RESEARCH ACHIEVEMENTS
(2013-2021)

PLANT PHYSIOLOGY DIVISION
Bangladesh Agricultural Research Institute
Gazipur-1701

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Preface

I am very pleased to know that Plant Physiology Division is going to publish a book on its research achievements from 2013 to 2021. The book includes the major findings of the experiments conducted under developmental physiology and stress physiology on different crops. Due to abiotic stresses (salinity, drought and waterlogging) a vast area of the country remains fallow in most of the years and it would increase in near future under climate change situation. To combat the climate change issues and bring the fallow land under cultivation abiotic stress tolerant variety development is urgently needed. Plant physiologist can identify a genotype which can withstand under stress situation and can explain its physiological mechanism of stress tolerance. Breeder can use these genotypes for variety development which can enhance crop productivity in stress prone environment. Plant Physiology Division of Bangladesh Agricultural Research Institute (BARI) has been doing such type of research from the very begging of its journey. The division has identified some genotypes on different crops which are relatively tolerant against abiotic stresses i.e. salinity, drought and waterlogging etc. and some of the identified genotypes already been released as crop variety. Besides, basic information generated through developmental physiological research activities would be helpful for agricultural scientists.

Thanks and appreciation are extended to the scientist of Plant Physiology Division of BARI who are engaged in research activities as well as represent their findings in an easy understandable format for common readers. Hope, this book would be very useful for breeder, agronomist, academician and extension personnel who are engaged in agricultural research and development in Bangladesh.

Dr. Debasish Sarker
Director General

Foreword

Plant Physiology is an integrative area of plant sciences that studies a wide array of physiological processes and environmental responses in plants. It provides a fundamental scientific foundation for understanding various aspects of metabolism, growth and development of plant. Physiological research is crucial for crop improvement or technology advancement in changing environment. Plant physiology division of BARI has been doing its research activities on developmental physiology and stress physiology of different crops such as oilseeds (mustard, rapeseed, groundnut, sunflower, linseed etc.), pulses (grasspea, chickpea, mungbean etc.), horticultural crops (vegetables), spices (onion, garlic, chilli etc.), tuber (potato) and cereals (maize, wheat, barley, sorghum, etc.) from very begging of its creation. Now the division is going to publish a book on its research achievement for the last nine years (2013 to 2021). The book focuses on the identified stress tolerant genotypes (salinity, drought, high temperature and waterlogging etc.) of different crops and their key features which enhanced their tolerance capacity against stresses. Some of the identified genotypes already been released as crop variety like salinity tolerant mustard BARI Sarisha-19, waterlog tolerant sesame BARI Til-6, and drought tolerant BARI Hybrid Maize-12 and BARI Hybrid Maize-13. Besides, some physiological research findings on different crops are also included in the book which would be helpful for breeder/scientist in stress tolerant variety development and knowledge enhancement. The readers can get the information about any of the studies in brief in the book but for details he/she may go through the divisional reports.

I would like to express my heartfelt thanks to the authority of Crop Research Centers/Divisions of BARI for their co-operations and providing genetic plant materials for running physiological research activities. Again I would like to thank the authority of other organizations who extended their support for enhancing our research activities. Finally I sincerely thank and appreciate the Scientists and associates who have worked hard in experimentation and prepared their research findings for this book. I hope this book would be very useful for the Scientists, Teachers, Students and other stakeholders who are engaged in agricultural research, improvement in crop productivity and nutritional security of the country.

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Chief Scientific Officer

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Abbreviations, Acronyms and Symbols

ADH	Alcohol Dehydrogenase
APX	Ascorbate Peroxidase
AsA	Ascorbic Acid/Ascorbate
BARI	Bangladesh Agricultural Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
BSA	Bovine Serum Albumin
°C	Degree Celsius
Car	Carotenoid
CAT	Catalase
Chl	Chlorophyll
C*i*	Intracellular CO_2 Concentration
CMSI	Cell Membrane Stability Index
CRD	Completely Randomized Design
CRI	Crown Root Initiation
DAE	Days After Emergence
DAG	Days After Germination
DAP	Days After Planting
DARW	Days After Removal of Waterlogging
DAS	Days After Sowing
DHAR	Dehydroascorbate Reductase
$dS\ m^{-1}$	Decisiemens per Metre
DTNB	5,5´-Dithio-bis 2-Nitrobenzoic Acid
EDTA	Ethylene Diaminetetraacetic Acid
Fig.	Figure
Fv/Fm	Chlorophyll Fluorescence
Gly-I	Glyoxalase I
Gly-II	Glyoxalase II
GPX	Glutathione Peroxidase
GR	Glutathione Reductase
G*s*	Stomatal Conductance
GSH	Reduced Glutathione
GSSG	Oxidized Glutathione
GST	Glutathione S-Transferase
H_2O_2	Hydrogen Peroxide
HRC	Horticulture Research Center
LDH	Lactate Dehydrogenase
LOX	Lipoxygenase
LSD	Least Significant Difference
MDA	Malondialdehyde
MDHAR	Monodehydroascorbate Reductase

MG	Methylglyoxal
mM	Milli Moles
MOP	Muriate of Potash
NaCl	Sodium Chloride
NADPH	Nicotinamide Adenosine Dinucleotide Phosphate
nmol	Neno mol
NTB	2-Nitro-5-Thiobenzoic Acid
$O_2^{\bullet -}$	Superoxide
ORC	Oilseed Research Center
PDC	Pyruvate Decarboxylase
PEG	Polyethylene Glycol
PGR	Plant Growth Regulators
PGRC	Plant Genetic Resource Centre
pH	Potential of Hydrogen
P*n*	Net Photosynthetic Rate
POD	Peroxidase
RCBD	Randomized Complete Block Design
ROS	Reactive Oxygen Species
RWC	Relative Water Content
SA	Salicylic Acid
SE	Standard Error
SMC	Soil Moisture Content
SOD	Superoxide Dismutase
SPAD	Soil Plant Analysis Development
STI	Stress Tolerance Index
TBA	Thiobarbituric Acid
TCA	Trichloroacetic Acid
TCRC	Tuber Crop Research Center
TDM	Total Dry Matter
TGA	Total Glycoalkaloid
TPC	Total Phenolic Content
T*r*	Transpiration Rate
TSP	Triple Super Phosphate
WL	Waterlogging
WRC	Wheat Research Center
WUE	Water Use Efficiency

Selection of Salt Tolerant Rapeseed/Mustard Genotypes for Coastal Areas of Bangladesh

Faruque Ahmed

Background

Rapeseed/mustard (*Brassica spp.*) is one of the most important oilseed crops of Bangladesh. It is cultivated in winter season in Bangladesh competing with other rabi crops. Domestic production of edible oil in Bangladesh mainly comes from mustard. Bangladesh has been facing acute shortage of edible oil for the last several decades. Our internal production can meet only about 21% of our consumption and the rest 79 % is met from the import. Mustard oil is used as cooking oil in the country. Increased oilseed production is needed not only to meet the demand of the increased population but also to reduce the import of edible oil to save foreign currencies. But in the present cropping system there is little scope to expand mustard production area due to competition with other rabi crops like boro rice, maize and pules etc. So we have to focus on the coastal district where after T. aman harvest, a vast area of lands remains either unused or covered by some minor crops. The coastal area of Bangladesh covers about one-fifth of the country and represents more than 30% of the country's cultivable lands (Rasel et al., 2013). Out of 2.86 million hectares of coastal and off-shore lands about 1.056 million hectare of arable lands are affected by varying degrees of salinity (SRDI, 2010). Large areas of land remain fallow in the dry season (January-May) because of soil salinity, lack of good quality irrigation water, and problems with water control (mostly drainage) (Mondal et al., 2006; SRDI, 2010). There is a possibility of bringing this vast fallow saline land under cultivation with salt tolerant rapeseed/mustard varieties in rabi season.

Rapeseed/mustard is considered as moderately salt tolerant crop. Salt stress results ionic imbalance and osmotic stress in plants which causes severe effects on morphology, biomass, and biochemical processes of the plants (Zhang et al., 2013). Soil salinity enhances the Na^+ and Cl^- contents in plants, increases the ratio of Na^+/K^+, which ultimately affects the regular ionic activities in plants (Singh et al., 2014). Several plants have developed different strategies to overcome these challenges. Among these, a high Na^+/K^+ ratio 0plays a vital role in maintaining membrane potential as well as osmotic and turgor pressures. It also helps in enzyme activation and tropisms (Rahneshan et al., 2018). Salt stress also leads to increase the level of reactive oxygen species (ROS) results in oxidative stress, which in turn affects the plants both at cellular and metabolic levels (Sahin et al., 2018). The plants overcome the oxidative damage through activation of antioxidants (enzymatic and non-enzymatic) mechanisms. The enzymatic component includes superoxide dismutase (SOD), peroxidase (POD), catalase (CAT), and ascorbate peroxidase (APX); (Soares et al., 2019). However, the existence of sufficient heritable variability may help for Genetic adaptation of crops to salinity which permits the identification and selection of salt tolerant strains and traits confer salt tolerance. Rapeseed/mustard is a glycophytes, but there might have variability among the genotypes to salinity stress. Identified salt tolerant rapeseed/mustard genotype may bring substantial changes in the agricultural practices in saline soils of the coastal districts of Bangladesh. Therefore, the present study was undertaken to identify salt tolerant genotype and to examine the physiological basis of salt tolerance of the selected genotypes. To fulfill the target, initial screening and genotypes selection was done by Oil Seed Research Center and provided us five genotypes to find out the best one on the basis of physiological evaluation.

Methodology

Experimental site	:	Vinyl house, pot culture (top dia-25 cm, bottom dia-18 cm, height-25 cm; 12 kg capacity)
Season	:	Rabi
Date of sowing	:	12 November, 2019
Genotypes	:	Jun-536, BJDH-12, BD-10115, BD-5960 and BARI Sarisha-14
Source of genotypes	:	ORC, BARI
Salinity levels	:	Control, 5 and 10 dS m^{-1}
Salinity imposed	:	20 DAS to maturity
Design and Replication	:	RCBD with 05 replications
Fertilizer dose and application	:	Fertilizers were applied @100-30-80-20-3-1 kg ha^{-1} NPKSZnB. Fertilizer were calculated for each pot depending on the amount of soil/pot. Half of N and all other fertilizers were applied as basal and remaining N was applied at 20 DAS.
Measured parameters	:	Ion uptake, chlorophyll, photosynthesis, leaf area, TDM, CAT, POD, MDA, yield components and yield

Findings

Jun-536 and BJDH-12 selected as salt tolerant genotypes.

Key features of selected genotypes

- Less uptake of Na^+ ion with higher K^+/Na^+ ratio
- Produced higher amount of ROS scavenging enzymes like CAT and POD
- Produce less amount of MDA
- Less affected in leaf area, photosynthesis, TDM and seed yield

Jun-536 has already been released as a salt tolerant variety-BARI Sarisha-19

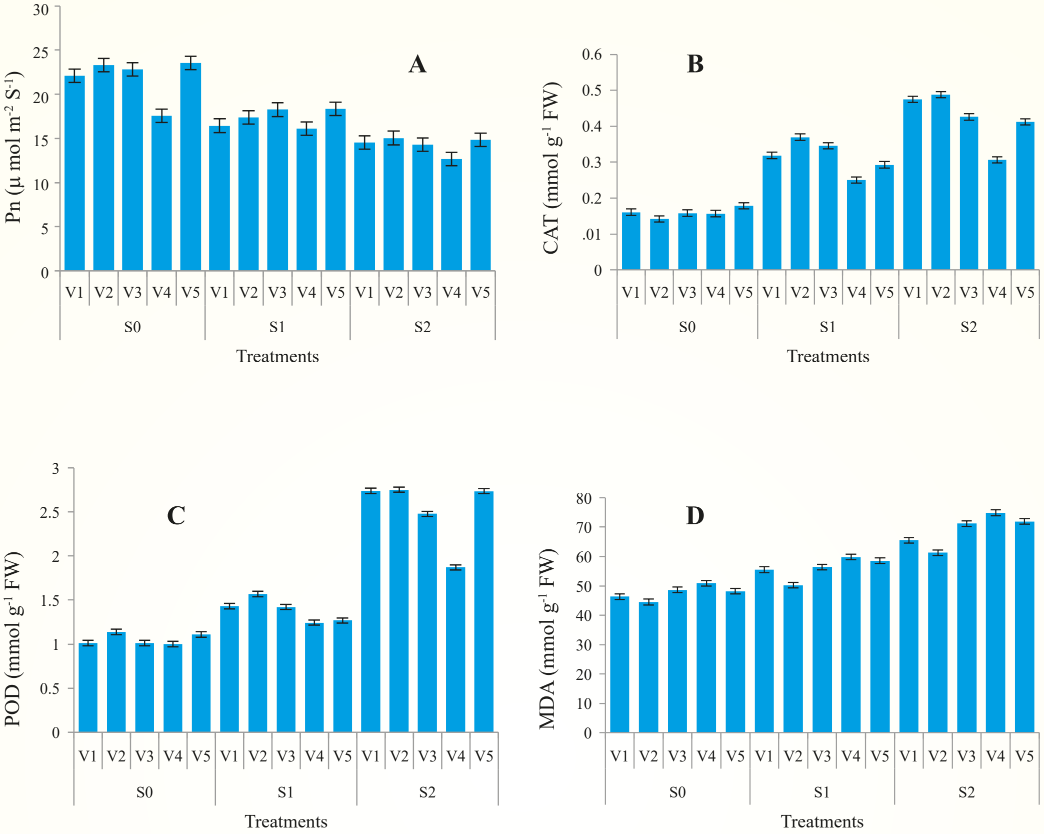
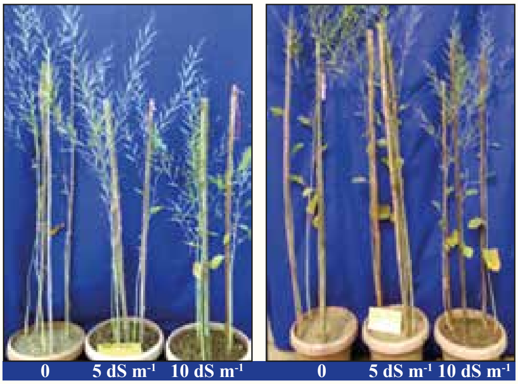


Fig.1: Interaction effect of genotype and salinity on photosynthesis (A), Catalyze (B), POD (C) and MDA (D) at 55 DAS (V_1= Jun-536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI-14, V_5 = BD-6950; S_0= 0, S_1= 5 and S_2=10 dS m^{-1} salinity).

Fig.2: Salinity measurement by EC meter.



Jun-536

BJDH-12

Fig.3: Selected salt tolerant Mustard genotypes.

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Identification of Salt Tolerant Wheat Genotypes

Imrul Mosaddek Ahmed

Background

Soil salinity is one of the major abiotic stresses affecting agricultural production in semi-arid regions and has negative impacts on plant growth and global crop productivity (Munns et al., 2006). The yield of grain crops over large areas of the world's farming land is limited by a number of physicochemical constraints in the subsoil including salinity and sodicity (Rengasamy, 2010). Attempts to develop viable management options to improve productivity of saline–sodic soils, such as irrigation and drainage, have met with minimal success to date. Wheat as the most important crop for human consumption or in the world is frequently grown in regions with saline and sodic soils. Therefore, breeding for improved salinity tolerance would be an effective way for improving yield and yield stability under such conditions (Genc et al., 2007).

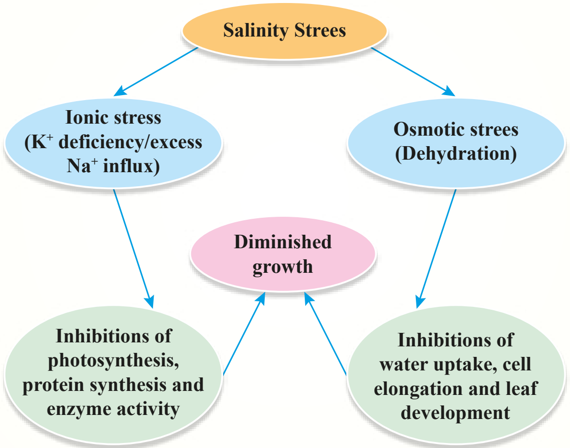

Fig. 1: Some important causes of growth reduction in plants under salinity stress (Ahmed, 2015)

Salinity inhibition of plant growth is the result of osmotic and ionic effects and the different plant species have developed different mechanisms to cope with these effects. Growth is accomplished through cell division, cell enlargement and differentiation, and involves genetic, physiological, ecological and morphological events and their complex interactions. The quality and quantity of plant growth depend on these events, which are affected by salinity stress (Fig. 1). Plant's ability to resist toxic effects of NaCl salinity depends on genetic make-up of plants or variations in physiological processes which enable the plants to cope with salt stress, which include degree of ion exclusion, tolerance to osmotic stress and tissue tolerance (Naeem et al., 2020; Ashraf et al., 2008). Even though, mechanism of salt tolerance varies with type of species, type of cultivar of the same species, plant developmental stage which makes it more complex (Pailles et al., 2020; Naeem et al., 2020; Athar and Ashraf, 2009). For example, it is well known that hexaploid wheat is more salt tolerant than tetraploid wheat, they did not difer over around 10 days of salinization (Munus et al., 1995). Thus, screening technique and parameters used to screen and select for salt tolerance is another uphill task. Identified salt tolerant crop cultivars with physiological traits contributing in salt tolerance can be used as donor in breeding for salt tolerance. For example, Munns et al. (2000) selected a salinity-stress tolerant durum wheat line 149 having greater K^+/ Na^+ ratio.

Wheat (*Triticum aestivum* L) is the second most important cereal in Bangladesh. There are 2.85 million hectares area of the costal and off shores is affected by varying degrees of soil salinity. This area remains uncultivated due to salinity and non-availability of salt tolerant crops. Due to severe and moderate salinity effect, crop growth is hampering in this area. There are no suitable varieties/lines of wheat to cultivate in the coastal area which can tolerate moderate and high salinity. Consequently, it is quite imperative to identify highly tolerant/ efficient accessions for use in breeding programs to develop wheat cultivars to salinity stress. Therefore, the primary objective of this study was to identify the most salt-tolerant wheat accessions, using root and shoot biomass and their ionic indicators.

Methodology

Experimental site	: Net house, Hydroponic experiment	
Season	: Rabi	
Date of sowing	: 22 November 2019 (1st year)	20 November 2020 (2nd year)
Genotypes	: 150 wheat genotypes (1st year)	10 wheat genotypes (2nd year)
Source of genotypes	: RWRC, BWMRI	
Salinity levels	: Control and 150 mM NaCl	
Hydroponic system	: Flash and drain hydroponic system was used in the study where lower container (40L) contains nutrient solution and upper container contain 40 small pots where seedlings were placed over the clay beads. There is a small pump in lower container which pumps the aerated nutrient solution to the seedlings placed on the upper container pots every 30-minute interval. Insert label into the pot (Fig.1). Repeat for all pots. The pH of the solution was adjusted to 6.0 ± 0.1 with NaOH or HCl as required. All solution was changed weekly.	
Salinity stress imposed	: Salinity was imposed to seven-day old plants, adding it incrementally by 50 mM NaCl per day to reach a final concentration of 150 mM. Control plants were grown under the same conditions, minus the NaCl.	
Design and Replication	: RCBD with 05 replications	

Fertilizer dose and application	:	Basal nutrient solution (mg l^{-1}): KNO_3, 6.5 mM; $Ca(NO_3)_2.4H_2O$ 4.0 mM as stock solution A, $NH_4H_2PO_4$ 100 µM, $MgSO_4.7H_2O$, 2.0 mM as stock solution B, $MnCl_2.4H_2O$, 0.5 µM; $ZnSO_4.7H_2O$, 0.2 µM; $CuSO_4.5H_2O$, 0.02 µM; H_3BO_3, 4.6 µM; $(NH_4)_6Mo_7O_{24}.4H_2O$, 0.1 µM.	
Measured parameters	:	Plant fresh weight, root length, shoot length, dry weight, Na^+, K^+ content and K^+/Na^+ ratio.	STI, SPAD value, chlorophyll fluorescence, plant height, root length, dry weight, fresh weight, shoot water content, Root water content, K^+, Na^+ content and K^+/Na^+ ratio.

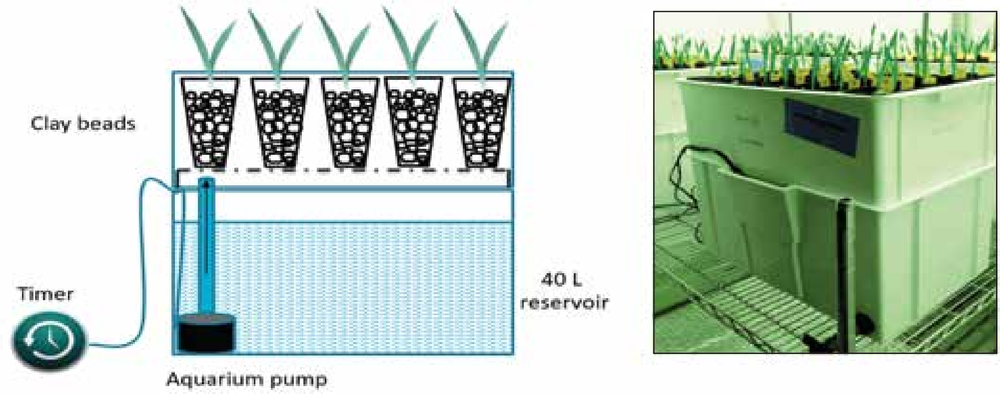

Fig.1: Flash and drain hydroponic system.

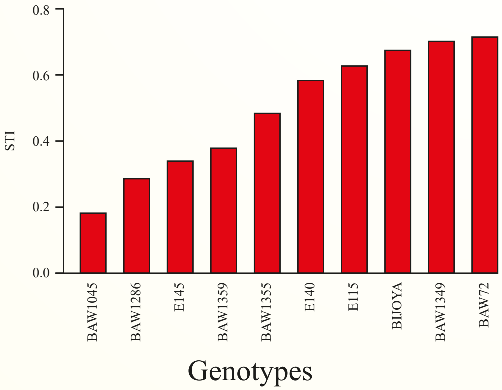

Fig. 2: Salt tolerance index of 10 wheat genotypes.

