernel recovery of semi auto sheller 2.84 kg/h, 74% and 82.70% respectively. Dried kernel was then brought out and the thin layers were manually cleaned. Finally, washed kernel were air dried at 6% moisture content by drier and packed them. The expelling capacity of the oil expeller for cashew nut was 18.63 kg/h. Average oil recovery of cashew nut shell was 29.30%. The sheller capacity and whole kernel recovery will be increased using adjusting of delivery cup for delivering single nut, the blades clearance on the basis of different moisture contents and different sizes of cashew nuts in the next year.

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EXPT NO. 4.8 IMPROVEMENT OF CHILLI SEED SEPARATOR

T N BARNA, M A HOSSAIN, M N AMIN, AND R ARA

Abstract

Improvement of BARI chilli seed separator was done at the workshop of the Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during 2020-2021. The overall dimension of the machine was 458×6610×1670 mm. The power transmission system of the machine was modified to obtain constant operating speed without flocking of feed materials. It enables constant operating speed of the drive and driven pulley. A gear box (1:1) was used for this purpose. The machine has a provision for continuous feeding and separate ways for outflow of seeds and chilli flakes. The separator was tested with dry chilli having 11-22.23% moisture content. The throughput capacity was found 47.18 kg/h, seed separation capacity of the separator was 2.07 kg/h and seed separating efficiency was 88.71%. No seed injury was observed as well as no significant effect was found in germination or seedling emergence. The economic analysis shows, a minimum use of 80 hours per year.The BCR of the system was 1.2. Field studies should be conducted for performance verification as well as for dissemination of the machine.

Introduction

Chilli (*Capsicum annuum* L.) is a valuable spice and also one of the most important cash crops grown in Bangladesh. Area under chilli cultivation was 239 thousand acre producing about 149 thousand metric tons of chilli during 2018-19. Per acre yield was 623 kg which indicates a necessity of quality seeds for standard production (BBS 2019). Chilli is used in green and dried forms. It is especially liked for its pungency, spicy taste and the appealing colour, it adds to the food (Mathukrishnan *et al.*, 1993). Various food, chemical and pharmacy industries need either seed or pulp separately or may be both. Moreover, seeds of dried chili can cause cancer of the stomach, intestinal infections, weak syndrome intestine, appendix and other health problems, if ingested with food (Hassan *et al.*, 2020). In Bangladesh, there is yet no mechanical option involved in separating chilli seeds out of fruit. Conventional method requires operators to cut chilies into small pieces and then squeeze manually by bare hands to remove the seeds. Other practices include, sun drying of red ripe chili followed by hammering with wooden stick or, separating seed from husk by hand. This traditional technique has limitations for a large quantity of seeds and has a great obstacle during rainy season. Manual method may cause health implications for the operator due to the hotness of chilli. The problem becomes severe on large scale i.e. seed processing plants, seed companies, etc. Also, the existing method has low output and efficiency. During rainy season, ripe chilies can't be sun dried, making the scenario even worse. Mechanical seed extraction serves a few important aspects. This is the quickest process with the least contact with chilli. Shayfull *et al.* (2011) developed a dried chilli seed separator with a production capacity of 40-50 kg per hour particularly to help chili-based industries to optimize productions. Hassan et al, 2020 reviewed the available chilli seed separators and concluded, a small, portable and easy operating seed separator is more suitable for extracting of quality seed as well as for purposes. Considering the above scenario, a power operated chilli seed separator was designed and developed at the workshop of the Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur during the period of 2018-2021. The flaws and recommendations were considered and improvement was done this year. The improved machine serves a better outcome than the previous design.

Objectives

a) To improve the power operated chilli seed separator
b) Testing and performance evaluation of the chilli seed separator

Materials and Methods

A chilli seed separator was redesigned and fabricated at the workshop FMPE Division of BARI, Gazipur during the period of 2020-2021 to improve its performance. The machine was operated by 0.5 hp electric motor. There were some problems faced during operation. Shaft was clogged during feeding while more than 600 grams of chilli were fed at a time. The system needed to be stopped and removal of the clogging was a hazardous job. It took time and hampered operation. To enable flawless

operation of the machine, the power transmission system was changed. Construction materials and major components of chilli seed separator is given in Table 1. The photograph of the improved chilli seed separator are shown in Fig. 1 and Fig. 2, respectively.

Table 1. Construction materials and major components of chilli seed separator

Sl. No.	Parameters	Dimension	Materials
1	Overall dimension, mm	458×6610×1670	
2	Main frame, mm	458×458×990	MS angle
3	Drum dimension, mm	457.2 × Ø 304.8	MS sheet
4	Hopper, mm	356×356×406	MS foliate
5	Seed separating Shaft size, mm	19	MS round bar
6	Blade, mm, degree	133.6×19-7.7×1.4, 10	MS flat bar
7	Seed outlet, mm	139.7×254×139.7	MS sheet
8	Sieve, mm	Ø 304.8	2.5 mesh perforated
9	Chilli flakes outlet, mm	140×140	MS sheet
10	Chilli flakes outlet cover, mm	142×142	MS sheet
11	Motor	0.38kW, 1450 rpm	
12	Pulley, mm	76.2, 177.8	Cast iron
13	Gearbox	1:1	Carburized hardened steel
14	Belt , pitch length, mm	39	A-size, v-belt

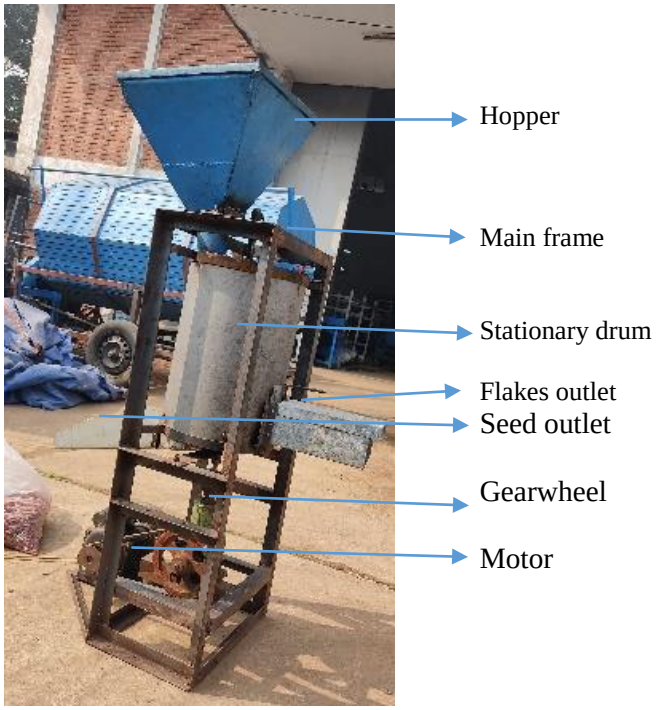

Fig. 1. Chilli seed separator.


Fig.2. Chilli seed separator in operatioin.

Power transmission system: The system includes motor, V-belt, pulley, gearbox (1:1) and bevel. The electric motor is attached with pulley through a V-belt (specification: A). The rated speed of the electric motor is 1500 rpm. Through the v-belt, the electric motor rotates the directly coupled gearbox that is attached with fixed pulley. The pulley and bevel are residing on the same shaft. The bevel rotates the central shaft containing the cutter blades. Thus, power is transmitted from electric motor to the cutter bar and gear reduces to 614 rpm from 1500 rpm. The final rpm of the cutter bar is suitable for chopping chilli and separation of seeds.

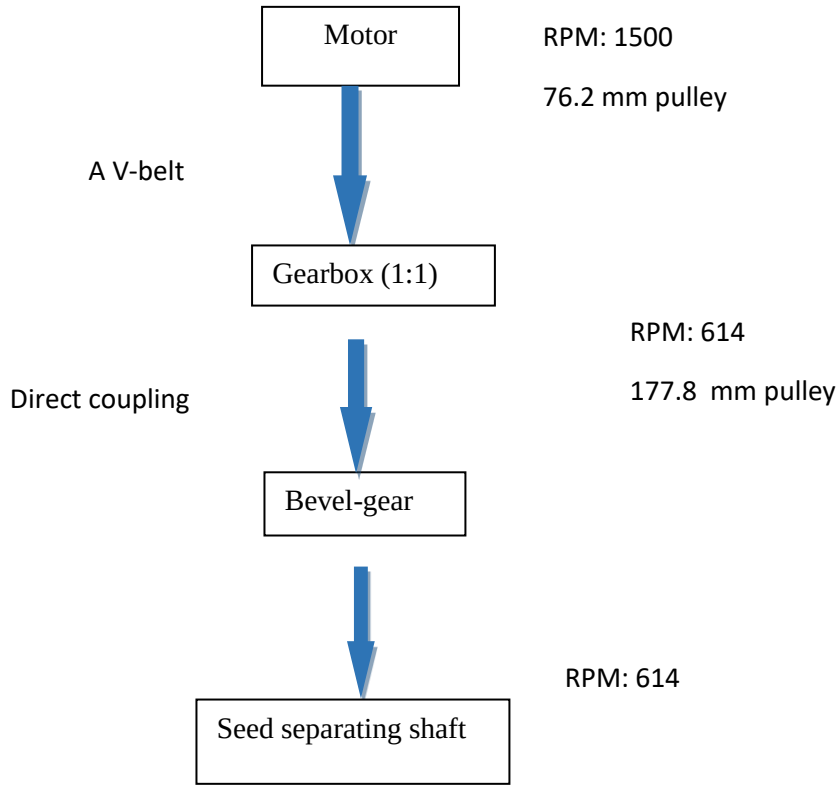

Fig. 3. Power transmission flow chart.

Operation and testing

At first, the machine was placed on a level place. The engine was started and the rpm was checked. Handful amount of chilies with stem are fed continuously into the hopper that slide under gravity to the cylinder. Through the power transmission system, the motor begins to turn the blades. The circular whirring motion cuts the chillies. The point load acting on each chillies separate the seeds from chillies. The seeds accelerated downwards by gravity forces and the sieve separates the seeds from the flakes. The centrifugal force pushes the seeds and flakes out of the cylinder by the seed outlet and flakes outlet.

Data collection and calculation of technical parameters

The performance of the separator was evaluated with chilies of different moisture content (11-22.23% wb). Average weight of a thousand dry chilli was 396 g. Seed content 41%.

Fig. 4. Pictorial views of lab experiment.

After each experiment, the seeds and flakes were carefully collected from the outlets and surroundings and were subsequently weighed. Percentages of shelled and unshelled chillies, seed damage, separating efficiency, machine capacity and throughput capacity were calculated using the following equations.

Flesh-seed ratio (FSr): A number of chillies with peduncle were weighted. Based on moisture content, it was done thrice. After separating seeds manually, the seeds were weighted. The flesh-seed ratio is calculated as

$$FSr = \frac{\mathrm{Sw}}{\mathrm{Tw}} \qquad (1)$$

Where, FSr=Flesh-seed ratio, S_w = Weight of seed (g) , Tw= Total weight of chilli (g)

Throughput capacity (C_t): It is the measure of quantity of chillies processed by the machine per unit time. It was calculated using Equation 2.

$$C_t = \frac{\mathrm{Mf}}{\mathrm{T}} \qquad (2)$$

Where, C_t = throughput capacity (kg h^{-1}), M_f= Mass (kg) of Chilli fed into the machine and T= processing time (s) from seed extraction till flakes out

Seed separation capacity (C_s): It is the measure of quantity of chilli seeds processed by the machine per unit time. It was calculated using Equation 3.

$$C_s = \frac{\mathrm{Ms}}{\mathrm{T}} \qquad (3)$$

Where, C_s = Seed separation capacity (kg h^{-1}), M_s= Mass (kg) of chilli seed separated at the seed outlet. T= processing time (s) from feeding into hopper to flakes removal

Friction loss (C_l): After seed separation, the seeds not found in seed outlet but anywhere is friction loss.

$$C_l = (FSr - \frac{Ms}{Mf}) \times 100 \qquad (4)$$

Where, C_l = Friction loss (%), FSr=Flesh-seed ratio, M_s= Mass (kg) of seed separated at the seed outlet, M_f= Mass (kg) of chilli fed into the machine

Seed separation efficiency (Se): Separation efficiency defines the ratio of the amount of material separated in the system to the amount of material to be separated entering the system.

$$\mathrm{Se} = \frac{\mathrm{Mf}-\mathrm{Ms}}{\mathrm{Mf}} \times 100 \qquad (5)$$

Where, Se = Separation efficiency (%), M_s= Mass (kg) of seed separated at the seed outlet, M_f= Mass (kg) of chilli fed into the machine

Results and Discussion

The performance of the chilli seed separator was evaluated with dry chilli having moisture content between 11-22.23% wb during 2020-2021, is shown in Table 2. It was observed that the average capacities of the seed separation and throughput were found to be 2.07 kg/h and 47.18 kg/h respectively. It was also found that seed separation efficiency was 88.71% and friction loss was 8.59%. However, there was no case of injured seed but unthreshed chilli percentage was found 0.5-1.3. The maximum capacity was obtained from minimum moisture content of chilli.

Table 2. Performance of the chilli seed separator

Trial No	Feed rate (g)	Time required (sec)	Flesh-seed ratio	Moisture content, %	Seed separation capacity, (kg/h)	Friction loss (%)	Throughput capacity (kg/h)	Seed separating efficiency (%)
1	510.0	35.49	0.45	11.00	2.16	8.70	51.31	89.05
2	725.0	51.7	0.45	11.00	2.21	8.66	50.49	89.43
3	813.0	59.87	0.49	17.70	2.06	7.98	48.88	87.06
4	670.0	51.23	0.49	17.70	1.98	8.55	47.07	87.32
5	1023.0	85.61	0.46	22.23	2.05	9.27	43.02	88.54
6	643.3	54.68	0.46	22.23	1.97	8.40	42.33	90.85
Average					2.07	8.59	47.18	88.71

Effect of the extraction method on seed quality was determined from seed germination and seedling emergence percentage. A hundred of seeds from both the treatments were kept in petridish for 15 days under ambient temperature and the result is shown in table 5. No remarkable effect was seen on seed quality, germination percentage and seedling emergence for mechanical extraction method. Effect of the extraction method on seed quality for dry chilli is shown in Table 3.

Fig. 5. Effect of seed extraction method on seed germination.

Fig. 6. Effect of seed extraction method on seedling emergence.

Table 3. Effect of the extraction method on seed quality for dry chilli

Treatments	Moisture content, wb (%)	Seed Germination (%)	Seedling Emergence (%)
Manual seed separation	11	95	94
Manual seed separation	11	97	97
Mechanical seed separation	22.23	98	98
Mechanical seed separation	22.23	97	95

The comparative performance of power and manual seed separation methods are presented in Table 4. It was observed that mechanical separation capacity was 25 times more efficient than that of manual separation method. Power extraction saves time at a rate of 29 times than that of manual method. There was 8.59% friction loss and 1.3% unthreshed chillies in power separation.

Table 4. Comparative performance of power and manual seed separation method for dry chilli

Parameters	Power peeling	Manual Peeling
Moisture content (%)	11	11
Throughput capacity (kg/h)	47.18	1.6
Time required/kg chilli, second	76.32	2250
Machine speed, rpm	1500	--
Friction loss (%)	8.59	--
Unthresed berries (%)	0.9	00
Injured seed, (%)	0	0
Seed Germination (%)	97	97

Financial Analysis

The fabrication price of the chilli seed separator was calculated including cost of materials, labour, overhead, incidental expenses and manufacturing profit

Break-even point of dehusker

Break-even point was calculated including fixed cost and variable cost. Fixed cost included two cost items namely capital consumption and shelter, whereas variable cost included labour, electricity, and R & M. It was observed that BEP of the machine was 80 hours per year. Therefore, chilli seed separator machine could be profitable to traders when the annual use of the machine exceeds 80 h.

Table 5 Cost analysis of BARI chilli seed separator

Sl.no.	Items		Amount, Tk.
1	Purchase price (P)		35000.00
2	Fixed cost calculation	(P-S)*CRF+S*i	8050.00
	where, P= Purchase price, S= Salvage value (10% of P), L= life (6 years), i= Bank interest rate (5%)		
3	Capital Recovery Factor (CRF)	$(i*(1+i)^L)/((1+i)^L-1)$ =0.20	
4	Fixed cost (2+3); Tk./yr		8050.00
5	Required labour	2	
6	Labour charge, Tk/day	500	
7	Working period days/year	80	
8	Labour cost, Tk/year	2*00*80	80000.00
9	Required fuel, tk/hr	50	50.00
10	Fuel cost	50*80	4000.00
11	Repair & maintenance, Tk/year	3.5% of purchase price	1225.00
12	Variable cost(8+10+11), Tk/year		85225.00
13	Total separating cost (4+12), Tk/year		93275.00
	Average separating capacity, kg/h	47.18 kg/h	
	Separating capacity, kg/yr	47.18*5*80	18872.00
	Separating Cost, Tk/kg		5.63
Gross return			
14	Custom hire rate, Tk/kg	Tk 11.25/kg	
15	Total net return, Tk/year	Tk 5.62/kg*18872	106060.64
16	BCR (15/13)		1.2

Conclusion

A cost effective power operated chilli seed separator was designed and fabricated for both the farmers and stakeholders. This machine can reduce drudgery and generate rural employment in our country. The average throughput capacity was found 47.18 kg/h and average seed separating capacity was 2.07 kg/h. It was observed that mechanical separation capacity was 25 times more efficient than that of manual extraction method. Power extraction saves time at a rate of 29 times than that of manual method. Average seed separating efficiency was 88.71%. No notable effect was found in germination percentage or seedling emergence due to machine extraction. The economic analysis shows a positive BCR of 1.2 value. It will be profitable to the farmers when a minimum use of 80 hours per year is sustained.

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EXPT NO. 4.9 IMPROVEMENT OF TOMATO SEED SEPARATOR CUM PULPER

T N BARNA, M A HOSSAIN, M N AMIN

Abstract

Bangladesh produces 388 thousand tons of tomato per year in an area of 70 thousand acres. There is still no effective mechanical approach of separating tomato seeds from fruits. Moreover, the fruit portion of the tomato is totally wasted in conventional method. The mechanical method is a better solution to this problem. Therefore, a power operated tomato seed separator was designed and fabricated at Farm Machinery and Postharvest Process Engineering Division, BARI during 2019-20 and was improved during 2020-21. Modifications were done on the seed separating unit and power transmission system. The average seed separation capacity was found 2.44 kg/h, average friction loss was 8.45%, average throughput capacity 49.52 kg/h and average seed separation efficiency was 93.95%. Extracting capacity of machine was 9 times greater than manual extraction. The average pulping capacity was found 45.94 kg/h, average cylinder loss 11.23 % and average cleaning efficiency was 62.12%. The pulp was finely crushed but the pulp outlet got stuck while continuous heavy feeding. The peels got accumulated on the openings of pulper. Modifications need to be done to improve the pulping part. No seed injury was observed as well as no significant effect was found in germination or seedling emergence due to machine extraction. The experiment will be continued to the next year for improvement of its performance.

Introduction

Tomato is one of the most popular vegetable crops with high economic value. It ranks next to potato and sweet potato in respect of vegetable production in the world (FAO, 2010). Bangladesh produces 388 thousand tons of tomato per year in an area of 70 thousand acre (BBS, 2019). Tomato farming is gaining popularity everywhere in the country as it is now considered the second cash crop and plays an important role in the economy, financially benefiting at least 0.2 million families in northern region of the country. According to officials at the Department of Agriculture Extension (DAE), the cultivation has been increased by five to six times during the last 15 to 20 years (Financial express, 2018). To retain the production potential moving, the necessity of quality seed production is a must. Seed quality is a vital input of crop production. Seeds are separated manually all over the country. In Bangladesh, tomato seed is processed in conventional method requiring the labor to cut tomatoes into pieces and draw out the middle part inside stale water. The seeds are then rubbed inside water in bare hands to remove them from the cluster and gel sac. Tomato seeds are enclosed in a gel-like sack that contains growth inhibitors, which prevent the seeds from sprouting inside fruit. So, the removed seeds are then fermented for a couple of days. After fermentation, the seeds are dried. Farmers often deliberately let the ripe tomatoes to degrade due to ease of removing the seeds. But a mechanical intervention can ease the seeding process to a facile level as well as can let the ripe tomato pulp get utilized by pulping the ripe fruit altogether during seed extraction. Therefore, the present experiment was conducted considering the need for this machinery.

Objectives

a) To improve the tomato seed separator cum pulper
b) Testing and performance evaluation of the tomato seed separator

Materials and Methods

A Tomato seed separator cum pulper was designed and fabricated by FMPE division during 2019-20. The seed separating shaft slowed down during continuous feeding. So the machine was improved during 2020-21. It consists of two main parts, the rotating drum part squeezes the seed out of tomatoes and the pulping part crushes the fruit into kneading pulp. It was made of locally available materials. Construction materials and major components of tomato seed separator is given in Table 1. The modified parts are stated in Table 2.

Table 1. Construction materials and major components of tomato seed separator

Sl. No.	Items	Specification	Materials
1	Overall dimension, mm	540×640×910	
2	Main frame, mm	560×335×470	MS angle
3	Drum dimension, mm	510× 260ϕ	MS pipe
4	Semi-circular press pleat	445×457.2	SS sheet
5	Seed separating Shaft size, mm	700×25ϕ	MS round bar
6	Fluted roller dimension, mm	510×55ϕ	Rubber sole
7	Primary hopper size, mm	530×470×18	SS sheet
8	Seed outlet, mm	495.3×533.4	MS sheet
9	Crushed tomato outlet, mm	381×355.6×177.8	MS sheet
10	Secondary hopper size, mm	127×127ϕ	MS sheet
11	Casing of spiral roller, mm	292.1×120ϕ, 127 ×120ϕ,	MS pipe
12	Pulping Shaft size, mm	700×25ϕ	MS round bar
13	Spiral roller , spiral size, mm	292.1×88ϕ, 16	MS pipe, MS rod
14	Spiral cone, spiral size, mm	127×88ϕ, 10	MS sheet curved and welded
15	Pulp outlet. mm	4.45ϕ	MS ring
16	Motor	0.38kW, 1450 rpm	Single phase, AC
17	Fixed pulley, mm	76.2, 177.8	Cast iron
18	Sprocket, mm	228.6,685.8	Hardened alloy steel
19	Belt, pitch size, mm	86,44	A-size, v-belt

Table 2. The redesigned parts of the machine compared with the previous model

Sl. No.	Parts	Previous model 2019-2020	Modified model 2020-2021
1	Seed separating shaft	Belt -pulley	Chain sprocket
2	Belt of separating shaft	A-86 V belt	Chain
3	Pulley of separating shaft	482.6 mm pulley	Sprocket
4	Chain-sprocket between pulping shaft and seed separating shaft	-	228.6 mm and 685.8 mm

The functional parts of the separator are described as follows:

1. Power source: A single phase AC motor of 0.37kW, 50Hz, 220V, 2.9 Amp. capacity and 1450 rpm is used.
2. Seed separating unit:
This portion comprises of a circular drum folded with rubber sole. Behind it, is a SS perforated press pleat attached with two controllable springs. The seed outlet is placed behind the semi-circular press pleat and this pleat ends at the crushed tomato outlet.

