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SOWING TIME AND VARIETAL PERFORMANCE OF WHEAT AT HIGHER ELEVATION IN HILL ENVIRONMENT AT KHAGRACHARI

M. ATAUR RAHMAN[1], M. MOHABBATULLAH[2], C. K. DAS[3]
U. K. SARKER[4] AND S. M. M. ALAM[5]

Abstract

The field experiment was conducted at the Hill Agricultural Research Station, BARI, Khagrachari for the two consecutive years (2009-10 and 2010-11) to find out the wheat variety suitable for hilly environment and investigate the interaction of sowing dates and varieties to recommend the promising variety with proper sowing time. The experiment was laid out in split-plot design with three replications where three dates of sowing (Nov. 20, Nov. 30 and Dec. 10) were assigned in the main plots and five modern wheat varieties (Shatabdi, Sufi, Sourav, Bijoy and Prodip) were tested in the sub-plots. The yield responses of wheat varieties during the two years showed that there were significant varietal differences under the experimental soil and environmental conditions. The variety Bijoy gave maximum grain yield closely followed by Sourav in both years. Shatabdi produced higher yield under early sowing (Nov. 20) but yield was decreased due to late sowing (Dec. 10). Initially the plant population and finally spikes/m^2 were affected by late sowing that caused less yield in Shatabdi. The mean yield of all varieties pulled over the sowing time indicated that wheat yield was not affected due to delay sowing up to 10th December. The experimental result demonstrated that Shatabdi could be recommended only for early sowing whereas Bijoy and Sourav could be recommended both for early and late sowing under the experimental soil and environmental conditions at hilly region of Khagrachari.

Keywords: Wheat variety, Sowing time, Adaptation, Higher elevation.

Introduction

Commercial farming of high value crops in traditional wheat growing regions and high crop competition in limited arable land caused gradual reduction of wheat areas in Bangladesh for the last decade. Wheat area and production were 0.77 million ha and 1.67 million tons, respectively, in 2000-01 whereas the area and production declined to 0.36 million ha and 0.98 million tons in 2011-12 (BBS, 2012). At present the national consumption of wheat is about four fold higher than annual domestic production and thus to meet the national demand a lion share is being imported at the cost of valuable foreign currencies and this food dependence is vulnerable for our national food security. Therefore, due attention is needed to increase the domestic production of wheat by expanding its

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cultivation in the non-traditional areas of the country where cropping intensity is low and there are scopes of wheat expansion. The Hill Tract regions comprises about one tenth of the country consisting 75% upland (hill), 20% undulating bumpy land and 5% valley plain land. A huge undulating bumpy land and the valleys remain fallow in the winter due to lack of irrigation water required for boro rice cultivation. Water requirement of wheat is less than one-fourth of that of rice, thus most of the areas can be brought under wheat cultivation with the limited water resource available in those regions. The physical and environmental conditions of the hill regions are different from that of conventional wheat growing areas of the country. Much works have been done to improve wheat yield through manipulating sowing time (Hossain *et al.*, 2009) and introducing new varieties (Rahman *et al.*, 2013, Barma *et al.*, 1994). The sowing date of wheat is considered as most important factor limiting the wheat yield and it is reported that wheat yield decreased at the rate of 1.3% per day delay sowing after 30th November under the short spell of winter in Bangladesh (Ahmed *et al.*, 1998). The pattern and spell of winter at the hill is different and, therefore, sowing time of wheat may be adjusted to explore the environmental benefit. Also there may have differences in relation to varietal adoption in hill regions that need to be explored for promoting the promising varieties in hill region. Several reports suggested that the yield performance of wheat varieties varied with soil type (Rahman *et al.*, 2013, Tang *et al.*, 2003), air temperatures (Rahman *et al.*, 2005), and management conditions (Rahman et *al.*, 2002; Timsina and Cornor, 2001). There may have varietal difference in response to change in elevation and environmental condition at the hill region. The wheat varieties which produce higher yield at the higher elevation of Khagrachuri might be considered as adaptable in hill regions. Therefore, the present experiment was aimed at investigating the varietal differences in response to higher elevation and to identify the appropriate sowing time preferable for that location with the final goal of wheat expansion in non-traditional hill valleys in Bangladesh.

Materials and Method

The field experiment was conducted in the valley land of Hill Agricultural Research Station, Khagrachari for the two consecutive years of 2009-10 and 2010-11. The experimental field is about 520 meters above the sea level and night temperature is cooler and the spell of winter is wider than the central part of Bangladesh. The annual temperature varies from 11.5° to 34.0° C with a mean of 17.5° to 24.0° C during the wheat growing period of December to March. Weekly mean of minimum and maximum temperature, relative humidity and rainfall for the wheat growing period in 2010-11 are presented in Fig. 1. The soils of experimental field was strongly acidic (pH 4.8-5.1) with higher levels of Fe, Al and Mn in surface soil (0-15 cm depth) and deficit in several essential plant nutrients including nitrogen (Total N = 0.08-0.09%), phosphorus (Olsen P = 5.5-6.5 ppm) and potassium (K = 0.17-0.21 meq/100g). The soil was rich in sulfur and zinc content but available boron content was critical to low. The physical and

chemical properties of the soil prior to conducting the experiment are presented in Table 1. The experiment was laid-out in such a soil in split-plot design with three replications where three sowing dates (November 20, November 30 and December 10) were assigned in the main plots and five wheat varieties namely Shatabdi, Sufi, Sourav, Bijoy and Prodip were tested in the sub plots. The size of each subplot was 5 m X 2 m. Fertilizers at the rates of 100 kg N, 30 kg P, 50 kg K, 20 kg S ha^{-1} and 2 kg B ha^{-1} were applied as urea, triple super phosphate, muriate of potash, gypsum and boric acid, respectively. All fertilizers including two-thirds of urea were uniformly applied in the field during final land preparation. The rest of urea was top dressed at the crown root initiation (CRI) stage at 21 days after sowing (DAS). The crop was irrigated thrice to bring the soil moisture near to field capacity during CRI, booting and grain-filling stages. Weeds were controlled once at 35 DAS manually by hand weeding. After maturity crops were harvested duly, sun-dried and threshed on sub-plot basis. Then the grains were dried in the atmosphere and grain moisture content was measured to convert the grain yield to t ha^{-1} at 12% moisture content. Before harvest ten plants were sampled from each plot to calculate plant height, spikelet/spike, grains/spike and 1000-grains weight. Initial plant population and spikes/m^2 were also counted at 20 DAS and at maturity following standard method. All the data were statistically analyzed and the mean value was tested by the least significant difference (LSD) at 5% level of significance.

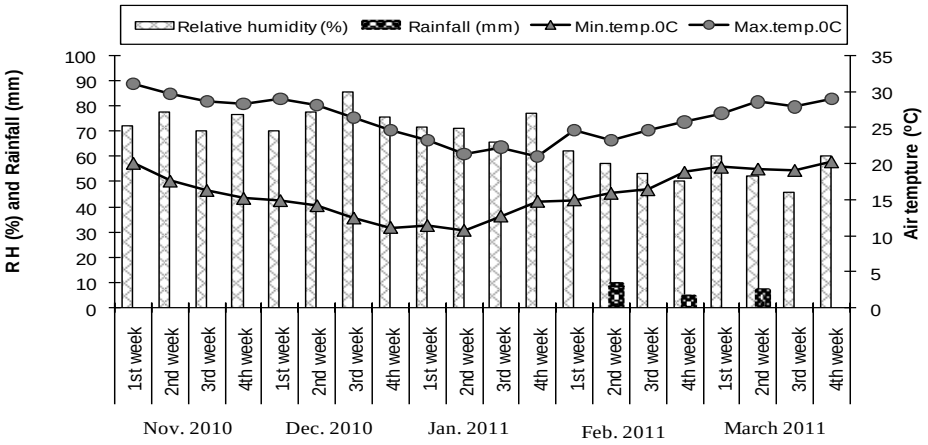

Fig. 1. Weekly average maximum and minimum air temperature, rainfall and relative humidity (RH) during the cropping period of 2010-11 at Khagrachuri.

Results and Discussion

a) Effect of sowing time

Different sowing dates had statistically similar effect on grain yield and all the yield components of wheat including plant height in both the experimental years

(Tables 2 and 3) with the exception of initial plant population (IPP) at 20 DAS in 2009-10. IPP was the maximum in the sowing date of Nov 20, followed by Nov 30 and Dec 10 in the years of 2009-10 but this advantage of higher plant population finally failed to contribute higher spikes/m^2 or grain yield. Thousand grain weight (TGW) is considered as most important yield component affected by late sowing induced heat stress. TGW was declined from 47.0 to 46.1 g and from 47.7 to 46.5 g due to 20 days delay sowing from November 20 to December 10, during the years of 2009-10 and 2010-11, respectively, which resulted in statistically similar wheat yield. The yield response of wheat to sowing dates had been studied intensively in Bangladesh conditions and several reports suggested that late sowing caused significant yield loss by reducing grain size expressed as TGW and thus yield drastically declines under late sowing. Late sowing caused the significant reduction in TGW (Rahman *et al.*, 2005); reduced number of spikes/m^2 (Rahman *et al.*, 2009) thus resulted drastic yield reduction in wheat. Ahmed and Meisner (1996) reported that under Bangladesh condition wheat yield decreased at the rate of 1.3% per day delay after 30th November that was due to decreasing TGW. In present study, such an adverse effect of late sowing was not noticed. Our experimental plants were also exposed to relatively higher day temperature from the end of February but yet the night temperature was cooler as indicated by average of minimum temperature (Fig. 1). Thus grain size measured by TGW was similar for different sowing dates. Spikes/m^2 was also statistically similar thus different sowing dates contributed to statistically similar yield. The result indicated that wheat sowing until 10th December could be recommended for the experimental soil and environmental conditions without yield loss. Jhum cultivation is the common practice in the hills that are usually planted at the beginning of rainy season. At the base of the hills, in the valleys the major cropping system are T. aman-Fallow-Fallow and T. aman-Boro-Fallow. Most of the T. aman rice varieties are long duration local varieties which are harvested in early December. Under such a condition, the experimental results are encouraging that wheat can be sown until 10th December without significant yield loss.

b) Response of variety

All the varieties tested in the present experiment were spring type semi-dwarf and its height and number of spikelet/spike were statistically similar in both the years but there were significant variations in several other traits like initial plant population, spikes/m^2, grains/spike, thousand grain weight and grain yield (Tables 2 and 3). IPP at 20 DAS and number of spikes/m^2 during harvest was the maximum in Bijoy followed by Sourav in 2009-10 (Table 2). During 2010-11 the same variety (Bijoy) produced highest IPP and spikes/m^2 which were statistically similar to other varieties but higher than Prodip (Table 3). Bijoy also scored second highest number of grains/spike next to Sufi and higher TGW similar to Prodip in both the years. All those facts ultimately resulted in the maximum grain yield of Bijoy similar to Sourav but higher than other varieties. Both variety Bijoy and Sourav were released earlier compared to Shatabdi and Prodip, and the yield

performance of latter two varieties was relatively higher (but not significant) than the former two varieties under the other areas in Bangladesh (WRC Annual report 2011). But in present experimental condition at Khagrachari, Bijoy and Saurav resulted in higher yield compared to other varieties. Prodip produced the least number of spikes/m^2 whereas other four varieties produced statistically similar number of spikes/m^2 for both the years. Initial plant population at 20 DAS was the minimum in Prodip which indicated that germination and stand establishment was seriously affected in Prodip resulting comparatively less number of spikes/m^2 which finally contributed to poor grain yield of the variety compared to other varieties. Number of grains/spike was the highest in Sufi followed by Bijoy and Saurav. However, this advantage of higher grains/spike of Sufi could not result in higher yield due to its smaller grain size as indicated by the least TGW. Thousand grain weight was the maximum in Prodip which was statistically similar to all other varieties except Sufi. Varietal difference in response to location x genotype interaction and drought had been reported by Barma *et al.* (1994) and Fisher and Maurer (1978). Rahman *et al.* (2013) reported that Bijoy gave higher yield and more adaptable under acidic soil condition in Sylhet. Present experimental result demonstrated that Bijoy and Sourav are preferable under higher elevation hilly environment at Khagrachari.

Table 1a. Physical and chemical properties of initial soil collected from surface layer (0-15 cm).

Physical Properties	Bulk density (g cm-3)	Particle density (g cm-3)	Porosity (%)	Soil moisture at sowing (%)	Soil moisture at field capacity (%)	Textural class
	1.42	2.48	42.74	21.04	28.12	Clay Loam

Table 1b. Chemical properties of initial soil collected from surface layer (0-15 cm).

Chemical properties	pH	OM (%)	Total N (%)	P	S	B	Zn	Cu	Fe	Mn	K	Ca	Mg
				µg g-1							meq 100 g-1		
2009-10	4.8	1.12	0.09	5.1	36	0.18	3.8	3.1	104	16	0.17	4.7	2.1
2010-11	5.1	0.98	0.08	6.5	41	0.16	4.1	3.1	97	16	0.21	5.1	2.0
Critical level	-	-	-	7	14	0.20	2.0	1.0	10.0	5.0	0.20	2.0	0.8

c) Interaction effect of sowing time and variety

Initial plant population, spikes/m^2 and grain yield of wheat were significantly influenced by the interaction of sowing time and variety (Table 2 and 3). Shatabdi gave the highest yield under the first sowing date and the yield was statistically similar to Bijoy and Sourav in both the years. The yield of Shatabdi was significantly declined due to late sowing on December 10 as compared to sowing on November 20. Similar trend of higher yield reduction with sowing

Table 2. Yield component and agronomic characters of wheat as influenced by dates of sowing and variety at Khagrachuri in 2009-10.

Treatment		IPP at 20 DAS	Plant ht. (cm)	Spikes m^{-2}	Spikelet $spike^{-1}$	Grains $spike^{-1}$	TGW (g)	Grain yield (t/ha)
Sowing date	Variety							
Nov. 20	Shatabdi	218.6	96.2	335.7	17.7	44.2	48.7	3.85
	Sufi	197.2	93.5	302.7	17.5	47.7	37.5	3.04
	Sourav	198.6	93.8	346.8	17.7	47.9	46.8	3.55
	Bijoy	222.3	96.8	360.1	18.5	48.7	49.8	3.80
	Prodip	205.7	88.9	248.7	16.5	39.2	52.1	3.32
Nov. 30	Shatabdi	178.0	95.7	298.5	17.1	45.8	46.8	3.25
	Sufi	181.3	93.2	312.8	16.9	49.5	36.8	3.05
	Sourav	214.8	94.5	325.5	17.3	47.8	45.8	3.82
	Bijoy	213.5	98.4	364.5	18.3	50.2	50.2	4.05
	Prodip	180.2	87.1	258.7	16.7	41.2	51.2	3.20
Dec. 10	Shatabdi	167.5	93.1	265.0	16.9	41.5	46.7	3.05
	Sufi	188.4	90.8	321.8	17.4	47.7	36.5	2.88
	Sourav	196.2	92.8	316.5	17.5	45.9	46.7	3.74
	Bijoy	215.6	95.8	355.8	18.1	47.5	49.8	3.88
	Prodip	166.6	88.9	247.8	16.8	38.7	49.5	3.02
Mean of Sowing dates								
Nov. 20		208.4	93.8	318.8	17.6	45.5	47.0	3.51
Nov. 30		193.5	93.8	312.0	17.3	46.9	46.2	3.46
Dec. 10		186.9	92.3	301.4	17.3	44.8	45.8	3.32
Mean of variety								
	Shatabdi	188.0	95.0	299.7	17.2	43.8	47.4	3.38
	Sufi	189.0	93.2	314.4	17.3	48.3	36.9	2.98
	Sourav	203.2	93.5	331.0	17.6	46.6	46.8	3.70
	Bijoy	217.1	97.0	360.1	18.3	48.7	49.9	3.91
	Prodip	184.2	88.3	251.7	16.7	39.7	50.9	3.18
$LSD_{(0.05)}$	Sowing dates	18.4	NS	NS	NS	NS	NS	NS
	Variety	21.0	7.5	32.4	NS	4.0	4.3	0.36
	Interaction	20.1	NS	28.5	NS	NS	NS	0.33
CV (%)		8.4	7.5	8.8	6.4	10.6	5.8	10.1

date was found in Shatabdi followed by Prodip in both the years. The yield reduction of Shatabdi and and Prodip in response to sowing date was mainly associated with initial plant population and spikes/m2 as both the parameters were significantly affected by the interaction of variety and sowing dates. On the contrary, Bijoy produced statistically similar yield like Shatabdi under first sowing date and under 2nd and 3rd sowing dates the yield of Bijoy was higher

than Shatabdi. However, Sourav performed second highest yield similar to Bijoy on 2nd and 3rd sowing in both the years. The yield variation due to sowing dates was the least in Bijoy following Saurav. The result indicated that both Bijoy and Sourav had the potentials to produce higher and stable yield over the sowing dates whereas Shatabdi was preferable only for early sowing under the experimental soil and environmental conditions.

Table 3. Yield component and agronomic characters of wheat as influenced by dates of sowing and variety at Khagrachuri in 2010-11.

Treatment		IPP at 20 DAS	Plant ht. (cm)	Spikes m^{-2}	Spikelet $spike^{-1}$	Grains $spike^{-1}$	TGW (g)	Grain yield (t/ha)
Sowing date	Variety							
Nov. 20	Shatabdi	212.5	97.8	320.5	17.7	44.2	49.8	4.18
	Sufi	206.0	97.3	308.7	17.3	49.7	40.1	3.21
	Sourav	195.8	97.7	312.0	17.9	44.8	47.4	3.88
	Bijoy	202.8	101.8	338.4	18.3	47.5	48.9	4.10
	Prodip	168.5	96.8	285.5	17.3	38.8	52.5	3.64
Nov. 30	Shatabdi	193.4	98.5	312.5	17.4	41.6	49.3	3.81
	Sufi	186.3	97.3	317.8	17.3	49.8	38.9	3.18
	Sourav	185.7	97.8	302.0	17.5	42.4	46.6	4.02
	Bijoy	212.7	101.2	338.4	17.9	45.5	48.7	4.28
	Prodip	156.0	97.6	278.3	16.7	37.8	51.8	3.52
Dec. 10	Shatabdi	172.0	96.8	278.5	17.1	40.1	47.5	3.46
	Sufi	197.8	96.4	308.2	17.3	48.9	37.3	3.08
	Sourav	192.6	97.8	312.5	17.5	44.2	48.1	3.94
	Bijoy	198.5	99.8	318.5	18.1	46.1	49.4	4.20
	Prodip	161.2	95.8	266.2	17.0	36.7	50.2	3.38
Mean of Sowing dates								
Nov. 20		197.1	98.3	313.0	17.7	45.0	47.7	3.80
Nov. 30		186.4	98.5	309.8	17.4	43.4	47.1	3.77
Dec. 10		184.8	97.3	296.8	17.4	43.2	46.5	3.61
Mean of variety								
	Shatabdi	192.1	97.7	303.8	17.4	42.0	48.9	3.78
	Sufi	197.0	97.0	311.6	17.3	49.5	38.8	3.16
	Sourav	191.5	97.8	308.8	17.6	43.8	47.4	3.95
	Bijoy	204.7	101.0	331.8	18.1	46.4	49.0	4.19
	Prodip	161.8	96.7	276.7	17.0	37.7	51.5	3.51
$LSD_{(0.05)}$	Sowing dates	NS	NS	NS	NS	NS	3.9	NS
	Variety	16.1	7.1	28.4	NS	3.9	4.2	0.37
	Interaction	18.2	NS	26.2	NS	NS	NS	0.34
CV (%)		8.9	6.2	7.4	5.8	9.1	6.1	7.6

Conclusion

The national average yield of wheat was 2.38 t/ha and 2.45 t/ha during the experimental year of 2009-10 and 2010-11, respectively. Under such a low national average yield, the yield performance of wheat varieties under experimental non-traditional hilly environment was found very encouraging. The wheat variety Bijoy and Sourav could be sown until 10th December without yield loss. The farmers in those areas prefer to cultivate long duration local rice which ripen lately in early December and boro rice is not suitable due to lack of irrigation water. Under such a condition the wheat variety Bijoy and Sourav could be recommended to promote in hill regions to improve the productivity.

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GENETIC DIVERSITY OF MAIZE (*Zea mays* L.) INBREDS UNDER SALINITY STRESS

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Abstract

The study was conducted to investigate the genetic diversity of some maize inbreds under salinity stress condition using Mahalanobis's statistic (D^2) and principal component analysis. Analysis of variance showed significant difference for all the characters. Results of multivariate analysis revealed that twenty five inbred lines formed five clusters at 8 dS level of salinity. The highest intra-cluster distance was recorded in cluster III containing eight genotypes and the lowest was in cluster II having one genotype. The highest inter cluster distance was observed between clusters II & V and lowest was between I & III. Cluster II had the highest cluster means for plant height, cob height, above ground dry mass, cob per plant, cob length, and grain yield per plant. Considering cluster distance, inter-genotypic distance and other agronomic performances the genotypes CZ12, CZ19, CZ26, CZ29, CZ31, CZ32, CZ33 & CML470 from cluster III and CZ27, CZ37, CML251 and CML456 from cluster V may be considered as better parents for future hybridization programs to obtain desirable segregate in respect of different yield and yield contributing characters under salinity stress.

Keywords: Maize *(Zea mays* L.), inbred lines, genetic divergence, salinity stress, cluster analysis, grain yield.

Introduction

Maize (*Zea mays* L.) plays a significant role in human and livestock nutrition worldwide. It is the world's most widely grown cereal and is the primary staple food in many developing countries (Morris *et al.* 1999). Maize is becoming an important crop in the rice based cropping system in Bangladesh. It is the third leading important cereal crop after rice and wheat. In recent years, maize is gaining popularity among the farmers mainly due to its high yield, more economic return and versatile uses. The area and production of maize is increasing day by day in Bangladesh and it continues to expand rapidly at an average rate of 20% per year (Anonymous, 2008). Plants in saline areas are often exposed to multiple abiotic stresses. High salinity is one of the most important abiotic stress factors limiting plant growth and productivity of a wide variety of crops (Flowers, 2004; Athar *et al.*, 2008). Thus, increased soil salinity has become an increasingly important topic (Flowers, 2004). Over 400 Mha across

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the world is affected by salinity that is about 25 % of the world's total area (including Bangladesh) (Ghassemi *et al.,* 1995). The response of plants to excess salinity is complex and involves changes in their morphology, physiology and metabolism. Morphologically the most typical symptom of saline injury to plant is reduction of growth (Azooz *et al.*, 2004), which is a consequence of several physiological reasons. Therefore, management and use of morphological variation under salinity condition might give a possibility in selecting inbred lines to develop salinity resistant maize. The genotype of extra polar salinity might offer good genetic combination of better homeostasis.

In southern belt of Bangladesh about 1.2 million hectare (Anonymous, 2010) of land remains fallow every year due to salinity hazard. To use this fallow land it needs to develop variety with high adaptability under salinity stress. This study will not only offer suitable parent for breeding program but also provide opportunity of developing base population for molecular study.

Materials and Method

Twenty five genotypes of maize, locally developed through recycling by plant breeding division, BARI, Gazipur were grown in a completely randomized design (CRD) with 3 replications at the research farm of Irrigation Division, coordinated by Plant Breeding Division of BARI, Gazipur, during rabi season of 2011-2012. Seeds of each inbred were sown uniformly into the soil of plastic pots by hand. The plastic pots were placed according to the FAO standard irrigation system for supplying the saline water. The soil was made wet by normal saline water. The seedlings emerged six to eight days after sowing. The seedlings were thinned to one per pot after ten days of emergence. Irrigation was given at two leaves stage with 8 dS concentration of saline water and repeated at 15 days interval. Fertilizers were applied @ 120, 80, 80, 20, 5 and 1 kg/ha of N, P, K, S, Zn and B respectively. Standard agronomic practices were followed (Quayyum, 1993) and plant protection measures were taken when required. Data were collected on grain yield/plant, plant height, above ground dry mass, cob per plant, cob height, cob length and cob diameter. Genetic diversity was estimated using Mahalanabis generalized distance (D^2) extended by Rao (1952). Tocher's method was followed to determine the group constellation. Canonical variate analysis was performed as per Rao (1964) to confirm the results of cluster D^2 analysis. Mean data for each character was subjected to both univariate and multivariate analysis. Univariate analysis of the individual character (analysis of variance) was done by computer using MSTAT-C software. Genetic diversity of twenty five genotypes at 8 dS level of salinity was analyzed using GENSTAT 5.13 software program (copyright 1987, Lawes Agricultural Trust, Rothamasted Experimental Station, UK).

Results and Discussion

The maize inbred lines showed significant variation for all the morphological characters. Eigen values of nine principal component axes and percentage of

variation of total variation accounting for them obtained from the principal component analysis are presented in table 1. The results revealed that the first axes accounted for 36.51% of the total variation among the genotypes, while seven of these with eigen values accounted for 100%. The first three axes of seven eigen values above the unity accounted for 76.86% of the total variation. Azam (2012) evaluated that days to 50% tasseling, days to 50% silking and plant height together accounted for 71.96% of the total genetic divergence in maize.

Table 1. Eigen values and percentage of variation for corresponding 7 component characters in 25 maize inbred lines.

Principal component axis	Eigen values	Percentage (%) of total variation	Cumulative percent of variation
Plant height (cm)	2.556	36.51	36.51
Cob height (cm)	1.545	22.08	58.59
Above ground dry biomass (g)	1.279	18.27	76.86
Cob /plant	0.602	8.60	85.46
Cob length (cm)	0.422	6.03	91.49
Cob diameter (cm)	0.321	4.58	96.07
Grain yield /plant (g)	0.275	3.93	100.00

Based on the principal component scores I and II obtained from the principal component analysis, a two-dimensional scatter diagram (Z_1-Z_2) was constructed using component score I (Z_1) as X-axis and II (Z_2) as Y-axis (Figure 1). The positions of the genotypes in the scatter diagram were apparently distributed into five groups, which indicated that considerable diversity exists among the genotypes.

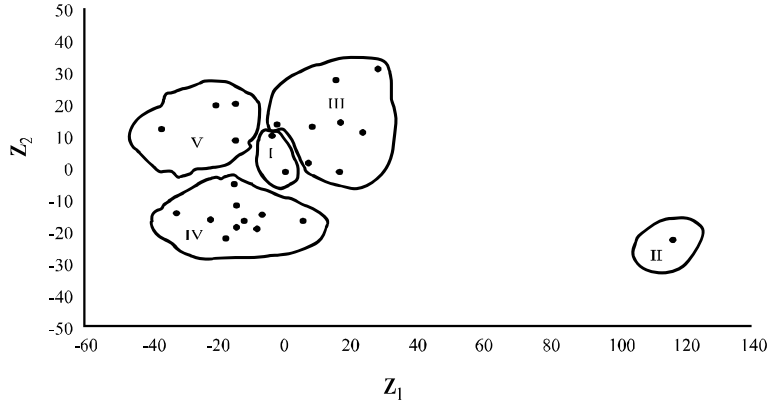

Fig. 1. Scatter distribution of 25 maize inbred lines based on their principal component scores superimposed with clusters.

The inter genotypic distances were used in computation of intra-cluster distances from distance matrix of PCO according to Singh and Choudhary (2001). The intra-cluster distances were not always proportional to the number of the

genotypes in the cluster (Table 2). In the present study, the clusters IV composed of the largest number of genotypes (10), but their intra-cluster distances were not the highest. The statistical distances represent the index of genetic diversity among the clusters. The intra-cluster distances ranged from 0.000 to 5.345. Intra-cluster distances in all the clusters were more or less low which indicated that the genotypes within the same cluster were closely related.

The highest intra-cluster distance was recorded in cluster III (5.345) containing eight genotypes followed by cluster V (5.125) containing four genotypes. The lowest intra-cluster distance was observed in cluster II (0.000) having one genotype. The intra-cluster distances of cluster I and IV were 4.440 and 3.560 consisting of 2 and 10 genotypes, respectively. These findings of the present study are in conformity with the findings of Datta and Mukherjee (2004), Singh *et al.* (2005) and Marker and Krupakar (2009).

Table 2. Average inter-cluster and intra-cluster (bold) distance (D^2) for 25 maize inbred lines obtained by canonical variate analysis.

Cluster	I	II	III	IV	V
I	4.440				
II	17.075	0.000			
III	3.724	14.837	5.345		
IV	4.884	15.648	4.703	3.560	
V	4.370	18.392	4.298	4.874	5.125

Canonical variate analysis was done to compute the inter-cluster Mahalanobis's D^2 values. The intra and inter-cluster distance (D^2) values are presented in table 2. Results indicated that the highest inter-cluster distance was between clusters II and V (18.392) followed by I and II (17.075) and II and IV (15.648). The higher inter-cluster distances between these clusters indicated to the wide spectrum of variability in the population. The lowest inter-cluster distance was observed between the clusters I and III (3.724) suggesting a close relationship among the genotypes within these clusters.

Statistical distances represent the index of genetic diversity among the clusters. The inter-cluster distances were larger than the intra-cluster distances which indicated wider genetic diversity among the genotypes of different groups. Debnath (1987) obtained larger inter-cluster distance than the intra-cluster distance in a genetic variability in maize. Similar results were also obtained by Abedin and Hossain (1990) in maize.

With the application of co-variance matrix for non-hierarchical clustering, 25 maize genotypes were grouped into five clusters. Gupta *et al*. (1991) found five clusters; Azam (2012) reported five clusters from 49 maize genotypes. The distribution pattern indicated that maximum 10 inbred lines were included in cluster IV followed by 8 in cluster III. The remainders have been distributed in three clusters. The least number 1 was included in cluster II (Table 3).

These results confirmed the clustering pattern of the genotype according to the principal component analysis. Composition of different clusters with their corresponding genotypes included in each cluster are presented in table 3. Results of the different multivariate techniques were super imposed with the clusters (Fig 1). The clustering pattern obtained was coincided with the apparent grouping patterns performed by PCA. For that reason it can be said that the results obtained through PCA were established by non-hierarchical clustering.

Table 3. Distribution of 25 maize inbred lines in different clusters.

Cluster	Total no. of genotypes in the cluster	Genotypes included in different clusters
I	2	CZ36, CML376-1
II	1	CZ35
III	8	CZ12, CZ19, CZ26, CZ29, CZ31, CZ32, CZ33, CML470
IV	10	CZ3, CZ10, CZ24, CZ28, CZ30, CML159, CML206-1, CML216, CML395, CML496
V	4	CZ27, CZ37, CML251, CML456

An attempt was made to characterize the individual genotypes in respect of their mean values for different characters with a view to getting the idea whether the genotypes having similar characteristics could be disseminated. The Intra-cluster mean values for all the 7 characters along with the marking of the highest (H) and the lowest (L) for each of the clusters is presented in table 4. The data revealed that different clusters exhibited different mean values for almost all the characters. Plant height had the highest intra-cluster means in cluster II followed by those in cluster I and cluster IV. The lowest intra-cluster mean for this trait was observed in cluster V. Cob height had the highest group means in cluster II followed by those in cluster I and cluster IV. It had the lowest mean in cluster V. The intra-cluster mean for above ground dry mass was the highest in cluster II followed by those in cluster IV. The lowest intra-cluster mean for this trait was observed in cluster I. Intra-cluster mean for cob per plant were the highest in cluster II (2.00) and the lowest in cluster I (1.00). Cob length had the highest group mean in cluster II (15.00) followed by those in cluster III (12.13) and cluster I (12.00). The lowest intra-cluster mean for this trait was observed in cluster V (8.06).

The lowest value for cob diameter was found in cluster V (3.17) followed by cluster IV (3.45) and cluster II (3.60), the highest was in cluster I (4.15). Grain yield per plant was the highest in cluster II (163.38) followed by cluster III (70.12) and cluster I (49.52) and the lowest was in cluster V (35.96).

The inter-cluster distance of cluster II with other clusters was higher than the inter-cluster distances between the remaining cluster combinations (Table 2). The

cluster means of this cluster for plant height, cob height, above ground dry mass, cob per plant, cob length and grain yield per plant was also divergent. These indicated that the genotype included in cluster II were very important to contribute to the total divergence among the inbreds for these characters. Cluster I provided the highest cluster means for cob diameter which indicated that the inbred lines within this cluster could be used for increasing cob diameter in maize. Based on cluster means Singh and Chaudhari (2003) also reported wide range of variation for grain yield and it's components in maize. Marker and Krupakar (2009), also have assessed the range of variability of 16 genotypes for 14 traits in maize. The present results are in agreement with those of Tang *et al.* (2002) and Alom *et al.* (2003) who also identified the above mentioned characters as the principal components contributing maximum to the total variation in maize.

Table 4. Cluster means for seven different characters of 25 maize inbred lines.

Characters	Clusters				
	I	II	III	IV	V
Plant height (cm)	114.00	135.00 H	95.75	108.05	87.03 L
Cob height (cm)	48.00	65.00 H	40.06	45.65	34.00 L
Above ground dry biomass (g)	45.31 L	86.91 H	56.55	76.83	56.25
Cob /plant	1.00 L	2.00 H	1.19	1.15	1.25
Cob length (cm)	12.00	15.00 H	12.13	11.50	8.06 L
Cob diameter (cm)	4.15 H	3.60	3.99	3.45	3.17 L
Grain yield /plant (g)	49.52	163.38 H	70.12	37.77	35.96 L

Note: H= High, L= Low

Generally genetic diversity is associated with geographical diversity but the former is not necessarily directly related with geographical distribution. In the present study, pattern of clustering revealed that genotypes originating from recycling of different high yielding hybrids were grouped in the same cluster and hybrids were collected from different countries. This indicates that geographic diversity was not related to genetic diversity, which might be due to continuous exchange of genetic materials among the countries of the world. Verma and Sachan (2000) observed no parallelism between geographic and genetic diversity. Chatterjee and Khare (1991) studied a negative relationship between geographic and genetic diversity. Gupta *et al.* (1991) showed no correlation between geographic and genetic diversity.

Contribution of characters towards the divergence obtained from canonical variate analysis is presented in table 5. In this method, vectors were calculated to represent the varieties in the graphical form (Rao *et al*., 1952). This is helpful in cluster analysis as it facilitates the study of group constellations and also serves as a pictorial representation of the configuration of various groups.

Table 5. Latent vectors for seven principal component characters of 25 maize inbred lines.

Characters	Vector I	Vector II
Plant height (cm)	-0.4484	-0.2755
Cob height (cm)	-0.5076	-0.1601
Above ground dry biomass (g)	-0.2299	-0.5423
Cob /plant	-0.1383	-0.3056
Cob length (cm)	-0.4654	0.3105
Cob diameter (cm)	-0.2635	0.6275
Grain yield /plant (g)	-0.4281	0.1445

In vector I (Z_1) obtained from PCA, no characters had positive values. In vector II (Z_2), the second axis of differentiation, cob length (0.3105), cob diameter (0.6275) and grain yield/plant (0.1445) were important because all these characters had positive values.

Plant height, cob height, above ground dry biomass and cob per plant had negative value in both the vectors, which indicated that they were the less important component characters having lower contribution to the genetic divergence among the materials studied. Among the characters, cob length, cob diameter and grain yield/plant contributed maximum towards the genetic divergence under salinity stress conditions. The current consequences are in concurrence with those of Tang *et al.* (2002), Alom *et al.* (2003) , Marker and Krupakar (2009) who also identified above mentioned characters as the principal components contributing maximum to the total variation in maize.

Conclusion

The results indicated that the cob length, cob diameter and grain yield per plant had maximum contribution to the genetic divergence among the genotypes. The cluster means of cluster II for plant height, cob height, above ground dry mass, cob per plant, cob length and grain yield per plant was also divergent. These indicated that the genotype included in cluster II were very important to contribute to the total divergence among the inbreds for these characters. Cluster I provided the highest cluster means for cob diameter which indicated that the inbred lines within this cluster could be used for increasing cob diameter in maize. Inbreds of cluster II and I may be selected for hybridization for obtaining desirable segregants for these traits under salinity stress.

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GENOTYPIC VARIATIONS IN GROWTH, YIELD AND YIELD COMPONENTS OF SOYBEAN GENOTYPES UNDER DROUGHT STRESS CONDITIONS

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A. R. M. SOLAIMAN[3] AND J. U. AHMED [4]

Abstract

A pot experiment was carried out in a venylhouse at Bangabandhu Sheikh Mujibur Rahman University during 2012 to investigate the growth, yield and yield contributing characters of ten selected soybean genotypes viz. Shohag, BARI Soybean-6, BARI Soybean-5, BD2331, BD2329, BD2336, BD 2340, BGM2093, G00015 and BGM2026 under drought stress and control conditions. Plant height, number of leaves, leaf area, shoot and root dry weight of all the genotypes were significantly affected by the stress. Among the genotypes Shohag, BARI Soybean-6 and BD2331 were found tolerant in relation to the growth under water stress conditions. The reduction in RGR values was more in the susceptible genotypes at the later stages of growth than in the tolerant genotypes. Seed yield of the genotypes was reduced from 42 to 68% due to drought (water) over non-stress. Susceptible genotypes showed greater reduction in seed yield than the tolerant genotypes.

Introduction

Soybean, a grain legume, is one of the most important oilseed crops of the world. It is the world's leading economic oilseed crop (Manavalan *et al.,* 2009). It is also an important source of plant protein of the people in semi-arid and tropical regions. It has a great value as food, feed and fuel. The production of the crop is often limited by the erratic nature of rainfall. It is reported that water stress affects soybean production worldwide. Among the crops, soybean has the highest sensitivity to drought (Maleki *et al.*, 2013). Drought may reduce yield of soybean by about 40% (Specht *et al*., 1999).

In Bangladesh, soybean is planted during post-monsoon when stored soil moisture rapidly declines and the crop encounters drought at the reproductive stage. Plant growth is affected by moisture stress including leaf expansion which is reduced due to sensitivity of cell growth to water stress. Reduction in leaf area reduces crop growth and thus affects biomass production (Brown *et al*., 1985). Shoot biomass accumulation is considered an important trait to attain high seed

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yield in grain legumes (Saxena *et al*., 1990). Significant differences have been observed for shoot and root biomass accumulation among soybean cultivars grown under severe drought stress. Root have an essential role in tolerating drought as they are the main organs responsible for sourcing valuable water (Eureka *et al*., 2000). Yordanov *et al.,* (1997) claimed that water stress reduces the biomass, seed yield, number of pods in main stem, pod and seed number per plant.

The objective of this study was to assess the morphological growth parameters of ten soybean genotypes subjected to drought stress at different growth stages and to identify the genotype that is most sensitive and most tolerant to water stress.

Materials and Methods

The experiment was conducted in a venylhouse constructed at the Environmental Stress Research Site in Agronomy farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during February to May 2012. Six relatively tolerant soybean genotypes viz., Shohag, BARI Soybean-6, BARI Soybean-5, BD2331, BD2329 and BD2336 and four susceptible viz, BD2340, BGM2093, G00015 and BGM2026 altogether selected from the previous experiment which were grown in plastic pots. The soil of the pot was filled with mixture of soil and cow dung at a ratio of 4:1. Pot contained 12.0 kg of soil which was equivalent to 9 kg oven dry soil and holds about 28% moisture at field capacity (FC). Soil use in the plastic pot was sandy loam and was fertilized uniformly with 0.15, 0.18, 0.36 and 0.1 g urea, triple super phosphate, muriate of potash and gypsum corresponding to 24-30-60-15 kg NPK and S hectare^{-1}, respectively. Total amount of all fertilizers were mixed with soil before the sowing of seeds.

Six seeds of each genotype were sown in each pot on 2 February 2012 and later thinned to three healthy seedlings per pot. Most of the seedlings emerged within 7 days after sowing. Plants of each pot received adequate watering regularly to maintain optimal soil moisture until the water stress treatment was imposed. Adequate plant protection measures were taken to keep the plants free from diseases, insects and weeds through the growing season.

Plants of all the genotype were subjected to two levels of water regime viz., S_0 = Non-stress (Control); water was applied as and when it is required and Sw = Drought stress (Water stress) throughout the growing period; pots were irrigated with water at 50% field capacity at appearance of wilting symptom. The experiment was laid out in a Completely Randomized Design with four replications. Three plants pot^{-1} considered as one replication. After 21 days after emergence (DAE), water stress treatments were applied.

Total dry matter of shoot and root was measured at different growth stages (vegetative, flowering and pod filling stages) by oven drying at 70^0C to a constant weight. For each and every sampling of all treatments four times number of replicated pots were maintained. Roots were washed thoroughly in tap water and blotted dry before drying. The leaf area plant^{-1} was measured with an automatic area meter (Model AAM-8, Hayashi denko, Japan) at vegetative, flowering and pod development stages. Yield and yield components were also determine at harvest. Relative growth rate (RGR) was calculated by using the following formula (Gardner *et al*., 1985):

$$RGR = \frac{LnW_2 - Ln\ W_1}{T_2 - T_1} \quad gg^{-1}day^{-1}$$

Where, W_1 = dry weight of plant at time T_1

W_2 = dry weight of plant at time T_2

Ln = natural logarithm

Yield contributing characters viz. number of pods plant-1, seeds pod-1, 100 seed weight and seed yield were measured at harvest. The recorded data were analyzed by 'MSTAT-C' statistical package. The difference between the treatments means were compared by Least Significant Difference (LSD) test (Gomez and Gomez, 1983).

Results and Discussion

Plant height

Drought significantly decreases the plant height of soybean genotypes. Plant height of ten soybean genotypes showed significant differences under both non-stress (NS) and water stress environments at all the growth stages (Table 1.). Under NS environment, BGM2026 produced the maximum plant height (50.42 cm) at vegetative stage which was followed by BARI Soybean-5 and G00015 but under water stress environment, BD 2331 obtained the maximum plant height (41.63 cm) which was identical with BGM2026. The shortest plant was recorded from BGM2093 (32.84 cm) under water stress condition. But from flowering stage to maturity, all the genotypes under non-stress environment produced significantly taller plants than that under water stress environment. The genotype BGM2026 attained the maximum height at non-stress environment but under water stress environment, BARI Soybean-6 produced the tallest plant followed by Shohag. Under water stress environment, BGM2026 was affected severely which produced the shortest plant. It was also observed that irrespective of genotype, plant height changed with the advancement of growth stages in both the environments. Plant height `increased sharply from vegetative to pod

development stage and thereafter slowly up to maturity stage. Reduction in plant height was more at maturity stage irrespective of genotypes.

Table 1. Plant height at different growth stages in soybean genotypes under non-stress and water stress conditions.

Genotypes	Plant height (cm)							
	at vegetative stage		at flowering stage		at pod development stage		at maturity stage	
	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress
Shohag	43.76	35.06	63.28	53.2	68.83	55.4	75.97	60.87
BD2329	42.35	33.03	62.1	51.97	70.12	55.31	74.22	57.2
BARI Soybean-5	49.39	35.77	64.56	50.59	69.75	54.17	77.31	59.27
BARI Soybean-6	45.57	40.35	67.6	55.11	74.67	59.22	78.74	64.51
BD2340	41.42	38.8	57.43	47.94	72.95	52.97	75.55	54.8
BD2336	44.74	39.57	58.18	45.44	73.54	52.04	76.68	58.63
BGM2093	39.27	32.84	54.58	46.67	71.85	53.5	78.38	57.32
BD2331	45.85	41.63	68.03	52.1	75.8	55.94	77.33	58.75
G00015	48.21	39.62	68.5	50.2	72.71	56.71	75.72	57.21
BGM2026	50.42	40.7	74.06	44.5	86.67	47.67	92.45	49.8
$LSD_{(0.05)}$ SxG	NS		NS		9.917		6.136	
CV%	9.58		9.86		9.38		5.46	

S=Stress, G=Genotypes, NS=Not significant

At maturity stage extent of plant height reduction under two moisture regimes are presented in Fig. 1. The reduction percent in plant height was found minimum in BARI Soybean-6 (18.07% reduction) and maximum in the genotype BGM2026 (46.13%) due to water stress. The differences in plant height reduction among the genotypes mainly due to genotypic differences. Water stress induced reduction in plant height was also observed by Khan *et al.* (2014) in soybean. The decrease in plant height could be resulted from a reduction in plant photosynthetic efficiency as reported by Hamid *et al.* (1990). It also might be due to decrease in relative turgidity and dehydration of protoplasm which is associated with a loss of turgor and reduced expansion of cell and cell division (Arnon, 1972).