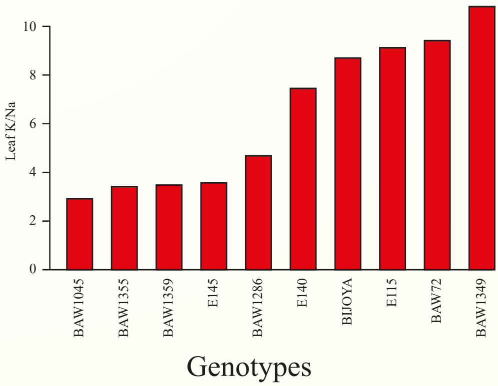

Fig. 3: Leaf K^+/Na^+ ratio of 10 wheat genotypes under 150 mM NaCl stress.

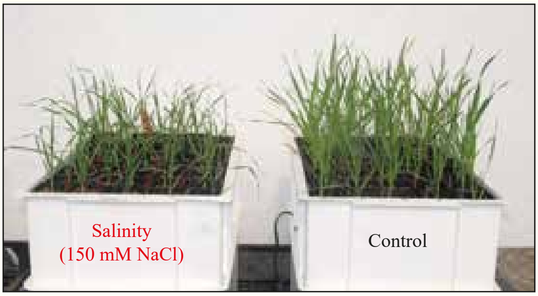

Fig.4: Phenotype of wheat genotypes as affected by salinity.

Findings

BAW 72, BAW 1349 and BIJOYA selected as salt tolerant genotypes.

Key features of selected genotypes

- Less affected of TDM
- Comparatively lower leaf and root Na^+ seen under 150 mM Salinity
- Less affected of *Fv/Fm* and SPAD value
- Higher STI

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Morpho-Physiological Responses of Soybean Varieties to Salinity Stress

Shamsun Nahar Mahfuza

Background

Soybean (*Glycine max* L. *Merr*) is a major source of high-quality protein and oil for human consumption (Katerji et al., 2000). The unique chemical composition, protein (35%), oil content (21%), and nitrogen-fixing ability (17-127 kg ha^{-1}) made soybean one of the most valuable agronomic crops worldwide (Thomas et al., 2003). The oil produced from soybean is highly digestible and contains no cholesterol (Essa, 2002). Soybean also contains minerals such as Fe, Cu, Mn, Ca, Mg, Zn, Co, P, and K. Vitamins B1, B2, and B6 as well as isoflavones are also available in soybean grains. Its production area is increasing day by day in Bangladesh because of its increasing demand as an ingredient in poultry and fish meal.

Salinity stress is the most damaging stress, and rising soil salinity in coastal areas has heightened concern about the possibility of crop damage in fields near the sea. In the next years, salinity will have an impact on agricultural crop output, particularly in arid and semiarid regions (IPCC, 2014). Salinity, whether natural or induced, is widespread environmental stress that limits the growth and development of salt-sensitive plants. Nearly 20% of the world's cultivated areas and nearly half of the world's irrigated lands are affected by salinity, which is the most serious environmental factor limiting the productivity of cultivated crops (Sairam and Tyagi, 2004). The soil salinity may be occurred due to poor water management, high evapotranspiration, and submerged irrigation and also due to pre-exposure of lands to seawater (Jin et al., 2007). In Bangladesh, 2.85 million hectares area of the coastal and off-shore is affected by varying degrees of soil salinity with pH ranges of 6.0-8.4 which is composed of the interface of various ecological and economic systems, including mangroves, tidal flat (Ahmad, 2019; Haque, 2006). The salinity problem has been increasing in Bangladesh, and over the last 35 years, salinity has increased by around 26 percent in the coastal region of Bangladesh (Mahmuduzzaman et al., 2014). Due to severe and moderate salinity crop growth is hampered in this area. Excess concentration of salt in soil has an immediate effect on cell growth and associated metabolism (Munns and Tester, 2008). The inhibition of plant growth due to salinity is attributed to salt-induced ion toxicity, nutrient deficiencies, salt-induced osmotic stress, hormonal imbalance, and salt-induced oxidative stress. Salinity also caused a drastic reduction in grain yield of many crops including soybean (Khan et al., 2016), mungbean (Aziz et al., 2006), and peas (Duzdemir et al., 2009). Among various crops tested, legumes have generally been found to be more sensitive to salinity. Since, the growth, development, and yield of a crop are the product of genetic potential interacting with the environment, soybean seed production may be limited by soil salinity (Ghassemi-Golezani et al., 2009). Thus, minimizing environmental stress will optimize the seed yield of a crop. The growing of salt-tolerant crops or varieties is one of the cost-effective strategies for coping with soil salinity. The comparison of the performance of different cultivars under salinity stress is useful to select the best one for cultivation to minimize the yield loss. Nonetheless, analyses of the morpho-physiological responses of a crop to salinity stress provide insight into the stress tolerance mechanisms of the crop. This study was undertaken to investigate the morpho-physiological basis of salinity tolerance of four soybean varieties, viz. Shohag, BARI Soybean-6, BARI Soybean-5, and BINA Soybean-4. All the varieties are popularly grown in the southern coastal area of Bangladesh, especially in Noakhali and Laksmipur districts, though their comparative salinity tolerance is not elucidated yet in a systematic study. It is hoped that the outcome of the study would help to identify the most salt-tolerant variety and to increase soybean productivity in the saline soils of Bangladesh.

Methodology

Experimental site	: Vinyl house, pot culture (top dia-25cm, bottom dia-18 cm, height-25cm; 12 kg capacity)
Season	: Rabi
Date of sowing	: 29 November, 2020
Variety(s)	: Shohag, BINA Soybean-4, BARI Soybean-5, and BARI Soybean-6
Source of varieties	: ORC, BARI
Salinity levels	: Control, 4, 8 and 12 dS m^{-1}
Salinity imposed	: 30 days after sowing and maintained up to maturity
Design and Replication	: RCBD with 06 replications
Fertilizer dose and application	: Fertilizers were applied @ 30-30-80-20-3-1 kg ha^{-1} N-P-K-S-Zn-B in the form of Urea, TSP, MOP, Gypsum, Zinc sulphate and Boric acid respectively. Half of N and all other fertilizers were applied as basal and remaining N was applied at 30 DAS.
Measured parameters	: Chlorophyll, Ion content (Na^+, K^+, Ca^{2+} and K^+: Na^+), H_2O_2, MDA, TDM, yield contributing traits and yield

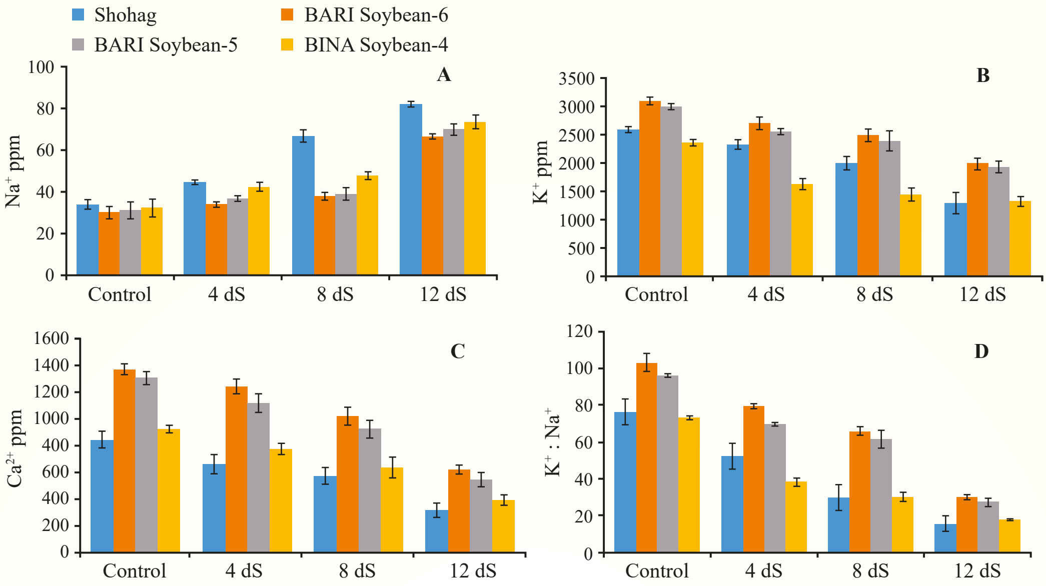

Fig. 1: Effect of salinity levels on Na^+ (A), K^+ (B), Ca^{2+} (C) and $K^+ : Na^+$ ratio (D) of soybean varieties. Bars indicate ± SE values.

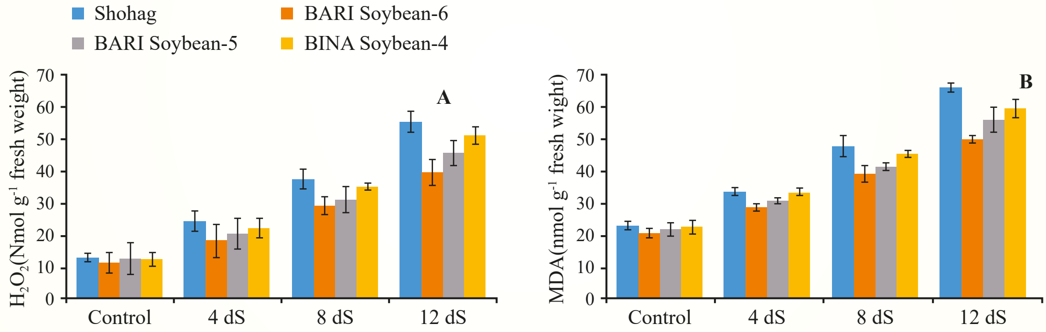

Fig. 2: Effect of salinity levels on H_2O_2 (A) and MDA content (B) of soybean varieties. Bars indicate ± SE values.

Fig. 3: Biochemical analysis (A) and ion meter reading (B) of different samples of soybean varieties in laboratory.

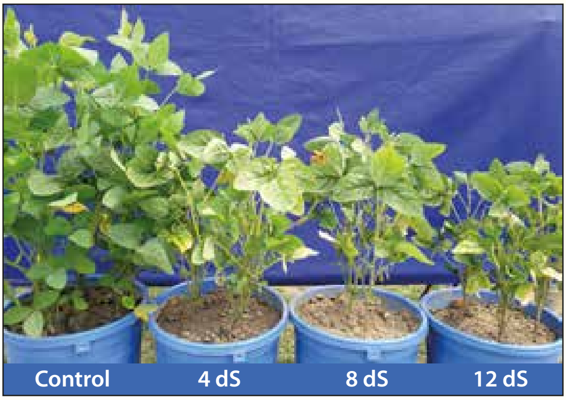

Fig. 4: Phenotype of BARI Soybean-6 as affected by salinity.

Findings

BARI Soybean-6 selected as relatively salt tolerant.

Key features of selected genotypes

- Relatively lower inhibition of chlorophyll synthesis
- High concentrations of Ca^{2+} and K^{+} and low concentrations of Na^{+}
- Less cell membrane damage and H_2O_2 contents at 12 dS m^{-1} salinity level
- Less affected in TDM, yield supporting traits and seed yield

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Morpho-Physiological Responses on Potato to Salinity Stress

A F M Shamim Ahsan

Background

Salt stress is the accumulation of excessive salt contents in the soil which eventually results in the inhibition of crop growth and leads to crop death. Salt stress is one of most detrimental abiotic stresses, and high exogenous salt concentrations cause ionic imbalance in the plant cells resulting in ionic toxicity, osmotic stress, and oxidative stress simultaneously (Tanveer and Shabala, 2018). A direct result of these primary effects is the enhanced accumulation of highly reactive oxygen species (ROS) that are harmful to plant cells at high concentrations. However, the absence of any protective mechanism they can seriously disrupt normal metabolism through oxidative damage lipids, proteins and nucleic acids (Apel and Hirt, 2004). Plants possess a number of antioxidant systems that protect them from these potential cytotoxic effects. Antioxidant enzymes are the most important components in the scavenging system of ROS (Rohman et al., 2016). Catalase (CAT) is one of the most important enzymes of antioxidant systems having the highest turnover rates among all enzymes (Garg and Manchanda, 2009). CAT, APX, GPX and a variety of general POD catalyze the breakdown of H_2O_2 (Chen and Asada, 1989; Brigelius-Flohé and Flohé, 2003). Therefore, this enzyme system eliminates the damaging effects of toxic oxygen species. Several studies have shown that higher GST activity can enhance abiotic stress tolerance of plants (Dixon et al., 2010). Over expression of GST in plants increases antioxidant activity and improves tolerance to oxidative stress (Yadav et al., 2005). On the other hand, salinity caused higher reduction in CMSI as well as increase in MDA and LOX in susceptible plants compared to tolerant ones. Therefore, CMSI, MDA and LOX have been used as indices of salt injury and salt tolerance as shown in some earlier studies, e.g., in salinity-tolerant genotypes of maize (Rohman et al., 2016) wheat (Borzouei et al., 2014) and rice (Rao et al., 2013).

Potato (*Solanum tuberosum* L.) is one of the important vegetables as well as cash crop in Bangladesh. Recently it has become major food crop due to multiple uses as vegetable and delicious processed items. At present nearly 476 thousand hectares of cultivable land is under potato cultivation and the country produced 9725 thousand tons potato in the year 2016-2017 (BBS, 2018). Though the potato production increases, still there is a wide gap between national average yield and that of coastal areas of Bangladesh. The cultivable areas in coastal districts are affected with varying degrees of soil salinity ranging from 3.63-27.67 dS m^{-1} (Akter et al., 2008). Potato is considered moderately sensitive to salinity (Katerji et al., 2000). Van Hoorn et al., (1993) reported that under irrigated potato with 5.9 dS m^{-1} of salinity a yield loss of up to 37% was incurred. It has been reported that potato production is limited by high level of salinity greater than 50 mM NaCl (Rahman et al., 2008). Increasing saline area demands salt tolerant cultivars for sustainable potato production in southern belt of Bangladesh. So far, BARI has released a salt tolerant potato variety and its tolerance mechanisms still unclear. Therefore, it is necessary to understand salinity tolerance mechanism in potato that will be helpful in developing stress tolerant potato varieties by using various modern techniques. Considering this scenario, the present investigation was undertaken to understand insight into the salt tolerance mechanism in potato.

Methodology

Experimental site	: Pot culture in Vinyl house, plastic pots (top dia-120 cm, bottom dia-90 cm, depth-42 cm) filled with 25 kg soil and cowdung in 4:1 ratio
Season	: Rabi
Date of sowing	: 27 November, 2018
Genotypes	: BARI Alu-72, BARI Alu-25 and BARI Alu-13
Genotype source	: TCRC, BARI
Salinity levels	: Control; 0.2, Moderate; 6-8 and Severe; 10-12 dS m^{-1}
Salinity imposed	: 9 DAE to maturity
Design and Replication	: RCBD with 4 replication
Fertilizer dose and application	: According to TCRC recommended fertilizer dose per hectare, the calculated amount of N-P-K-S for each pot was 4, 1.13, 3.75 and 0.5g N, P, K and S for each pot, respectively as 1 ha land contains 2×10^6 kg fresh soil (Hadis et al., 2019). Full amount of TSP, MOP, gypsum and 50% of urea were applied as basal during pot preparation and the remaining amount of urea was side dressed at 30 DAP.
Measured parameters	: Chlorophyll, carotenoids, Na^+ and K^+, CMSI, MDA, CAT, POD, GPX, APX, GR, GST, LOX, TDM , yield and yield attributes

Fig. 1: Comparative tolerance to salinity of potato varieties under salinity stress.

Table 1. Soil salinity levels in the pot-soil during salinity stress period (from 10 DAE to crop maturity)

Variety	Treatment	Soil salinity levels (dS m^{-1})										
		3rd week (11-17 Dec.)	4th week (18-24 Dec.)	5th week (25-31 Dec.)	6th week (01-07 Jan.)	7th week (08-14 Jan.)	8th week (15-21 Jan.)	9th week (22-28 Jan.)	10th week (29 Jan. -04 Feb.)	11th week (05-11 Feb.)	12th week (12-18 Feb.)	13th week (19-25 Feb.)
BARI Alu-25	Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Moderate	3.8	6.8	7.9	7.7	7.8	7.5	7.6	7.8	7.6	7.4	7.3
	Severe	4.0	6.9	10.3	11.7	11.8	11.4	11.7	12.0	11.8	11.4	11.3
BARI Alu-13	Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Moderate	3.7	6.6	7.8	7.3	7.4	7.6	7.2	7.4	7.5	7.4	7.1
	Severe	3.9	6.7	10.0	11.8	11.7	11.4	11.8	11.9	12.0	11.6	11.8
BARI Alu-72	Control	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Moderate	3.8	6.6	7.9	7.5	7.7	7.8	6.9	7.5	7.7	7.8	7.6
	Severe	3.9	6.8	10.2	11.9	11.6	11.5	12	11.8	11.9	11.7	11.6

Control: 0.2 dS m^{-1}, Moderate: 6-8 dS m^{-1} and Severe: 10-12 dS m^{-1}

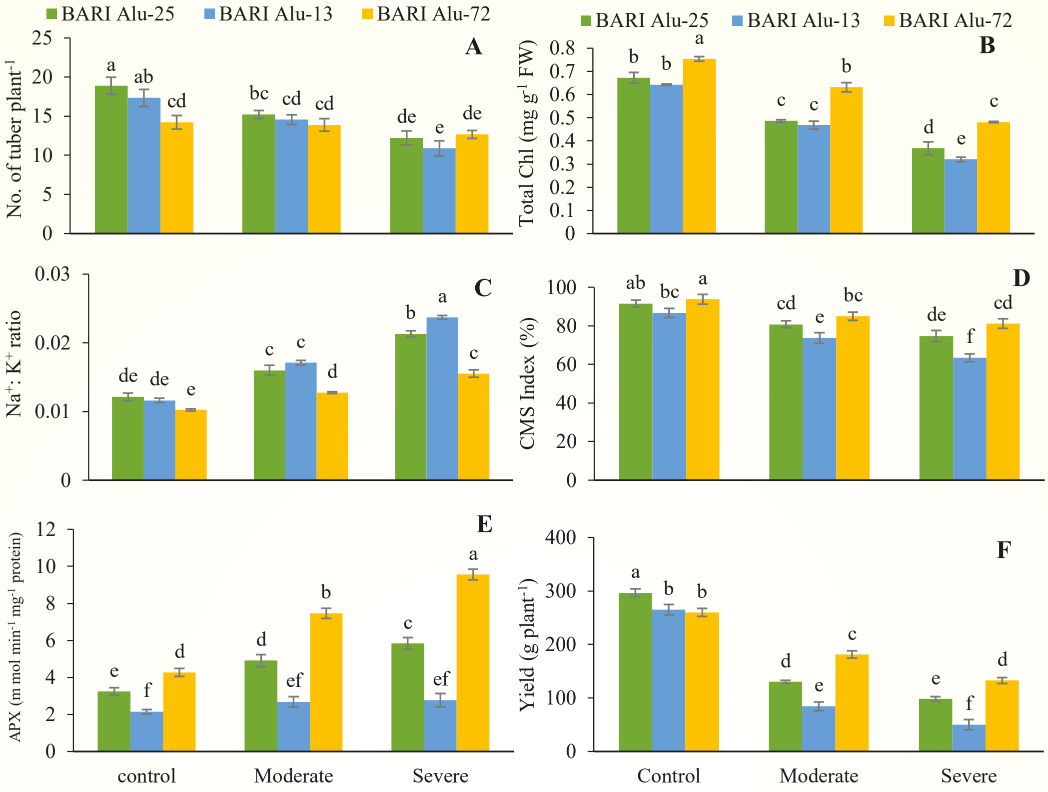

Fig. 2: Effect of salinity stress on tuber No. (A), total chlorophyll (B), Na:K ratio (C), CMS index (D), APX activity (E) and yield plant^{-1} (F) of potato varieties at 60 DAP. Vertical bars indicate SE; Control = 0.2, Moderate = 6-8 and Severe = 10-12 dS m^{-1}.

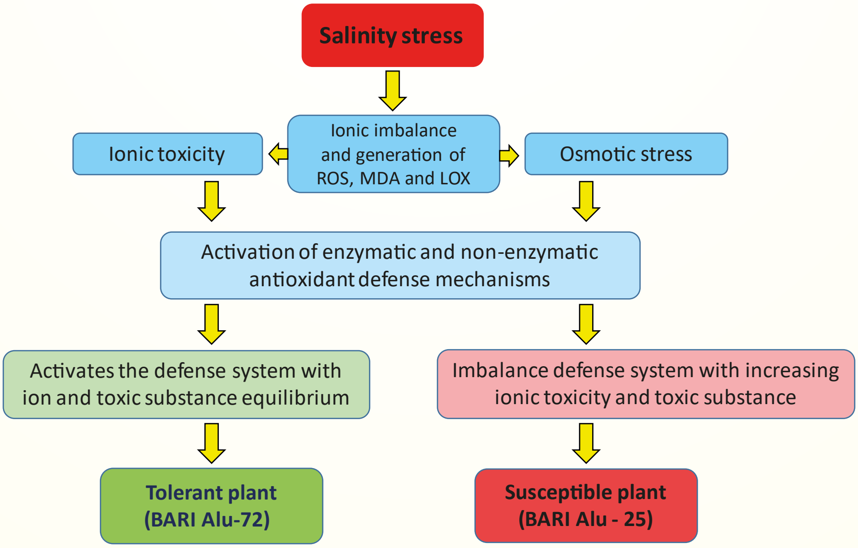

Fig. 3: Possible mechanisms in potato plant under salinity stress.