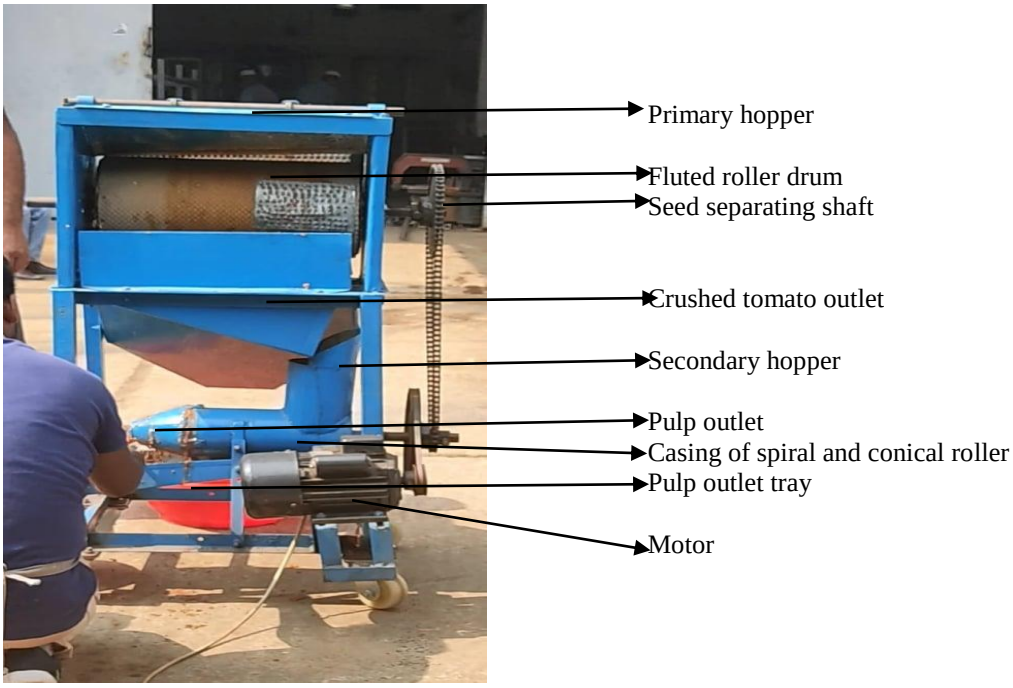

Fig. 1. Tomato seed separator cum pulper.

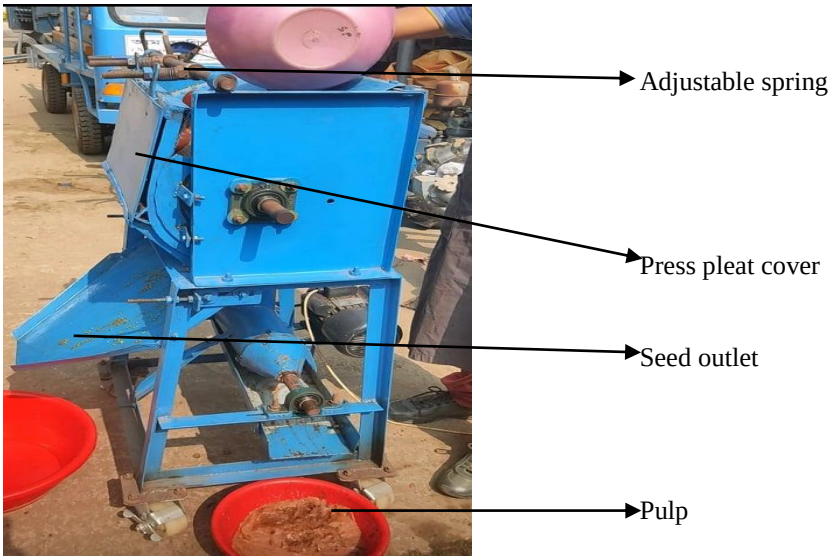

Fig. 2. Tomato seed separator cum pulper in operation.

3. Pulping unit:

The crushed tomato outlet ways out at the secondary hopper inlet. The pulper casing is a funnel shaped pentagon which can be opened and closed through three nuts and bolts. The pulping shaft holds the spiral roller attached with a spiral cone. The roller is spirally welded with a 16mm notched rod and the attached cone is welded with a 10 mm notched MS rod. The conical casing has rifts in between to remove extra juice and the mouth has leaks to accumulate the pulp.

Power transmission system: The system includes a motor, V-belt, chain-sprocket and two fixed pulleys. The electric motor is attached with a 76.2 mm pulley with V-belt (specification: A44) driving 254 mm pulley coupled with the pulping shaft. The pulping shaft conjoin a 228.6 mm sprocket that transmits power linking the seed separating shaft via a 685.8 mm sprocket affiliated by roller chain. The rated speed of the electric motor is 1450 rpm. In the first step, rpm was stepped down from 1450

rpm to 420 rpm through drive and driven pulley. Likewise, the rpm was further reduced to 175 in the seed separating rotary cylinder. The power transmission system is shown in fig 3.

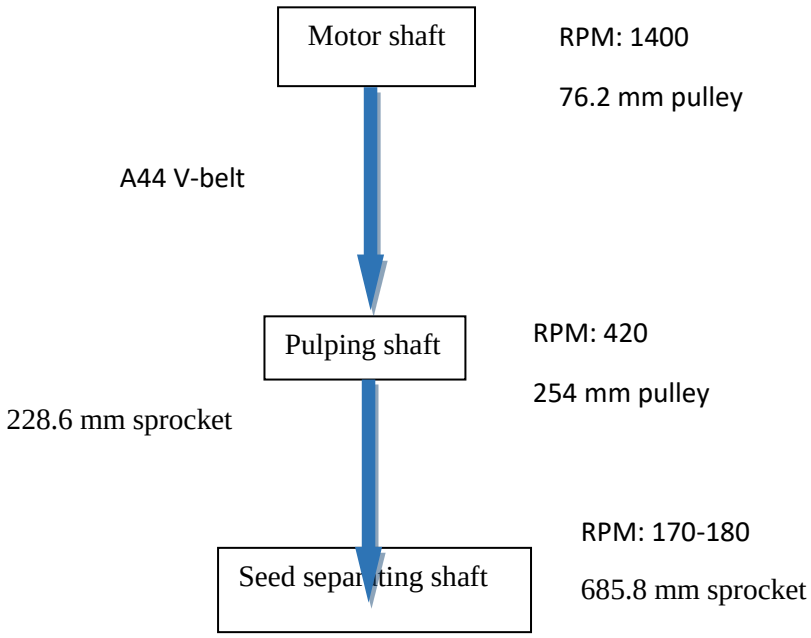

Fig. 3. Power transmission flow chart.

Working principle

Ripe tomatoes are fed into the hopper. The midst of the fluted roller drum and press pleat squeeze out the tomato seeds. The separated seeds drop in the seed outlet within the perforated press pleat. Meanwhile the crushed tomatoes fell inside the pulping cylinder and the spiral roller kneads the tomatoes into fine pulp. Conical shaped spiral roller is attached at the end of spiral roller which mashes and kneads the tomatoes into fine pulp. The pulp outlet effuses the pulp into pulp tray.

The photographs of tomato seed separator in operation, extraction and pulping are shown in Fig. 4.

Tomato being fed into hopper.

Crushed tomato falling in secondary hopper.

Tomato pulp being collected.

Tomato seeds being collected.

Fig. 4. Tomato seed separator in operation.

Testing and performance evaluation

Ripe tomatoes of 48.4-92.7% moisture content were used for performance testing. No load or mock testing were done to check for desired rpm and performance. The performance parameters (Choszcz et.al 2020) are described below:

Flesh-seed ratio (FSr): A number of tomatoes were collected and weighted. After separating seeds manually, the seeds were weighted. The flesh-seed ratio is calculated as

$$FSr = \frac{\mathrm{Sw}}{\mathrm{Tw}} \quad (1)$$

Where, FSr=Flesh-seed ratio, S_w = Weight of seed (g) , Tw= Total weight of tomato flesh+ seed (g)

Throughput capacity (C_t): It is measure of quantity of tomatoes processed by the machine per unit time. It was calculated using Equation 2.

$$C_t = \frac{\mathrm{Mf}}{\mathrm{T}} \quad (2)$$

Where, C_t = throughput capacity (kg h^{-1}), M_f= Mass (kg) of tomato fed into the machine and T= processing time (s) from seed extraction to pulping

Seed separation capacity (C_s): It is measure of quantity of tomato seeds processed by the machine per unit time. It was calculated using Equation 3.

$$C_s = \frac{\mathrm{Ms}}{\mathrm{T}} \quad (3)$$

Where, C_s = Seed separation capacity (kg h^{-1}), M_s= Mass (kg) of tomato seed separated at the seed outlet. T= processing time (s) from seed extraction to pulping.

Friction loss (C_r): After seed separation, the seeds attached to the crushed tomato is friction loss.

$$C_r = (FSr - \frac{Ms}{Mf}) \times 100 \quad (4)$$

Where, C_r = Friction loss (%),M_s= Mass (kg) of tomato seed separated at the seed outlet, M_f= Mass (kg) of tomato fed into the machine

Seed separation efficiency (Se): Separation efficiency defines the ratio of the amount of material separated in the system to the amount of material to be separated entering the system.

$$\mathrm{Se} = \frac{\mathrm{Mf}-\mathrm{Ms}}{\mathrm{Mf}} \times 100 \quad (5)$$

Where, Se = Separation efficiency (%), M_s= Mass (kg) of tomato seed separated at the seed outlet, M_f= Mass (kg) of tomato fed into the machine

Pulping capacity (C_p): It is measure of quantity of crushed tomatoes processed by the machine per unit time.

$$Cp = \frac{Mp}{Tp} \quad (6)$$

Where, Cp = Pulping capacity (kg h^{-1}), M_p= Mass (kg) of crushed tomato fed into secondary hopper and Tp = processing time (s) for pulping

Cylinder loss (C_l): For pulping, the pulp stuck inside the machine is cylinder loss.

$$C_l = \frac{Mp - Mo}{100} \quad (7)$$

Where, C_l = Cylinder loss (%),M_p= Mass (kg) of crushed tomato fed into secondary hopper *Mo* =Mass (Kg) of pulp in the pulp outlet

Cleaning efficiency (Ce): It describes the effectiveness of a pulping process. It is the ratio of the amount of material separated in the system to the amount of material to be separated entering the system.

$$Ce = \frac{Mp - Mo}{Mp} \times 100 \quad (8)$$

Where, C_e = Cleaning efficiency, (%),M_p= Mass (kg) of crushed tomato fed into secondary hopper *Mo* =Mass (Kg) of pulp in the pulp outlet

Results and Discussion

After the modification of the seed separating shaft, the seed separator cum pulper was tested with both semi-ripe, ripe and over-ripe tomatoes. The problem faced with previous model was, the rotation of the seed separating shaft was found to vary as feed rate increased. After modifying the power transmission system, the problem resolved this year. It was observed that, the performance was better with over ripen tomatoes. It varied with ripening and firmness index. However, the relationship was not established with present data. It will be done upcoming year.

Machine performance was evaluated based on the equations mentioned above. The seeding part performance is elaborated in Table 3 and the pulping part performance is elaborated in Table 4. It was found that, machine performance is better with higher moisture content of tomato. No belt slippage was observed as the transmission system has been changed. The average seed separation capacity was found 2.44 kg/h, average friction loss was 8.45%, average throughput capacity 49.52 kg/h and average seed separation efficiency was 93.95%.

Table 3. Performance of the tomato seed separator cum pulper

Trial No	Feed rate (g)	Time required (sec)	Flesh-seed ratio	Moisture content (%)	Seed weight, (g)	Seed separation capacity, (kg/h)	Friction loss (%)	Throughput capacity (kg/h)	Seed separating efficiency (%)
1	521	36.23	0.139	92.7	35.56	2.52	7.08	51.76	93.12
2	590	43.34	0.139	92.7	36.96	2.55	7.64	49.02	93.74
3	670	50.16	0.145	71.3	40.87	2.44	8.40	48.23	94.00
4	610	44.00	0.145	71.3	37.88	2.42	8.29	49.92	93.79
5	570	41.40	0.151	48.4	30.55	2.36	9.74	49.58	94.64
6	513	37.98	0.151	48.4	28.52	2.33	9.54	48.64	94.41
Average						2.44	8.45	49.52	93.95

After the seed separation process, the crushed tomatoes are automatically fed into secondary hopper through crushed tomato outlet. The spiral roller, casing and the inner part of the pulper holds an amount of pulp which cannot be retrieved unless the machine is washed. The average pulping capacity was found 45.94 kg/h, average cylinder loss 11.23 % and average cleaning efficiency was 62.12%. The pulp outlet got stuck while loading more than 5 kg of tomatoes continuously. Although the pulp was finely crushed with a small number of 3.3% impurities (i.e seed and skin), the opening of the pulping part needs further improvement.

Table 4. Performance of the tomato seed separator cum pulper

Trial No	Feed rate (g)	Time required (sec)	Flesh-seed ratio	Moisture content (%)	Seed weight, (g)	Flesh weight without seed, (g)	Pulp weight (g)	Pulping capacity, (kg/h)	Cylinder loss (%)	Cleaning efficiency (%)
1	521	36.23	0.139	92.7	35.56	485.44	179.61	47.87	9.12	63.03
2	590	43.34	0.139	92.7	36.96	553.04	198.43	45.55	9.10	64.12
3	670	50.16	0.145	71.3	40.87	629.13	237.62	44.81	10.91	62.23
4	610	44.00	0.145	71.3	37.88	572.12	217.17	45.39	11.09	62.04
5	570	41.40	0.151	48.4	30.55	539.45	215.67	46.44	13.74	60.02
6	513	37.98	0.151	48.4	28.52	484.48	187.69	45.58	13.40	61.26
Average								45.94	11.23	62.12

Mechanical means are introduced in agricultural operation to reduce time and drudgery. Tomatoes were taken for both manual and power extraction for a period of time and within the middle of time, a portion was considered ideal for the comparison of both the extraction methods. Comparative performance of power and manual seed extraction method is shown in Table 5. Machine extraction reduced time at the rate of 9 times than that of manual method. The capacity of power extraction is 9.01 times higher than manual extraction. No significant effect was found in germination due to machine or manual extraction. However, there's a friction loss of 8.45% in case of machine extraction. A tomato seed is typically encased in a gel sac. The gel sac prohibits germination. The tomato itself is a perfect environment for seed germination. It naturally suppresses germination by encasing the seeds. The machine extraction doesn't still have prohibition for removing the gel sac of tomato seeds. After mechanical extraction, the seeds are fermented for 2/3 days to remove the gel sac. In manual extraction, the gel is instantly removed and the seeds are ready to be sun dried and stored.

Table 5. Comparative performance of power and manual seed extraction method

Parameters	Power extraction	Manual extraction
Moisture content (%)	71.3	71.3
Weight of tomatoes, gram	510	510
Time required, sec	40	360
Throughput capacity (kg/h)	45.54	5.01
Machine speed, rpm	1480	--
Cleaning loss (%)	8.45	0
Injured seed, (%)	0	0
Seed separating efficiency (%)	93.95	100
Seed Germination (%)	98	98

Fig. 5. Effect of seed extraction method on seed germination.

Conclusion

The machine can separate seeds from small to large size tomatoes as it has variable spring press controller. It is a cost effective power operated tomato seed separator cum pulper which can add extra income from wastage tomato flesh processed as tinned, canned or sauce and ketch up. This will add extra income to the farmers and stake holders. This machine can reduce drudgery and generate rural employment in our country. Based on the result and discussion, the rotational speed did not vary further along with feed rate after the modification done this year. The pulp outlet stuck during continuous heavy feeding of tomatoes. The experiment will be continued to the next year for improvement of the study.

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EXP NO. 4.10 PERFORMANCE EVALUATION OF FLAT BED DRYER FOR MAIZE DRYING

M A HOQUE, M HOSSAIN, S K BISWAS AND M A HOSSAIN

Abstract

Drying is the removal of moisture by the application of heat and drying is practiced to maintain the quality of grains during storage to prevent the growth of bacteria and fungi and the development of insects and mites. The safe moisture content for cereal grain is usually 12 to 14% moisture on a wet basis. Seed moisture content is one of the factors which determine whether or not seed can be stored safely without loss of germination and vigor. The maize grains were dried in flat dryer in Farm Machinery and Postharvest Process Engineering Division, BARI, Gazipur during 2019-20. Maize grains were dried in a flat dryer at 60, 50 and 40°C to find out the drying temperature and drying time. The lowest time required to dry from an initial moisture content of 30% (wb) to final moisture of 14% (wb) was 9 hours at 60°C when air velocity was 1.5 m/s and grain thickness was 20 cm. The lowest time required to dry from an initial moisture content of 26% (wb) to final moisture of 12% (wb) was in 5 hours at 60°C when air velocity was 1.5 m/s and grain thickness was 10 cm. Drying characteristics for different loading capacity, air velocity and temperature will be determined and economic analysis will be done in the next year.

Introduction

Maize is a food material for both humans and animals. Its annual production is 3569321 tons (BBS, 2019) in Bangladesh. Bangladesh is facing a problem of malnutrition due to high population growth and low productivity of crops. The traditional crop including rice and wheat are unable to meet up the nutritional requirements to the increasing population. So, it is a time demand to introduce a new crop like maize to the existing cropping pattern of the country. Maize can be a potential grain crop for nutritional support to the country population. Moreover, the country environment is more suitable for cultivation of this crop. Storage of maize by farmers is difficult. It is more hygroscopic than paddy and wheat and thus, absorbs moisture from the air quickly. Consequently, grain quality is deteriorated due to a fungus disease commonly called mycotoxin which is more harmful when used as food and feed. Its moisture content should be below 13.5%. Such a high degree of drying on earthen yards is difficult with maize, but is easily possible with paddy. Sometimes maize absorbs moisture when left on earthen floor or kept stored in jute bags. Actually, the optimum temperature for the growth of storage fungi is between 29°C to 35°C (Sidiq, 2017). Maize harvested in the monsoon is especially difficult to store because the humidity rises to above 80 percent. Ondier *et al.* (2010) reported that low- temperature, low relative humidity drying of rough rice resulted in moisture removal rate was high at primary stage of drying process followed by a gradual leveling of the drying curve. The deduction in drying rate at the termination of drying may be due to the drop of surface moisture as drying process advances (Tiwari *et al.*, 1994). Similar outcomes were also pointed from the study of (Sharma and Prasad, 2001).

Production and preservation of maize is important to make it available throughout the year. The preservation of maize can be regarded as one of the first and most important processing technique. Maize is usually harvested with high moisture contents that make its storability difficult; to overcome this maize dryer is an important. Maize drying is a vital operation which involves removal of moisture from the cobs/grains. High moisture of maize will deteriorate the grain quality rapidly due to respiration and heating, mould (fungal) growth, subsequent incidence of mycotoxins (e.g., Aflatoxin) and increase insect multiplication. The optimum moisture content of maize should be 14% or less. For maize, sun drying is very common which is laborious and frequently deteriorated due to bad weather. During continuous rains, huge amounts of maize are damaged due to lack of proper drying techniques.

Objectives

1. To evaluate the performance of flat dryer for maize drying
2. To analysis the economic performance of the dryer

Materials and Methods

Description of Flat dryer

The experiment was conducted in a flat dryer. This dryer was designed and fabricated at Suncue com. Ltd. The specification of the flat bed dryer is shown in Table 1. The dryer basically consisted of a heating unit and a drying unit. A Pictorial view of a flat dryer is shown in Fig.1. A brief description of flat dryer is given below. The overall dimension of the dryer was 5077 x 2458 x 1740 mm. The loading capacity of the dryer was 2000 kg of maize seeds. Effect of drying air temperature and velocity were investigated for drying of maize in the flat dryer. A direct heating way was connected in side of the dryer to draw the atmospheric air in the dryer and to push out the heated air with a desired air velocity. Air flow was controlled by a regulator connected to the blower. A temperature controller along with a sensor was set in the drying chamber to maintain constant temperature in the dryer. The drying tray was located at the extreme end of the dryer. The hot air was passed through the product and distributed in the drying area. The tray was made of aluminum frame and iron net. The drying air was heated with fire burned by kerosene in the heating unit. The drying air came from the heating unit through some pipes of small diameter. The hot air then moved to the drying unit, flew through the drying tray and exhausted through the dried product.

Treatments

Three different temperatures i.e. 60, 50 and 40 ^{o}C were used as temperature treatments. The samples were dried up to the constant weights of safe moisture content (14%). This experiment was conducted to determine the optimum drying temperature of maize seeds. The maize seeds were dried in the temperature 60, 50 and 40^{0}C. The initial moisture content of seeds was 26% (weight basis) and it was dried up to final moisture content (about 12% wb) at the temperature of 60, 50 and 40^{0}C. These temperatures were taking for drying of maize. When temperature was 40 ^{0}C the colour of maize was the best. But it is the temperature considered for maize seed drying. For grain storage the drying temperature was taken as 50 and 60 ^{0}C the colour of maize grain was not changed. But drying temperature above 60 ^{0}C deteriorated the grain colour of maize.

Experimental procedure

Maize seeds (BARI Hybrid Bhutta-13) were obtained from Farm Machinery and Post-Harvest Engineering Division and the experiment was conducted in Bangladesh Agricultural Research Institute during 2020-21. The flat bed drying chamber was loaded with 1000 kg maize. The average thickness of bed was 10.0 cm. Periodical weight reduction data were collected from different two location of the drying bed. Then average data were taken for moisture curve. Initial seed moisture content was determined taking three samples of seeds which were randomly collected from the bulk harvest and by drying at 105^{o}C in an oven for 24 hours. The initial seed moisture content was about 26 % (wb). Drying experiments were performed at different drying temperature to determine the optimum drying temperature of maize seeds. Before starting an experimental run, the whole apparatus was operated for at least one hour to stabilize the drying air temperature and air velocity in the dryer. Drying was started and continued until it reached the constant moisture content. Weight losses of the samples in the dryer were recorded during the drying period at half an hour interval with an electronic balance. The temperature of ambient air and drying air temperatures were measured with a digital thermometer connected with k type thermocouples. Air velocity affects the drying rate over a certain range and above this range drying rate becomes independent of air velocity. Air velocity has effect on the dried product. So, drying air velocity was maintained at 1.5 m/s. Velocity of drying air was measured with a thermo-anemometer. After completion of drying, the dried samples were collected, cooled in a desiccator to the ambient temperature and then sealed it in the plastic bags.

Table 1. Specifications of flatbed dryer

Model	SKS-580M High-temp direct heat type
Heating Way	Direct
Dimension L × W × H (mm)	5077 × 2458 × 1740
Net weight (kg) approx.	Double layer: 955
Type	Gun type
Max.Combustion (approx.)	7.8 liter/h
Temp. range (Ambient Temp.)	20℃~ 40 ℃
Fuel	Kerosene / Premium diesel
Electricity	3P, 220v / 380v / 415v / 440v , 50Hz / 60Hz
Power Consumption	1.55kW
Drying Bin Double Layer	9.10 m^3, 8.76m^2

(a) Flat dryer

(b) Sample of BARI Hybrid Bhutta-13

(c). Drying chamber

Fig.1. Pictorial view of the flat bed dryer and dried grains.

Results and Discussion

Effect of temperature on drying rate

The effects of drying temperatures on the moisture content of maize grains in the drying time found in 2019-2020 was shown in Fig. 2. Time required to dry maize grain in flat bed dryer from an initial moisture content of 30% (wb) to final moisture of 14% (wb) was 9 hours at 60°C.When drying temperature was 50 ^{0}C, the required drying time was 14 hours to dry from initial moisture content of 30% (wb) to final moisture of 14% (wb). Again when the maize grain drying was conducted at 40 ^{0}C, the drying time requirement was 17 hours. Drying time decreased with the increase of drying air temperature. The lowest drying time was required to dry in 60 ^{0}C. The reduction of drying time during drying at 60 ^{0}C was 55.55% and 88.88% compared with the drying time required in 50 ^{0}C and 40 ^{0}C.