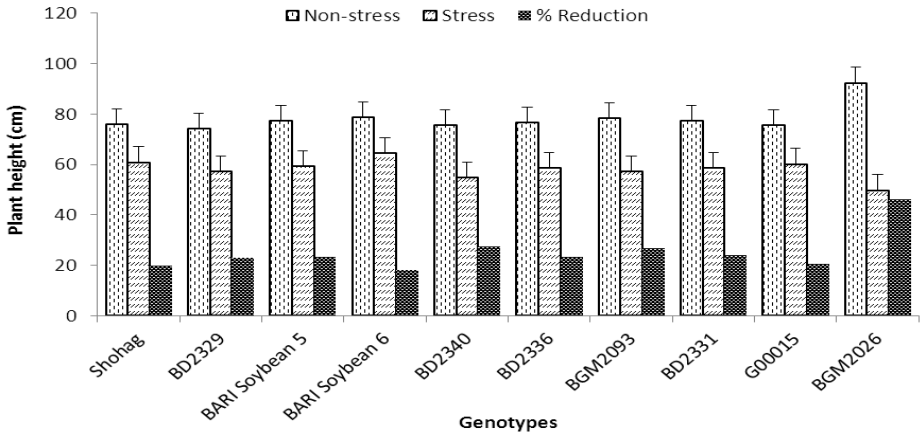

Fig 1. Extent of plant height reduction at maturity under non-stress and water stress environments of 10 selected soybean genotypes. (Vertical bar represent LSD value at 5% level of significant.)

Table 2. Leaf number at flowering and pod development stages in soybean genotypes under non-stress and water stress conditions.

Genotype	Total leaf number					
	Flowering stage			Pod development stage		
	Non-stress	Water stress	% reduction	Non-stress	Water stress	% reduction
Shohag	25	20	20	30	22	26
BD2329	24	18	25	29	20	31
BARI Soybean-5	26	18	30	34	22	35
BARI Soybean-6	26	22	15	28	23	17
BD2340	24	17	29	30	21	30
BD2336	23	14	39	28	16	42
BGM2093	22	14	36	29	17	41
BD2331	24	17	29	28	18	35
G00015	19	13	31	26	17	34
BGM2026	29	14	51	37	15	59
$LSD_{(0.05)}$ S×G	NS			5.513		
CV%	15.23			13.44		

S= Stress, G= Genotype, NS=Not significant

Leaf number plant^{-1}

Decrease in leaf number was observed at two growth stages under water stress environments (Table 2.). Genotypic variations in number of leaves were also found under both non-stress and water stress environment. In all the genotypes

decrease in leaf number was higher at pod development stage, than that at flowering stage. Water stress condition reduces the leaf number because drought stress reduces leaf initiation and accelerates leaf senescence. At flowering stage, reduction percent varied from 15 to 51%, whereas it was 17 to 59 % at pod development stage. Razakou *et al*. (2013) observed 5 to 64% reduction in leaf number in cowpea. Under water stress condition, lowest number of leaf was found in BGM2026 genotype but at non-stress condition, it produced the highest number of leaf. Due to water stress the less affected varieties were BARI Soybean-6 and Shohag. Reduction in leaf number occurred may be due to less number of leaf initiation (Thrikawela, and Bandara, 1992)

Leaf area

Reduction in leaf area is convenient morphological parameters for measuring drought stress experienced by the plant (Ku *et al*., 2013). Water stress significantly reduced the total leaf area. Under stress, drought tolerant soybean cultivars exhibited a larger leaf area when compared with less tolerant cultivars (Moreira *et al*., 2010). Leaf area of ten soybean genotypes at different growth stages under non-stress and water stress environments showed significant differences (Table 3.). At vegetative stage, the reduction of leaf area varied from 8.04 to 22.63% and reduction percent does not show any trend among tolerant and susceptible genotypes. But at the later stages of growth these situations were changed. With the advancement of growth the susceptible genotype showed the higher reduction than tolerant genotypes. Under non-stress condition highest leaf area was found in BGM2026 at both flowering and pod development stages but not under stress condition. Under stress condition Shohag produced the highest leaf area. In case of reduction percent BGM2026 showed the highest reduction and BARI Soybean-6 showed the lowest reduction in leaf area at both flowering and pod development stages. Less leaf expansion, leaf growth reduction and leaf senescence acceleration might be responsible for lower leaf area. Khan *et al.* (2014) in soybean and Samson and Helmut (2007) in cowpea reported earlier that water deficit stress reduced significantly the total leaf area. Krishnamoorthy (1993) reported that water stress causes a reduction in the size of leaves as because cell division in the leaf primordial ceases due to water stress. According to Ludlow and Muchow (1990) reduced leaf growth and accelerated leaf senescence is common responses to water deficits and the parameters both reduce leaf area.

Table 3. Leaf area at different growth stages in soybean genotypes under non-stress and water stress conditions

Genotypes	Leaf area (cm^2 $plant^{-1}$)					
	Vegetative stage		Flowering stage		Pod development stage	
	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress
Shohag	728.78	650.54 (10.73)	1043.0	823.97 (21.0)	1204.7	875.69 (27.31)
BD2329	669.21	530.01 (20.8)	936.12	655.67 (29.95)	1164.02	737.66 (36.62)
BARI Soybean-5	674.24	598.91 (11.17)	1027.79	793.96 (22.75)	1212.22	842.37 (30.51)
BARI Soybean-6	616.45	566.86 (8.04)	879.96	747.09 (15.09)	1159.4	862.25 (25.62)
BD2340	638.59	581.11 (9.0)	904.73	653.91 (27.72)	1200.3	733.98 (38.85)
BD2336	665.66	515.02 (22.63)	928.77	606.82 (34.66)	1035.28	630.11 (39.13)
BGM2093	551.96	502.15 (9.02)	902.9	565.58 (37.35)	1179.27	636.64 (46.01)
BD2331	641.32	561.67 (14.18)	895.79	688.06 (23.18)	1081.37	730.79 (32.41)
G00015	582.0	497.09 (14.58)	710.97	527.82 (25.76)	897.4	593.89 (33.82)
BGM2026	735.78	539.61 (26.66)	1066.19	560.57 (52.48)	1311.13	577.98 (55.91)
$LSD_{(0.05)}$ SxG	47.81		64.07		78.78	
CV%	4.74		4.87		5.11	

S=Stress, G= Genotypes

Value in the parentheses represents the percent reduction of the parameters under water stress over non-stress.

Shoot and root dry weight

Due to water stress the reduction in shoot dry weight was not significant at vegetative stage in any genotype. But numerically, reduction was higher in G00015 followed by BGM2026 at vegetative stage (Figs. 2). At this stage BD2336 produced more shoot dry weight under stress condition than non-stress

condition (Fig: 2). At flowering or pod development stage the reductions were conspicuous in all the genotypes due to water stress. A large reduction in

shoot dry weight was found in the genotype BGM2026 which was 33.65% at flowering, 48.29% at pod development and 58.98% at maturity stage. On the contrary, the shoot dry weight of tolerant genotypes Shohag, BARI Soybean-6, BARI Soybean-5 and BD2331 were affected the least by the stress. A similar finding was observed by Khan *et al*. (2014) in soybean, Eureka *et al*. (2000) and OO *et al*. (2008) in mungbean. Leaf area has been frequently reported to have a close relationship with crop growth (OO *et al*., 2008; Anyia and Herzog, 2004). The decrease in leaf area (Table 3) by the WS condition was closely related to the shoot dry weight (Figs. 2). This means that tolerant genotypes having a better sustainability in producing more leaf area to keeping a high shoot dry weight under WS condition.

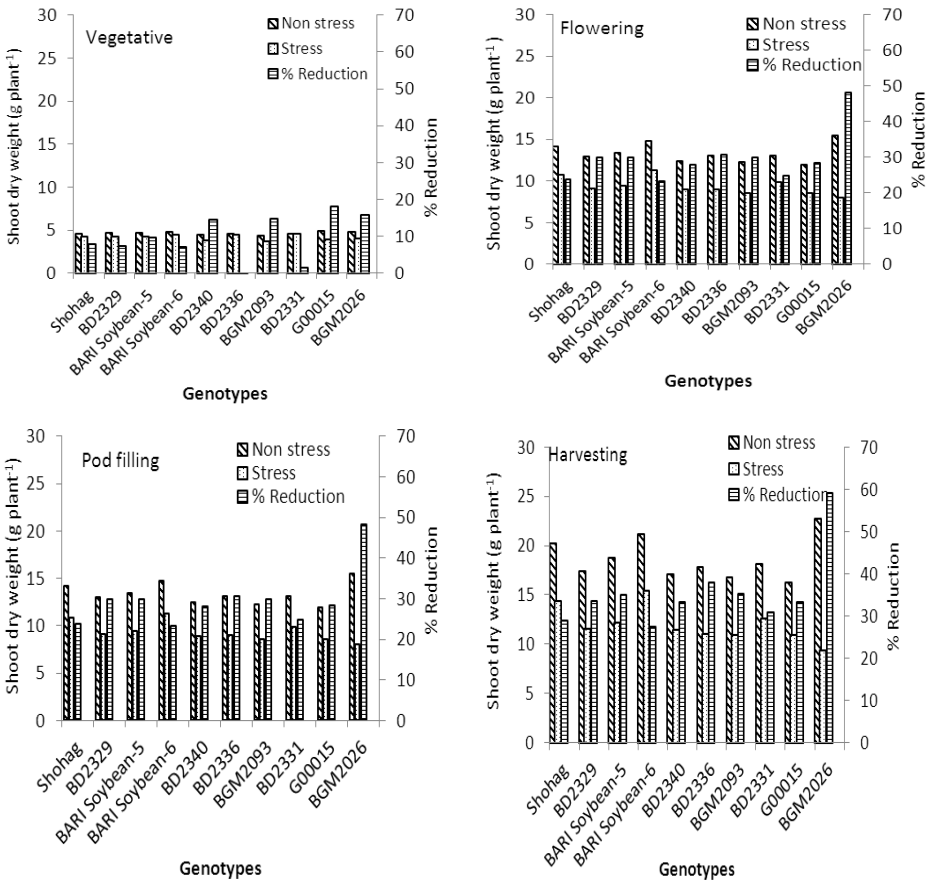

Fig. 2. Dry weight and reduction percent of shoot of 10 selected soybean genotypes at different growth stages under non-stress and water stress conditions.

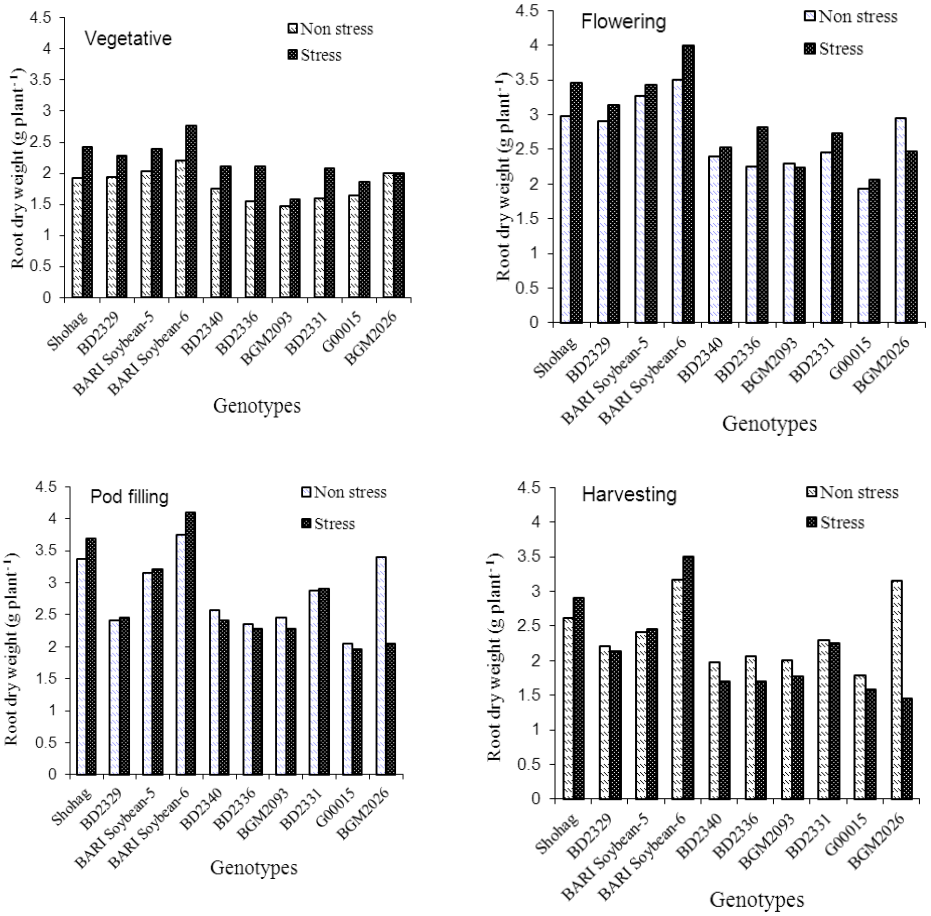

Fig. 3. Root dry weight of 10 selected soybean genotypes at different growth stages under non-stress and water stress conditions

At vegetative stage a remarkable increase in root dry weight was observed in all the genotypes under stress and non-stress conditions (Fig. 3). But root dry weight decreased under WS environment in BGM2026, BD2336, BD2340, BGM2093 and G00015 at pod development stage and onwards. At all the growth stages the genotypes Shohag and BARI Soybean-6 maintained higher root dry weight under water stress environment over non-stress. Islam *et al*. (2004) reported that root dry weight of bushbean measured at harvest remarkably increased with the decrease in the moisture level. Eureka *et al*. (2000) observed that reduction in root dry matter occurred in susceptible genotypes but tolerant genotype were able to maintain their root dry weight under drought at the level of the respective control values. The water uptake was limited by the amount of roots, and the enhancement of root growth could increase drought resistance (Klepper and

Rickman, 1990). Increase in root biomass of water stressed genotypes may be due to ability to divert assimilates to enhance the growth of the roots so as to exploit deeper parts of the soil water (Razakou *et al*., 2013). Maintenance of root growth during water deficit is an obvious benefit to maintain an adequate plant water supply, and is under genetic control (Sponchiado *et al*., 1989). The higher value of root dry weight and less suppressed in shoot dry weight were shown in Shohag and BARI Soybean-6 that might be related to drought resistance (Fig. 3).

Relative growth rate (RGR)

Relative growth rate of all genotypes decreased with the advancement of growth stages at both the moisture regimes (Fig. 4). The RGR recorded in soybean genotypes were always higher in control than under water stress condition. Under water stress condition genotypes BD2336, BGM2093, G00015, BD2340 and BD2329 maintained relatively higher RGR at the early growth stages but at later stage higher RGR was maintained in Shohag, BARI Soybean-5,

BARI Soybean-6 and BD2331. At the later stage of the growth, the value of RGR of BGM2026

was more inhibited compared to other genotypes under water stress environment. The highest value of RGR in Shohag, BARI Soybean-5, BARI Soybean-6 and BD2331 under water stress

was an indication of their drought tolerance, while the lowest value of RGR in the genotype BGM2026 and BD2336 indicated their drought susceptibility. A similar finding was reported by Lizana *et al*. (2006) and Costa-Franca *et al*. (2000) in common bean.

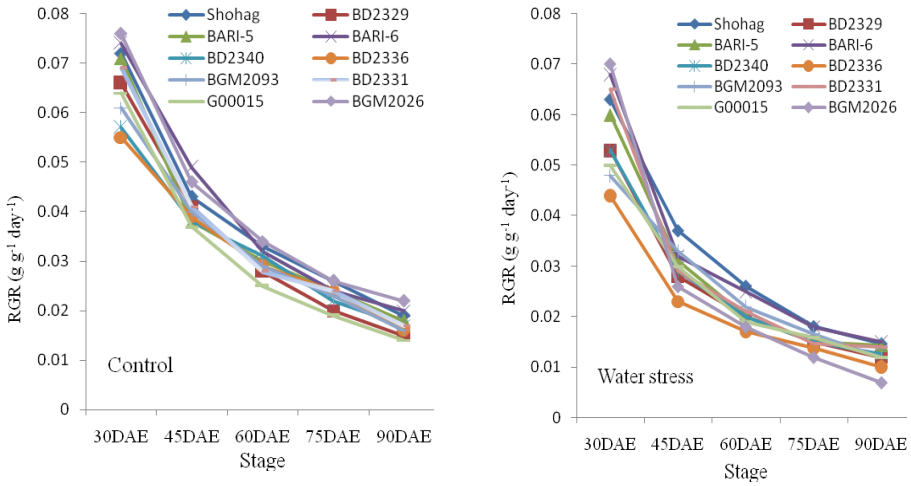

Fig 4. Relative growth rate of ten soybean genotypes at different growth stages under non-stress and water stress conditions

Seed yield and yield contributing characters

Water stress caused significant differences in pods plant^{-1}, seeds pod^{-1} and seed size of soybean genotypes (Table 4 and 5). The highest number of pod plant^{-1} was found in BGM2026 (59.25) which significantly differed from all other genotypes under non-stress environment. Under water stress condition, the maximum number of pod plant^{-1} (30.65) was obtained from BARI Soybean-6, which was statistically identical with Shohag, and BD2331. The rate of reduction was ranges from 31.37 to 55.88% the lowest where was in BARI Soybean-6 followed by BD2331 and Shohag (Table 4). The reduction in pod number plant^{-1} due to WS was reported earlier in french bean (Omae *et al*., 2005), in soybean (Kokubun *et al*., 2001; Liu *et al*., 2004) and in mungbean (Islam, 2008). The highest number of seeds pod^{-1} was observed in the genotype BGM2093 and the lowest from BARI Soybean-5 in both the environment. The genotype BGM2026 also produced the least number of seed pod^{-1} under water stress condition but not in non-stress condition. The rate of reduction varied from 2.65 to 20.43% under water stress over non-stress environment across the genotypes. The maximum reduction of seeds pods^{-1} (Table 4) was obtained from genotype BGM2026 (20.4%) followed by genotypes BD2331 (11.36%). However, the reduction rate was the lowest in BARI Soybean-5 (2.66%). In case of seed size the rate of reduction varied from 14.06 to 26% across the genotypes. The highest 100-seeds weight was found in G00015 at both the environments but its reduction percent was high. Lowest reduction occurred in Shohag followed by BARI Soybean-6 and BD2331. The genotype BGM2093 had the smallest seed size at both the environments.

Water stress-induced yield reduction has been reported in many crop species (Farooq *et al*., 2009). Seed yield plant^{-1} was reduced by water stress in all the soybean genotypes studied (Table 5). The rate of reduction ranged from 42.68 to 68.96% across the genotypes. The seed yield plant^{-1} under non-stress environment was the highest in genotype BARI Soybean-6 followed in decreasing order by BARI Soybean-5, BD2329, BGM2026, Shohag, BD2331, BD2340, G00015, BGM2093, and BD2336 genotypes. Pod number plant^{-1} and 100-seed weight might be responsible for highest seed yield in BARI soybean-6 and lowest in BD2336. Under water stress, the highest seed yield plant^{-1} was also obtained from BARI Soybean-6 followed in decreasing order by Shohag, BD2331, BARI Soybean-5, BD2339, BGM2026, BD2340, G00015, BD2336 and BGM2093. The reduction in seed yield was primarily due to a decrease in pod number plant^{-1}. The decrease in pod number plant^{-1} and seed size under drought stress was possibly due to reduction of photosynthesis, translocation of assimilates and increased rate of reproductive organs abortion (Kukubun *et al*., 2001; Liu *et al*., 2003 and 2004; Tera'n and Singh, 2002). The number of seeds pod^{-1} and seed weight were reported to be more stable and less affected by environmental stress (Tera'n and Sigh 2002).

Table 4. Number of pods plant^{-1} and seeds pod^{-1} in soybean genotypes under non-stress and water stress condition.

Genotypes	Pods plant^{-1} (no.)			Seeds pod^{-1} (no.)		
	Non-stress	Water stress	% Reduction	Non-stress	Water stress	% Reduction
Shohag	44.16	29.57	33.03	2.25	2.15	4.44
BD2329	40.25	22.13	45.01	2.2	2.1	4.54
BARI Soybean-5	42.6	25.95	39.08	1.88	1.83	2.65
BARI Soybean-6	44.66	30.65	31.37	2.2	2.0	9.09
BD2340	41.5	19.14	53.87	2	1.92	4.00
BD2336	44.58	24.96	44.01	2.3	2.2	4.34
BGM2093	49.25	25.11	49.01	2.5	2.3	8.00
BD2331	42.16	28.44	32.54	2.2	1.95	11.36
G00015	25.66	12.08	52.92	2.25	2.04	9.33
BGM2026	59.25	26.14	55.88	2.3	1.83	20.43
$LSD_{(0.05)}$ SxG	9.585			NS		
CV%	16.88			7.14		

S= Stress, G= Genotype, NS=Not significant

Table 5. 1000-seeds weight and seed yield plant^{-1} of soybean genotypes under non-stress and water stress condition.

Genotypes	1000-seeds weight (g)			Seed Yield plant^{-1} (g)		
	Non stress	Water stress	% Reduction	Non stress	Water stress	% Reduction
Shohag	110.2	90.6	14.28	8.62	4.79	44.43
BD2329	110.3	80.8	22.12	9.11	3.38	62.90
BARI Soybean-5	120.1	100.0	17.35	9.18	4.67	49.12
BARI Soybean-6	110.9	100.2	14.28	9.22	5.17	43.92
BD2340	110.3	90.05	19.91	7.99	2.48	68.96
BD2336	60.08	40.86	20.06	5.52	2.18	60.50
BGM2093	50.89	40.53	23.08	5.97	2.18	63.48
BD2331	90.88	80.49	14.06	8.2	4.7	42.68
G00015	130.9	100.4	25.17	6.42	2.22	65.42
BGM2026	70.5	50.55	26	9.1	3.05	66.48
$LSD_{(0.05)}$ SxG	NS			0.5305		
CV%	6.49			5.63		

S= Stress, G= Genotype, NS=Not significant.

Conclusion

The results of the study indicated that the ten genotypes showed marked variations in plant growth characters, yield and yield attributes under water stress condition. Genotypes Shohag, BARI Soybean-6 and BD2331 were relatively water stress tolerant than others in respect of physiological adaptation associated with yield attributes and seed yield under water stress condition.

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Water stress tends to increase biomass partitioning to roots, increasing the root: shoot ratio (Manavalan *et al*., 2009).

Plant productivity under drought stress is closely related to the processes of dry matter partitioning and the spatial and temporal root distribution (Kage *et al*., 2004).

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ADOPTION OF RAISED BED TECHNOLOGY IN SOME SELECTED LOCATIONS OF RAJSHAHI DISTRICT OF BANGLADESH

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Abstract

The study evaluated the adoption and farmers' practice of raised bed technology at farm level since the close of the Soil Management Collaborative Research Support Program (SMCRSP) through a follow-up survey conducted at Durgapur Upazila of Rajshahi district. Data for the study were collected from 195 adopters and 65 non-adopters through a pre-tested interview schedule during May, 2011. The survey findings showed that the raised bed technology had a strong demonstration effect and were adopted well (56%) by the respondent farmers. The probability of adopting this technology was significantly influenced by extension contact, societal membership, and the number of male member in the household. Due to lack of machine, most farmers prepared raised bed by hand (82.7%) without maintaining recommended bed size. The most cultivated crops on bed were wheat (cultivated by 97.95% farmers) maize (27.69%) onion (16.41%) and mungbean (12.31%). Respondent farmers mentioned various positive benefits of bed technology and willing to continue this practice in future with increased area of land. This immerging technology increased cop productivity and farmers' income to some extent. To popularize the raised bed technology among farmers, bed planter should be available to the farmers and the positive benefits should be broadcasted in the mass media

Keywords: Bed planter, raised bed technology, adoption.

Introduction

Crop establishment through bed planting is a good technique in the farming systems of South Asia. This system is being extensively used in cultivating wheat both in India and Pakistan. This system was originated from Mexico's Yaqui Valley, where more than 90% of farmers had adopted this practice for wheat cultivation. Its use is very negligible in the eastern Gangetic Plains of South Asia, due to lack of machinery for smaller land holdings (Hossain *et al*., 2004a). Raised bed cultivation facilitates more optimum planting time for rice, wheat, maize, and pulses by providing timelier field access because of better drainage. Additionally, once the beds are established there are new opportunities to reduce crop turn-around time by re-using the same bed without tillage (Sayre, 2003). In addition, this system has many advantage, such as reducing the seed rate, requiring less irrigation water, imparting higher nitrogen use efficiency, reducing

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crop lodging, and increasing crop yield over the conventional tillage/sowing systems (Meisner *et al.*, 1992; Hobbs *et al.*, 1997; Fahong *et al.*, 2003; Lauren *et al.*, 2008).

The mechanized bed planter creates a trapezoidal raised bed and can perform seeding operations on the top of the bed simultaneously in one operation behind a power tiller. There is also a provision of fertilizer application along with seed sowing. The farm level performance of bed planter was tested for wheat, maize, mungbean, and other crop cultivation in different areas of Dinajpur and Rajshahi districts. On-farm research results revealed that this system saved 20-34% irrigation water, 16-69% planting cost, and ensured higher crop yield compared to conventional system (Hossain *et al.*, 2010). The BCR of wheat cultivation on raised bed and permanent bed were 4.5 and 4.7 which was 41% and 47% higher than conventional method respectively (Hossain *et al.*, 2004b). Lauren, *et al*. (2008) found mean yield response to N fertilization greater on raised beds than on the flat, and greater with rice than wheat. They also recorded consistent improvements in yield and reductions in irrigation inputs, together with cost savings in labour, land preparation, fertilizer, and seed inputs, on permanent beds which convinced a group of Bangladeshi farmers to adopt this innovative technology.

Realizing the importance of the raised bed for improved crop production, the scientists of Cornell University (USA) in collaboration with Bangladesh Agricultural Research Institute (BARI) and CIMMYT introduced the raised bed technology through the SM CRSP project (2003-2008) entitled 'Enhancing technology adoption for the rice-wheat cropping system of the Indo-Gangetic Plains'. The focus area for the initial work was in Rajshahi and Natore districts. The technology was disseminated to 26 farmers from Duary, Santospur and Durgapur areas, who were interested in reducing their labor/input costs and diversifying their cropping system for more profitable production. All the farmers received hands-on training in the use of the power tiller with the bed former attachment and then used the knowledge and a bed former on loan from the project to compare raised bed versus conventional flat cultivation in a wheat-mungbean-rice rotation on their own farms. A research scientist from BARI-Rajshahi provided technical backstopping and monitoring support throughout.

The participating farmers were enthusiastic about raised bed because the practice improved livelihoods and food security for their families. Interest in the raised bed technology expanded beyond the initial group to farmers in the surrounding communities, who were part of a federation of 22 community groups which had formed from CARE farmer field schools. One farmer group took the lead to disseminate the raised bed technology to the other farmers through rallies and hands-on equipment trainings. Some group members obtained loan from a local NGO (CAR) to purchase the equipment and then provided bed formation services on a for-hire basis. By the end of the SM CRSP project in 2008, the use of raised bed cultivation had expanded from 26 farmers on 4.05 ha to over 900

farmers on 196.76 ha. In 2010, Cornell University, USA initiated the Food for Progress Project for Bangladesh with funding from the US Department of Agriculture. The objective of this project was to continue dissemination of the raised bed technology for smallholder farmers in the drought prone region of Rajshahi Division. Feedback from farmers who were involved with raised bed from the SM CRSP phase can be used to ensure the success of the new project.

With this background, a follow-up survey in the introduction area is needed to understand farmers' practice of raised bed since the close of the SM CRSP project. Therefore, an attempt was made in this study to document the status of current use of raised bed technology, farmers' perceptions, and overall impact of this technology at farm level. The findings of the study will be very much helpful to the farmers, researchers, policy makers and donor agency for wider expansion of this proven technology throughout the country.

Objectives:

1. To know the present status of using raised bed technology for cultivating crops at the farm level.
2. To assess the status of adoption of the raised bed technology at farm level and to find out the factors affecting its adoption and non-adoption.
3. To assess farmers' perceptions on the impact of raised beds on input use and income through higher productivity.

Methodology

Sampling and data collection: The study followed purposive sampling in order to select study areas and sample raised bed using farmers. At the first stage of sampling, the study selected those areas where the raised bed technique of crop production was first introduced through SM CRSP between 2003 and 2008. Besides, the primary focus population of this survey was those farmers who are currently using the raised bed practice or have used the technique in the recent past. Thus, a total of 13 villages namely Alipur, Uzalkhalshi, Namordakhali, Nandigram, Nowapara, Sunpukuria, Shyampur, Sakundhighi, Dorampur, Debipur, Usappur, Tiokhum, and Kashipur under Durgapur Upazila of Rajshahi district were selected purposively for the study.

A total of 195 raised bed technology using farmers taking 15 farmers from each village were selected for interview. Again, 65 non-using farmers taking five farmers from each village were interviewed to know the causes of non-adoption of this technology. Thus the total number of sample was 260. Data were gathered through a pre-tested interview schedule during May, 2011.

Analytical technique: The collected data were scrutinized, edited, tabulated and analyzed for fulfilling the objectives of the study. Data were mostly analyzed

through tabular method using descriptive statistics. The level of adoption of the raised bed technology was measured by the following formula.

$$\text{Technology adoption (\%)} = \frac{\text{Total number of adopted farm families}}{\text{Total number of farm families}} \times 100$$

Probit regression model has been extensively used by agricultural production and farming systems economists for studying and analyzing farmer adoption and diffusion of agricultural interventions. Therefore, the following empirical Probit regression model was used to ascertain the probability of adoption of raised bed technology at farm level.

$A_i = \alpha + \beta_i X_i + \ldots\ldots U_i$

Where,

Ai = Farmers adopting raised bed technology; (If, Adopted = 1; Otherwise = 0)

α = Intercept

Xi = Independent variables (i = 1, 2, 3 ------6)

Ui = Error term; and

The independent variables were:

X_1 = Age of the respondent (year)

X_2 = Male member (No/household)

X_3 = Education (Year of schooling)

X_4 = Total cultivated land (in decimal)

X_5 = Extension contact (Scores, 0-20)

X_6 = Membership of the society (Scores, 0-24)

Results and Discussion

1. Present Status of Raised Bed Cultivation at Farm Level

Crops and bed size: Using raised bed technique farmers in the study areas cultivated various crops such as wheat, lentil, mungbean, sesame, onion, maize and rice. The highly cultivated crop was wheat followed by maize, rice and onion. Most of the farmers prepared bed by hand (82.7%) without maintaining recommended bed size. Few beds (11.3%) were prepared by bed planters. The bed widths were found to vary from crop to crop. They maintained the highest bed width for onion (73.9cm) and the lowest for wheat (42.8cm). Detailed information on bed size maintained by the respondent farmers has been shown in Table 1.

Many farmers in the study areas started cultivating crops on raised bed from 2003 and reported to be continued up to 2011. After ending the SMCRSP project activities many farmers started using bed technology due to its strong and positive demonstration impact. Table 2 further shows that the average length of using bed technology was found to vary from crop to crop. The longest period involvement of the farmers was reported to be with T.Aman (5 years) followed by mungbean (4.42 years) and onion (4.09 years).

Table 1. Information on cultivated crops and bed size in using raised bed technology.

Crops grown with beds	Respondent (n=195)		Width of bed (cm)	Raised bed prepared by (%)			Cultivation length (yr)
	Number	%		Machine	Hand	Both	
1. Lentil	4	2.05	63.0	-	100	-	1.50
2. Wheat	191	97.95	42.8	3.7	89.5	6.8	3.52
3. Mungbean	24	12.31	48.1	37.5	54.2	8.3	4.42
4. Jute	9	4.62	44.0	22.2	77.8	-	3.78
5. Sesame	5	2.56	45.7	40.0	40.0	20.0	1.40
6. Onion	32	16.41	73.9	3.1	96.9	-	4.09
7. Maize	54	27.69	49.5	9.3	85.2	5.6	3.02
8. Rice	36	18.47	17.6	25.0	69.5	7.4	3.61
• *Boro*	18	9.23	44.9	5.6	88.9	5.6	3.33
• *Aus*	9	4.62	45.7	44.4	55.6	-	2.78
• *T.Aman*	9	4.62	43.7	44.4	44.4	11.1	5.00
Overall	391	--	--	11.3	82.7	6.1	--

Table 2. Information regarding farmers' raised bed in the study areas.

Particular	No. of respondent	% of responce
Tillage operation (No./bed)	195	3.2
Cost of bed preparation (Tk/decimal)	195	38.0
Bed-to-bed distance (cm)	195	18.1
Furrow-to-furrow distance (cm)	195	43.4
Measuring devices or instruments	195	
• Scale	11	5.6
• Ware/rope	23	11.8
• Stick	134	68.7
• Spade	14	7.2
• Based on idea	9	4.6
• Foot	4	2.1

Adopting farmers generally plough their lands 3-4 times with country plough or power tiller before preparing raised bed. The average cost of land preparation was Tk. 9,391 per ha. Irrespective of crops, the average distances from bed-to-bed and furrow-to-furrow were reported to be 18.1cm and 43.4cm. They used

measuring scale, rope/ware, stick, spade and foot in measuring bed-to-bed and furrow-to-furrow distance. In most cases, they used sticks (68.7%) for measuring the distances mentioned above. At first, they measure two sticks by hand and these sticks are used later to make furrow between beds with the help of rope/ware. Sometimes, they dig furrow between beds with spade and in that case the distance of furrow is equal to the width of the spade. Furrow distance was sometime determined through farmers' foot (Table 2).

Causes of bed preparation by hand: Preparation of raised bed through bed planter has many advantages. Bed planter creates a trapezoidal raised bed and can perform seeding operations on the top of the bed simultaneously in one operation. It has also fertilizer application provision along with seed sowing. Machine made raised bed can save 20-34% irrigation water, 16-69% planting cost and ensure less human labour (Hossain *et al.* 2010a). Nevertheless, many farmers were found enthusiastic toward using bed planter in the study areas. Despite these advantages, most of the farmers reported to prepare raised bed by hand. The principal reason was the non-availability of bed planter (96.41%) in the study areas. A few farmers have access to bed planter use due to close association with BARI scientists.

About 7% farmers of this category complained that bed planter was scarce at the time of need and because of that reason they prepared bed by hand. Some bed planter using farmers could not bring bed planter to their fields due to lack of road. Sometimes it is difficult to bring bed planter to the desired fields crossing other crop fields. Due to these types of constraints 3.59% farmers prepared raised bed by hand. Few farmers opined that broadcasting of seed by hand was better than that of bed planter. Bed and furrow length can easily be maintained by hand which was mentioned by 3.08% farmers (Table 3).

Table 3. Reasons for preparing raised bed by hand (multiple response).

Reason	Frequency	Percentage
Number of respondent (n)	*195*	*100*
1. Non-availability of bed planter or power tiller	188	96.41
2. Scarcity of bed planter at the time of need	13	6.67
3. Constraints to using bed planter	7	3.59
4. Hand seed sowing is better than bed planter	9	4.62
5. Bed and furrow length can easily be maintained	6	3.08

Modifications made in bed technology: At the initial stage of using bed technology, the recommended widths of bed and furrow were 127cm and 63.5cm respectively for wheat, maize and onion. Besides, the recommended widths were 101.6cm and 50.8cm for mungbean. But a good proportion of the adopting farmers have modified these widths of bed and furrow from the way they originally learnt about it from scientists or any other person (Table 2). Table 4 shows that 30.8% adopting farmers told that they modification their bed size

(width of bed and furrow). The rest 69.2% of adopting farmers did not modify the bed size because they learnt and adopted bed technology with modified forms that need no modification. Table 4 further shows that 29.2% of the adopting farmers shortened bed width whereas only 8.7% shortened furrow width. Some adopters also shortened plant to plant distance, changed measuring instrument and applied more fertilizer than recommended dose.

Table 4. Percent responses on modifications made in the raised bed technology.

Particular	Frequency	Percentage
Number of respondent (n)	*195*	*100*
Responses on modifications		
Yes	60	30.8
No	135	69.2
Types of modifications		
1. Shorten bed width	57	29.2
2. Shorten furrow width	17	8.7
3. Shorten plant to plan distance	4	2.1
4. Change measuring instrument	2	1.0
5. Apply more fertilizer	3	1.5

Sources of assistance: The respondent farmers mentioned various sources from which they received assistance for preparing raised bed at the first time. The highly reported source was neighbouring farmers (56.9%). Generally farmers became enthusiastic toward bed technology observing positive benefits of the technology and later seek assistance from neighboring farmers to prepare bed for crop cultivation. About 26% farmers received assistance from local BARI scientists in preparing bed in the initial stage of using bed technology. Some respondents prepared raised bed at the first time without taking any help from others. They observed the technique of preparing raised bed from others and did it themselves. Service provider, relatives, and CARE personnel had some contribution to assist farmers in preparing seed bed in the study areas (Table 5).

Table 5. Sources of assistance in preparing raised bed at the first time

Sources of assistance	No. of respondent	% of responces
1. Neighbouring farmer	111	56.9
2. BARI scientist	50	25.6
3. Self or observed others' field	19	9.8
4. Sub Assistant Agriculture Officer	6	3.1
5. IPM club	3	1.5
6. Service provider	2	1.0

7. Relatives	2	1.0
8. CARE personnel	2	1.0
All sources	195	100

2. Adoption of Raised Bed Technology and Its Determinants

Adoption status: In order to reduce input costs and diversify cropping system for more profitable crop production, the scientists of BARI in collaboration with Cornell University (USA) and CIMMYT disseminated the raised beds technology through SMCRSP project among the farmers of the study areas during the period from 2003 to 2008. After that period many farmers were found to practice this production technique for its versatile advantages. The survey result showed that on an average 56% of the respondent farm families adopted raised based technology for cultivating different types of crops. Table 6 showed that the highest level of adoption was observed at Sunpukur village (76.3%) followed by Namudarkhali (73.5%) and Nawapara (69%).

Table 6. Status of adoption of raised bed technology for crop cultivation.

Name of village	Total farm household	Total adopting farm	% of adopter
1. Alipur	613	312	50.9
2.Debipur	897	344	38.4
3. Darmapur	473	171	36.2
4. Isabpur	310	147	47.4
5. Kashipur	303	180	59.4
6. Namudarkhali	347	255	73.5
7. Nandigram	928	515	55.5
8. Nawapara	449	310	69.0
9. Shampur	530	316	59.6
10. Sukandipur	122	48	39.3
11. Sunpukur	940	717	76.3
12.Tiorkuri	116	56	48.3
13. Uzalkhalsi	591	330	55.8
All villages	**6619**	**3701**	55.9

Determinants of adoption: The adoption of raised bed technology is likely to be influenced by different socio-economic factors. At first nine explanatory variables, such as age, male family member, education, cultivated land, extension contact, membership with social organization, cosmopolitness, contact with mass media, and innovativeness of the respondent farmers were hypothesized to be major determinants of raised bed technology adoption in the study areas. After testing the level of significance, six variables were finally included in the model. Table 7 shows that age, education, and farm size had positive influence on bed technology adoption but these influences were not significant at desired level. The reason behind this relationship was that farmers with younger age, lower

education, and smaller holdings might be the adopters of this bed planting technology in the study areas.

Many respondent farmers opined that crop cultivation on raised bed required more human labour compared to conventional flat method. The coefficient of variable household male member is positive and highly significant at 1% level implying that the farm families having higher male member adopted bed technology more than that of families having less male member (Table 7). It is important to note that female members in the study areas do not usually work in the field. Marginal coefficient indicates that if the male member in the family is increased 10% the probability of adopting raised bed technology will be 1.032% (Table 8).

Table 2 further shows that respondent's contact with different extension personnel such as Agriculture Officer, Sub Assistant Agriculture Officer, BARI scientist and neighbouring farmers had a positive and highly significant relationship with the probability of adopting bed technology. The probability of adopting bed technology will be increased by 3.36% if the extension contact is increased by 100% (Table 8).

It was observed that the respondent farmers who involved different social organizations like farmers' co-operative society, IPM club, youth development society, school/Madrasa (religious school)/mosque managing committee, etc. adopted bed technology more than the farmers who involved less with social organizations. Probit estimate also shows that there is a positive and significant relationship between bed technology adoption and involvement with the society. The probability of adopting bed technology will be increased by 5.22% if the respondent's involvement was increased by 100% (Table 8).

Table 7. Maximum likelihood estimates of variable determining adoption of raised bed technology among respondent farmers.

Explanatory variable	Coefficient	Standard Error	z-statistic	Probability (P>z)
Constant	-1.3541***	0.52117	-2.60	0.009
Age (year)	0.0039	0.00904	0.44	0.660
Male member (No./HH)	0.3804***	0.00904	3.24	0.001
Education (year of schooling)	0.0037	0.02283	0.16	0.873
Cultivated land (decimal)	0.0004	0.00089	0.45	0.654
Extension contact (score; 0-20)	0.1239***	0.03075	4.03	0.000
Membership of the society (score; 0-24)	0.1925***	0.07403	2.60	0.009

Note: No. of observation = 260; LR Chi-square (6) = 50.86; Log likelihood = -120.77505.

***Co-efficient significant at 1% level.

Reasons for not adoption: A good number of non-adopting farmers were asked to answer the reasons of not adopting raised bed technology for crop cultivation. They mentioned different reasons for not adopting raised bed technology. The highest proportion of the respondent farmers (69.2%) did not adopt the technology due to higher labour required for bed preparation and seed sowing at the initial stage of cultivation. Majority of the respondents (67.7%) considered it as a laborious and cumbersome job since there are scarcity of labour prevailed in their households as well as in the study areas. A good percentage of farmers (47.7%) also reported the lacking of awareness and technical know-how about the bed technology behind their non-adoption of this technology. Some respondent farmers considered broadcasting of seed on flat field to be a better technique compared to bed planter since it requires less labour and time (Table 9).

Table 8. Marginal effect after probit.

Explanatory variable	dy/dx	Standard Error	z-statistic	Probability (P>z)
Age (year)	0.00108	0.00245	0.44	0.660
Male member (No./HH)	0.10322***	0.03090	3.34	0.001
Education (year of schooling)	0.00099	0.00620	0.16	0.873
Cultivated land (decimal)	0.00011	0.00024	0.45	0.652
Extension contact (score; 0-20)	0.03364***	0.00834	4.03	0.000
Membership of the society (score; 0-24)	0.05224***	0.01896	2.75	0.006

Table 9. Reasons for not adopting raised bed technology (multiple responses).

Reasons	Frequency	Percentage
Number of respondent (N)	*65*	*100*
1. Required much labour	45	69.2
2. Bed preparation is a laborious and cumbersome job	44	67.7
3. Lack of awareness or know-how about bed technology	31	47.7
4. Scarcity of bed planter in the area	19	29.2
5. Required longer time	17	26.2
6. Hand broadcasting of seed is better than bed planter	13	20.0

3. Farmers' Perceptions in Using Raised Bed Technology

Farmers' observation: Crop establishment through raised bed technology has many advantages such as higher crop yield, reduction in input use, reduction in production cost over conventional practice. The respondent farmers in the study areas observed many positive benefits of the technology during crop production. The highest proportion of farmers (81.5%) told that they got much higher crop yield due to use raised bed technology. The results of on-farm experiments (Hossain *et al.*, 2004b; Lauren *et al.*, 2008) also supported this statement. Another important observation (77.9%) of the farmers was that the established

crops on raised bed were not attacked by rats. Sometimes few plots were attacked by rats, but it could easily be controlled manually. Many farmers mentioned that raised bed technology could successfully reduce the amount of various production inputs like irrigation water, seed, fertilizer, and labour. These observations were also similar to the observations made by Hossain *et al.* (2004b) and Lauren *et al.* (2008). The respondent farmers in the study areas mentioned that intercultural operations like weeding and insecticide application are become easy due to cultivate crop on raised bed. The other positive observations of the farmers were erectness of plant; lower cost of production; and birds can't take seed from field (Table 10).