Findings

Salt tolerance of BARI Alu-72, depends on the activities of antioxidant enzymes, Na^+ exclusion and its tissue tolerance ability.

Key features of selected genotypes

- Produced more photosynthetic pigments like Chl*a*, Chl*b* and carotenoids in salt-tolerant potato
- Maintained higher activities of antioxidant like CAT, POD, APX, GPX, GST and GR under salt stress over control
- Less affected lipid peroxidation and better membrane stability in salt-tolerant potato
- Maintained lower concentration of Na^+ and Na^+: K^+ ratio including higher K^+ concentration under salinity stress

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Identification of Salt Tolerant Tomato Genotypes for Coastal Areas

A F M Shamim Ahsan

Background

Gratitude for its nutritional value; its numerous uses; and alluring properties related to touch taste, and aroma, tomato (*Solanum lycopersicum* L.) is the most important and popular vegetable in Bangladesh (Schreinemachers et al., 2016). In Bangladesh, it ranks second after brinjal in terms of both production area and yield, and the national average yield (14.57 t ha^{-1}) is very low (BBS, 2021). As a tropical plant, tomato is suitable for almost all climate zones around the world; but, abiotic stresses are the most significant constraints to its yield potential (Loudari et al., 2020). Among the abiotic stresses, soil salinity is an important suffering factor that constrains vegetable productivity mainly in semi-arid or coastal areas (Bünemann et al., 2018). The area under saline land in the coastal belt of Bangladesh is also increasing day by day and is being affected with varying levels of salinity ranging from 3.63-27.67 dS m^{-1}. Shrivastava and Kumar (2015) also reported that the productivity of most crops is significantly reduced by soil salinity when the value of electric conductivity approaches 4.0 dS m^{-1}. About 58.5% of the cultivated land of the coastal and offshore regions of Bangladesh is affected above this threshold level of salinity 4.01 to >16 dS m^{-1}. In the short term, salinity stress causes osmotic stress due to a decrease in water availability, and in the long term, ion toxicity due to an imbalance of cytosol nutrients (Sheteiwy et al., 2019). A high concentration of exogenous salt causes an ionic imbalance in the cells which leads to ion toxicity and osmotic stress (Chakraborty et al., 2018), nutrient imbalances, membrane damage, and reduced photosynthetic activities (Chourasia et al., 2021), and alteration of NO_3^- uptake by plants, which affect plant growth and yield (Yasuor et al., 2017).

Tomato is moderately sensitive to salinity (Zushi and Matsuzoe, 2017), and cannot endure or tolerate with very low yields. Salinity level above 3-5.5 dS m^{-1} markedly reduces leaf area index, total chlorophyll and also reduces tomato yield by 12-32% (Zhai et al., 2015). Salt stress influences a series of major physiological processes such as photosynthesis, ion partitioning as well as Na^+: K^+ ratio, reactive oxygen species (ROS), and hydraulic conductivity which affects the bioenergetic processes of the electron transport chain (Almeida et al., 2017). Earlier researchers investigated the response of salinity on different vegetables (Taïbi et al., 2016; Kumar et al., 2017; Raza et al., 2017), where they observed stressed plants with significantly reduced the biomass, leaf area, and growth. Root and shoot weight, tap-root length, chlorophyll content, and transpiration rate are some of the morph-physiological traits that can be employed to develop salt-tolerant cultivars (Taïbi et al., 2016). Among the physiological markers, selective ion uptake is the important indicator for salinity tolerance, with tolerant cultivars having enhanced K^+: Na^+ ratio and maintained low Na^+ (Ahsan et al., 2020). However, scientists around the world have screened up to 20 dS m^{-1} at vegetative stage and developed salt-tolerant tomato varieties (Kumar et al., 2017; Raza et al., 2017). Similarly, scientists in Bangladesh also conducted research, but their activities were confined to release varieties only (Moniruzzaman et al., 2013; Rashed et al., 2016). The results of the studies showed that these varieties were not able to give such promising yields in coastal areas. Therefore, it has become imperative to develop salt-tolerant tomato varieties for use in uncultivated areas due to soil salinity including meeting the food demands of growing population. In this connection, plant breeders have developed some new advance lines and hybrids, which are expected to be suitable for cultivation in coastal areas. Moreover, recalling the adverse impacts of climate change on the farm sector and according to “The 2030 Agenda for Sustainable Development” adopted by the UN’s general assembly in 2015, more emphasis should be given on the development of resilience and high-yielding genotypes. So, the present study was initiated in hydroponic systems subjecting to salt stress of some newly developed tomato parents and their crosses at the early vegetative stage for detecting salt tolerance.

Methodology

Experimental site	: Hydroponic culture (ambient environment)
Season	: Rabi
Date of sowing	: 06 November 2019
Genotypes	: 6 parents, 15 F1 hybrids, and 3 commercial varieties were screened-out
Source of Genotypes	: Olericulture Division of HRC, BARI
Salinity levels	: 20, 100 and 150 mM NaCl
Salinity imposed	: Salinity imposed at 35 DAS and the seedlings were grown up to 10 days after achieving the desired level of salinity in each container
Design and Replication	: CRD with three replication
Fertilizer dose and application	: Modified Hoagland Nutrient solution was used and its pH value was maintained at 6±0.5
Measured parameters	: Visual scoring of salt injury (1-5), length, fresh and dry weights of root and shoot, leaf area, CMSI, Ion content and their ratios (Na^+, K^+, Ca^{2+}, K^+: Na^+ and Ca^{2+}: Na^+)

Fig. 1: Root and shoot growth of tomato genotypes under salinity stress in hydroponic culture.

Table 1. Evaluation parameters of seedlings under salt stress

Phenotypes of the seedlings	Score
Plants with or without subtle inward curly leaves that are normally green in color	1
Plants green and complete innermost twisted leaves	2
All leaves are curly, dry leaves from reasonable to severe damages	3
About 50-80% leaves are drying with damages	4
All leaves are damages	5

Table 2. Visual assessment of tomato genotypes under salinity stress

Genotypes	Scale (1-5)A	Score	Genotypes	Scale (1-5)A	Score
SL0303	2.2 b-d	3	SL0304×SL0308	4.4 ij	5
SL0304	5 j	5	SL0304×SL0313	1.3 a	1
SL0307	3.2 fg	4	SL0304×SL0323	3.4 f-h	4
SL0308	1.4 ab	1	SL0307×SL0308	1.6 ab	2
SL0313	2.2 b-d	3	SL0307×SL0313	2.2 b-d	3
SL0323	3.4 f-h	4	SL0307×SL0323	3.6 gh	4
SL0303×SL0304	1.8 a-c	2	SL0308×SL0308	4.4 ij	5
SL0303×SL0307	3.2 fg	4	SL0308×SL0313	4.6 ij	5
SL0303×SL0308	4.6 ij	5	SL0313×SL0323	3 e-g	3
SL0303×SL0313	2.4 c-e	3	BARI Hybrid Tomato-4	4.8 j	5
SL0303×SL0323	2.8 d-f	3	BARI Hybrid Tomato-8	5 j	5
SL0304×SL0307	4 hi	4	BARI Hybrid Tomato-10	4.8 j	5
LSD $_{(0.05)}$	0.606	CV (%)		1.99	

[A] Increasing scale class from 1-5 indicates increases in salt damages. Means in the same column followed by a different letter(s) differ significantly at $p<0.05$

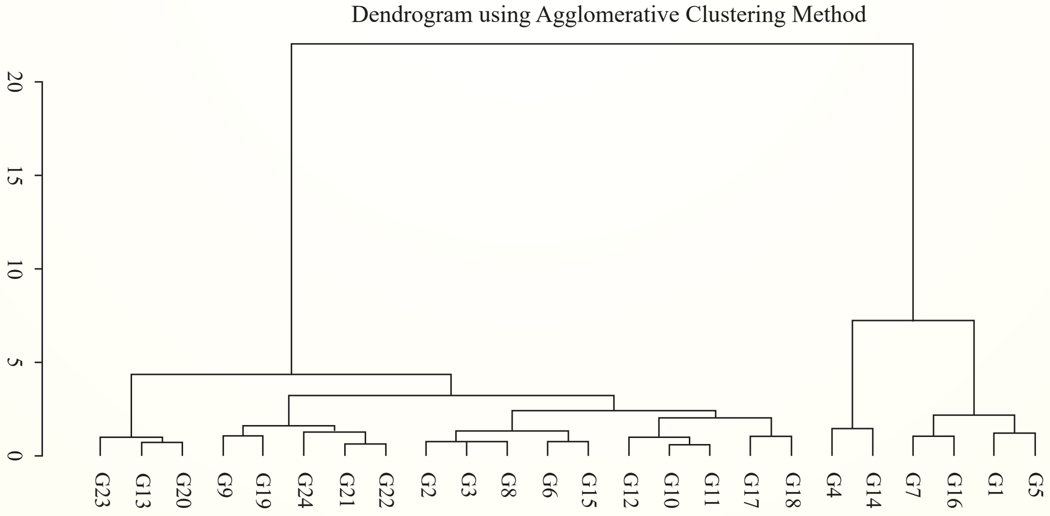

Fig. 2: Dendrogram using agglomerative clustering method, summarizing data on variation among 24 tomato genotypes according to the performance of morphological traits under salinity stress at vegetative stage.

Findings

SL0308, SL0303×SL0304, SL0304×SL0313 and SL0307×SL0308 tomato genotypes selected as relatively tolerant against salinity stress.

Key features of selected genotypes

- Least reduction of root and shoot length under salt stress
- Less affected in fresh and dry biomass
- Maintained lower salt injury and Na^+ uptake
- Associated with Na^+ prohibition and improved absorption of K^+ and Ca^{2+} to sustain a helpful symmetry of K^+: Na^+ and Ca^{2+}: Na^+ ratios under salt stress

Selected genotypes could be used for breeding programs to develop salt-tolerant tomato variety

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Evaluation of Garlic Varieties under Salt Stress for Coastal Areas

A H M Motiur Rahman Talukder and Bulbul Ahmed

Background

Salinity stress is a major inanimate problem that harms the agriculture by deteriorating the productive capacity all over the earth (Arif et al., 2020). A prediction by Qadir et al. (2014) was, global annual cost would be 27.3 billion US$ due to hamper of crop manufacture in salt induce soil. Bangladesh's population is growing rapidly and is estimated to reach 187.6, 203.0 and 215.4 million by the year 2031, 2041 and 2050 (Kabir et al., 2015). Therefore, to fulfill rising demand, main crop production will need to increase ~60% by 2050 (Tilman et al., 2011) as well as supplementary crop. Therefore, identifications of salt tolerant cultivars would be a great endeavor to feed rising population of the world. Salt has a detrimental influence on crop intensification and productivity, which is interconnected to metabolic and physiological activities. Plant physiological changes as a result of salinity, including the changes in photosynthetic pigment accumulation, diffusion rate, leaf water potential ability, K^+, Ca^{2+} and Mg^{2+} content (Ferdous et al., 2018) and causes a chain of responses like the stomatal closure and therefore a restricted CO_2 fixation (Hirdi et al., 2016). Salinity accelerates the manufacture of reactive oxygen species (ROS), which are highly toxic to the cell and disturb cell redox homeostasis, finally causes oxidative stress. Therefore, plant cells are equipped with well evolved to accumulate the proteolytic and non-proteolytic antioxidant enzymes like catalase (CAT), peroxidase (POD), ascorbate peroxidase (APX) which is strong quencher and scavenger of ROS. Previous extensive literatures expressed that extreme salt stress has a depressing effect on crop morphological performances such as root-shoot length, leaf area, and biomass production and among other things. Salinity affects growth differently in different species and to a lesser extent, in different variants within a species. Garlic (*Allium sativum*) is a highly nutritive crop; it contains large number of important enzymes, antioxidants and vitamins (Mohamed and Akladious, 2014; El-Saadony et al., 2017). Further, Garlic is a valuable spice used in a variety of dishes all over the world for its pungent taste as a seasoning or condiment. Garlic is also used to treat several of diseases, including incurable stomach and intestinal dysentery, typhoid, cholera, and lung diseases according to Ayurvedic and Unani medicine. Garlic clove's aqueous extracts substantially lower cholesterol levels. Each cultivar has become more susceptible to abiotic stress as a result of the rapid loss of genetic diversity caused by cultivar substitution. Furthermore, research organization like BARI has developed a few number of high yielding Garlic cultivar but their response to salinity stress has not yet evaluated. So, the foremost objective of this research was to examine the escalation and physiochemical responses of native and high yielding *Allium sativum* cultivars to diverse salinity stress and meanwhile to explore the association among salt tolerance. By understanding physiological aspects of garlic's reaction to salinity stress, researchers may be able to create salt-tolerant cultivars for coastal areas.

Methodology

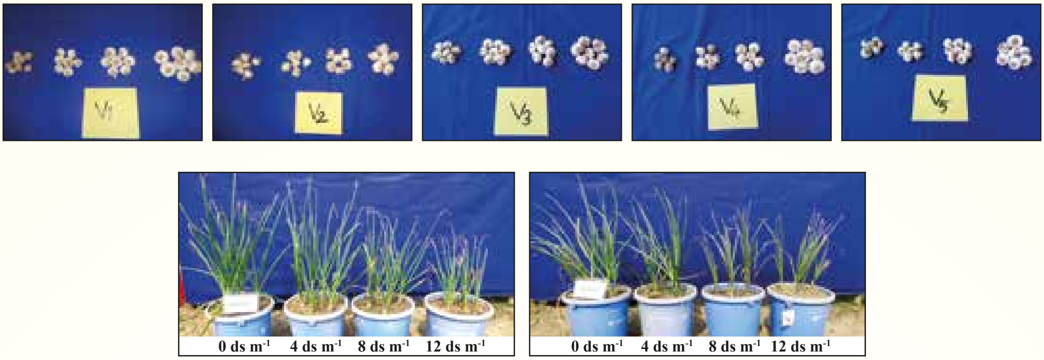
Experimental site	: Vinyl house, Pot culture (top dia-25cm, bottom dia-18 cm, height-25cm; 12 kg capacity)
Season	: Rabi
Date of sowing	: 15 November, 2019; 26 November, 2020
Genotypes	: BARI Rashun-1, BARI Rashun-2, BARI Rashun-3, BARI Rashun-4, Local (Natore local)
Source of genotypes	: RSRC, BARI
Salinity levels	: Control, 4, 8 and 12 dS m^{-1}
Salinity imposed	: 30 DAE to maturity
Design and Replication	: RCBD with 15 replications
Fertilizer dose and application	: Fertilizers @ 114-48-90-30-3-3 kg ha^{-1} of N-P-K-S-Zn-B were applied in the form of urea, TSP, MOP, sulphur and zinc sulphate and boron respectively. Each pot received double rate of urea, TSP, MOP, sulphur and zinc sulphate and boron respectively as per calculation of one hectare cultivated field contained 2×10^6 kg soil in root zone of crop.
Measured parameters	: Chlorophyll content, leaf area, TDM, Ion uptake (Na^+ and K^+), CAT, POD, MDA, APX, proline and yield components

Findings

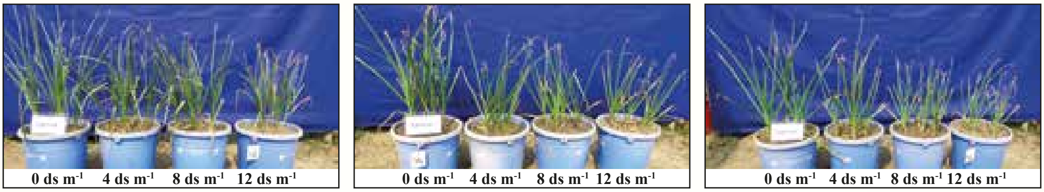
BARI Rashun-3 and BARI Rashun-4 was found relatively salt tolerant.

Key features of selected genotypes

- TDM productions, yield and yield supporting traits were less degraded in BARI Rashun-4 and BARI Rashun-3 at 12 dS m^{-1} salinity and had a stronger ability to continue constant osmotic potential maintaining the uttermost K^+/Na^+ ratio.
- BARI Rashun-4 showed higher activity of antioxidant enzyme and less cell membrane damage at 12 dS m^{-1} salt level.



BARI Rashun-1 (V_1) BARI Rashun-2 (V_2)



BARI Rashun-3 (V_3) BARI Rashun-4 (V_4) Natore local (V_5)

Fig. 1: Garlic varieties under different salinity stress (0 to 12 dS m^{-1}).

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Water logging tolerance in Sesame: Selection of Waterlog Tolerant Sesame Genotypes

A F M Shamim Ahsan

Background

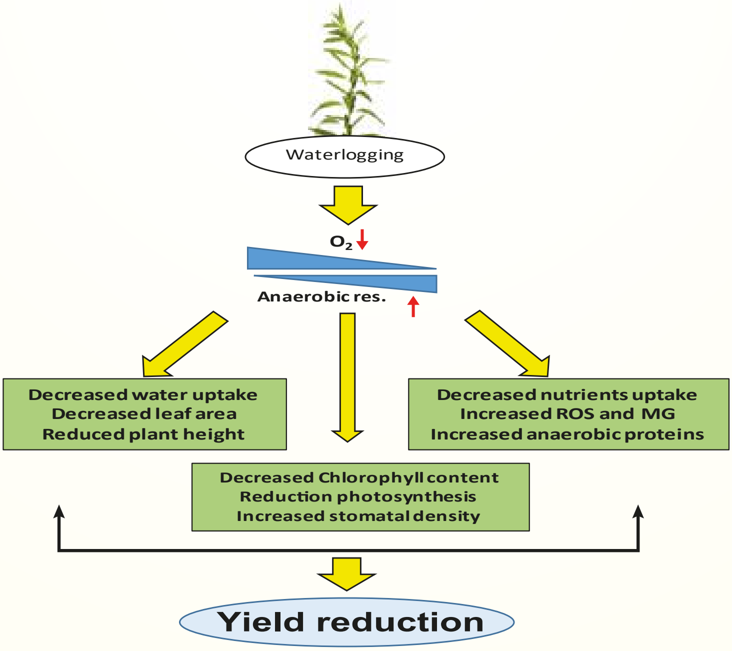
Waterlogging is the situation in which the soil profile is saturated with water for a short or long period. In waterlogged lands, the water table rises to the point that the soil pores in the crop root zone become saturated, preventing normal air circulation. As a result, the soil has less oxygen and more carbon dioxide, which causes yield reductions or at times, total crop failure. In this situation results in anaerobic respiration causes injury and reduction in growth of roots as well as shoots (Kramer, 1951). Short-term waterlogging often firstly causes oxygen deficiency (hypoxia or anoxia) in plants and leads to roots damage and leaf wilting and chlorosis under transient or sustained flooding conditions (Grassini et al., 2007). And long-term waterlogging can cause crop yield losses up to 30% when it occurs early in the season (IPCC, 2007). Waterlogging causes a shortfall in oxygen availability to plants, which is felt directly by the root system, and indirectly by the shoots. During waterlogging, leaf stomata close, whereas chlorophyll degradation, leaf senescence, and yellowing reduce the ability of leaves to capture light and ultimately lead to a decline in photosynthetic rate (Kuai et al., 2014; Yan et al., 2018). As a result, plants experienced growth reduction, yield loss, and death of plants at both vegetative and reproductive stages (Hasanuzzaman et al., 2010). Waterlogging is one of the main abiotic stresses suffered by plants. In recent years, it has become a devastating problem in Bangladesh agriculture.

Sesame (*Sesamum indicum* L.) is an ancient oil crop widely cultivated in many parts of the world. However, it is highly susceptible to waterlogging and strong rain (Mai et al., 2021). In Bangladesh, sesame is mainly grown in the Kharif-I season and almost every year the crop has to face waterlogging problems in some parts of its life cycle. Therefore, the average yield of sesame (500-600 kg ha^{-1}) in Bangladesh is much lower than in other sesame-producing countries. This low yield may be attributed to several reasons, but waterlogging is a primary factor that has a severe effect on sesame production. Therefore, the acreage and production of sesame have dramatically decreased. More precisely, the area under sesame cultivation was 90.82 thousand hectares in 1989, whereas it decreased to 40.47 thousand hectares in 2016 (BBS, 2017). In this situation, the development of waterlogging tolerant sesame varieties has become essential. As a result, the current study was carried out to identify the waterlogging tolerant sesame genotype(s).

Methodology

Four experiments were conducted in different conditions to screen out the waterlogging tolerant sesame genotypes.

Experimental site	:	Plant physiology laboratory	Plant physiology field	Vinyl house, Pot culture	Vinyl house, Pot culture
Season	:	Rabi	Kharif-I	Kharif-I	Kharif-I
Date of sowing	:	2 January 2017	15 March 2017	13 March 2018	26 February 2019
Genotypes	:	110		40	7
Source of genotypes	:	BARI (ORC and PGRC), BINA and Local			
Waterlog duration	:	Control and 48 h	Control and 48 h	Control, 24, 48 and 72 h	Control, 48 and 60 h
Waterlog imposed	:	10 DAG	48 DAS	56 DAS	55 DAS
Design and Replication	:	CRD with 05 replications	Augmented design	RCBD with 05 replications	RCBD with 04 replications
Fertilizer dose and application	:	10 ml DW water with 1,000-fold diluted Hyponex solution applied in each petri-dish	Fertilizers were applied @100-30-55-25-3-1 kg ha^{-1} N-P-K-S-Zn-B, respectively. Fertilizer was calculated for each pot depending on the amount of soil of pot. All fertilizers were applied as basal.		
Measured parameters	:	Seedling survival%, total length and weight of seedling	Survival% and yield reduction%	Survival%, yield and yield contributing traits, stress tolerance indices, cluster analysis of qualitative traits and ranking of Indices	Green leaf No., plant height, root volume, root dry weight, seed yield plant^{-1}, Chl *a*, Chl *b*,Total Chl, Car, Pn, Gs, Tr and Ci.