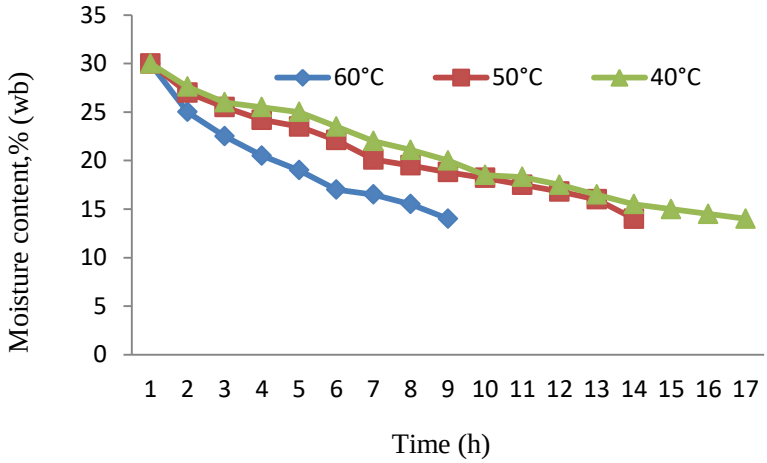

Fig. 2. Effect of different drying temperature on moisture content of maize.

Time required to dry maize grain in flat bed dryer from an initial moisture content of 26% (wb) to final moisture of 12% (wb) was 5 hours at 60°C.When drying temperature was 50 ^{0}C, the required drying time was 6.5 hours to dry from initial moisture content of 26% (wb) to final moisture of 12%

(wb) (Fig. 3). Again, when the maize grain drying was conducted at 40 ^{0}C, the drying time requirement was 8 hours. Drying time decreased with the increase of drying air temperature. The lowest drying time was required to dry in 60 ^{0}C.

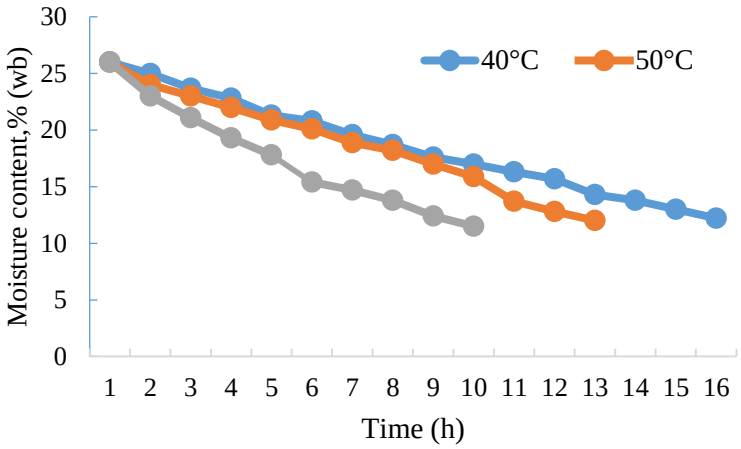

Fig. 3. Effect of different drying temperature on moisture content %, (wb) of maize.

Conclusion

The drying temperature and drying time for the maize grains have been determined experimentally. Drying time in flat bed dryer was found 8, 6.5 and 5 hours at drying temperature of 40, 50 and 60 ^{0}C, respectively to obtain the final moisture content was found 12% (wb). The lowest drying time was recorded in drying at 60 ^{0}C. Drying time was reduced with the increase in drying temperature. Drying characteristics will be determined for different loading capacity, air velocity and initial moisture variability in the next year. The economic analysis will be also done in the next year to evaluate suitability of the flat bed dryer for maize grain drying.

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EXPT NO. 4.11 DEVELOPMENT OF A SUITABLE FRUIT BAGGING TOOL

M HASAN, M N AMIN, M S MIAH AND M R KARIM

Abstract

Several good agricultural practices (GAP) are becoming popular throughout the world for the production of high-quality fruit with less dependence on chemicals. Among such practices, pre-harvest fruit bagging has emerged as an effective method for producing good quality fruits. Manual bagging method is the most common method for fruit bagging in the tree. Due to different heights, most of the fruits are not possible to use bag easily. For this reason, this method is very effective for different heights of the trees where the manual bagging is not possible. A baging tool was fabricated using locally available materials such as plastic pipe, MS sheet, nut-bolts, bamboo, nylon rope, elastic garter, fruit covering bag etc. During operation the minimum time for fruit bagging was 37 sec and the maximum time for fruit bagging was 47 sec and the average time required for bagging of a mango was 42.4 sec. It depends on operators' skill. Though there are some problems in fruit bagging tool, but after improvements it will be useful for both the residential growers and commercial cultivators. The total weight of the machine is 1.0 kg. The price of the machine is calculated about Tk. 1000. The experiment will be continued next year to make it more effective.

Introduction

Fruit bagging is a physical protection method which has been used extensively in several fruit crops to improve skin color and to reduce the incidence of disease, insect pests, mechanical damage, sunburn of the skin, agrochemical residues on the fruits and bird damage. Recently different methods are being practiced for crop improvement to avert the losses caused by biotic and abiotic factors throughout the world. The tool for the development of techniques to improve the yield, appearance, quality of fruit and to reduce disease and insect infestations is becoming increasingly important. This is to raise awareness towards reducing the use of pesticides to ensure worker safety, consumer health, and environmental protection (Sharma *et al.*, 2009). The bags are more importantly used for the export markets and processing units by improving production and quality of fruit. Bagging may offer direct and almost full protection from mechanical damages (scratches, fruit dropping), birds, physiological disorders caused by the climate (sun scald, cracking, splitting), pests and diseases which are the major cause of heavy losses. These protective effects have been frequently conveyed in regard to many types of fruits, indicating a clear favorable result.

Preharvest fruit bagging has been a popular physical protection technique in several countries, such as China, Japan, and the United States. It is an effective way to improve fruit appearance, control pests and diseases, and reduce pesticide residues (Amarante *et al.*, 2002; Hofman *et al.*, 1997; Huang *et al.*, 2009; Sharma and Sanikommu, 2018). China is the largest fruit planting and output area in the world (Wu, 2017). Lower quality and poor market competitiveness are concerning problems for Chinese fruit growers (Zhang, 2017). Fruit bagging is a favorable solution to raise fruit prices and increase economic benefits for Chinese fruit farmers (Guo, 2017; Li *et al.*, 2016; Matsumoto *et al.*, 2018; Sharma *et al.*, 2014; Zhou *et al.*, 2019). Compared with the single-layer fruit paper bag, the multilayer fruit paper bag has been used more widely, because it provides larger lightproof property and lower temperature for better coloration of fruits (Zhao and Wu, 2015). The fruit bagging process with ordinary multilayer paper bag consists of the following major steps: taking out one bag, opening the bag, putting the young fruit into the bag, and sealing the upper end of the bag. Because of the complicated operation process, automatic fruit bagging machinery suitable for the ordinary multilayer fruit paper bag is still in the research phase.

Research on mechanical fruit bagging machinery for paper fruit bags dates back to the 1990s (Monta *et al.*, 1995a). Monta *et al.* (1995b) and Li *et al.* (2011) developed a bagging end-effector that could open or close the bag by pressing two leaf springs, which were set face to face at the upper end of the bag. Hua *et al.* (2016) developed a portable, low-cost semiautomatic fruit bagging apparatus. The bag was fit with rubber bands along the rim and four plastic rings on its four corners, and could be delivered by a screwed pipe and slid out individually. Xu *et al.* (2007) developed an automatic bag-opening mechanism that could separate piled bags one by one by using a couple of vacuum sucking pans, and enlarge the bag inside maximally through arc fingers. Four wires were set on the upper end of the bag. Leng (2015) invented a bag-opening device that could separate two sides of the bag by

magnet attraction. Many metal wires were set on the front side of the bag. Zhang (2016) designed an apple bagging apparatus that opened the bag by two pneumatic suction cups.

Most previous studies were based on robot technology (Fang, 2011; Ge, 2005; Wang, 2016; Wen *et al.*, 2017), and the structure of the fruit paper bag has been improved to simplify the bagging operation. Those research achievements have not been widely applied in China because of cost considerations. According to the special terrain feature of Chinese orchards, a cheap auxiliary fruit bagging device is more desirable and applicable than the expensive automatic fruit bagging robot (Wang *et al.*, 2018). A type of manually operated fruit bag case has been widely used in Chinese orchards, as shown in Fig. 1. The fruit paper bags are set in the fruit bag case by the spring-driven push plate and two bottom side plates. The snap plate on the upper side of the fruit bag case presses against the crescent of the outermost bag, so that the upper end of the outermost bag forms a small opening. In the process of artificial fruit bagging, farmers hang the fruit bag case on their right side. They first hold their right-hand fingers together to form a taper, then insert the held fingers into the outermost bag, and finally pull their hand outward to take the outmost bag out of the fruit bag case, and extend the held fingers to open the bag fully. The device is suitable for an ordinary single-layer paper bag, but not the ordinary multilayer fruit paper bag. As the inner bag of the multilayer paper bag is every thin and easy to adhere, taking out one bag and opening it fully by hand is time-consuming, labor intensive, costly, and it is easy to bring out a broken bag. In addition, it is possibly dangerous to the farmers' health because their hands need contact with the inner bag repeatedly. Therefore, there is a demand for a mechanized method of taking out and opening the ordinary multilayer fruit paper bag for fruit bagging.

Bagging is a physical protection technique, which improves their visual quality and also reduces the occurrence of fruit cracking and changes the microenvironment for fruit development (Fan and Mattheis, 1998). Bagging affects the size and the weight of apple (Arakawa *et al.*, 1994), banana (Rajan *et al.*, 2017), pomegranate (Padmavathamma and Hulamani, 1996) etc. The increase in temperature inside bagging results in improving fruit size or a result of humidity increase (Wang *et al.*, 2007). There are also studies showing bagging did not affect fruit size and yield (Jia *et al.*, 2005) During low temperature condition, the bagging techniques are used for the protection of several fruits and has been shown to reduce winter stress under optimal condition, which resulted in early fruit maturation (Muchui *et al.*, 2010). This "bagging" method is useful in protecting the fruits from the attack of fruit flies and also prevents the laying of eggs by the moth. Cloth bags, paper sacks or plastic bags can be used.The bagging materials and forms gave the best quality of fruits, regulate the forms on pest incidence and find out which of the bagging resources and forms gave the highest yield and net income. Fruit bagging also improved the fruit quality in terms of TSS, total sugars and TSS: acid ratio. Birds are major pests at the fruit-ripening stage in fruit such as banana, mango, apple, and date, and cause economic losses. Fruit bagging is one of the best may practice to preventing bird damage of fruit. Bagging is commonly applied to many fruits for improving quality, protecting from pests, extreme environmental conditions, and pesticide residues (Sharma *et al.*, 2014). Therefore, this study has been undertaken to develop a fruit bagging tool which will help the user for bagging of fruits at different heights of the trees more comfortably and easily.

Objectives

a) To design and fabricate a fruit bagging tool
b) To evaluate the performance of the fabricated fruit bagging tool

Materials and Methods

The fabrication work of a fruit bagging tool was completed at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute (BARI), Gazipur during 2020-2021. It was made with locally available materials. The materials used for fabrication of different parts of the fruit bagging tool were plastic pipe, MS sheet, bamboo, nylon rope, elastic rubber band, fruit covering bag, nut-bolt etc. Pictorial and operational views of the tool is shown in Fig.1 and 2.

Description of the fruit bagging tool

The materials used for this tool are locally available and very cheap. The materials used for this tool are plastic pipe, MS sheet, nut-bolts, bamboo, nylon rope, elastic garter, fruit covering bag etc. The total weight of the machine is 1.0 kg. Major components of the fabricated fruit bagging tool with specifications are shown in Table 1.

Table 1. Specifications of developed fruit bagging tool

Sl. No.	Particulars	Values
01	Plastic cylinder length (L), mm	175
02	Plastic cylinder inner diameter of upper side (Ø) , mm	84
03	Plastic cylinder inner diameter of lower side (Ø) , mm	90
04	Thickness of plastic cylinder, mm	4.5
05	Taper length, mm	20
06	Elastic rubber band circle from the upper surface, mm	10
07	Clamp outer diameter (Ø), mm	27
08	Clamp inner diameter (Ø), mm	26
09	Length of the clamp, mm	130
10	Length of bamboo handle, mm	2240
11	Diameter of bamboo (Ø), mm	26
12	Length of the nylon rope, mm	2500
13	Hole diameter in plastic cylinder (Ø), mm	3.5
14	Weight of bagging tool, kg	1.0

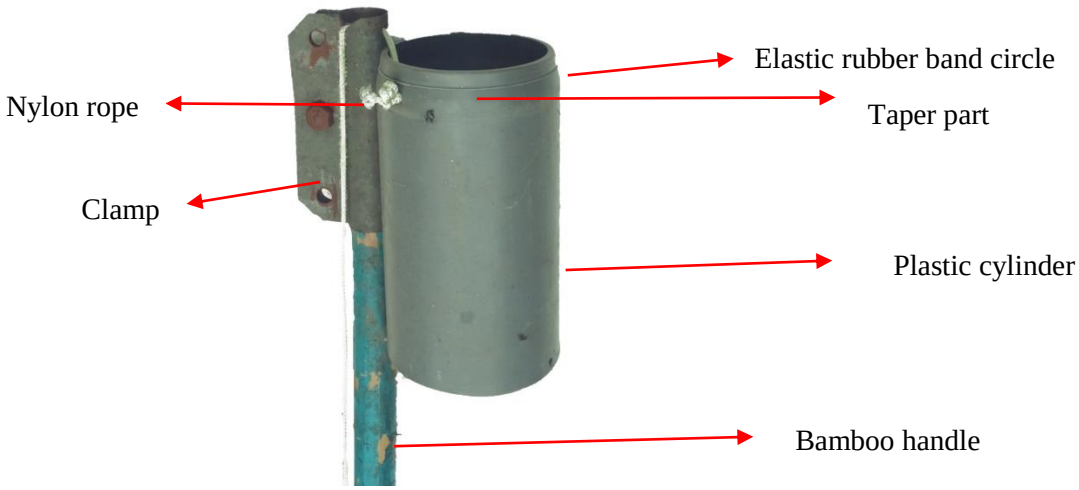

Fig. 1. Pictorial view of the fabricated fruit bagging tool.

Fig. 2. Operational view of the fruit bagging tool.

Results and Discussion

The fabricated fruit bagging tool was tested for bagging mango in a mango tree at the Engineering Complex of BARI campus. At first, the elastic rubber band was set on the elastic rubber band circle of the plastic cylinder pulling the top portion of the rope making U-shape into the elastic rubber band. Then the fruit covering bag was set into the plastic cylinder. The bagging of mango was done by the pulling of the rope of the tool. This method was very effective for different heights of the trees where the manual bagging was not possible. Five brown fruit bags were taken as sample test. Performance of the fabricated fruit bagging tool is given in the Table 2.

Table 2. Performance of fabricated fruit bagging tool

Sample nos	Fruit bag and elastic rubber band setting time (sec)	Fruit bagging time (sec)	Total time required for bagging (sec)	Average time required for bagging (sec)
1	32	15	47	
2	30	12	42	
3	35	10	45	42.4
4	28	13	41	
5	25	12	37	

Performance of fruit bagging tool is shown in Table 2. From the Table 2, it was observed that the average time required for bagging of a mango was 42.4 sec. During operation of the tool, some problems were observed. The tightness of the elastic rubber band was not enough for this brown fruit bag, so some improvement should be done in the next year.

Conclusion

The fabricated fruit bagging tool was tested for bagging mango in a tree at the FMPE Division, BARI, Gazipur. At first, the elastic rubber band was set on the elastic rubber band circle of the plastic cylinder that holding the rope into the elastic rubber band. Then the fruit covering bag was set into the plastic cylinder. The bagging of mango was done by the pulling the bottom portion of the rope of the tool. This method was very effective for different heights of the trees where the manual bagging was not possible. Five brown fruit bags were taken as sample test. It was observed that the average time required for bagging of a mango was 42.4 sec. During operation of the tool, some problems were observed. The tightness of the elastic rubber band was not enough for this brown fruit bag, so the proper selection of elastic rubber band and fruit covering bag are needed for better results. Moreover, some improvements of the tool should be done. This tool will be more appropriate for guava bagging with polythene bag. This experiment will be continued next year to make it more effective.

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EXPT NO. 5.1: UP-SCALING AND APPLICATION OF SOLAR PHOTOVOLTAIC PUMP FOR SMALLHOLDER IRRIGATION AND HOUSEHOLD APPLIANCES IN THE CENTRAL COASTAL REGION OF BANGLADESH

M A HOSSAIN, M A HOQUE, S S A KAMAR, M A RAHMAN

Abstract

Bangladesh is endowed with abundant supply of solar energy. With the advancement of technology, the price of photovoltaic panel is declining remarkably. The uses of solar-powered irrigation system are increasing in developing countries. BARI has developed a solar pump based solar home system (SHS). Six solar pumps along with SHS were installed for field trials in six Upazila of Barguna, Patuakhali and Bhola districts with 1300 W_p solar panel for each pump and one solar pump was installed at BARI, Gazipur. A field experiment was conducted in the research field of FMPE Division, BARI, Gazipur for testing of solar pump drip irrigation system during rabi season of 2020-21. The tested crop was tomato (BARI Tomato-14). A mini solar pump of 280 W motor capacity and flow rate of 40 L/min was designed, fabricated and installed among 12 farmers in the project areas as per the demands and affordability of the farmers. In farmers' fields, experiments were conducted with three treatments such as drip, alternate furrow and farmers' practice (every furrow irrigation) during the Rabi season of 2020-21 for tomato, brinjal and chilli. For watermelon three treatments such as drip, ring basin irrigation and farmers' practice (every furrow irrigation) were set up. In farmers' fields, the highest yield was obtained from drip irrigated tomato, brinjal, chilli and watermelon than other treatments. Water savings from alternate furrow and drip irrigation methods for tomato were 32% and 49%, brinjal were 29% and 51%, chilli were 35% and 62% respectively. Water savings in watermelon by ring basin irrigation method and drip method over farmers' practice in different locations southern region were 34% and 55%, respectively. For solar irrigation in vegetables MBCR (Marginal benefit cost ratio) of large solar pump, mini solar pump, shallow tubewell and low lift pump was found to be 1.88, 1.28, 1.21 and 1.56, respectively. The selected farmers in the project areas are using solar panel for lighting, operation of fan, supplying of drinking water, sanitation, etc. Therefore, BARI solar pump may be recommended for irrigation and operation of household appliances, especially in the off-grid areas.

Introduction

Solar-powered irrigation systems are increasingly in demand in developing countries as they can provide a cost-effective and clean solution to increase agricultural productivity (FAO, 2015). In Bangladesh, there are 1.77 million irrigation pumps of which 1600 are solar power operated. The government has targeted to install about 50,000 solar pumps by 2025 (IDCOL, 2019). There is 68% irrigation coverage in the country out of which 82% is covered by diesel engine operated pumps and 18% by electric motor operated pumps. So, during the peak irrigation period 2000 MW of power demand is solely required for running the electric pumps. The diesel-run irrigation pumps on the other end consume more than half a million tons of diesel. Although initial capital costs are high, with the help of subsidies, the operating cost of a solar pump is about half that of a diesel operated pump and has almost zero carbon emissions (FAO, 2015).

In the southern region, irrigation coverage is about 50% which is less than the national irrigation coverage. Land remains fallow due to scarcity of irrigation water during the rest periods of the year although surface water is abundant in southern zone (Bala and Hossain, 2010). If a suitable water lifting device can be introduced in low cost, this water resources can be utilized for boost up crop production. Government of Bangladesh has taken the 'Master Plan for Development in the Southern Region', to increase cropping intensity on currently fallow and rainfed crop land using surface water irrigation (MoA and FAO, 2012). Surface water is perceived as being abundant in parts of the south where river and canal networks have perennial flow, and where salinity levels do not cross crop-damaging thresholds. Surface water irrigation, therefore, offers a means by which double cropping could be encouraged on southern Bangladesh's fallow or rainfed and water-stressed dry season land, which is estimated about 800000 ha. Solar pump may be an alternative to diesel operated pumps for irrigating vegetables in the off-grid area especially in the char areas of Bangladesh.

Bangladesh is endowed with abundant supply of solar energy. The ranges of solar radiation are between 4.0 and 6.5 kWh/m^2/day and the bright sunshine hours vary from 6 to 9 hours/day (Biswas and Hossain, 2013). At present photovoltaic (PV) cell is expensive which the main reason for its low

acceptance is. But with the advancement of technology, the price is declining remarkably. Hossain *et al.* (2014) studied the performance of solar pump for irrigation in rice and non-rice crops. They concluded that solar pump is technically and economically suitable for irrigation in vegetables (BCR 2.22) but not economically viable for Boro rice (BCR 0.31).

Therefore, an experiment was undertaken and the upscaling of BARI solar pump was done increasing the capacity from 100 L/m to 180 L/m during 2018-19. The performance test of the developed solar pump and home appliance was conducted last year and found satisfactory result. Another mini solar pump was developed for homestead irrigation as well as using solar home system for small farmers in southern region. During 2020-21, experiments were conducted for field trials of large and small solar pumps for irrigation of high value crops and use solar panels for solar home systems.

Objectives

a) Up-scaling and improvement of solar pump for higher capacity and efficiency
b) Test the efficacy of application of solar energy for pumping and household appliances for year round uses, and
c) Field trials of solar pump for irrigation of high value crops and year round uses of solar energy in household appliances in the central coastal region of Bangladesh

Materials and Methods

Design of solar pump and household appliances

Two categories of solar pumps (Large and mini) were designed, fabricated and installed in the selected project sites with SHS (Solar Home System) and irrigation in the project areas. A solar pump of 910 W dc motor capacity and 180 L/min flow rate was designed and fabricated according to the farmers' needs as obtained from base line survey. Another solar pump of 280 W motor capacity and 40 L/min flow rate was designed and fabricated according to the demands and affordability of farmers as obtained from field demonstrations during 2019-2020. The large centrifugal pump having inlet and outlet diameters of 51 mm was coupled with a 910 W DC motor having a flow rate of 180 L/min. The mini solar pump (smaller one) having inlet and outlet diameter of 25 mm was coupled with a 280 W DC motor and has a discharge of 40 L/min. The performance of the pumps was tested in the testing bed of FMPE Division, BARI, Gazipur. Six sets of large solar pumps were installed for farmers' field trials in the selected six Upazila. Field experiments were conducted during Rabi season of 2020-2021 with two categories of solar pumps in all locations. Pictorial views of solar pumps tested at FMPE Division, BARI, Gazipur are shown in Fig. 1.

a. Large solar pump (910 W, 180 L/min)

b. Solar panel (1300W @325W)

c. Mini solar pump (280W, 40L/min)

d. 365Wp ARCO PV at FMPE Mosque

Fig.1. Photographic views of solar pumps and SHS testing at Gazipur.

Selection of solar panel for pump and SHS

Considering the characteristics of solar panels available in the market and the environmental condition in Bangladesh, the selected solar panel size was calculated out to be, 162.16 W×2 = 324.32 $W_p \cong 325$ W_p. The specification of selected solar panel is given in Table 1. Thus, the solar panel (325 W_p) was used for large model and the solar panel (365 W_p) was used for mini model.

Table 1. Specification of selected solar panel

Type	Poly-crystaline
Brand and make of solar module	Chinaland, China
Model	CHN325-72P
Rated peak power (P_{max})	325 W_p / 365 W_p
Size of each module	1950 mm×990 mm×40 mm
Rated voltage (V_{mp})	37.70 V
Rated current (I_{mp})	8.62 A
Open circuit voltage (V_{oc})	44.90 V
Short circuit current (I_{sc})	9.10 A
Firerating	CLASS-A

Installation of large solar pumps in farmers' fields

Six fabricated solar pumps and SHSs were installed at farmers' fields of Kolapara and Golachipa upazilas of Patuakhali district, Borguna Sadar and Amtoli upazila of Borguna district and Charfassion and Lalmohon upazila of Bhola district. Names and addresses of selected farmers for solar pump demonstrations for irrigation and SHSs at different locations are given in Table 2.