Table 10. Farmers' observations about raised bed technology in the study areas.

Observation	Frequency	Percentage
Positive observations (*n = 195*)		
1. Higher crop yield	159	81.5
2. Less attack by rats/ Easy to control rats	152	77.9
3. Require less irrigation water	147	75.4
4. Crop weeding is easy	107	54.9
5. Require less amount of seed	101	51.8
6. Crop harvesting is easy	68	34.9
7. Require less fertilizer	52	26.7
8. Insecticide application is easy	42	21.5
9. Less infestation by insect-pest	31	15.9
10. Reduce crop lodging	25	12.8
11. Require less labour	14	7.2
12. Lower cost of production	11	5.6
13. Birds can't take seed from field	5	2.6
Negative observations (*n = 133*)		
1. No negative side is observed	62	31.8
2. Required higher labour	125	94.0
3. Require higher amount of irrigation water	22	16.5
4. Seed dropping is disrupted in case machine	4	3.0
5. Planter can't prepare bed in the field side	6	3.8

Table 10 further reveals that 31.8% respondent farmers did not observe any negative side of the raised bed technology. The rest 68.2% farmers mentioned some negative sides of this technology. Of them 94% mentioned about the higher requirement of labour for bed preparation and seeding through bed planter compared to conventional technique. It is important to state here that bed planter requires less number of labours and it has already been proved in many on-farm experiments. But, most respondent farmers prepared raised bed manually for crop production due to non-availability of bed planter. Bed technology has already been proved as a water saving technology, but some farmers claimed that this

technique of cultivation needs more irrigation water than that of conventional technique. Such response might be due to their ignorance.

Future plan on raised beds use: The bed technology practicing farmers were asked to answer whether they increase land area for cultivating crops on raised bed or not in the next year. In this respect about 88% farmers wanted to increase area in the next year. They wanted to increase an average area of 28.5 decimal for the next year (Table 11). They mentioned many reasons for increasing land for cultivating crops on beds. These reasons were mostly similar to the positive observations of the farmers regarding bed use (Table 10). Only 12.3% adopting farmers will not increase area due to some reasons such as lack of suitable land (100%), scarcity of land for mortgage in (37.5%) and lack of hired labour (12.5%).

Table 11. Reasons for increasing and not increasing crop cultivation on raised beds.

Particulars	Frequency	Percentage
Responses on increase crop cultivation on bed	*n = 195*	*100*
Yes	171	87.7
No	24	12.3
Amount of land area increased (decimal)	171	28.5
Reasons for not increasing crop area		
1. Lack of suitable land	24	100
2. Scarcity of land for mortgage in	9	37.5
3. Lack of hired labour	3	12.5

Table 12. Actions needed for increasing adoption of raised bed technology in future.

Type of actions	Frequency	Percentage
Number of respondent (n)	*195*	*100*
1. Raised bed planter should be made locally available	165	84.6
2. Provide training to the farmers on raised bed technology	154	79.0
3. Broadcast positive impacts of RBT through mass media	59	30.3
4. Provide soft loan to the enthusiastic farmers	41	21.0
5. Demonstrate bed planting technique in new areas	29	14.9
6. Provide subsidy to the enthusiastic farmers	10	5.1
7. Develop effective monitoring mechanism for technology disseminators	4	2.1

Actions needed for higher adoption: The respondent farmers suggested many ways and means for increasing the adoption of this promising and versatile technology at farm level. The highest proportion of respondent (84.6%) mentioned that the government should make bed planter available to the farmers since it reduces input use and increases crop productivity. Seventy nine percent

farmers suggested the government to provide practical and field oriented training on raised bed technology to the enthusiastic farmers. Mass media like radio, TV and daily newspaper can play important role in creating awareness and motivating farmers towards new technology.

Therefore, the government should broadcast the positive impact of raised bed technology using mass media suitable for farmers. In order to increase the use of bed planter soft loan and subsidy may be provided to the interested farmers. About 15% farmers stresses on the demonstration of bed planting technique in other new areas. Monitoring is important to keep farmers' interest toward new technology adoption and its continuous use. Some respondent farmers complained that scientists/extension personnel involved in technology dissemination did not come to the farmer after the completion of the project. Therefore, few farmers also gave emphasis on developing effective monitoring mechanism for technology disseminators (Table 12).

4. Impact of Raised Bed Technology

Raised bed technology has created a positive impact on crop productivity, income and livelihood of the farmers. Survey results revealed that one hundred percent respondent farmers opined that bed technology brought them positive impacts to some extent on household income, household food security and livelihood improvement. Most farmers mentioned about the livelihood improvement but types of improvements were not clear to them since it was associated with overall socio-economic development of the society. Respondent farmers also stated various positive impacts of raised bed technology. About 70% farmers experienced with higher crop productivity. The results of the last 8 years on-farm experiment revealed that crop yield on new raised bed always higher than permanent bed (Hossain *et al.,* 2010; Hossain *et al.,* 2004). More than 82% farmers received increased income due to use raised bed technology. The amount of food intake was also increased for some of the respondent households (Table 13).

Table 13. Responses on the impact of bed technology on crop productivity and income of the respondent farmers.

Particulars	Farmers' responses	
	Frequency	Percentage
Impacts on income	*n = 195*	
Positive impact	195	100
No impact	-	-
Type of positive impacts		
1. Increase in crop productivity	136	69.7
2. Increase in household income	160	82.1
3. Increase in livelihood standard	113	57.9
4. Increase in food intake	26	13.3

Raised bed technology has also created a significant impact on input use. The preparation of raised bed by hand needs higher labour compared to bed planter. That's why majority of the respondent farmers (75.4%) opined that crop cultivation on bed needs higher human labour compared to conventional system. Some farmers argued that at the stage of bed preparation this technique required higher labour but intercultural operations and harvesting need less labour than that of conventional system. As a result bed technology reduces labour requirement in crop cultivation. About 22% farmers stated this view regarding labour use. Bed technology also reduces the use of seed, fertilizer and irrigation water per unit area (Hobbs *et al*., 1997; Fahong *et al*., 2003). Majority of the respondent farmers reported that bed technology reduced the use of seed (94.4%), fertilizer (73.3%), and irrigation water (61%). Few farmers (21%) argued that this new technology required higher irrigation water because the furrow between beds contained more water and the rate of evaporation from bed is much higher than that of conventional system (Table 14).

Table 14. Impact of raised bed technology on input use.

Inputs	Frequency of responses *(n=195)*			% of responses		
	Increased	Constant	Decreased	Increased	Constant	Decreased
1. Use of labour	147	6	42	75.4	3.1	21.5
2. Use of seed	-	11	184	-	5.6	94.4
3. Use of fertilizer	9	43	143	4.6	22.1	73.3
4. Use of water	41	35	119	21.0	18.0	61.0

Table 15. Comparative scenario of productivity and profitability of wheat and maize cultivation under two cultivation systems.

Particular	Bed system	Conventional system	% higher or lower
A. Wheat			
Yield (t/ha)	4.3	2.3	87
Total cost (Tk/ha)	13540	10270	32
Gross benefit (Tk/ha)	60903	33403	82
Benefit cost ratio (BCR)	4.5	3.2	41
B. Maize			
Yield (t/ha)	9.7	7.8	24
Total cost (Tk/ha)	20561	22166	-7
Gross benefit (Tk/ha)	61164	49764	23
Benefit cost ratio (BCR)	2.98	2.2	35

Source: Adopted from Hossain *et al.,* 2004.

The use of raised bed technology is cost-effective and profitable to most of the farmers because this technology ensures lower input use in one hand and higher crop yield on the other. Hossain *et al.,* (2004) found that wheat cultivation on

raised bed incurred 32% higher cost compared to conventional system. But the cost of maize cultivation on bed is 7% lower than that of conventional system. In both the cases, the benefits are much higher compared to the conventional system.

Conclusion

The study has evaluated farmers' practice of raised bed technology since the close of the SM CRSP project through a follow-up survey. The survey findings show that the raised bed technology has a strong and positive demonstration effect and has been adopted well by the farmers of the study areas. The probability of adopting this technology is significantly influenced by extension contact, societal membership and number of male member in the household. Due to lack of machine, most farmers prepare raised bed by hand without maintaining recommended bed size. The most cultivated crops on bed are wheat, maize, onion and mungbean. Responded farmers have mentioned various positive benefits of raised bed cultivation and willing to continue this practice in future with increased area of land. This versatile and immerging technology has created a positive impact on crop productivity and farmers' income to some extent.

Recommendations

Based on the findings of the study, Government should take the following steps for wider adoption of this technology.

a) Bed planter should be available to the farmers since it reduces input cost and increases crop productivity.

b) Hand-on training on raised bed technology should be provided to the enthusiastic farmers.

c) The positive impacts of raised bed technology should be broadcasted among farmers through mass media in creating awareness towards this new technology.

d) Soft loan and subsidy may be provided to the interested farmers for increasing the use of raised bed planter.

e) Monitoring is important to keep farmers' interest toward new technology adoption and its continuous use. Therefore, emphasis should be given on developing effective monitoring mechanism for technology disseminators.

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INFLUENCE OF ETHEPHON ON RIPENING AND QUALITY OF WINTER TOMATO FRUIT HARVESTED AT DIFFERENT MATURITY STAGES

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Abstract

An experiment taking tomato fruits (cv. BARI Tomato-14) of three maturity stages (mature green stage, breaker stage and half ripen stage) and four ethephon levels [control (distilled water spray), 500, 750 and 1000 ppm] was carried out at the laboratory of plant physiology section of Horticulture research centre, Bangladesh Agricultural Research Institute) during February 14, 2013 to February 27, 2012 to find out the suitable stage of fruit maturity for post harvest application of ethephon (ethrel) for tomato ripening. The source of ethrel was Spectrum (ethephon 39%) manufactured in the United States of America. Treatment with 500 - 1000 ppm ethephon hastened ripening of tomato by 4 days in mature green stage but by 2 and 4 days in breaker stage tomatoes when compared with control fruits. The highest value of rotting was shown by half ripen tomatoes. The 1000 ppm ethrel gave the maximum rotting irrespective of maturity stages. However, the maximum weight loss and shelf life were found in green mature tomatoes. The shelf life of tomato fruits of green mature and breaker stage tomatoes treated with 500 and 750 ppm was also high. The percentage of rotting and weight loss was increased with gradual advancement of time. The highest value of weight loss and shelf life was recorded in green mature tomatoes without ethephon and with 500 and 750 ppm ethephon treatment. The highest value of vitamin-C, TSS and titrable acidity were shown by half ripen and pH by green mature tomatoes at different days of storage. The ethephon concentration of 750 ppm the gave maximum vitamin-C at 6 and 9 days of storage but 1000 ppm gave the maximum TSS% followed by 750 ppm ethephon. The ethephon @ 750 ppm produced the maximum TSS at 9 day of storage in mature green tomatoes but in breaker and half ripen stage tomatoes 750 ppm ethephon gave TSS identical to 1000 ppm at different days of storage. The residue level of ethrel in tomato fruits treated with all ethephon concentrations at 3 and 5 days of storage was below 2 mg/kg which is safe for human health. Therefore, treated tomatoes should be consumed after 3 days of ethephon application.

Keywords: Maturity stage, ethephon (ethrel), ripening, quality, postharvest, tomato.

Introduction

Tomato (*Solanum lycopersicon* L.) is one of the most important and popular vegetables in Bangladesh with a considerable total production of 190.2 thousand

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tons produced in an area of 23,828 hectares (BBS, 2011). Tomato is an important horticultural commodity worldwide and plays a key role in the human diet. Tomatoes are rich in flavonoids and other phytochemicals that have anticarcinogenic properties. They are also an excellent source of lutein, zeaxanthin, vitamin C, which is most concentrated in the jelly-like substance that surrounds the seeds, as well as vitamins A, E and B-complex, potassium, manganese and phosphorus.

Proper harvesting at suitable stage determines the nutrient contents as well as storage durability of any fruit. Tomatoes are harvested at different maturity stages, such as green mature stage, breaker stage, half ripen stage and red ripen stage all over the world. Fruits are often harvested at the mature green stage to minimize the damage during post harvest handling. The fruits may later ripen spontaneously or after treatment with ethylene releasing compound (ethephon) before shipment to retailers (Wills and Ku., 2002). Losses often occurred from excessive deterioration during holding and marketing of tomatoes. This problem is especially acute with tomato when harvested at the breaker or more advanced stages of ripeness. Although ripening makes fruit edible and flavourful, it also initiates the gradual deterioration of fruit quality especially in climacteric fruits such as tomato, in which the onset of ripening is considered to be initiated by endogenous ethylene (Abeles *et al*., 1992). Shelf life is the most important aspect in loss reduction biotechnology of fruits and vegetables. There is a natural tendency for the perishable fruits and vegetables to degrade to the simpler compounds (CO_2, H_2O and NH_3) through spontaneous biochemical reaction. This type of reaction reduces the shelf life as well as other qualities of fruits and vegetables. Anju-Kumari *et al*. (1993) reported that the shelf life for all tomato cultivars were longest with harvesting at the mature green stage (10.9-13.5 days). The acid content is lower in immature fruit and is the highest at the stage when colour starts to appear, with a rapid decrease when the fruit ripens (Cantwell, 1994). During maturation and ripening of fruit there are changes in total soluble solid (TSS). TSS increases from mature green stage to red ripen stages (Helyes *et al.*, 2006). The palatability of fruits depends on TSS which increases throughout the development of fruit.

Ethephon or ethrel (2-chloroethylphosphonic acid), an ethylene releasing compound, is known as a plant growth regulator which stimulates ripe evenly fruit, decreasing preservation time and minimizing post-harvest losses (Quoc, *et al.*, 2012). Recently, there have been many mixed opinions on the toxicity of ethephon that confused the customers in Bangladesh. Ethephon has been registered with EPA (US Environmental Protection Agency) since 1973 as a plant growth regulator used to promote fruit ripening and flower induction. Ethephon is irritant to the skin or the eyes but is not a skin sensitizer, it was not a carcinogen and is classified by IARC (International Agency for Research on Cancer) as group D (not carcinogenic to humans) and FAO pointed out a maximum allowable daily intake for ethephon at 0.05 mg/kg body weight/day

(Bui, 2007). The recommended residue level of ethephon is 2 mg/kg of tomato fruit (Anon., 2001). The tomato fruits which are harvested at mature green or breaker stage are treated with different ethephon containing compounds for the colour development and ripening. At present ethephon present in different commercial products viz. Tomtom, Profit and Ripen-15 is being utilized for ripening of immature tomato fruit indiscriminately in high doses (100 ml/5-7 litre of water for 600-800 kg tomatoes) (BARC, 2012) in Bangladesh. Suitable stages of fruit maturity and optimum doses of ethephon for quality and storage of tomato has not yet been developed for developing countries like Bangladesh. Keeping all above facts in mind, this experiment was conducted to find out the suitable stage of tomato fruit for post harvest application of ethephon and to determine the optimum ethephon dose (s) for tomato ripening without affecting its nutrients.

Materials and Method

Site: The experimental site was in the physiology laboratory, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The experiment was conducted during February 14, 2013 to February 27, 2012 at ambient condition. Tomato fruits of different maturity stages were dipped in various concentrations of ethephon (etherl) for five minutes.

Plant material: Freshly harvested tomato fruits of the variety BARI Tomato-14 were collected as per requirement of the study from the vegetable field of HRC, where tomato plants have been grown for this purpose. Tomato fruits were harvested at two maturity stages according to the description by Mitcham *et al.* (1989): mature green (fully expanded but unripe fruit with mature seed) and breaker (first visible sign of carotenoid accumulation on bottom). Another set of fruits were harvested at half ripen stages (50% of the fruit surface are pink coloured) (Moneruzzaman *et al.* 2008a). After drying in air, each group of fruits was further divided into two parts. One as for the inoculation experiment; the other was directly placed into plastic boxes with approx. 90% relative humidity (RH), stored at 20 ^{o}C, and sampled from fruit pericarp at various time of intervals

Treatment setting: The experiment consisted of three maturity stages (M_1 = Mature green stage, M_2 = breaker stage and M_3 = Half- ripen stage) and four levels of ethephon concentrations (T_1 = control , T_2 = 500 ppm, T_3 = 750 ppm and T_4 = 1000 ppm). Fruits were selected based on the uniform size and no physical injuries or infections. Prior to use, fruits were surface-disinfected with 2% (v/v) sodium hypochlorite for 2min, rinsed with tap water, and air-dried. Then, fruits at each stage were immersed in different solutions for 5 min. Ten tomato fruits weighing 1000 g were placed for each treatment. The experiment was laid out in CRD with three replications. The source of ethephon was Spectrum (Ethephon 39%) manufactured in the United States of America. The temperature and relative humidity was 23.5 ^{0}c ± 1.5^{o}C and 65-70%, respectively in the laboratory.

Parameter studied: The parameters studied were days required for ripening, shelf life, weight loss (%), rotting (%), vitamin-C in tomato pulp, pH of tomato juice, total titrable acidity content, TSS content of tomato pulp. Each data was recorded at 3 days interval upto 9 days but rotting (%) and shelf life was observed up to 11 and 14 days.

Days required for ripening: In order to determine days required for ripening, tomatoes were daily observed for their colour and the time (days) required to reach light red stage, between 60 and 90% fully red ripe stage (that is red colour of tomato surface between 60 and 90%) was measured.

Shelf life: The shelf life was calculated by counting the days required to attain the last stage of ripening but up to the stage when fruit remained still acceptable for marketing.

Weight loss: The weight loss of tomato fruit sample was calculated by using the following formula:

$$\textit{Total weight loss of fruit (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Rotting (%): Rotting was determined by visual observation. Unmarketable tomatoes including fruits with various spots developed on the peel, rotten, decayed and shriveled fruits were considered as rotten.

Vitamin-C content of tomato pulp: Vitamin-C in tomato pulp was estimated by 2,6-Dichlorophenol-indophenol visual titration method as described by Rangana (1986). The reagents used for the estimation of vitamin-C were as follows: 1) Metaphosphoric acid (6%), 2) standard ascorbic acid solution, 3) 2-6 dichlorophenol-indophenol dye. For estimation of vitamin-C, the following steps were followed: Standardization of dye solution, preparation of solution and titration.

$$\textit{Vitamin-C content (mg per 100 g of fruit pulp)} = \frac{T \times D \times V1 \times 100}{V2 \times W}$$

Where, T = Titre, D = Dye factor, V_1 = Volume made up, V_2 = Volume of extract taken for estimation and w = weight of sample taken for estimation

Total titrable acidity content of tomato pulp: Total titrable acidity was determined using the following steps (Rangana, 1986): At first sample blended, filtered, transferred to volumetric flax and volume made up to the mark. Ttitrated with 0.1 0.1N NaOH. Percentage of titrable acidity was calculated using the following formula:

$$\textit{Total titrable acidity (\%)} = \frac{T \times N \times E \times V1 \times 100}{V2 \times W}$$

Where, T = Titre, N = normality of NaOH, V_1 = Volume made up,E = Equivalent weight of acid V_2 = Volume of extract taken for estimation and w = weight of sample taken for estimation.

pH of tomato juice: The sample for pH determination was prepared by the method described by Rangana (1986). One gram of sample was homogenized in 1 ml of boiled distilled water and 1 ml of de-ionized water of pH 7.0 and the pH of tomato juice was recorded by an electronic pH meter. The pH meter was standardized with the help of buffer solution.

TSS content of tomato pulp: Total Soluble Solid (TSS) content of tomato fruit pulp was determined by using Digital Hand Refractometer by placing a drop of pulp solution on its prism. The percentage of TSS was obtained from the direct reading of the refractometer.

Residue level of ethephon: Residue level of ethephon in ethrel (0-1000 ppm) treated tomatoes of green mature stage was measured by Gas Chromatography flame-ionized detector in Toxicology laboratory, Entomology Division, Bangladesh Agricultural Research Institute *(*Rahman *et al*., 2012*)*. Extra treatment (tomatoes treated with 2000 ppm ethrel) was also analyzed for clear understanding although this treatment was not included in this experiment.

The data collected were subjected to an analysis of variance using MSTAT-C. Mean separation was performed by DMRT at 5% level of probability.

Results and Discussion

Days required for ripening

The mature green tomatoes took about 6 days to reach the full ripening stage whereas breaker stage tomatoes took 5 days and half ripen tomatoes 4 days (Table 1). The ethephon hastened ripening of tomatoes compared to control (Table 1). The 500, 750 and 1000 ppm ethephon hastened tomato ripening by 2, 3 and 4 days compared to control. In mature green tomatoes, 500 ppm ethephon accelerated ripening by 4 days while 750 and 1000 ppm ethephon accelerated ripening by 6 days (Table 2). But in breaker stage tomatoes 500 and 700 ppm ethephon accelerated ripening by 2 days and 1000 ppm by 3 days. In case of half ripen tomatoes 500 ppm ethephon hastened ripening by 2 days while 750 and 1000 ppm by 3 days. Moura *et al.* (1997) found 1000 ppm ethephon solution was more efficient in hastening tomato ripening. It was found by Olympio and Norman (2000) that concentrations of 500 and 1000 ppm ethephon reduced the ripening time. The mango cultivars treated with 0.8% (8000 ppm) ethephon accelerated ripening (Thanh Hai, *et al*., 2009).

Shelf life of tomato

Mature green tomato had a higher storability than the breaker stage followed by half ripen tomatoes (Table 1). Maximum shelf life was 11.3 days in mature green tomatoes followed by breaker stage (8.6 days) and minimum was 7.6 days for half ripen tomatoes. It was found by Moneruzzaman *et al*. (2008a) that mature green tomatoes of cv. Roma VF had the highest shelf life (13 days) followed by

half ripen tomato (12 days). Ethephon levels had also significant effect on shelf life of tomatoes (Table 1). Control was recorded to give the longest shelf life (10.22 days), followed by 500 ppm (9.33 days) and 750 ppm (9.00 days). The lowest shelf life was recorded by 1000 ppm ethephon (8.00 days). After penetration into cell ethephon might cause damage to some tissues that helps in rotting of fruits and thus reduced the shelf life (Anon., 2010).

Table 1. Main effect of maturity stage and ethephon on days required for ripening and shelf life of treated tomato (var. BARI Tomato-14).

Treatment	Days required for ripening	Shelf life (days)
Maturity stages		
Mature green stage (M_1)	5.9 a	11.3 a
Breaker stage (M_2)	5.0 b	8.6 b
Half ripen stage (M_3)	4.0 c	7.6 c
Ethephon concentration		
Control (distilled water) (T_1)	7.4 a	10.22 a
500 ppm (T_2)	5.1 b	9.33 b
750 ppm (T_3	4.1 c	9.00 b
1000 ppm (T_4)	3.2 d	8.00 c
CV (%)	8.87	6.32

Means within a column having different letters are significantly different at 5% level by DMRT.

Table 2. Combined effect of maturity stages and ethephon on days required for ripening and shelf life of tomato (var. BARI Tomato-14).

Treatment		Days required for ripening	Shelf life (days)
Maturity stage	Ethephon conc.		
M_1	T_1	9.7 a	12.3 a
	T_2	6.0 c	11.3 a
	T_3	4.3 ef	11.3 a
	T_4	3.7 fgh	10.0 b
M_2	T_1	7.0 b	9.3 bc
	T_2	5.3 cd	8.3 cd
	T_3	4.7 de	9.00 bcd
	T_4	3.0 h	7.7 de
M_3	T_1	5.7 c	9.0 bcd
	T_2	4.0 efg	8.3 cd
	T_3	3.3 gh	6.7 ef
	T_4	3.0 h	6.3 f
CV (%)		8.87	6.32

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage, T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm.

The maximum shelf life (12.3 days) was recorded in case of mature green tomatoes without ethephon application (Table 2). The lowest shelf life was found from 1000 ppm ethephon applied in half ripen tomatoes (6.3 days) closely followed by 750 ppm ethephon (6.7 days) applied in the same stage tomatoes. The ethephon level of 500 and 750 ppm coupled with mature green tomatoes gave shelf life identical to green mature tomatoes treated with distilled water (control). Similar results were given by 500 and 750 ppm ethephon in breaker stage tomatoes. The ethephon level of 500 ppm coupled with half ripen tomatoes gave shelf life identical to same stage tomatoes treated with distilled water (control).

Table 3. Main effect of maturity stages and ethephon on weight loss and rotting of tomato at different days of storage.

Treatment	Duration of storage								
	Weight loss (%)				Rotting (%)				
	0D	3 D	6 D	9 D	0D	3 D	6 D	9 D	11D
Stage of maturity									
M_1	0.00	3.52a	5.25a	7.64a	0.00	0.00	0.00c	6.67c	8.33c
M_2	0.00	2.93b	4.35b	6.04b	0.00	0.00	2.23b	23.17b	35.83b
M_3	0.00	2.65c	4.02b	5.90b	0.00	0.00	5.83a	30.83a	50.83a
Ethephon Conc.									
T_1	0.00	2.31c	3.82b	5.16c	0.00	0.00	0.00c	2.22c	2.22d
T_2	0.00	2.78b	3.49b	5.12c	0.00	0.00	0.00c	15.56b	22.22c
T_3	0.00	3.48a	5.26a	7.77b	0.00	0.00	5.56b	32.22a	45.56b
T_4	0.00	3.56a	5.60a	8.54a	0.00	0.00	11.11a	30.22a	56.67a
CV (%)		7.23	7.68	7.09			11.58	13.56	13.39

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage, T_1 = Control Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm, D = Day.

Weight loss (%)

Maturity stages, ethephon levels and their combination were found to have significant effect on total loss in weight of fruit (Tables 3 and 4). Total weight loss in mature green tomatoes was always higher during the entire period of storage. At the third day of storage, it was 3.52% that rose to 7.64% at 9th day. In half ripen tomatoes, weight loss was the lowest, being 2.65% at 3rd day and 5.90% at 9th day of storage. Weight loss in mature green tomatoes was higher because of higher rate of dehydration that generally happened in tender tissue. This is in line with the result of Moneruzzaman *et al.* (2008a). Ethephon solution also had significant effect on weight loss of tomato (Table 3). The ethephon solution of 750 and 1000 ppm gave higher weight loss than other treatments at 3 and 6 day of storage. Ethephon 1000 ppm gave the highest weight loss at 9 day

of storage. The ethephon level of 500 ppm produced higher weight loss than control at 3 day of storage but this level gave weight loss identical to control at 6 and 9 day of storage. The interaction effect was significant at 3, 6 and 9 day of storage with regard to total weight loss in fruit (Table 4). Here the weight loss gradually increased with the advancement of storage period. Ethephon at 750 and 1000 ppm at the 3rd and 6th day of storage and 1000 ppm at 9 day of storage gave maximum weight loss in green mature tomatoes. The half ripen tomatoes coupled with control gave minimum weight loss at all days of storage. It was also found by Quoc *et al*. (2012) that during post harvest ripening, weight loss rate in acerolas fruit treated with ethephon increased over the preservation time.

Rotting (%)

Stages of maturity, ethephon levels, and their combinations were found to have significant effect on rotting (%) of tomatoes (Tables 3 & 4). Rotting in half ripen tomatoes was found always higher during the entire period of storage. There were no rotten tomatoes found at 3rd day in all maturity stages. The green mature tomatoes also did not get rotten at 6 day of storage. At the 6th day of storage total rotting percent was 5.83% that rose to 50.83% on 9 day of storage in half ripen tomatoes (Table 3). On the other hand rotting percent in mature green tomatoes being 6.67% at 9th day and was 8.33% at 11 day of storage. In breaker stage the rotting percent was 2.23% at 6 day, 23.17% at 9 day that rose to 35.83% at 11 day of storage. The rotting percent was higher in half ripen tomatoes because of higher rate of transpiration, more skin permeability for water loss and high susceptibility to decay organism of this climacteric type of fruit. This corroborates the report of Moneruzzaman *et al*. (2008a). The highest rotting of 11.11% was recorded in 1000 ppm ethephon at 6 day of storage. But at 9 day of storage the maximum rotting % was noticed in 750 ppm and 1000 ppm ethephon. Again at 11 day of storage rotting % was found highest in 1000 ppm ethephon. The ethephon level of 1000 ppm gave the highest rotting percent irrespective of maturity at 6 day of storage (Table 5). The ethephon 500 and 750 ppm did not show any rotting at 6 day of storage. The ethephon solution of 750 ppm gave no rotting at 6 days storage. At 9 day of storage there was no significant difference between 750 and 1000 ppm ethephon irrespective of maturity stages. The highest rotting percent was recorded from 1000 ppm ethephon in half ripen tomatoes closely followed by same ethephon solution in breaker stage tomatoes and 750 ppm ethrel in half ripen tomatoes at 11 day of storage. This is perfect agreement with the results of Dhall and singh (2013) who reported that rotting percentage of green mature tomatoes increased with increase in the concentration of ethephon (500-1500 ppm) and with the duration of days for which the fruits were kept for ripening. The green mature and breaker stage tomatoes gave no rotting when no ethephon was applied.

Table 4. Combined effect of maturity stages and ethephon on weight loss of tomato (cv.BARI Tomato-14) fruit during storage.

Days after storage					
Treatment		0D	3D	6D	9D
Maturity stages	Ethephon conc.				
M_1	T_1	0.00	2.68cd	4.40de	5.93e
	T_2	0.00	3.21bc	3.92ef	5.71e
	T_3	0.00	4.01a	6.18a	9.02b
	T_4	0.00	4.17a	6.51a	9.90a
M_2	T_1	0.00	2.25de	4.74fg	5.04f
	T_2	0.00	2.72cd	3.4gh	5.00f
	T_3	0.00	4.40b	5.03bc	7.54c
	T_4	0.00	3.37b	5.25b	8.03c
M_3	T_1	0.00	2.00e	3.34gh	4.50f
	T_2	0.00	2.42de	3.17h	4.65f
	T_3	0.00	3.02bc	4.56cd	6.75d
	T_4	0.00	3.15bc	5.03bc	7.70c
CV(%)			7.23	7.68	7.09

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage, T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

Table 5. Combined effect of and maturity stages and ethephon on rotting of tomato (cv.BARI Tomato-14) fruits during storage.

Days after storage						
Treatment		0D	3D	6D	9D	11D
Maturity stages	Ethephon conc.					
M_1	T_1	0.00	0.00	0.00d	0.00e	0.00d
	T_2	0.00	0.00	0.00d	10.00d	10.00c
	T_3	0.00	0.00	0.00d	10.00d	10.00c
	T_4	0.00	0.00	6.68c	6.68d	6.68cd
M_2	T_1	0.00	0.00	0.00d	0.00e	0.00d
	T_2	0.00	0.00	0.00d	13.34d	13.33bcd
	T_3	0.00	0.00	6.68c	36.67ab	53.33ab
	T_4	0.00	0.00	13.33a	36.67ab	76.67a
M_3	T_1	0.00	0.00	0.00d	6.68d	6.68d
	T_2	0.00	0.00	0.00d	23.34bc	36.67bcd
	T_3	0.00	0.00	10.00b	50.00a	73.33a
	T_4	0.00	0.00	13.33a	47.33a	86.67a
CV (%)				11.58	13.56	13.39

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage,T_1 = Control Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = day.

Vitamin-C content of tomato pulp

Vitamin-C content of tomato pulp varied significantly in fruits of different maturity (Table 6). Results showed that vitamin-C content was decreased with the advancement of time. Half ripen tomato contained the highest quantity of vitamin-C (18.10mg/100g) while the mature green tomato contained the lowest quantity of vitamin-C (11.43mg/100g) at harvest. This is perfect agreement with Moneruzzaman *et al.* (2008b). At 6 and 9 day of storage ethephon treatment with all concentrations maintained a lead over control in respect of vitamin-C content. This in agreement with Thanh Hai, *et al*. (2009) who got the maximum Vitamin-C content in mango compared to control using 0.8% (8000 ppm) ethephon. The 1000 ppm ethephon gave the highest vitamin-C at 6 day of storage whereas 750 ppm ethephon gave the maximum at 9 day of storage. Maturity stages, ethephon and their combinations were found to have significant effect (Table 7). The maximum vitamin-C content at 6^{th} and 9^{th} day of storage was recorded in half ripen tomato coupled with 1000ppm ethephon which was statistically similar to 1000 ppm ethephon coupled with the same maturity. In mature green and breaker stage tomatoes 1000 ppm ethephon produced the maximum vit.-C.

Table 6. Main effect of maturity stages and ethephon on vitamin -C and pH content of tomato (cv. BARI Tomato-14) at different days of storage.

Treatment	Duration of storage							
	Vitamin-C (mg/100g)				pH			
	0D	3 D	6 D	9 D	0D	3 D	6 D	9 D
Maturity stages								
M_1	11.43c	10.34c	10.25c	7.51c	4.12a	4.14	4.18a	4.22a
M_2	14.26b	12.93b	13.20b	11.75b	4.09b	4.10	4.13ab	4.18b
M_3	18.10a	16.45a	16.93a	14.54a	4.04c	4.06	4.09b	4.14c
Ethephon conc.								
T_1	14.56	14.38a	12.87d	11.02c	4.08	4.09	4.14	4.18
T_2	14.60	13.00b	13.43c	10.81c	4.09	4.12	4.13	4.17
T_3	14.60	13.82b	13.67b	11.88a	4.08	4.10	4.13	4.18
T_4	14.62	12.76b	13.87a	11.36b	4.09	4.10	4.13	4.19
CV (%)	3.74	4.73	3.52	3.87	4.06	3.17	4.05	2.74

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green, M_2 = Breaker stage, M_3 = Half ripen stage,T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

pH of tomato juice

The pH content of tomato juice varied significantly in fruits of different maturity (Table 6). It was found that pH increased with the advancement of ripening of fruit. Matsumoto *et al.* (1983) declared that organic acids are metabolized by the fruit during ripening and storage. During entire period of storage the highest pH value was observed in mature green tomatoes followed by breaker stage and half ripen fruit, respectively. This result corroborates the results of Moneruzzaman *et al.* (2008b). The effects of ethephon on pH of tomato were not found significant during storage. The interaction effect on pH was also insignificant.

Table 7. Combined effect of maturity stages and ethephon on vitamin-C content of tomato (cv. BARI Tomato-14) fruits during storage.

Duration of storage					
Treatment		0D	3D	6D	9D
Maturity stages	Ethrel conc.				
M_1	T_1	11.41	11.38	10.04g	7.45g
	T_2	11.47	10.15	10.14f	7.82g
	T_3	11.41	9.45	10.35f	7.87g
	T_4	11.43	9.88	10.47f	6.91h
M_2	T_1	14.20	14.15	12.54d	11.16f
	T_2	14.25	12.68	12.52d	11.79e
	T_3	14.29	12.40	12.40e	12.32d
	T_4	14.29	12.50	12.48e	11.73e
M_3	T_1	18.06	17.61	16.04b	14.44b
	T_2	18.08	16.18	13.12c	12.82c
	T_3	18.10	16.12	16.09b	15.45a
	T_4	18.15	16.89	16.46a	15.45a
CV (%)		3.74	4.73	3.52	3.87

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage,T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

Table 8. Main effect of maturity stages and ethrel and on TSS and titrable acidity content of tomato (cv. BARI Tomato-14) at different days of storage.

Duration of storage								
Treatment	TSS				Titrable acidity			
	0D	3 D	6 D	9 D	0D	3 D	6 D	9 D
Maturity stages								
M_1	3.83c	4.20c	4.21c	4.45b	0.35c	0.37c	0.42c	0.43
M_2	4.06b	4.28b	4.38b	4.57a	0.38b	0.41b	0.44b	0.44
M_3	4.27a	4.39a	4.50a	4.61a	0.42a	0.45a	0.46a	0.44
Ethephon conc.								
T_1	4.06	4.111c	4.24d	4.36c	0.38	0.39	0.41c	0.43
T_2	4.06	4.32b	4.32c	4.58b	0.37	0.41	0.43b	0.44
T_3	4.08	4.36ab	4.42b	4.58b	0.39	0.42	0.46a	0.45
T_4	4.02	4.37a	4.46a	4.65a	0.39	0.43	0.46a	0.46
CV (%)	3.55	2.69	3.84	4.06	2.78	2.52	3.45	4.13

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage,T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

TSS content of tomato pulp

TSS content of tomato pulp varied significantly in fruits of different maturity (Table 8). Half ripen tomato contained the highest quantity of TSS (4.27%) while it was the lowest (3.83%) in mature green tomatoes at harvest. For all maturity stages, TSS increased gradually with the advancement of ripening process. This is in consonance with the results of Moneruzzaman *et al*. (2008b) and Helyes *et al.* (2006). Ethephon levels were also found to have significant effects on changes in TSS content of tomato juice at 3, 6, and 9 days of storage. The

ethephon level of 1000 ppm gave the maximum TSS content at 3, 6 and 9 day of storage, followed by 750 ppm ethephon in all days of storage. This corroborates the results of Bal and Kok (2007) who found the highest value of TSS at 1000 ppm ethephon compared to 500 ppm ethephon. At 3 day of storage there was no significant difference between 750 and 1000 ppm with regard to TSS content.

Table 9. Combined effect maturity stages and ethephon on TSS content of tomato (cv. BARI Tomato-14) fruits during storage.

Duration of storage					
Treatment		0D	3D	6D	9D
Maturity stage	Ethephon conc.				
M_1	T_1	3.82	3.92g	4.11g	4.26f
	T_2	3.85	4.25e	4.18f	4.46de
	T_3	3.85	4.31de	4.25e	4.49d
	T_4	3.80	4.32de	4.28e	4.59c
M_2	T_1	4.07	4.12f	4.23e	4.42e
	T_2	4.05	4.31de	4.35d	4.61bc
	T_3	4.09	4.35bcd	4.44c	4.61bc
	T_4	4.03	4.34cd	4.51b	4.65bc
M_3	T_1	4.28	4.30de	4.38d	4.40e
	T_2	4.05	4.40abc	4.43c	4.68ab
	T_3	4.28	4.42ab	4.57a	4.65abc
	T_4	4.22	4.46a	4.61a	4.72a
CV (%)		3.55	2.69	3.84	4.06

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green, M_2 = Breaker stage, M_3 = Half ripen stage, T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

The TSS content was also found to be significantly influenced by the combined effect of maturity stages and ethephon levels at 3, 6 and 9 days of storage (Table 9). At 3, 6 and 9 days of storage 500, 750 and 1000 ppm ethephon gave the highest total soluble solid (TSS) compared to control. In green mature tomatoes there was no significant difference between 750 and 1000 ppm ethephon with regard to TSS%. In breaker stage 500, 750 and 1000 ppm ethephon maintained a lead over control but they give identical results in respect of TSS content at 3 and 6 days of storage. Again in full ripen stage 750 and 1000 and 2000 ppm ethephon produced statistically similar TSS % at all days of storage.

Titrable acidity content of tomato pulp

The total titrable acidity in tomato pulp varied significantly in fruits of different maturity (Table 8). The half ripen tomato pulp gave the maximum titrable acidity at harvest and also during entire period of storage except 9 day of storage and contained the highest quantity of titrable acidity (0.46%) at 6 day of storage followed by breaker stage tomatoes. The mature green tomatoes produced lower titrable acidity in fresh and 3 and 6 day of storage. This is in consonance with the

results of Moneruzzaman *et al*. (2008b). However, there was no significant difference among green mature stage, breaker stage and half ripen stage in respect of titrable acidity at 9 day of storage. The ethephon effect on titrable acidity was significant at 6 day of storage. The ethephon level of 750 and 1000 ppm gave the highest titrable acidity (0.46%) at 6 day of storage but no significant effect was found at 3 and 9 day of storage. The interaction effect was insignificant.

Table 10. Estimated residue level of ethrel (ethephon) (ppm) in treated tomato (var. BARI Tomato-14).

Ethephon level	Days after application	
	3 day	5 day
T_1	0.00	0.00
T_2	0.520	0.471
T_3	0.658	0.569
T_4	0.881	0.802
T_5*	1.468	1.234

T_1 = Contro (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_4 = 1000 ppm, *T_5 = 2000 ppm (extra treament), Existing CXL (codex residue level)-2 mg/kg (2 ppm) ethephone (Anon., 2001).

Residue Level of ethephon

Table 10 revealed that the tomato fruits treated with 2000 ppm ethrel solution showed the maximum residue value at 3 and 5 day of storage. The residue level in treated tomatoes decreased at 5 days compared to 3 days. It might be the reason that ethephon was a volatile compound. This was in perfect agreement with Beitz *et al.* (1977). The resdue level of ethrel in tomato fruits treated with 500-2000 ppm ethephon was less than the recommended residue level of ethephon (2 mg/kg) (Anon., 2001).

Based on the results and discussion it might be concluded that tomato fruits should be harvested at mature green stage and breaker stage for distant marketing for ethephon application @ 750 ppm for tomato ripening. The ethephon treated fruits should be consumed after 3 or 4 days of ethephon application.

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PERFORMANCE OF SEPARATED TILLERS OF TRANSPLANT AMAN RICE AT DIFFERENT LEVELS OF UREA SUPER GRANULES

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Abstract

An experiment was conducted at the research field of Department of Agronomy, Bangladesh Agricultural University, Mymensingh during June to December 2012 to investigate the effect of age of tiller seedlings, number of tiller seedlings hill^{-1} and application of urea super granules (USG) on the yield and yield contributing characters of transplant *Aman* rice (cv. BRRI dhan52). The experiment consisted of two ages of tiller seedlings *viz.* 25 and 35-days old, three levels of tiller seedlings hill^{-1} *viz*. 1, 3 and 5 seedlings hill^{-1} and three levels of USG *viz*. 0, 1.8 (55 kg N ha^{-1}) and 2.7g USG (80 kg N ha^{-1}) four hill^{-1} in every alternate row. The experiment was laid out in a Randomized Complete Block Design (Factorial) with three replications. The highest plant height, number of effective tillers hill^{-1}, number of total tillers hill^{-1}, number of total spikelets panicle^{-1}, number of grains panicle^{-1}, grain yield and harvest index were found in 1.8 g USG applied @ one granule 4-hill^{-1}. The highest number of sterile spikelets panicle^{-1} was found in control treatment and the lowest in 1.8 g USG. The highest number of effective tillers hill^{-1}, number of total spikelets panicle^{-1} and grain yield ha^{-1} was found when 5 tiller seedlings were transplanted hill^{-1} combined with 1.8 g USG. Application of urea super granules 1.8 g (55 kg N ha^{-1}) at 10 days after transplanting @ one granule 4-hill^{-1} in every alternate row with 25 day old tiller seedlings using 5 tiller seedlings hill^{-1} was found beneficial for grain yield of transplant Aman rice. Tiller separation could be an alternative source of seedling during seedling scarcity.

Keywords: Age of tiller seedlings, transplant Aman rice, USG, yield.

Introduction

Aman rice is very common in Bangladesh but damage occurred due to early or late flash flood. Due to unavailability of seedlings farmers cannot re-transplant their field after the recession flood water. If available, seedlings are either too young or too old to produce a good crop. Re-transplantation of separated clonal tillers from an unaffected *Aman* crop and subsequent management practices could be a remedy to overcome this loss. This technique of transplanting of separated clonal tillers may be a promising alternative for growing a post-flood transplant *Aman* crop (Sarkar *et al*., 2011; Mridha *et al*., 1991 and Siddique *et al*., 1991). Clonal propagation was somewhat superior to nursery seedlings and yield did not decrease with the removal of clonal tillers (Sharma, 1994). In some flood-prone lowlands, where the transplanted crop is damaged by natural hazard,

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vegetative propagation using tillers separated (4 tillers hill^{-1}) from the previously established transplanted crop gave higher yield than nursery seedlings transplanted on the same date (Biswas and Salokhe, 2001).