Some important causes of yield reduction in sesame plant under waterlogging stress

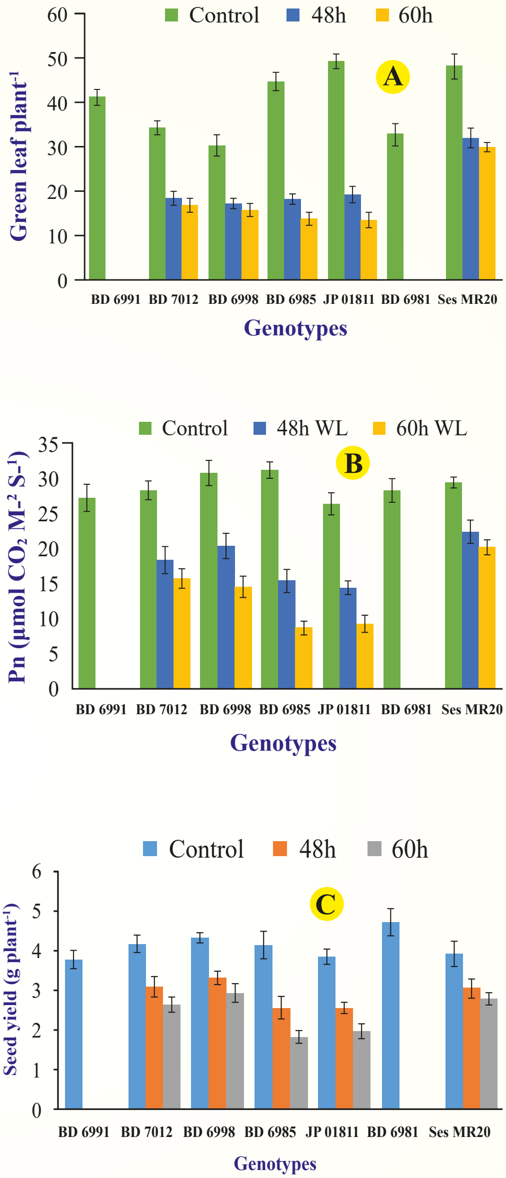


Fig.1: Pictorial view of the experiments under laboratory (A), field (B) and pot culture (C)

Fig. 2: The effect of waterlogging on number of green leaf (A), photosynthetic rate (B) and seed yield plant^{-1} (C) of sesame genotypes. Vertical bars represent ±SE.

Findings

Ses MR-20, BD-6998 and BD-7012 sesame genotypes selected as relatively tolerant to waterlogging stress.

Key features of selected genotypes

- Less visible of leaf chlorosis
- Perform the best ranks mean and low standard deviation of ranks in consideration of all indices
- Survived from waterlogging injury with the higher Pn, Gs, Tr and photosynthetic pigments
- Less affected in TDM and seed yield production

Selected genotypes can be used in breeding programs to develop waterlogging tolerant variety

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Water logging tolerance in Sesame: Biochemical and Anatomical Adaptations of Waterlogging Tolerance in Selected Sesame Genotypes

A F M Shamim Ahsan

Background

Waterlogging, which arises from the excess soil water and causes severe constraint on crop growth and productivity, has currently become a major abiotic stress in large areas of the world. Among the abiotic stresses, waterlogging leads to a series of morphological, physiological, biochemical and anatomical changes that are adversely affected to plant growth, development and production. For example, waterlogging causes leaf chlorosis, leaf senescence, wilting, and fruit drop, as well as the crop yield is severely reduced. Generally, plant adaptations to waterlogging or oxygen deprivation in the soil include avoidance strategies at the combination of morpho-physiological, biochemical and anatomical levels (Sharma et al., 2021). Adventitious root formation and stem elongation are examples of morphological adaptations, while aerenchyma formation is the most common type of anatomical adaptation to waterlogging stress. Shifting from the aerobic to the anaerobic fermentation, through use of the anaerobic proteins (ANPs), such as PDC, ADH and LDH enzyme, is a method of biochemical adaptation. However, the well-balanced antioxidant defence system is the most significant adaptive mechanism, which promotes scavenging of damaging ROS, comprising of both enzymatic e.g., catalase (CAT); glutathione peroxidase (GPX); ascorbate peroxidase (APX); monodehydroascorbate reductase (MDHAR); dehydroascorbate reductase (DHAR); and glutathione reductase (GR) and non-enzymatic antioxidants e.g., ascorbate (AsA); glutathione (GSH); and carotenoids (Apel and Hirt, 2004). The activity of the antioxidant enzymes in this mechanism varies substantially with stress intensity and plant genotype. Methylglyoxal (MG) is a cytotoxic compound, normally present in a lower amount in plant cells, but increases several fold under stress conditions depending on stress intensity and duration (Yadav et al., 2005 and 2008; Rohman et al., 2016). Therefore, upregulation of the glyoxalase system is crucial for plants to build up stress tolerance against toxic MG-induced oxidative stress (Yadav et al., 2005 and 2008). The tolerance of plants under environmental or abiotic stress conditions depends on the results of the coordinated action of the antioxidant defense and the glyoxal detoxification system.

Sesame is highly susceptible to waterlogging stress which results in reduced growth and yield (Ahsan et al., 2019). Therefore, the acreage and production of sesame have drastically decreased in Bangladesh. In this situation, the better understanding of the underlying tolerant mechanism is very important to develop waterlogging tolerant sesame. However, the waterlogging tolerance mechanism of our native germplasm is not fully understood. Therefore, the present investigation was taken to uncover some of the mechanisms involved in waterlogging tolerance in selected sesame genotypes and help to develop waterlogging tolerant sesame variety.

Methodology

Experimental site	: Pot culture in Vinyl house
Season	: Rabi
Date of sowing	: 20 February 2020 and 15 October 2020
Genotypes	: Ses MR-20 and BD-6998 (relatively waterlogging tolerant) and BD-6991 (susceptible genotype)
Source of genotypes	: ORC and PGRC of BARI
Waterlog imposed	: Waterlogging treatment was imposed at 28 DAE
Waterlog duration	: Control, 72 and 120 hours
Design and Replication	: RCBD with 05 replications
Fertilizer dose and application	: Fertilizers were applied @100-30-55-25-3-1 kg ha^{-1} N-P-K-S-Zn-B, respectively. Fertilizers were calculated for each pot depending on the amount of soil of pot. All fertilizers were applied as basal.
Measured parameters	: Proline, MDA, H_2O_2, SOD, CAT, POD, APX, GPX, AsA, GSH and GSSG DHAR, MDHAR, Gly I, Gly II, $O_2^{\bullet -}$, MG and anaerobic proteins such as LDH, ADH and PDC and root tissue anatomy. Samples were collected from 34 DAE for control treatment and 3 DARW for other treatments.

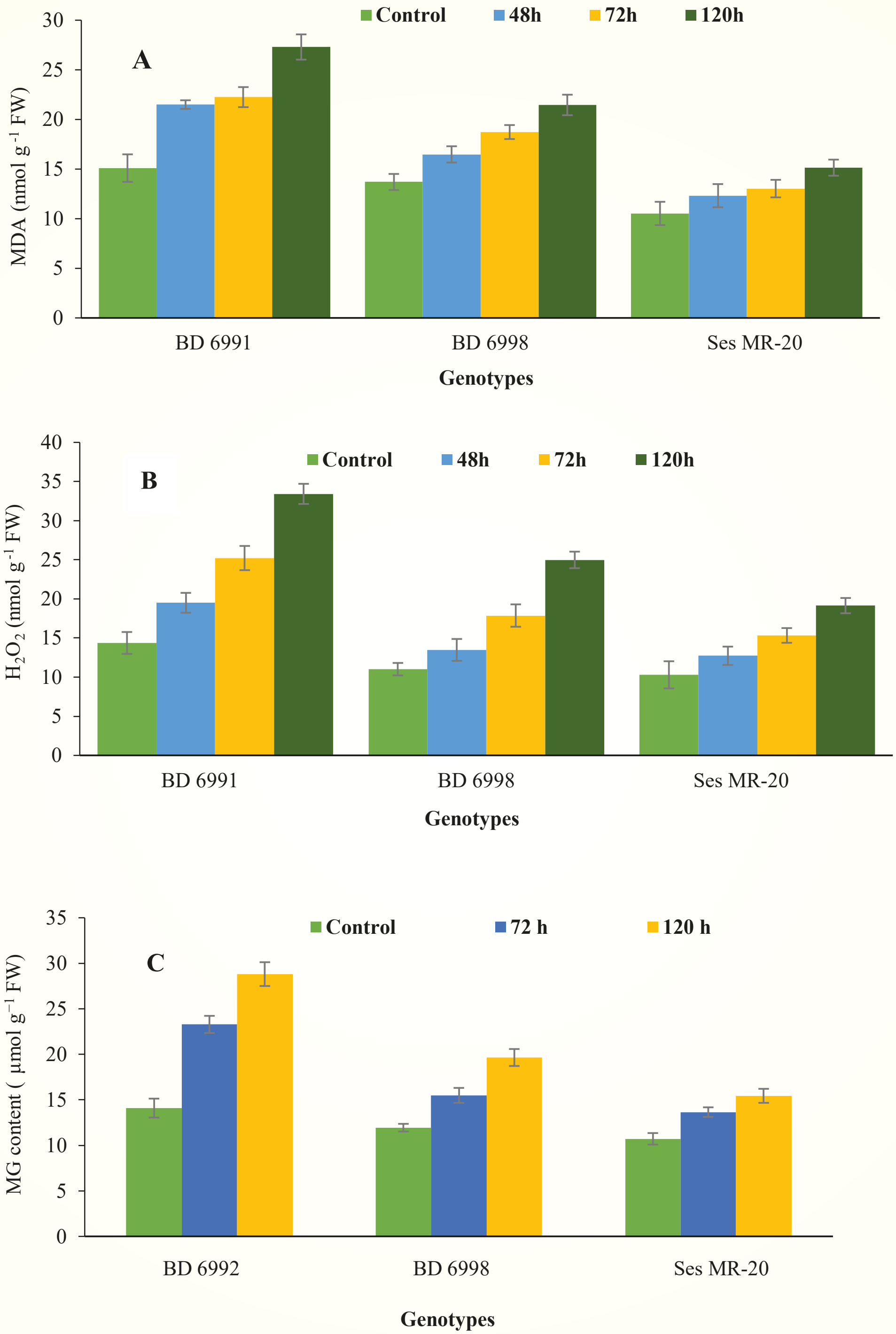

Fig. 1: Effect of waterlogging on MDA (A), H_2O_2 (B) and MG content (C) in sesame genotypes. Vertical bars represent ±SE.

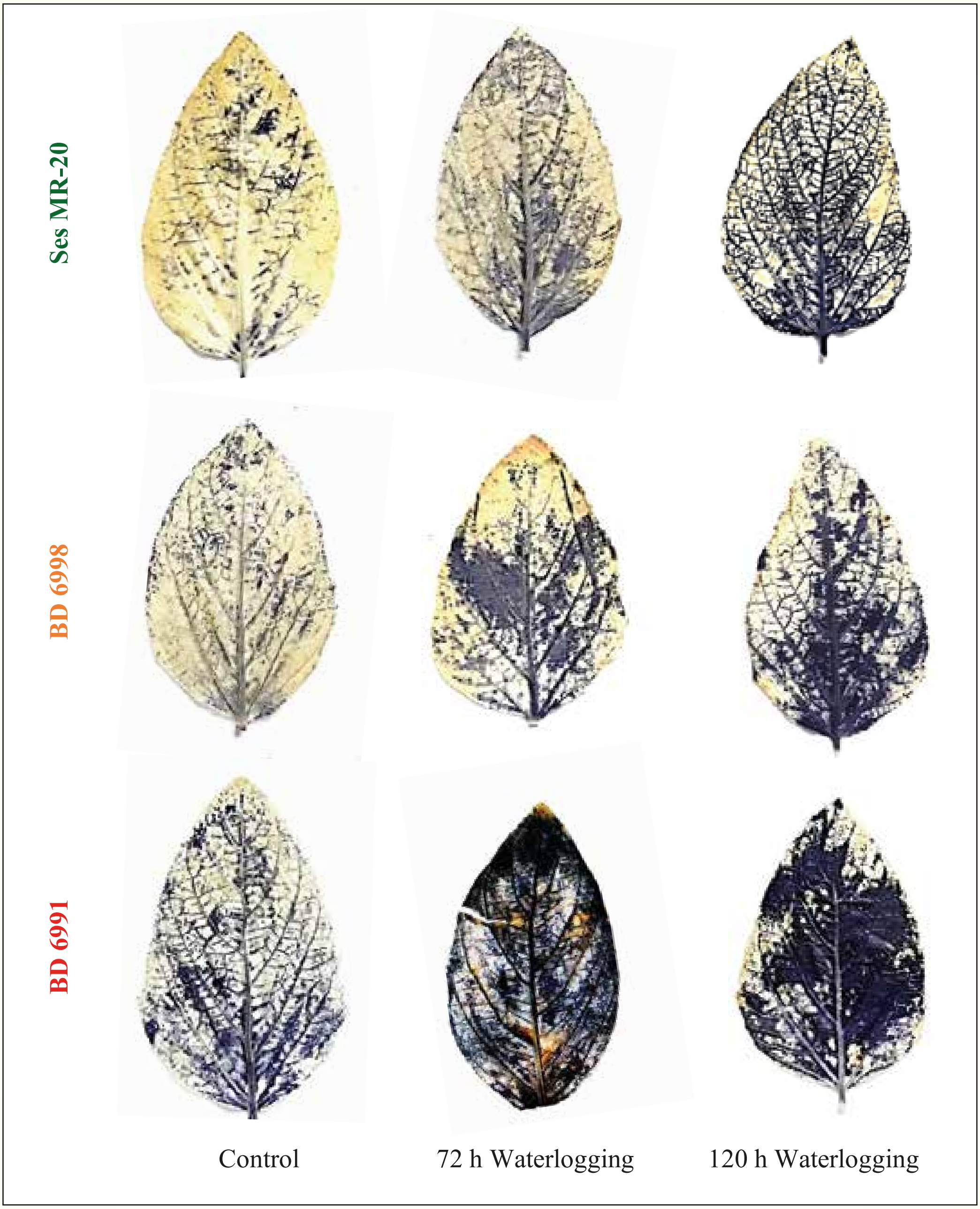

Fig. 2: Histo-chemical detection of $O_2^{\bullet-}$ generation (bluish) in leaves of sesame seedlings under waterlogging stress.

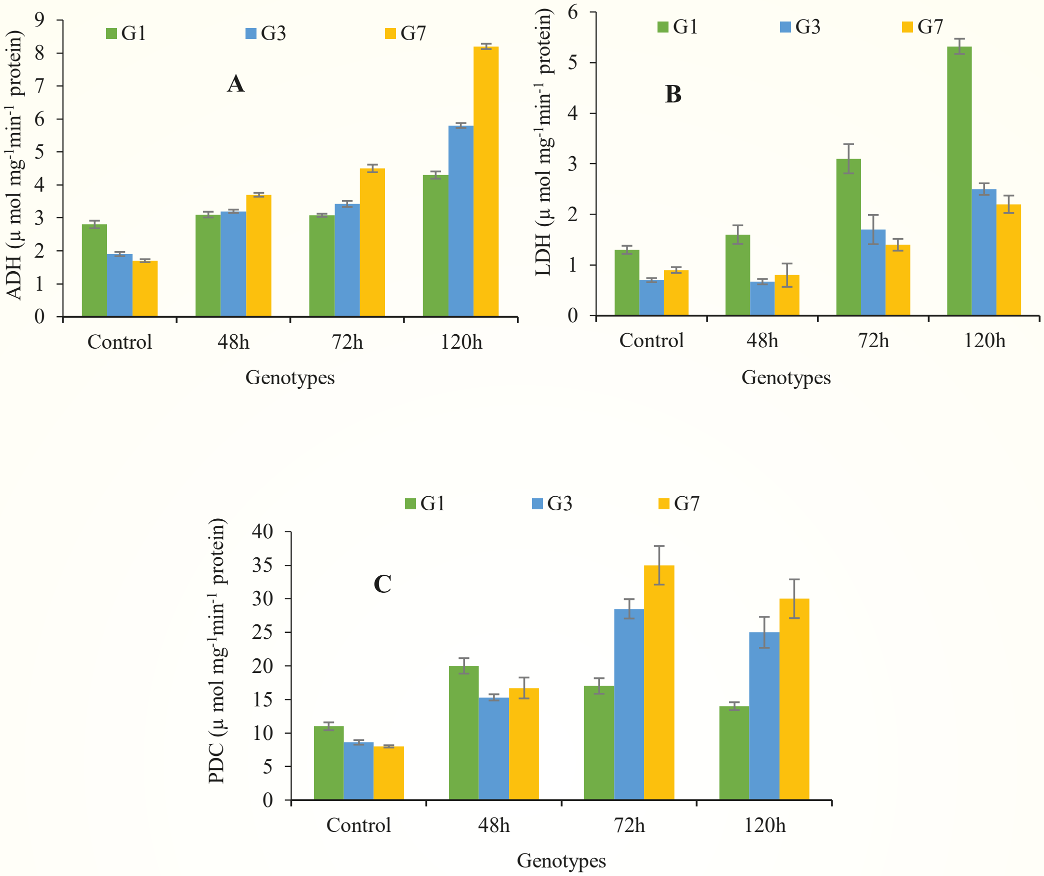

Fig. 3: Effect of waterlogging on the activity of ADH (A), LDH (B) and PDC (C) in the leaves of sesame genotypes. G1= BD 6991, G3= BD 6998 and G7= Ses MR-20. The results represent the mean of three replicates ±SE.

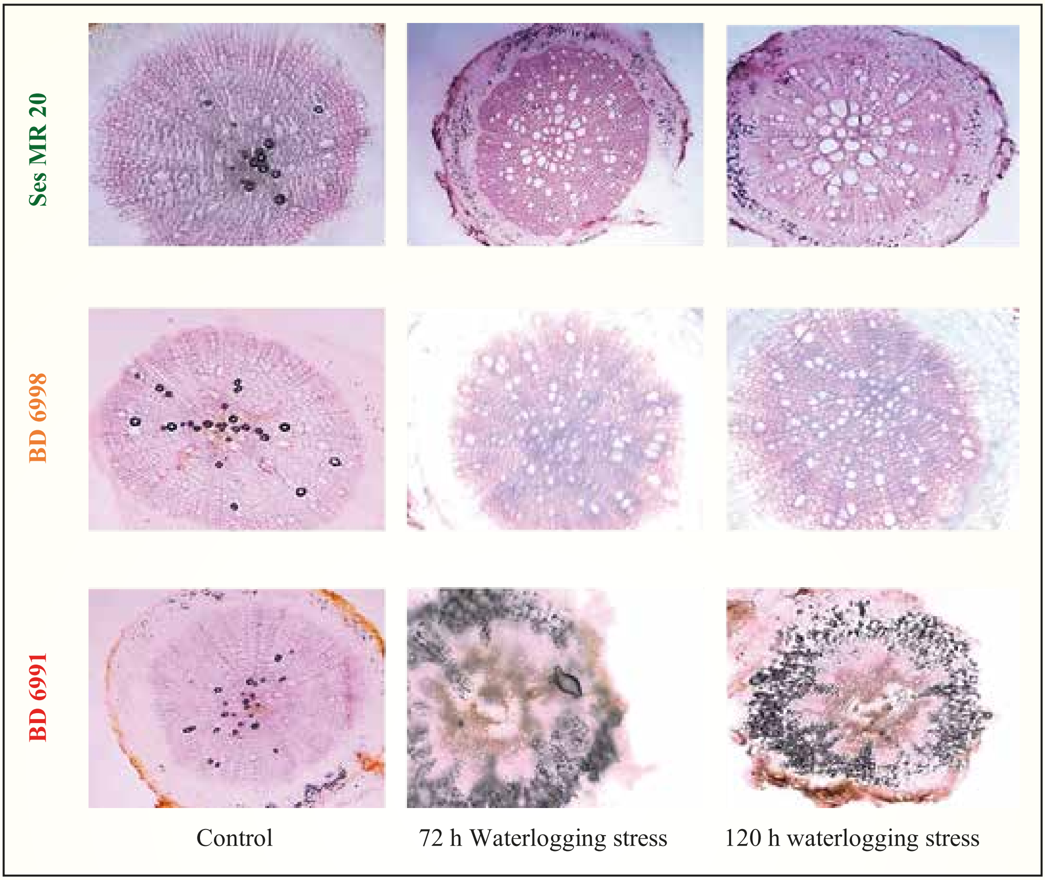

Fig. 4: Transverse root section of relatively tolerant (Ses MR-20 and BD 6998) and susceptible (BD 6991) sesame genotypes under waterlogging stress.

Findings

Ses MR-20 can be tolerate 72 hours waterlogging at vegetative stage.