Table 2. Names and addresses of selected farmers for large solar pumps

District	Upazilla	Farmer's name	Address
Patuakhali	Galachipa	1. Md. Sohrab Hossen Jomaddar	Village: Nijsuhuri Post- Office: Badura Cell-01771498643
	Kalapara	2. Zillur Rahman Bashir	Village:Masuakhali, Post- Office: Champapur Cell-01721187235
Borguna	Borguna Sadar	3.Md. Sajahan Mia	Village: Kumrakhali Post- Office: Baowalkor Cell-01794792557
	Amtoli	4.Md. Nur Alam	Village: Amragassiya, Post- Office: Kukuya Cell-01719985151
Bhola	Charfassion	5.Fazle Ali Biswas	Village: Aowajpur Post- Office: Sosibhuson Cell-01745375589
	Lalmohon	6.Nurul Islam Mia	Village: Dholigouronagar, PO: Dholigouronagar Cell-01951024682

Fabrication and installation of mini solar pumps in farmers' fields

Mini solar pump was made with 25 mm centrifugal pump directly coupled with 280 W DC motor. The performance of the pump was tested in the testing bed of FMPE Division, BARI, Gazipur. Seven numbers of fabricated mini solar pumps and SHSs were installed at farmers' fields of Kolapara and Golachipa upazila of Patuakhali district, Borguna Sadar and Amtoli upazila of Borguna district and Charfassion and Lalmohon upazila of Bhola district. Names and addresses of selected farmers for mini solar pump demonstration for irrigation and SHSs at different locations are given in Table 3.

Table 3. Names and addresses of selected farmers for mini solar pumps

District	Upazilla	Name of farmer	Address
Borguna	Borguna Sadar	1.Md. Milon	Village: Gazi Mahmud Post- Office: Nissan Baria Cell-01726826920
	Borguna Sadar	2.Md. Abdul Rabb	Village: Kotbaria Post- Office: Kotbaria Cell-01729326604
	Amtali	3.Md. Delowar	Village: Purbo Chunakhali Post- Office: Hat Chunakhali Cell-01725729528
	Amtali	4.Md. Abdur Razzak Mia	Village: North Ghotkhali Post- Office: Ghatkhali Cell-01768912667
Patuakhali	Galachipa	5.Md. Bablu Jomadder	Village: South Charbiswas Post- Office: Charbiswas Cell-01747146648
	Galachipa	6.Md. Firoz Rari	Village: Boro Char Kajol Post- Office: Chatkajol Cell-01759664282
	Galachipa	7.Sukha RanZan Vhat	Village: Soto Siba Post- Office: Soto Shiba Cell-01739400305

On-station Field Experiments

A field experiment was set with solar pump irrigation system for tomato in the research field of FMPE Division during the rabi season of 2020-2021.The experiments were laid out in RCB design with three treatments and four replications. The treatments were T_1= Drip irrigation system, T_2= Alternate furrow irrigation system, T_3= Farmers practice (control). Total land areas including tomato was 250 m^2 and individual plot size was 17.5 (5×3.5) m^2. The seedlings of tomato (BARI Tomato-14) were planted on 6 December 2020. Fertilizers were applied as recommended doses (FRG, 2018). The weeding and pesticide spraying were done as and when necessary. The tomato was harvested during February-March, 2021. Pictorial views of the field experiments are shown in Fig. 2.

a. Tomato field

b. Harvested tomato

Fig. 2. Field experiments of solar irrigated tomato in FMPE research field.

Field Experiments in project sites with large solar pump

During the rabi season of 2020-21, vegetables (tomato and brinjal) were planted in the selected farmers' fields in Patuakhali, Barguna and Bhola districts under solar pump irrigation systems. The selected varieties of tomatoes were Super and Super Bijli as these varieties are popular in the areas. BARI Bt Begun-1 was transplanted in all locations. Row to row and plant to plant distances of tomato and brinjal were 60 cm and 40 cm and 100 cm and 75 cm, respectively. The name and address of field experiments with large solar pumps were given in Table 4. Experiments of tomato and brinjal were laid out in RCB design with three treatments and four replications. The treatments were T_1= Drip irrigation system, T_2= Alternate furrow irrigation system and T_3= Farmers' practice i.e. every furrow irrigation (control).

Table 4. The name and address of field experiments with large solar pump

District	Upazila	Farmers Name	Unit plot size, m^2	Crops	Date of Planting	Date of harvesting
Barguna	Barguna Sadar	Md. Sajahan Mia	20.8 m^2 (5.2 m×4 m)	Tomato (Super bijli)	07 Jan 2021	March-April
	Amtali	Nur Alam	32 m^2 (8 m×4 m)	Brinjal (BARI Bt Begun-1)	05 Jan 2021	March-April
Patuakhali	Galachipa	Md. Sohrab Hossen Jomaddar	18 m^2 (6 m×3 m)	Brinjal (BARI Bt Begun-1)	09 Jan 2021	March-April
Bhola	Lalmohon	Nurul Islam Mia	16.2 m^2 (6 m×2.7 m)	Tomato (Super)	25 Nov 2020	Feb-March
	Charfassion	Fazle Ali Biswas	32 m^2 (8 m×4 m)	Brinjal (BARI Bt Begun-1)	16 Jan 2021	Feb-March

The Photographic views of field experiments at Patuakhali, Barguna and Bhola Districts during 2020-21 Rabi season with large solar pump at different crops were given below in Fig. 3.

a. Tomato at Barguna Sadar

b. Harvesting brinjal Amtali

c. Harvested brinjal at Galachipa

d. Tomato field at Kolapara

e. Brinjal field at Charfassion

f. Tomato at Lalmohon

Fig.3. Photographic views of field experiment in Patuakhali, Barguna and Bhola with large solar pump for different crops.

Field Experiments with mini solar pump

Before beginning Rabi season of 2020-2021, BARI developed a mini solar pump and SHS. The installment was during Rabi season of 2020-21. Vegetables (tomato, brinjal,Chilli, and watermelon) were planted in the selected farmers' fields of Patuakhali, Barguna and Bhola districts under mini solar pump irrigation systems. The varieties Manik, Super Bijli of tomato, BARI Bt Begun-1 of Brinjal, Kanya and Dragon variety of watermelon and BARI Marich-1 and Bombai of Chilli were transplanted in all locations respectively. Row to row and plant to plant distances of tomato, brinjal and chilli were 100 cm and 80 cm, respectively. But row to row and plant to plant distance of water melon was 300 cm and 150 cm, respectively. The name of farmers and their address under field experiments with 40 L/min solar pump were given below in Table 5.

Experiments of tomato and brinjal and chilli were laid out in RCB design with three treatments and four replications as T_1= Drip irrigation system, T_2= Alternate furrow irrigation system, T_3= Farmers' practice i.e. every furrow irrigation (control). Experiments of watermelon were conducted in RCB design with four replications and three treatments were T_1= Drip irrigation system, T_2= Ring basin irrigation system and T_3= Farmers' practice.

Table 5. The name of farmers and their address under field experiments with mini solar pump

District	Upazila	Farmers Name	Unit plot size,m^2 (m×m)	Crops	Date of Planting	Date of harvesting
Barguna	Barguna Sadar	Milon	17.76 (4.8 ×3.7)	Brinjal (BARI Bt Begun-1)	08 Jan 2021	March-April
		Md. Abdul Rabb	30 (10 ×2.7)	Watermelone (Dragon)	16 Jan 2021	April-May
	Amtali	Md. Delowar	7.02 (2.7 ×2.6)	Watermelone (Dragon)	10 Jan 2021	April-May
		Md. Abdur Razzak Mia	37.5 (15 ×2.5)	Watermelone (Dragon)	22 Jan 2021	April-May
Patuakhali	Galachipa	Md. Bablu Jomadder	18 (6 ×3)	Chilli (BARI Marich-1)	20 Jan 2021	March-May
		Md. Firoz Rari	50 (20 ×2.5)	Watermelone (Dragon)	25 Dec 2020	April-May
		Sukha RanZan Vhat	200.16 (7.2 ×2.8)	Brinjal (Super Muhini)	25 Nov 2020	March-May

		Md. Monir dhali	27 (10 ×2.7)	Watermelone (Kanya)	16 Jan 2021	April-May
		Md. Delower Hossain	7.02 (2.7 ×2.6)	Chilli (Bombai)	14 Jan 2021	March-May
	Kolapara	Md. Joynal Abedin	18 (6 ×3)	Brinjal (BARI Bt Begun-1)	31 Jan 2021	March-May
Bhola	Lalmohon	Md. Jasim uddin	32 (8 ×4)	Tomato (Super Bijli)	21 Dec 2020	Feb-March
	Charfassion	Md. Abdul Kadir	10.4 (2.6 ×4)	Tomato (Manik)	16 Jan 2021	Feb-March

The Photographic views of field experiments at Patuakhali, Barguna and Bhola districts during Rabi season of 2020-21 irrigation with mini solar pump for different crops are given in Fig. 4.

a. Brinjal at Barguna Sadar, Barguna

b. Water melonat Barguna Sadar, Barguna

c. Watermelon at Amtali, Barguna

d. Watermelon at Galachipa, Patuakhali

e.Brinjal at Kolapara, Patuakhali

f.Chilli at Charkajol, Patuakhali

g. Toamto at Lalmohon, Bhola

h. Tomato at Charfassion, Bhola

Fig. 4. Photographic view of field experiments at different locations irrigated by mini solar pump for different crops.

Results and Discussion

Performance of the large solar pump

The performance of large solar pump with solar radiation at 1.20 m suction head tested at FMPE pump test bed, BARI, Gazipur is shown in Fig 5. A positive relationship was found among voltage, current, discharge and solar radiation. The average voltage, current and discharge were found 25.75V, 12.38 A, 180.00 L/min at 723.86 W/m^2 solar radiation. The highest discharge was found 202.34 L/min at 1.30 pm at 886 W/m^2 solar radiation and at that time the voltage and current were also recorded as 30.35 V and 16.76 A, respectively. Motor speed (rpm) increased with the increase of voltage and the discharge also increased with the motor speed.

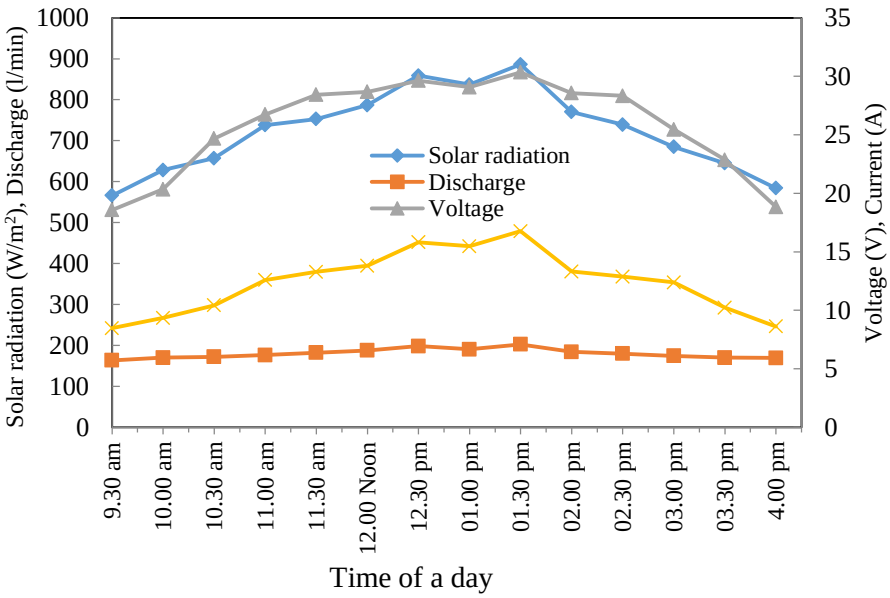

Fig 5. Relationship among voltage, current, discharge and solar radiation at the suction head of 1.20 m on 18 February 2020 in Gazipur.

The large solar pump was also tested at different suction heads as shown in Fig. 6. At 0.46, 0.91, 1.37, 1.68, 1.98, 2.90 and 3.35 m suction heads the discharges were found 182.56, 180, 145.40, 132.32, 122.61, 96.67 and 87.46 L/min, respectively. The discharge decreased with the increase of suction heads. The highest and the lowest discharges were found 182.56 and 87.46 L/min. at 0.46 and 3.35 m suction heads, respectively.

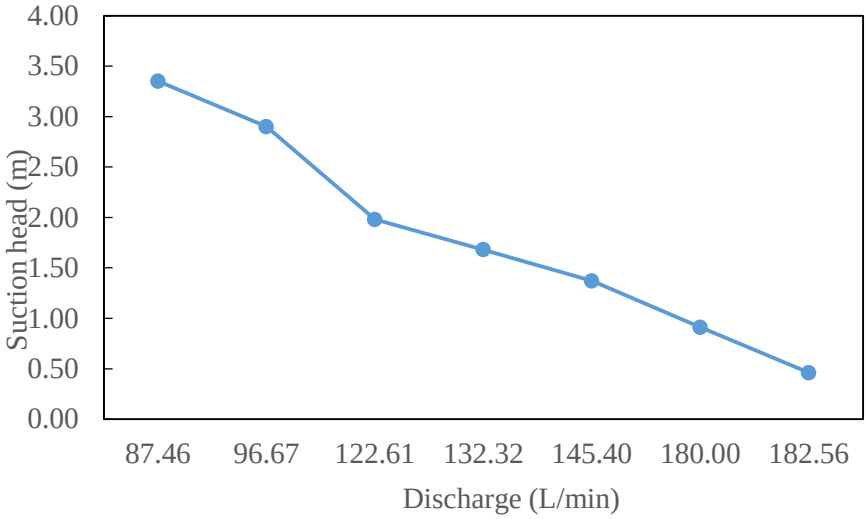

Fig 6. Discharges of large solar pump at different suction heads.

SHS status in the project sites

The results of field tests of solar home systems (DC mode) at different locations are given in Tables 6-11. The performance of solar home systems was found quite satisfactory.

Table 6. Field performance of SHS at Galachipa, Patuakhali

Item	PV (W)	Battery (W)		Name of appliances	Numbers/ quantity	Power per appliance (W)/services	Total Load (W)/ quantity	Remarks
		AH	Volt					
SHS	325	100	12	Light Fan Mobile phone	4 2 1	7 12 8	28 24 8	Working well
Water supply	1300			Sanitation and drip irrigation	500 L tank	Yard tap Basin tap Toilet tap Bath tap	1 1 1 2	Improved sanitation and hand wash

Table 7. Field performance of SHS at Kolapara, Patuakhali

Item	PV (W)	Battery (W)		Name of appliances	Numbers/ quantity	Power per appliance (W)/services	Total Load (W)/ quantity	Remarks
		AH	Volt					
SHS	325	100	12	Light Fan Mobile phone	5 2 2	7 12 8	35 24 16	Working well
Water supply	1300			Sanitation and drip irrigation	500 L tank	Basin tap Toilet tap Bath tap	1 1 2	Improved sanitation and hand wash

Table 8. Field performance of SHS at Barguna Sadar, Borguna

Item	PV (W)	Battery (W)		Name of appliances	Numbers/ quantity	Power per appliance (W)/services	Total Load (W)/ quantity	Remarks
		AH	Volt					
SHS	325	100	12	Light Fan Mobile phone	6 2 2	7 12 8	42 24 16	Working well
Water supply	1300			Sanitation and drip irrigation	500 L tank	Basin tap Toilet tap Bath tap Kitchen tap	1 1 2 1	Improved sanitation and washing

Table 9. Field performance of SHS at Amtali, Barguna

Item	PV (W)	Battery (W)		Name of appliances	Numbers/ quantity	Power per appliance (W)/services	Total Load (W)/ quantity	Remarks
		AH	Volt					
SHS	325	100	12	Light Fan Mobile phone	3 1 1	7 12 8	21 12 8	Working well
Water supply	1300			Sanitation and drip irrigation	500 L tank	Basin tap Toilet tap Bath tap Yard tap	2 3 2 1	Improved sanitation and hand wash

Table 10. Field performance of SHS at Lalmohon, Bhola

Item	PV (W)	Battery (W)		Name of appliances	Numbers/ quantity	Power per appliance (W)/services	Total Load (W)/ quantity	Remarks
		AH	Volt					
SHS	325	100	12	Light Fan Mobile phone	7 4 2	7 12 8	49 48 16	Working well
Water supply	1300			Sanitation and drip irrigation	500 L tank	Basin tap Toilet tap Bath tap	2 3 2	Improved sanitation and hand wash

Table 11. Field performance of solar pump and SHS at Charfassion, Bhola

Item	PV (W)	Battery (W)		Name of appliances	Numbers/ quantity	Power per appliance (W)/services	Total Load (W)/ quantity	Remarks
		AH	Volt					
SHS	325	100	12	Light Fan Mobile phone	8 3 2	7 12 8	56 36 16	Working well
Water supply	1300			Sanitation and drip irrigation	500 L tank	Basin tap Toilet tap Bath tap	2 3 2	Improved sanitation and hand wash

The multiple uses of solar pumps and solar panels in different household and solar home appliances at Patuakhali, Barguna and Bhola district are shown in Fig. 7

a. SHS at Amtali, Barguna

b. SHS at Barguna Sadar, Barguna

c. SHS at at Kolapara, Patuakhali

d. SHS at Galachipa, Patuakhali

e. SHS at Lalmohon, Bhola

f. SHS at Charfassion, Bhola

Fig. 7. SHS and householad uses of solar pump at different locations.

Results and Discussion

On-station experiments

Yield and yield contributing parameters of tomato in different irrigation methods are shown in Table 12 Significantly highest tomato yield was found from treatment T_1 (Drip irrigation) followed by treatments T_2 (Alternate furrow irrigation) and T_3 (Furrow irrigation). The lowest yield was found from T_3 (Furrow irrigation). Yield parameters among the treatments were found insignificant except unit fruit weight.

Table 12. Yield and yield contributing parameters of tomato in different treatments in Gazipur

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	103.33	41.59	108.2a	5.28	5.28	63.29a
AFI	100.36	41.11	95.57b	4.99	4.99	57.21b
FP	98.13	39.53	92.96b	4.86	4.86	52.86b
CV	4.85	3.38	11.95	5.53	5.53	5.66
LSD	8.45	2.38	20.31	0.48	0.48	5.65

Note: AFI=alternate furrow irrigation, FP= Farmers' practice (every furrow irrigation)

Seasonal water use by irrigation sequences

Water applied by different irrigation methods by solar pump for irrigation in tomato is shown in Table 13. It is observed from the table that about double amount of water was required in farmers' practice i.e. furrow irrigation than drip method. Irrigation water savings in tomato by alternate furrow method and drip method over farmers' practice were 49.63%, and 35.21% respectively. So, drip irrigation method was found the best water saving technology for tomato cultivation followed by alternate furrow irrigation method.

Table 13. Water savings in different treatments of tomato

Treatment	Applied water (mm)	Water saving over furrow irrigation (%)
Drip	206	49.63
AFI	265	35.21
FP	409	-

Experiments at farmers' fields

Crop: Tomato

Yield and yield contributing parameters of tomato at different project locations were shown at different locations are shown Tables 14-16. The significantly the highest yield was found from drip irrigation than alternate furrow irrigation followed by farmers practice or every furrow irrigation (FP) treatments. But alternate furrow irrigation (AFI) and furrow irrigation (FP) were statistically similar.

Table 14. Yield and yield contributing characters of tomato at Boguna Sadar, Boguna

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	154.98 a	39.82 a	89.05 a	5.23 a	5.23 a	35.01 a
AFI	136.22 b	34.02 b	82.06 ab	4.72 ab	4.50 ab	29.60 ab
FP	131.44 b	27.42 c	77.18 b	4.43 b	4.06 b	25.09 b
CV	7.25	3.12	5.8	7.45	11.82	12.11
LSD	17.69	1.82	8.31	0.61	0.94	6.26

Note: AFI=alternate furrow irrigation, FP= Farmers practice (every furrow irrigation)

Table 15. Yield and yield contributing characters of tomato at Lalmohon, Bhola

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	149.61 a	42.90 a	92.32 a	5.30 a	5.28 a	40.70 a
AFI	130.85 b	37.09 b	85.33 ab	4.79 ab	4.55 ab	35.29 ab
FP	126.07 b	30.50 c	80.45 b	4.50 b	4.15 b	30.78 b
CV	7.54	6.89	5.58	7.35	11.69	10.18
LSD	17.69	4.39	8.31	0.62	0.94	6.26

Table 16. Yield and yield contributing characters of tomato at Matabbar bari, Charfassion, Bhola

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	82.75 a	41.72 a	88.33	6.89	6.59	44.29a
AFI	80.45 ab	35.46 b	86.42	6.6	6.47	38.41b
FP	76.40 b	34.94 b	85.52	6.4	6.35	37.69b
CV	4.23	6.48	4.38	4.33	5.01	7.13
LSD	5.84	4.19	6.57	0.49	0.56	4.95

Water applied by different irrigation methods by solar pump for irrigation in tomato is shown in Table 17. It is observed from the table that about double amount of water was required in farmers' practice

than drip method. Irrigation water savings in tomato by alternate furrow method and drip method over farmers' practice in different locations of southern region were, 28-32% and 47-49%, respectively. So, drip irrigation method was found the best water saving technology for tomato cultivation followed by alternate furrow irrigation method.

Table 17. Amount of water applied and water savings in tomato in different treatments at different locations

Treatments	Boguna Sadar, Borguna		Lalmohon, Bhola		Charfassion, Bhola	
	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)
Drip	225	48.28	235	48.69	247	48.11
AFI	294	32.41	325	29.04	342	28.15
FP	435	-	458	-	476	-

Crop: Brinjal

Yield and yield contributing parameters of brinjal at different project locations were shown in Table (18-22). The highest yield of brinjal was obtained from drip irrigation than AFI and FP methods. But it was statistically similar with FP.

Table 18. Yield and yield contributing characters of brinjal at Galachipa, Patuakhali

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	77.91	41.68 a	89.7	9.32	2.26	47.71
AFI	75.96	37.08 b	87.77	9.07	2.16	44.62
FP	74.25	35.90 b	80.25	8.06	1.91	44.04
CV	13.58	2.96	6.96	12.89	10.89	9.85
LSD	17.87	1.96	10.35	1.96	0.39	7.75

Table 19. Yield and yield contributing characters of brinjal at Amtali, Barguna

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	81	40.75 a	88.98 a	12.89	3.49	47.49
AFI	79.05	36.75 b	82.39 ab	12.64	3.39	44.4
FP	77.34	35.50 b	79.15 b	11.63	3.14	43.82
CV	13.05	3.16	4.94	9.18	6.89	9.89
LSD	17.87	2.05	7.15	1.96	0.39	7.74

Table 20. Yield and yield contributing characters of brinjal at Barguna Sadar, Borguna

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	75.93	40.35 a	95.55	10.90 a	2.5	38.88
AFI	73.98	35.75 b	93.62	10.65 a	2.4	35.81
FP	72.27	34.57 b	86.1	9.64 b	2.15	35.27
CV	13.94	3.07	6.52	5.59	9.78	8.36
LSD	17.87	1.96	10.35	1.00	0.39	5.3

Table 21. Yield and yield contributing characters of brinjal at Kolapara, Patuakhali

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	74.78	51.61	83.58 a	14.37 a	7.96 a	45.1
AFI	73.17	47.85	76.99 ab	13.62 ab	7.74 ab	42.01
FP	72.61	43.7	73.75 b	12.75 b	7.16 b	41.43
CV	8.03	10.06	5.29	5.23	5.88	10.44
LSD	10.22	8.31	7.15	1.22	0.77	7.74

Table 22. Yield and yield contributing characters of brinjal at Charfassion, Bhola

Treatment	Plant length (cm)	No. of fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Yield (t/ha)
Drip	72.04	49.43 a	82.40 a	14.19 a	7.17 a	42.35
AFI	70.43	45.67 b	75.81 ab	13.44 ab	6.95 ab	39.26
FP	69.87	41.52 c	72.57 b	12.57 b	6.37 b	38.68
CV	8.34	4.34	5.37	6.82	6.56	11.16
LSD	10.22	3.42	7.15	1.58	0.77	7.74

Water applied by different irrigation methods by solar pump for irrigation in brinjal is given in Table 23. Irrigation water savings in brinjal by alternate furrow method and drip method over farmers' practice in different locations southern region were 27-29% and 48-51%, respectively. So, drip irrigation method was found the best water saving technology for irrigation in brinjal followed by alternate furrow irrigation method.