Age of tiller seedlings is an important determinant that may influence the tiller production, growth, grain formation and other yield contributing characters of rice. The highest grain yield could be obtained by transplanting tiller seedlings which were separated from mother plants 35 days after transplanting (Biswas *et al*., 1987). Tillers could be separated at 30-40 days after transplanting (BRRI, 1988). Paul *et al.* (2002) reported that tillers can be separated at 25 or 35 days after transplanting (DAT) without hampering grain yield. Planting density, number of tillers and their growth are greatly affected by number of seedlings hill^{-1}. Optimum number of tiller seedlings may enable the rice plant to grow properly both in its aerial and underground parts which ultimately may lead to enhancement of yield. While the least number of tiller seedlings hill^{-1} may cause insufficient tiller growth. Urea super granules (USG), a slow release nitrogenous fertilizers dissolves slowly in the soil providing a steady supply of available nitrogen throughout the growing period of the crops can be applied in the root zone of the rice plants at 8-10 cm depth of soil (reduced zone of rice soil), which can save 30% nitrogen compared to prilled urea. Placement of USG in rice gave significantly higher grain and straw yields than split application of prilled urea (Mohanty *et al*., 1989, Bowen *et al*., 2005 and Hasan, 2007). It increases absorption rate, improves soil health and ultimately increases rice yield. It is therefore, necessary to find out the influence of age of tiller seedlings, number of tiller seedlings hill^{-1} and application of urea super granules on the yield performance of transplant *Aman* rice cv. BRRI dhan52.

Materials and Method

The experiment was conducted at the research field of Department of Agronomy, Bangladesh Agricultural University, Mymensingh during the period from June to December 2012. The experimental sites belongs to the Sonatola Soil Series of Old Brahmaputra Floodplain (AEZ 9) having non calcareous dark grey floodplain soil. The land was medium high with sandy loam texture having pH 6.5. Soil contained 1.67% organic matter, 0.10% total N, 26.0 ppm available P, 0.14 (me) % exchangeable K and 13.9 ppm available S. The experiment consisted of two ages of tiller seedlings *viz.* 25 and 35 days old, three levels of tiller seedling hill^{-1} *viz.* 1, 3 and 5 seedlings hill^{-1} and three levels of USG *viz.* 0, 1.8 and 2.7g USG. The experiment was laid out in a Randomized Complete Block Design (Factorial) with three replications. The size of unit plot was 4.0m × 2.5m. A high yielding variety BRRI dhan52 of transplant *Aman* rice was used as the test crop. Tillers were separated from 25 and 35 days after transplanting from previously transplanted rice field and then re-transplanted in the main field on 13

September 2012 according to treatments. Fertilizer P, K, S and Zn were applied @ 21, 35, 11 and 3.5 kgha^{-1} in the form of triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate respectively. TSP, MoP, gypsum and zinc sulphate were applied at the time of final land preparation. Nitrogen was applied according to experimental specification in the form of Urea Super Granules (USG) at 10 days after transplanting @ one granule 4-hill^{-1} in every alternate row. Irrigation, weeding and other intercultural operations were done as and when required.

The crop was harvested on 20 November 2012. Grain and straw yields were recorded from the harvest of 2.5m x 2.0m harvest area from the middle portion of each plot. The grain yield was adjusted to 14% moisture content and straws dried to record the straw yield. Grain yield and straw yield altogether were regarded as biological yield i.e. Biological yield = Grain yield + Straw yield.

Harvest index is the relationship between grain yield and biological yield. Harvest index was calculated by the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}(t\,ha^{-1})}{\text{Biological yield}(t\,ha^{-1})} \times 100$$

The recorded data were statistically analyzed with the help of MSTAT-C software. The differences among treatment means were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Age of Tiller Seedlings

Age of tiller seedlings is an important determinant as that of nursery seedling for the production of transplant Aman rice. Plant height and yield contributing characters were significantly affected by age of tiller seedlings. The highest plant height, number of total spikelet panicle^{-1}, number of grains panicle^{-1} and number of sterile spikelets panicle^{-1} were found in 25-day old tiller seedlings where effective tillers hill^{-1}, number of total tillers hill^{-1} and panicle length were found in 35-day old tiller seedlings (Table 1). Plant height, number of grains panicle^{-1}, total number of sterile spikelets panicle^{-1}, grain yield ha^{-1}, biological yield ha^{-1} and harvest index were decreased with the increase of age of tiller seedlings. Younger tiller seedling (25 days) and long duration for vegetative growth might have influenced plant height, number of total spikelet panicle^{-1} and grains panicle^{-1} (Table 1). Similar results were reported by Sarkar *et al.* (2011). On the contrary, older tiller seedlings get less time for their proper vegetative growth and rapidly entered into the reproductive phase producing decreased number of total spikelet panicle^{-1} and grains panicle^{-1}. Transplanting 25-day old tillers produced higher

Table 1. Effect of age of tiller seedlings, no. of tiller seedlings hill^{-1} and USG application on yield and yield contributing characters of transplant *Aman* rice.

	Plant height at harvest (cm)	Effective tillers hill^{-1} (no.)	Total tillers hill^{-1} (no.)	Panicle length (cm)	Total spikelets panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	Weight of 1000-grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Age of tiller seedlings (days)												
25	108.23a	6.44b	8.22b	24.65b	186.19a	155.78a	30.41a	24.66	5.17a	5.83b	11.00a	47.00a
35	107.09b	8.19a	9.56a	25.46a	142.81b	121.70b	21.11b	24.71	4.73b	6.07a	10.80b	43.79b
CV%	3.91	10.09	8.98	9.31	4.16	3.9	10.94	3.45	6.96	18.38	10.66	10.54
No. of tiller seedlings hill^{-1}												
1	107.19	6.06c	7.50c	24.89	155.83c	127.06c	28.78a	24.58	4.72b	5.77	10.49	45.11
3	108.97	7.33b	8.94b	25.72	162.39b	135.72b	26.67b	24.68	4.92b	6.11	11.03	44.98
5	106.82	8.56a	10.22a	24.56	175.28a	153.44a	21.83c	24.79	5.20a	5.97	11.17	46.77
CV%	3.91	10.09	8.98	9.31	4.16	3.9	10.94	3.45	6.96	18.38	10.66	10.54
USG application (g)												
0	104.76b	4.56c	5.83b	24.82	128.17c	94.39c	33.78a	24.42	4.24b	5.85	10.08	42.21b
1.8	109.42a	9.17a	10.72a	25.91	185.44a	167.00a	18.44c	24.67	5.40a	6.14	11.55	47.52a
2.7	108.80a	8.22b	10.11a	24.44	179.89b	154.83b	25.06b	24.96	5.20a	5.86	11.06	47.14a
CV%	3.91	10.09	8.98	9.31	4.16	3.9	10.94	3.45	6.96	18.38	10.66	10.54

Means having same or without letter do not differ significantly at 5% level of probability by DMRT.

Table 2. Interaction effect of age of tiller seedlings and no. of tiller seedlings hill^{-1} on yield and yield contributing characters of transplant *Aman* rice.

Age of tiller seedlings (days)	Tiller seedlings hill^{-1} (no.)	Plant height at harvest (cm)	Effective tillers hill^{-1} (no.)	Total tillers hill^{-1}(no.)	Panicle length (cm)	Total spikelets panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	Weight of 1000-grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
25	1	106.78	5.11	6.78	25.59ab	143.44	108.56	34.89a	24.63	4.61	5.40	10.01	45.90a
	3	108.34	6.33	8.11	25.12ab	149.78	118.44	31.33b	24.47	4.59	6.69	11.28	40.84b
	5	106.16	7.89	9.78	23.25b	163.11	138.11	25.00c	24.86	4.98	6.11	11.09	45.16ab
35	1	107.61	7.00	8.22	24.19ab	168.22	145.56	22.67cd	24.52	4.83	6.14	10.97	44.33ab
	3	109.60	8.33	9.78	26.32a	175.00	153.00	22.00d	24.90	5.24	5.53	10.77	49.13a
	5	107.47	9.22	10.67	25.87a	187.44	168.78	18.67e	24.72	5.42	5.83	11.25	48.38a
CV (%)		3.91	10.09	8.98	9.31	4.16	3.9	10.94	3.45	6.96	18.38	10.66	10.54

Means having same or without letter do not differ significantly at 5% level of probability by DMRT.

Table 3. Interaction effect of age of tiller seedlings and USG application on yield and yield contributing characters of transplant *Aman* rice.

Age of tiller seedlings (days)	USG application (g)	Plant height at harvest (cm)	Effective tillers hill^{-1} (no.)	Total tillers hill^{-1} (no.)	Panicle length (cm)	Total spikelets panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	Weight of 1000-grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
25	0	104.28	4.33e	5.56d	23.72	120.3f	79.44f	40.89a	24.48	3.86	5.83	9.69	40.03
	1.8	109.31	8.00c	9.78c	26.29	171.78c	149.22c	22.56c	24.42	5.24	6.45	11.69	45.16
	2.7	107.68	7.00d	9.33c	23.95	164.22d	136.44d	27.78b	25.07	5.08	5.92	10.99	46.70
35	0	105.24	4.78e	6.11d	25.91	136.00e	109.33e	26.67b	24.36	4.61	5.86	10.47	44.38
	1.8	109.52	10.33a	11.67a	25.53	199.11a	184.78a	14.33d	24.92	5.57	5.83	11.40	49.12
	2.7	109.92	9.44b	10.89b	24.93	195.56b	173.22b	22.33c	24.85	5.32	5.81	11.13	48.33
CV (%)		3.91	10.09	8.98	9.31	4.16	3.9	10.94	3.45	6.96	18.38	10.66	10.54

Means having same or without letter do not differ significantly at 5% level of probability by DMRT.

grain yield compared to older tiller seedlings but higher straw yield ha^{-1} from 35-day old tiller seedlings (Table 1). Similar results were reported by Sarkar *et al*. (2011) and Kirttania *et al*. (2013). The crop of 25-day old tiller seedlings received relatively more time for their growth, development and grain filling and resulted in the increased grain yield. In this case, the yield components were improved and sterile spikelets panicle^{-1} were decreased which were mainly responsible for the improvement of grain yield. Paul *et al*. (2002) reported that cultivar BR23 appeared to be resistant to tiller separation and tillers could be separated at 25 or 35 DAT without hampering grain yield.

Number of Tiller Seedlings Hill^{-1}

Yield attributes and grain yield were significantly influenced by number of tiller seedlings hill^{-1}. The highest number of effective tillers hill^{-1}, number of total tillers hill^{-1}, number of total spikelets panicle^{-1}, number of grains panicle^{-1}and grain yield ha^{-1} were found in the crop raised from 5 tiller seedlings transplanted hill^{-1} and the lowest from 1 tiller seedling hill^{-1} (Table 1). Sarkar *et al.* (2011) reported that in cultivar BR 23, two tiller seedlings hill^{-1} appeared to be enough for the cultivation of transplant Aman rice. Planting of one seedling hill^{-1} was at par with planting of 2 seedlings hill^{-1} in terms of grain yield (Dongarwar *et al*., 2002). Paul *et al.* (2002) reported that the highest number of effective tiller hill^{-1}, grains panicle^{-1} and grain yield ha^{-1} were obtained when 2 tillers were kept hill^{-1}. Biswas and Salokhe (2001) mentioned that higher densities of clonal tillers transplanted hill^{-1} gave lower panicle number and grain weight. Intra-tiller seedlings competition for nutrients, light, air and water in a hill resulted in the reduced grain yield when 6 tiller seedlings were transplanted hill^{-1}. There was no significant difference in biological yield due to number of tiller seedlings hill^{-1} highest grain yield was observed when 5 tiller seedlings hill^{-1} (Table 1). Therefore, increased grain yield was the main reason for increase of number of effective tillers hill^{-1} and number of grains panicle^{-1}. Transplanting 5 tiller seedlings hill^{-1} produced highest the number of tillers hill^{-1} and also highest number of grains panicle^{-1} thus produced the highest grain yield.

Urea Super Granules (USG) Application

Plant height, yield contributing characters, grain yield ha^{-1} and harvest index were significantly influenced by the application of USG (Table 1). The highest number of effective tillers hill^{-1}, number of total spikelets panicle^{-1} and number of grains panicle^{-1} were found when 1.8 g USG was applied but both 1.8 g and 2.7 g USG applied per 4 hills in every alternate row showed results identical in respect of plant height, total tillers, grain yield and harvest index. Grain yield and other plant characters were lower where USG was not applied. Grain yield was the highest in 1.8 g USG due to increasing number of grains panicle^{-1} for the

adequacy of nitrogen as USG probably favored the cellular activities during panicle formation and development which led to increased number of productive tillers hill^{-1}. These results also agreed by Singh and Singh (1997). The increased number of tillers hill^{-1} with increased nitrogen levels USG (Hasan, 2007).

Interactions

Panicle length, number of sterile spikelet's panicle^{-1} and harvest index were significantly influenced by the interaction between the age of tiller seedlings and number of tiller seedlings hill^{-1}. The longest panicle was produced when 35-day old tiller seedlings by transplanting 3 tiller seedlings hill^{-1} and the shortest panicle with 25-day old tiller seedlings with 5 tiller seedlings hill^{-1}. Similar result was reported by Kirttania *et al*. (2013). The highest number of sterile spikelets panicle^{-1} was produced in the crop raised from 25-day old tiller seedlings using 1 tiller seedlings hill^{-1} and the lowest in 35-day old tiller seedlings with 5 tiller seedlings hill^{-1}. The maximum harvest index was produced by transplanting 35-day old tiller seedlings using 5 tiller seedlings hill^{-1} followed by other treatments except lowest in 25 day old tiller seedlings with 3 tiller seedlings hill^{-1} (Table 2).

Age of tiller seedlings and USG application significantly influenced number of effective tillers hill^{-1}, number of total tillers hill^{-1}, total spikelets panicle^{-1}, number of grains panicle^{-1} and sterile spikelets panicle^{-1}. The highest number of effective tillers hill^{-1}, number of total tillers hill^{-1}, number of total spikelets panicle^{-1} and grains panicle^{-1} were produced by transplanting 35-day old tiller seedlings when 1.8 g USG was applied and the lowest one was in the crop raised from 25-day old tiller seedlings without USG (Table 3). Kirttania *et al*. (2013) reported that 35-day old tiller seedlings of BRRI dhan49 fertilized with 2.7g USG produced the higher number of effective tillers hill^{-1} and grains panicle^{-1} compared to 25-day old tiller seedlings with 1.8 g USG. The highest number of sterile spikelets panicle^{-1} was produced from 25-day old tiller seedlings without USG but lowest in 35-day old tiller seedlings when 2.7 g USG was applied (Table 3).

Number of effective tillers hill^{-1}, total tillers hill^{-1} and total spikelets panicle^{-1} were significantly influenced by the interaction between number of tiller seedlings hill^{-1} and USG application. The highest number of effective tillers hill^{-1} was produced in the crop raised from 5 tiller seedlings hill^{-1} when 1.8 g USG was applied and the lowest in 1 tiller seedling hill^{-1} when USG was not applied (Table 4). The maximum number of total tillers hill^{-1} was produced in 5 tiller seedlings hill^{-1} along with application of 1.8 g USG followed by 2.7 g USG of same no. of tiller. The lowest was produced in 1 tiller seedling hill^{-1} without application of USG. Similar trend was followed in case of total spikelets panicle^{-1}. Grain yield was significantly influenced by the interaction between number of tiller seedlings hill^{-1} and USG application. Higher grain yield ha^{-1}was produced in the crop raised from 5 tiller seedlings hill^{-1} when 1.8 g USG was applied followed by 1 and 3

Table 4. Interaction effect of no. of tiller seedlings hill^{-1} and USG application on yield and yield contributing characters of transplant *Aman* rice

No. of tiller seedlings hill^{-1}	USG application (g)	Plant height at harvest (cm)	Effective tillers hill^{-1} (no.)	Total tillers hill^{-1} (no.)	Panicle length (cm)	Total spikelets panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	Weight of 1000-grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
	0	104.26	4.00g	5.00f	25.17	122.67f	84.33	38.33	24.28	3.92d	5.38	9.29	42.17
1	1.8	108.81	7.50de	9.17cd	26.27	175.00c	154.50	20.50	24.61	5.25abc	5.97	11.22	47.07
	2.7	108.51	6.67e	8.33d	23.23	169.83d	142.33	27.50	24.84	5.00bc	5.96	10.96	46.09
	0	104.72	5.17f	6.33e	24.27	125.67f	90.67	35.00	24.81	4.38c	6.29	10.67	41.23
3	1.8	110.61	8.83c	10.50b	26.34	184.50b	165.83	18.67	24.31	5.16abc	6.42	11.57	45.12
	2.7	111.59	8.00cd	10.00bc	26.54	177.00c	150.67	26.33	24.93	5.22abc	5.63	10.84	48.60
	0	105.32	4.50fg	6.17e	25.01	136.17e	108.17	28.00	24.17	4.42c	5.88	10.29	43.22
5	1.8	108.83	11.17a	12.50a	25.12	196.83a	180.67	16.17	25.10	5.81a	6.04	11.85	49.24
	2.7	106.30	10.00b	12.00a	23.55	192.83a	171.50	21.33	25.11	5.38ab	6.00	11.38	47.85
CV(%)		3.91	10.09	8.98	9.31	4.16	3.9	10.94	3.45	6.96	18.38	10.66	10.54

Means having same or without letter do not differ significantly at 5% level of probability by DMRT.

Table 5. Interaction effect of age of separated tiller seedlings, no. of tiller seedlings hill^{-1} and USG application on grain yield of transplant *Aman* rice

Age of tiller seedlings (days)	Tiller seedlings hill^{-1} (no.)	USG application (g)		
		0	1.8	2.7
25	1	3.33h	5.33bcd	5.17bcd
	3	3.92g	4.84def	5.00cde
	5	4.33fg	6.42a	5.07b-e
35	1	4.50efg	5.17bcd	4.83def
	3	4.83def	5.47a-d	5.43bcd
	5	4.50efg	5.55abc	5.58b
CV (%)		6.96	6.96	6.96

Means having same or without letter do not differ significantly at 5% level of probability by DMRT.

tiller seedlings hill^{-1} (Table 4). Maximum seedlings without USG showed lower grain yield. Kirttania *et al*. (2013) found that maximum number of effective tillers hill^{-1}, grains panicle^{-1} and grain yield were produced when 1.8 g USG was applied.

Only grain yield ha^{-1} was significantly influenced by the interaction of age of tiller seedlings, number of tiller seedlings hill^{-1} and USG application (Table 5). The maximum grain yield was produced in the crop raised from 25-day old tiller seedling using 5 tiller seedlings hill^{-1} with 1.8 g USG followed by 35-day old seedlings using 3 tillers hill^{-1} of same amount of USG application. The lowest grain yield was produced in 25-day old tiller seedling using 1 tiller seedlings hill^{-1} when USG was not applied.

Conclusion

It appears that 25-day old tiller seedlings @ 5 hill^{-1} fertilized with 1.8g USG @ one granule 4-hill^{-1} in every alternate row was found to be a promising practice to obtain the highest grain yield of transplant Aman rice cv. BRRI dhan52. The highest grain yield of transplant Aman rice could also be obtained by transplanting 35-day old tiller seedlings with 3 or 5 seedlings hill^{-1} and fertilized with 1.8 g USG @ one granule 4-hill^{-1} in every alternate row.

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EFFECT OF PLANT GROWTH REGULATORS ON FLOWER AND BULB PRODUCTION OF HIPPEASTRUM (*Hippeastrum hybridum* Hort.)

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Abstract

The experiment was conducted at the Horticultural research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during October 2008 to July 2009 to investigate the effect of plant growth regulators on flower and bulb production of Hippeastrum. There were ten treatments comprising of three concentrations of three growth regulators viz., IAA (20, 60 and 100 ppm), ethrel (100, 300 and 500 ppm) and GA_3 (100, 300 and 500 ppm) along with control (soaked in water). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Flower and bulb characteristics of Hippeastrum were influenced significantly by different levels of growth regulators. Application of IAA at 60 and 100 ppm and GA_3 at 100, 300 or 500 ppm twice as foliar spray at an interval of 30 days promoted the number of bulblets on the treated plants. Ethrel at a concentration of 100 ppm increased the number of flowers per scape (4) and showed earliness in days to flower scape emergence (72.33 days) and first flower open (88.67 days). On the other hand, the biggest size of flower (15.14 cm x 12.44 cm) and flower scape (40.28 cm x 21.95cm) at harvest and the maximum days for flowering (11.50 days) were evident from plants treated with 500 ppm GA_3. The highest number of bulblets per plot (40.00), bulbs weight per plot (4056 g) along with bulb yield (40.56 t/ha) were also obtained in GA_3 at 500 ppm.

Keywords: Hippeastrum, indole-acetic acid (IAA), 2-chloroethylphosphonic acid (Ethrel), gibberrellic acid (GA_3), Hippeastrum flower and bulb yield.

Introduction

Hippeastrum (*Hippeastrum hybridum* Hort.) is an important ornamental bulbous plant used as cut flowers because of their large size, attractive colour, and good keeping quality. In Bangladesh, the agro-ecological conditions are very conducive for the survival and culture of Hippeastrum. It has great potential for local as well as export market.

Ornamental crops like Hippeastrum find extensive use of growth regulators for modifying their developmental processes. The major areas where growth regulators have successfully played their roles in ornamental plants are in vegetative propagation, inhibition of abscission, prevention of bud dormancy,

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growth control, promotion of flowering, prolonging the vase life of flowers and retarding their senescence (Murti and Upreti, 1995).

Growth and flowering of Hippeastrum is influenced by several factors. Among the various external factors, growth regulators play an important role in developmental process of the plants. There are only a few floricultural crops on which growth regulators were applied for the purpose of enhancing growth. The gibberrelic acid (GA_3) has been of considerable use for growth promotion. The cases in which growth promotion by growth regulators would be helpful are those where environmental factors delay or inhibit growth or where problems are encountered due to excessive application of retardants.

Application of growth regulators was found to improve the growth and flowering of Hippeastrum. Bhattacharjee (1983a) reported that treatment with GA_3 at 10 ppm markedly improved the flower production of lily (*Lilium tigrinum*, Ker-Gawl). Naphthalene acetic acid (NAA) at 100 ppm and GA_3 at 100 or 200 ppm induced early flowering in *Lilium longiflorum* whereas NAA at 200 ppm and GA_3 at 200 ppm markedly increased flower production as reported by Pal and Das (1990). In an experiment with growth regulators on Asiatic hybrid lily, Dantuluri *et al.* (2002) found that GA_3 at 200 ppm produced the tallest plants and GA_3 at 200 ppm exhibited earliest bud formation and flowering. Spraying with 2-chloro ethylphosphonic acid (ethrel) at 1000-4000 ppm, 1-3 times has been found to hasten the flower induction in Golden Shower Oncidium (Bose *et al.*, 1999).

Soaking of Hippeastrum bulbs in three concentrations each of Indole acetic acid (IAA), GA_3, Chlorocholine chloride (CCC) and ethrel showed various responses on growth and flowering. IAA increased the weight and number of bulblets while GA_3 enhanced the flower diameter and bulb weight. Application of IAA at 100 ppm and GA_3 at 10, 100 or 1000 ppm twice as foliar spray at an interval of 15 days promoted the number of bulbs on the treated plants while ethrel increased the weight of bulblets. All concentrations of IAA and GA_3 increased the number and size of flowers as reported by Bose *et al.* (1980). Bhattacharjee (1983b) concluded that ethrel had beneficial effect on bulb formation. Application of IAA and GA_3 each at 10 to 1000 ppm also promoted vegetative growth, induced early flowering, increased flower size and stalk length, enhanced the number of flower per stalk, extended flower longevity, improved number, size and weight of bulb. Information regarding the use of plant growth regulators on flower and bulb production of Hippeastrum in Bangladesh is very scanty. Keeping these views in mind, the present investigation was undertaken to study the effect of IAA, ethrel and GA_3 on flower and bulb production of Hippeastrum.

Materials and Method

The experiment was carried out at the Horticultural research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during October 2008 to July 2009. The experiment was laid out in a Randomized Complete Block Design (RCBD) having ten concentrations of growth regulators viz., T_1 = 20 ppm

IAA, T_2 = 60 ppm IAA, T_3 = 100 ppm IAA, T_4 = 100 ppm ethrel, T_5 = 300 ppm ethrel, T_6 = 500 ppm ethrel, T_7 = 100 ppm GA_3, T_8 = 300 ppm GA_3, T_9 = 500 ppm GA_3 and T_{10} = Control (soaked in water) with three replications. The experimental field was first disc-ploughed and harrowed. Final land preparation was done by a power tiller followed by leveling with scrapper. Clods were broken and weeds were removed from the field to obtain desirable tilth. Irrigation and drainage channels were made around the block. There were 30 (10 x 3) unit plots; each measuring 1 m x 1.5 m with 15 cm raised bed to prevent the bulbs from fungal disease caused by water logging. The plots were separated from one another by 1 m spaces. Bulb to bulb distance 25 cm and row to row distance 50 cm were maintained which constituted 12 plants per plot. Total 360 (30 x 12) bulbs were used for different treatments in the experiment. Uniform sized (5 cm in diameter) bulbs were collected from the field and kept two weeks for curing. Curing is a drying process intended to dry off the necks and outer scale leaves of the bulbs to prevent the loss of moisture and the attack by decay during storage. After harvesting when the bulbs were matured as indicated by yellowing and drying of leaves, the bulbs were dug out and tops were cut down. Then the bulbs were stored in trays and kept in a cool room (13^0 C). Selected bulbs were cleaned carefully by removing the roots, leaves and dry scales by using a sharp knife which was sterilized to avoid spread of diseases. Selected bulbs were soaked for 24 hours in different concentrations of IAA, ethrel and GA_3 solution and also in water as per the treatment schedule. After soaking, the treated bulbs were wrapped in tissue paper and immediately planted in the field. The crop was fertilized with Cow dung = 10t/ha, Urea = 200 kg/ha, TSP = 400 kg/ha and MP = 200 kg/ha (Jana and Bose, 1980). Total amount of cow dung, TSP and MP were applied at the time of final land preparation. Urea 200 kg/ha was applied in two equal installments of 30 and 60 days after emergence which was followed by irrigation. Cultural operations such as irrigating the crop at different growth stages, weeding and pest and disease control measures were taken as and when necessary. The scape of the flower was cut when the buds were fully elongated. Harvesting of scape was done early in the morning and the stalks were placed in water. Diameter of mother bulb and bulblets were measured after curing of bulb. Necessary data on different characters were recorded and analyzed statistically using MSTAT- C program to find out the variation among the treatments by F-test. Treatment means were compared by Duncan's Multiple Range Test (DMRT) for interpretation of results (Gomez and Gomez, 1984).

Results and Discussion

The results obtained in the study have been described and discussed along with tables and figures.

Days to first flower scape emergence

Days to flower scape emergence of Hippeastrum was significantly influenced by different growth regulators (Table 1). From the table it can be revealed that first

flower scape emergence (72.33 days) commenced the earliest with ethrel at 100 ppm while late (93.67 days) in plants with control. This is in agreement with the findings of Bose *et al.* (1999) who reported that spraying with ethrel at 1000-4000 ppm, 1-3 times at intervals, has been found to hasten the flower induction in Golden Shower Oncidium. In this connection a little bit different results were found by Dhiman (1997) where earlier flowering in *Lilium hybrids* (115.50 and 120.20 days) was observed with GA_3 at 100 ppm. Pal and Das (1990) also reported that NAA (100 ppm) and GA_3 (100 or 200 ppm) induced early flowering in *Lilium longiflorum*.

Days to first flower open

Different growth regulators was found to influence significantly the days to first flower open of Hippeastrum (Table 1). It can be revealed that days to first flower open was the earliest (88.67 days) in plants treated with ethrel at 100 ppm which was closely followed by ethrel at 300 ppm. The control plants took the longest period (113.40 days) for first flower open. This result is supported by Bose *et al.* (1999) who reported that spraying with ethrel at 1000-4000 ppm, 1-3 times at intervals, hastened the flower induction in Golden Shower Oncidium.

Flower scape per plant

Flower scape per plant of Hippeastrum was counted at the time of flower scape harvest. Significant variation was not found in flower scape per plant due to different growth regulators (Table 1). However, the highest flower scape per plant (2.00) was produced in ethrel at 500 ppm treated plant and the lowest (1.00) in control and IAA at 20 ppm.

Flowers per scape

The effect of different growth regulators showed significant influence on flowers per scape of Hippeastrum (Table 1). The maximum flowers per scape (4.00) was recorded in plants treated with ethrel at 100 ppm and the control plants produced the minimum (2.44). The result is in agreement with the report of Sujatha *et al.* (2002) and Karaguzel *et al.* (1999) who stated that the number of flowers per plant increased with different growth regulators. Similar trend in flowers per scape of Hippeastrum was also reported by Bose *et al.* (1980).

Length of flower

Length of flower of Hippeastrum was significantly influenced by different growth regulators (Fig. 1). However, the highest length of flower (15.14 cm) was recorded from plants treated with GA_3 at 500 ppm. The lowest value for flower length (12.24 cm) was noted in control. This might be due to the fact that GA_3 treated plant produced more number of leaves compared to control and other treatments, which might have resulted in production and accumulation of more photosynthates that were diverted to flowers resulting in longer and larger size flower. The findings are in agreement with those of Pal and Choudhury (1998)

who found that GA_3 at 100 ppm significantly increased leaf area, induced early appearance of flower spike, highest number of florets/spike and largest individual florets in gladiolus cv. Hunting Song. Prakash and Jha (1998) also observed that application of GA_3 at 150 ppm improved all the floral traits (time of flowering, inflorescence length, spike length, floret length and number of florets/spike) in gladiolus, cv. Friendship.

Table 1. Effect of plant growth regulators on flowering characteristics of Hippeastrum.

Treatment	Days to flower scape emergence	Days to first flower open	Flower scape per plant	Flowers per scape
IAA				
20 ppm (T_1)	91.00 ab	109.6 b	1.00	3.06 bc
60 ppm (T_2)	90.00 ab	105.9 c	1.06	3.42 ab
100 ppm (T_3)	88.67 bc	104.3 c	1.17	3.39 ab
Ethrel				
100 ppm (T_4)	72.33 e	88.67 h	1.11	4.00 a
300 ppm (T_5)	84.33 d	92.28 g	1.22	3.28 ab
500 ppm (T_6)	85.33 cd	95.83 f	2.00	3.06 bc
GA_3				
100 ppm (T_7)	93.33 a	102.1 d	1.28	3.45 ab
300 ppm (T_8)	92.67 ab	99.22 e	1.28	3.45 ab
500 ppm (T_9)	91.00 ab	95.11 f	1.28	3.72 ab
Control (T_{10})	93.67 a	113.4 a	1.00	2.44 c
Level of significance	**	**	ns	**
CV(%)	2.34	1.52	11.98	6.22

Means having same letter(s) in a column are not significantly different by DMRT. ** indicates significant at 1% level.

Diameter of flower

A significant variation in the diameter of flower of Hippeastrum was observed due to the effect of different growth regulators (Fig. 1). GA_3 at 500 ppm showed the maximum diameter of flower (12.44 cm) which was statistically similar with that of plants treated with ethrel at 500 ppm and the control plants produced the narrowest flower (10.89 cm). This might be due to the fact that GA_3 treated plant produced more food that was diverted to only a fewer sink and hence bigger flowers were produced. Similar result is reported by Bose *et al.* (1980) who studied the effect of growth regulators on the growth and flowering in Hippeastrum. Sujatha *et al.* (2002) found that foliar application of 100 ppm GA_3 at monthly interval from January to May was the best for obtaining best growth of plants, maximum number of cut blooms with stalk length as well as flower size in gerbera.

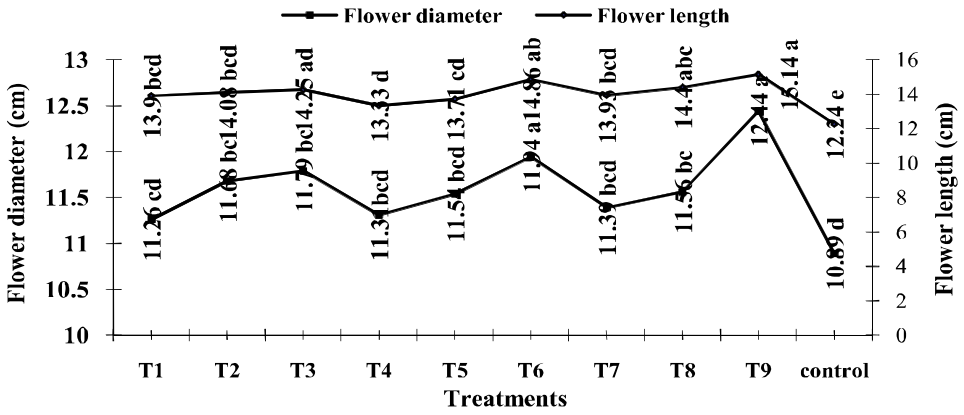

Fig. 1. Effect of growth regulators on flower length and diameter of Hippeastrum.

T_1 = 20 ppm IAA T_4 = 100 ppm Ethrel T_7 = 100 ppm GA_3
T_2 = 60 ppm IAA T_5 = 300 ppm Ethrel T_8 = 300 ppm GA_3
T_3 = 100 ppm IAA T_6 = 500 ppm Ethrel T_9 = 500 ppm GA_3 and
T_{10} = Control (soaked in water)

Flower scape length

Flower scape length of Hippeastrum was measured at the time of harvest. It was observed that flower scape length was significantly influenced by different growth regulators (Fig. 2). The longest flower scape (40.28 cm) was recorded from GA_3 at 500 ppm and the shortest (29.60 cm) was produced by control plants. This might be due to the fact that gibberrellic acids promote cell division and cell enlargement which ultimately resulted in longer flower scape. Similar results were reported by Karaguzel *et al.* (1999), Pal and Choudhury (1998) in gladiolus at 100 ppm GA_3, and Prakash and Jha (1998) in gladiolus at 150 ppm GA_3.

Flower scape diameter

Different growth regulators exhibited significant variation on flower scape diameter of Hippeastrum (Fig. 2). The maximum value for flower scape diameter (21.95 cm) was obtained from plants treated with GA_3 at 500 ppm and the minimum (17.09 cm) from control plants. This might be due to that the highest concentration of GA_3 enhanced plant growth which increased the diameter of flower scape. This is in line with the findings of Karaguzel *et al.* (1999) in gladiolus. They found that soaking of corms at 100 ppm GA_3 for one hour increased the length of flower stem and spikes, the number of flowers per spike and the diameter of flower stem.

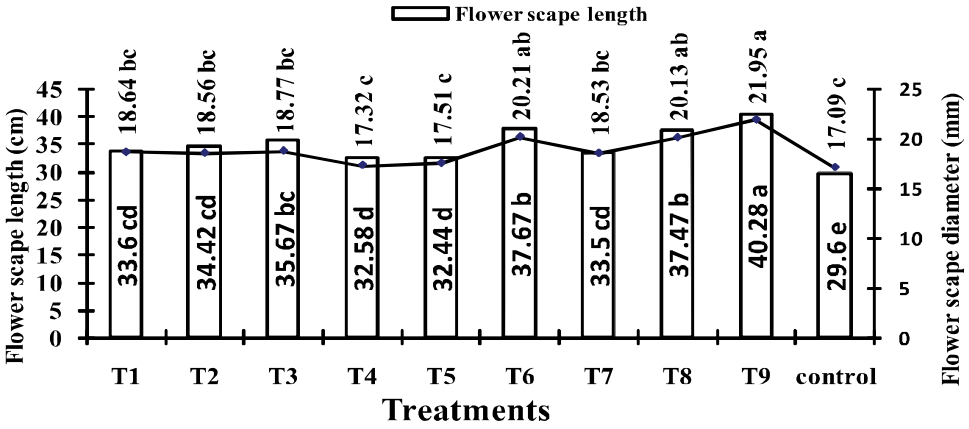

Fig. 2. Effect of growth regulators on flower scape length and diameter of Hippeastrum at harvest.

T_1 = 20 ppm IAA T_4 = 100 ppm Ethrel T_7 = 100 ppm GA_3
T_2 = 60 ppm IAA T_5 = 300 ppm Ethrel T_8 = 300 ppm GA_3
T_3 = 100 ppm IAA T_6 = 500 ppm Ethrel T_9 = 500 ppm GA_3 and
T_{10} = Control (soaked in water)

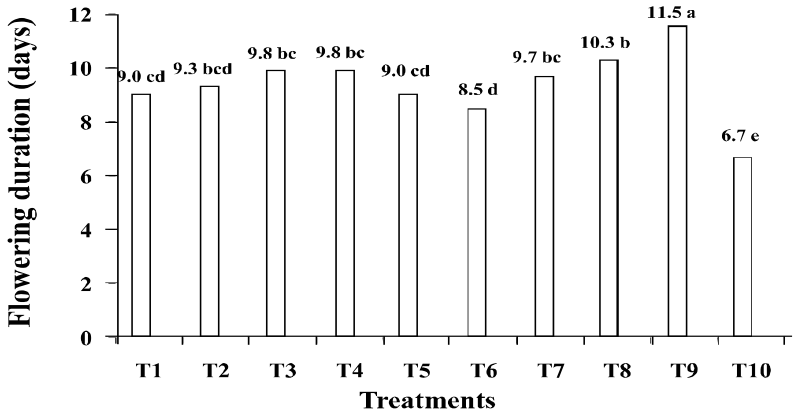

Fig. 3. Effect of growth regulators on flowering duration of Hippeastrum.

T_1 = 20 ppm IAA T_4 = 100 ppm Ethrel T_7 = 100 ppm GA_3
T_2 = 60 ppm IAA T_5 = 300 ppm Ethrel T_8 = 300 ppm GA_3
T_3 = 100 ppm IAA T_6 = 500 ppm Ethrel T_9 = 500 ppm GA_3 and
T_{10} = Control (soaked in water)

Flowering duration

Significant influence was observed on flowering duration of Hippeastrum by different growth regulators (Fig. 3). The maximum duration of flowering (11.50 days) was observed in T_9 (i.e. 500 ppm GA_3) while the minimum (6.70 days) was in control. The increased flowering duration could be attributed to the higher root

development by GA_3 and increased the efficiency of manufacturing carbohydrate which maintained the freshness of flower for longer time. Similar findings were reported by Verma *et al.* (1995) that a single foliar spray of GA_3 (100 and 200 ppm) in chrysanthemum enhanced vegetative growth and flowering. Application of 40 ppm GA_3 produced spikes having the longest (16.20 days) life in the field (Pal and Chowdhury, 1998).

Bulblets per plot

Number of bulblets per plot of Hippeastrum was counted after digging out of bulb. It was observed that different growth regulators significantly influenced the bulblets per plot (Table 2). The maximum number of bulblets per plot (40.00) was obtained from GA_3 at 500 ppm and the minimum (24.00) from control. This result is in full agreement with that of Bose *et al.* (1980). They reported that GA_3 at 10, 100 or 1000 mg l^{-1} twice as foliar spray at an interval of 30 days promoted the number of bulblets of the treated plants.

Table 2. Effect of plant growth regulators on bulb characteristics of Hippeastrum.

Treatment	Bulblets/plot	Bulb diameter (mm)		Bulb yield/plot (g)
		Mother bulb	Bulblets	
IAA				
20 ppm (T_1)	30.67 cd	68.14 b-e	28.67 bcd	3091 f
60 ppm (T_2)	36.00 abc	70.17 a-d	30.27 ab	3138 e
100 ppm (T_3)	38.67 ab	72.63 ab	32.48 a	3458 d
Ethrel				
100 ppm (T_4)	29.33 cd	64.19 ef	26.35 cd	2879 h
300 ppm (T_5)	30.67 cd	65.14 def	27.35 bcd	2898 g
500 ppm (T_6)	32.00 bc	66.75 c-f	28.35 bcd	2902 g
GA_3				
100 ppm (T_7)	34.67 abc	70.64 abc	29.71 abc	3615 c
300 ppm (T_8)	38.67 ab	72.34 ab	32.39 a	3927 b
500 ppm (T_9)	40.00 a	75.49 a	32.99 a	4056 a
Control (T_{10})	24.00 d	62.17 f	25.21 d	2639 i
Level of significance	**	**	**	**
CV%	7.52	2.72	4.22	16.35

Means having same letter(s) and without letters in a column are not significant by DMRT. ** indicates significant at 1% level.

Bulb diameter

Highly significant variation in diameter of bulb due to different growth regulators was found in this study (Table 2). However, the highest value for bulb diameter (75.49 mm) in case of mother bulb was recorded from GA_3 at 500 ppm and the lowest (62.17 mm) was found in control. Similar trend was also found in case of bulblets diameter. Gibberellin might accelerated cell division and cell elongation which lead to increased elongation of root (Stewart and Jones, 1977). Thus, it

enhanced the diameter of bulbs. The results are in partial agreement with Biswas *et al*. (1982) who reported that GA_3 at 100 ppm produced the highest diameter of bulb in tuberose.

Bulb yield per plot

The effect of different growth regulators on bulb yield per plot was found significant (Table 2). The maximum bulb yield (4056 g) was obtained from GA_3 at 500 ppm and the minimum (2639 g) from control. This may be due to that GA_3 enhanced better growth of bulbs and consequently produced the higher bulb yield per plot. These results are in conformity with the findings reported by Umrao *et al*. (2007) where they found increased weight of corm for treating with GA_3. A similar result was also reported by Bose *et al.* (1980) in Hippeastrum.

Bulb yield per hectare

Bulb yield per hectare of Hippeastrum varied significantly due to the influence of different growth regulators (Fig. 4). From the figure it can be revealed that the highest bulb yield (40.56 t/ha) was recorded in T_9 while the lowest (26.39 t/ha) in control. This finding is in full agreement with that of Bose *et al.* (1980) who reported that GA_3 enhanced the flower diameter and bulb yield of Hippeastrum.

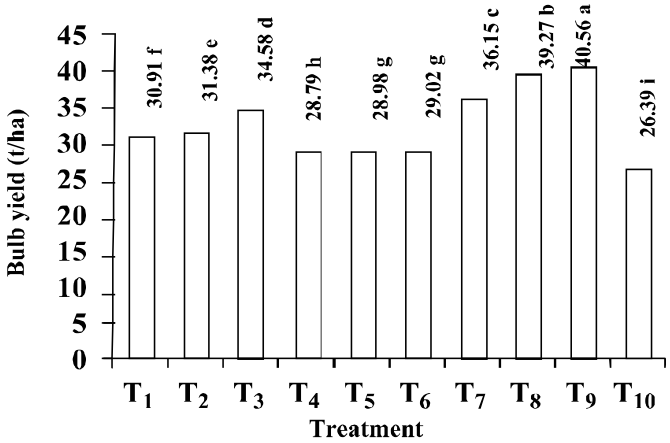

Fig. 4. Effect of growth regulators on bulbs yield (t/ha) of Hippeastrum.

T_1 = 20 ppm IAA T_4 = 100 ppm Ethrel T_7 = 100 ppm GA_3
T_2 = 60 ppm IAA T_5 = 300 ppm Ethrel T_8 = 300 ppm GA_3
T_3 = 100 ppm IAA T_6 = 500 ppm Ethrel T_9 = 500 ppm GA_3 and
T_{10} = Control (soaked in water)

Conclusion

Based on the above discussion, it can be concluded that the plant growth regulators has significant effect on flower and bulb production of Hippeastrum. Bulbs treated with ethrel at 100 ppm enhanced early emergence of flower scape and flowering, maximum flowers per scape while GA_3 at 500 ppm performed

better for bigger size flower and flower scape, flowering duration and bulb production of Hippeastrum.