Key features of selected genotypes

- Less accumulation of ROS (H_2O_2 and $O_2^{\bullet -}$), MG and MDA
- Maintained higher antioxidant like POD, APX, GPX, AsA and Proline
- Higher activity of the ADH and PDC including lower activity of LHD
- Formation of aerenchymatous tissues in roots
- Alcoholic fermentation occur to provide a source of energy

Ses MR-20 has already been released as a waterlogging tolerant sesame variety (BARI Til-6)

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Selection of Maize Genotypes for Drought Prone Areas

Faruque Ahmed

Background

Maize (*Zea mays* L.) is one of the most important cereal crops in Bangladesh. The rapid expansion of the poultry industry in the 1990s increased the demand for maize grain as poultry feed. The farmers, particularly in northern and western parts of the country, adopted maize as a cash crop. Maize is high yield potential crop however; higher yield of maize depends on several factors like use of quality seed, balanced fertilizer and proper management of irrigation water etc. Proper water management plays a vital role for higher yield of maize. Maize yields would be reduced as a result of climate change, and maize would be more susceptible to drought stress (Webber et al., 2018). In Bangladesh, major maize growing areas is under rabi cultivation which is grown with irrigation using mostly underground water. Scarcity of underground water and high prices of irrigation makes it difficult for the farmers to grow maize profitably. Although maize as a C4 plant consumes water more efficiently than those of C3, drought stress still contributes to the reduction of maize production up to half of its optimum yield as well as the other vegetative traits such as plant height and ear production. Under drought stress, plant developed numerous adaptive mechanisms for better growth such as modification of the root system, osmotic adjustments, stomatal regulation, chemical production, and accumulation. Changes in the photochemistry of the chloroplasts in the leaves of drought-stressed plants result in dissipation of excess light energy, thus, generating reactive oxygen species (ROS) which are potentially dangerous to plants (Peltzer et al., 2002). To mitigate the oxidative damage initiated by ROS, plants have developed a complex defense antioxidative system, including antioxidative enzymes, such as superoxide dismutase (SOD), catalase (CAT), peroxidase (POD), guaiacol peroxidase (GPX) and glutathione reductase (GR) (Noctor and Foyer, 1998). The SOD and POD are the major O_2- scavengers and their enzymatic actions result in H_2O_2 and O_2 formation. The H_2O_2 produced is then scavenged by CAT and several classes of peroxidases such as POD. There are several reports on increasing in activity of antioxidative enzymes in maize and other plant species under stress conditions (Sairam et al., 2002). So, the genotypes which are able to produce more antioxidant could be selected as tolerant one. Besides various drought indices were determined and used for the identification of best drought-tolerant genotypes. Several reports demonstrate the important role of Stress Tolerant Index (STI) and Geometric Mean Productivity (GMP) as the most suitable indices to identify resistant genotypes in drought-stress conditions (Darkwa et al., 2016). The main approach to mitigate the risk of drought-linked harvest failure in maize is through developing varieties tolerant to drought. The adoption of drought-tolerant varieties showed an increase in production by 15%. Additionally, the risk of harvest failure dropped by 30% compared to non-drought tolerant varieties (Simtowe et al., 2019). So, we have to find out suitable maize genotypes which would be able to produce good yield under soil moisture scarce situation. Therefore, the experiment was conducted to find out suitable variety/inbred lines for growing in water scarce environment.

Methodology

Experimental site	Field
Season	Rabi
Date of sowing	20 November 2013
Genotypes	$P_1 \times P_4$, $P_1 \times P_7$, $P_2 \times P_5$, $P_2 \times P_6$, $Q_1 \times Q_2$, $Q_1 \times Q_8$, $Q_8 \times Q_6$ and BARI Maize-9
Source of genotypes	Plant Breeding Division, BARI
Treatments	Control (Irrigated) and Irrigate with wilting symptom visible + one irrigation at tasseling stage (Drought)
Drought imposed	By withholding irrigation water
Design and Replication	RCBD with 03 replications
Fertilizer dose and application	Fertilizers were applied @ 250-55-100-30 kg ha^{-1}. Half of N and all other fertilizers were applied as basal and remaining N was applied at tasseling stage.
Measured parameters	SPAD value, leaf area, Stomatal conductance, TDM, STI, SOD, CAT, APX, GPX, yield components and yield.

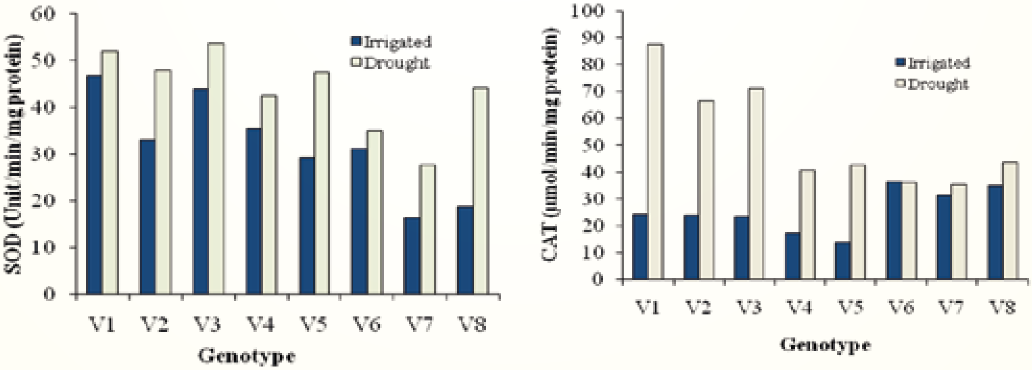

Fig.1: Effect of drought stress on super oxide dismutase (SOD) and catalase (CAT) activity of maize genotypes. ($V_1 = P_1 \times P_4$, $V_2 = P_1 \times P_7$, $V_3 = P_2 \times P_5$, $V_4 = P_2 \times P_6$, $V_5 = Q_1 \times Q_2$, $V_6 = Q_1 \times Q_8$, $V_7 = Q_8 \times Q_6$ and V_8 = BARI Maize 9).

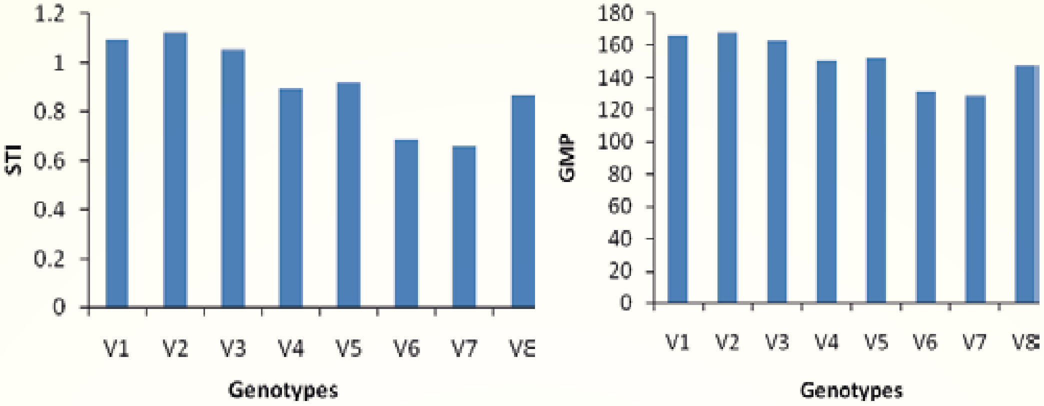

Fig.2: Effect of drought stress on stress tolerance index (STI) and geometric mean productivity (GMP) of maize genotypes.

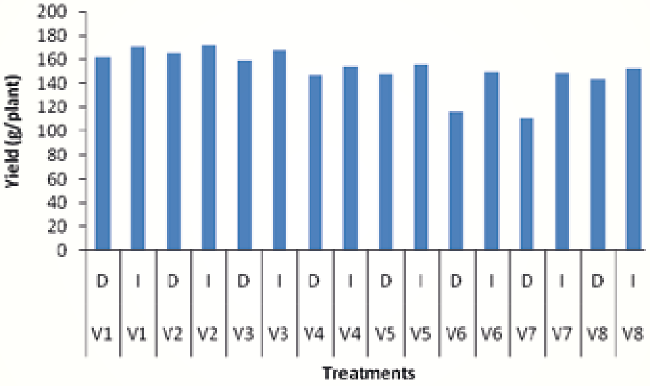

Fig.3: Interaction effect of genotypes and treatment on seed yield plant^{-1} ($V_1=P_1 \times P_4$, $V_2= P_1 \times P_7$, $V_3=P_2 \times P_5$, $V_4=P_2 \times P_6$, $V_5=Q_1 \times Q_2$, $V_6=Q_1 \times Q_8$, $V_7=Q_8 \times Q_6$ and V8=BARI Maize 9).

Fig.2: Mize genotypes under irrigated and drought conditions.

Fig. 3: Stomatal conductance measurement in maize with Leaf Porometer (SC-1, USA).

Findings

Genotypes $P_1 \times P_4$, $P_1 \times P_7$ and $P_2 \times P_6$ identified as drought tolerant.

Key features of selected genotypes

- Higher leaf area and stay green up to harvest
- Produced higher amount of ROS scavenging enzymes like CAT and APX
- Higher STI and GMP
- Less affected in stomatal conductance, TDM and seed yield

$P_1 \times P_4$ and $P_1 \times P_7$ already been released as drought tolerant variety
BARI Hybrid Maize-12 and BARI Hybrid Maize-13

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Identification of Wheat Genotypes for Drought Prone Areas

Imrul Mosaddek Ahmed

Background

Drought is the most devastating abiotic stress which constraints crop productivity (Farooq et al., 2012). The climate model emerging from Intergovernmental Panel on Climate Change (IPCC) in 2013 has predicted increase in atmospheric carbon dioxide and temperature with regional changes in precipitation. Among the impending climate change, drought will have a profound impact on crop productivity (Shanker et al., 2014). Drought causes an early switching from the vegetative to reproductive stage and the effects are usually phase-specific and species-specific. For instance, selection of wheat genotypes that can tolerate water scarcity would be helpful tools for breeding program aiming to development of drought tolerant variety under water limited regions (Naeem et al., 2015). Emphasis is given on the problem drought in the recent years. Moreover, it is a constraint for dryland farming or rainfed crop production which retards crop growth and ultimately reduced yield of crops. Therefore, an improvement in drought tolerance in crops is a pre-requisite for achieving greater economic gains. The best and most effective approach in this regard is to develop drought tolerant crop varieties. It is therefore important to identify the genetic resources that have high tolerances and to understand the mechanisms of drought tolerance in plants.

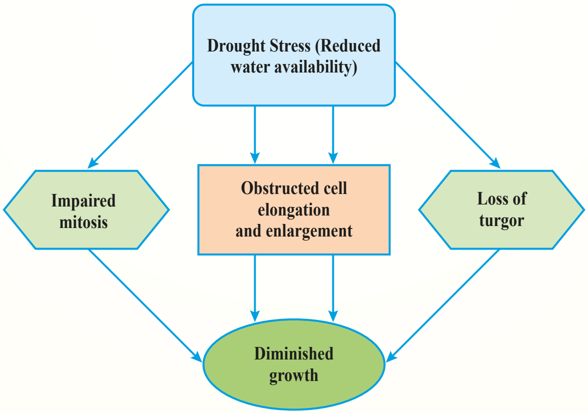

Fig. 1: Description of possible mechanisms of growth reduction under drought stress (Ahmed, 2015).

Under drought stress conditions, cell elongation in higher plants is inhibited by reduced turgor pressure. Reduced water uptake results in a decrease in tissue water contents. As a result, turgor is lost. Likewise, drought stress also trims down the photo-assimilation and metabolites required for cell division. As a consequence, impaired mitosis, cell elongation and expansion result in reduced growth (Fig.1).

Wheat (*Triticum aestivum*) is the second most important cereal crop in Bangladesh in respect of area and production cultivated in winter season. But scanty rainfall and scarcity of available irrigation facilities in the winter season, it suffers from soil moisture stress during the growing period. Villarreal et al. (1999) showed that crown root initiation (CRI) and anthesis are the two stages at which yield losses from drought stress can be most critical to wheat. In Bangladesh, up to 60% of the land surface is subject to continuous or frequent stress and drought occurs of about 3.5 million ha of land area causing a great damage to crop production. At first we examined the different responses to drought stress of 43 wheat genotypes during CRI to vegetative stage in terms of plant growth, biomass accumulation, and soil–plant analyses development (SPAD) value (based on chlorophyll meter readings) and grain yield. Afterthat our recent studies have demonstrated that wheat genotypes BWSN 31 and BWSN 33 have a high tolerance and sensitive to drought stress, respectively, during CRI to before anthesis (Ahmed et al., 2019). However, crop plants are especially sensitive to drought stress during the reproductive stage (Fischer, 1985; Saini and Westgate, 1999). Therefore, a question arises as to whether the wheat genotypes BWSN 31 and BWSN 33 are tolerant/ sensitive to drought at reproductive stage. If this is the case, the question arises whether the mechanisms of drought tolerance/ sensitive in these two wheat genotypes are different from those in cultivated wheat. Thus, the main objective of the present study was to compare the morphogenetic and physiological effects of drought stress on the wheat genotypes at reproductive stage. The study also improved our understanding of stress avoidance mechanisms that can be executed to enrich cultivated wheat for drought stress tolerance.

Methodology

Experimental site	:	Vinyl house, Pot culture (top dia-25cm, bottom dia-18 cm, height 25cm; 12 kg capacity)		
Season	:	Rabi		
Date of sowing	:	27 November 2017	23 November 2018	22 November 2019
Genotypes	:	43 wheat genotypes including 13 varieties	20 wheat genotypes including 4 varieties	3 wheat genotypes including 1 variety
Source of genotypes	:	WRC, BARI		
Treatments	:	Control (at a 60-80% water holding capacity) and Drought stress (until withholding irrigation to 10% SMC)		
Drought stress imposed	:	CRI to vegetative stage	CRI to before anthesis	Late vegetative stage to reproductive stage
Design and Replication	:	RCBD with 05 replications		
Fertilizer dose and application	:	Fertilizers were applied @120-30-90-15-6-2-1 kg ha^{-1} NPKSMgZnB. Fertilizer was calculated for each pot depending on the amount of soil/pot. Half of N and all other fertilizers were applied as basal and remaining N was applied at CRI.		
Measured parameters	:	Plant growth, biomass, SPAD value and grain yield	Plant height, relative shoot dry weight, SPAD, leaf area and total soluble sugar, yield components and yield	Plant height, relative shoot dry weight, SPAD, leaf area, water relation, chlorophyll content, Pn, Osmolyte accumulation, Antioxidant enzymes, ROS, yield components and yield

Fig. 2: Phenotype of wheat genotypes as affected by drought.

Findings

BWSN 31, KRL 19 and Borlaug 100 selected as drought tolerant genotypes.

Key features of selected genotypes

- Enhanced WUE, and less reduction in Pn, *Fv/Fm*, gs and Tr
- Maintaining high relative water content
- Increase activities of CAT, POD and APX
- Lower lipid peroxidation and H_2O_2 accumulation
- Increased activities of proline, soluble sugar, glycine-beatine and soluble protein, showed the role of osmotic potential
- Stay green up to harvest
- 20-25 % yield reduction due to drought stress

Borlaug 100 has already been released as WMRI Gom 3

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Morpho-Physiological Evaluation of Selected Tomato Variety under Drought Condition

Shamsun Nahar Mahfuza

Background

Tomato (*Lycopersicon esculentum*) is one of the most consumed and widely grown vegetable crops worldwide as well as cash crop in Bangladesh. It gains popularity very rapidly and attain the status of widely consumed. Although tomato is a tender perennial crop, which is susceptible to frost as well as high temperature but it is being grown in a variety of climatic conditions. However, tomato needs enough irrigation based on climatic conditions and soil type, every week about 20 to 70 mm (Passam, 2008). On the other hand, most commercial tomato cultivars are drought sensitive at all stage of plant development. Moreover, the yield and quality of tomato were affected by a variety of abiotic stresses when they were in a complex environment. Due to the population growth and climate change, water shortage and drought stress have become a problem attracting global attention, usually imposing severe influence on crop growth and bringing huge losses to agricultural production in recent years (Hamdy et al. 2003; Vinocur and Altman 2005). Drought causes a reduction in plant photosynthetic efficiency and stomatal conductance, inhibit RuBisCo activity, and disrupt energy balance and distribution during photosynthesis (Demirevska et al., 2010; Rapacz et al., 2010) and these often result in increased accumulation of reactive oxygen species, ROS (superoxide, $O_2^{\cdot-}$; hydrogen peroxide, H_2O_2; hydroxyl radical, $OH^{\bullet}$) (Ashraf, 2009; Hasanuzzaman et al., 2012; Hasanuzzaman et al., 2014). During the last decade, stomatal closure was generally accepted to be the main determinant for decreased photosynthesis under mild to moderate drought (Cornic and Massacci, 1996). Plant species adapt to this adverse condition through different ways. To deal with drought stress, plants usually evolve a range of morphological and physiological changes medicated by the alteration of gene expression associated with plant response to multiple stresses (Chaves et al., 2003). Some plants can (a) complete their life cycle under optimum conditions, (b) reduce water loss by reducing leaf size or reducing stomatal pores, (c) maintain growth even during water deficit by retaining water content, or (d) increase water use efficiency (WUE) of limited available water. These mechanisms can be utilized as indicators in a breeding strategy to improve crop drought tolerance. In recent years, crop physiology and genomics have led to new insights in drought tolerance providing breeders with new knowledge and tools for plant improvement. Drought stress is the major problem for agriculture because its adverse environmental factors prevent plants from realizing their full genetic potential (Yu et al., 2002). Plants are often through the changes of external morphology, photosynthetic mechanism, osmotic adjustment, antioxidant enzymes and other aspects to adapt or resist water stress of the environment. BARI has developed many tomato varieties which are very much popular to farmers. But due to climatic changes farmers are fetching problem in tomato production. Earlier in Plant physiology division, a screening was conducted to find out relatively drought tolerant variety. Some varieties showed batter performance.

Therefore, the experiment was undertaken to evaluate the ability to withstand the water deficit situation of some selected tomato varieties.

Methodology

Experimental site	: Vinyl house, pot culture (top dia-25cm, bottom dia-18 cm, height-25cm; 12 kg capacity)
Season	: Rabi
Date of sowing	: 07 December, 2020
Varieties	: BARI Tomato-17, BARI Tomato-19, BARI Tomato-20 and BARI Tomato-21
Source of varieties	: HRC, BARI
Treatments	: Control (no drought) and irrigation at 2, 3 and 4 days interval (throughout the growing period)
Drought imposed	: Pre flowering stage by withholding watering
Design and Replication	: RCBD with 06 replications
Fertilizer dose and application	: Fertilizers were applied @ 90-12-40-1-2-2^{-1} kg^{-1} ha NPKSZnB in the form of Urea, TSP, MOP, Gypsum, Zinc sulphate and Boric acid, respectively. Half of N and all other fertilizers were applied as basal and remaining N was applied at 30 DAS.
Measured parameters	: Pn, Gs, Ci, Tr, Chlorophyll, RWC, MDA,TDM, Root volume, yield and yield contributing traits.

Findings

BARI Tomato-21 selected as relatively drought tolerant.

Key features of selected genotypes

- Relatively lower inhibition of chlorophyll synthesis
- Higher photosynthetic activity and relative water content
- Less degree of membrane lipid peroxidation
- Less affected in TDM, yield supporting traits and fruit yield

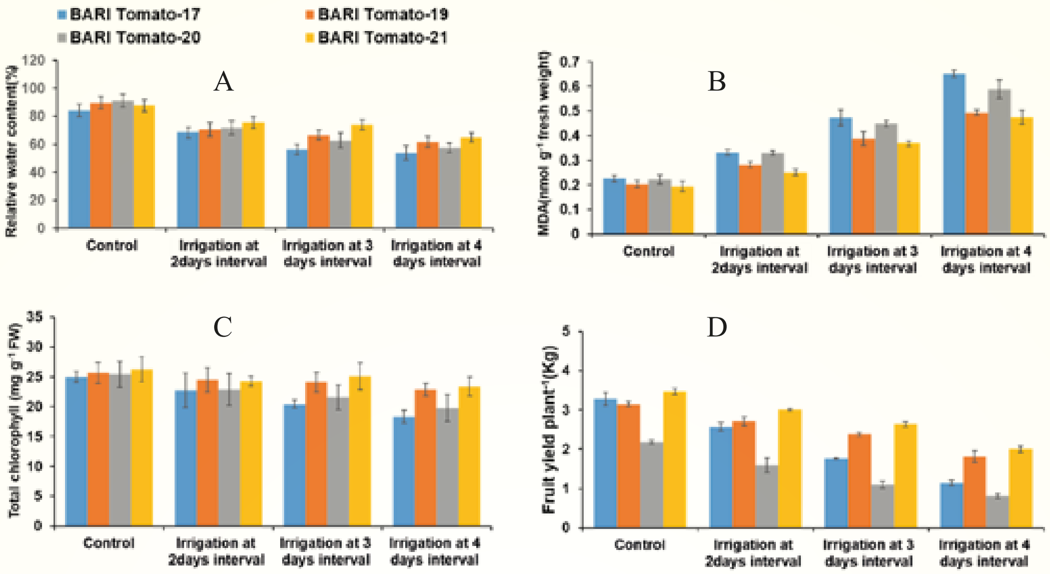

Fig.1: Effect of drought stress on relative water (A), MDA (B), total chlorophyll content (C) and fruit yield plant^{-1} (D) of four tomato varieties.

Fig.2: Pictorial view of tomato in pot culture under drought.

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Selection of Heat Resilience Rapeseed/Mustard Genotypes for Late Sowing

Faruque Ahmed

Background

Heat stress is a major factor limiting crop productivity and adaptation, especially when extreme temperatures coincide with the critical stage of plant growth. Excessive heat can disrupt by denaturing enzymes and damaging metabolism so that changes occur in the morphological structure, phenology, physiology and molecular level of plants. Rapeseed/mustard constitutes an important source of edible oil in Bangladesh. It grows under diverse agro-ecological situations such as timely/late sown, rainfed/irrigated, sole or mixed crop with cereals (wheat, barley etc.) and rabi (October-March) pulses (chickpea, lentil etc.), where high temperature is the main constraint not only at germination but also at grain filling stage. Late sown mustard normally faces higher temperature most part of its life cycle. Flowering and grain filling are the most sensitive stages to temperature stress damage probably due to vulnerability during pollen and grain development, anthesis and fertilization leading to reduce crop yield (Hall, 1992). High temperature in Brassica enhance plant development and cause flower abortion and poor grain filling with appreciable loss in seed yield. A rise of 3 °C in maximum daily temperature (21-24 °C) during flowering and grain filling caused a decline of 430 kg ha^{-1} in canola seed yield (Singh et al., 2014). When the environmental temperature overpasses the physiological threshold of a plant, the concentration of reactive oxygen species (ROS) can increase inside the cells (Mittler, 2002). ROS are currently produced in plants, and they are needed for cellular signaling; however, under stress conditions and when the antioxidant defenses are overcome, their concentration can increase to harmful levels producing oxidative stress. They can seriously disrupt the normal metabolism of plants through the oxidation of membrane lipids, proteins, and nucleic acids, thus fatally affecting the plant metabolism and limiting the growth and yield (Wilson et al., 2014). The coordinated action of the antioxidant defenses is necessary to protect the plants against the high concentration of ROS (Awsthi et al., 2015). Plants have developed both enzymatic and non-enzymatic detoxification systems to counteract ROS, thereby protecting cells from oxidative damage (Sairam and Tyagi, 2004). These enzymes include peroxidase (POD), catalase (CAT), superoxide dismutase (SOD), ascorbate peroxidase (APX) etc.; whereas non-enzymatic metabolites include glutathione (GSH), proline, glycinebetaine etc. (Wahid et al., 2007). Screening of germplasm for high-temperature tolerant/resistant genotypes and understanding their biochemical basis for heat stress tolerance would help in designing strategies for sustainable crop yield under high temperature stress. Therefore, the experiment was undertaken to find out heat tolerant rapeseed/mustard genotype under late sown condition. To fulfill the objective initial screening and genotypes selection was done by Oilseed Research Center and provided us five genotypes to find out the better genotypes on the basis of physiological evaluation.