Table 23. Amount of water applied and water savings in brinjal in different treatments at different locations

Treatments	Galachipa, Patuakhali		Amtali, Barguna		Barguna Sadar Borguna		Kolapara, Patuakhali		Charfassion, Bhola	
	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)
Drip	287	48.93	276	48.12	270	50.64	297	49.14	283	48.82
AFI	406	27.76	386	27.44	397	27.42	425	27.23	402	27.31
FP	562	-	532	-	547	-	584	-	553	-

Crop: Watermelon

Yield and yield contributing parameters of brinjal at different project locations were shown in Table (24-28). The highest yield of brinjal was obtained from drip irrigation than AFI and FP methods. But it was statistically similar with FP.

Table 24. Yield and yield contributing characters of watermelon at Boro Char Kajol, Galachipa, Patuakhali

Treatment	Vine Length (cm)	No. of Fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)
Drip	494.81 a	1.75 a	10925.00 a	56.62 a	27.33 a	44.59 a
RBI	468.31 a	1.25 ab	9962.50 a	47.79 b	23.47 b	40.33 b
FP	404.95 b	1.00 b	8551.25 b	40.59c	21.28 b	38.70 b
CV	7.22	7.95	7.04	4.42	6.35	4.81
LSD	57.02	0.64	1196.28	3.7	2.64	3.43

Table 25. Yield and yield contributing characters of watermelon at Char Badai, Galachipa, Patuakhali

Treatment	Vine Length (cm)	No. of Fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)
Drip	450.22 a	2.75 a	10475.00 a	55.71 a	55.82 a	47.24 a
RBI	423.72 a	2.00 ab	9262.50 b	46.88 b	46.99 b	42.98 b
FP	360.36 b	1.50 b	7751.25 c	39.68 c	39.79 c	41.35 b
CV	8.01	2.62	5.95	4.5	4.49	4.51
LSD	57.02	0.81	943.65	3.7	3.7	3.43

Table 26. Yield and yield contributing characters of watermelon at Amtali, Borguna

Treatment	Vine Length (cm)	No. of Fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)
Drip	495.58 a	2.75 a	11550.00 a	57.60 a	29.22 a	49.14 a
RBI	469.09 a	2.25 ab	9587.50 b	48.77 b	25.36 b	44.88 b
FP	405.72 b	1.75 b	7576.25 c	41.57 c	23.17 b	43.25 b
CV	7.21	14.81	10.24	4.33	5.88	4.33
LSD	57.01	0.57	1696.57	3.7	2.64	3.43

Table 27. Yield and yield contributing characters of watermelon at Chunakhali, Amtali, Borguna

Treatment	Vine Length (cm)	No. of Fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)
Drip	486.798 a	2.75	10350.00 a	52.13 a	24.84 a	42.36 a
RBI	460.303 a	2.25	8387.50 b	43.30 b	20.98 b	38.10 b
FP	396.938 b	2	6376.25 c	36.10 c	18.79 b	36.47 b
CV	7.35	2.42	11.71	4.87	7.08	5.08
LSD	57.01	0.86	1696.57	3.7	2.64	3.43

Table 28. Yield and yield contributing characters of watermelon at Kotbaria, Barguna Sadar, Borguna

Treatment	Vine Length (cm)	No. of Fruits /plant	Unit weight (g/fruit)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)
Drip	400.74	2.25	9233.75 a	38.49a	21.09a	32.08
RBI	391.14	2	8575.50 ab	37.11ab	19.09b	29.83
FP	388.39	1.5	8242.50 b	35.45b	18.46c	27.51
CV	3.9	5.85	5.45	4.35	1.29	12.15
LSD	26.57	1.18	819.96	2.79	0.43	6.26

Water applied by different irrigation methods by solar pump for irrigation in watermelon is given in Table 29. Irrigation water savings in watermelon by ring basin method and drip method over farmers' practice in different locations southern region were 30-34% and 52-55%, respectively. So, drip irrigation method was found the best water saving technology for irrigation in watermelon followed by alternate furrow irrigation method.

Table 29. Amount of water applied and water savings in watermelon in different treatments at different locations

Treatments	Boro Char Kajol, Galachipa, Patuakhali		Char Badai, Galachipa, Patuakhali		Ghatkhali, Amtali, Borguna		Chunakhali, Amtali, Borguna		Kotbaria, Barguna Sadar, Borguna	
	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)
Drip	315	53.40	318	52.11	322	53.06	328	53.93	338	54.08
RBI	473	30.03	463	30.27	452	34.11	486	31.74	489	33.56
FP	676	-	664	-	686	-	712	-	736	-

Crop: Chilli

Yield and yield contributing parameters of chilli at different project locations were shown in Tables 30-31. The highest yield of chilli was obtained from drip irrigation than AFI and FP methods. But it was statistically similar with FP.

Table 30. Yield and yield contributing characters of chilli at Panpotti, Galachipa, Patuakhali

Treatment	Plant height (cm)	No. of fruits /plant	Unit weight of fruit (g)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)
Drip	29.67	451.25 a	1.27	5.66	2.62	10.47
AFI	28.50	442.00 b	1.26	5.52	2.59	10.42
FP	27.15	438.50 b	1.16	5.44	2.56	10.22
CV	6.00	1.16	7.25	4.41	7.54	6.22
LSD	2.95	8.92	0.15	0.42	0.34	1.12

Table 31. Yield and yield contributing characters of chilli at Char Biswas, Galachipa, Patuakhali

Treatment	Plant height (cm)	No. of fruits /plant	Unit weight of fruit (g)	Fruit length (cm)	Fruit dia (cm)	Yield (t/ha)
Drip	29.67	451.25 a	1.27	5.66	2.62	10.47
AFI	28.50	442.00 b	1.26	5.52	2.59	10.42
FP	27.15	438.50 b	1.16	5.44	2.56	10.22
CV	6.00	1.16	7.25	4.41	7.54	6.22
LSD	2.95	8.92	0.15	0.42	0.34	1.12

Water applied by different irrigation methods by solar pump for irrigation in chilli is shown in Table 32. It is observed from the table that about double amount of water was required in farmers' practice than drip method. Irrigation water savings in chilli by alternate furrow method and drip method over farmers' practice in different locations of southern region were, 30-35% and 60-62%, respectively. So, drip irrigation method was found the best water saving technology for chilli cultivation followed by alternate furrow irrigation method.

Table 32. Amount of water applied and water savings in chilli in different treatments at different locations

Treatments	South Char Biswas,Galachipa, Patuakhali		Panpotti, Galachipa, Patuakhali	
	Irrigation applied (mm)	Water saving (%)	Irrigation applied (mm)	Water saving (%)
Drip	98	61.26	96	60.66
AFI	162	35.97	170	30.33
FP	253	-	244	-

Conclusion

The discharges of large (1300 W_p) and mini (365W_p) solar pumps were found to be 180 L/min and 40 L/min, respectively. Significantly the highest yields of tomato were found from drip irrigation than furrow irrigation method in Gazipur. Irrigation water savings in tomato by alternate furrow method and drip method over farmers' practice were 49.63%, and 35.21% respectively. Significantly the highest yield of tomato was found from drip irrigation than alternate furrow irrigation (AFI) and farmers practice (FP) or every furrow irrigation treatment in four farmers' fields in three districts. The highest yield of brinjal was obtained from drip irrigation than AFI and FP methods. The highest yield of watermelon was obtained from drip irrigation than AFI and FP methods in five farmers' field of three districts. The highest yield of chilli was obtained from drip irrigation than AFI and FP methods in two farmers' field in three districts. Irrigation water savings in tomato by alternate furrow method and drip method over farmers' practice in different locations were 28-32% and 47-49%, respectively. Irrigation water savings in brinjal by alternate furrow method and drip method over farmers' practice in different locations were 27-29% and 48-51%, respectively. Irrigation water savings in watermelon by ring basin irrigation method and drip method over farmers' practice in different locations were 30-34% and 52-55%, respectively. Irrigation water savings in chilli by alternate furrow method and drip method over farmers' practice were 30-35% and 60-62%, respectively. So, drip irrigation method was found the best water saving technology for irrigation. SHS in all locations are running well and farmers are very happy to use SHS.

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EXPT. NO. 5.2 DEVELOPMENT AND ADOPTION OF A SOLAR CABINET DRYER FOR VEGETABLE SEEDS

M. N. AMIN, M. A. HOSSAIN AND T. N. BARNA

Abstract

Drying of seeds in Bangladesh is normally carried out by traditional sun drying method which is very slow and it often results in inferior quality due to dependence on weather conditions and vulnerability to contaminate with insects, pests, dust and dirt. Sometimes, continuous rain occurs for a few days that spoils the seeds. Two solar cabinet dryers having capacities of 2-6 kg and 10-12 kg per batch were designed and fabricated at Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur for drying of moist vegetable seeds. The dryer was designed to generate desirable temperature (<45°C) from solar radiation suitable for vegetable seeds drying. They were fabricated with locally available materials such as, MS box, MS flat bar, MS angle bar, MS sheet, GP sheet, SS net, insulation materials, dc fan, PV module, polyethylene sheet, cork sheet etc. These were indirect solar cabinet dryers that consisted of drying chamber, collector and auxiliary heating source (electric heater). The moisture content of sweet gourd seeds was reduced from 41.59% to 9.23% (wb) in 6 hours. The moisture content of the bottom tray containing seeds was 1.13% lower than that of upper tray whereas moisture content reduction was higher than that of upper tray. Germination of seeds were found to be 98% for sweet gourd. The prices of the large and small dryers are Tk.80000.00 and Tk. 50000.00 respectively. Break-even-point, BCR and payback period of the dryers were obtained to be 1100 hours per year, 1.14 over net return and 75 days respectively for large size and 450 hours per year, 1.04 over net return and 64 days for small size respectively. The dryer was introduced and created awareness among the farmers (male:294 and female:66), scientists (60), seed contact growers and manufacturers through conducting inception workshop, trainings, adaptive trials, booklet, electronic media, print media and completion worshop. The dryers (small and large) may be recommended for drying vegetable seeds in Bangladesh.

Introduction

Currently there are over 150 private seed companies and 17,500 registered seed dealers in Bangladesh. However, only ten of these companies have own R&D activities which are primarily focused on hybrid seeds of vegetables, maize, and rice (USDA FAS, 2014). More than 47% of seed used in Bangladesh is farm saved seed (Humayun, 2016). Without knowing the exact need for quality seed, all stakeholders within the seed sector express a genuine concern over the lack of good quality seed in the country. It has been observed in a few studies that seed germination is in generally lower in farm saved seed compared to certified seed, and the frequency of spotted and infected seed is higher. Simple cleaning of seeds through physical sorting has shown to have a markedly reduction in the number of infected seed and a yield increase of 12% (Fakir. 2004; Rahman and Mia, 1998; Huda, 2001). Gavhale *et al.* (2015) developed a small scale village level solar dryer for tomato that consisted of tray, reflective walls and glass roof, a preheating air absorber plate, inner panels for removal of moisture and chimney through which air stream passes across the dryer. Evaluation of the dryer showed a raised temperature of about 47°C attainable in the drying chamber. The dryer temperature and drying rate was found to be higher than the natural open sun drying method. The results showed a considerable advantage of solar dryer over the traditional open sun drying method in term of drying rate and less risk for spoilage.

Agricultural production can be increased by 15-20% through use of quality seed keeping other things constant (Humayun, 2016). While the majority of the small and medium size companies focus on marketing of seeds of high yielding varieties vegetables and potato, the large companies focus on hybrid seeds of vegetables, rice, and maize. The quality analyses results revealed that the farmers' homegrown seed is of inferior quality than that of research organization's seed in terms of seed moisture, germination, vigour and seed health. Because in most cases farmers do not apply recommended packages used for quality seeds, (balanced fertilizers, isolation, rouging, irrigation, plant protection and different postharvest activities) for seed production as prescribed by the SCA. On the other hand, most of the farmers do not have adequate knowledge regarding modern cultivation and postharvest technologies of seed processing. As a result, huge numbers of seeds are spoiled due to inappropriate postharvest handling. Seed moisture plays a vital role in regulating the longevity of

seeds. Most of the vegetable seeds can withstand drying to extend their storage life with low moisture content. Depending on types of seeds (Dicotyledonous Exalbuminous seeds, Dicotyledonous Albuminous seeds, Monocotyledonous Albuminous seeds and Monocotyledonous Exalbuminous seeds), any common emperature or method of drying do not suit equally well under given set of conditions in retaining viability and vigor of seeds. Drying of seeds too rapidly or with high air temperature is certainly injurious to seed (Copland, 1976). Vegetable seeds normally contain 60-80 percent moisture at the stage of physiological maturity. It has to be reduced to safe moisture level of 8-9 percent by drying under sun, shade or mechanical drying to preserve the high quality of seed during storage (Rajkumar 1973; Javaregowda *et.al*, 1994; Gowda, 1997). Seeds should be dried at constants and optimum temperature to ensure seed quality (Hossain, 2011). But in case of sun drying, constant temperature can not be maintained due to variation of solar radiation. In open environment, while sun drying, seeds often dry at low temperature and sometimes at high temperature which accelerates the deterioration of seed quality. Typical *drying* times in *solar dryers* range from 1 to 3 days depending on solar radiation, air movement, humidity and the type of seed to be dried. During drying period, if continuous rain occurs for a few days or even for a week, spoils the whole amount of seeds restricting traditional sun drying. In this circumstance, an eco-friendly cabinet type solar dryer is needed for drying of vegetable seeds to reduce the loss of seeds and produce good quality seed.

A cabinet type solar dryer was designed, fabricated and performances were studied to dry spices in 2013 at Spices Research Centre, Bogura. The area of the collector and dryer was 7.5 m^2 and 4 m^2 respectively. The dryer was fabricated with PVC sheet, angle bar, square bar, polythene film, wheel, nut and bolt, poly coated wire net, corrugated iron sheet, paint, solar panel and fan. The dryer demonstrated good drying rate than that of conventional sun drying method. However, in case of seed drying, the dryer exhibited poor germination performance as the temperature increased significantly than that of safe drying temperature. Moreover, the upper tray temperature was always higher (average 5^oC) than that of bottom tray temperature, which demonstrates unequal drying rate. A solar assisted hybrid dryer was designed, fabricated and tested for drying of grain seeds in 2010 at FMPE, BARI, Gazipur with the financial support of Krishi Gobeshona Foundation (KGF). It consisted of a flat-plate concentrating collector, an auxiliary electric heater and a drying unit. The special feature of the dryer was that it could be operated in a sunny day using solar radiation and in a rainy or cloudy day or at night using auxiliary electric heating unit. The dryer was tested and found suitable for drying 200-300 kg of grain seeds (Hossain, 2012).

Objective(s)

a) Designing and fabrication of solar powered and electricity backup vegetable seed dryer
b) Evaluation of technical and economic performance of dryer for producing quality vegetable seeds
c) To test and demonstrate the dryer in the farmers' fields
d) To disseminate the dryer among the seed growers and traders through training, field demonstration, workshop and printing media

Materilas and Methods

Description of dryer

Design of the indirect solar cabinet dryer for drying of vegetable seeds was done based on the energy balance along with heat and mass balance equations. The following design assumptions of the solar cabinet dryers (large: 10-12 kg/batch and small: 2-6 kg/batch) were considered (Table 1). The dryers consisted of a flat plate collector, auxiliary heating unit and drying chamber. The specifications of the solar cabinet dryers were presented in Table 2. The special feature of the dryer was that it could be operated in a sunny day using solar radiation and in a rainy or cloudy day or at night using auxiliary electric heaters. The length, width and height of the drying chambers were 82 cm, 81 cm and 134 cm for large size; and 80 cm, 75 cm and 87 cm for small size. Solar collectors are used as air heater in the dryer. The length, width and height of the collectors were 236 cm, 118 cm and 38 & 16 cm for large size and 139 cm, 71 cm and 34-18 cm for small size. Drawings of the dryers were done with Solid Work 2016. A brief description of the dryer and testing procedure is given below.

Fabrication of the dryers

Design of the indirect solar cabinet dryer for drying of vegetable seeds was done based on the energy balance and heat and mass balance equations. Solar cabinet large and small dryers were designed and fabricated with the local materials at Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur. They consisted of drying chamber having six and three trays, solar collector, exhaust and inlet fan operated by solar panel of 20W, heaters etc. respectively. Overall dimensions of the dryers were 120×100×170cm and 10.7×10.1×111.5 cm respectively. The drying chambers' dimensions were 82×81×133.5 cm and 80×75×87 cm respectively. Size of the collector were 23.6×11.8× (3.8-1.6) cm and 13.9×7.1× (3.4-1.8) cm respectively. Capacities of the dryers were 10-12 kg per batch and 2-6 kg/batch depending on seed size. Estimated prices of the dryers (large and small) were Tk. 80000.00 and Tk. 50000.00 (Appendix I and II) and weight was 50 kg and 35 kg respectively.

Table 1. Design assumptions of solar cabinet dryers

Parameters	Assumptions
Air flow mode	axial
Drying temperature for vegetable seeds	40 to 43 °C
Temperature of ambient	20 to 37 °C
Density of air (surrounding)	1.1455 to 1.204 4 kg/m^3
Transfer fluid	Air
Amount of seeds to be dried per batch	10-12 kg for large and 2-6 kg for small
Type of air flow	Streamline flow
Nature of vegetable seeds	Small and hygroscopic

Table 2. Specifications of solar cabinet dryer

Parameters	Specifications	
A. Drying chamber	Large size	Small size
Overall dimension, cm	120×100×170	107×101×1115
Dimension of drying chamber, cm	82×81×134	80×75×87
Number of tray, nos	6	3
Type of tray	mesh tray	mesh tray
Material of mesh	Steel mesh	Steel mesh
Length of tray, cm	80	75
Width of tray	75	66
Height of tray, cm	5	3
Mesh number, no per 2.54 cm	20	12
Diameter of inlet, cm	22×22	12
Diameter of outlet, cm	16×16	8
Number of supporting legs, nos (12 cm)	4	4
Length of each leg from ground, cm	40	27
Insulating materials (Cork sheet) cm	2.54	2.50
A.1 Electric system		
Fan, cm	15 ϕ	13 ϕ and 7.5 ϕ
Number of electric heater, nos	4	2
Power of each electric heater, kW	1.5	2
Temperature controller (range), ° C	0-399	0-400
Magnetic contact, A	40	32
Circuit breaker , A	63	32
B. Collector		
Overall dimension of collector, cm	236×118×(38-16)	139×71×(34-18)
Opening space of inlet of air, cm	225×10	130×10
Opening space of outlet of hot air, cm	40×30	39×32
Angle inclination of polyethylene cover to chamber	21°	21°

Parameters	Specifications	
Length of transparent polyethylene cover, cm	230	134
Width of transparent polyethylene cover, cm	120	68
Thickness of transparent polyethylene cover, cm	0.2	0.15
Number of supporting legs, nos	2	2
Absorbing material	Black corrugated iron sheet	Black corrugated iron sheet

Drying chamber

Drying chambers of the dryers consisted of trays, heater zone, inlet and outlet opening. Six and three drying trays of the large and small dryers were placed in the drying unit respectively. Each tray was made of metallic frame and stainless steel net. The drying trays' dimensions of the dryers were 80 × 75× 5 cm and 75× 66 ×3 cm respectively.The stainless steel mesh was used having 20 and 12 mesh number respectively. The drying air was passed through the products. The drying air was heated up in the collector and passed to the drying chamber through a curved passage at the end of the drying unit and flew over and under all the drying trays and exhausted from the outlet. For auxiliary heating of large dryer, two electric heaters out of four, each of 1.5 kW capacity were installed at the bottom and other two were installed in the middle of the drying chamber. For auxiliary heating of small dryer, two electric heaters each of 2 kW capacity were installed at the bottom of the drying chamber. Two temperature controllers for the large size dryer were set for controlling bottom and middle heaters indivitually to maintain constant temperature in the dryer. One temperature controller for the small size dryer was set to maintain constant temperature in the dryer. Two small dc fans (each of 5W) were set in inlet and outlet opening sides of the large dryer and three small dc fans were set in inlet, bottom and at the outlet opening for flowing of heated air inside the dryer. Fans are operated by a small solar panel (25 W) and in absence of solar energy it is operated by alternative current (electricity). One 5W axial flow fan was connected in inside of the drying chamber to draw the atmospheric air in the collector and to push out the heated air to the dryer with a desired air velocity. Another 5 W axial flow fan was located at top of the drying chamber. The isometric and photographic views of the large size dryer are shown in Fig. 1 and Fig. 2, respectively.

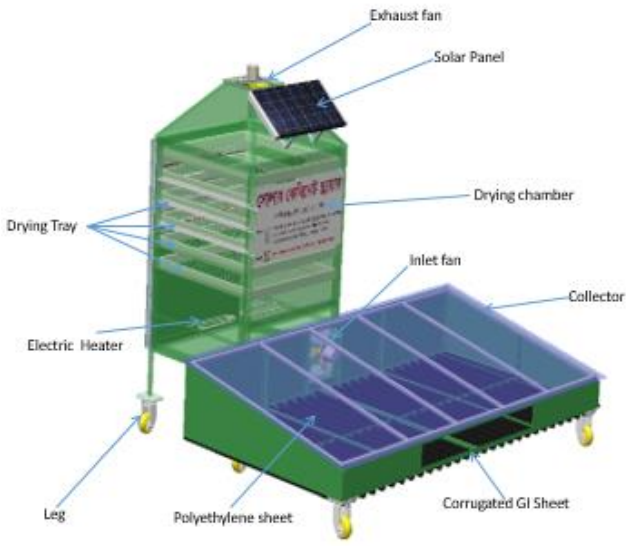

Fig. 1. Isometric view of the large size dryer indicated main parts of the dryer.

Fig. 2. Photographic view of large size solar cabinet dryer.

The isometric and photographic views of the small size dryer are presented in Fig. 3 and Fig. 4, respectively.

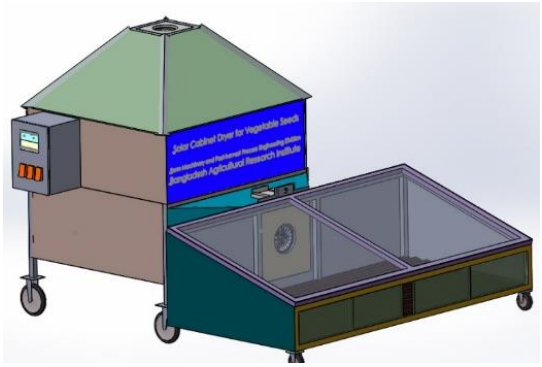

Fig. 3. Isometric view of the small solar cabinet dryer.

Fig. 4. Photographic view of the small solar cabinet dryer.