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EFFECT OF BAP AND SUCROSE ON THE DEVELOPMENT OF CORMEL IN MUKHI KACHU

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Abstract

In vitro cormel development in Mukhi Kachu *(Colocasia esculenta)* Var. Bilashi was assessed in an experiment using three levels of BAP (0, 5 and 10 mg/l) and four levels of sucrose (0, 5, 10 and 15 %). Individual shoot excised from multiple shoot was used as explant in this experiment. *In vitro* cormel formation of *Colocasia* is an important means of organogenesis, which initiated earlier with 10% sucrose in 15% culture, whereas 15% sucrose produced cormels in 50% culture. While BAP at 10 mg/l formed cormels in 32.5% cultures but these two factors together formed cormels in 85% cultures, having 2.5 cormel per culture. The cormel weighed upto 1.7 g and contained 81.5% dry matter.

Keywords: Mukhi Kachu, BAP, Sucrose, Cormel development.

Introduction

Mukhi Kachu (*Colocasia esculenta)* is known as taro, cocoyam, eddoe and dasheen in different places and used as an important vegetable in various parts of the tropics (Denham *et al.,* 2003). In Bangladesh, it comes to market as an important summer vegetable when most of the vegetable are not available. It is grown in high land and covering an area of 23,897 ha of land and production 236217 tones (Annon, 2012). Nutritionally, this crop is very rich in iron and yield potentially of this crop is 30-32 tons per hectare (Rashid, 1990).

The variety Bilashi produces corm and cormels which are the propagating materials but this cormels are also an important summer vegetables in Bangladesh. The major part of this crop is generally used as vegetable keeping a very small portion as seed. As cormels are used as planting materials in mukhi kachu and seed cormel supply is a limiting factor, propagation of cormels in *in vitro* can speed up the seed production program. *In vitro* cormels can be produced year round and can be used as a basic material for quality seed production in the country (Chandra *et al.,* 1988; Rahim and Alamgir, 1995).

In vitro tuberization of potato has been studied by many authors (Wang and Hu, 1982; Tover *et al*., 1985; Pelacho and Mingo- Castel, 1991; Chandra *et al.,* 1992; Zakaria, 2003). But reports on taro are very scarce though these two crops are identical (Zhou *et al*., 1999). The first report on taro micro-propagation was by Yamamoto and Matsumoto (1992), who induced *in vitro* cormels after adding 8

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% sucrose in MS liquid medium. Many authors reported that Sucrose (Yamamoto and Matsumoto, 1992; Zhou *et al*., 1999) and Benzyl adenine (Zhou *et al*., 1999) are responsible for *in vitro* cormel production in taro. However, the work on *in vitro* cormel induction of taro is very scanty in abroad and there is no report in our country. Therefore, to develop cormels in *in vitro* plantlets, the present investigation has been under taken.

Materials and Method

The experiment was conducted at the tissue culture laboratory of the Tuber Crops Research Centre (TCRC), BARI, Joydebpur, Gazipur. Well sprouted cormels of Mukhi Kachu variety ``Bilashi'' was used. The cormels were cut into small size with approximate 2.0 cm long sprout and were disinfected following the method as described by Hossain *et al*. (1998). This small size sprout was put in to test tube containing multiple shoot inducing MS media. Individual shoots were excised from multiple shoot and cultured in this experiment for cormel production.

Basic salts of Murashige and Skoog (Murashige and Skoog, 1962) culture media were used. In order to induce cormels in detached multiple shoots, three levels of BAP (0, 5 and 10 mg/l) and four levels of sucrose (0, 5, 10 and 15%) were used in this experiment. Individual shoots were excised from multiple shoot and multiplied. Shoots were inoculated into MS agar-solidified medium without growth regulators and grew for 25 DAC (Days after culture) before placing into corm induction medium. The cultures were maintained in a growth chamber at 22 $\pm$ 1^0c with a 16 h photoperiod, and a photosynthetic photon flux of 3000 lux was provided by white fluorescent lamps.

Shoots cultured in *in vitro* multiplication medium were cut off (3-5 cm high) above the roots and transplanted into culture vessels with MS (Murashige and Skoog, 1962) liquid medium, which was supplemented with sucrose and BAP according to the treatment. Cultures were maintained under light (16 h photoperiod). The number of DAC (days after culture) required for *in vitro* cormel induction was recorded as swelling of cormel was visible. The average number and weight was counted and recorded at harvest. The experiment was set in a Complete Randomized Design (CRD), replicated thrice. Each replication included three tubes. Data were analyzed following DMRT at 1% level of probability.

Results and Discussion

Effect of sucrose

Results of cormel formation with sucrose is presented in Table 1. Cormel formation did not occurred up to 5 % sucrose and the highest percentage of

cormel (50.0) formed with 15 % sucrose. Cormel first appeared at 10 % sucrose after 12.5 DAC (days after culture) and it was 22.5 DAC for 15 % sucrose, which produced higher number of cormel per culture (1.5) than that with 10 % sucrose (0.3). The size of cormel was 0.4 cm in diameter, which on weight basis was 1.1 mg at 15 % sucrose. There values for 10 % sucrose were 0.2 cm and 0.5 mg, respectively. The DM % was highly varied over sucrose percentage; it was 22.5 % and 51.7 % for 10 and 15 % sucrose, respectively. In an experiment Zhou *et al.* (1999) found that 5-10% sucrose promoted corm formation. They reported that 15 % sucrose inhibited cormel formation. But in the present study 10-15 % sucrose promoted cormel formation. Zhou *et al.* (1999) used a diploid type variety which was quite different from that was used in the present study (a triploid type variety).

Table 1. Main effect of sucrose on cormel induction and other parameters.

Sucrose (%)	Cormel formed/ culture (%)	DAC to Cormel formation	Number of cormels / culture	Wt. of cormel (g)	Dia. of cormel (cm)	DM (%) of cormel
0	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c
5	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c
10	15.0 (3.9) b	12.5 b	0.3 b	0.5 b	0.2 b	22.5 (2.7) b
15	50.0 (7.1) a	22.5 a	1.5 a	1.1 a	0.4 a	51.7 (5.9) a

Figures in parenthesis indicate square root transformed data. In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT

Table 2. Main effect of BAP on cormel induction and other parameters.

BAP (mg/l)	Cormel formed/culture (%)	DAC to cormel formation	Number of cormel/ culture	Weight of cormel (g)	Diameter of cormel (cm)	DM (%) of cormel
0	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c
5	16.3 (4.0) b	8.8 b	0.5 b	0.4 b	0.1 b	18.4 (2.1) b
10	32.5 (5.7) a	17.5 a	0.9 a	0.8 a	0.3 a	37.3 (4.3) a

Figures in parenthesis indicate square root transformed data. In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT

Detail explanation of the role/ function of sucrose in *in vitro* cormel formation is not enough in the literature. The question may pose as to whether it performs an osmotic role or purely a nutritional one. It is thought that sucrose dissociates to allow a higher osmotic potential within the cells. Thus the role of sucrose in plant tissue culture media as an osmoticum as well as a carbohydrate source has been established. Cormel induction may depend on the osmotic stress of a high concentration of sucrose solution. However, developing cormels are sink for sucrose from the culture medium (Zakaria, 2003).

Effect of BAP

The effect of BAP on cormel formation is shown in Table 2. No cormel was formed in the control. The highest (32.5%) cormel formed with BAP 10 mg/l. Whereas, it appeared first with 5 mg/l BAP after 8.8 DAC, whereas 10 mg/l BAP took 17.5 DAC. The number of cormel was 0.5 with 5 mg/l BAP, which increased to 0.9 with 10 mg/l BAP. The size of cormel was bigger for 10 mg/l BAP (0.3 cm in diameter) compared to 0.1 cm diameter for 5 mg/l. These values on weight basis were 0.8 and 0.4 mg, respectively. The DM % was higher for larger cormel (37.3) than smaller cormel (18.3). Cytokinins or BAP are believed to have strong promotive effects on cormel formation (Zakaria, 2003). The results are in agreement with the findings of many scientists (Priyakumari and Sheela, 2005 and Zhou *et al.*, 1999).

Table 3. Combined effect of sucrose and BAP on cormel induction and other parameters

Treatment		Cormel formed/ culture (%)	DAC to Cormel formation	Number of cormel /culture	Wt. of cormel (g)	Dia. of cormel (cm)	DM (%) of cormel
Sucrose (%)	BAP (mg/l)						
0	0	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
	5	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
	10	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
5	0	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
	5	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
	10	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
10	0	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
	5	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
	10	45.0 (6.7) c	37.5 a	1.0 c	1.4 c	0.5 b	67.5 (8.2) c
15	0	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
	5	65.0 (8.1) b	35.0 ab	2.0 b	1.5 b	0.6 a	73.5 (8.6) b
	10	85.0 (9.2) a	32.5 b	2.5 a	1.7 a	0.7 a	81.5 (9.1) a

Figures in parenthesis indicate square root transformed data. In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT.

For several reasons, cytokinin has often been considered to be a major importance in cormel development process. Firstly, cytokinins are known to stimulate cell division (Skoog and Miller, 1957); secondly, there are indications that it inhibits cell elongation, while promoting cell expansion (Scott and Liverman, 1956). These phenomenon are required for cormel formation and development.

Combined effect of BAP and sucrose

The combined result of BAP and sucrose for cormel formation is presented in Table 3. Cormel formation did not occurred in most of the treatments except 10 mg/l BAP + 10% sucrose (45.0%), 5 mg/l BAP + 15% sucrose (65.0%) and 10 mg/l BAP + 15% sucrose (85.0%). The cormel formation was the earliest (32.5 DAC) in 10 mg/l BAP + 15% sucrose, which was followed by 5mg/l BAP + 15% sucrose (35.0 DAC). The maximum cormel was obtained from 10 mg/l BAP + 15% sucrose (2.5) (Fig. 1a) and the minimum was with 10 mg/l BAP + 10% sucrose (Fig. 1b). The size of cormel was the highest with 10 mg/l BAP + 15% sucrose (0.7 cm diameter), which on weight basis was 1.7 mg. The DM % was also higher for larger cormel (81.5). The detached cormels were shown in Fig. 1c. These results suggested that medium components are essential for cormel formation. In this experiment BAP and sucrose both promoted cormel formation, which is in accordance with previous work on potato (Ivan *et al.*, 1995; Khuri and Moorby, 1996) and on taro (Zhou *et al.*, 1999).

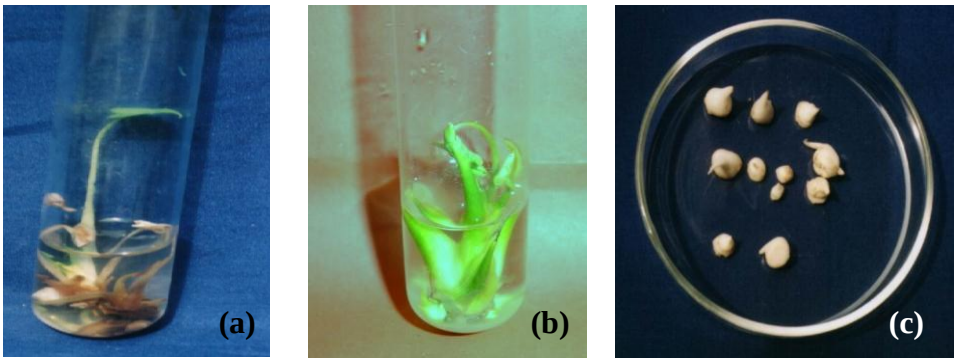

Fig. 1. (a-c) : Cormel production in Mukhi Kachu (a) (sucrose 15% + BAP 10 mg/l) (b) (sucrose 10% + BAP 10 mg/l) (c) Detached cormels ready for planting in Mukhi Kachu.

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VARIABILITY, CORRELATION AND PATH CO-EFFICIENT ANALYSIS OF BITTER GOURD (*Momordica charantia* L.)

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Abstract

Seventeen genotypes of bitter gourd (*Momordica charantia* L.) were studied in a field experiment conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, during April 2009 to September 2010. The objectives of the study were to measure the variability among the genotypes for yield and yield contributing characters, estimate genetic parameters, association among the characters and their contribution to yield. There was a great deal of significant variation for all the characters among the genotypes. Considering genetic parameters high genotypic co-efficient of variation (GCV) was observed for branches per vine, yield per plant and number of fruit per plant whereas low genotypic co-efficient of variation (GCV) was observed for days to first male and female flowering. In all the cases, it was found that phenotypic co-efficient of variation was greater than genotypic co-efficient of variation. Highest genotypic and phenotypic co-efficient of variation was observed in branch per vine, fruit length, fruit weight and number of fruit plant which indicated a wide variability among the genotypes and offered better scope of selection. The results obtained showed that fruit length showed low direct and positive effect on yield per plant and indirect positive effect on yield per plant via fruit diameter and average fruit weight. Similar result was found for fruit diameter. Average fruit weight and number of fruits per plant showed high direct and positive effect on yield per plant. Path analysis revealed that average fruit weight, number of fruits per plant, days to male flowering and fruit length had positive direct effect on fruit yield. Considering group distance and the agronomic performance, the inter genotypic crosses between G2& G5; G2&G14; G14&G15; G2&G15; G10&G11; G10&G13; G11&G13; G5&G15; G5&G14 might be suitable choice for future hybridization programme.

Introduction

Bitter gourd *(Momordica charantia* L.), is one of the most important and a popular cucurbit vegetable grown in Bangladesh. Bitter gourd contains a reasonable amount of different nutrients such as proteins, carbohydrates, fats, minerals and vitamins A, B2, and C etc. Raja *et al.* (1984) reported very high amount of vitamin C (95mg/100g) and protein (930mg/100g) in some Indian bitter gourd variety. The fruits are bitter to taste due to the presence of substance

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called cucurbitacin. Bitter gourd is also reported against diseases like paralysis, indigestion and vomiting pain and diabetes (Mier and Yaniv, 1985). According to BBS (2009-10) total area of bitter gourd in Bangladesh was 22143 acres, per acre yield was 1871 kg and production was 41419 M.ton. Bitter gourd may contribute to the nutritional shortage of the people of Bangladesh. Particularly, it can provide added proteins, minerals and vitamins to the diet. There are a lot of variabilities among the existing bitter gourd germplasm of Bangladesh. An understanding of the nature and magnitude of the variability among the genetic stocks of bitter gourd is of prime importance for the breeder. A good knowledge of genetic wealth might also help in identifying desirable cultivars for commercial production. Because of its nature of high cross pollination, hardly any genetically pure strain is available to the growers. The basic key to a breeder is to develop high yielding varieties through selection, either from the genotypes or from the segregants of a crop. Expression of different plant character is controlled by genetic and environmental factors. So, the study of genetic parameters is necessary for a successful breeding program which will provide valuable information on the mode of inheritance of different characters which would be useful in selecting plants having desirable characters to develop new varieties. In a hybridization program knowledge of interrelationship among and between yield and yield components is necessary. Thus, determination of correlation between the characters is a matter of considerable importance in selection. Path analysis partitions the components of correlation co-efficient into direct and indirect and visualizes the relationship in more meaningful way (Bhatt, 1973). Among the local cultivated varieties, a wide range of genetic variability exists in this crop which can be exploited for its improvement. The basic key to a breeder is to develop high yielding varieties through selection, either from the genotypes or from the segregants of a crop. Expression of different plant character is controlled by genetic and environmental factors. So, the study of genetic parameters is necessary for a successful breeding program which will provide valuable information on the mode of inheritance of different characters which would be useful in selecting plants desirable characters to develop new varieties of bitter gourd in the country.

Materials and method

Seventeen genotypes of bitter gourd were used for the present research work. The genetically pure and physically healthy seeds of these genotypes were collected from different location. The name and source of collection of these genotypes are presented in Table 1. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The genotypes were distributed into the every plot of each block of the experiment. The individual plot was 3 m × 1 m in size. The seventeen genotypes of the experiment were assigned at random into plots of each replication. The distance maintained spacing row to

row 50 cm and plant to plant 2 m. The distance maintained between two blocks was 1 m. Seeds of different accessions were sown in the pit on 5thMay, 2010.Germination of seeds were completed within twelve days and in each pit four seeds were sown and the soil around the plant was firmly pressed by hand.

Table 1. Name and sources of seventeen Bitter gourd genotypes used in the present study.

Sl. No.	Genotypes No.	Source
1	G_1	Siddiq Bazar, Gulistan, Dhaka
2	G_2	Siddiq Bazar, Gulistan, Dhaka
3	G_3	Narayanganj local market
4	G_4	Agargaon local market, Agargaon, Dhaka
5	G_5	Siddiq Bazar, Gulistan, Dhaka
6	G_6	Agargaon local market, Agargaon, Dhaka
7	G_7	Agargaon local market, Agargaon, Dhaka
8	G_8	Siddiq Bazar, Gulistan, Dhaka,
9	G_9	Narayanganj local market
10	G_{10}	Kawran bazar,Dhaka
11	G_{11}	Kawran bazar,Dhaka
12	G_{12}	Narayanganj local market
13	G_{13}	Agargaon local market, Agargaon, DhAka
14	G_{14}	Siddiq Bazar, Gulistan, Dhaka,
15	G_{15}	Kawran bazar,Dhaka
16	G_{16}	Agargakn local market, Agargaon, Dhaka
17	G_{17}	Narayanganj local market

The experiment plot was prepared by several ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about good tilth in the middle week of February 2010. Weeds and other stables were removed carefully from the experimental plot and leveled properly. After final land preparation, pits of 50 cm × 50 cm × 45 cm were prepared in each plot with a spacing of 3 m × 1.25 m. The dose of manure and fertilizers used in the study are Cow dung 10 ton/ha, Urea 150 kg/ha, TSP 100 kg/ha, MOP 150 kg/ha, Gypsum 80 kg/ha, Zinc Oxide 8 kg/ha. The intercultural operations were done from time to time throughout the cropping season for proper growth and development of the plants. Only one healthy seedling was kept per pit for the proper development and avoid crowd environment. Fruits were picked on the basis of horticultural maturity, size, colour and age. Frequent picking was done throughout the harvesting period. The following data such as, Days to first male flowering, Days to first female flowering, Vine length (m), Number of nodes

per vine, Branches per vine, Fruit length (cm), Fruit diameter (cm), Number of fruit per plant, Weight per fruit (g), Yield per plant (kg), were recorded on parameters from the studied plants during the experiment. Mean data of the characters were subjected to multivariate analysis. Univariate analysis of the individual character was done for all characters under study using the mean values (Singh and Chaudhury, 1985) and was estimated using MSTAT-C computer programme. Duncan's Multiple Range Test (DMRT) was performed for all the characters to test the differences between the means of the genotypes. Mean, range and co-efficient of variation (CV %) were also estimated using MSTAT-C. For calculating the genotypic and phenotypic correlation co-efficient for all possible combinations the formula suggested by Miller *et al.,* (1958), Johnson *et al.,* (1955) and Hanson *et al.,* (1956) were adopted. Broad sense heritability was estimated (Lush, 1943) by the following formula, suggested by Johnson *et al.,* (1955). Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985), using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect independent variables on the dependent variable.

Results and Disussion

The experiment was conducted to investigate the yield performance, variability, character association and yield contributing characters of seventeen bitter gourd genotypes. The result of the experiment have been presented and interpreted under the following headings. The analysis of variance indicated the existence of sufficient genetic variability among the 17 genotypes for all the plant characters (Table 2).Vine length as observed in this experiment varied significantly among the genotypes. Significantly, the highest vine length was found in G_9 (4.53 m) which were statistically similar with the genotypes G_1, G_2, G_3, G_5, G_6, G_7, G_9, G_{10}, G_{12}, G_{14}, G_{16} and G_{17}. On the other hand, the lowest vine length was recorded in G_{15} (2.13 m). The results obtained related with the findings of Robinson and Decker-Walters (1997). Prasad and Sing (1992) reported a wide range of variability among the cucumber genotypes for vine length at final harvest. Phenotypic expression of any traits depends on the genotypic and the environmental variation. Generally, the higher environmental influence suppresses the expression of genetic effect. Estimation of genotypic variance was low and phenotypic variance was fairly high for vine length (Table 3).

Genotypic co-efficient of variation was found lower than the corresponding phenotypic one, which indicated the larger influence of environment. It was observed that branch per vine varied significantly among the genotypes and ranged from 30.67 to 45.60 with the mean value of 38.21. The highest branch per vine (45.60) was found in G_5 followed by G_3, G_6, G_7, G_9, G_{10}, G_{14}, G_{16} and G_{17},

where as the lowest branch per vine was observed in G_2 (30.67) (Table 2). Differences between phenotypic (25.27) and genotypic (14.01) variances and also phenotypic (81.33%) and genotypic (60.55%) co-efficient of variation indicating environmental effect upon the expression of the characters of branch per vine (Table 3). The nodes per vine was observed significantly varied among the genotypes and ranged from 81.33 to 91.23 with the mean value of 85.73 (Table 2). The highest nodes per vine (91.23) was found in G_2 followed by G_3, G_{13} and G_{15}, where as the lowest nodes/vine was observed in G_{11} (81.33). Considerable differences between phenotypic (12.64) and genotypic (9.98) variances and also phenotypic (38.41%) and genotypic (34.13%) co-efficient of variation indicating environmental effect upon the expression of the characters of nodes per vine (Table 3). The highest range of variation was recorded in days to first male flower opening among the genotypes and ranged from 53.77 to 61.20 days with the mean value of 56.59 days (Table 2). The plant of G_{14} and G_{16} showed the minimum days to first male flowering which was statistically similar with G_3, G_5, G_7, G_8, G_9, G_{10}, G_{11}, $G_{13,}$ G_{15} and G_{17} .The G_1 showed the maximum days to first male flowering (61.20) followed by G_2, G_6 and G_{12}. Differences between genotypic (3.44) and phenotypic (6.74) variances as well as genotypic (24.68%) and phenotypic (34.54%) co-efficient of variation (Table 3) was high indicating considerable environmental effect upon the expression of this trait. Abusaleha and Dutta (1990) found high genotypic and phenotypic (33.22 and 33.88) value for days to male flowering in bitter gourd.

The range of variation in days to first female flower opening among the genotypes ranged from 62.90 to 71.43 days with the mean value of 66.29 days (Table 2). The plants of genotype 1 showed the maximum days (71.43) to first male flowering which was statistically similar with G_2, G_4, G_6 and G_8. The genotype G_9, G_{11}, G_{13}, G_{15} and G_{16} showed the minimum days to first male flowering (62.90). Differences between genotypic (7.37) and phenotypic (9.13) variances as well as genotypic (33.37%) and phenotypic (37.14%) co-efficient of variation (Table 3) was high indicating considerable environmental effect upon the expression of this trait. Abusaleha and Dutta (1990a) observed that the genotypic and phenotypic variances were high (77.38 and 74.03) for days to first female flowering in bitter gourd.

Significant variation in respect of fruit length was found among the studied accessions. Genotypes 11 had the longest fruit (21.59cm) and the smallest fruit was found in genotypes 5 (15.55cm). Sharma *et al.*,(2000), Krisna Prasad and Singh (1994), Hormuzdi and More (1989) were found the similar results. Comparatively higher degree of genotypic variance (5.56), phenotypic (5.91) variance as well as genotypic (52.09%) and phenotypic (53.70%) co-efficient of variation was found for fruit length. It was similar with the findings of Saha *et al.*,(1992).

Table 2. Plant characteristics and mean performance in respect of vine length, branch per vine, nodes per vine, days of 1st male flowering, days of 1st female flowering, fruit length, fruit diameter, fruit weight, no of fruits per plant and fruits per plant of seventeen bitter gourd accessions.

Genotypes	Vine length (cm)	Branch per vine	Nodes per vine	Days of 1st male flowering	Days of 1st female flowering	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	No of fruits per plant	Fruits per Plant (Kg)
Genotype-1	4.20	30.87	85.00	61.20	71.43	20.19	11.77	119.3	23.33	2.267
Genotype-2	3.63	30.67	91.23	59.67	69.07	21.40	11.33	127.8	19.67	2.200
Genotype-3	3.80	41.03	89.60	56.07	68.50	21.10	11.84	130.2	22.33	2.640
Genotype-4	3.27	34.10	82.10	57.77	69.10	19.08	9.86	105.8	24.67	2.777
Genotype-5	4.07	45.60	85.37	56.43	66.73	15.55	10.75	102.7	20.67	2.290
Genotype-6	3.57	39.70	83.33	58.03	69.07	21.43	11.13	110.5	27.67	3.093
Genotype-7	3.77	40.83	82.47	55.10	64.53	20.86	10.67	113.7	27.33	3.170
Genotype-8	3.37	35.63	85.37	57.13	69.93	20.72	10.47	114.2	30.00	3.420
Genotype-9	4.53	43.70	82.87	56.57	63.47	20.75	10.42	117.0	29.33	3.290
Genotype-10	3.73	39.13	87.20	54.27	65.37	20.38	10.65	116.8	29.33	3.110
Genotype-11	3.23	37.60	81.33	54.83	62.90	21.59	10.52	117.3	27.33	2.797
Genotype-12	3.53	34.93	82.43	59.27	66.47	20.77	10.82	112.5	25.00	2.587
Genotype-13	3.20	37.07	90.50	55.37	63.47	20.63	10.22	110.7	28.33	2.880
Genotype-14	4.30	39.50	86.50	53.77	64.63	21.20	10.73	119.3	26.00	2.973
Genotype-15	2.13	36.23	90.73	55.07	62.90	21.32	10.69	116.7	23.33	2.440
Genotype-16	4.27	43.47	87.30	53.77	62.97	20.83	10.65	112.5	21.00	2.327
Genotype-17	3.50	39.47	83.10	55.93	64.70	20.54	9.87	110.8	25.00	2.747
LSD(0.05)	0.97	5.58	2.71	3.02	2.20	0.97	0.65	9.25	3.74	0.40
Maximum	4.53	45.6	91.23	61.2	71.43	21.59	11.84	130.2	30	3.42
Minimum	2.13	30.67	81.33	53.77	62.9	15.55	9.86	102.7	19.67	2.2
Mean	3.61	38.20	85.73	56.59	66.29	20.28	10.74	115.30	25.26	2.769
CV (%)	16.01	8.78	1.90	3.22	2.00	2.87	3.64	4.83	8.90	8.76
SE	0.153	48.73	141.17	30.93	13.78	31.31	5.07	0.003	0.43	0.09

Table 3. Estimation of genetic parameters of yield and yield contributing characters of seventeen bitter gourd accessions.

Accession	Vine length (cm)	Branch per vine	Nodes per vine	Days of 1st male flowering	Days of 1st female flowering	Fruit length	Fruit diameter	Fruit weight	No of fruits per plant	Fruits per Plant (Kg)
Genotypic Variance	0.20	14.01	9.98	3.44	7.37	5.56	0.25	36.75	8.75	0.12
Phenotypic Variance	0.54	25.27	12.64	6.74	9.13	5.91	0.40	67.69	13.83	0.18
Genotypic co-efficient of variation (%)	23.40	60.55	34.13	24.68	33.37	52.09	15.26	56.49	58.79	20.83
Phenotypic co-efficient of variation (%)	38.45	81.33	38.41	34.54	37.14	53.70	19.31	76.67	73.92	25.52
Range	2.13-4.53	30.67-45.60	81.33-91.23	53.77-61.20	62.90-71.43	15.55-21.59	9.86-11.84	102.7-130.2	19.67-30.0	2.2-3.42
CV (%)	16.01	8.78	1.9	3.22	2.00	2.87	3.64	4.83	8.9	8.76

Significant variation in respect of fruit diameter was found among the studied accessions. Genotypes 3 had the longest fruit diameter (11.84cm) which was statistically similar to genotype 1 and genotype 2. On the other hand, the smallest fruit diameter was found in genotypes 4 and genotype 17 (9.86 cm). Sharma *et al.*,(2000), Krisna Prasad and Singh (1994), Hormuzdi and More (1989) were found the similar results. Higher degree of genotypic variance (0.25), phenotypic (0.40) variance as well as genotypic (15.26%) and phenotypic (19.31%) co-efficient of variation was found for fruit diameter. It was similar with the findings of Saha *et al.*,(1992).

Average fruit weight varied significantly among the accessions and ranged from 102.7g to 130.2g where mean value was 115.30g. The genotype 3 had the highest fruits weight (130.20g) followed by genotype 2. On the other hand genotype 5 was carried the lowest weighty (102.70g) fruits which was statistically similar with G_4, G_6, G_{13}, G_{16} and G_{17} (Table 2). Prasad and Singh (1992) observed high variability among the bitter gourd genotypes for this trait. High genotypic (36.75) and phenotypic (67.69) variances as well as genotypic (56.49%) and phenotypic (76.67%) co-efficient of variation (Table 3) for this character indicated the maximum amount of variability within the genotypes for average fruit weight and offered better scope of selection. This finding was supported by Rastogi *et al.*,(1990). The number of fruit per plant varied significantly among the genotypes and ranged from 19.67 to 30.00 (Table 2). The genotype 8 obtained the maximum number of fruits per plant (30.00) which was statistically similar with G_6, G_7, G_9, G_{10}, G_{11} and G_{13}. On the other hand, the minimum number of fruits per plant (19.67) was obtained in genotype 2 followed by genotype number G_1, G_3, G_5, G_{15} and G_{16} (Table 2). Anonymous (2000) reported that number of fruits per plant varied significantly among the studied cucumber lines. Slight differences were observed between genotypic (8.75) and phenotypic (13.83) variance as well as genotypic (58.79%), phenotypic (73.92%) co-efficient of variation indicating low environmental influence on this trait (Table 3).

The cultivars showed a significant difference in producing yield per plant and ranged from 2.2kg to 3.42kg (Table 3). From the above result, the data indicated that genotype 8 (3.42kg) had the highest yield per plant followed by genotype G_6, G_7, G_9, G_{10} and G_{14} which were statistically similar with each other. The genotype 2 (2.2kg) had the lowest yield per plant followed by genotype 1, G_3, G_5, G_{12}, G_{15} and G_{16} which were statistically similar to each other but significantly different from the other accessions (Table 2). In a trial at BARI, Joydebpur (Anonymous, 1997) with 28 bitter gourd lines, yield per plant varied from 0.48kg to 3.69kg, which was more or less similar to the above findings. Little differences were found between genotypic (0.12) and phenotypic (0.18) variance as well as genotypic (20.83%) and phenotypic (25.52%) co-efficient of variation (Table 3)

resulting low environmental influence on this character. Abusaleha and Dutta (1990a) recorded low genotypic and phenotypic variances for this trait in bitter gourd.

Correlation studies

Estimation of simple correlation co-efficient was made among seven important yield components towards yield of the seventeen genotype of bitter gourd accessions. The values of 'r' and the components correlated are presented in Table 4.

Correlation co-efficient revealed that vine length had positive correlation with days to first male flowering (0.026), female flowering (0.006), fruit length (0.018), fruit diameter (0.15), individual fruit weight (0.10) and number of fruits per plant (0.178). This indicates that days to first male and female flowering, fruit length, fruit diameter, average fruit weight and number of fruits per plant will be increased with the increased of vine length (Table 4). This finding was supported by Abusaleha and Dutta (1989). Days to first male flowering had highly significant and positive correlation with days to first female flowering (0.422) and negative correlation with fruit length (-0.171), fruit diameter (-0.215), individual fruit weight (-0.052), number of fruits per plant (-0.193) and yield per plant (-0.184). This indicates that yield per plant will be decreased with the increase of days to first male flowering (Table 5). This study agrees with the finding of Li *et al.,* (1997) and stated that days to first flowering was negatively correlated with yield per plant in selected bitter gourd inbred lines.

It was observed that days to first female flowering was not positively correlated with any of the parameter and negatively and significantly correlated with fruit length (- 0.297), fruit diameter (- 0.331), individual fruit weight (- 0.287) and yield per plant (- 0.332) (Table 5). Which indicate that days to first picking increased and yield per plant decreased with the increase of days to first female flowering. Ananthan and Pappiah (1997) reported that days to first female flowering were negatively correlated with total fruit yield per plant in bitter gourd. Days to first picking was also negatively correlated with yield per plant (-0.145). With the respect of, the association of fruit characters, fruit length (0.202), fruit diameter (0.407), individual fruit weight (0.601) and number of fruits per plant (0.873) had the high degree of significant positive association with yield per plant. This indicates that yield per plant will be increased with the increase of fruit length, fruit diameter, individual fruit weight and number of fruit per plant and average fruit weight.

Table 4. Correlation co-efficient among eight important yield and yield contributing characters of seventeen genotype bitter gourd.

Characters	Days to 1st male flowering	Days to 1st female flowering	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	No of fruits per plant	Yield per plant (kg)
Vine length (cm)	0.026	0.006	0.108	0.15	0.10	0.178	0.185
Days to 1st male flowering		0.422**	-0.171	-0.215	-0.052	-0.193	-0.184
Days to 1st female flower flowering			-0.297*	-0.331*	-0.287*	-0.247	-0.332*
Fruit length (cm)				0.154	0.427**	-0.015	0.202
Fruit diameter (cm)					0.504**	0.203	0.407***
Average fruit weight(g)						0.153	0.601***
No of fruits per plant							0.873***

** Significant at 1% level of probability, *Significant at 5% level of probability.

Table 5. Path analysis showing direct and indirect effects on yield components of seventeen genotype bitter gourd.

Characters	Vine length (cm)	Days to 1st male flowering	Days to 1st female flowering	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	No of fruits per plant	Yield per plant (kg)
Vine length (cm)	**-0.00865**	0.00002	0.00008	0.00187	0.0018	0.04703	0.14262	0.185
Days to 1st male flowering	-0.00022	**0.00056**	0.00595	-0.00296	-0.00258	-0.02445	-0.15464	-0.184
Days to 1st female flowering	-0.00005	0.00024	**0.0141**	-0.00514	-0.00397	-0.13497	-0.1979	-0.332
Fruit length (cm)	-0.00093	-0.0001	-0.00042	**0.0173**	0.00184	0.20081	-0.01202	0.202
Fruit diameter (cm)	-0.00129	-0.00012	-0.00467	0.00266	**0.01998**	0.23702	0.16265	0.407
Average fruit weight(g)	-0.00086	-0.00003	-0.00404	0.00739	0.00605	**0.047027**	0.12259	0.601
No of fruits per plant	-0.00154	-0.00011	-0.00348	-0.00026	0.00244	0.07195	**0.80123**	0.873

Underlined figures indicated the direct effects. Residual effect (R) =0.117.

Association of characters determined by correlation co-efficient may not provide an exact picture of the relative importance of direct and indirect influence of each of the yield components towards yield. As a matter of fact, in order to find a clear picture of inter-relationship between fruit yield and yield contributing characters, direct and indirect effects were worked out using path analysis.

The results of the path analysis in table 5 revealed that direct effect of vine length on yield per plant was very low and negative (-0.00865). Where as positive indirect effect of vine length on yield per plant was contributed via days to first male and female flowering, days to first picking, fruit length, fruit diameter, individual fruit weight and number of fruits per plant (Table 5). Days to first male flowering showed very lower direct and positive effect (0.00056) on yield per plant. This trait had also negative effect on yield per plant via fruit length, fruit diameter, average fruit weight and number of fruits per plant (Table 5). Days to flowering were negatively correlated with yield per plant reported by Li *et al.*,(1997). Days to first female flowering showed very low direct and positive effect (0.0141) on yield per plant. This trait had also negative effect on yield per plant via fruit length, fruit diameter, average fruit weight and number of fruits per plant (Table 5). Fruit length showed low direct and positive effect (0.0173) on yield per plant and indirect positive effect on yield per plant via fruit diameter and average fruit weight. Similar result was found for fruit diameter and average fruit weight. Number of fruits per plant showed high direct and positive effect (0.801) on yield per plant (Table 5). Three characters namely average fruit weight, number of fruits per plant and average fruit length had the largest direct effect of yield per plant in bitter gourd stated by Zhang *et al.*,(1999). Rajput *et al.*,(1991) found a significant positive correlation between number of fruits per plant and fruit yield among the indigenous and exotic bitter gourd cultivars. The residual effect was 0.117 indicating that about 88 percent of the variability in yield per plant was contributed by the eight characters studied in path analysis. In the present study this residual effect towards yield might be due to many reasons such as other characters which were not studied, environmental factor and sampling errors. The path analysis carried out in the present investigation suggested that average fruit weight and number of fruits per plant which are the main components of yield should be given priority in the selection programme and as well as variety development.

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EFFECT OF NITROGEN ON DIFFERENT GENOTYPES OF MUNGBEAN AS AFFECTED BY NITROGEN LEVEL IN LOW FERTILE SOIL

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Abstract

A pot experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif- II season (August to November) of 2010 to find out the nitrogen acquisition and yield of mungbean genotypes affected by different levels of nitrogen fertilizer in low fertile soil. Ten mungbean genotypes viz. IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Bina moog- 5 and six nitrogen fertilizer levels viz. 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results indicated that increasing applied nitrogenous fertilizer in low fertile soil increased nitrogen acquisition of mungbean which increased number of pods $plant^{-1}$ and seeds pod^{-1} and finally increased yield of mungbean upto 60 kg N ha^{-1} irrespective of genotype and thereafter decreased. Genotype IPSA -12 produced the highest seed yield (14.22 g $plant^{-1}$) at 60 kg N ha^{-1}. The lowest yield (7.33 g plant $^{-1}$) was recorded in ACC12890053 in control. From regression analysis, the optimum dose nitrogen for mungbean cultivation in the low fertile soil is 54 kg ha^{-1}.

Keyword: Yield, Nitrogen level, Nitrogen acquisition, Low fertile soil.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) is an ancient and widely cultivated crop in many Asian countries including China, India, Pakistan, Philippines, Indonesia and Bangladesh (Akbari *et al.*, 2008). Mungbean is a short duration crop and very effective for intensive cropping system. Mungbean can be easily fitted in mungbean - T. aus - T. aman (southern region), mungbean -T. aman wheat (north western region) and mungbean - aus - aman - potato (northern region) cropping systems without considering the fertility status of the soil (Haque, 2001). One of the reasons of ignoring soil fertility in mungbean cultivation is its ability to fixation of atmospheric nitrogen (Hardarson and Danso, 1993). However, amount of nitrogen fixed by microbial association varies over many soil and environmental factors which might not be sufficient for proper growth and yield formation of mungbean. Most of the researchers evaluated mungbean genotype in optimum soil

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condition but they ignored low nutrient environments for evaluation of mungbean (Anjum, *et al.*, 2006; Akbari, *et al.*, 2008 and Malik *et al.*, 2002). There exists ample scope to evaluated mungbean genotypes that have inherent capability for producing higher yield under nutrient poor conditions. Therefore, the present study was undertaken with view to yield and nitrogen acquisition behavior of mungbean under low nitrogen condition in different nitrogen level.

Materials and Method

The pot experiment was conducted at Bangbandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during kharif II season (August to November) of 2010. The soil was used in this experiment belongs to Codda series, under Madhupur tract. The soil is called low fertile soil because nutrient content in soil below the critical limit in the fertilizer recommendation guide (FRG, 2005). The experimental pots were filled with 12 kg soil. Ten mungbean genotypes (IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Bina moog- 5 and six nitrogen levels (0, 20, 40, 60, 80 and 100 kg N ha^{-1}) were used as treatment variables.. Four (4) seeds per pot were sown on 31 August 2010. The treatments were factorial combination of the two factors and the experiment was conducted using a completely randomized design with four replication. One plant pot^{-1} was considered as one replication. Nitrogen fertilizers were top dressing at 15 days after sowing. All agronomic practices like two weeding (15 days and 30 days after emergence), three irrigation (12, 25 and 40 days after emergence) and one mulching was done at pod developing stage. Insect pest was controlled by spraying admire 0.5 ml $litre^{-1}$ of water during the entire growth period of the crop. Genotypes differed in attainment of maturity and then the harvesting was done twice one on 31 October and another on 13 November, 2010.

Table 1. Chemical properties of the experimental soil before sowing.

Soil properties	Present value	Critical level
Organic matter (%)	0.536	-
Total N (%)	0.05	0.10
Available P (ppm)	0.16	8.00
Exchangeable K meg 100^{-1}g soil	0.85	0.08
Available S (ppm)	7.00	8.00
Available B (ppm)	0.15	0.16
Available Zn (ppm)	0.25	0.50
Exchangeable Ca meg 100^{-1}g soil	14.83	2.00
Exchangeable Mg meg 100^{-1}g soil	1.76	0.50
CEC meg 100^{-1}g soil	6.90	3-7.5

Data on yield, yield components and nitrogen content of mungbean genotypes were recorded. Total nitrogen contents in plant were determined by modified

Kjeldahl digestion colorimatric method (Cataldo *et al.,* 1974). Nitrogen uptake by plant (shoot) of ten genotypes determined at maturity stage. The data on different parameters were subjected to statistical analysis Microsoft Excel and MSTAT C software programs were used wherever appropriate to perform statistical analysis.

Results and Discussion

Plant height

Genotype and nitrogen interacted significantly in plant height of mungbean (Table 2). Although plant height of mungbean increased with the increase of nitrogen levels but it attained peak differently in different genotypes treated by different nitrogen levels. Thus, the tallest plant (63.66 cm) of IPSA 12 was observed at 60 kg N ha^{-1} , GK 27 (43.00 cm) at 40 kg N ha^{-1}, IPSA 3 (65.33 cm) at 80 kg N ha^{-1}, IPSA 5 (78.33 cm) at 80 kg N ha^{-1}, ACC 12980053 (75.00 cm) at 40 kg N ha^{-1}, BU mug 4 (60.06 cm) at 40 kg N ha^{-1}, BARI Mung 6 (57.00 cm) at 60 kg N ha^{-1} and Binamoog 5 (68.33 cm) at 60 kg N ha^{-1}. The lowest plant height was obtained at o kg ha-1 irrespective of genotypes. The results revealed that genotypes itself are responsible for variation in plant height while applied nitrogen enhanced the growth of mungbean. Increase in plant height of mungbean at higher nitrogen levels may be ascribed to increase of N in chlorophyll which increased photosynthesis and enhanced meristematic activity of plant (Sawwar *et al*., 1989). Besides, nitrogen is essential component of amino acids which are vital building blocks for development of tissues and consequently increased plant height. This result is an agreement with the findings of Rahman *et al*. (1992) of French bean at higher level of nitrogen (120 kg ha^{-1}).

Table 2. Plant height (cm) of mungbean genotypes as affected by nitrogen level.

Genotypes	Nitrogen levels (kg ha^{-1})					
	0	20	40	60	80	100
IPSA -12	50.00cC	54.66bB	56.66bC	63.66aB	57.00bC	48.66cC
GK -27	40.00bC	42.66aC	43.00aD	42.66aC	42.66aC	40.00bC
IPSA- 3	63.00abA	64.66aAB	62.40bC	63.00abB	65.33aB	63.00abB
IPSA -5	58.30cB	63.44cAB	69.00bB	63.00bbB	78.33aA	69.66bA
ACC12890055	61.56bcA	63.00bAB	65.66bB	62.00bB	78.66aA	58.61cBC
GK -63	44.96bC	47.37aC	47.00aD	43.00bcC	41.66bcC	41.00cC
ACC12890053	56.64cB	68.66bA	75.00aA	71.33abA	70.65abA	70.00abA
BUmug -4	43.66bcC	46.06cC	60.60aC	59.00aC	42.66cC	43.00bcC
BARI Mung -6	41.66cC	44.12cC	54.00abC	57.00aC	53.66aC	51.33abC
Binamoog -5	54.33cBC	65.00abA	65.0abB	68.33aAB	60.33bcB	58.33bcBC

Means followed by same small letter (row) and capital letter (column) did not differ significantly at 5% level of probability.