Methodology

Experimental site	: Vinyl house, pot culture (top dia-25cm, bottom dia-18 cm, height-25cm; 12 kg capacity)
Season	: Rabi (2016-17 and 2017-18)
Treatments	: Mid November and Mid December
Genotypes	: BJDH-11, BJDH-12, BJDH-20, BARI Sarisha-14 and BARI Sarisha-16
Source of genotypes	: ORC, BARI
High temperature imposed	: Late sowing on 15 December
Design and Replication	: RCBD with 10 replications
Fertilizer dose and application	: Fertilizers were applied @100-30-80-20-3-1 $kgha^{-1}$ NPKSZnB. Fertilizer was calculated for each pot depending on the amount of soil of pot. Half of N and all other fertilizers were applied as basal and remaining N was applied at 20 DAS.
Measured parameters	: Phenology, leaf area and TDM, CAT, POD, MDA, yield components and yield

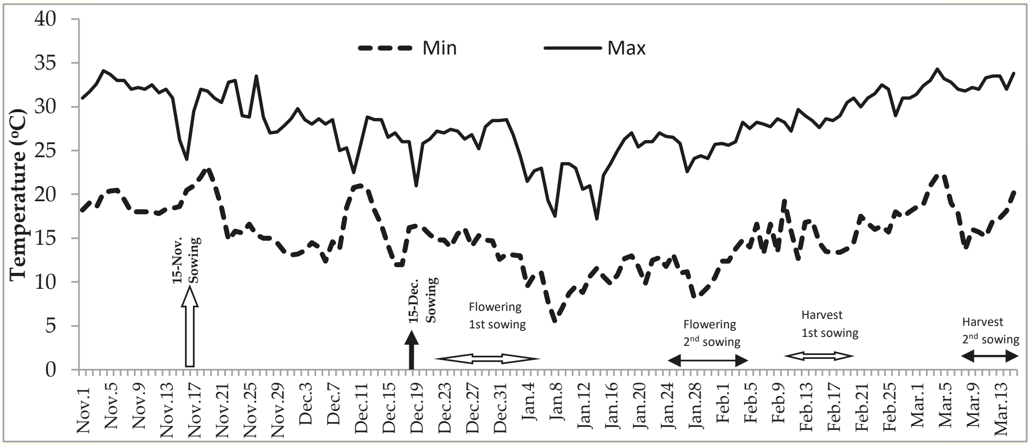

Fig. 1: Daily maximum and minimum temperature (°C) during crop growing period.

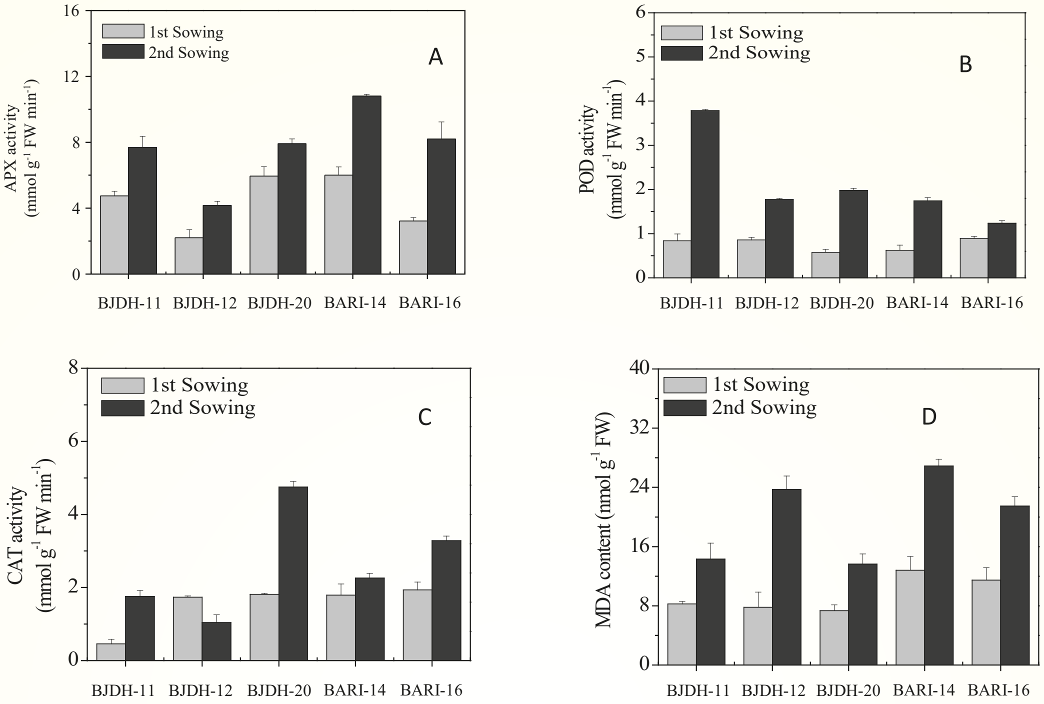

Fig. 2: Effect of high temperature stress on (A) APX, (B) POD, (C) CAT and (D) MDA activity of the mustard genotypes at Mid November and Mid December sowing.

Mid November sown crop.

Mid December sown crop.

Findings

Genotypes BJDH-11 and BJDH-20 found as heat tolerant

Key features of selected genotypes

- Higher leaf area and TDM under late sown induced higher temperature
- Produced higher amount of ROS scavenging enzymes like CAT, APX and POD
- Produce less amount of MDA
- Produced higher seed yield than others

Genotypes BJDH-11 and BJDH-20 can be used for heat tolerant mustard variety development

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Identification of Heat Tolerant Wheat Genotype

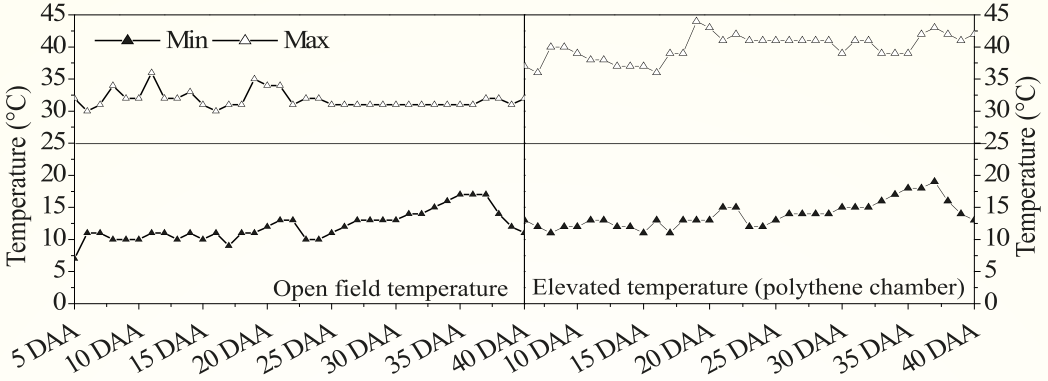
Imrul Mosaddek Ahmed

Background

Climate change is severely affecting cereal production across the world (Qin et al., 2002), through increase in CO_2 concentration and temperature, resulting in heat stress (Farooq et al., 2011). Climate model predicts that temperature will increase by 1.8-5.8 °C at the end of this century (IPCC, 2007) and terminal heat stress will increase in wheat growing regions in near future (Mitra and Bhatia, 2008; Semenov, 2009). Heat stress is more detrimental especially when it occurs at reproductive and grain filling stages (Hays et al., 2007; Farooq et al., 2011). Heat stress affects photosynthetic capacity of plants (Wahid et al. 2007), causes metabolic limitations (Farooq et al., 2011), promotes the production of oxidative reactive species (Wang et al. 2011), reduces pollen tube development and causes pollen mortality (Saini et al., 2010), encourages ethylene production thus increasing grain abortion (Hays et al., 2007) and causes oxidative damage to the chloroplast resulting in minimum grain yield (Farooq et al., 2011). Limited grain yield due to heat stress at reproductive stages may be attributed to minimum time duration for resource capture (Wheeler et al., 1996). Heat stress shortens the grain filling duration but accelerates the grain filling rate (Dias and Lidon, 2009). Under Bangladesh condition a large number of findings are available regarding late planting induced heat stress effect on grain yield and yield attributes (Sikder and Paul, 2010). In all of them, the temperature regimes were created by seeds sown on different dates. There are fewer reports so far in which two temperature regimes were created by seeds sown on the same day to study the response to terminal heat stress. Such results possibly have included effects of some coexisting climatic factors apart from late seeding heat stress by itself like infestation of foliar diseases, frequent crop lodging due to high wind velocity together with early monsoon rainfall, and so forth.

Methodology

Experimental site	:	Vinyl house, Pot culture (top dia-25cm, bottom dia-18 cm, height 25cm; 12 kg capacity)		
Season	:	Rabi		
Date of sowing	:	27 November 2017	23 November 2018	22 November 2019
Genotypes	:	46 wheat genotypes including 13 varieties	20 wheat genotypes including 6 varieties	3 wheat genotypes including 1 variety
Source of genotypes	:	WRC, BARI		
Treatments	:	Open field temperature Elevated temperature (3-5±1°C consider of open field temp.)		
Heat stress imposed	:	After anthesis stage		
Design and Replication	:	RCBD with 05 replications		
Fertilizer dose and application	:	Fertilizers were applied @120-30-90-15-6-2-1 kg ha^{-1} NPKSMgZnB. Fertilizer was calculated for each pot depending on the amount of soil/pot. Half of N and all other fertilizers were applied as basal and remaining N was applied at CRI stage.		
Measured parameters	:	plant growth, biomass accumulation, SPAD and grain yield	Plant height, relative shoot dry weight, SPAD, leaf area and CMSI, yield components and yield	Plant height, relative shoot dry weight, SPAD, leaf area, leaf temperature, chlorophyll content, Pn, osmolyte accumulation, antioxidant enzymes, ROS, grain growth, yield components and yield



Horizontal strait line indicates the critical level of temperature for grain growth of wheat.

Fig. 1: Daily mean air temperature received by wheat cultivars from 5 to 40 DAA under open field and elevated temperature conditions.

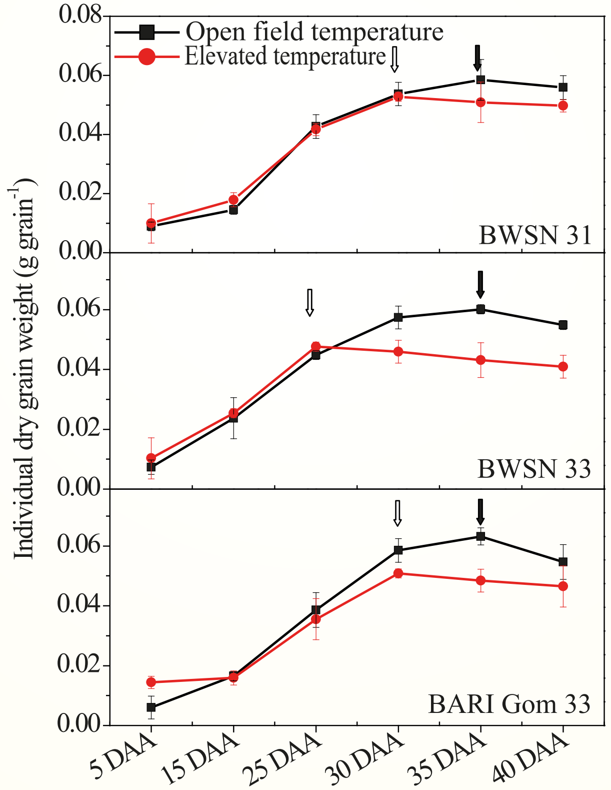


Fig. 2: Individual grain dry weight of three wheat genotypes under open field and elevated temperature conditions at different days after anthesis. Unfilled and filled arrows indicate physiological maturity of wheat cultivars under open field and elevated temperature conditions, respectively. Vertical lines are standard errors of selected data point.

Fig.3: Phenotype of wheat genotypes as affected by heat.

Findings

BWSN 31, BAW 1208 and BWSN 48 selected as heat tolerant genotypes.

Key features of selected genotypes

- Less reduction in Pn, *Fv/Fm*, gs and Tr
- Maintaining high relative water content
- Increase activities of CAT, POD and APX
- Lower lipid peroxidation and H_2O_2 accumulation
- Increased activities of proline, soluble sugar, glycine-beatine and soluble protein, showed the role of osmotic potential
- Less affected in grain filling duration
- 20-25 % yield reduction due to heat stress.

BAW 1208 has already been released as a heat tolerant variety-WMRI Gom 2

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Physiological Mechanism Related to Drought and Heat Stress Tolerance in Wheat Genotypes

Imrul Mosaddek Ahmed and Nadira Mokarroma

Background

Drought and heat are among the main abiotic stresses dramatically limiting crop growth and productivity worldwide (Wang et al., 2003). In the field, the co-occurrence of several abiotic stresses, rather than an individual stress condition is most damaging to crop production (Mittler, 2006). For example, the combined effects of heat and drought on yield are more detrimental than the effects of each stress alone, as seen in sorghum (*Sorghum bicolor* L.; Craufurd et al., 2008), wheat (Prasad et al., 2011), and barley (Savin and Nicolas, 1996). Therefore, an improvement in drought and heat tolerance in crops is a pre-requisite for achieving greater economic gains. The best and most effective approach in this regard is to develop drought- and heat- tolerant crop varieties. It is therefore important to identify the genetic resources that have high tolerances and to understand the mechanisms of drought and heat tolerance in plants. Plants usually share a common response to drought and heat stress. Usually, heat stress is associated with drought stress in field conditions (Ahuja et al., 2010), which makes it indispensable to study the response of plants to combined heat and drought stress. However, drought stress as a magnitude of inadequate rainfall or underprovided soil moisture prompts numerous physiological, biochemical, and molecular responses in plants, which rigorously hamper plant growth and productivity (Seki et al., 2007; Vadez et al., 2011). The plant response to drought stress generally varies from species to species depending on plant growth stage and other environmental factors (Demirevska et al., 2009). Due to global warming, heat stress has gradually damaging effects on crop production and crops cultivated through summer are more liable to heat stress (Hall, 2010). High temperature stress may cause severe damage to the proteins, disturb their synthesis, inactivate major enzymes and damage membranes. Heat stress could also have major effects on the process of cell divisions (Smertenko et al., 1997). Therefore, a complete understanding of the combinational responses of plants to these two stresses and effects on plant growth is of considerable, practical and ecological significance for the improvement of abiotic stress tolerance. Drought stress leads to stomatal closure, as a consequence of limited CO_2 difusion into the leaf inhibition of photosynthesis is caused through unhinge between light reaction and Calvin–Benson cycle (Chaves et al., 2009). In contrast, heat stress limits plant photosynthesis mostly by disturbing biochemical reactions (Allakhverdiev et al., 2003; Havaux, 1993). Higher photosynthetic rate and stomatal conductance during heat stress were observed in heat-tolerant wheat as compared to heat-sensitive cultivars where decreased rates of photosynthesis and stomatal conductance were observed (Sharma et al., 2015). A combination of drought and heat stress explicitly leads to the accumulation of photosynthetic products like sugars (Rizhsky et al., 2004). The most sensitive component to heat stress is Photosystem II (PSII) (Čajánek et al., 1998). An effectual and non-destructive procedure to quantify the photochemical efficiency of PSII is chlorophyll fluorescence and thus senses the harm of stress in PSII (Baker and Rosenqvist 2004). An estimation of the maximum quantum efficiency of PSII is provided by (*Fv/Fm*), which is mostly affected by heat stress (Sharma et al., 2012; Zhou et al., 2015).

Wheat (*Triticum aestivum*) is the second most important cereal crop in Bangladesh in respect of area and production cultivated in winter season. But scanty rainfall and scarcity of available irrigation facilities in the winter season, it suffers from soil moisture stress during the growing period. At Present, heat shocks due to the rising atmospheric temperatures are becoming one of the major limiting factors to wheat cultivation in Bangladesh. This rising temperature may cause a change in the growing periods and the distribution of the agricultural crops (Porter, 2005). Moreover, the staple cereal crops can only tolerate narrow temperature ranges, which, if exceeded during the flowering phase, can damage fertile seed production and thus reduce yield (Porter, 2005). Hence, our recent studies have demonstrated that wheat genotypes BWSN 31 and BWSN 33 have a high tolerance and sensitive to drought and heat stress alone, respectively, during CRI to before anthesis (Ahmed et al., 2019). However, crop plants are especially sensitive to drought and heat stress during the reproductive stage (Fischer, 1985; Saini and Westgate, 1999). Therefore, a question arises as to whether the wheat genotypes BWSN 31/ BWSN 33 are tolerant/ sensitive to combined stresses of drought and heat at reproductive stage. If this is the case, the question arises whether the mechanisms of drought and heat tolerance/ sensitive in these two wheat genotypes are different from those in cultivated wheat. Thus, the main objective of the present study was to compare the morphogenetic and physiological effects of combined drought and heat stress on the wheat genotypes at reproductive stage. The study also improved our understanding of stress avoidance mechanisms that can be executed to enrich cultivated wheat for drought and heat stress tolerance.

Methodology

Experimental site	: Vinyl house, Pot culture (top dia-25cm, bottom dia-18 cm, height-25cm; 12 kg capacity)
Season	: Rabi
Date of sowing	: 18 November, 2020
Genotypes	: BWSN 31, BWSN 33 and BARI Gom-33
Source of genotypes	: WRC, BARI
Treatments	: Control (at a 60-80% water holding capacity) Drought stress (SMC is reduced upto 10%) Heat stress i.e. elevated temperature (polythene chamber) Combined drought and heat stress (D+H) treatment
Combined drought and heat stress imposed	: Wheat plants were subjected to combined drought stress (D) and heat (H) treatment, in which water was added to each pot and the plants were then subjected to drought stress over 20 d by withholding irrigation until the SMC was reduced to 10%; Heat stress i.e. elevated temperature (polythene chamber). Polythene chamber (4m × 3m area) was covered by transparent polythene sheet. The chambers were constructed using GI pipe frame of 2.5 m high keeping 30 cm open space near the ground surface. The daily mean temperature was raised by 5 ±1 °C compared to open field mean air temperature (~24°C). Irrigation was given to maintain more or less a field capacity and to avoid the drought stress. The volumetric water content of random pots was checked weekly using a TDR 300 soil moisture meter fitted with 24 cm probe rods.
Design and Replication	: RCBD with 05 replications
Fertilizer dose and application	: Fertilizers were applied @120-30-90-15-6-2-1 kg ha^{-1} N-P-K-S-Mg-Zn-B. Fertilizer was calculated for each pot depending on the amount of soil pot^{-1}. Half of N and all other fertilizers were applied as basal and remaining N was applied at crown root initiation (CRI).
Measured parameters	: Plant height, relative shoot dry wight, SPAD, leaf area, water relation, chlorophyll content, Photosynthesis, osmolyte accumulation, antioxidant enzymes, ROS, total phenol, DPPH activity, flavonoids, secondary metabolism-related enzyme activity, Single cell gel electrophoresis assay, Semi-quantitative RT-PCR analysis, yield components and yield

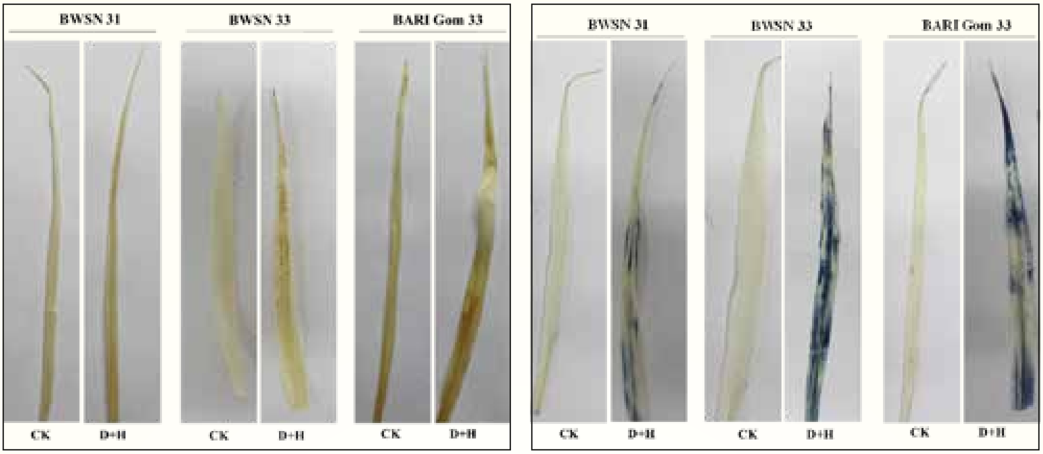

Fig. 1: Effect of combined stresses of drought and heat on H_2O_2 and $O_2^{\cdot -}$ accumulation in leaves of three wheat genotypes.