Collector

The collector was fabricated with transparent polyethylene sheet, corrugated iron sheet, MS flat bar, wood, MS angle bar. Overall dimensions of the flat plate concentrating solar collectors of the dryers (large and small) were 23.6×11.8× (3.8-1.6) cm and 13.9×7.1× (3.4-1.8) cm respectively. The transparent cover of the collectors was 2 mm and 1.5 thick clear polythene sheet respectively. About one millimeter black painted corrugated iron sheet is used as an absorber plate. The collectors were placed on 2 legs with 140 mm diameter wheels to turn the solar collector horizontally and change its direction according to the change of the sun's angle.

Working principle solar dryer

Drying is the process of moisture removal. Since vegetable seed is a hydroscopic material which can either absorb or desorb moisture from or to the air depending on the difference in vapour pressure. Moisture transferred from higher vapour pressure, to the lower one. In the sun drying process, seeds are heated by solar radiation thus creating a higher vapour pressure in seed than the surrounding air. In the same manner, when the heated air (by conduction) comes in contact with the seeds, it collects moisture from the seeds. Heated air carries moisture from the seed surface. Internal moisture of seed diffuses and comes out to the surface of seeds due to influences of vapour pressure. Thus the heated

air again vapourizez the moisture and comes out from the surface of the seed. This process continues until drying is completed. Therefore, the drying rate of the specific kind of seeds is dependent on air temperature, relative humidity and air flow rate, types of crops and status of moisture content.

Drying procedure

The dryer was placed in plane and sunny area. The collector was connected outside of drying chamber and was faced towards sun. The heaters' switch was on and fans are started through solar panel. The collector absorbs the heat through black corrugated iron sheet and direct radiation on the polyethylene. So, the temperature of air raises inside the collector compared to ambient air temperature. Hot air entered into the drying chamber from collector through fan or blower that runs by solar panel. On the other hand, air of the drying chamber was heated by electric heaters. Hot air coming from collector was more heated upto desired temperature for drying of seeds. Desired air temperature was controlled using temperature controller. Then vegetable seeds were spreaded over the tray in single layer. Each layer had more or less one kg of vegetable seeds. The loaded trays were put in the drying chamber for drying. A sample of approximately 50 g was evenly spreaded on a drying pot (0.75 × 0.75 × 0.10 cm) to form a single layer.

The data recorded were time, solar radiation, temperature and humidity. Solar radiation was recorded using solar meter, temperature and humidity were measured altogether with hygrometer. Ambient and inside collector temperatures, temperature of each tray and air outlet were recorded. Ambient humidity and humidity inside each tray were recorded.

Labour required

One labour was required for operating the dryer and for spreading the seeds on the tray of the dryer.

Estimation for fabrication of solar cabinet dryer

The fabrication cost of the dryer was calculated including cost of materials, labour, overhead, incidental expenses and manufacturing. Overhead cost included power consumption, machine depreciation, house rent, etc. (appendix-I and II).

Economic analysis

Economic analysis of the solar cabinet dryer was done. Cost analysis included the operating cost of the dryer. Operating cost of the dryer included the fixed cost and variable cost.

Fixed cost

Fixed cost of the dryer included annual depreciation, interest on investment, and shelter. Capital consumption included depreciation and interest.

Capital consumption (CC)

$$CC = (P - S)CRF + Sxi \qquad (1)$$

Where,

P=Purchase price (Tk.), S=Salvage value (Tk.) and CRF= Capital recovery factor.

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \qquad (2)$$

where

i= Rate of interest, L=Life of dryer (yr), T=0.5% of purchase price of the dryer (Tk.).

Total fixed cost per year

$$FC = CC + T \qquad (3)$$

Variable Cost

In calculation of variable cost, the following relations were assumed

Labour cost per hour, L_b=Tk man-h^{-1}

Electricity cost per hour, E=Tk h^{-1}

Repair and maintenance (R&M) cost per year =3.5% of purchase price of the dryer

Total variable cost

$$VC = L_b + E + R \& M \quad (4)$$

Annual cost/operating cost

$$AC = FC + VC \quad (5)$$

Break-even-point (BEP)

Break-even-point is the level at which an investment neither incurs a loss nor produce a profit. For mechanization, it is defined as the use level at which the dryer must be operated. Fixed cost and variable cost were calculated using the above mentioned equations.

Performance test of the small dryer without seeds

Small size solar cabinet dryer was tested without seeds using both the solar energy and electrical energy, and also only solar energy and only electrical energy during 27-31 November 2020 at Farm Machinery and Process Engineering Division, BARI, Gazipur. Air temperature, inlet and outlet temperature of dryer were measured by thermometer and solar radiation was measured by solar meter. The small dryer was tested during 27-29 August 2020 for evaluating of performance test.

Measurement of moisture content of seeds

Empty container (aluminum dish) was weighed on electronic micro balance and recorded (A). Seed sample of 10 g were put into the container and was weighed (B). The samples were placed in an air ventilated electric oven at 105 °C for 24 hours (Kushman *et al.*, 1966). The samples were transferred with the container from oven into desiccators and cooled at room temperature and weighed to obtain the dry samples (C).

Percentage moisture and dry matter content of the samples were calculated by using the following formula.

Wet weight of sample (D) = B-A (6)

Dry weight sample (E) = C-A (7)

$$\text{Moisture content, (\%) (wb)} = \frac{D - E}{D} \times 100$$

Testing of seed quality

Quality test of sweet gourd seeds

Each seed sample was used for germination test in sand media. The standard germination test was conducted by placing seed samples on moist sand media under ambient condition overnight in order to equilibrate with the ambient temperature and reduce the stress within the seed. Three replications of 20 seeds were taken for each sample. The samples were placed under room temperature to germinate. The seeds that had root or shoot longer than 2 mm were considered as germinated seeds. Germination of the amarnth seeds was found to be 98% (Fig. 5).

Fig. 5. Germination of sweet guard seed.

Seed Vigor Index of sweet gourd: This is calculated by determining the germination and seedling length of the same seed lot. Twenty seed each in three replications are germinated in sand. While evaluating the number of normal seedling at the time of final count, the seedling length of 5 randomly selected seedlings are also measured. Seed vigor index is calculated by multiplying germination (%)

and seedling length, mm. The seed lot showing the higher seed vigor index is considered to be more vigorous (Baki and Anderson, 1973).

Workshop conducted

The completion workshop of the project was held on 6 January 2021 at Farm Machinery and Postharvest Process Engineering Division, BARI, Gazipur. Fifty participants attended the workshop physically (96%) and 4% in online. Director General of the BARI was present in the workshop as a chief guest. DAE, BADC, BRAC, KGF, BARC personnels participanted in the workshop.

Training program

Four batches of training program were conducted at Jashore on 18-19 November 2020 and 30-31 December 2020. In total 120 participants (males and females) participated in the training program. Principal investigator, Co-principal Investigator of the sub-project, Metal private company, BADC personnel and BARI regional personnel were present in the program. **Adaptive trials conducted**

Four adaptive trials on "Vegetable solar cabinet dryer" among the farmers and seed growers was conducted with the help of RARS, Jashore and DAE at Bagarpara, Jikorghasa, on 18-19 November 2020. Two batches were conducted at FMPE premise of BARI, Gazipur on 8-9 December 2020.

KGF personnel observed the dryer

Dr Tapon Kumer Dey, senior program specialist (crops), investigated the dryer on 15 December 2020 at FMPE Divisional Workshop, BARI, Gazipur (Fig.6)

Fig. 6. KGF personnel investigated the dryer.

Results and Discussion

Test of dryer without load using electrical energy

Relationship between temperature and relative humidity of air in both the ambient and heater zone for a period of 5 hours is shown in Fig. 7. It was observed that ambient temperature increased and relative humidity decreased with exposure period. Same trend of these parameters was observed in heater zone. On the other hand, both of these parameters in the heater zone slightly increased up to one hour and later it was steady up to 41.2 °C and 42.2% respectively. Average temperature in the heater zone was 10.4 °C higher and relative humidity was 31.1% lower than those of ambient.

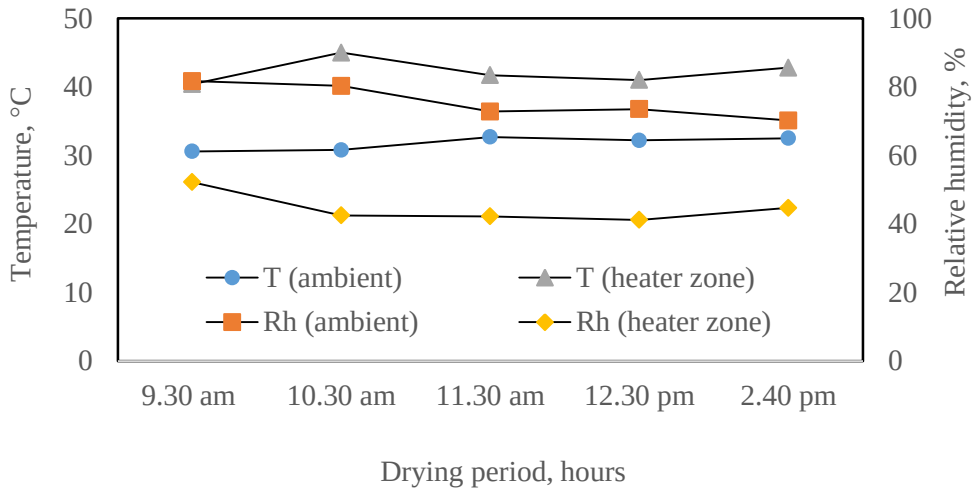

Fig. 7. Relationship between temperature and relative humidity of air in both the ambient and heater zone for a period of 5 hours.

Test of dryer with sweet guard seeds using electrical energy

Changes of temperature of air for a period of 5 hours are shown in Fig. 8. Average temperature of trays varied with heater zone temperature. Average temperature among the trays gradually decreased from the bottom to top tray. It was observed that the differences of temperature of successive trays are very minimal. Temperature in top tray was 2.9 °C lower than that of bottom tray. Without load, it was not desirable for dryer. Temperature difference among the trays is a problem of dryer that was found out from the test. There is scope to further research to minimize the problem.

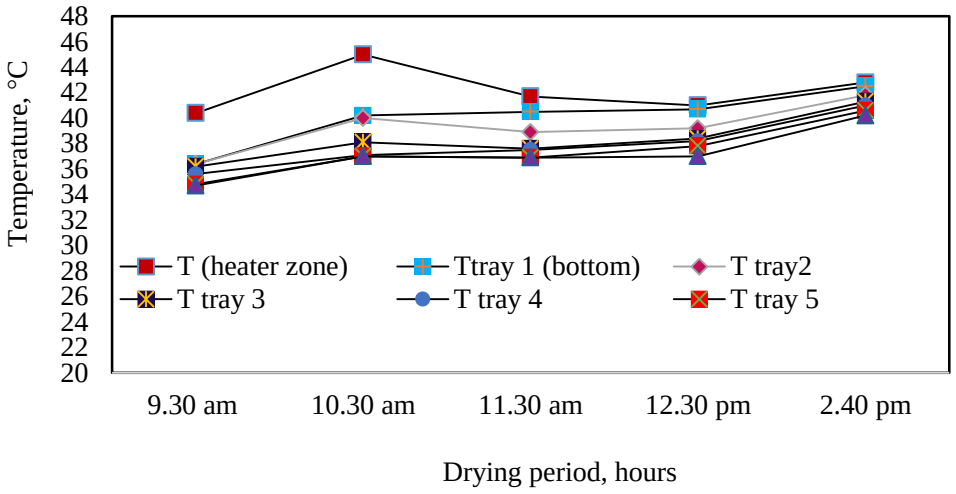

Fig. 8. Relationship between temperature and relative humidity of air in both the ambient and heater zone for a period of 5 hours.

Changes of relative humidity of air for a period of 5 hours are shown in Fig. 9. Average relative humidity of trays varied with heater zone relative humidity. Average relative humidity among the trays gradually increased from the bottom to top tray. It was observed that, the successive trays show more fluctuation of relative humidity. Relative humidity in top tray was 7.6% higher than that of bottom tray.

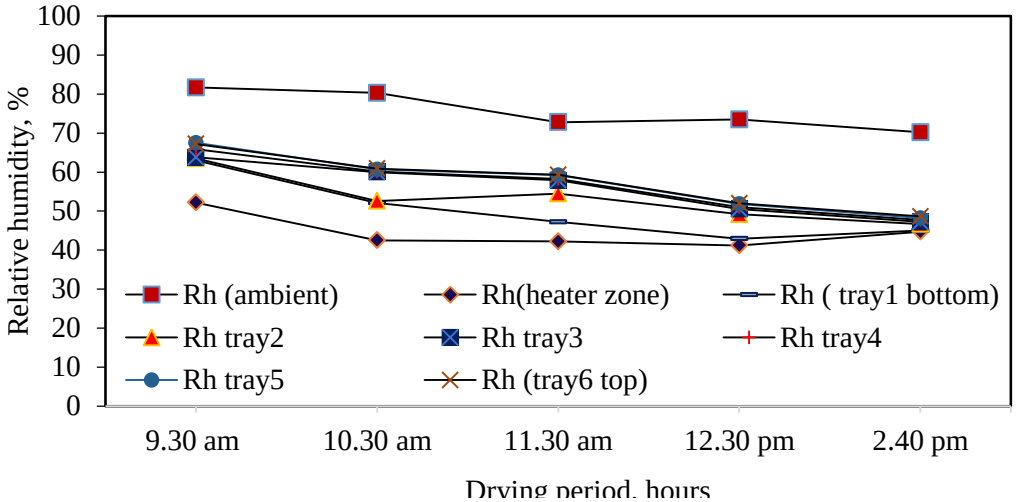

Fig. 9. Changes of relative humidity of air for a period of 5 hours.

Test of large size dryer without seeds using solar energy

Variations of air temperature of ambient, collector and dryer with global solar radiation at different times of a typical day are shown in Fig. 10. It is observed that ambient temperature and solar radiation varied with time of a days and these were found to reach the peak in between 12.00 pm and 12.40 pm. Variations of ambient temperature were due to the variations of global solar radiation. Collector temperature was measured at the outlet of the collector. Higher temperature (7.7°C) was observed in collector outlet than that of the ambient temperature. Collector temperature varied with the ambient temperature as well as solar radiation. Inside temperature of the dryer chamber (heater zone) was equal to outlet temperature of the collector due to using only solar energy. It was found that ambient temperature increased from 33.5 to 38.40 °C with global solar radiation from 345 to 652 W/m^2. Average, maximum and minimum temperature of the drying chamber was 43.95, 41.0 and 45.6 °C respectively. The temperature was maintained almost constant using adjusting airflow. Uniform temperature is very important to maintain equal thermal stress on the product for its quality. But in sun drying it is not possible to maintain uniform temperature as solar radiation varies with time.

Variations of relative humidity of collector and drying chamber with global solar radiation in a typical day are shown in Fig. 11. It is observed that ambient air relative humidity and solar radiation varied with time of a day and these were found to reach the peak in between 12:00 pm and 12:40 pm. Variations of ambient air relative humidity were due to the variations of global solar radiation. Collector outlet air relative humidity was found lower (14.35%) than the ambient air relative humidity. Air relative humidity in the collector varied with the ambient temperature as well as solar radiation. Inside air relative humidity of the drying chamber was same as outlet of the collector. Inside relative humidity of the drying chamber varied from 37.5 to 53.3% that was suitable for drying of vegetable seeds.

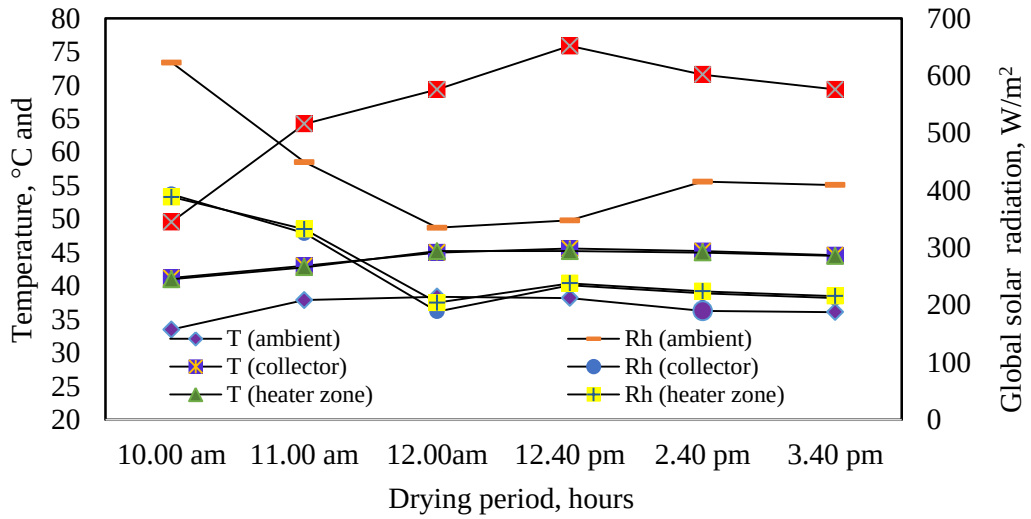

Fig. 10. Variations of air temperature of ambient, collector and dryer with global solar radiation at different times of a typical day.

Variations of air temperatures among the different trays of the drying chamber in a typical day are shown in Fig. 16. It is found that drying air temperature of bottom tray was higher (1.21°C) than that of top trays but successive upper tray's temperature was gradually little decreased. It was fact that first tray absorbed temperature from hot air and middle trays absorbed temperature from the desorbed air temperature of first tray. Temperature of all trays varied from 42.77 to 43.98°C which are suitable for drying of vegetable seeds.

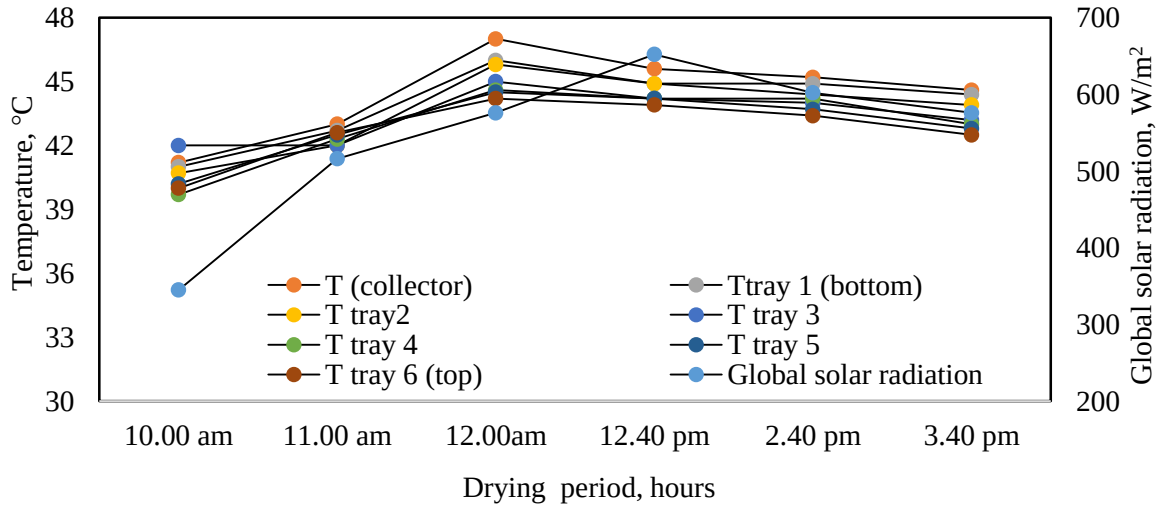

Fig. 11. Variations of air temperatures among the different trays of the drying chamber in a typical day.

Test of small size dryer without seeds using solar and electric energy

Variations of air temperature of ambient (Ta), drying chamber temperature (Th), temperature controller (Tcontrol), temperature of different trays (Tray1: bottom; Tray 2: middle and Tray 3: top) and global solar radiation at different times of a typical day are shown in Fig. 12. It is observed that ambient temperature and solar radiation varied with time of a day and these were found to reach the peak in 11.00 pm. Variations of ambient temperature were due to the variations of global solar radiation. Higher temperature (8.8°C) was observed in collector outlet than that of the ambient temperature. Collector temperature varied with the ambient temperature as well as solar radiation. It

was found that ambient temperature increased from 34.6 to 35.60 °C with global solar radiation from 270 to 474 W/m^2.

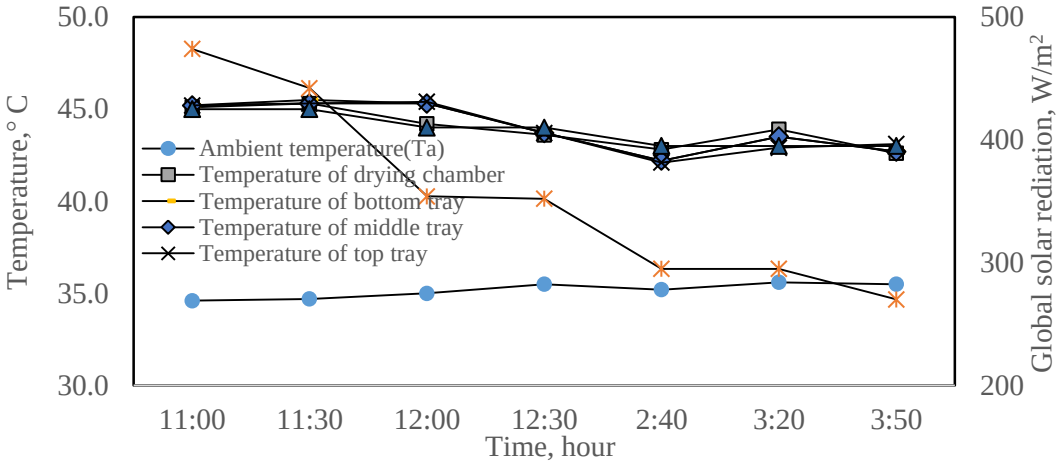

Fig. 12. Variations of air temperatures among ambient, drying chamber, terperatue controller and the different trays with global solar radiation in a typical day.

The average, maximum and minimum temperature of the inside drying chamber was 43.90, 42.6 and 45.3 °C respectively. The temperature was maintained almost constant using adjustable airflow. Uniform temperature is very important to maintain equal thermal stress on the product for its quality. And it is not possible to maintain uniform temperature for solar drying as solar radiation varies with time. It was observed that temperatures of the trays (tray-1, tray-2 and tray-3) were similar and were insignificant among them at 5% level.

Air velocity of inlet and outlet in the dryer varied with the time of the day is illustrated in Fig 13. Air velocities of inlet and outlet varied from 1.0 to 1.4 m/s and from 1.1 to 2.0 m/s respectively. This variation was due to the change of global solar radiation that runs the dc fans. Drying rate increased with the air velocity but drying rate becomes independent to a certain air velocity.

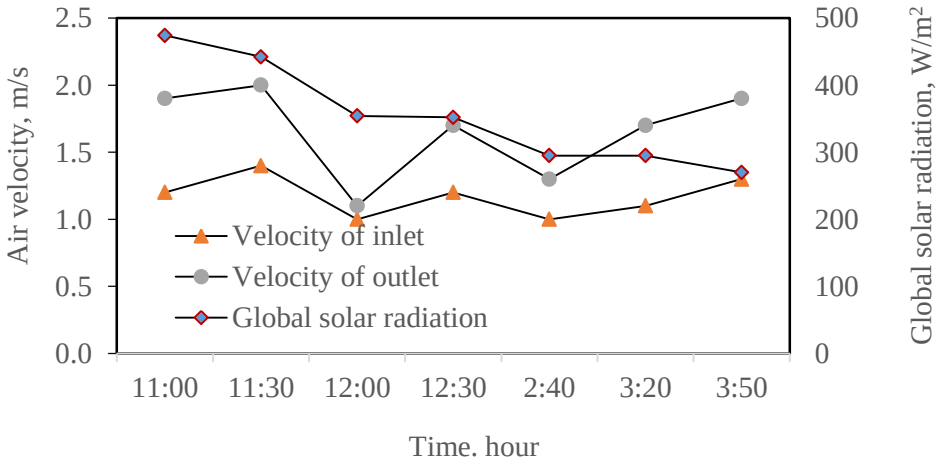

Fig.13. Variation of air velocity in respect to global solar radiation and time.