Yield components and yield

Pods plant^{-1}

Number of pods plant^{-1} of mungbean genotypes significantly influenced by the N levels. Increasing nitrogen level led to increase pod plant^{-1} up to 60 kg N ha^{-1} irrespective of genotypes and thereafter decreased due to increase in N rates (Table 3). These results are agreed with the findings of Peter and Patel (1991) they reported that number of pod plant^{-1} of mungbean increased with application of nitrogen fertilizer and excess application reduced pod number of mungbean. There were genotypic variations in pod development where the genotype IPSA 12 produced the highest pods plant^{-1} (30.16) with 60 kg N ha^{-1} and it was statistically similar to IPSA 5 at same N level (Table 3). The lowest number of pods plant^{-1} (16.16) was recorded in genotype GK- 63 which was identical with pods plant^{-1} (16.83) with Binamoog-5 with 100 kg N ha^{-1}. Control plant (no fertilizer with N) produced lower number of pods in all the mungbean genotypes. Plant absorbed nutrient from the soil which is required in the formation of seed is not sufficient in control condition. Increased nitrogen level in the no fertile soil were increased nutrient availability and increased number of pod plant^{-1} up to 60 kg N ha^{-1}.Further increased nitrogen levels nutrient toxicity occur and decreased pod plant^{-1}. These results are supported by Ashraf (2001) that number of pods plant^{-1} was significantly affected by application of N fertilizer. These means that mungbean genotypes require additional N for better pod development although it is capable to fix atmospheric N through rhizobium species living in root nodules (Anjum *et al*., 2006).

Table 3. Number of pods per plant of mungbean genotype as affected by nitrogen level.

Genotype	Nitrogen levels (kg ha^{-1})					
	N_0	N_{20}	N_{40}	N_{60}	N_{80}	N_{100}
IPSA 12	22.00cA	24.83bcA	27.50bA	30.16aA	26.16bA	22.66cA
GK 27	20.00bA	22.50abAB	23.60aB	23.50aC	22.33abB	19.66bB
IPSA 3	19.66cAB	22.16bAB	23.16bB	25.16aB	22.50bB	20.33bcB
IPSA 5	21.83bcA	25.33aA	26.33aA	27.50aB	26.00aA	23.16bA
ACC12890055	20.16cA	23.00abAB	23.16abB	25.00aB	21.66bB	20.83bcB
GK 63	16.83cC	21.33bB	21.63bC	23.33aC	22.33abB	17.16cC
ACC12890053	20.33cA	22.00bcAB	22.66bC	25.83aB	22.00bB	22.16bA
BU mug 4	19.00cAB	22.00bAB	24.16aAB	25.16aC	21.83bBC	21.00bcAB
BARI Mung 6	18.93cB	20.50bB	22.50abC	23.33aC	22.33aB	20.83bBC
Binamoog 5	16.83dC	19.83cC	23.33aB	24.83aC	21.50bB	17.66dC

Means followed by same small letter (row) and capital letter (column) did not differ significantly at 5% level of probability.

Seeds pod^{-1}

Interaction effect of genotype and nitrogen was not significant but genotype had significant effects on seeds pod^{-1} of mungbean (Table 4.). The highest seed pod^{-1} (12.40) was obtained in IPSA 12 and the lowest seed pod^{-1} (10.20) was recorded in BUmug 4 at o kg N ha^{-1}. Seed pod^{-1} was highest in IPSA 12 in control condition because lower number of pod plant^{-1} were obtained in this condition and more nutrient were available in formation in seed but not significantly different with other nitrogen level. These findings are agreed with Asaduzzaman *et al.* (2008) where they reported that nitrogen level and irrigation had no significant effect on seeds pod^{-1}. The number of seeds pod^{-1} is mostly genetically controlled but its number may be regulated by canopy photosynthesis during pod developing stage. Seed number also may be limited by the activity of the source (Akther, 2005). During seed filling, the ability of the individual seed to utilize assimilate determines number of seeds pod^{-1} and limitation of assimilate reduce the seeds pod^{-1} (Jenner *et al.* 1992). This results however contrasting with the findings of Rashid *et al.* (1999) who reported that application of N fertilizer increases seeds pod^{-1} significantly.

Table 4. Number of seeds per pod of mungbean genotype as affected by nitrogen levels.

Genotypes	Nitrogen levels (kg ha^{-1})					
	0	20	40	60	80	100
IPSA 12	12.40A	12.33A	12.13A	12.03A	11.66A	11.83A
GK-27	10.93A	11.11A	10.85A	10.76B	10.76B	10.66B
IPSA 3	11.65A	11.20A	11.91A	11.08A	11.38A	11.05A
IPSA 5	11.46A	12.15A	11.98A	11.96A	11.60A	11.86A
ACC12890055	10.60B	11.20A	11.16A	11.20A	11.00A	11.05A
GK-63	10.83B	11.23A	11.20A	11.36A	10.83A	10.23A
ACC12890053	10.40B	11.65A	11.25A	10.66B	11.23A	10.40B
BU mug 4	10.20B	10.84A	10.65B	11.15A	11.06A	11.20A
BARI Mung 6	10.30B	10.76A	10.75B	11.01A	11.40A	11.11A
Binamoog 5	11.40A	11.28A	10.73B	11.13A	11.10A	11.54A

Means followed by same capital letter (column) did not differ significantly at 5% level of probability.

1000 - seed weight

Thousand seeds weight was not significantly affected by N fertilizer application as it is largely governed by genetic factors. Thus, 1000- seeds weight varied in among the mungbean genotypes where maximum 1000 -seed weight (50.2 g) was recorded in GK -27 which was similar (50.1 g) to GK 63 and the lowest seed

size (34.2 g) was recorded in ACC12890053 (Table 5). In present study although, soil N fertilizer failed to enhanced 1000 -seed weight but it increased in faba bean (Elsheikh and Elzidany, 1997) and groundnut (Chetti *et al.*, 1995) due to soil N fertilizer application.

Table 5. Effect of nitrogen fertilizer on 1000 -seed weight (g) of mungbean genotypes.

Genotypes	Nitrogen levels (kg ha^{-1})					
	0	20	40	60	80	100
IPSA 12	41.5	38.8	38.7	39.2	40.7	40.3
GK-27	50.2	49.4	49.9	49.9	49.7	49.8
IPSA 3	47.1	47.7	46.5	47.8	45.5	46.1
IPSA 5	38.5	38.1	39.5	41.5	41.0	36.8
ACC12890055	43.7	46.2	45.7	43.9	45.9	42.9
GK-63	49.8	50.1	49.9	49.4	49.6	49.7
ACC12890053	34.7	34.2	35.8	34.9	37.7	34.5
BU mug- 4	46.1	43.4	41.6	40.3	43.5	40.8
BARI Mung -6	49.3	48.9	48.9	50.0	49.0	48.6
Binamoog -5	39.0	40.3	37.2	37.0	40.7	41.1

Seed yield $plant^{-1}$

Seed yield $plant^{-1}$ was significantly affected by the interaction of mungbean genotypes and N fertilizer applications. Seed yield of mungbean varied from 7.33 g to 14.22 g $plant^{-1}$ and it was the highest in IPSA 12 (14.22 g $plant^{-1}$) grown with 60 kg N ha^{-1} and the lowest in ACC12890053(7.33 g $plant^{-1}$) under control condition (Table 6). The genotype IPSA 12 however respond well (11.32 g $plant^{-1}$) under control condition. There was general trend of increase seed yield with the increase of N fertilizer up to 60 kg N ha^{-1} and thereafter decreased. Increase nitrogen fertilizer in low fertile soil gradually increased seed yield upto 60 kg N ha^{-1} due to increase pod $plant^{-1}$. These findings agreed with Biswas and Hamid (1989) and Mitra and Ghildiyal (1988) that seed yield of mungbean is limited by nitrogen supply. Application of N fertilizer upto 60 kg N ha^{-1} enhanced leaf area, dry matter production and consequently improved number of pods $plant^{-1}$ and seeds pod^{-1} of mungbean genotypes and hence increased the yield. Plants grown without added nitrogen or lower levels of fertilizer produced the lowest seed yield $plant^{-1}$ irrespective of genotypes. the negative response of higher N doses (beyond 60 kg N ha^{-1}) might be the toxic effect or produced some barriers on nutrition of mungbean plants. Yield of mungbean decrease in beyond 60 kg N ha^{-1} may be explained by quadratic equation $y = 9.37 + 0.101x - 0.001x^2$ as illustrated in Fig. 1. This equation states that seed yield of mungbean is

maximum (11.92 g plant^{-1}) at 54 kg N ha^{-1} and thereafter, yield decrease at the rate of $0.001x^2$ for each unit of applied N fertilizer. The value of R2 (0.97) indicates that the nitrogen rates can account for 97% of the total variable in each yield.

Table 6. Seed yield (g plant $^{-1}$) of mungbean genotype as affected by nitrogen fertilizer.

Genotypes	Nitrogen levels (kg ha^{-1})					
	0	20	40	60	80	100
IPSA 12	11.32Ac	11.87Ac	12.87Ab	14.22Aa	12.41Ab	10.80Ac
GK-27	10.97Ab	12.34Aa	12.80Aa	12.61Ba	11.94Ab	10.43Ab
IPSA 3	10.78Abc	11.83Ab	12.82Aa	13.32ABa	11.65Ab	10.35Ac
IPSA 5	9.60Bc	11.72Ab	12.45Aa	13.64Aa	12.36Aa	10.10Abc
ACC12890055	9.33Bc	11.90Aab	11.81Bab	12.29Ba	10.93Bb	9.87ABb
GK-63	10.06Bb	12.00Aa	12.20Ba	13.09Ba	11.99Aa	9.23ABb
ACC12890053	7.33Dcd	8.49Db	9.12Cab	9.60Ca	9.31BCab	7.95Cc
BU mug 4	8.93Bbc	10.35Bab	10.85Ba	11.14Ba	10.40Bab	9.59ABbc
BARI Mung -6	8.55Bbc	10.78Bb	11.82Bab	12.84Aa	12.40Aa	11.24Aab
Binamoog 5	7.48Dc	8.61Cb	9.31BCab	10.23Ca	9.71Cab	8.37Cbc

Means followed by same small letter (row) and capital letter (column) did not differ significantly at 5% level of probability.

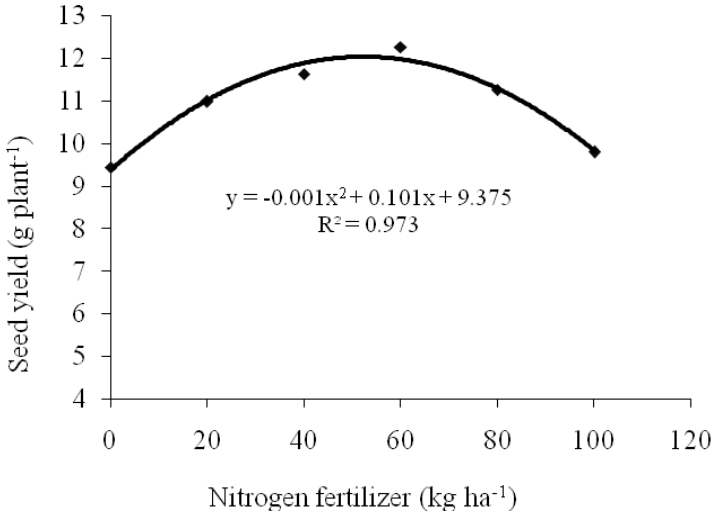

Fig. 1. Relationship between nitrogen fertilizer and seed yield of mungbean genotypes.

Nitrogen acquisition

As nitrogen deficiency in soil of Bangladesh is common (FRG, 2005), the ability of the plants to acquire nitrogen and their efficient use is important for crop adaptation to soils with low fertility. Genotypic differences in nitrogen acquisition revealed that the genotype IPSA 12 acquired maximum amount of nitrogen (0.767 g plant^{-1}) under 60 kg N ha^{-1} and it was the lowest in Binamoog 5 (0.381 g plant^{-1}) at control condition (Table 7). It was observed that most of the mungbean genotype acquired maximum nitrogen at 40 or 60 kg N ha^{-1} except ACC12890053. This genotype needs even 80 kg N ha^{-1} to acquire maximum nitrogen which supposed to be very expensive. Nitrogen regulates soil pH through NH+ and increases P availability (Havlin *et al.*, 2006), and phosphorus enhances nodulation and subsequently accumulates more N in mungbean plants (Marschner *et al.*, 1997).

Table 7. Plant nitrogen acquisition (g plant^{-1}) of mungbean genotypes as affected by different nitrogen levels.

Genotypes	Nitrogen levels (kg ha^{-1})					
	N_0	N_{20}	N_{40}	N_{60}	N_{80}	N_{100}
IPSA 12	0.536	0.639	0.710	0.767	0.662	0.591
GK -27	0.437	0.495	0.533	0.531	0.531	0.483
IPSA 3	0.480	0.506	0.530	0.604	0.555	0.506
IPSA 5	0.430	0.537	0.650	0.676	0.643	0.541
ACC12890055	0.472	0.614	0.674	0.601	0.579	0.510
GK -63	0.402	0.481	0.508	0.525	0.480	0.446
ACC12890053	0.412	0.527	0.584	0.630	0.620	0.526
BUmug 4	0.420	0.516	0.565	0.531	0.517	0.484
BARI Mung -6	0.433	0.492	0.560	0.595	0.554	0.501
Bina moog 5	0.381	0.443	0.534	0.556	0.519	0.46

Conclusion

The results revealed that nitrogen is necessary to ensure better growth and productivity of mungbean with low fertile soil. Increased N level mungbean production increased up to 60 kg N ha^{-1} in low fertile soil irrespective of genotypes. The genotype IPSA 12 performed the best in low fertile soil. The optimum dose of nitrogen for mungbean cultivation in the low fertile soil is 54 kg ha^{-1}.

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PERFORMANCE OF DIFFERENT CROPS PRODUCTIVITY ENHANCEMENT THROUGH ADAPTATION OF CROP VARIETIES AT CHARLAND IN BANGLADESH

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Abstract

Charland that are emerged as islands within the river channel or as attached land to the riverbanks as a result of erosion and accretion. In crop production systems, screening of adaptable crop varieties for charland is necessary to address the climate change issues. Hence, five separate experiments were conducted at charland of the Padma River in Kushtia district during November 2012 to May 2013 to select suitable varieties of lentil, hybrid maize, soybean, potato and mustard for increasing crop productivity. The experiment comprised of four lentil varieties viz. BARI Masur-4, BARI Masur-5, BARI Masur-6 and a local cultivar; four hybrid maize varieties namely BARI Hybrid maize-5, BARI Hybrid maize-7, BARI Hybrid maize-9 and Pacific-11; three soybean varieties like BARI Soybean-5, BARI Soybean-6 and Shohag; four potato varieties viz., BARI Alu-7, BARI Alu-8, BARI Alu-31 and Belgium; and five mustard varieties viz., BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-14, BARI Sarisha-15 and BARI Sarisha-16 were evaluated separately in five trials for their adaptation in charland. Among the studied crops, lentil var. BARI Masur-6, maize var. BARI Hybrid maize-9, soybean var. BARI Soybean-6, potato var. BARI Alu-7 and mustard var. BARI Sarisha-11performed better in the charland under climate change situation in Bangladesh.

Keywords: Crop Productivity, Adaptation, Crop Varieties, Charland, Climate Change.

Introduction

Climate change refers to a change of climate that is attributed directly or indirectly to human activities. Bangladesh is extremely vulnerable to climate change impacts because of its geographical location, high population density, high levels of poverty, and the dependence of many livelihoods on climate-sensitive sectors, particularly agriculture and fisheries. Climate change will result in greater variation in weather patterns or weather events such as irregular floods (Mirza, 2002), increase in droughts (Amin *et al*., 2008), too much rainfall in monsoon and too little rainfall in the dry season (Tanner *et al*., 2007), frequent cyclone and storms (Salauddin and Ashikuzzaman, 2012), gradual rise in average temperature (Islam *et al*., 2008), increase in intrusion of saline water (Ali *et al*.,

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2014), rise in sea-levels (Islam, 1994) as well as frequent river bank erosion and formation of char land (Ahmed, 2006) in Bangladesh. In crop production systems, screening and introducing adaptable crop varieties for char land eco-system would be needed to address the climate change issues.

Chars are the lands that emerge as islands within the river channel or as attached land to the riverbanks as a result of the dynamics of erosion and accretion in the rivers of Bangladesh (Sattar and Islam, 2010). Char land areas are estimated to be 0.72 million hectares in Bangladesh which is about 5% of the country area and about 6.5 million people (5% of the country's population) live there (EGIS, 2000). It is mentionable that 64 to 97% of the char areas are cultivable (Ahmed *et al*., 1987). The Char dwellers mainly depend on agriculture and agriculture related activities. Other opportunities such as off farm activities are marginal there. So, to increase cropping intensity and crop productivity in stress prone areas like charland is urgently needed. Generally farmers in char lands cultivate potato, hybrid maize, sweet potato, mustard, lentil, grasspea, field pea, blackgram, chilli, proso millet, muskmelon, bitter gourd, sweet gourd, groundnut, sugarcane etc. in *rabi* season and *aus* rice, jute, foxtail millet and sesame etc. in *kharif* season with local variety and low management practices. As a result, much lower yield is achieved in char areas (Islam *et al*., 2012). Introduction of new crops with modern varieties (MV) along with appropriate agronomic management practices would boost up the farm productivity that will reduce the poverty level of resource poor farmers of that area.

Improvement of crop productivity and livelihood pattern as well as enhancement of food security of all char land people is very cumbersome in relation to climate change situation. As such char area under Bheramara Upazilla in Kushtia district (Agro-ecological zone 11) was selected as the experimental site. Information relating varietal adaptability of different crops like lentil, mustard, potato, hybrid maize and soybean in the study areas of char land eco-system under climate change situation is meagre. Therefore, five separate experiments were conducted to select adaptable varieties of aforesaid crops for charland of the Padma River under Kushtia district to increase crop productivity in that area.

Materials and Method

Five separate experiments were conducted at Golapnagar char of the Padma River under Bheramara Upazilla in Kushtia district during the period from November 2012 to May 2013. The soil of the experimental area was silty loam in texture belonging to Calcareous Dark Grey Foodplain soil (Agro-ecological zone 11). Soil samples from experimental area were collected from 0-20 cm depth prior to set up experiments and analyzed in the laboratory. Results of soil analysis are presented in Table 1. The soil was neutral in soil reaction, low in organic matter and available P content. Total N and available S content were very

low but medium in exchangeable K and available B content. Each experiment was laid out in randomized complete block design with five disperse replications. The unit plot size was 8m x 10m.

Table 1. Chemical properties of experimental soil

Location	pH	OM (%)	Total N (%)	Available P (µg/ml)	Exchange-able K (meg/100g)	Available S (µg/ml)	Available B (µg/ml)
Golapnagar char	7.04	1.14	0.070	7.33	0.190	5.10	0.285
Status of soil		L	VL	L	M	VL	L

OM= Organic matter, L= low, VL= very low, M= medium.

Experiment 1

Three high yielding lentil varieties viz. BARI Masur-4, BARI Masur-5 and BARI Masur-6 were tested for their adaptability and compared with local variety in charland eco-system under climate change situation. The crop received total rainfall of 13 mm during growing period. The average maximum and minimum air temperatures during crop period were 26.9 ^{o}C and 14.1 ^{o}C, respectively. The initial soil moisture content at the time of sowing was 20-22% by weight. Seeds of lentil were sown 30 cm apart in solid line on 12 November, 2012. Fertilizers @ 20-36-25 kg/ha of NPK (FRG, 2012) were applied at the time of final land preparation in the form of urea, triple super phosphate and muriate of potash. One hand weeding was done at 25 days after sowing (DAS). The crop was harvested on 03 March, 2013 (111 DAS).

Experiment 2

Three BARI developed hybrid maize varieties viz. BARI Hybrid maize-5, BARI Hybrid maize-7 and BARI Hybrid maize-9 were evaluated for their adaptability and compared with Pacific-11(an imported maize hybrid) in char land under climate change situation. The crop received total rainfall of 156 mm during growing period. The average maximum and minimum air temperatures during crop period were 28.9 ^{o}C and 20.5 ^{o}C, respectively. The initial soil moisture content at the time of sowing was 19-21% by weight. Seeds were sown on 27 November in 2012 with 60 cm x 20 cm spacing. The crop was fertilized with 250-55-110-50-5 kg/ha of NPKSZn (FRG, 2012). One third N and full amount of other fertilizers were applied at the time of final land preparation in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate. Rest amount of N were applied in two equal splits at 30 and 60 DAS followed by irrigations. One hand weeding and earthing up was done at 20 and 40 DAS,

respectively. The crop was harvested at maturity stage on 26 April, 2013 (150 DAS).

Experiment 3

Three soybean varieties viz. BARI Soybean-5, BARI Soybean-6 and Shohag were evaluated for their adaptability in char land under climate change situation. The initial soil moisture content at the time of sowing was 18-20% by weight. Seeds were sown with a spacing of 30 cm ×5 cm on 22 January, 2013. The crop received total rainfall of 295 mm during growing period. The average maximum and minimum air temperatures during crop period were 30.6 ºC and 18.4 ºC, respectively. Crops were fertilized with 28-35-60-20 kg/ha of NPK (FRG, 2012) as urea, triple super phosphate, muriate of potash, and gypsum, respectively. All fertilizers were applied during final land preparation as basal. Two irrigations were applied at 30 and 60 DAS. One hand weeding was done at 25 DAS. The crop was harvested at maturity stage on 17 May, 2013 (115 DAS).

Experiment 4

Three BARI developed potato varieties viz. BARI Alu-7 (Diamant), BARI Alu-8 (Cardinal) and BARI Alu-31 (Sagita) were evaluated for their adaptability and compared with Belgium (farmers practicing variety) in char land under climate change situation. The initial soil moisture content at the time of sowing was 22-24% by weight. Potato tubers were planted on 20 November, 2012 with 60 cm x 25 cm spacing. The crop received total rainfall of 13 mm during growing period. The average maximum and minimum air temperatures during crop period were 26.0 ºC and 13.9 ºC, respectively. The crop was fertilized with 198-44-194-24-6-1.2 kg/ha NPKSZnB (FRG, 2012). Half of N and full dose of other fertilizers were applied as basal in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively. The remaining N was top dressed at 30 days after potato planting followed by irrigation. Earthing up of potato and other intercultural operations were done as and when required. The crop was harvested on 25 February, 2013 (97 DAS).

Experiment 5

Five HYV mustard varieties viz., BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-14, BARI Sarisha-15 and BARI Sarisha-16 were tested for their adaptability in char areas under climate change situation. The crop received total rainfall of 14 mm during growing period. The average maximum and minimum air temperatures during crop period were 26.2 ºC and 14.1 ºC, respectively. Mustard was grown with 160-46-120-36-4 kg/ha NPKSZn (FRG, 2012). Half of nitrogen and full quantity of PKSZn were applied as basal in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate,

respectively. The initial soil moisture content at the time of sowing was 22-22% by weight. Seeds of each variety were sown in 30 cm apart solid line on 20 November, 2012. Remaining half of nitrogen was applied at the time of flower initiation (20-25 DAS) as top dressing followed by irrigation. The crop was kept weed free up to 20 DAS by two hand weedings at 10 and 20 DAS. Harvesting of different varieties was done from 12 February to 02 March, 2013 depending on maturity.

In each experiment, data on plant population per square metre were recorded from randomly selected three places and on yield contributing characters from randomly selected 10 plants in each plot. Yield was taken from whole plot. Collected data were analyzed statistically and the means were adjudged using Least Significant Difference (LSD) test at 5% level of significance.

Results and Discussion

Experiment 1

Yield and yield contributing characters of lentil varieties are presented in Table 2. Number of days required from sowing to harvesting (108-111 days) of different high yielding variety (BARI Masur-4, BARI Masur-5, BARI Masur-6) and local variety of lentil did not differ significantly. However, BARI developed lentil varieties required 2-3 days more than local variety. Plant population/m^2 of different lentil varieties were statistically similar and numerically higher in local variety. Number of pods/plant of different lentil varieties varied significantly. The maximum number of pods/plant (67) was recorded in BARI Masur-6, which was statistically identical to BARI Masur-5 (59). The lowest number of pods/plant was observed in local variety. The highest number of pods/plant in BARI Masur-6 was contributed due to profuse pod setting. Number of seeds/pod between BARI Masur-6 (1.9) and BARI Masur-5 (1.8) was statistically at par. The minimum number of seeds/pod was obtained from local variety (1.2). Thousand seed weight i.e. seed size is a genetically controlled trait of lentil. The maximum 1000-seed weight was recorded in BARI Masur-6 (22.5 g) which was statistically identical with BARI Masur-4 (21.4 g) and BARI Masur-5 (21.9g). The lowest 1000-seed weight (18.0 g) was observed in local variety. Seed yield of lentil varieties also differed significantly (Table 2). The maximum seed yield was recorded in BARI Masur-6 (1042 kg/ha) and it was statistically similar with BARI Masur-5 (1032 kg/ha) and BARI Masur-4 (1019 kg/ha). Local lentil variety produced the lowest seed yield (875 kg/ha). Seed yield of BARI developed lentil varieties was 16.5 – 19.1% higher than local lentil variety. The higher seed yield in BARI developed lentil varieties were attributed to higher pods/plant, seeds/pod and 1000- seed weight. Similar findings were obtained by Islam *et al.* (2010). The results revealed that high yielding variety of lentil developed by BARI performed better in char land eco-system under climate change situation.

Table 2. Seed yield and yield contributing characters of lentil varieties at char land eco-systems under climate change situation (Kushtia, 2012-13)

Varieties	Days to maturity	Plant/ m^2 (no.)	Pods/ plant (no.)	Seeds/ pod (no.)	1000 seed wt. (g)	Seed yield (kg/ha)	Yield increase over local (%)
BARI Masur- 4	110	159	54	1.7	21.4	1019	16.5
BARI Masur- 5	111	169	59	1.8	21.9	1031	17.8
BARI Masur- 6	111	154	67	1.9	22.5	1042	19.1
Local variety	108	177	43	1.2	18.0	875	-
LSD $_{(0.05)}$	NS	NS	6	0.1	1.2	150	-
CV (%)	13	11	8	6	4	11	-

NS = Not significant

Table 3. Grain yield and yield contributing characters of hybrid maize varieties at char land eco-systems under climate change situation (Kushtia, 2012-13).

Varieties	Plants /m^2 (no.)	Cobs/ plant (no.)	Grains/ cob (no.)	1000 grain wt.(g)	Grain yield (t/ha)	Yield increase over Pacific 11 (%)
BARI Hybrid maize-5	7.96	1.0	410	312.6	7.14	1.4
BARI Hybrid maize-7	8.24	1.2	403	334.3	9.32	32.4
BARI Hybrid maize-9	8.24	1.2	431	345.0	10.29	46.2
Pacific-11	8.24	1.0	392	311.5	7.04	-
LSD $_{(0.05)}$	NS	0.1	23	10.8	1.18	-
CV (%)	8.2	6	4.1	2.4	10.1	-

NS = Not significant

Experiment 2

Yield and yield components of hybrid maize varieties except plant population/m^2 differed significantly (Table 3). Plant population/m^2 in all maize hybrids was identical but it was slightly lower in BARI Hybrid maize-5 (7.96) due to lower germination of seed. Similar number of cobs/plant (1.2) was recorded in BARI Hybrid maize-7 and BARI Hybrid maize-9 while lower cobs/plant (1.0) was obtained from BARI Hybrid maize-5 and Pacific-11. The maximum number of grains/cob was recorded in BARI Hybrid maize-9 (431) which was identical with BARI Hybrid maize-5 (410). The lowest number of grains/cob (392) was found from Pacific-11 but at par with BARI Hybrid maize-7 (403) and BARI Hybrid maize-5 (410). Thousand grain weight of maize hybrids is a genetically control

parameter but it may be changed through changing the environment of growing place. The maximum 1000-grain weight was obtained from BARI Hybrid maize-9 (345.0g) which was at par with BARI Hybrid maize-7 (334.3g). Grain size of Pacific -11 was minimum (311.5g) followed by BARI Hybrid maize-5 (312.6g). The highest grain yield was recorded in BARI Hybrid maize-9 (10.29 t/ha) and it was statistically identical with BARI Hybrid maize-7 (9.32 t/ha) and these two varieties produced 46.2% and 32.4% higher yield, respectively than Pacific-11 (an imported maize hybrid). On the contrary, yield performance of BARI Hybrid maize-5 (7.14 t/ha) and Pacific-11 (7.04 t/ha) was similar in char areas under climate change situation. The higher grain yield of BARI Hybrid maize-9 and BARI Hybrid maize-7 was contributed to the cumulative effect of yield attributes. Similar findings were reported by Begum *et al.* (2010). The results revealed that BARI Hybrid maize-9 exhibited the best performance in char land areas under climate change situation. Alternately, BARI Hybrid maize-7 could be grown for getting higher grain yield as compared to Pacific-11. Though BARI Hybrid maize-5 is a quality protein variety but failed to show higher yield due to lower cobs/plant and 1000- grain weight and can not be suitable in charland area.

Table 4. Seed yield and yield contributing characters of soybean varieties at char land eco-systems under climate change situation (Kushtia, 2012-13).

Varieties	Days to maturity	Plant/m^2 (no.)	Pods/ plant (no.)	Seeds/ pod (no.)	1000 seed wt. (g)	Seed yield (kg/ha)
BARI Soybean-5	113	35.6	48.8	2.5	141.0	1531
BARI Soybean-6	115	35.9	57.2	2.8	146.0	2099
Sohag	113	36.2	54.3	1.9	107.3	1002
$LSD_{(0.05)}$	NS	NS	4.5	0.1	3.2	185
CV (%)	8.9	9.3	7.2	3.5	2.1	10.3

Experiment 3

Plant population/m^2, number of pods/plant, seeds/pod, 1000-seed weight and seed yield/ha of soybean varieties are presented in Table 4. Plant population/m^2 and days to maturity of different soybean varieties did not differ significantly due to uniform planting system. Number of pods/plant, seeds/pod and 1000-seed weight of soybean varieties varied significantly in char land eco-system under climate change situation (Table 4). BARI Soybean-6 produced profuse pods, as a result, the highest number of pods/plant (57.2) was recorded in this variety and it was statistically identical with Sohag (54.3). BARI Soybean-5 produced minimum number of pods/plant (48.8). Seeds/pod is a genetically controlled trait and sometimes it may be changed by environmental influence. The highest number of seeds/pod (2.8) was obtained from BARI Soybean-6 and the lowest

(1.9) from Sohag. Thousand seed weight followed a similar trend to seeds/pod. Seed yield of soybean varieties differed significantly in char land eco-system. BARI Soybean-6 produced the highest seed yield (2099 kg/ha) while Sohag was the lowest yielder (1002 kg/ha). Yield variation in different soybean varieties was attributed to the cumulative effects of different yield components. Similar finding was also reported by Islam and Biswas (2010). The results revealed that the performance of BARI Soybean-6 was the best in char land eco-system under climate change situation.

Table 5. Tuber yield and yield contributing characters of potato varieties at char land eco-systems under climate change situation (Kushtia, 2012-13).

Varieties	Plant/m^2 (no.)	Tuber/plant (no.)	Tuber wt /plant (g)	Single tuber wt. (no.)	Tuber yield (t/ha)	Yield increase over local (%)
BARI Alu-7 (Diamant)	6.66	9.6	522	54.4	27.82	33.9
BARI Alu-8 (Cardinal)	6.66	8.9	473	53.1	25.18	21.2
BARI Alu-31 (Sagita)	6.66	8.3	460	55.4	24.50	18.0
Local (Belgium)	6.66	6.4	390	60.9	20.77	-
$LSD_{(0.05)}$	NS	0.7	33	3.8	3.11	-
CV (%)	2.3	6.5	5.2	4.9	9.2	-

Experiment 4

Number of tubers/plant, tuber weight/plant, single tuber weight and tuber yield/ha of potato varieties differed significantly (Table 5). Tuber producing capacity of potato varieties was different. BARI developed potato varieties were superior to Belgium (farmers practicing variety) in respect of tubers/plant. The maximum number of tubers/plant (9.6) was recorded in BARI Alu-7 which was statistically identical with BARI Alu-8 (8.9). The minimum number of tubers/plant (6.4) was found from Belgium. Tuber weight/plant varied among potato varieties. The highest tuber weight/plant (522g) was found from BARI Alu-7. Tuber weight/plant of BARI Alu-8 (473g) and BARI Alu-31 (460 g) was at par while the lowest in Belgium (390 g).Tuber weight/plant directly contributed to the variation in yield of potato varieties rather than single tuber weight/plant. The largest sized tuber (60.9 g) was obtained from Belgium variety. On the contrary, tuber size of BARI potato varieties was identical (53.1-55.4 g) and significantly lower than Belgium variety. Tuber yield of potato varieties varied significantly and the highest tuber yield (27.82 t/ha) was obtained from BARI Alu-7 which was at par with BARI Alu-8 (25.18 t/ha). The higher tuber yield in the aforesaid variety was occurred due to tuber/plant and tuber weight/plant though single tuber weight was much lower than Belgium variety.

Similar finding was corroborated with Abdullah *et al.* (2009). Belgium potato variety produced the lowest tuber yield (20.77 t/ha) due to lower tuber/plant as well as tuber weight/plant. Tuber yield of BARI developed potato varieties showed 18.0-33.9% higher than Belgium variety. The results revealed that BARI Alu-7 exhibited the best performance in char land eco-systems under climate change situation. Alternately, BARI Alu-8 might be grown in char land areas.

Experiment 5

Yield and yield components of mustard varieties are presented in Table 6. Number of days required from sowing to harvesting (84-102 days) of mustard varieties differed significantly. The duration of BARI Sarisha-16 was the longest (102 days) which was at par with BARI Sarisha-11 (101 days) and BARI Sarisha-13 (101 days). On the contrary, duration of BARI Sarisha-14 (84 days) and BARI Sarisha-15 (88 days) was identical but 8-14 days shorter than BARI Sarisha-16. Plant population/m^2 of different mustard varieties was statistically similar (55-60 plants/m^2) due to same planting system. On the other hand, number of siliqua/plant was significantly different among the varieties (Table 6). The highest number of siliqua/plant was recorded in BARI Sarisha-11 (155) which was identical with BARI Sarisha-16 (146). Inversely, BARI Sarisha-13 (69) and BARI Sarisha-15 (60) produced statistically similar number of siliqua/plant but much lower than BARI Sarisha-16 (146). The lowest number of siliqua/plant was observed in BARI Sarisha-14 (44). Number of seeds/siliqua is a genetically controlled trait and it also differed significantly in different mustard varieties. BARI Sarisha-14 had the highest number of seeds/siliqua (31). BARI Sarisha-11 (12) and BARI Sarisha-16 (12) produced statistically identical number of seeds/siliqua. Thousand seed weight of mustard varieties also varied significantly. Seed size i.e. 1000-seed weight of BARI Sarisha-13 (3.0 g), BARI Sarisha-14 (3.1 g) and BARI Sarisha-15 (3.2 g) was identical. BARI Sarisha-11 produced the smaller sized seeds (2.8g) which was statistically similar with BARI Sarisha-16 (2.9 g).

Yield is directly proportional to the cumulative effect of yield components. The highest seed yield was recorded in BARI Sarisha-11 (1536 kg/ha) which was at par with BARI Sarisha-16 (1499 kg/ha). The higher seed yields in the aforesaid varieties were occurred due to higher number of siliqua/plant though much lower in seeds/siliqua and also seed size. Mian and Islam (2010) also reported higher seed yield due to higher siliqua/plant. On the contrary, as a short duration varieties, BARI Sarisha-14 (1205 kg/ha) and BARI Sarisha-15 (1267 kg/ha) produced significantly lower yield compared to long duration varieties (101-102 days). The results revealed that BARI Sarisha-11 and BARI Sarisha-16 (long duration varieties) could be grown in char land areas for higher yield but if other crops grown in kharif-I then short duration mustard variety BARI Sarisha-14 and BARI Sarisha-15 may be grown.

Table 6. Seed yield and yield contributing characters of mustard varieties at char land eco-system under climate change situation (Kushtia, 2012-13).

Varieties	Days to maturity	Plant /m^2 (no.)	Siliqua/ plant (no.)	Seeds/ siliqua (no.)	1000- seed wt. (g)	Seed yield (kg/ha)
BARI Sarisha-11	101	59	155	12	2.8	1536
BARI Sarisha-13	101	55	69	25	3.0	1423
BARI Sarisha-14	84	57	44	31	3.1	1205
BARI Sarisha-15	88	60	60	22	3.2	1267
BARI Sarisha-16	102	59	146	12	2.9	1499
$LSD_{(0.05)}$	9.0	NS	9.5	0.9	0.2	111
CV (%)	7.3	10.1	7.5	3.4	5.1	6.0

NS = Not significant

Conclusion

The results revealed that BARI Masur-6 of lentil; BARI Hybrid maize-9 of hybrid maize; BARI Soybean-6 of soybean; BARI Alu-7 of potato and BARI Sarisha-11 of mustard performed the best in Golapnagar charland under climate change situation in Bangladesh.

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IMPACT OF HARVEST STAGE ON SEED YIELD QUALITY AND STORABILITY OF FRENCH BEAN

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Abstract

Good quality seeds are one of the least expensive but vital factors influencing yield potential and key to agriculture progress. Studies were conducted both in the field and laboratory with the objective to observe the impact of harvest stage on the seed, quality and storability of French bean. Five harvest stages viz. H_1-deep green with light yellow colours of pod, H_2-50% green and 50% yellowing of pods, H_3-light brown with few yellow colour pods, H_4-90% brown colour of pods and H_5-100% brown colour and dried pods were considered as treatments for field trial. Harvested seeds were then stored in both cool room and ambient conditions up to 16 months and performed seed quality studies in every 4 months. The treatments combination of laboratory studies were T_1: H_1 seed storage in cool room (SSCR), T_2: H_1 seed storage in ambient (SSAB), T_3: H_2 SSCR, T_4: H_2 SSAB; T_5: H_3 SSCR; T_6: H_3 SSAB; T_7: H_4 SSCR; T_8: H_4 SSAB; T_9: H_5 SSCR and T_{10}: H_5 SSAB. Experiments were laid out in a RCBD and CRD in the field and laboratory, respectively. Results revealed that the highest seed yield and quality of French bean was observed in H_3. On the contrary, seed harvested in H_4 and stored in cool room (with the mean temperature 18-20^{o}C and relative humidity around 60-70%) recorded the highest storability compared to ambient condition. However, seeds harvested in H_3 and H_5 were also showed better storability in cool room as well as ambient conditions. To sum up, all the seed quality parameters were satisfactorily well up to 12 months of storage then it declined in quality.

Keywords: Harvest stage, French bean, seed yield, seed storage, seed quality

Introduction

French bean (*Phaseolus vulgaris* L.) is a pulse crop but used as vegetable in Bangladesh. It is ranked high as cheap sources of nourishing food, rich in protein, carbohydrates, vitamins, calcium, iron etc. The immature pod and tender and also dry beans of French bean has a possibility to meet up a good share of vegetables demand in Bangladesh (BARI, 2011). The crop is generally cultivated in Chittagong hill tracts districts, Sylhet and also some parts of northern region in Bangladesh. The requirement of quality seeds of French bean was 10.5 t ha^{-1} in

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the country but the supply was only 6.2 t ha^{-1} (Rakhi, 2000). There are many factors that can narrow down the gap between potential and farm level yield. Among them, use of quality seed is the most important one (Ahmad, 2001), as quality seeds ensure better germination and increase yield as high as 30% keeping the other factors of production as constant (BARI, 1993). Huda (2001) reported that ten to fifteen percent production could be reduced due to use of poor quality seed. Kumar *et al*. (2002) asserted that seed yield and quality largely depends on the stage of maturity of crops. Results from the study of Mehta *et al.* (1993) found that chickpea seed attained maximum dry matter when most pods are appeared as light brown with a few yellow green colour stages.

Greven *et al*. (2004) reported that later sowing, higher plant populations, desiccation and earlier harvesting reduced seed size of dwarf French beans, but significant differences were found in seed vigour. Seed storability depends on storage conditions (humidity and temperature), moisture content and physical state of seeds, stage of seed maturity, external factors (temperature, relative humidity and micro flora) and genetic factors (Ayyub *et al*., 2007). Although, Mahesha *et al*. (2001) alluded that storability of seed is mainly a genetical character and is influenced by pre-storage history of seed, seed maturation and environmental factors during pre and post-harvest stages. There is hardly any literature available on appropriate harvest stage of French bean in Bangladesh condition where seed quality will be maximized and that will affects on subsequent viability and storability. Considering the above points of view, the present experiments were undertaken to find out the impact of harvest stage on seed, quality and storability of French bean.

Materials and Method

Experimental site, design and management

Studies were conducted at the research field and laboratory of Seed Technology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh during *rabi* season from 2008 to 2011. Five harvest stages viz. H_1-characterized by deep green with light yellow colours of pod, H_2-50% green and 50% yellowing of pods, H_3-light brown with few yellow colour pods, H_4-90% brown colour of pods and H_5-100% brown colour and dried pods were considered as treatments for field trial. Harvested seeds were then stored in both cool room and ambient conditions up to 16 months and conducted seed quality studies in every 4, 8, 12 and 16 Month in the laboratory. Thus, the combination of treatments for laboratory studies were T_1: H_1 seed storage in cool room (SSCR), T_2: H_1 seed storage in ambient (SSAB), T_3: H_2 SSCR, T_4: H_2 SSAB; T_5: H_3 SSCR; T_6: H_3 SSAB; T_7: H_4 SSCR; T_8: H_4 SSAB; T_9: H_5 SSCR and T_{10}: H_5

SSAB. Experiments were laid out in a RCBD and CRD in the field and laboratory, respectively. The unit plot size was 12 m^2. The land was fertilized with 23-75-75-20 kg ha^{-1} of NPKS in the form of Urea, TSP, MoP and Gypsum, respectively. Half of N and all other fertilizers were applied at the time of final land preparation. The rest of N was applied at 30 days after sowing. Seeds of French bean (cv. BARI Jharsheem-I) were sown in furrows @ 60 kg ha^{-1} in 30 cm apart from lines on 22 and 24 November in the year 2008 and 2009, respectively. Before sowing, all seeds were treated with Bavistene @ 0.2 ml kg^{-1} of seed. Field emergences were recorded at 7 and 10 days after sowing of seed and approximately more than 90% seeds germination were recorded. Intercultural operations like weeding viz. two times each at 15 and 40 days after emergence (DAE), thinning at 30 DAE, irrigation two times, each at 30 and 50 DAE, respectively were accomplished. Fungicides Ridomil Gold and Diathene M 45 @ 2 ml l^{-1} of water were sprayed 4 times alternatively at 7-10 days interval for controlling of damping of disease. Pods were then harvested based on the specified treatments. The collected pods were then threshed and seeds were sun dried until the moisture content reach at 10-12%.

Weather recording

The average maximum and minimum air temperatures and total rainfall data were collected from the weather station BRRI, Gazipur in every week during the experimentation. Temperatures and relative humidity data were also recorded daily during storability study trial in the laboratory by using wall thermometer and moisture meter.

Data recording

Data on seed yield was recorded from individual plot and converted into t ha^{-1}. Dried seeds of different harvest stages were stored in air tied tin container at moisture content 11.50% in cool room and ambient conditions up to sixteen months. In every four month, seeds stored in cool room and ambient conditions were sun dried and cooled at normal temperature under shade and then again stored in the same way. The following quality parameters and seed vigour contributing characters of seed were recorded:

Determination of moisture content

Moisture content of seed sample was determined according to ISTA (1999). Moisture content data were taken before storage and every four months of storage of French bean seed. Ground seed samples harvested at different stage were taken into moisture cup and put into a pre heated oven at temperature of 103 ± 2^0C for one hour according to Morshed *et al.* (2003). After cooling, the weight of the container with its cover and contents were taken. The seed samples

were cooled in desiccators and weighted to work out the percent moisture content of the grains. The seed moisture content was determined by dry weight basis and was calculated by the following formula:

$$\text{Seed moisture content} = \frac{M_2 - M_3}{M_2 - M_1} \times 100 \quad \text{..... (A)}$$

Here,

M_1 is the weight in 'g' of the container and its cover, M_2 is the weight in 'g' of the container, its cover and its contents before drying and M_3 is the weight in 'g' of the container, its cover and contents after drying.