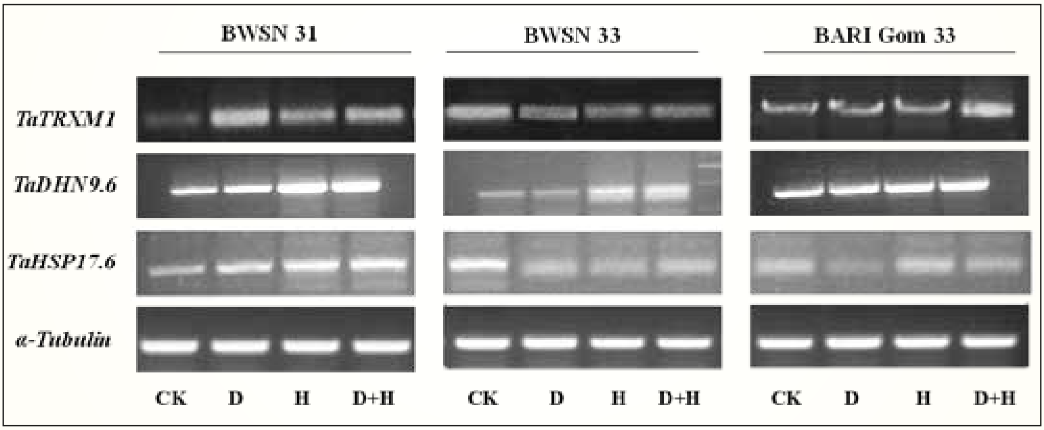

Fig. 2: Effect of alone and combined stresses of drought and heat on the transcript levels of certain genes in leaves of three wheat genotypes.

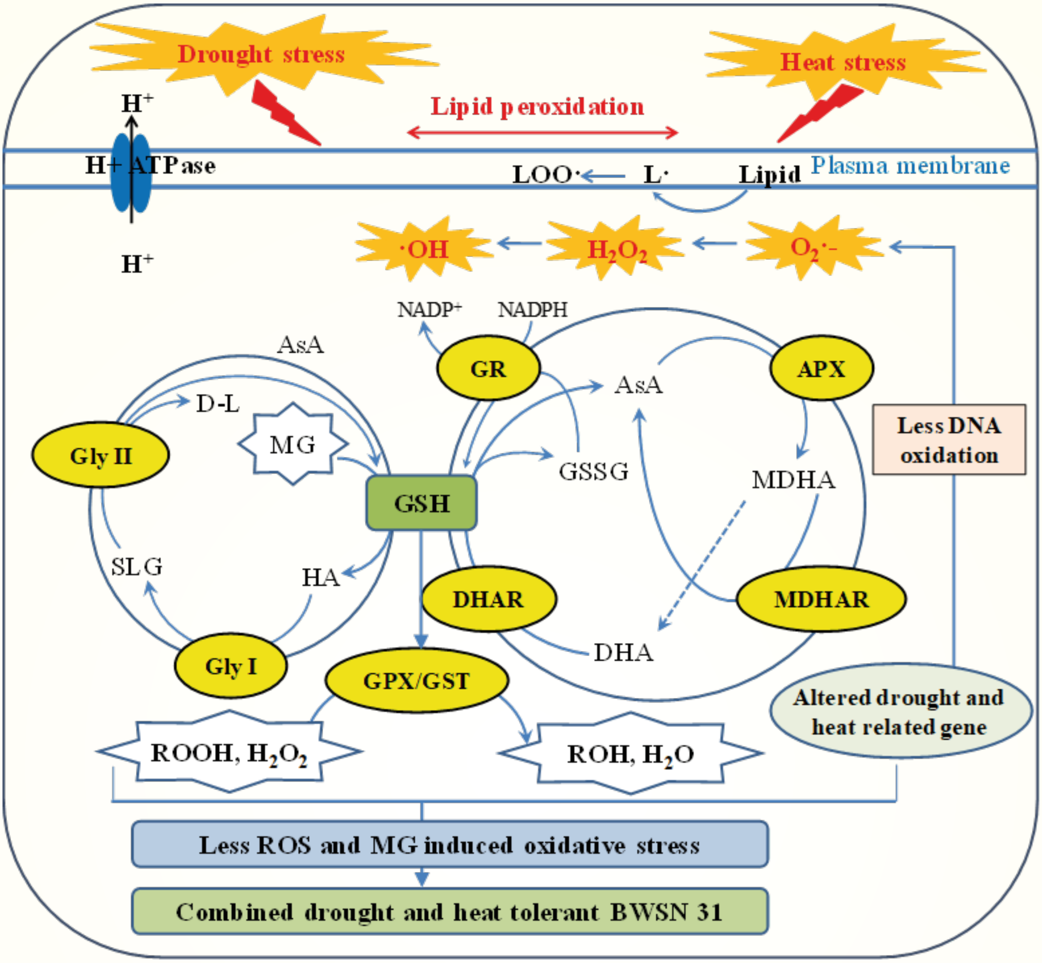

Fig. 3: Graphic depiction based on this study's findings (Modified from Ahmed et al., 2018). The potential regulatory mechanisms involved in acclimation to drought and heat of BWSN 31 and how drought and heat stress interferes with this acclimation are shown. Wheat genotypes BWSN 31 had increased GSH concentrations and showed less damage to DNA after treatment with combined drought and heat stress, which might occur through the induction of ROS production and MG detoxification by increasing Gly I and Gly II activities as well as redox homeostasis, leading to better stress tolerance. The dotted arrow indicates spontaneous conversion. Small and large circles indicate the Gly system and ASA-GSH system, respectively. Arrows indicate the potential connections and dotted arrow indicates spontaneous conversion.

Findings

BWSN 31 selected as drought and heat tolerant genotype

Key features of selected genotypes

The tolerant performance and responses of BWSN 31 against drought and heat stress

Responses of drought and heat strees

- Maximal photochemical efficiency of PSII (*Fv/Fm*)
- Increased contents of GSH and ASA
- Increased antioxident activity
- Enhanced WUE
- Inproved secondary metabolites
- Higher accumulation in GB, Pro and TSS
- Increased TP and TAC
- Altered transcript levels of drought and heat-related genes

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Screening of Shade Resilience Chilli Genotypes

A H M Motiur Rahman and Nadira Mokarroma

Background

Light principally sun-based radiation is one of the major environmental factors that affect the process of plants development (Chen et al., 2019). The Light-Use-Efficiency (LUE) basically fluctuates with the architecture genetic organs that play a vital role in photo morphogenesis. The estimated annual radiation that reaches on the surface of the earth from sun is known to be around 1000 Wm^{-2} (Neri et al., 2017) but assuming that due to climate consequences total solar irradiance may be reduced by 0.25% over a 50-year period from 2020 to 2070 (UC San Diego, 2018). Previously, a lot of researchers such as Chen et al. (2019), Yang et al. (2020), Zadoks (1974), Mu et al. (2010) examined the development and yield responses of cereal crops under different illumination intensities, but research on spices and condiments is still scarce. A corresponding type of chloroplasts is formed by the shade type of plants that helps to survive and perform photosynthesis under adverse conditions (Mathur et al., 2018). To acclimate, plants develop a small, thick leaf with well-developed palisade tissue, higher stomatal density under sunlight or high light condition compare to shade leaves or low light condition. Earlier research revealed that, fluctuating light reprobated the photosynthesis rate for wheat (15-21% day^{-1}) (Taylor and Long, 2017; Salter et al., 2019) for tree species (<37.75) (Martins et al., 2014) than the optimum level because changes light irradiance evokes photosynthetic responses that vary among plant species. Low irradiance negatively affects in stomata conductance and engenders elevated level of intercellular CO_2 (Yang et al., 2011). Moreover, stomata conductance and photosynthetic efficiency were degraded 24.31% and 79.84%, respectively under low light condition than the natural light (Sato and Kim, 1980). Chilli (*Capsicum sp.*) is an important crop of spices and vegetables that has been used extensively as food and medicament (Herath et al., 2021). Chilli contains wide array of phytochemicals such as vitamin C, vitamin A, vitamin E most B vitamins and in particular vitamin B5 (Ganguly et al., 2017) and high in potassium, magnesium, iron and rich in calcium and phosphorus in desiccated fruits (Khadi et al., 1987). Chillies prefer full sun, and while they will grow in partial shade, they will produce fewer fruits. Chilli is generally grown in large scale as a sole crop in an open field condition. But now it has been gaining popularity in cultivation as an intercropping, indoor and kitchen garden systems where plants experience reduce solar radiation and results the lower yield. However, an endeavor was taken to confirm the shade affectionate Chilli genotype from a screening trial that will be a suitable candidate for intercropping, indoor and kitchen garden system.

Methodology

Experimental site	: Vinyl house, Pot culture (top dia-25cm, bottom dia-18 cm, height-25cm; 12 kg capacity)
Season	: Rabi
Date of transplanting	: 29 November, 2017; 27 November, 2018
Genotypes	: 18 (First year) & 8 (Second year) genotypes
Source of genotypes	: Regional Spices Research Center, BARI
Shading levels	: Control (no shading), 25% and 50% shading
Shading imposed	: 20 DAT to maturity
Design and Replication	: RCBD with 15 replications
Fertilizer dose and application	: Fertilizers @ 96-57-96-15-1.5-1 kg ha^{-1} of N-P-K-S-Zn-B were applied in the form of urea, TSP, MOP, sulphur and zinc sulphate and Boron respectively. Each pot received double rate of 20-30-10-23-23 g urea, TSP, MOP, sulphur and zinc sulphate and Boron respectively as per calculation of one hectare cultivated field contained 2×10^6 kg soil in root zone of crop.
Measured parameters	: Phenological parameters, Relative plant height, Leaf area, TDM, SPAD value, Total Chlorophyll, Pn and Ci, Stomatal frequency of leaf (m^{-2}) and yield and yield contributing traits.

Findings

Co-640 and Co-639 genotypes were selected as shade tolerant (50% shading)

Key features of selected genotypes

- Suitable homestead gardening and intercropping
- Less affected in Pn and stomata frequencies was higher under shade
- Yield: Co-640: 350 g $plant^{-1}$ and Co-639: 275 g $plant^{-1}$

Genotypes Co-640 and Co-639 were found shade tolerant that can be consider for shade tolerant variety development

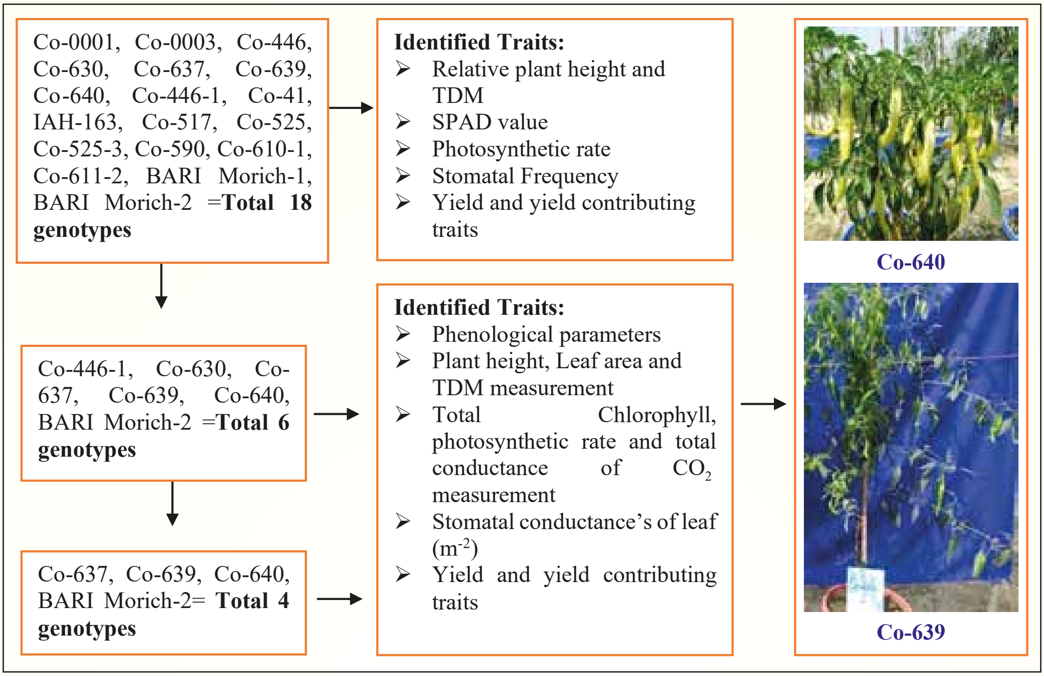

Fig. 1: Flow chart of shade tolerant Chilli genotypes identification.

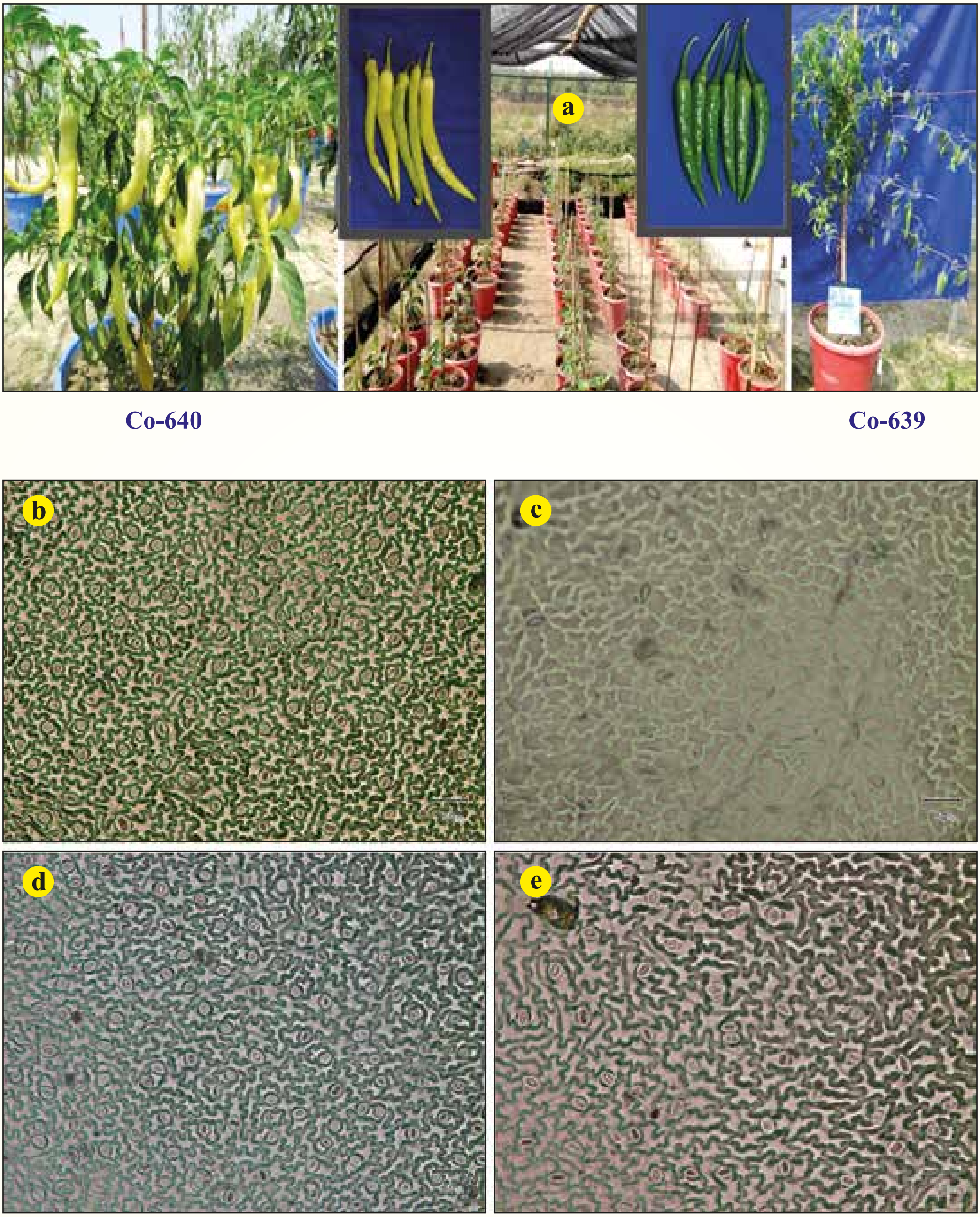

Fig. 2: Shade tolerant Chilli genotypes (a) Morphology of shade tolerant genotypes (b) Abaxial stomatal frequency (mm^{-2}); (c) Adaxial stomatal frequency (mm^{-2}) of Co-640 genotype; (d) Abaxial stomatal frequency (mm^{-2}); (e) Adaxial stomatal frequency (mm^{-2}) of Co-639 genotype.

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Optimizing Plant Spacing and Row Orientation in Hybrid Maize

Faruque Ahmed

Background

Maize (*Zea mays* L.) is one of the most important cereal crops of Bangladesh. In Bangladesh, the demand for maize is increasing for the poultry and fish sectors along with food for the population (Adnan et al., 2019). Maize grain yield is strongly impacted by plant density, planting patterns, tillage types, water management, soil types, soil hydrological and chemical properties, and other management practices (Assefa et al., 2016). Optimization of plant density is the main strategy for increasing yield. In maize increasing planting density has proven to be an effective agronomic practice for improving grain yield and resource use efficiency worldwide (Testa et al., 2016). Planting density affects the absorption and utilization of radiation, water, and nutrients in plants by changing the canopy and/or root system architecture (Du et al., 2021). Increased planting density improves the intercepted photosynthetically active radiation (IPAR) by rapid canopy closure and increases the leaf area index (LAI) (Teixeira et al., 2014). It is reported that canopy light interception and photosynthesis are closely related to LAI up to a "critical" LAI, which is rewired to intercept 95 per cent incident solar radiation. Grain yield is functionally related to LAI and hence structure of the canopy in maize (Williams et al., 1968). The amount of light that enters into the canopy within a row of maize depends on the row orientation when the sun moves across the sky during the day. Light interception or penetration is also influenced by plant population. The main effect of spacing on yield is believed largely due to a change in the light distribution. The effect of population on yield is also partly due to a change in the light distribution. With closer and more uniform spacing of plants more light is intercepted by the plants. Changes in row direction or plant density have shown to change spectral light quality and influence crop growth and development. Several reports revealed that maize yield increase with the increase of plant density. Under this condition, yield per plant is reduced, but a higher number of harvested plants compensates for this reduction (Hashemi et al., 2005). Furthermore, maximum yield per unit area can be obtained with a density of 100,000 plants ha^{-1} (Huseyin et al., 2003). However, it depends on variety, row orientation as well as other agronomic managements. Malaviarachchi et al. (2007), reported that cultivation of 88888 to 111111 plants ha^{-1} would be economically profitable. However, effects of row orientation and plant population on light spectra within maize canopies and the resultant growth response are not well defined in Bangladesh. Therefore, the experiment was carried out to evaluate row orientation and plant population effect on canopy light interception, growth and yield of hybrid maize.

Methodology

Experimental site	: Field
Season	: Rabi
Date of sowing	: 29 November, 2016
Variety	: BARI Hybrid Maize-9
Source of variety	: Plant Breeding Division, BARI
Treatments	: Row Orientation: 02 North-South and East-West Spacing: 03 60 cm × 20 cm (83,333 plants ha^{-1}) 45 cm × 20 cm (1,11,111 plants ha^{-1}) 45 cm × 25 cm (88,888 plants ha^{-1})
Design and Replication	: RCBD with 03 replications
Fertilizer dose and application	: Fertilizers were applied @ 250-55-100-30 kg ha^{-1} N-P-K-S-Zn-B.
Measured parameters	: Leaf area and above ground dry matter starting from 40 DAS to harvest. PAR interception $F=(1-\frac{I}{I_o})\times100$ Where, F is the fractional amount of radiation interception, I_o is the measured incident PAR above canopy and I is the incident PAR below canopy.

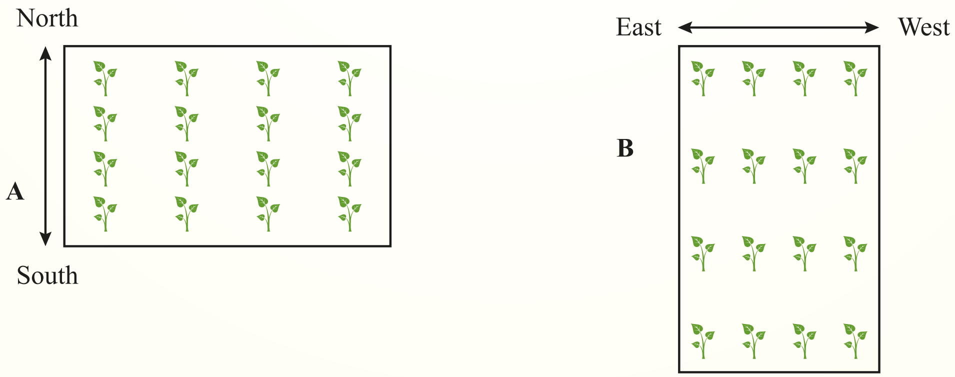

Figure 1: Schematic presentation of Row orientation; A) North-south directions; B) East-west directions

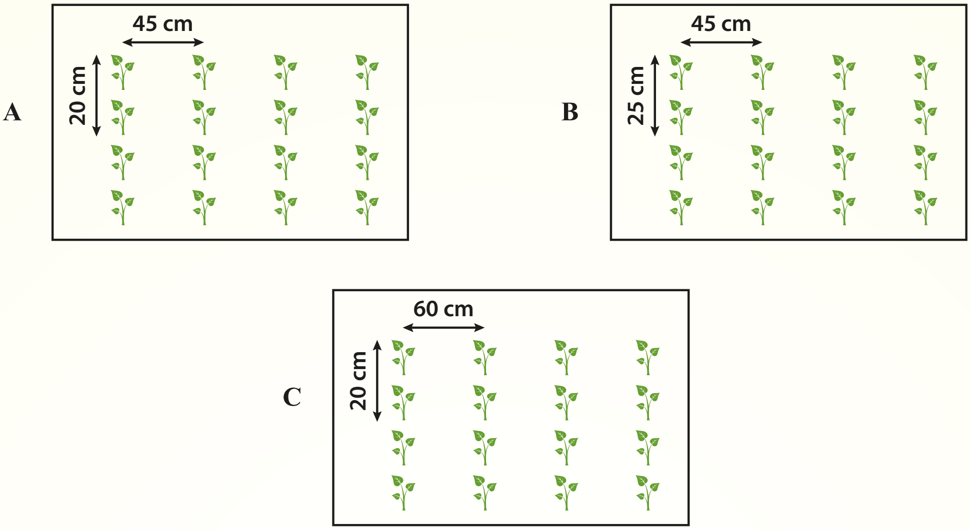

Figure 2: Schematic presentation of Maize population at different spacing; A) 45 cm × 20 cm (1,11,111 plants ha^{-1}); B) 45 cm × 25 cm (88,888 plants ha^{-1}); C) 60 cm × 20 cm (83,333 plants ha^{-1})

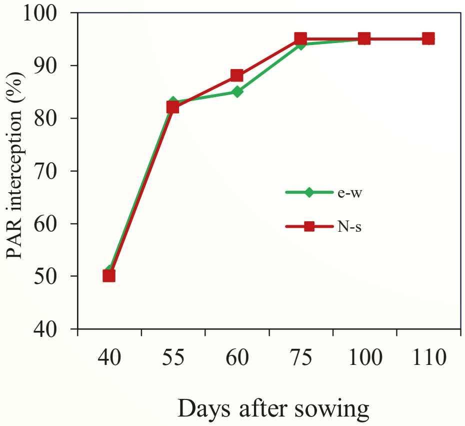

Fig.3: Effect of row orientation on PAR interception.