Test of small size dryer without load using electric energy

Variations of air temperature of ambient (Ta), drying chamber temperature (Th), temperature controller (Tcontrol), and temperature of different trays (Tray1: bottom; Tray 2: middle and Tray 3: top) at different times of a typical day using only electric energy are shown in Fig. 14.

It is observed that higher temperature (9-10°C) was observed in drying chamber than that of the ambient temperature. When temperature controller is set on 44°C, 41-42°C was maintained in the trays that were suitable for drying of vehetable seeds. There was no significant differens in temperatures among the trays at 5% level.

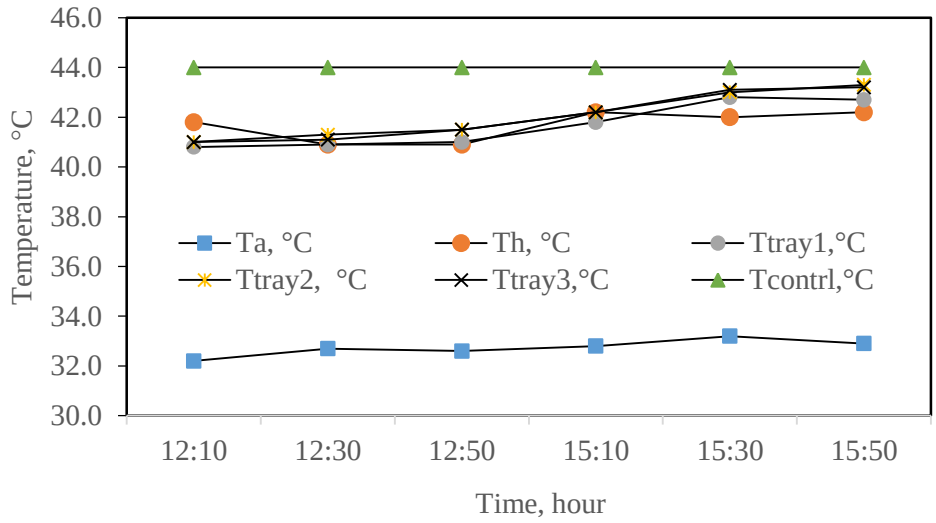

Fig. 14. Variations of air temperature of ambient (Ta), drying chamber temperature (Th), temperature controller (Tcontrol), temperature of trays (Tray1: bottom; Tray 2: middle and Tray 3: top) at different times of a typical day using electric energy.

Test of small size dryer without load using solar energy

Variations of air temperature of ambient (Ta), drying chamber temperature (Th), temperature controller (Tcontrol), temperature of the trays (Tray1: bottom; Tray 2: middle and Tray 3: top) and global solar radiation at different times of a typical day using only solar energy are shown in Fig. 15. It is observed that ambient temperature and solar radiation varied with time of a day and these were found to reach the peak in 12.00 pm. Variations of ambient temperature were due to the variations of global solar radiation. Higher temperature (3.9°C) was observed in collector outlet than that of the ambient temperature. Collector temperature varied with the ambient temperature as well as solar radiation. It was found that ambient temperature increased from 34.7 to 35.8 °C when global solar radiation varied from 163 to 930 W/m^2. It was observed that temperatures of the trays (tray-1, tray-2 and tray-3) were similar and had insignificant difference among them at 5% level.

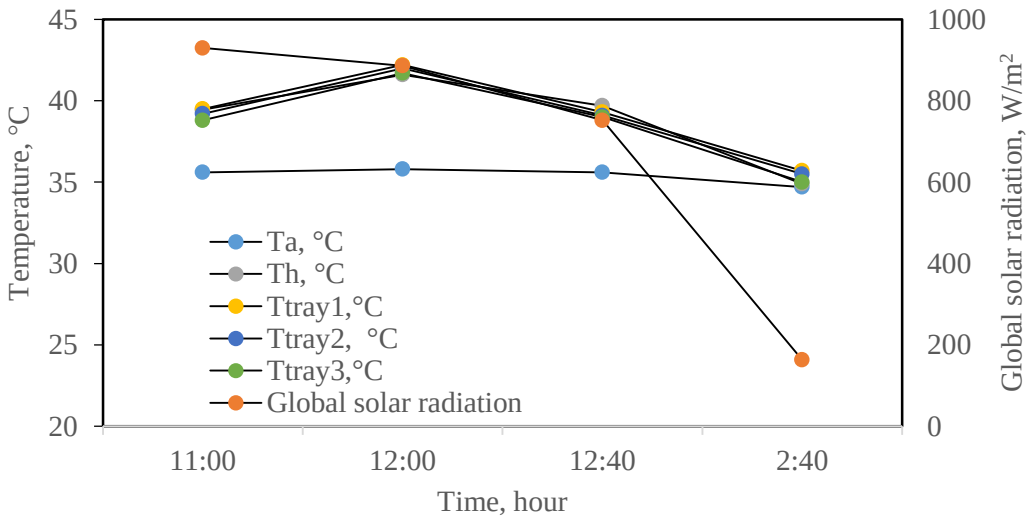

Fig. 15. Variations of air temperature of ambient (Ta), drying chamber temperature (Th), temperature controller (Tcontrol), temperature the trays (Tray1: bottom; Tray 2: middle and Tray 3: top) at different times of a typical day using solar energy.

Germination of seeds

Germination of sweet guard seeds after drying up was 98% in sand media. It revealed that all seeds were good for production of vegetable (Fig. 16).

Fig. 16. Germination of sweet guard seeds after drying.

Seed Vigor Index: The germination of sweet guard seeds before and after drying in solar and air were found to be 70.2%, 74% and 74.4% respectively (Table 3). Air drying refers to drying the seeds in open air condition close to window, without supplying any artificial air circulation. The highest germination was found in air drying seeds compared to solar drying and fresh (before drying) seeds whereas the highest seedling length was in normal seeds. Ther was no significant difference in germination and seedling length between sun drying and solar drier drying seeds. Fresh seeds are more vigorous than solar dried and solar dried are vigorous than air dried seeds.The seed lot showing the higher seed vigor index is considered to be more vigorous (Abdul Baki and Anderson, 1973).

Table 3. Seed germination and seed vigor index of before and after drying of sweet guard seeds

Seed lot (Before drying)	% germination	Seedling length, mm	Vigor index
A	80	15.50	1240.00
B	53	17.50	972.50
C	85	20.40	173400
D	72	23.70	1706.40
E	61	15.80	963.80
Average	**70.2**	**18.60**	**1323.34**
Seed lot (After solar drying)			
A	75	16.50	1237.50
B	72	15.10	1087.20
C	89	14.3	1272.70
D	79	22.00	1738.00
E	55	17.40	957.00
Average	**74**	**17.10**	**1258.48**
Seed lot (After Air drying)			
A	79	18.20	1437.80
B	72	12.30	885.60
C	75	26.40	1980.00
D	61	17.30	1055.30
E	85	10.10	858.50
Average	**74.40**	**16.86**	**1243.44**

Financial analysis

The drying cost and payback periods of large and small solar cabinet dryers are shown in Table 4. Profitability analysis revealed that the method of drying incurred fixed and variable costs. The lion share of cost was estimated for variable cost for the method. Fixed cost included two cost items namely capital consumption and shelter, whereas variable cost included labour, electricity, R & M, and materials. The drying costs of the dryers were found to be 117.00 Tk./kg and 163.00 Tk./kg respectively. It was also found that payback periods of the dryers was 75 days and 64 days respectively. BCR over net return of the dryers were was 1.14 and 1.04 respectively.

Table 4. Treatment costs of the solar cabinet dryers

Cost item	Taka	
	Large size	Small size
Fixed cost (FC)		
1. Capital consumption (CC), Tk./yr	18967.00	11566.00
2. Shelter (T), Tk/yr	410.00	250.00
Sub-total , Tk./yr	19377.00	11816.00
Tk./h	**16.00**	**10.00**
Variable cost (VC)		
Labour, Tk./h	62.50	62.50
Electricity, Tk./h	36.00	24.00
R&M, Tk./h	2.40	1.46
Sub-total	**101.00**	**88.00**
Total cost (FC+VC), Tk/h	**117.00**	**98.00**
Tk./10 hours	**1170.00**	**980.00**
Capacity of the dryer, kg/10 hours	10.00	6.00
Drying cost (Total cost/capacity), Tk./kg	117.00	163
Payback period of the dryer, days	75	64
BCR over net return	1.14	1.04

Break-even-point

Fig 17 shows the break-even-point (BEP) of large solar cabinet dryer for vegetable seeds. Break even point was calculated including fixed cost and variable cost. Fixed cost included two cost items namely capital consumption and shelter, whereas variable cost included labour, electricity, R & M, and materials. The operating cost per hour of the large dryer was 117 Tk and per batch 1170 Tk. (more or less 8-10 hours requires for one batch of seeds (10-12 kg/batch) drying. The operating cost per hour of the small dryer was 98 Tk and per batch 980 Tk. (more or less 8-10 hours requires for one batch of seeds (2-6kg/batch) drying. Hiring charge of the drying of one batch seeds was 2500 Tk. The net return over drying of one batch seeds was 1330 Tk or 133 Tk per hour. It was observed that break even point of the dryer was 1100 hours per year. Therefore, seeds drying by the dryer could be profitable to traders when the annual use of the dryer exceeds 1100 hours.

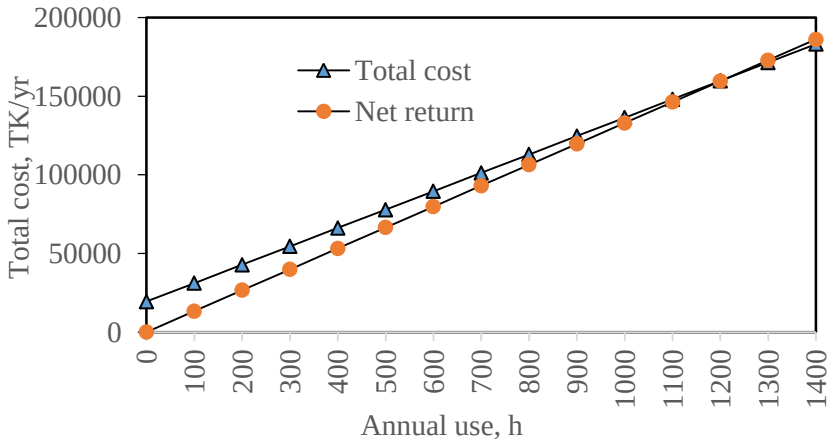

Fig. 17. Break-even-point of the large solar cabinet dryer.

Fig. 18 shows the break-even-point (BEP) of small solar cabinet dryer for vegetable seeds. Break even point was calculated including fixed cost and variable cost. Fixed cost included two cost items namely capital consumption and shelter, whereas variable cost included labour, electricity, R & M, and materials. The operating cost per hour of the small dryer was 98 Tk and per batch 980 Tk. (more or less 8-10 hours requires for one batch of seeds (2-6 kg/batch) drying. Hiring charge of the drying of one batch seeds was 2000 Tk. The net return over drying of one batch seeds was 980 Tk or 98 Tk per hour. It was observed that BEP of the dryer was 400 hours per year. Therefore, seeds drying by the dryer could be profitable to traders when the annual use of the dryer exceeds 400 h.

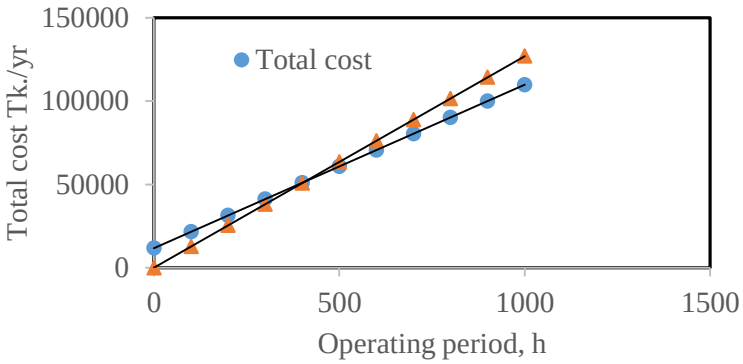

Fig. 18. Break-even-point of the small solar cabinet dryer.

Conclusion

Two solar cabinet dryers were designed and fabricated at Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur for drying of 2-6 kg and 10-12 kg per batch of moist vegetable seeds. The dryer was tested with harvested sweet gourd (616 g) seeds. Temperature of the chamber varied 40.7 - 44.5°C for drying of sweet gourd seeds. Germination of seeds were found to be 98% for sweet gourd. Break-even-point, BCR and payback period of the dryers were obtained to be 1100 hours per year, 1.14 over net return and 75 days respectively for large size and 450 hours per year, 1.04 over net return and 64 days for small size respectively. Further research works, adaptive trials and training would be conducted in vegetable seed growing areas such as Jibonnagar, Rangpur etc.

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EXPT NO. 5.3 DEVELOPMENT OF COST-EFFECTIVE, INTENSIFIED AND SUSTAINABLE RECIRCULATING AQUACULTURE SYSTEM (RAS) IN BANGLADESH

M A HOQUE, M A HOSSAIN AND A M SHAHABUDDIN

Abstract

People are now very much concern about the food safety issue that influences farmers to produce fish in the contaminant free environment. Recirculating Aquaculture System (RAS), is a healthy fish production system that can be located virtually anywhere. Fishes are grown at high density under controlled environmental conditions. Almost all the RAS used in Bangladesh, have been imported from abroad. The application of RAS for commercial producers in many cases has been found as failure. The small and marginal entrepreneurs could not attempt to use RAS with experiences of traditional fish culture. That is why the present research project was designed to develop a low-cost RAS system using locally available technology for intensive culture and to validate RAS along with business model analysis. To acquire knowledge about RAS, two imported RASs were visited by the research team. A low cost mini RAS was designed and started to fabricated at FMPE Division, BARI, Gazipur during 2020-21. Fabrication of RAS was started but could not be completed due to fund constraint and COVID pandemic lockdown of the office. The fabrication of the RAS and component wise evaluation and improvement will be done year.

Introduction

Aquaculture is a growing industry all over the world striving to satisfy a growing market for protein rich food. It is also the fastest growing sector in Bangladesh. People are now very much concern about the food safety issue that influences farmers to produce fish on the contaminant free environment. Recirculating Aquaculture System (RAS), as a healthy and safe fish production system and can be located virtually anywhere. In this method, fishes are grown at high density under controlled environmental conditions. The system recycles the water through filtering both mechanically and biologically, so it can be reused. As aquaculture proved to be more economically viable than agriculture, a large extent of the paddy fields is turning into aquaculture ponds, which could raise serious food security concerns near future. RAS will help to solve the land use conflict. On an average about 0.6 kg fish is producing per square meter of pond area in Bangladesh (DOF, 2018), whereas an indoor RAS is capable of up to 80-100 kg and more of fish per m^3 of system volume. For this reason, mechanization and intensification in aquaculture is a crying need to adapt to the modern world. The technology is well suited and established in developed countries. Until now RAS machines are dependent on the import, however, due to particular local farming and operating conditions, lack of expertise, and the high price tag, these systems might not be suitable for local species. The RAS system needs to be efficient, cost-effective, and simple to operate. The design needs to consider the use of local materials under specific fish culture and environmental conditions. The development of an efficient RAS necessitates testing of local species. Establishing and testing of cost-effective RAS using local resources is, therefore, one of the most significant approaches for maximizing water reuse and intensifying fish production in Bangladesh. Energy is an important issue for the RAS. Minimizing energy cost through solar system would be an effective approach. Hence, RAS will be affordable for the marginal farmers using solar energy. That is why the present research project is designed to develop a cost-effective RAS system using locally available resources for intensive culture of high value species. Our main goal is to develop, adapt, and validate a cost-effective RAS for high value species. RAS application will be more reliable, profitable and meet the demand of aquatic enterprise to produce fish in a sustainable manner with international standards to ensure food safety issue.

Recirculating Aquaculture System (RAS), as a healthy fish production system and can be located virtually anywhere, where fishes are grown at high density under controlled environmental conditions. The system recycles the water to reuse. As aquaculture proved to be more economically viable than agriculture, a large extent of the paddy fields is turning into aquaculture ponds, which could raise serious food security concerns near future. For this reason, mechanization and intensification in aquaculture is a crying need to adapt.

With recirculating finfish systems operating at intensive culture densities, it is important to have the proper water treatment components to handle solids removal, biofiltration, oxygenation, and

degasification (Shahabuddin, 2016). In temperate regions, RAS has been developed to culture tilapia under controlled condition. Closed recirculating system was evaluated for Sea Cucumber, Scallop, Clam and finfishes controlling the appropriate temperature (Shahabuddin, 2016, Shahabuddin *et al.*, 2017). It was reported that production a recirculating system ranges from 60 to 120 kg/m^3 for rearing tank volume (Towers, 2014).

The most of all RAS used in Bangladesh, have been imported from abroad. The application of RAS for commercial producers in many cases has also been found as failure cases (Timmons *et al.*, 2002). Many commercial RAS have failed because of component failure due to poor design, technical support and inferior management (Masser *et al.*, 1999). The initial investment cost is very high to achieve the production target (Hutchinson *et al.*, 2004). Capital invests for the setup of RAS is normally much higher than that of the conventional production system, as it required additional equipment to treat water for reuse and failure of the treatment would result in huge economic losses (Summerfelt *et al.*, 2001). Thus, the small and marginal entrepreneurs could not attempt to use RAS with experiences of traditional fish culture and even with experiences of partially mechanized bio flock culture. Minimizing energy cost through solar system would be an effective approach. There was no attempt to design a RAS system to reduce the huge investment cost to make it affordable by the medium entrepreneurs. That is why the present research project was designed to develop a low-cost RAS system using locally available mini RAS for intensive culture.

Objectives

a) To design and set-up a mini-RAS
b) To develop a cost-effective RAS using locally available resources
c) Validate the RAS for commercial species, reduction of operational cost and Business model analysis.

Materials and Method

Recirculating Aquaculture System (RAS) is a new approach in the aquaculture of Bangladesh. Some innovative entrepreneurs have imported RAS from abroad specially from china. Two imported RAS were visited by research team to understand the RAS components and working procedure during 2020-21 (Fig. 1). First visited RAS was at Bangladesh Council of Scientific and Industrial Research (BCSIR) laboratory, Dhaka and another was Agosal Ltd., Bagher Bazar, Gazipur sadar, Gazipur.

BCSRI, Dhaka AgroSal, Bagher Bazar, Gazipur

Fig. 1. RAS site visit at BCSRI and AgroSal.

Recirculating Aquaculture System is a mechanical process with some components to satisfy the suitable environment in densely cultured high value aquaculture species. In a RAS, series of machinery were used to assure circulation and purification of water for intensive fish culture (Fig 2).

The main working component is water tank where high value fishes were inserted. Fish tank was designed and constructed with a frame made of mild steel angle and covered with a rubber coated poly sheet. The materials were selected to maintain suitable environment in both monsoon and winter. The waste water from the fish tank leads to a mechanical filter. Mechanical filter is a critical component of RAS. This equipment separates the large particles of the waste from the water. Effective waste removal and reuse of the water in the fish tank ensured by the mechanical filter. A drum type mechanical filter was designed to separate the solid particles from the water. The waste was drained out from the system. A backwash system was designed for the effective flow of the water. Water filtering and fine net flash cleaning were done automatically after prefixed certain time interval. Then the filtered water was pumped to the higher elevation having biological filters. Biological filters incorporated in the tank used to expand the surface area and to create suitable environment for biological activity for water purification. Biologically filtered water was flown through Ultra Violet (UV) treatment plant with a gravitational flow. The water then again returned to the fish tank. One oxygen generator was working to add oxygen to the water. Air insertion rate could be determined based on the fish density and available oxygen concentration.

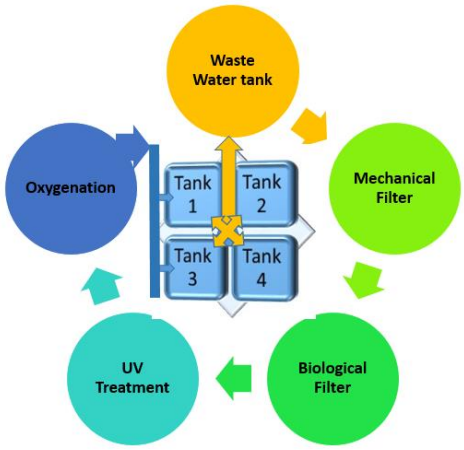

Fig. 2. Cycle of water in Recirculating Aquaculture System

Evaluation of flow rate, water quality parameters

Water supply and flow rate

A good supply of water, adequate in both quantity and quality, is essential to a successful fish farming enterprise. RAS recycle most of their water; they consume considerably less than other types of culture systems. Though the RAS system required only less amount of water and required only 10% of the water volume to replace, the selected site should be able to provide at least 20% of the system volume for daily water exchange and additional water needed for cleaning and waster loss in the reservoir tanks (Hutcchinson *et al.*, 2004).

Tank

Tank size and shape was important for the species-specific fish. The size of the tank depends on the variety of factors like stocking rates, species selected, water supply, water quality and economic considerations. The tank must be designed to correspond with the capacity of other components specially biofilter and mechanical filter of the system. In our study, we will consider both the size and shape of the tank for our local fish species.

The volume of the tank would calculate by the formula

$$V = \frac{\pi d^2 h}{4}$$

Where, V= Volume (m^3), d= Diameter of the tank (m), h= height of the tank (m).

Biofiltration

The biological filter is the heart of the RAS. The bacteria provide the waste treatment by removing pollutants. Biofilter provides a large surface area on which nitrifying bacteria can grow. The biofilter can be constructed of a variety of materials including plastic, concrete, HDPE, polyethylene or any other non-toxic substance. The size of the biofilter directly determines the carrying capacity of fish in the system. Volume of biofilter will be calculated based on the bio media available and the system capacity. The project will try to fabricate the filter media using local technology and entrepreneurs.

Recirculation rate

The water treatment system of a recirculating system must have a unit process designed to either remove or convert ammonia-nitrogen to a less toxic nitrogen compounds. The turnover rate could be calculated with a water pump rate at

$P=m^3/sec$

Water flow rate

The water flow rate can be calculated by the equation

$$Q = AV$$

$$A = \frac{\pi d^2}{4}$$

Results and Discussion

The designing of the RAS was done but due to fund constrain and COVID pandemic, the fabrication could not have completed. A RAS fish tank was fabricated (Fig. 3). Drum filter is an important part to separate solid waste from the recirculated water. A drum filter was designed and fabrication is going on (Fig. 4).

Fig. 3. Fabricated fish tank.

Fig. 4. Visit of research team during fabrication of drum filter.

Conclusion

Fabrication of RAS was started but could not be completed due to fund constraint and COVID-19 pandemic lockdown of the office. The fabrication of the RAS and component wise evaluation and improvement will be done in the coming year.

Acknowledgement

The experiment was conducted with research fund of Krishi Gobeshosa Foundation (KGF). The Project was jointly implemented by Fisheries Faculty of Shere bangla Agricultural University (SAU) and FMPE Division of BARI.