Determination of germination percentage

The data on seed germination (%) was carried out by the following formula (ISTA, 1999). For each treatment, 100 seeds were put into large petridishes and then put at room temperature (25 ± 2^0C). After eight days, normal, abnormal and diseased seeds were counted.

$$\text{Seed germination} = \frac{\text{Number of seed germinated}}{\text{Total seed}} \times 100 \quad \text{..... (B)}$$

Measurement of root and shoot length

From the eight days of seedlings, 10 plants were randomly selected. Seedlings were then cut and root and shoot parts were separated and their lengths were measured in each replication of each treatments using centimeter scale.

Determination of fresh and dry weight of seedling

After measurement of root and shoot length, fresh weight and dry weight of seedlings were recorded. Then the roots and shoots were put into paper packet and placed into the preheated oven (70^0C$\pm$ 2^0C) for 48 hours. After cooling in desiccators, the dry weights were taken.

Determination of vigour index

Seed vigour index is calculated and determined by multiplying germination (%) and seedling length (Reddy and Khan, 2001).

Vigour index (VI)=(MRL+MSL)×PG…….(C)

Here,

VI, MRL, MSL and PG are for Vigour index, Mean root length (mm), Mean shoot length (mm) and Percentage germination, respectively.

The collected data were analyzed statistically following the ANOVA technique with the help of MSTAT-C software. The mean differences among the treatments were adjudged by LSD (Gomez and Gomez, 1984). The correlation co-efficient was done for different variables wherever needed.

Results and Discussion

Weather data and results of experiments are presented in Fig.1-5 and Tables 1-5. These are furnished below:

Weather conditions

The air temperature and rainfall regime experienced at the site in 2008-2010 were considered normal for this region and are presented in Fig.1. It was found that average maximum air temperature (34^{o}C) was in the month of April in both the years while the lowest minimum air temperature (just above 9^{o}C) was recorded in middle of January. There was almost no rainfall observed during the growing period (November to February) of French bean both the years except in the last week of February where a very little amount of precipitation (5 mm) was recorded. However, total rainfall was recorded more or less in all rest of the months ranging from 5 mm to well above 160 mm. Average temperature and relative humidity (RH) data during storability study in the laboratory are also presented in Fig. 2 and 3. Fig. 2 shows that in 2009-10, the temperatures in cool room were ranged between 17-19^{o}C from March 2009 to August 2010. While at ambient condition these were varied between 25-32^{o}C except in mid December 2009 to January 2010 where it was remained almost 20-22^{o}C. The RH in cool room was recorded 78-84% up to October 2009 with some minor fluctuations then it increased and peaked (90%) at early December and remained static up to last week of January 2010. From this point, it decreased dramatically to about 68% RH in mid February 2010. After that the RH was 5-12% increasing in trend with some fluctuations up to August 2010, where it was just above 78% in RH. At ambient condition, the RH was just above 35% in March 2009 and after that it was got an increasing in trend having the mean 60-65% RH and reached at apex 78% with some fluctuations in mid July 2009. From this point, there was a decrement of RH (about 45%) up to last week of September then increased up to mid October 2010. After that it turned slightly down up to 1st week of March 2010 with fluctuations. There was a slightly ceiling trend of RH (50%) from mid March to August 2010 (just below 80%) with some fluctuations (Fig. 2).

Similarly, in 2010-11, it was remarked that temperatures in cool room were fluctuated between 18-20^{o}C from March 2010 to August 2011 (Fig. 3). But, ambient temperatures were recorded higher (22-31^{o}C) than cool room during study periods. The cool room temperature ranged from 25-34^{o}C from 3rd week of March to mid May 2010. After that the temperatures were remained within 30-35^{o}C up to mid October 2010 with some fluctuations. The temperature decrement started from end of October and touched the lowest mark about19^{o}C in January 2011. From this point, temperatures rose with some oscillation and reached at peak (35^{o}C) at end of April 2011 and almost unchanged up to August 2011. Observations of RH in cool room during 2010-11 showed that it was just above 80% in early of March and remained static up to August 2010 having the range 65-82% in RH. The RH trend line turned upward and touched the highest mark

88% in November 2010 and then remained the same up to early February 2011. After that it decreased to 68% in RH in mid March 2011 then an upward tendency was observed up to mid June 2011 amounting about 86% RH. After remaining almost the static up to mid August 2011, it was observed decreasing in trend in RH. While in ambient condition, the RH was recorded about 60% in 1st week of March 2010 then deliberately decreased to just above 40% in mid March 2010. From this point there was an increasing in trend of RH with some fluctuations by touching the highest mark around 80% in mid June 2010. After that the RH became static up to mid September 2010 (around 75%) then there was a decrement of RH with some oscillations up to mid December 2010 (around 45%). It was noted that from December 2010 to mid April 2011, the RH was remained around 55% and from this point there was an upward trend of RH up to August 2011 and onward (Fig. 3).

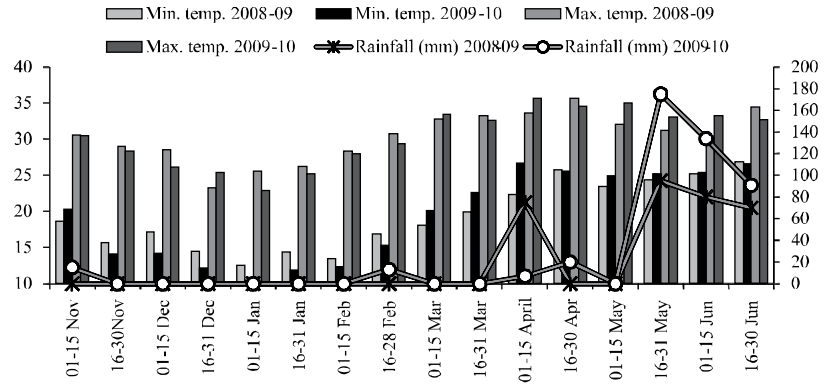

Fig. 1. Average maximum and minimum air temperatures (ºC) and total rainfall (mm) data from November to June in the year 2008-09 and 2009-10 at Joydebpur, Gazipur

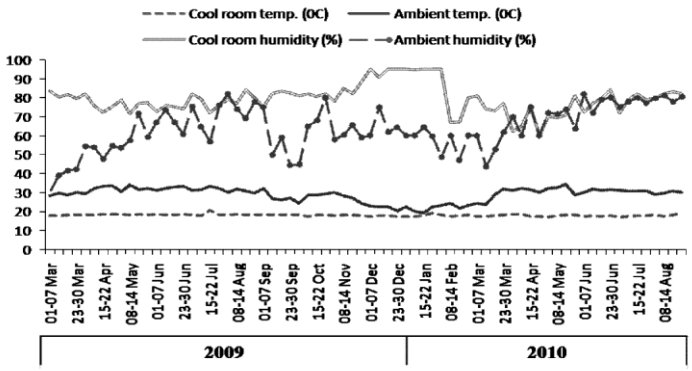

Fig. 2. Temperatures and relative humidity in cool room and ambient storage of French bean during March 2009 to August 2010 (Source: Weather data register book, Seed Technology laboratory, Seed Technology Division, BARI, Gazipur).

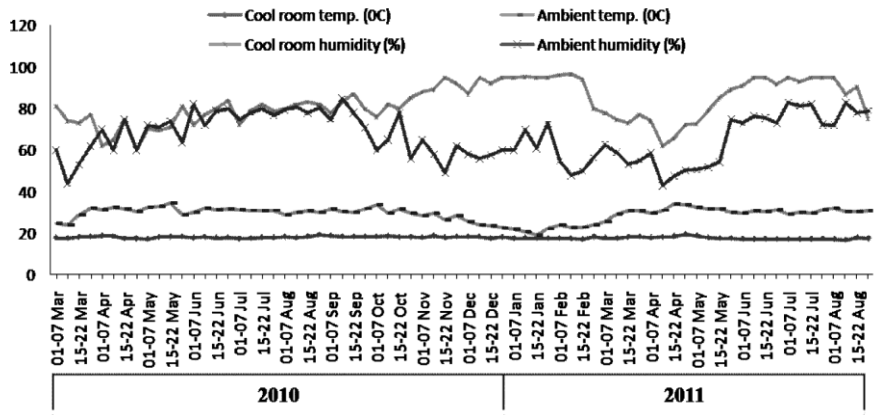

Fig. 3. Temperatures and relative humidity in cool room and ambient storage of French bean during March 2010 to August 2011(Source: Weather data register book, Seed Technology laboratory, Seed Technology Division, BARI, Gazipur).

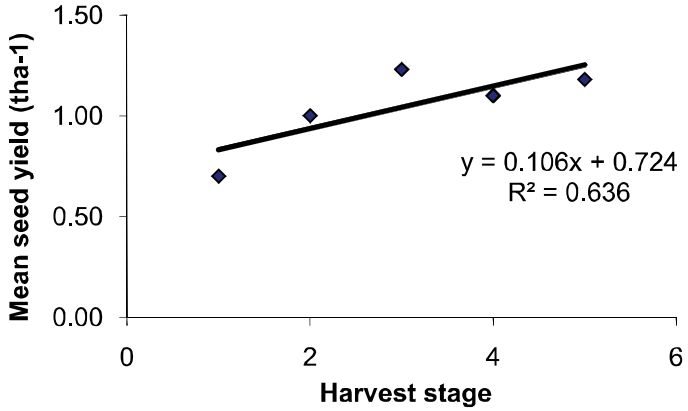

Fig. 4. Relationship between harvest stages on the seed yield of French bean (Pooled of two years).

Seed yield of French bean

Result from the pooled data revealed that seed yield of French bean was significantly influenced due to different harvest stages (Fig. 4). The highest seed yield 1.23 t ha^{-1} was recorded in H_3 and the lowest seed yield (0.69 t ha^{-1}) was obtained in H_1. Pooled of two years regression co-efficient study revealed that associations between harvest stage and with seed yield (r^2 =0.63) showed highly significant positive correlations. The present findings are in agreement with the findings of Khatun *et al.* (2010) who observed that highest seed yield of chickpea was recorded from the pods harvested at light brown with a few yellow green

colour stages. Kavak *et al.* (2012) observed that early and late harvests not only decrease physical quality of seed lots but also decrease seed quality**.** Thus, maximum seed quality of French bean may be ascertained during harvest at physiological maturity (H_3 stage).

Moisture content percentage (MC)

Before storage, the MC of French bean harvested seed was brought at 11.50% (Table 1). Results observed that MC of French bean during storage was significantly influenced by the harvest stage, storage conditions and periods (Table 2). The lowest MC at 4 months (M) storage was recorded in T_9 (12.20%) and T_7 (12.28%) while the maximum MC was observed in T_8 and T_4, respectively. At 8 M storage, the MC was the lowest in T_7 (12.62%) and the maximum was in T_{10} (13.38%). Similar results were also observed in the seed stored after 12 M. However, the minimum MC was recorded in T_7 (12.51%) that was statistically similar to T_5 (12.82%) and T_9 (12.83%). On the contrary, the MC at 16 M storage was the lowest in T_7 (12.59%) and the maximum was in T_8 (14.44%). But, at end of 16 M storage, the MC was increased in trend specially those who had stored in ambient condition (Table 2). Results revealed that moisture content of seeds of all harvest stages found comparatively lower up to 12 M of storage then it increased onwards. Temperature and relative humidity (RH) data both in cool room and ambient storage showed that seeds stored in cool room got cooler temperatures 18-20^{o}C that was much lower than ambient storage in both the years (Fig. 2 and 3). RH was higher all the time in cool room storage compared to ambient one. Therefore, RH around 60-70% and 18-20^{o}C temperature in cool room storage might be favoured to maintain lower MC in the seed that might be played an important role to higher seed storability of French bean. The findings are partially agreed with Ayyub *et al*. (2007) who reported that good storage conditions, low MC of seed, stage of seed maturity etc. are significantly influenced seed storability. The results of this study are also in conformity with the findings of Coolbear (1995).

Germination percentage (GP)

Significant variations were found among seeds of different harvest stage on GP of French bean both at before and during storage (Table 1 and 2). It was revealed that the maximum GP (93.78 and 94.12%) were found in H_3 in the year 2008-09 and 2009-10, respectively which was also similar to H_4 and H_5 for both the years. The lowest GPs (62.7 and 64.11%) were recorded in H_1 for both the years, respectively. On the other hand, the highest GP of French bean seed at 4 M storage was recorded in T_9 (90.22%) while the lowest GP was found in T_1 (58.33%). Similar results were also recorded at 8 and 12 M storage that were statistically similar to T_7 and T_5, respectively. But the lowest GPs were observed

Table 1. Effect of harvest time on the seed quality parameters of French bean before storage.

Treatments*	Moisture content (%)	Germination (%)		Root length (cm)		Shoot length (cm)		Seedling dry weight (g)		Vigour index (VI)	
		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
H_1	11.50	62.67	64.11	8.39	7.98	18.57	19.60	0.11	0.11	1687	1769
H_2	11.50	74.89	73.11	8.52	8.17	19.42	21.25	0.12	0.11	2092	2153
H_3	11.50	93.78	94.12	9.59	10.01	21.25	22.59	0.14	0.13	2891	3069
H_4	11.50	92.89	90.56	9.58	8.97	20.81	20.96	0.14	0.13	2823	2711
H_5	11.50	92.56	92.00	9.26	8.55	21.26	20.91	0.12	0.12	2825	2712
LSD (0.05)	-	5.121	5.218	0.3859	0.7531	0.812	1.131	0.019	NS	118.4	183.8
CV (%)	-	3.26	3.35	2.5	4.58	2.13	2.85	9.88	4.32	2.25	3.93

* H_1-deep green with light yellow colours of pod, H_2-50% green and 50% yellowing of pods, H_3-light brown with few yellow colour pods, H_4-90% brown colour of pods and H_5-100% brown colour and dried pods and Y_1-2008-09 and Y_2-2009-2010.

Table 2. Effect of harvest time, storage condition and periods on the seed moisture content and seed germination of French bean (pooled of two years).

Treatments*	Seed moisture content (%)				Seed germination (%)			
	4 M	8 M	12 M	16 M	4 M	8 M	12 M	16 M
T_1: H_1 SSCR	12.42	12.76	12.81	12.89	58.33	74.11	78.61	75.43
T_2: H_1 SSAB	12.67	12.93	13.59	13.94	60.00	76.67	78.33	75.00
T_3: H_2 SSCR	12.76	13.03	12.85	12.66	73.22	78.17	84.33	87.23
T_4: H_2 SSAB	13.15	12.99	13.40	13.81	72.33	80.67	81.33	79.63
T_5: H_3 SSCR	12.32	12.79	12.82	12.76	88.78	86.22	93.28	87.83
T_6: H_3 SSAB	12.84	13.04	13.67	14.03	83.67	85.00	83.33	84.07
T_7: H_4 SSCR	12.28	12.62	12.51	12.59	85.22	86.61	91.29	87.73
T_8: H_4 SSAB	13.17	13.26	12.68	14.44	82.50	84.50	90.50	85.25
T_9: H_5 SSCR	12.20	12.80	12.83	12.51	90.22	87.89	93.65	87.33
T_{10}: H_5 SSAB	12.74	13.38	13.37	14.00	84.89	86.00	89.50	83.50
LSD(0.05)	0.60	0.15	0.44	0.45	5.92	4.75	5.93	6.94
CV (%)	2.78	2.02	1.95	1.97	4.46	3.37	4.03	4.89

* SSCR-Seed Storage in Cool Room, SSAB-Seed Storage in ambient and M-Month

Table 3. Effect of harvest time, storage period and storage conditions on the seedling root and shoot length of French bean (pooled of two years).

Treatments*	Seedling root length (cm)				Seedling shoot length (cm)			
	4 M	8 M	12 M	16 M	4 M	8 M	12 M	16 M
T_1: H_1 SSCR	8.24	9.68	9.62	9.57	18.93	16.12	16.45	16.83
T_2: H_1 SSAB	8.17	8.88	9.43	9.42	18.42	17.12	15.42	15.93
T_3: H_2 SSCR	8.36	9.51	8.39	9.18	19.26	16.99	15.94	17.46
T_4: H_2 SSAB	8.77	9.24	9.53	9.24	19.33	17.19	16.36	16.39
T_5: H_3 SSCR	9.61	11.47	12.41	11.37	21.46	20.19	19.42	17.98
T_6: H_3 SSAB	9.10	10.52	10.86	10.82	21.03	17.17	18.40	17.07
T_7: H_4 SSCR	9.27	10.87	12.20	11.73	21.53	20.56	18.64	18.83
T_8: H_4 SSAB	8.77	10.28	10.46	10.83	20.77	19.17	17.67	17.02
T_9: H_5 SSCR	9.24	10.71	12.60	11.97	21.07	19.83	19.11	17.42
T_{10}: H_5 SSAB	8.90	10.16	10.57	10.62	20.43	17.49	17.85	16.77
LSD(0.05)	0.42	0.55	0.90	0.65	0.68	1.73	1.21	1.38
CV (%)	2.81	3.22	4.98	3.63	1.99	5.58	4.06	4.74

* SSCR-Seed Storage in Cool Room, SSAB-Seed Storage in ambient and M-Month

in T_1 (74.11%) and T_2 (78.33%) at an end of 8 and 12 M storage, respectively. In case of 16 M storage, the maximum GP of seed was recorded in T_5 (87.33%) that was statistically identical with T_7 (87.73). The lowest GP was recorded in T_2 treatment (75%) (Table 2). Results of this study are in conformity with the findings of Seshu and Dadlani (1989) who reported that higher in seed quality indicated by high seed germination % and vigour of the seed. Poor storage conditions have been reported to cause 10% loss in seed quality (Genchev, 1997). However, Eliud *et al.* (2010) asserted that longevity of bean seeds depends on the ambient temperature and relative humidity at the stockiest stores**.**

Seedlings root length (SRL)

Results observed that harvest stage and storage conditions affected the SRL of French bean both at pre-storage and during storage (Table 1 & 3). The longest SRLs of French bean (9.59 and 10.01 cm) were found in H_3 while the shortest SRLs (8.39 and 7.98 cm) were recorded in H_1 in the year 2008-09 and 2009-10, respectively (Table 1). But, the longest SRL at 4 M storage of French bean was recorded in T_5 (9.61cm) and the shortest SRL was found in T_2 (8.17 cm). Similar results were also recorded at 8 M storage of French bean seed where, the maximum SRL was found at T_5 (11.47 cm) followed by T_7 (1087 cm). It was indicated that the longest SRL of French bean at 12 M storage was obtained in T_9 (12.60 cm) and the shortest SRL was observed in T_2 (9.43 cm). Statistically similar result was also recorded in 16 M storage, where the longest SRL was observed in T_9 (11.97 cm) (Table 3).

Seedlings shoot length (SSL)

It was noted that harvest stage and storage conditions influenced significantly to the SSL of French bean (Table 1 and 3). Similar to SRL, the longest SSLs of French bean before storage (21.26 and 22.59 cm) were remarked in H_5 and H_3 in the year 2008-09 and 2009-10, respectively while the shortest SSLs (18.57 and 19.60 cm) were recorded in H_1 stage in both the years, respectively (Table 1). Results from the storage of French bean seed at different storage conditions showed that the longest SSL at 4 M storage was recorded in T_7 (21.53 cm) while the shortest SSL was found in T_2 (18.42 cm). Similar results were also recorded at 8 M storage of French bean seed. Result indicated that the maximum SSL of French bean at 12 M storage was obtained in T_5 (19.42 cm) that was statistically similar with T_9 (19.11cm) while the shortest SSL was observed in T_2 (15.42cm). Relevant results were also gained in 16 M storage, where the longest SSL was observed in T_7 (18.83 cm) and the shortest SSL was found in T_2 (15.93 cm) (Table 3).

Seedling dry weight (SDW)

SDW of French bean both at before (except in 2nd year) and during storage were significantly influenced by different harvest stage and storage conditions (Table 1 and 4). It was revealed that the highest SDW (0.14 g) was recorded in both H_3 and H_4 while the lowest SDW (0.11g) was found in H_1 and H_2. SDW of French bean at 4 M storage was recorded the maximum (0.134 g) in T_8 followed by T_7 and T_5 (0.132 g) while the lowest SDW (0.111 g) was found T_1. Significantly, the maximum SDW of French bean at 8 M storage was recorded in T_7 (0.144 g) that was followed by T_9 (0.143 g) and the lowest SDW (0.119 g) was gained in T_2. Results found that the highest SDW of French bean at 12 M storage was remarked in T_5 (0.159g) that was statistically similar with T_7 (0.158 g). Furthermore, at 16 M storage, the highest SDW was observed in T_9 (0.148 g) while the lowest SDW was confirmed in T_2 (0.127 g) (Table 4).

Vigour index (VI)

It was observed that VI of before and during storage of French bean was significantly varied due to different harvest stages, storage conditions and periods (Table 1 and 4). It was indicated that the maximum VI of French bean (2891) before storage was recorded in H_3 that was statistically similar with H_5 (2825) and H_4 (2823). Similar trends of VI were also observed in the year 2009-10 (Table 1). Results showed that the highest VI at 4 M storage was recorded in T_5 (2759) while the lowest VI was found in T_1 (1584). The same trends of result were also recorded in VI of French bean at 8 M storage. But, at 12 M storage, significantly higher VI (2972) of French bean was found in T_9 that was statistically similar with T_5 (2971) and T_7 (2814). However, VI of French bean at 16 M storage was found the maximum in T_7 (2681) that was statistically similar with T_5 (2577) and T_9 (2566) while the lowest VI was observed in T_2 (1901) (Table 7). The findings of the present investigation are agreed with Seshu and Dadlani (1989) who reported that higher seed germination % and vigour resulted in better seed quality. The results are also partially agreed with that of Bailly *et el*. (2002) and Ayyub *et al*. (2007).

Correlation

Correlation matrix among the seed quality characters of French bean during storage has been shown in Table 5. A positive and significant correlation was observed between germination percentage and seedling root and shoot length of French bean stored in all 4, 8, 12 and 16 months of storage. Similar results were also observed in case of germination percentage and seedling dry weight and vigour index in all the months of storage. Significantly, a positive and strong correlation was also observed between seedling root and shoot length and seedling dry weight; vigour index and seedling root length and shoot length and

Table 4. Effect of harvest time, storage period and storage condition on the seedling dry weight of French bean (pooled of two years).

Treatments*	Seedling dry weight (g)				Vigour index (VI)			
	4 M	8 M	12 M	16 M	4 M	8 M	12 M	16 M
T_1: H_1 SSCR	0.111	0.124	0.129	0.127	1584	1912	2050	1992
T_2: H_1 SSAB	0.122	0.119	0.148	0.132	1597	1994	1947	1901
T_3: H_2 SSCR	0.119	0.131	0.137	0.136	2023	2071	2052	2324
T_4: H_2 SSAB	0.125	0.128	0.158	0.141	2032	2131	2105	2041
T_5: H_3 SSCR	0.132	0.138	0.159	0.136	2759	2728	2971	2577
T_6: H_3 SSAB	0.130	0.130	0.148	0.144	2521	2352	2438	2346
T_7: H_4 SSCR	0.132	0.144	0.158	0.143	2624	2723	2814	2681
T_8: H_4 SSAB	0.134	0.135	0.147	0.136	2437	2488	2546	2376
T_9: H_5 SSCR	0.131	0.143	0.165	0.148	2735	2683	2972	2566
T_{10}: H_5 SSAB	0.125	0.138	0.159	0.139	2489	2379	2543	2285
LSD(0.05)	0.12	0.12	0.12	0.12	178.4	179.3	239.3	234.8
CV (%)	5.69	5.53	7.79	6.67	4.59	4.49	5.75	5.97

* SSCR-Seed Storage in Cool Room, SSAB-Seed Storage in ambient and M-Month

Table 5. Correlation matrix among different parameters of French bean during storage.

Characters	Months	Correlation coefficient (r value)				
		Moisture content	Germination percentage	Seedling root length	Seedling shoot length	Seedling dry weight
GP	4	-0.010ns				
	8	0.123ns				
	12	-0.264ns				
	16	-0.306ns				
SRL	4	-0.206ns	0.796**			
	8	-0.087ns	0.696**			
	12	-0.280ns	0.731**			
	16	-0.215ns	0.564**			
SSL	4	-0.095ns	0.862**	0.780**		
	8	-0.377*	0.053*	0.660**		
	12	-0.219ns	0.683**	0.812**		
	16	-0.483**	0.454*	0.491**		
SDW	4	0.031ns	0.660**	0.608**	0.527*	
	8	0.154ns	0.709**	0.669**	0.436*	
	12	-0.083ns	0.453*	0.453*	0.400*	
	16	-0.077ns	0.499**	0.371*	0.117ns	
VI	4	-0.060ns	0.490**	0.848**	0.915**	0.655**
	8	-0.149ns	0.869**	0.851**	0.875**	0.678**
	12	-0.290ns	0.912**	0.919**	0.890**	0.508*
	16	-0.397*	0.893**	0.802**	0.733**	0.446*

*Significant at 5% level and ** Significant at 1% level, ns-Not significant

vigour index and seedling dry weight of French bean in all the months of storage. But a negative correlation was found between moisture content and germination percentage of French bean except in the 8 months of storage; seedling root and shoot length, seedling dry weight except in the months of 4 and 8 months of storage and vigour index in all the months of storage. A positive correlation (r=0.596) between germination and dry matter was also found by Mehta *et al.* (1993). They also observed that germination showed negative correlations (r=0.856) with moisture content of seed and (r=0.573) with fresh weight of pod wall. Reddy and Khan (2001) recorded a positive and significant correlation between germination and seedling dry weight (0.68*), vigour index I (0.91**) and vigour index II (0.97**). Similar results were also reported by Khatun *et al.* (2009).

Conclusion

Present investigations revealed that the highest seed yield and seed quality in respect to seed vigour and higher seed germination of French bean was obtained in H_3 (while pods were shown light brown with few yellow in colour). On the contrary, seeds stored in cool room up to 16 month, H_3 (pods appeared 90% of brown in colour) observed the highest storability in terms of higher germination percentage and vigour index. It was also indicated that all the seeds stored in cool room were found better in seed quality compared to ambient condition. However, seeds harvested in H_3 and H_4 also showed better seed quality and storability in cool room as well as ambient conditions. In addition, it was remarked that all the seed quality parameters were satisfactorily well up to 12 months of storage then declined in quality onwards. The findings of present investigations will help researchers to formulate further study of seed preservation of French bean as these seeds lose their germinability rapidly due to poor storage and shorter periods.

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EFFICACY OF SOME INSECTICIDES AGAINST INSECT PESTS OF MUNGBEAN (*Vigna radiata* L.)

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Abstract

Efficacy and profitability of insecticidal management practices using different insecticides were tested against insect pests of mungbean at Pulses Research Center, Ishurdi, Pabna, Bangladesh during two consecutive seasons of kharif-1 2013 and 2014. Insect infestations were reduced significantly by the application of synthetic insecticides. Spraying of Imidachloprid (Imitaf 20 SL) @ 0.5 ml/l of water showed the best efficacy in reducing flower infestation and thrips population followed by Fipronil (Regent 50 SC). Spraying of Thiamethoxam + Chlorantraneliprol (Voliam flexi 300 SC) @ 0.5 ml/l of water showed the best efficacy in reducing pod borer and flea beetle infestations. Spraying of Fipronil (Regent 50 SC) performed highest efficacy against stemfly infestation. The yield and the highest net return were obtained from Voliam flexi 300 SC, the highest benefit was obtained from Regent 50 SC treated plots. This might be due to the higher cost of Voliam flexi that reduced the profit margin and showed the lower marginal benefit cost ratio (MBCR) compared to Regent. Therefore, considering the efficacy and benefit, spraying of Fipronil (Regent 50 SC) @ 0.5 ml/l is the most profitable insecticidal management approach against insect pests of mungbean followed by Imidachloprid (Imitaf 20 SL) at the same dose.

Keywords: Insecticide, management, insect pests, mungbean

Introduction

Mungbean (*Vigna radiata* L.) is one of the important pulse crops in Bangladesh. Due to availability of short duration varieties, farmers are becoming more interested to cultivate this valuable crop after harvesting of rabi crops in kharif-I season. However, insect pests usually cause significant yield loss. More than twelve species of insect pests were found to infest mungbean in Bangladesh (Rahman *et al*., 2000). Among them, stemfly, flea beetles, flower thrips and pod borers are the most important.

Larvae of stemfly feed inside the main stem and finally tunnels even up to roots. The affected plants have stunted growth with poor yield. The adult flea beetles feed on the cotyledons and leaves of young plants making innumerable round holes. The damaged leaves dried up and the plant growth is rendered with few pods. Thrips (*Megalurothrips distalis* Karny, *Megalurothrips usitatus* Bagnall and *Caliothrips indicus* Bagnall) is associated mostly with the damage of tender buds and flowers of mungbean. Severe infestation of thrips resulted flower shedding causing significant yield loss (Chhabra and Kooner, 1985; Lal, 1985).

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Pod borer is another insect pest causing significant yield reduction. Pod borer (*Maruca vitrata*) damages flowers, flower buds and developing or mature pods (Poehlman, 1991). In Bangladesh, pod borers (*Maruca vitrata*, *Helicoverpa armigera* Hubner and *Euchrysops* spp.) often cause serious problem resulting severe loss of the crop (Bakr, 1998). Farmers usually do not take any measure to control the insect pests due to its low profit margin. However, recent development of high yielding and short duration varieties and increased market value of mungbean, farmers become interested on the cultivation of mungbean following pest management measures. Due to easy availability of insecticides, farmers generally take action to control mungbean pests by applying synthetic chemical insecticides. Information regarding insecticidal management practices of insect pests in mungbean is not very available. Therefore, it is needed to develop insecticidal management approach to control mungbean pests and save the crop from significant yield loss. Keeping this in view, attempts have been made to evaluate the efficacy of some synthetic insecticides and economics of the management of mungberan insect pests.

Materials and Method

The experiment was conducted in the Pulses Research Center, Ishurdi, Pabna, Bangladesh during two consecutive seasons of kharif-I 2013 and 2014. Application of synthetic insecticides considered as treatments of the experiments which were: T_1 = Spraying Cypermethrin (Ripcord 10 EC) @ 1 ml/l of water, T_2 = Spraying Chlorpyrifos + Cypermethrin (Nitro 505 EC) @ 1 ml/l of water, T_3 = Spraying Lambda Cyhalothrin (Reeva 2.5 EC) @ 1 ml/l of water, T_4 = Spraying Dimethoate (Tafgor 40 EC) @ 2 ml/l of water, T_5 = Spraying Thiamethoxam + Chlorantraneliprol (Voliam flexi 300 SC) @ 0.5 ml/l of water, T_6 = Spraying Emamectin Benzoate (Wonder 5 G) @ 1 g/l, T_7 = Spraying Fipronil (Regent 50 SC) @ 0.5 ml/l of water T_8 = Spraying Imidachloprid (Imitaf 20 SL) @ 0.5 ml/l of water and T_9 = Untreated control (water spray)

The experiment was laid out in randomized complete block design (RCBD) with three replications. The treatments were randomly allotted in each block. The unit plot size was 3m X 4m with a distance of 1m between the plots and 1.5m between the replications. The seeds of BARI Mung 6 were sown on March 28 in rows with the spacing of 30 cm in both the seasons. The plant populations were maintained constant by keeping plant to plant distance 7 cm. Urea, triple super phosphate and muriate of potash fertilizers were applied @ 40-90-40 kg/ha in both the seasons. But in 2014, 7.5 kg/ha boric acid was applied during final land preparation for reducing flower shedding and increasing pod setting with higher number of seed setting.

Three sprays were done, first at 20 days after sowing (DAS) when plants were in active vegetative growth stage (i.e., two trifoliate leaf stage) against leaf feeding and sucking insect pests. Second spray was done at 100% flowering stage (35 DAS) and the third at 100% podding stage (42 DAS) for flower thrips and pod borers because both the pests appeared that time.

The population data for thrips in flowers were collected before spraying and one day after spraying. Thrips population was assessed from 20 opened flowers which were randomly collected from two rows of each side of the plot avoiding border and central four rows. The collected flowers were immediately opened on the white paper board and counted the adult and immature thrips present in the flowers. Central four rows were kept undisturbed for recording yield data.

Percentage of leaf area damaged by flea beetle was determined by eye estimation.

At the maturity, all pods were collected from 10 randomly selected plants from central four rows of each plot and examined. The infested (bored) and total numbers of pods were counted and the per cent pod infestation was calculated.

For recording stemfly infestation, ten mature plants were randomly selected also uprooted from two rows from each side of the plot avoiding border rows of each plot. The plants were brought to the laboratory and dissected the stem of each plant for determining the tunnel produced by stemfly larvae. Percentage of stemfly infestation was determined on the basis of stem tunneling.

The pods of central four rows of each plot comprising 4.8m^2 (1.2m X 4m) area were harvested. The pods were then threshed; grains were and. The grains obtained from each plot were cleaned, sun dried and converted into kg/ha.

The experimental data were analyzed by MSTAT-C software. The per cent infestation data were transformed by square root and arc sine transformation as needed for statistical analysis. Mean comparisons for treatment parameters were compared using Duncan's Multiple Range Test at 5% level of significance.

The marginal benefit cost ratio (MBCR) was calculated on the basis of prevailing market prices of mungbean and cost of insecticidal spraying. Marginal benefit cost ratio was calculated as follows:

$$\text{Marginal BCR} = \frac{\text{Benefit over control}}{\text{Cost of treatment}}$$

Results and Discussion

Effect of insecticides on flower infestation and thrips population

Spraying of synthetic insecticides reduced flower infestation and thrips population significantly (Table 1 & 2). During 2013, after one day of spray application, the lowest number of infested flower (1.67/20 flowers) was observed in Imitaf sprayed plots which was statistically identical to Regent, Nitro, Ripcord, Voliam flexi and Tafgor. More than 80% flower infestation reduction was observed in Imitaf and Regent sprayed plots. Accordingly the lowest number of thrips (2.00/20 flowers) was observed in Imitaf sprayed plots which was statistically similar to Regent, Nitro, Ripcord and Reeva. All insecticides reduced more than 80% thrips population but Voliam flexi reduced little beat less (Table 1).

In 2014, after one day of spray application, the lowest number of infested flower (0.83/20 flowers) was observed in Imitaf sprayed plots which was statistically identical to Nitro, Regent, Voliam flexi, Reeva and Tafgor. Like previous year Imitaf also reduced more than 80% flower infestation. Accordingly the lowest number of thrips (1.33/20 flowers) was observed in Imitaf sprayed plots which was statistically at par with Regent. Imitaf reduced more than 80% thrips population also (Table 2). These findings were agreed with the findings of Bhede *et al.* (2008) who reported the best effect of Imidachloprid for control of thrips in chilli. Hossain *et. al.* (2013) cited the best efficacy of Fipronil (Regent 50 SC) in managing thrips of onion with highest benifit. Hossain *et al.* (2011) and Hossain (2014) also found the best results of Imidachloprid (Imitaf 20 SL) to reduce flower infestation and suppression of thrips population in mungbean flowers.

Effects of insecticides on the incidence of stemfly, flea beetle and pod borers

Stemfly infestation varied depending on the efficacy of the insecticides. During cropping season of 2013, stemfly infestation among different treatments was non significant but varied 40.67 to 63.33% (Table 3). The lowest infestation (40.67%) was found in Voliam flexi sprayed plots and the highest (63.33%) was observed in untreated control plots.

In 2014, stemfly infestation significantly varied among the treatments. It ranged 40.00 to 80.00% (Table 3). The lowest infestation (40.00%) was found in Regent sprayed plots which were statistically similar to Voliam flexi, Wonder and Reeva. The highest (80.00%) was observed in untreated control plots.

Leaf area damaged by flea beetle was also varied among the insecticidal sprays. During 2013, it was non significant and ranged from 5.33 to 9.67% (Table 3). The lowest percentage of leaf area damaged by flea beetle (5.33%) was observed in Voliam flexi, Regent, and Reeva treated plots and the highest was in untreated plots.

But in 2014, leaf area damaged by flea beetle was significantly varied and ranged from 3.00 to 18.00% (Table 3). The lowest percentage of leaf area damaged by flea beetle (3.00%) was observed in Voliam flexi followed by Wonder and the highest (18.00%) was in untreated plots.

Pod borer infestation was low to moderate but varied significantly among the efficacy of the treatments. During 2013, pod infestation was low and varied from 1.02 – 8.02% (Table 3). The lowest pod borer infestation (1.02%) was found in Voliam flexi sprayed plots which were statistically similar to Reeva, Nitro, Dimethoate, Wonder, Imitaf and Regent. The highest pod infestation (8.02%) was found in untreated plots.

In 2014, pod borer infestation was moderate and it varied from 3.10 – 10.64% (Table 3). The lowest pod borer infestation (3.10%) was found in Voliam flexi sprayed plots which were statistically similar to Wonder, Regent, Nitro and Tafgor. The highest pod infestation (10.642%) was found in untreated plots.

Table 1. Efficacy of insecticides on the incidence of flower infestation and thrips population in mungbean during Kharif-1, 2013.

Treatments (Insecticides)	Dose	Mean no. of thrips infested flowers/20 open flowers		Reduction of flower infestation after 1 day of spray (%)	Mean no. of thrips/ 20 open flowers		Reduction of thrips population after 1 day of spray (%)
		Before spray	After 1day of spray		Before spray	After 1 day of spray	
Cypermethrin (Ripcord 10 EC)	1 ml/l	14.33 b-d	3.67 bc	74.39	27.67 c	4.67 b-d	83.12
Chlorpyrifos + Cyp. (Nitro 505 EC)	1 ml/l	14.00 cd	3.00 bc	78.57	27.67 c	3.33 cd	87.97
Lambda Cyhalothrin (Reeva 2.5 EC)	1 ml/l	16.00 a-c	4.67 b	70.81	39.67 a	5.00 b-d	87.40
Dimethoate (Tafgor 40 EC)	2 ml/l	16.00 a-c	4.33 bc	72.94	37.33 ab	5.33 bc	85.72
Thiamethoxam + Chlorantraneliprol (Voliam flexi 300 SC)	0.5 ml/l	12.67 d	3.67 bc	71.03	25.00 c	6.67 b	73.32
Emamectin Benzoate (Wonder 5 G)	1 g/l	16.33 ab	4.67 b	71.40	36.67 ab	6.00 bc	83.64
Fipronil (Regent 50 SC)	0.5 ml/l	15.00 a-c	3.00 bc	80.00	31.00 bc	3.33 cd	89.26
Imidachloprid (Imitaf 20 SL)	0.5 ml/l	14.67 a-d	1.67 c	88.62	27.67 c	2.00 d	92.77
Untreated control (water spray)	500 l/ha	16.67 a	13.00 a	22.02	41.00 a	24.67 a	39.83

Note: In a column, treatment means having the same letter(s) are not significantly different by DMRT at 5% level.

Table 2. Efficacy of insecticides on the incidence of flower infestation and thrips population in mungbean during Kharif-1, 2014.

Treatments (Insecticides)	Dose	Mean no. of thrips infested flowers/20 open flowers		Reduction of flower infestation after 1 day of spray (%)	Mean no. of thrips/ 20 open flowers		Reduction of thrips population after 1 day of spray (%)
		Before spray	After 1day of spray		Before spray	After 1 day of spray	
Cypermethrin (Ripcord 10 EC)	1 ml/l	6.83	2.17 b	68.22	8.17 c	3.50 bc	57.16
Chlorpyrifos + Cyp. (Nitro 505 EC)	1 ml/l	6.17	1.33 bc	78.44	10.33 bc	3.0 bc	70.96
Lambda Cyhalothrin (Reeva 2.5 EC)	1 ml/l	7.33	1.83 bc	75.03	10.83 bc	4.17 b	61.50
Dimethoate (Tafgor 40 EC)	2 ml/l	8.50	1.83 b	78.47	14.33 ab	4.33 b	69.78
Thiamethoxam + Chlorantraneliprol (Voliam flexi 300 SC)	0.5 ml/l	6.50	1.67 bc	74.30	7.83 c	2.33 cd	70.24
Emamectin Benzoate (Wonder 5 G)	1 g/l	8.50	2.00 b	76.47	13.17 ab	3.50 bc	73.42
Fipronil (Regent 50 SC)	0.5 ml/l	6.50	1.67 bc	74.31	7.83 c	2.33 cd	70.24
Imidachloprid (Imitaf 20 SL)	0.5 ml/l	6.67	0.83 c	87.55	10.17 bc	1.33 d	86.92
Untreated control (water spray)	500 l/ha	8.67	7.00 a	19.26	16.33 a	10.67 a	34.66
-	-	ns	-	-	-	-	-

Note: In a column, treatment means having the same letter(s) are not significantly different by DMRT at 5% level.

Table 3. Efficacy of insecticides on the incidence of stemfly, flea beetle and pod borer in mungbean during 2013 and 2014.

Treatments (Insecticides)	Stemfly infested plant (%)		Leaf area damaged by flea beetle (%)		Pod infestation by pod borer (%)	
	2013	2014	2013	2014	2013	2014
Cypermethrin (Ripcord 10 EC)	50.00	73.33 abc (59.33)	6.33	10.00 d (3.15)	4.54 ab (2.11)	6.95 b (2.63)
Chlorpyrifos + Cyp. (Nitro 505 EC)	50.00	76.67 ab (56.56)	6.33	11.00 d (3.26)	2.07 bc (1.16)	4.50 bcd (2.11)
Lambda Cyhalothrin (Reeva 2.5 EC)	50.00	56.67 bcd (49.23)	5.33	13.00 bc (3.65)	2.06 bc (1.17)	6.58 bc (2.55)
Dimethoate (Tafgor 40 EC)	53.33	70.00 abc (57.10)	6.00	16.00 ab (4.0)	2.07 bc (1.16)	5.10 bcd (2.26)
Thiamethoxam + Chlorantraneliprol (Voliam flexi 300 SC)	40.67	53.33 cd (47.21)	5.33	3.00 f (1.73)	1.02 c (0.81)	3.10 d (1.75)
Emamectin Benzoate (Wonder 5 G)	50.00	56.67 bcd (49.14)	5.67	5.33 e (2.30)	2.39 bc (1.54)	3.56 d (1.87)
Fipronil (Regent 50 SC)	56.67	40.00 d (39.44)	5.33	16.67 a (4.07)	2.74 a-c (1.65)	4.25 cd (2.05)
Imidachloprid (Imitaf 20 SL)	40.33	70.00 abc (57.62)	6.33	12.00 cd (3.46)	2.39 bc (1.54)	6.23 bc (2.48)
Untreated control (water spray)	63.33	80.00 a (68.28)	9.67	18.00 a (4.24)	8.02 a (2.83)	10.64 a (3.25)
-	ns	-	ns	-	-	-

Means in a column having same letter(s) did not differ significantly at 5% by DMRT.

Values in the parentheses are the arc sine and square root transformed mean values.

In both the years Voliam flexi performed the best in suppressing pod borer infestation. These findings agreed with the findings of Rouf and Islam (2012) and Hossain (2014) who reported that the best efficacy of Voliam flexi in controlling pod borers of mungbean.

Yield, return and marginal benefit cost ratio (MBCR)

Yield of mungbean varied significantly with the level of insect pest's infestation depending on the efficacy of different insecticides (Table 4). During 2013, the highest yield (1570 kg/ha) obtained from Regent sprayed plots which was statistically identical to Wonder, Tafgor, Voliam flexi and Imitaf followed by Ripcord, Nitro and Reeva. The lowest yield (1166 kg/ha) was recorded from untreated control plots.