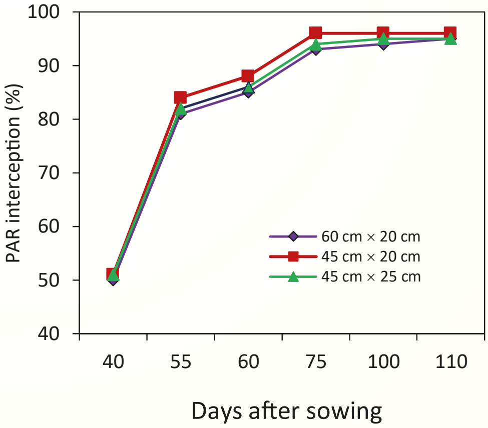

Fig.4: Effect of plant spacing on PAR interception.

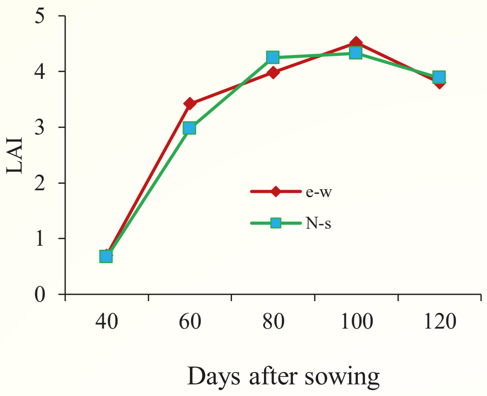

Fig.5. Effect of row orientation on LAI.

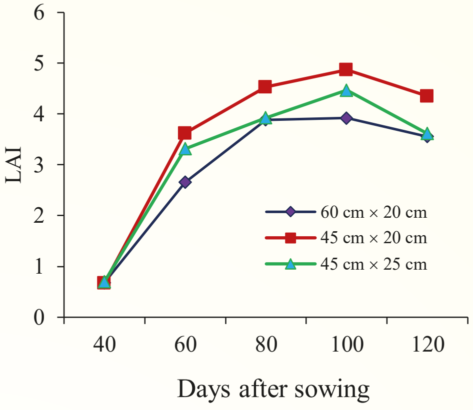

Fig. 6. Effect of plant spacing on LAI.

Table 1. Effect of row orientation on yield and yield components of hybrid maize

Row orientation	Plant height (cm)	No. of grains cob^{-1}	1000-grain wt. (g)	Grain yield plant^{-1} (g)	Grain yield (t ha^{-1})
East-West	245	469	281.67	143.85	10.79
North-South	241	456	288.55	144.15	10.83
LSD (0.05)	NS	NS	NS	NS	NS
CV (%)	4.54	5.87	3.33	5.65	6.45

Table 2. Effect of spacing (plant population) on yield and yield components of hybrid maize

Spacing	Plant height (cm)	No. of grains cob^{-1}	1000-grain wt. (g)	Grain yield plant^{-1} (g)	Grain yield (t ha^{-1})
60 cm × 20 cm (83333 plants ha^{-1})	244	469	290.56	151.61	10.11
45 cm × 20 cm (111111 plants ha^{-1})	247	457	279.56	134.67	11.97
45 cm × 25 cm (88888 plants ha^{-1})	244	461	285.20	145.72	10.36
LSD (0.05)	NS	9.54	4.48	15.44	1.25
CV (%)	6.10	7.34	2.54	7.22	8.54

Findings

Spacing 45 cm×20 cm i.e. 1,11,111 plants ha^{-1} would be preferable for higher grain yield.

Key features of selected genotypes

- Produced higher LAI ≥ 4.5
- Intercepted ≥95% of PAR
- Produced higher TDM and grain yield

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Morpho-Physiological Responses on Winter Onion to High Temperature Stress

Faruque Ahmed

Background

Onion can be grown under the wide range of climatic conditions, but winter onion grows best under mild climate without extreme heat or cold or excessive rainfall. For winter onion optimum temperature for vegetative phase and bulb development is 13-24 °C and 16-25 °C, respectively. Bulb formation and subsequent growth are influenced by temperature and photoperiod (Brewster, 1977). Bulb formation is promoted by long days and high temperatures (Magruder and Allard, 1937; Heath, 1945; Kato, 1964). Temperature stimulates the onion plant to stop making a bulb and begin sending up flower shoots and forming seeds called bolting. Bolting is the setting of seed and cessation of bulb development is driven by temperatures between 7.2° to 10 °C depending on variety, planting date, plant size, temperature, and duration of temperature all factor into whether and when an onion plant bolts. Temperature variations have been shown to influence the rate of vegetative growth (Butt, 1968; Brewster, 1979; Seabrook, 2005), leaf initiation, and emergence. It is probable that the response of tropical onions to short day variations in day length may be further influenced by temperature. Tropical onion varieties can be classified as "short day onions" because these plants will initiate and form bulbs in less than 12 h photoperiods (day length) and are suitable for warm climates (Rabinowitch and Currah, 2002). Although temperature and photoperiod are known to interact to induce bulbing (Brewster, 1990). There has been little work in which the photothermal requirements for bulbing in the field have been specified in Bangladesh. Therefore, the experiment was conducted to evaluate the effect of high temperature on physiological and biochemical changes in winter onion and to assess yield reduction.

Methodology

Experimental site	: Vinyl house, Pot culture (top dia-25cm, bottom dia-18 cm, height-25cm; 12 kg capacity)
Season	: Rabi
Date of sowing	: 02 January, 2019, 19 December, 2019 and 27 December, 2020
Variety	: BARI Peaj-1
Treatments	: Control (Open field), Inside polythene chamber from 20 to 35 DAT, 35 DAT to maturity and 20 DAT to maturity.
Impose of treatments	: The treatment (high temperature) was imposed by using transparent white polythene chamber (4m × 3m). 1.5 to 5.5 higher temperatures inside polythene chamber depending on time of the day.
Design and Replication	: RCBD with 05 replications
Fertilizer dose and application	: Fertilizers were applied @ 90-45-120-30-3-1.4 kg ha^{-1} N-P-K-S-Zn-B. Fertilizer was calculated for each pot depending on the amount of soil pot^{-1}. Half of N and K along with all other fertilizers were applied as basal. remaining N and K was top dressed in two equal splits at 25 and 50 DAT.
Measured parameters	: Daily air temperature, leaf area, TDM, CAT, ASA, POD, MDA, yield and yield contributing parameters.

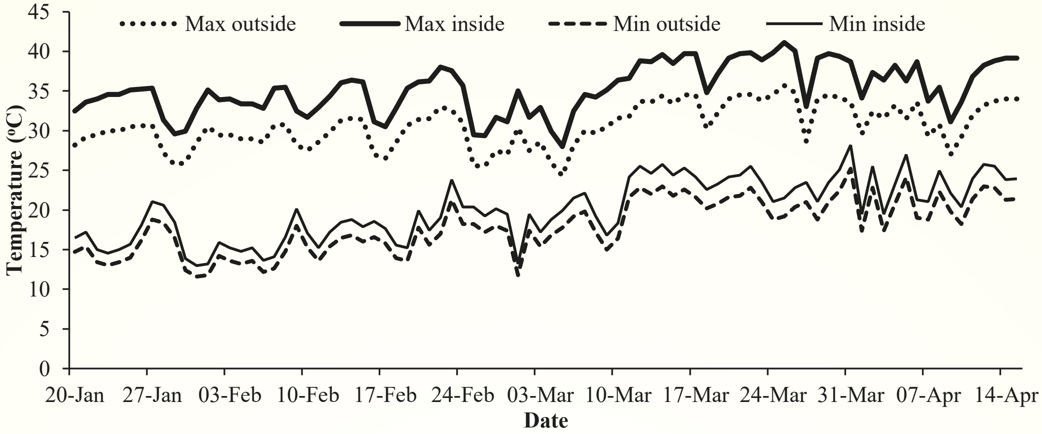

Fig. 1: Daily air temperatures (inside and outside of the polythene chamber) during experimental periods of onion.

Table 1. Effect of temperature stress on yield and yield contributing characters of onion

Treatments	Plant height* (cm)	Leaf number plant $^{-1}$	Bulb length (mm)	Bulb diameter (mm)	Bulb yield plant $^{-1}$ (g)	Yield reduction (%)
T_1	46.0	6.40	42.26	45.27	30.22	-
T_2	44.6	5.80	38.45	38.68	23.93	20.81
T_3	46.2	5.20	37.29	38.75	22.93	24.12
T_4	44.9	6.00	41.53	45.05	27.75	8.17
LSD (0.05)	NS	NS	4.80	5.72	3.94	-
CV (%)	11.3	10.2	8.70	10.10	10.90	-

* At 65 DAT; T_1= open field (control), T_2= Inside polythene chamber from 20 DAT to 35 DAT, T_3= Inside polythene chamber from 35 DAT to maturity, T_4= Inside polythene chamber from 20 DAT to maturity.

Findings

Higher and fluctuating temperatures are very much harmful at bulb development stage of onion.

Key features of selected genotypes

- Higher bulb yield reduction (24%) was found when heat stress was imposed from 35 DAT to maturity.
- The lowest bulb yield reduction (8%) was found when heat stress was imposed from 20 DAT to maturity.
- Antioxidant activities (CAT, ASA and POD) and MDA were found more when onion was grown inside polythene chamber from 35 DAT to maturity and 20 DAT to 35 DAT treatments indicating that plants in these two treatments faced more temperature stress than others.

Fig. 2: Growing of onion under polythene chamber and open field.

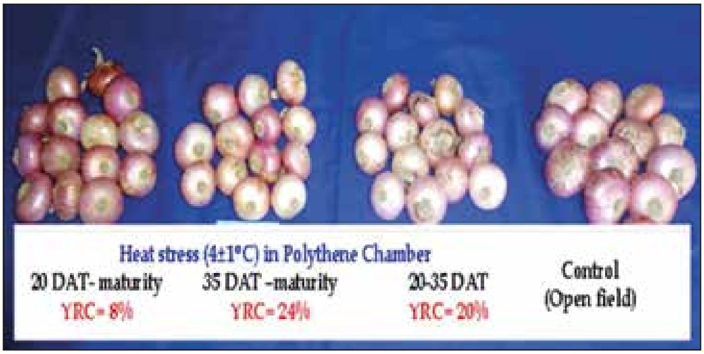

Fig. 3: Bulb yield reduction% due to heat stress.

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Phytochemicals Accumulation in Early Harvested Potato Cultivar

Imrul Mosaddek Ahmed

Background

Potato is the third most important crop in Bangladesh next to rice and wheat. It is one of the promising crops for the country due to its high productivity, short duration and wide adaptability. Besides its nutritional value, potato plants produce a variety of secondary metabolites during growth and post-harvest storage. These secondary compounds include glycoalkaloids, phenolic acids, protease inhibitors and lectins (Friedman, 2006). The glycoalkaloids are nitrogen containing steroidal glycosides, derivatives of aglycone solanidine having major constituents known as α-solanine and α-chaconine (Friedman and McDonald, 1997).

The normal season for potato cultivation is start from mid-November after harvesting of traditional Aman variety paddy. However, early potato can be harvested in only 60 days, and farmers can cultivate traditional potato on the same land, making them doubly benefited. But, the quality of early harvested edible potato tuber may problem due to its flavor, state, smell and raw flesh. This attribute determines potato suitability for consumption and is connected with flesh consistency, mealiness, moisture, texture and chemical composition. Moreover, potato plants produce a variety of secondary phytochemicals during growth and post-harvest storage such as glycoalkaloids (α-chaconine & α-solanine), phenolic acids, protease inhibitors and lectins. Among these phytochemicals, glycoalkaloids have been widely studied because of their toxicity to humans (Rytel, 2012). Glycoalkaloids concentrations exceeding the upper safety limit of 20 mg/100g fresh weight are potential neurotoxin (Carlson-Nilsson et al., 2000). Early cultivars have often been connected with glycoalkaloid levels above the recommended safety limit (Zolnowski et al., 2002). High levels of glycoalkaloids are reported to inhibit cholinesterase and disrupt cell membranes with clinical symptoms of poisoning that includes abdominal colic pain, dairrhea & vomiting; however, phenolics provide valuable health promoting antioxidants (McGehee et al., 2000). Yet, no information is available on patterns of glycoalkaloids and phenolic change during growth and harvest of early cultivars in Bangladesh. Therefore, the objective of the study was to determine the changes in the concentration of different phytochemicals like glycoalkaloids and phenolic compounds during the different harvesting dates of five farmer preferred varieties of potato grown in Bangladesh.

Methodology

Experimental site	: Field
Season	: Rabi
Date of sowing	: 23 November, 2020
Varieties	: BARI Alu-13, BARI Alu-29 and BARI Alu-41
Source of varieties	: TCRC, BARI
Treatments	: Potato varieties viz, BARI Alu-13, BARI Alu-29 and BARI Alu-41 with four harvesting time i.e 55, 65, 75 and 90 DAP.
Design and Replication	: RCBD with 03 replications
Fertilizer dose and application	: Fertilizers were applied @150-45-125-20 kg ha^{-1} NPKS in the form of urea, TSP, MOP and gypsum, respectively. Full amount of TSP, MOP, gypsum and 50% of urea were applied as basal during planting and the remaining amount of area was side dressed at 35 DAT.
Measured parameters	: Leaf area, Biomass, TGA, TPC and tuber yield

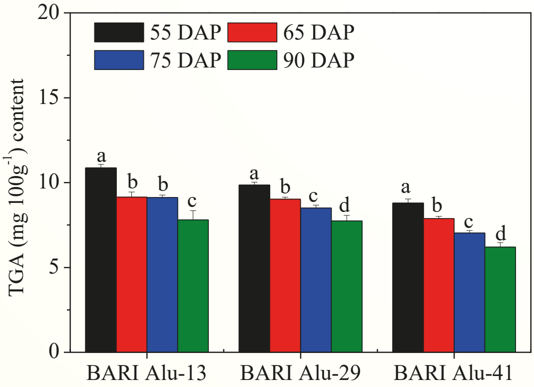

Fig. 1: TGA content of potato tubers at different stages of maturity.

Fig. 2: Early Harvest Potato tuber.

Findings

Early marked immature potato (BARI Alu-13, BARI Alu-29 and BARI Alu-41) has no harmful effect for human health.

Key features of selected genotypes

- Glycoalkaloid content in immature-potato (BARI Alu-13, BARI Alu-29 and BARI Alu-41) were well below the safety limit (20 mg 100 g^{-1} FW).

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Exogenous Trehalose Improve Drought Tolerance in Wheat

A F M Shamim Ahsan

Background

Wheat (*Triticum aestivum* L.) is the most important cereal crop, being used as staple food, for more than one-third of the world population. In Bangladesh, it ranks second after rice in respect of acreage. Wheat is grown as Rabi crop (winter season) in Bangladesh, and the season is usually dry due to inadequate rainfall. As a result, this crop suffers from soil moisture stress during the growing period, which is responsible for the reduction in potential yield of wheat. During water deficit environment, oxidative stress occurs in the plant cell which leads to the accumulation of methylglyoxal (Hossain et al., 2014). As a result a number of adverse effects such as increasing the degradation of proteins and inactivating the antioxidant defense system. Therefore, the highly cytotoxic and reactive MG must be removed or modified in the cell. Numerous research findings supported that regulation of the glyoxalase pathway enzymes is necessary for the detoxification of MG to enhance tolerance against drought stress.

Organic compatible solutes like trehalose play important roles under multiple abiotic stresses. Trehalose is a non-reducing disaccharide of glucose that stabilizes biological structures and macromolecules such as proteins and membrane lipids during dehydration and other abiotic stresses (Luo et al., 2010). Therefore, exogenously applied trehalose could be considered as a shotgun approach to withstand the ill effects of drought stress. However, the information is still limited. In this circumstance, the experiment was conducted to find out the role of trehalose in the detoxification of MG caused by drought stress.

Methodology

Experimental site	: Petri-dish culture under control condition (light intensity, 100 $\text{molm}^{-2}\text{s}^{-1}$; temperature, 23 ± 2 °C; relative humidity, 60–65%)
Season	: Rabi
Date of sowing	: 19 December, 2016
Genotypes	: CSISA Dr 30 and BAW 1163 wheat genotypes
Source of genotypes	: WRC, BARI
PEG levels	: Control, 15% PEG and 15% PEG with 10 mM trehelose
PEG imposed	: Eight day-old seedlings were imposed to 15% PEG for 6 days
Source of genotypes	: WRC, BARI
Design and Replication	: CRD with 03 replications
Fertilizer dose and application	: Germinated seedlings in petri dishes were grown in growth chamber with 1,000-fold diluted 20 ml Hyponex nutrient solution.
Measured parameters	: Proline, Gly I, Gly II, GSH and MG

Findings

Exogenous trehalose boosted drought tolerance of wheat seedlings.

Key features of selected genotypes

- Enhance the activities of glyoxalase system enzymes (Gly I and Gly II)
- Produce higher amount of ROS scavenging enzyme GSH
- Increase the accumulation of proline
- Trehalose play significant role in detoxification of MG

Application of Trehalose @ 10 mM L^{-1} water enhanced drought tolerance in wheat seedling

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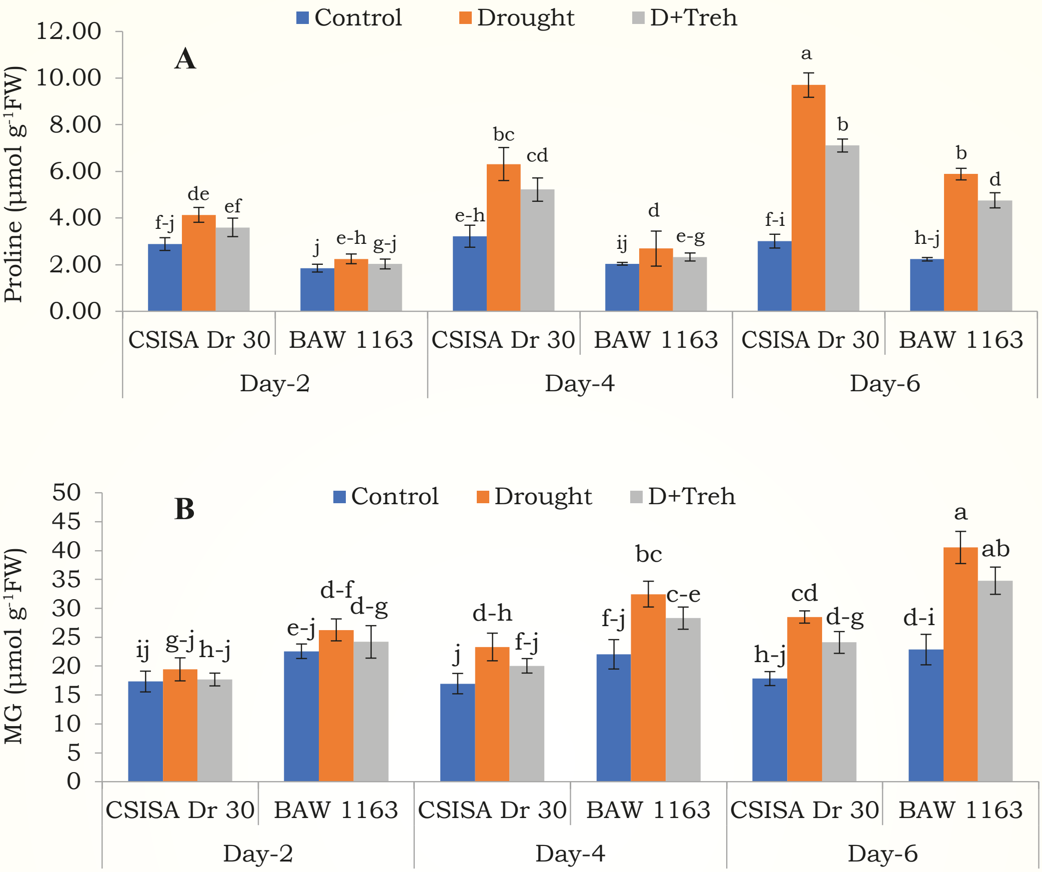

Fig. 1: Effect of drought stress induced by 15% PEG with or without 10 mM trehelose on proline (A) and MG content (B) in leaves of two wheat genotypes at different duration. Values represent the mean ± SE.

Control

Drought (15% PEG)

Drought with 10 mM trehalose

Fig. 2: Comparative tolerance to drought of two wheat genotypes in presence or absence of trehalose. Eight day seedlings were imposed to 15% PEG for 6 days.

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