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EXPT. NO. 6.1 ADAPTIVE TRIAL OF BARI DEVELOPED AGRICULTURAL MACHINERY FOR CROP PRODUCTION IN THE COASTAL AREAS OF BANGLADESH

M S MIAH, M R KARIM, M A HOSSAIN AND A K CHOWDHURY

Abstract

Smallholder Agricultural Competitiveness Project (SACP) has been implemented (especially mechanization part) in six different coastal districts by Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur during 2020-21. BARI developed six types of agriculture machinery (BARI Seeder, BARI Bed Planter, BARI Weeder, BARI Axial Flow Pump, BARI Sunflower Thresher, BARI Compost Separator) were disseminated to farmers and local service providers through 49 adaptive trials with the help of OFRD, BARI. The selected crops were soybean, mungbean, groundnut, sunflower, mustard, cowpea, maize, and wheat. In each adaptive trial, 40 farmers and service providers participated who were practically demonstrated at least one machine in the farmers' fields. Farmers opined that the machine reduced their drudgery and cost significantly and often obtained higher yields compared to hand sowing. Additionally, sowing in lines by seeder reduced labour requirement for weeding. Seven local service providers (LSPs) in the working areas were developed. They covered 121 ha of crop land during the reporting period. Four consultation workshops on linkage development among GO, NGO and manufacturers were arranged in Satkhira, Patuakhali, Noakhali and Gazipur. This program will be continued next year to train the farmers/service providers/operators to disseminate the machinery, get feedback from farmers' fields and improve the machinery as needed.

Introduction

Agricultural mechanization has now been considered as one of the most essential inputs for crop production in Bangladesh. Agriculture has been facing trimetric challenges of decreasing agricultural land area, reduced agricultural workforce and increased climate hazards to increase food production sustainably to feed our ever growing population. Agricultural production in the coastal areas is more vulnerable to these challenges of natural hazards and climatic and environmental changes such as floods, storms, cyclones, soil and water salinity, high residual soil moisture delaying sowing, water logging as well as shortages, etc. (Mottalib *et al.*, 2019). Therefore, wide adoption of agricultural machinery in the coastal region is crucial specially for the smallholder farmers.

The coastal region of Bangladesh covers about 20% of total land area and over 30% of the cultivable lands of Bangladesh (Gathala *et al.*, 2011). Excessive soil moisture at planting, soil salinity, drought, rains or flash floods at crop harvest, etc. are some of the major challenges for growing crops in the coastal region. In addition, farmers rely heavily on human labourers for planting, intercultural operations, harvesting and postharvest operations that increases their production cost and often limits their ability to timely complete the cropping operations adversely affecting productivity. As a result, food security of millions of people living in the region is at risk (Hossain *et al.*, 2018). To plant crops in high soil residues, reduce dependency on human labourers, minimize production cost and overcome other production challenges BARI has developed some machinery such as seeders, bed planters, mechanical weeders, axial flow pumps, threshers, maize shellers, winnower, millet dehullers, etc. These machineries can be field tested and promoted to increase cropping intensity and minimize risk of crop production in the region.

In order to intensify cropping by horizontal (limited scope) and vertical (greater scope) expansions, increase land and labour productivity, improve input use efficiency, and reduce postharvest losses agricultural machinery can play a vital role (Hossain *et al.*, 2015). BARI has developed 43 agricultural machines, but majority of the farmers in the country are not aware of the availability and benefits of using these machines. Therefore, their countrywide adoption is low. Considering the cropping and soil conditions of the coastal Bangladesh, BARI developed machinery such as power tiller operated seeder (PTOS), manual and mechanical weeder, flow pump (AFP), maize sheller, sunflower thresher, compost separator, etc. are highly suitable for smallholder farmers in the region. In order to disseminate these machines in coastal Bangladesh adaptive trials and field days on machinery would play a significant role.

These trials have been conducted under the IFAD and GoB funded SACP (Smallholder Agricultural Competitiveness Project). SACP project aims to increase is to increase income and livelihood of smallholder farmers (2,50,000) in the coastal Bangladesh. The project is being jointly implemented by BADC (lead), DAE, DAM and BARI. Its project farmers, machinery service providers, extension and NGO personnel has been facing troubles to set up, operate, and adjust the machines to suit soil/crop types and conditions as well as maintain the machines at their best conditions. The adaptive trials and field days (method/results demonstrations) included in this project proposal will create opportunities for the farmers and other stakeholders to practically observe/visualize how the machinery can help them reduce production cost, save labour, improve timeliness, reduce drudgery, and increase production. Thus, these activities would thus help in adoption of the machinery by the smallholder farmers in the coastal Bangladesh.

Objectives

a) Evaluation of the performance of BARI developed machinery for crop production in the coastal areas of Bangladesh
b) Fine tuning of the machinery based on farmers' and service providers' feedbacks
c) Dissemination of the machinery in the coastal areas

Materials and Methods

Working areas and demonstrated machinery

The project locations were 30 different upazilla under 11 coastal districts of Bangladesh shown in Fig.1. Six districts were selected for conducting adaptive trials and demonstrations of different BARI developed farm machinery. The selected districts were Patuakhali, Bhola, Satkhira, Noakhali, and Laksmipur considering cropping diversity, machinery availability, working facility, helping manpower, BARI stations, etc. The selected farm machinery were BARI Seeder, BARI Bed Planter, BARI Axial Flow Pump, BARI Dry Land Weeder, BARI Power Weeder, BARI Sun Flower Thresher and BARI Compost Separator based on cropping diversity and local farmers' demand.

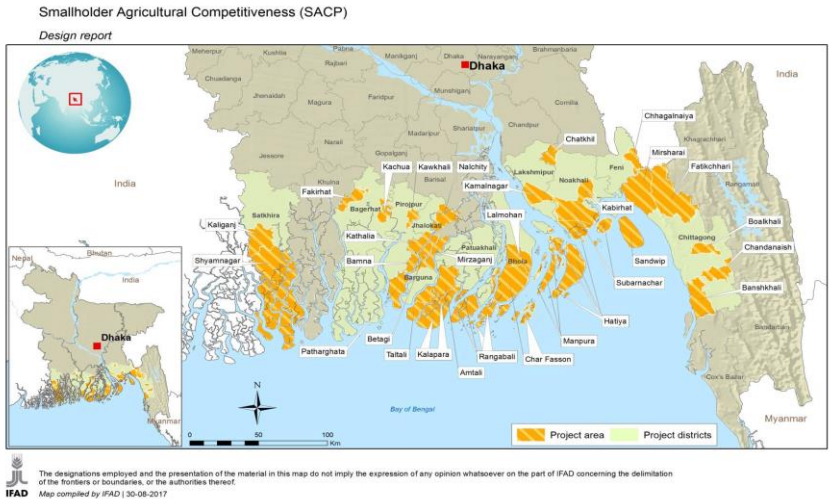

Fig. 1. SACP Project Locations throughout the coastal Bangladesh (Source: Final PDR, IFAD, 2008).

Adaptive trials

An adaptive trial is a trial in the presence of a user that evaluates a machine by observing performance on a prescribed schedule, and also collected feedback from the users. We also try to teach them how to operate those machineries and troubleshooting. Local On-Farm Research Division (OFRD) office closely monitor all of them work until harvesting.

Crop selection

We try to fit our developed machinery on the existing crops grown in the project location. BARI Seeder and BARI bed planter are suitable for all cereal crops. It is used for tilling and seeding at a time by a single pass. We used for sowing soybean, mungbean, groundnut, sunflower, mustard, cowpea, maize, and wheat in different coastal areas.

Local service provider (LSP)

A local service provider is a person who provides the machine for doing different agricultural operation in a different farmer's field on rental basis along with his labor or not. We have a target to develop LSP in the project location for smoothly running agricultural mechanization

.

Results and Discussion

Forty-nine numbers of the adaptive trials were conducted in the different coastal regions of Bangladesh shown in Table 1. Under each adaptive trial, 40 farmers were present and demonstrate at least one machine in the farmer field. Sometimes farmers operated the machine, and we try to learn them about different operating techniques and troubleshooting of the machine. Under the SACP project, awareness was built up among 1960 farmers on BARI developed machinery through demonstration as well as adaptive trials up to this year. Now some of them are using BARI developed machinery for different agricultural operations such as BARI Seeder for tilling and seeding, BARI Dry Land Weeder for weeding, BARI Axial Flow pump for irrigation, BARI Compost Separator for separating earthworm and compost fertilizer, etc. Last June 2021, BARI sunflower thresher was demonstrated among sunflower producing farmers of Subarnochar, Noakhali through four adaptive trials for threshing the sunflower heads and through those adaptive trials, the sunflower cultivation area will increase next year. They wanted to the use this machine next year and already placed advance order to purchase two machines next year.

Table 1. Progress on Adaptive Trial of BARI Developed Farm Machinery in the coastal Bangladesh

Name of machine	Location		Crops	No. of trials	Field size, ha	Date of sowing	Yield, t/h
	District	Site					
BARI Seeder, BARI Weeder, BARI Axial flow pump, BARI Slicer, BARI Sunflower thresher	Bhola	Jahanpur, Charfassion	Wheat, maize, groundnut soybean, mungbean, sunflower, mustard and cowpea	1	0.4	Nov 2020	Mungbean: 1.6
		Char Madras, Charfassion		6	4.0	Nov 2020 to May 2021	Groundnut: 2.3 Mungbean: 1.6 Cow pea: 1.5
		Aslampur, Charfassion		1	0.1	Nov 2020	Mungbean: 1.4
		Aminabad, Charfassion		3	0.8	Nov 2020 to May 2021	Mustard: 2.3 Groundnut: 2.3
		Char Omad, Lalmohon		3	0.7	Nov 2020 to May 2021	Mung bean: 1.5 Wheat: 1.5
		Duligornogor, Lalmohon		2	1.20	May 2021 to June 2021	Groundnut: 2.2 Mungbean: 1.5
		Uchapul, Betua, Charfassion		1	0.40	Feb 2021	
	Patuakhali	Diarumpur Kolapara	Wheat, maize, groundnut	1	0.6	Nov 2020	Wheat: 3.5, Maize: 10.0, Groundnut: 2.3
		Fashipara, Kolapara	Groundnut mungbean	4	1.0	Nov 2020 to June 2021	Groundnut: 2.2 Mung bean: 1.5
	Borguna	Uttor tiakhali, Amtoli	Mungbean, maize	2	0.8	Nov 2020	Mung bean: 1.6 Maize: 9.0
		Cholabanga, Amtoli	Soybean,	4	1.3	Nov 2020	Soybean: 1.9,

			sunflower, mungbean			to June 2021	Sunflower: 2.2, Mungbean: 1.7
		Amtoli Bazar		1	Machine demonstration	May 2021	
	Satkhira	Ram Jibonpur, Shamnogor	Maize	1	0.2	Dec 19	Maize: 8.0
		Pirgonj, Kaliganj	Wheat	1	0.2	Dec 19	Wheat: 1.5
BARI Seeder and weeder	Satkhira	Jibonnagor, Shamnagar	Soybean, sunflower, mungbean	1	Machine demonstration	11 June 21	1.8
		Kaliganj	Dry run for hand on learning	1	Machine demonstration	11 June 21	Capacity: 0.02 ha/h
BARI Seeder		Alamin Bazar, 4 No. charwapda Subarnochar	Soyabean	1	0.12	07 January 2021	1.8
		Char Amanuallah, Subarnochar	Soyabean	1	0.12	08 January 2021	1.9
	Noakhali	Siddique Bazar, Char Kazimukhles, Subarnochar	Soyabean	1	0.12	08 January 2021	1.9
		Panditer Hat, Char Jublee, Subarnochar	Soyabean	1	0.12	09 January 2021	1.85
		Charwapda, Subarnochar	Mungbean	1	0.24	06 Feb.21	1.2
BARI Weeder	Noakhali	Katabuniya,Subarnochar	Soyabean	1	0.24	07 Feb. 21	1.9
BARI Seeder and weeder	Laxmipur	Char Martin, Komol Nagar	Soyabean and mungbean	2	Machine demonstration	07 May 21	2.0
	Noakhali	Kukizmarket,Subarnochar	Soyabean and mungbean	1	Machine demonstration	09 May 21	1.8
		Bogarbazar,Subarnochar	Soyabean and mungbean	1	Machine demonstration	09 May 21	1.8
		Charzubilee, Subarnochar	Soyabean and mungbean	1	Machine demonstration	10 May 21	1.9
		Charwapda, Subarnochar	Soyabean and mungbean	1	Machine demonstration	10 May 21	1.9
BARI Sunflower Thresher		Purba badamtoli, Subarnochar	Sunflower	1	Machine demonstration	02 June 21	1.6 ton
	Noakhali	Alamin Bazar, Subarnochar	Sunflower	1	Machine demonstration	02 June 21	120 kg
		Uttar Kocchopiya,	Sunflower	1	Machine	03 June 21	120 kg

	Subarnochar		demonstration		
	Bhuiyarhat, Subarnochar	Sunflower	1	Machine demonstration	03 June 21	1.0 ton
Total			49	12.66 (ha)		

BARI developed farm machinery were demonstrated over 12.66 ha of land in the different project locations. More areas could not be covered due to the COVID-19 situation. Most of the machinery were used for tilling and seeding of soybean, mungbean, groundnut, sunflower, mustard, cowpea, maize, and wheat in different coastal areas (Fig. 2) and other intercultural operations such as weeding, irrigation and threshing. Yield data could not be collected physically by technical manpower but were collected from the farmers through cell phone.

BARI Dryland Weeder in operation in Charwapda, Subarnachar, Noakhali

Mustard in growth stage, Char Madras, Charfassion

adaptive trial BARI Seeder in Lalmohon, Bhola

Groundnut in growth stage, Diarumpur, Kolapara,Patuakhali

Adaptive trial in Amtoli, Bargona

Mustard in Charfassion, Bhola

Mungbean in Kolapara, Patuakhali

Adaptive trial in Amtoli, Barguna

Charwapda, Subarnochar, Noakhali

Charwapda, Subarnochar, Noakhali

Adaptive trial on BARI Weeder at Katabuniya, Subarnochar, Noakhali

Soyabean crop in Adaptive trial field, Alamin Bazar, Noakhali.

Soyabean crop established under Adaptive trial in charwapda, Noakhali.

Adaptive trial on BARI sunflower thresher in Vnuiyarhat,Subarnochar, Noakhali.

Fig. 2. Pictorial views of different adaptive trials and crop condition in the project areas.

Local service provider

One of the important task of the project is to develop local service provider (LSP). During this year we developed LSPs in the project location presented in Table 2.

Table 2. List of service providers developed in the project areas during 2020-21

Sl. No.	Name of Service provider	Main occupation	Address	Contact No.
1.	Md. Abdul Kadir	Power tiller Operator	Uttor Madras, Charfassion, Bhola	01724-771818
2.	Md. Akter Hossain	UP Member	Aminabad, Charfassion, Bhola	01718743108
3.	Md. Rifiq Ullah	Power tiller Operator	3 No. Char Wapda, Shubarnachar, Noakhali	01812339152
4.	Md. Nurul Huda	Power tiller Operator	3 No. Char Wapda, Shubarnachar, Noakhali	0185664115
5.	Md. Nur Uddin	Power tiller Operator	Subarnachar, Noakhali	01736512729
6.	Md. Abul Kalam	Power tiller Operator	Siddique Market, Subarnachar, Noakhali	01839836624
7.	Md. Zafar	Farmer	Katabuniya,Subarnachar, Noakhali	01322239575

The LSPs covered 121 ha of land in the different project sites (adaptive trial plots and outside of trial plots). One LSP Mr. Rofiqullah covered near about 100 ha of land alone using his two BARI seeder and three BARI weeder in his own land as well as provide service in other's field. He operated his machine by himself along with two machine operators who were employed as daily basis salary of Taka 800 for 8 hours of duty during machine operating season. All of them were trying to develop an agricultural machinery based custom hire services business. One of the LSP (Mr. Rofiqullah) made a profit of Taka 1,20,000 just using two BARI seeders in Shubarnachar, Noakhali in during Rabi season 2020-21.

Capacity building of local workshops

There is no farm manufacturing workshop in the project areas. A few repairing workshop exists some project locations. Through this project capacity building of two engineering workshops were done. These workshops are- (i) Chowmuhuny Metal & Engineering Workshop, Char Bata, Shubarnachar, Noakhali and (ii) Hedayetullah Engineering Workshop, Alamin Bazar, Shubarnachar, Noakhali. Due to Covid-19 pandemic capacity building of local workshop could not be done.

Fig. 3. Capacity building of local workshops in Subarnachar, Noakhali.

Consultation Workshop

Four consultation workshops on linkage development among GO, NGO and manufacturer were arranged physically in Satkhira, Patuakhali, Noakhali and Gazipur as shown in Table 3 and views are shown in Fig. 4. Different stakeholders like scientists, academicians, extension personnel, BADC Officers, NGOs, farm machinery manufacturers, LSPs and farmers were present in the workshops. The participants actively participated in discussion and gave valuable suggestions on linkage development among GO, NGO and manufacturer.

Table 3. List of workshop arranged on linkage development among GO, NGO and Manufacturer

Sl. No.	Workshop Title	Venue	Date	Number of participant
1	Scientists, Extension personnel, NGOs, Manufacturer, LSPs and farmers	BINA-Substation, Satkhira	31-12-2020	50
2	Scientists, Professor, Extension personnel, BADC Officers, NGOs, Manufacturer, LSPs and farmers	Khamarbari, Patuakhali	16-02-2021	50
3	Scientists, Extension personnel, NGOs, Manufacturer, LSPs and farmers	Sagorica, Chorbata, Subornachor, Noakhali	28-03-2021	50
4	Scientists, Extension personnel, NGOs, Manufacturer and LSPs	FMPE Division, BARI, Gazipur	30-05-2021	50

BINA Sub-station, Benerpota, Satkhira

Khamarbari, Patuakhali

Sagorica, Subornachor, Noakhali

FMPE Division, BARI, Gazipur

Fig. 4. Views of workshops on linkage development among GO, NGO and Manufacturer at different locations

Immediate demand of machinery in the areas

- BARI Seeder (2 sold, 1 ordered, 4 more to follow)
- BARI Hand Weeder (5 sold, 25 ordered, more to follow)
- Sunflower thresher (2 to follow)

Future demand for machinery/technology in the areas we worked

- Soybean thresher
- Soybean harvester
- Compost separator
- Sunflower thresher
- Drainage & Irrigation

Model of strengthening GO-NGO-Manufacturer Linkage

We have been working to develop linkages among GO-NGO-Manufacturers to up scale the use of agricultural machinery in the project areas. We have done four consultation workshop on linkage development among GO, NGO, and Manufacturer in four different district in the project areas.

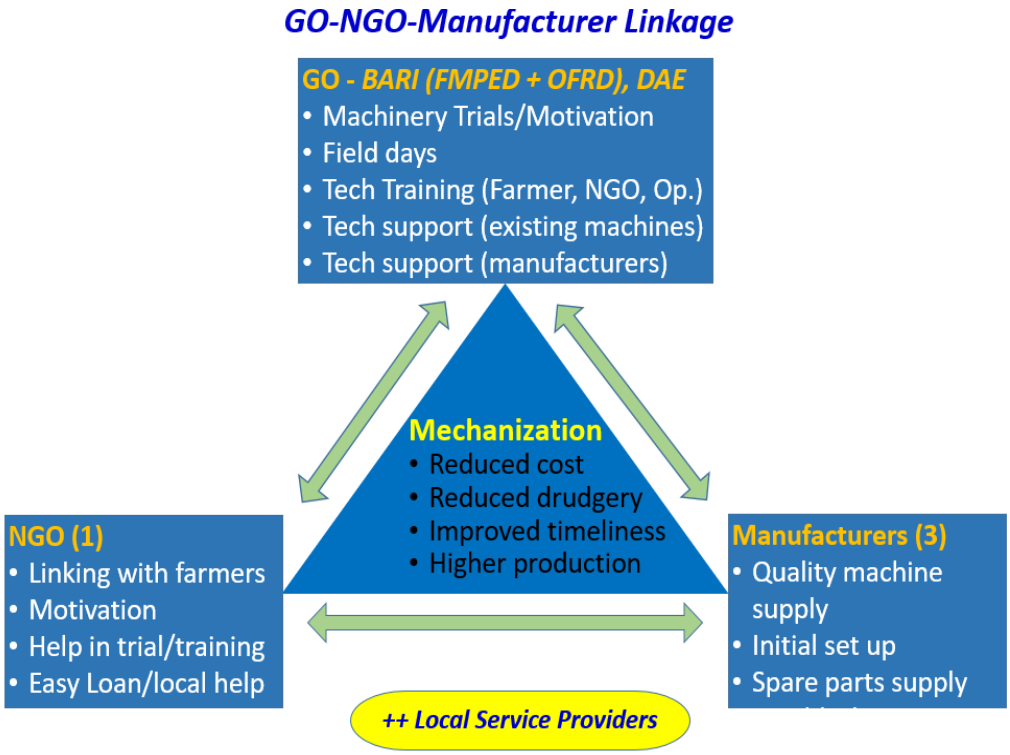

Fig. 4. Model of GO-NGO-Agri-Machinery Manufacturer Linkage development under SACP.

Conclusion

BARI developed farm machinery (five types) were demonstrated in the coastal areas of Bangladesh. The machine was used for various agricultural operations like tilling, seeding, weeding, irrigation, threshing, etc. The machines used for planting soybean, mungbean, groundnut, sunflower, mustard, cowpea, maize, and wheat. Forty nine adaptive trials were conducted covering 12.66 ha of land areas. Seven LSPs were developed in different project areas for providing custom hire services to the farmers. The LSPs covered 121 ha of land in the different project sites. Four consultation workshops on linkage development among GO, NGO and manufacturers were arranged in Satkhira, Patuakhali, Noakhali and Gazipur.

Acknowledgement

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Appendix-1

DEVELOPMENT OF A POWER TILLER OPERATED GARLIC PLANTER

M A MOTTALIB, M A HOQUE, M A HOSSAIN, M A ISLAM, M M ALAM, K HASSAN, S N MOZUMDER AND M H REZA

Available in the Annual Research Report 2020-21, Spices Research Centre, Bogura.

EVALUATION OF TILLAGE PRACTICES OF GROUNDNUT IN CHARLAND ECOSYSTEM OF JAMALPUR REGION

M M RAHMAN, M A HOQUE, M A RAHMAN, Z RAHMAN AND M M KADIR

Available in the Annual Research Report 2020-21, Regional Agricultural Research Station, Jamalpur.

EFFECT OF TILLAGE SYSTEM AND CROP RESIDUE RETENTION ON SOIL CARBON SEQUESTRATION IN WHEAT-MUNGBEAN-T. AMON CROPPING SYSTEM IN JAMALPUR REGION

M M RAHMAN, M A HAQUE, M YASMIN, Z RAHMAN AND M M KADIR

Available in the Annual Research Report 2020-21, Regional Agricultural Research Station, Jamalpur.

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4.	Md. Mahedi Hasan	Scientific Officer
5.	Md. Sumon Miah	Scientific Officer
6.	Muhammad Zakaria Hossain	Scientific Officer (Deputation for higher study)
7.	Md. Ashrafuzzaman Gulandaz	Scientific Officer
8.	Nusrat Jahan	Scientific Officer (Deputation for higher study)
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7.	Md. Azimuddin	Guard
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9.	Md. Abed Ali	Guard
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5.	Md. Meshabul Islam	Senior Fitter
6.	Md. Mahbubul Alam	Bench Mechanic
7.	Md. Monjur Alam	Mechanic
8.	Kamol Chandra Karmokar	Black Smith
9.	Md. Abdul Khaleque	Turner
10.	Md. Al Zabbir Hossain	Laboratory Attendant
11.	Khandaker Nizam Uddin	Welder
12.	Md. Mizanur Rahman	Furnace man
13.	Gazi Shazedul Kabir	Welder
14.	Chitto Ranjon Bhowmik	Milling Machine Operator
15.	Md. Abu Alam	Molder Helper
16.	Md. Delower Hossain	Junior Fitter
17.	Md. Shariful Islam	Molder Helper
18.	Md. Mahmudul Hassan	Letheman
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