But in 2014, the highest yield (2347 kg/ha) obtained from Voliam flexi sprayed plots which was statistically identical to Tafgor and Wonder followed by Regent, Ripcord and Imitaf. The lowest yield (1701 kg/ha) was recorded from untreated control plots (Table 3). Considering two years average yield Voliam flexi provided the highest. Again, it is apparent that yield of mungbean was higher in kharif-I of 2014 than that of 2013. This might be due to the less thrips infestation with relatively favourable weather condition prevailing in kharif-I of 2014 compared to 2013 and also with boric acid application during 2014 cropping season might have some effect to produce more pods and seeds which influencing higher yield in later season. Alam *et. al*. 2010, Quddus *et. al*. 2011 and Abou EL-Yazied and Mady 2012 cited the positive effect of boron application to increase yield of mungbean. They reported that application of boric acid increased number of formed flowers, setted pods per plant, seed yields, as well as reduced shedding of flowers and pods.

Return and marginal benefit cost ratio are also presented in Table 4. The net return and marginal benefit cost ratio was varied depending on cost of insecticidal application. During 2013, the highest net return (Tk 21390/ha) was recorded from Regent sprayed plots followed by Wonder (Tk 15780/ha). And accordingly the highest monetary benefit (MBCR 7.51) come from Regent sprayed plots. But the second highest benefit (MBCR 4.78) obtained from Imitaf followed by Tafgor (MBCR 4.07). Due to higher cost of Wonder and Voliam flexi profit margin goes down and showed lower MBCR.

For each taka spent, Regent gave profit of Tk 7.51 as against Tk 4.78, Tk 4.07, Tk 2.77, Tk 2.43, Tk. 2.01, Tk. 1.98 and Tk. 1.48 in Regent, Imitaf, Tafgor, Wonder, Ripcord, Voliam flexi, Reeva and Nitro, respectively.

During 2014, the highest net return (Tk 33060/ha) was recorded from Voliam flexi sprayed plots followed by Tafgor, Wonder, Regent, Ripcord and Imitaf. But the highest monetary benefit (MBCR 7.34) also comes from Regent sprayed plots followed by Tafgor, Imitaf, Ripcord, Voliam flexi and Wonder. Though the Voliam flexi offered the highest net return but its higher cost broad down the profit margin and showed lower MBCR.

Table 4. Yield, cost and return analysis of insecticidal management on of mungbean insect pests during kharif-1, 2013 and 2014.

Treatments (Insecticides)	Yield (kg/ha)		Addl. yield over control (kg/ha)		Addl. return over control (Tk/ha)		Cost of insecticide appl. (Tk/ha)		Net return (Tk/ha)		Marginal benefit cost ratio	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Cypermethrin (Ripcord 10 EC)	1355 bc	2077 b	189	376	11340	22560	3300	3300	8040	19260	2.43	5.84
Chlorpyrifos + Cyp. (Nitro 505 EC)	1321 c	1842 d	155	141	9300	8460	3750	3750	5550	4710	1.48	1.26
Lambda Cyhalothrin (Reeva 2.5 EC)	1300 c	1877 cd	134	176	8040	10560	2700	2700	5340	7860	1.98	2.91
Dimethoate (Tafgor 40 EC)	1483 a	2188 ab	317	487	19020	29220	3750	3750	15270	25470	4.07	6.79
Thiamethoxam + Chlorantraneliprol (Voliam flexi 300 SC)	1452 ab	2347 a	286	646	17160	38760	5700	5700	11460	33060	2.01	5.80
Emamectin Benzoate (Wonder 5 G)	1524 a	2195 ab	358	494	21480	29640	5700	5700	15780	23940	2.77	4.20
Fipronil (Regent 50 SC)	1570 a	2097 b	404	396	24240	23760	2850	2850	21390	20910	7.51	7.34
Imidachloprid (Imitaf 20 SL)	1448 ab	2047 bc	282	346	16920	20760	2925	2925	13995	17835	4.78	6.10
Untreated control (water spray)	1166 d	1701 d	-	-	-	-	-	-	-	-	-	-

Addl. = Additional, appl. = application.

For calculating income and benefit the following market prices were used: Mungbean = Tk. 60/kg.

Ripcord 10 EC = Tk. 140/100 ml, Nitro 505 EC = Tk. 170/100 ml, Reeva 2.5 EC = Tk. 100/100 ml, Tafgor 40 EC = Tk. 85/100 ml, Voliam flexi 300 SC = Tk. 600/100 ml, Wonder 5 G = Tk. 300/100g, Regent 50 SC = Tk. 220/100 ml and Imitaf 20 SL = Tk. 230/100 ml. Labour wage for spraying insecticides = Tk. 200/day/labourer (8 hours day).

For each taka spent, Regent gave profit of Tk 7.34 as against Tk 6.79, Tk 6.10, Tk 5.84, Tk 5.80, Tk. 4.20, Tk. 2.91 and Tk. 1.26 in Tafgor, Imitaf, Ripcord, Voliam flexi, Wonder, Reeva, and Nitro, respectively.

These profit findings showed very encouraging results of spraying in mungbean. Spraying of Imidachloprid (Imitaf 20 SL) @ 0.5 ml/l of water showed the best efficacy in reducing flower infestation and thrips population followed by Fipronil (Regent 50 SC). Spraying of Thiamethoxam + Chlorantraneliprol (Voliam flexi 300 SC) @ 0.5 ml/l of water showed the best efficacy in reducing pod borer and flea beetle infestation. Spraying of Fipronil (Regent 50 SC) performed best against stemfly infestation. Therefore, considering overall efficacy and benefit spraying of Fipronil (Regent 50 SC) at the concentration of 0.5 ml/l is the most profitable insecticidal management approach against insect pests of mungbean in Bangladesh followed by Imidachloprid (Imitaf. 20 SL) at the same dose.

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FARM LEVEL IMPACT STUDY OF POWER TILLER OPERATED SEEDER ON SERVICE PROVIDERS' LIVELIHOOD IN SOME SELECTED SITES OF BANGLADESH

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Abstract

The custom hiring of power tiller operated seeder (PTOS) is highly profitable at farm level and service providers could improve their livelihood through this machine. The data and information on these aspects are scarce in Bangladesh. Therefore, an attempt was made to conduct this study to assess the uses pattern and the impacts of PTOS operations on service providers' livelihood. A total of 53 service providers were randomly selected and interviewed for this study from Dinajpur and Rajbari districts. The study revealed that most respondents provided PTOS services almost throughout the year. The custom hiring of PTOS created many positive impacts on the livelihoods of the service providers. PTOS made a remarkable improvement in the livelihoods of its service providers in the study areas. The respondent service providers experienced a considerable increase in their land holdings (8.6%), annual income (63.4%), livestock resources (44%), farm equipment (20%), household assets position, and dwelling houses (42%). The increased income of beneficiaries are mostly spent on farm machinery, nutritious food, cloths, health care, education, and making of houses that indicate higher standard of riding to some extent, compared to pre PTOS service period. The service providers faced some problems like higher fuel cost, lack of riving facility, non-availability and higher price of spare parts, roller jam, and lack of trained driver. Financial support and technical assistance regarding PTOS should be made available by the government for service providers and local manufacturers for the higher adoption of PTOS in Bangladesh.

Keywords: PTOS, custom hire, service provider, livelihood.

1. Introduction

Most tillage operations in Bangladesh are now done by power tiller (PT) for lower cost and require less time for cultivation (Islam, 2000; Miah, 2000; Barton, 2000; Miah *et al*., 2002; Haque *et al*., 2008). This tillage implement is introduced basically for land preparation, but now it is used for different purposes depending on environment, ability of farmers for buying attachments, and availability of credit facilities. The percentage of area cultivated under PT is 67% and the average growth rate of power tillers in Bangladesh was 21% during 1993-2003

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(Quayum and Ali, 2012). There are about 7,00,000 PTs in Bangladesh (Hossain, 2014). The traditional tillage method reduces soil organic carbon at double rate and decreases soil fertility (Grace, 2003), losses irrigation water and soils (Sayre and Hobbs, 2003), and damages ecological environment (Grace, 2003). Therefore, the concept of conservation tillage has been arisen all over the world which is relatively new in Bangladesh.

PTOS is a two wheel tractor operated seed drill and widely used for various crop establishments through conservation tillage, sowing of seeds and laddering operations are done simultaneously in a single pass in many areas of Bangladesh. Three operations could be done in one operation, i.e., prepare lands with fine tilth, sowing seeds at the 2-3 cm depth and planking simultaneously. It performs well at 15 to 36% of soil moisture level. If optimum soil moisture exists, it could reduce turn-around-time up to zero days in between two crops establishment. It's width of operation is 120cm having six rows sowing capacity at a time.

The service providers remove seeding unit from PTOS and convert only for High Speed Rotary Tiller (HSRT). Most of the grain seeds like wheat, paddy, maize, jute, pulses, oilseeds etc are sown in line using PTOS. The owners of PTOS are using this device for their own land cultivation and earning cash income through custom hiring to other farmers. The use of PTOS is getting popularity throughout the country since its spare parts, repair and maintenance mechanics and workshops are available at the village level. Nevertheless, the custom hiring of PTOS is highly profitable at farm level (Miah *et al*. 2010) and many service providers could improve their livelihood through this machine. The socioeconomic impacts of this popular conservation tillage implement have not been done in the country. Therefore, an attempt was made to conduct this study with the following objectives.

Objectives

a) To describe the socio-economic profile of the PTOS service providers;

b) To determine the impacts of PTOS on the livelihoods of service providers; and

c) To find out the uses pattern and problems of PTOS at service providers' level.

2. Methodology

Sampling and data collection: The present study followed purposive sampling technique in order to select study areas and sample service providers. At first stage of sampling, four *Upazillas* namely Bochagonj, Fulbari and Dinajpur Sadar under Dinajpur district and Baliakandi under Rajbari district were purposively selected for the study. The reason of this selection was that PTOS is being widely

used in the aforesaid study areas. In Rajbari, PTOS is being used for sowing wheat, jute, and sesame seed directly. In Dinajpur, it is widely used for planting the seeds of wheat, maize, chickpea, lentil, mungbean, jute and sesame. Nevertheless, PTOS is also being used for land preparation for transplanting onion and garlic seedlings, paddling rice field in both the areas.

A total of 53 service providers[1] taking 47 persons from Rajbari and six persons from Dinajpur district were randomly selected for the study. Data and information were gathered from selected service providers of PTOS through conducting household survey using pre-tested interview schedules during July, 2008.

Analytical technique: The collected data were scrutinized, edited, tabulated, and analyzed for fulfilling the objectives of the study. The impacts of PTOS on the livelihoods of service providers were assessed through analyzing *'Before'* and *'After'* socio-economic standings of the service providers. Data regarding land holdings, livestock resources, yearly household income, farm equipment, household assets, liability status, and food intake were analyzed and compared for measuring the impacts of PTOS service on its provider's livelihoods. The values of different household assets were collected based on present value. For example, a house was built five years back with the amount of Tk.50,000 but due to price hiking, the present value of this house is Tk.70,000 which is used for reporting. Besides, if that farmer invested extra money for renovation and/or extension of the house that amount is also added with the present value in this report. T-test was also employed to show the level of significant difference between two periods. Tabular method of analysis with descriptive statistics was adopted to present the findings of the study.

3. Results and Discussion

3.1 Socioeconomic Profile of PTOS Service Providers

Socio-economic characteristics of the farmers are important in influencing farm decision making and production planning. There are numerous interrelated and constituent attributes that characterize a person and these profoundly influence development behavior. Some related socioeconomic characteristics of the PTOS Service Providers are shown in Table 1.

Age is an important factor that may be influenced entrepreneurs' decision to operate PTOS as a commercial business. The average age of the respondents was 40 years with minimum age of 23 years and the maximum of 90 years. They were grouped into five categories based on their level of education. More than 47% of them completed secondary levels of education, followed by 34% of

[1] Prepared land on contractual basis.

primary level. Only 3.8% were found to complete their higher level of education. Only 2% service providers were not received any formal education. The average length of experience of service providers in PTOS operations was four years ranging from two to six years. Most of them were experienced by three years. Three types of financing sources were reported in the study areas. More than half of the respondents bought PTOS by own cash, cash from commercial banks or PTOS sellers and from CIMMYT. A good number of service providers bought by own cash. Many service providers owned a number of farms implement namely power tiller, power thresher, shallow tube well (STW), sprayer and hand weeder that were mostly used for renting out to others for earning cash income. Nearly 86% of sample PTOS owners owned STW, 39.6% owned power thresher and 18.9% owned sprayer. Furthermore, 26.4% of them bought an additional power tiller for their own use as well as service providing business (Table 1).

Table 1: Socioeconomic profile of PTOS service provider in the study areas.

Items	Frequency	Mean
1. Farmers' age (year)	53	40.0
2. Level of education (%)		
a. Illiterate	2	3.8
b. Completed primary level	18	34.0
c. Completed secondary level	25	47.2
d. Completed higher secondary level	6	11.3
e. Degree and above	2	3.8
3. Experience with PTOS service (%)		
a. 6 years (2002/03 to 2007/08)	2	3.8
b. 5 years (2003/04 to 2007/08)	6	11.3
c. 4 years (2004/05 to 2007/08)	9	17.0
d. 3 years (2005/06 to 2007/08)	23	43.4
e. 2 years (2006/07 to 2007/08)	13	24.5
4. Source of financing for PTOS (%)		
a. Self	24	45.3
b. Credit	2	3.8
c. Both self & credit	27	50.9
5. Type of farm machineries owned (%)		
a. Power tiller	14	26.4
b. Power thresher	21	39.6
c. Shallow tube well	45	86.8
d. Sprayer	10	18.9
e. Hand weeder	7	13.2

3.2 Uses Pattern and Trend of PTOS Operations

The sample service providers provided PTOS services almost throughout the year. They rented out PTOS services for land preparation for sowing and transplanting seeds/seedlings of different crops. Onion transplanting requires fine tilth of soil. So, the highest land preparation was for onion followed by rice and jute in the study areas. The period ranged from mid-October to mid-January was reported to be the peak season of PTOS service since most of the *Rabi* crops are grown within these periods. Contrarily, the periods ranged from mid-August to mid-October and mid-May to mid-June were treated as lean period for PTOS service (Fig-1).

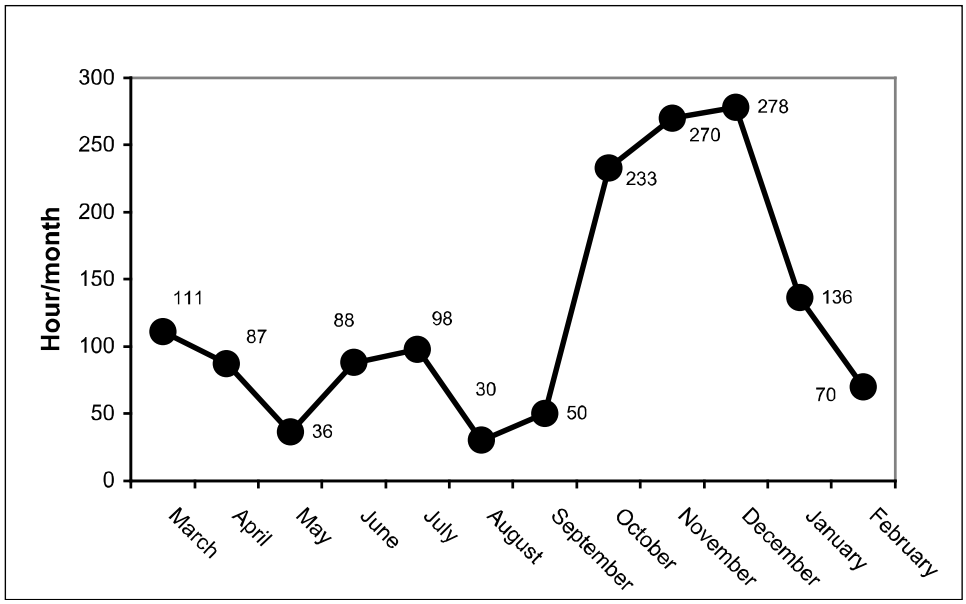

Fig. 1. Seasonality of PTOS in the study areas.

3.3 Socioeconomic Impacts of PTOS on Service Providers' Livelihood

A livelihood is a means of making a living. It encompasses people's capabilities, assets, income, and activities required to secure the necessities of life. In another words, livelihood is defined as a set of activities, involving securing water, food, fodder, medicine, shelter, clothing, and the capacity to acquire above necessities working either individually or as a group by using endowments for meeting the requirements of a household (http://en.wikipedia.org/wiki/ Livelihood). Livelihood development is a broad issue usually which depends on the wider economic development of the society. It was reported that PTOS had positive and direct effects on its owners in generating employment and income; creating household assets, and increasing the standard of living to a great extent in the

study areas. It was somewhat difficult to assess the socioeconomic impacts of PTOS on the livelihoods of service providers because many factors might be contributed to uplift their standard of living. However, the socioeconomic impacts of PTOS on the livelihoods of service providers are discussed in the following sections.

Impact on land holdings: Table 2 shows that the land holding size of the service providers increased to some extent along with different land categories after having PTOS. Irrespective of providers' categories, the average holding size was increased by 8.6%. Significant change was occurred in the mortgaged-in land that might be due to the direct effect of PTOS service. The amount of rented-in land was decreased by 2.9% and rented-out land was increased by 5.5% implying the economic upliftment of the service providers in the study areas.

Table 2. Change in farm size before and after ownership of PTOS in the study area.

(Fig .in ha)

Land category	N	After having PTOS	Before having PTOS	Mean difference	P(T<=t) value
1. Own land	51	2.392	2.347	0.045	0.9198
2. Rented in	14	0.381	0.392	-0.011	0.9571
3. Rented out	19	0.492	0.466	0.027	0.8600
4. Mortgaged in	33	0.337	0.076	0.260***	0.0000
5. Mortgaged out	14	0.310	0.183	0.127	0.2481
6. Homestead	53	0.136	0.114	0.022	0.2820
7. Orchard	39	0.112	0.085	0.027	0.3353
8. Pond	44	0.129	0.106	0.023	0.3742
*Farm size	53	2.685	2.472	0.212 (8.6)	0.6104

Note: *** indicates significant at 1% level. Figure in the parenthesis indicates percent increased over pre-ownership period.

*Farm size = (Own land+ Rented in+ Mortgaged in +Homestead+ Orchard+ Pond) –(Rented out+ Mortgaged out)

Impact on livestock resources: Due to the increased income of the service providers that earned from renting out PTOS service, the most livestock and poultry resources were increased during post-ownership period. Remarkable decrease was found in the quantity of bullocks, but significant increase was registered in the value of calves (which will be ultimately milking cows), goats and adult chickens (Table 3).

Table 3. Change in livestock resources before and after ownership of PTOS

Livestock and poultry	N	After having PTOS		Before having PTOS		Mean difference	
		Quantity	Value (Tk)	Quantity	Value (Tk)	Quantity	Value (Tk)
1. Bull/Ox	24	0.93	11691	1.52	13122	-0.59***	-1431
2. Cow	48	1.83	26669	1.56	21792	0.27	4877
3. Calves	40	1.33	9500	1.00	4095	0.33	5405***
4. Goat	33	3.48	5979	1.91	2218	1.57	3761***
5. Duck (Adult)	36	6.81	818	3.28	432	3.53	386
6.Chicken (Adult)	39	8.46	1204	6.64	793	1.82	411*
All types		22.84	55861	15.91	42452	6.93(44)	13409 (32)

Note: *** and * indicate significant at 1% and 10% level, respectively.

Figures in the parentheses indicate percent increased over pre-ownership period.

Impact on household income: The principal components of household income of the service providers were crop farming, service, farm machinery, business, and livestock and poultry farming. Table 4 shows the remarkable positive impact of PTOS on the annual income of the service providers in the study areas. The annual household income was significantly increased by 63.4% during post-ownership period. The percent increase in income was found to be highest in case of farm machineries followed by livestock rearing and crop production. The service providers earned 19% of total income from PTOS. They stated that it could be possible for them to buy other farm machineries like power tiller (PT), STW, and thresher by the income received from PTOS.

Table 4. Change in yearly household income before and after ownership of PTOS.

Income source	N	After having PTOS	Before having PTOS	Mean difference	P(T<=t) value
1. Crop production	53	236460 (34)	179933 (53)	56527*	0.073
2. Service	15	140703 (20)	80933 (24)	59770	0.289
3. Business	13	51846 (8)	41615 (12)	10231	0.443
4. Livestock	40	18672 (3)	10097 (3)	8575***	0.008
5. Fruit sale	6	7767 (1)	7300 (2)	467	0.959
6. Farm machinery	143	231851(34)	20874 (6)	210977***	0.000
PTOS	53	130510 (19)	0	130510	-
PT	36	44833 (7)	8194 (2)	36639***	0.000
STW	35	11929 (2)	2943 (1)	8986***	0.000
Thresher	19	44579 (6)	9737 (3)	34842*	0.062
Total (Tk/year)	53	687299 (100)	340752 (100)	216037***	0.002

Note: *** and * indicate significant at 1% and 10% level, respectively.

Figures within parentheses are the percentages of total income.

Impact on farm equipment: Increasing the household assets is closely related to the financial condition of the service providers of PTOS. Renting out of PTOS service in the study areas has boosted up their asset position to a great extent. Table 5 revealed that the total quantity and value of farm equipment was increased by 20% and 239% respectively during post-ownership period of PTOS. Most service providers mentioned that they purchased modern farm equipment like PT, STW, thresher, and sprayer by the income that earned from renting out of PTOS service. That's why the highest and significant increases were apparent both in the number and value of STW, hand tube well (HTW), thresher, and sprayer. Besides, the number of wooden plough decreased with the increase in the use of PT and PTOS.

Table 5. Change in farm equipment before and after ownership of PTOS.

Farm equipment	N	After having PTOS		Before having PTOS		Mean difference	
		Quantity	Value	Quantity	Value	Quantity	Value
1. PTOS	48	1.02	81,590	0	0	1.02	81,590***
2. Power tiller	25	1.00	54,760	0.64	35,620	0.36	19,140*
3. STW	49	1.08	15,106	0.65	8,551	0.43***	6,555*
4. HTW	53	1.28	7,404	0.89	4,726	0.39***	2,678***
5. Sprayer	23	1.13	2,355	0.65	527	0.48***	1,828
6. Thresher	22	1.14	32,414	0.50	5,732	0.64**	26,682***
7. Wooden plough	27	0.19	52	1.44	743	-1.25***	-691***
8. Ladder	50	1.36	372	1.40	403	-0.04	-31
Total		8.2	194,053	6.17	56,302	2.03 (33)	1,37,751*** (245)

Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively.

Figures in the parentheses indicate percent increased over pre-ownership period.

Impact on household assets: Due to increased income, the housing assests of all service providers of PTOS has improved to a great extent. They have made remarkable improvements in their dwelling houses and kitchens during post-ownership period. Table 6 revealed that the number and value of semi-pacca building were significantly increased by 42% and 69% respectively during post-ownership period. On the contrary, the numbers of Katcha-pacca and Katcha houses decreased by 3.7% and 17.1% respectively. Remarkable improvements were also found in the number and value of both semi-pacca and Katcha-pacca kitchen. Most sample service providers had to construct more number of valuable store houses due to increase in both crop production and household assets.

Table 6. Change in house types before and after ownership of PTOS.

House type	N	After having PTOS		Before having PTOS		Mean difference	
		Quantity	Value (Tk)	Quantity	Value (Tk)	Quantity	Value (Tk)
1.Dwelling house		**7.07**	**529128**	**5.86**	**218224**	**1.21**	**310904**
Pacca[1]	4	1.75	202500	1.00	10000	0.75	192500
Semi-pacca[2]	42	2.40	236310	1.69	139929	0.71**	96381**
Katcha-pacca[3]	19	1.32	49318	1.37	40895	-0.05	8423
Katcha[4]	5	1.60	41000	1.80	27400	-0.20	13600
2. Kitchen		**3.28**	**93029**	**2.81**	**69319**	**0.47**	**23710**
Pacca	2	1.00	50000	1.00	50000	0	0
Semi-pacca	19	1.11	29000	0.84	13968	0.27**	15032**
Katcha-pacca	35	1.17	14029	0.97	5351	0.20	8678**
3. Other houses		**3.66**	**58656**	**3.14**	**43600**	**0.52**	**15056**
Cow shed	43	1.12	26988	1.10	18290	0.02	8698
Poultry shed	25	1.44	1768	1.24	1510	0.20	258
Storehouse	10	1.10	29900	0.80	23800	0.30***	6100

Note: [1] House with concrete roof and brick wall.

[2] House with corrugated iron (CI) sheet roof and brick wall.

[3] House with CI sheet roof and thrashed bamboo/jute stick/straw wall.

[4] House with straw roof and thrashed bamboo/jute stick/straw wall.

***, ** and * indicate significant at 1%, 5% and 10% level, respectively.

Providing PTOS service has incredible impact in increasing the household assets in the study areas. Table 7 shows the comparative scenarios of the household asset positions of PTOS service providers. The quantity and quality (in terms of value) of different types of furniture, modern amenities and other household assets of the service providers were significantly increased after having PTOS. However, no change was made in the quantity and quality of *Chowki*, radio and boat in the study areas.

Impact on liabilities: The service providers of PTOS were reported to be received loan from commercial bank, cooperative society, and local NGOs and borrowed money from moneylender, relatives, and many other sources for various purpose. Table 8 revealed that the average amount of loan received during PTOS ownership period was about 50.5% higher than that of pre-ownership period that might be due to purchase of PTOS and related accessories. This scenario also clearly indicates their higher access to the institutional credit facility in study areas.

Table 7. Change in household assets before and after ownership of PTOS.

Household assets	N	After having PTOS		Before having PTOS		Mean difference	
		Quantity	Value (Tk)	Quantity	Value (Tk)	Quantity	Value (Tk)
1. Furniture		**27.35**	**57,592**	**14.12**	**23,944**	**13.23**	**33648**
Cot	38	3.16	24,066	1.37	9,408	1.79***	14658***
Chowki[1]	50	3.18	3,942	2.88	3,912	0.30	30
Almirah	36	1.64	9,500	0.72	3,819	0.92***	5681***
Dressing table	25	1.56	5,544	0.24	1,000	1.32***	4544***
Tables	53	2.79	3,104	1.34	1,340	1.45***	1764***
Chairs	52	5.75	2,578	2.90	1,099	2.85***	1479***
Bench	36	1.19	785	0.89	538	0.30*	247**
Dress-stand	48	2.75	2,543	1.27	1,115	1.48***	1428***
Basket (large)	42	2.26	4,802	1.10	1,429	1.16***	3373***
Tool[2]	41	3.07	728	1.41	284	1.66***	444***
2.Modern amenities		**12.98**	**120,376**	**5.75**	**26,509**	**7.23**	**93867**
Mobile phone	47	1.81	7,569	0.15	543	1.66***	7026***
Motor cycle	14	1.14	95,786	0.29	19,643	0.85***	76143***
Television	35	1.31	11,589	0.49	3,397	0.82***	8192***
Cassette player	24	0.92	2,119	0.50	1,313	0.42***	806*
Radio	32	0.88	352	0.88	352	0	0
Wrist watch	41	2.49	1,390	1.39	599	1.10**	791***
Table/wall clock	45	1.91	573	0.78	228	1.13***	345***
Torch light[3]	48	2.52	998	1.27	434	1.25***	564***
3. Other assets		**3.68**	**18,892**	**2.74**	**14,927**	**0.94**	**3965**
Bicycle	47	1.79	6,004	1.23	3,574	0.56**	2430***
Rickshaw/van	26	0.92	3,312	0.54	1,777	0.38***	1535***
Boat	33	0.97	9,576	0.97	9,576	0	0

[1]a four legged wooden bedstead; [2]a wooden seat without a back for one person; [3]a light to be carried in the hand

Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively.

Table 8. Change in liability position after ownership of PTOS.

Source of credit	N	After having PTOS	Before having PTOS	Mean difference	P(T<=t) value
1. Commercial bank	22	28,591	19,273	9,318	0.3037
2. Cooperative society	1	5,000	0	5,000	-
3. Local NGO	9	50,667	33,000	17,667	0.6570
4. Moneylender	2	17,500	27,500	-10,000	0.7788
5. Relatives	3	8,333	1,667	6,666	0.2522
6. Others	2	20,000	5,000	15,000	0.2048
All sources		**21,682**	**14,407**	**7,275**	

Impact on food intake: Due to increased income that earned from renting out PTOS service to others, the frequency and quality of food intake were significantly increased in the study areas. One of the highest improvements was reported in the case of weekly intake of milk, egg, and meat. Fish and vegetable intake also increased remarkably (Table 9).

Table 9. Change in food intake pattern after ownership of PTOS.

Food intake pattern	N	Frequency of food intake		Mean difference	P(T<=t) value
		After having PTOS	Before having PTOS		
1. Food intake (times/day)	53	3.32 (5)	3.15	0.17**	0.0400
2. Fish intake (time/week)	53	5.00 (25)	3.75	1.25***	0.0000
3. Meat intake (time/month)	51	3.10 (30)	2.18	0.92**	0.0507
4. Egg intake (time/week)	52	3.10 (37)	1.97	1.13***	0.0000
5. Milk intake (time/week)	53	5.79 (48)	3.02	2.77***	0.0000
6. Vegetable intake (kg/week)	53	10.94 (28)	7.91	3.03***	0.0043

Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively.

Figures within parentheses indicate percent increase over pre-ownership period.

Impact on overall livelihood status: The overall standard of living social status of the service providers of PTOS was improved remarkably. Table 10 showed that irrespective of service providers' category, more than 94% of respondents used safe drinking water from hand tube-well and use sanitary toilet, and about 50% extra households get connection of electricity at their residences. Awareness development was another positive impact that was found in the service providers during post-ownership period. It was reported that the awareness of service providers regarding contraceptive use, sending children to school, and consultation with MBBS doctor was increased (6.3-27%) to some extent. Furthermore, better economic standing enabled them to buy more costly new clothes for several social

and religious events. It revealed that the members of service providers with local level cooperative society increased by about 74% in the study areas.

Table 10. Increase in livelihood status before and after ownership of PTOS.

Livelihood criteria	% responses		% increased
	After having PTOS	Before having PTOS	
Sample size (N)	*53*	*53*	*53*
1. Using tube well water	94.3	83.0	13.6*
2. Using sanitary toilet	94.3	69.8	35.1***
3. Using electricity	56.6	37.7	50.1*
4. Adopting contraceptive method	56.6	45.3	24.9*
5. Sending children to school	88.7	69.8	27.1*
6. Consultation with MBBS doctor	94.3	88.7	6.3
7. Buying new cloths in religious festivals	92.5	81.1	14.1*
8. Offering gifts in social events	94.3	83.0	13.6*
9. Membership with cooperative society	49.1	28.3	73.5**

3.4 Problems of Service Providers

About 38% of total service providers did not face any major problem except few minor things during renting out of PTOS service to the farmers. Among different problems, higher diesel price was ranked first which was mentioned by over 60% of the service providers. Driving of PTOS by walking sometimes create problem for them. The non-availability and higher price of spare parts and roller jam due to soil store were mentioned by 47.2% and 28.3% of the service providers as problems. Some service providers told that trained and efficient driver become scares, especially in the peak season (*Rabi* season). A few respondents also mentioned that PTOS tilled land with shallow depth (Table 11).

Table 11. Problems encountered by sample service provider of PTOS/HSRT.

Type of problem	Responses *(N = 53)*	
	Number	%
1. No problem at all	20	37.7
2. Fuel cost is high	32	60.4
3. Driving by walking	28	52.8
4. Non-availability and higher price of spare parts	25	47.2
5. Soil store in roller/roller jam	15	28.3
6. Scarcity of trained driver	12	22.6
7. Shallow depth in cultivation	10	18.9
8. Others*	8	15.1

***** Difficult to drive during rainy season; unable to drive at night; licking fuel from reservoir; problem in radiator and sprocket

4. Conclusions and Recommendations

The study assessed the uses pattern of PTOS operations and its impacts on service providers' livelihood. Custom hiring business through PTOS made a remarkable improvement in the livelihoods of its service providers in the study areas. The average land holding of the service providers was increased to some extent. Significant increase was registered in the value of livestock and poultry resources. The annual household income and number and value of *semi-pacca* building were also significantly increased by a great extent during post-ownership period. Both the quantity and value of farm equipment and household assets were significantly increased after having PTOS. The amount of loan received during PTOS ownership period was much higher in the post-ownership period compared to pre-ownership period. The increased income of beneficiaries are mostly spent on farm machinery, nutritious food, cloths, health care, education expenses and making of houses that indicate higher standard of living of service providers. The service providers encountered problems like higher fuel cost, lack of riving facility, non-availability and higher price of spare parts, roller jam, and lack of trained driver.

Due to higher adoption of PTOS, financial support and technical assistance should be made available by the government of Bangladesh for service providers and local manufacturers. Fuel cost may be reduced for small holder farmers. Training on repair and maintenance of PTOS for operators is highly required. Furthermore, research work should be carried out to improve the machine with riding facilities and adding fertilizers application system with existing PTOS that will improve fertilizer uses efficiencies.

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GENETIC DIVERGENCE IN PUMPKIN (*Cucurbita moschata* L.) GENOTYPES

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Abstract

Genetic diversity using Mahalanobis's D^2 technique was studied for yield and its components on twenty one genotypes of pumpkin (*Cucurbita moschata* L.). Quantification of variability for each character was done using the Shannon Weaver Diversity Index. High degree of variation was exhibited within the collection, as reflected by mean diversity index value of 0.80. Data were subjected to principal component analysis (PCA), principal coordinate analysis (PCO), canonical variate analysis (CVA) and non-hierarchical clustering to identify suitable parents having distant relationship for hybridization program. The genotypes were grouped into five different clusters. Cluster IV contained the maximum number of seven genotypes whereas cluster I contained least number having only one genotype. The lowest inter-genotypic distance (0.75) was found between BD-2174 and BD-9489 where the highest (47.46) was between BARI Mistikumra-1 and BD-2150. The maximum inter cluster distance was observed between cluster II and III (17.922) and the minimum inter cluster distance was observed between cluster II and IV (6.825). The maximum intra cluster distance was noticed for the cluster V (0.261) and the minimum intra cluster distance was found in cluster I (0.00). Cluster I contained the highest mean values for pedicel length of male flower, number of male flowers/plant, fruit length, fruit breadth, single fruit weight and fruits/plant. Cluster II contained the highest mean values for days to first male and female flowering. Cluster III contained the highest mean values for leaf breadth, pedicel length of female flower and number of female flowers/plant. Leaf breadth, pedicel length of male flower, number of male flowers/plant and fruits/plant were the important components of genetic divergence in the studied materials. Based on inter cluster distance, inter genotypic distance and consideration of desirable characters for high yield potential, the genotypes G19 (BARI mistikumra-1) and G20 (BARI mistikumra-2) from cluster II; G21 (BD-2150) from cluster I and G1 (BD-2151) and G13 (BD-266) from cluster III can be selected as better parents for future hybridization program.

Keywords: *Cucurbita moschata* L., principal component analysis, cluster analysis, genetic divergence.

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Introduction

Pumpkin (*Cucurbita moschata* L.) is locally known as 'Misti kumra' or 'Misti lau' or 'Misti kadu' and is considered to have originated from Central and North America (Whitaker and Davis, 1962). It is an under exploited popular vegetable but has higher demand in Bangladesh. It is relatively high in energy and carbohydrates and a good source of vitamins, especially high carotenoid pigments and minerals (Bose and Som, 1986). It may contribute to improve the nutritional status of the people, particularly the vulnerable groups in respect of vitamin A requirement. It becomes available even in the lean period when other vegetables are scarce in Bangladesh. Among the non-traditional crops, Bangladesh has been earning a handsome amount of foreign currency by exporting pumpkin to the U.K., Pakistan and Middle East (Alamgir, 1998). The total production of pumpkin is 0.218 million tons in a year in this country (BBS, 2011). Lack of high yielding, disease and pest tolerant variety is the main constrains towards its production. For developing a high yielding variety with desired characters needs good parents. The selection of potential good parents in a breeding program is based on the knowledge of genetic diversity amongst them. Evaluation of genetic diversity is important to know the source of genes for a particular character within the available germplasm (Tomooka 1991). To realize heterosis, genetically divergent parents are generally considered to be useful. In such crosses more variability could be expected in the resulting segregating progenies. Genetic divergence can be estimated by D^2 Statistic suggested by Mahalanobis and in turn is based on multivariate analysis of quantitative characters. The present study has been undertaken to generate information on genetic divergence in pumpkin so that the useful parental material for the breeding programs could be selected.

Materials and Method

The investigation was carried out at the experimental field of Sher-e-Bangla Agricultural University, Bangladesh during the period from March 2010 to August 2010 to study the genetic diversity in pumpkin. Twenty one genotypes of pumpkin were used in Randomized Complete Block Design (RCBD) with three replications. Those genotypes were assigned at random into pits of each replication. Pits of 55 cm x 55 cm x 50 cm were prepared in each plot with spacing of 3 m x 3 m. Number of pits/plot were 3. Standard package of cultural practices was followed for raising healthy crops. For studying different genetic parameters and inter-relationships, thirteen characters were taken into consideration like leaf length (cm), leaf breadth (cm), internodes distance (cm), days to first male flowering, days to first female flowering, pedicel length of male flower (cm), pedicel length of female flower (cm), number of male flowers, number of female flowers, fruit length (cm), fruit breadth (cm), fruit weight (Kg) and fruit yield/ plant (Kg).

Quantification of variability for each character was done using the Shannon-Weaver Diversity Index. Estimate of variability for each character was computed using the standardized Shannon-Weaver Diversity Index, designated as H' and has the formula:

$$H' = -\sum Pi(\log_2 Pi)/\log_2 n$$

Where, Pi is the proportion of the total number of genotypes belonging to the i^{th} class.

For each quantitative characters, the overall genotype means (x) and standard deviation (σ) were used to subdivide the population values (x_i) into 10 frequency classes, ranging from class 1 (if $x_i \leq -2\sigma$} to class 10 (if $xi \leq X+2\sigma$), the class interval being 0.5σ. The lowest and highest values were considered to determine the number of classes construct. The diversity considered high when H' > 0.75, moderate when H' = 0.50 – 0.75 and low when H' < 0.50. The Shannon-Weaver Diversity Index has a value ranging from 0 to 1, where 0 indicates absence of diversity and 1 indicates maximum diversity.

For both univariate and multivariate analysis, mean data for each character was used. In case of univariate analysis, analysis of variance was done individually by F test (Panse and shuhkhatme, 1978) and MSTATC software was used for this purposes. Multivariate analysis viz. Principal Component Analysis (PCA), Principal Coordinate Analysis (PCO), Cluster Analysis, and Canonical Vector Analysis (CVA) were done by using Genestat 5.13 software program.

Result and Discussion

The analysis of variance showed significant variations among the genotypes for all the characters studied (Table 1).

Estimation of variation Using the Shannon- Weaver Diversity Index

Only two characters like days to first male flowering (0.73) and leaf breadth (0.74) exhibited medium variation while all the rest gave high diversity values. The computed diversity ranged from 0.73 (days to first male flowering) to 0.85 (leaf length) with a mean diversity value of 0.80 indicated existence of high variation within the collection (Table 2).

Cluster analysis

Based on cluster analysis, the twenty one genotypes were grouped into five clusters (Table 3). Cluster IV contained the maximum number of seven genotypes followed by cluster III, V and II having six, five and two, respectively, while cluster I contained least number of one genotype. In many cases, the same cluster included genotypes from different eco-geographic region indicating that

the geographic distribution and genetic divergence did not follow the same trend. The mean performances of thirteen characters in five clusters are shown in Table 4. Most of the characters showed distinct differences among the clusters. Cluster I contained the highest mean values for pedicel length of male flower (22.60), number of male flowers/plant (9.33), fruit length (74.40), fruit breadth (35.00), single fruit weight (3.58) and fruits/plant (7.15), whereas the lowest mean values for internodes distance (11.33). Cluster II contained the highest mean values for days to first male flowering (85.83), days to first female flowering (86.83) and the lowest mean values for leaf length (12.83), leaf breadth (18.33), pedicel length of male flower (8.23), pedicel length of female flower (2.09), number of male flowers/plant (1.00), number of female flowers/plant (1.00), fruit length (40.06), fruit breadth (18.03), single fruit weight (0.85) and fruits/plant (0.85). Cluster III got the highest mean values for pedicel length of female flower (5.52) and number of female flowers/ plant (4.78) while the lowest values for days to first male flowering (63.06) and days to first female flowering (67.78). Cluster IV contained the highest mean values for leaf breadth (25.77) and internodes distance (15.19).

Table 1. Range, Mean, Mean sum of square (MS_G), Percent coefficient of variation (CV) of 21 pumpkin genotypes.

Parameters	Range	Mean	MS_G	CV (%)
Leaf length without petiole (cm)	11.33-21.60	17.20	24.51**	5.23
Leaf breadth (cm)	15.20-30.67	23.39	38.32**	4.70
Internodes distance	10.00-20.00	14.17	29.12**	14.73
Days to first male flowering	60.00-86.33	70.38	150.44**	6.07
Days to first female flowering	65.67-87.00	75.17	135.82**	5.31
Pedicel length of male flower (cm)	8.07-26.47	16.67	105.05**	6.73
Pedicel length of female flower (cm)	2.07-8.63	4.45	9.94**	8.35
Number of male flowers/plant	1.00-15.33	6.77	40.94**	34.57
Number of female flowers/plant	1.00-7.00	3.53	11.34**	52.68
Fruit length (cm)	39.60-74.40	53.34	201.36**	9.87
Fruit breadth (cm)	17.33-35.00	27.59	65.34**	10.04
Single fruit weight (kg)	0.80-3.58	2.09	1.77**	17.02
Fruit yield/plant (kg)	0.80-9.92	4.01	21.00**	40.09

** Variation is significant at 1% level of probability.

Table 2. Computed diversity indices (H') for 13 different characters of 21 pumpkin genotypes.

Characters	H'
Leaf length without petiole (cm)	0.85
Leaf breadth (cm)	0.74
Internodes distance	0.81
Days to first male flowering	0.73
Days to first female flowering	0.82
Pedicel length of male flower (cm)	0.81
Pedicel length of female flower (cm)	0.83
Number of male flowers/plant	0.78
Number of female flowers/plant	0.81
Fruit length (cm)	0.84
Fruit breadth (cm)	0.75
Single fruit weight (kg)	0.84
Fruit yield/plant (kg)	0.82
Average	0.80

Table 3. Distribution of genotypes in different clusters.

Cluster no.	No. of Genotypes	No. of population	Name of genotypes
I	G21	1	BD-2150
II	G19, G20	2	BARI mistikumra-1, BARI mistikumra-2
III	G1, G2, G9, G10, G11, G13	6	BD-266, BD-2214, BD-2151, BD-2153, BD-2229, BD-2222
IV	G3, G4, G6, G14, G15, G16, G18	7	BD-2174, BD-2177, BD-2196, BD-9489, BD-9494, BD-9491, BD-9490
V	G5, G7, G8, G12, G17	5	BD-264, BD-2203, BD-2212, BD-9493, BD-4590

Principal Coordinate Analysis (PCO)

Inter-genotypic distances (D^2) were obtained from PCO for all possible combinations between pair of genotypes. Intergenotypic distances among the pumpkin genotypes ranged from 0.75 (between BD-2174 and BD-9489) to 47.46 (between BARI mistikumra-2 and BD-2150) (Table 5). The difference between the highest and lowest inter genotypic distance indicated the presence of variability among the twenty one pumpkin genotypes.

Table 4. Cluster mean values of 13 different characters of 21 pumpkin genotypes.

Characters	I	II	III	IV	V
Leaf length without petiole (cm)	17.67	12.83	18.40	17.83	16.53
Leaf breadth (cm)	21.87	18.33	23.47	25.77	22.29
Internodes distance	11.33	13.00	14.33	15.19	13.60
Days to first male flowering	70.67	85.83	63.06	69.91	73.60
Days to first female flowering	74.33	86.83	67.78	76.19	78.13
Pedicel length of male flower (cm)	22.60	8.23	20.86	12.47	19.71
Pedicel length of female flower (cm)	5.10	2.09	5.52	4.65	3.72
Number of male flowers/plant	9.33	1.00	7.72	7.05	7.07
Number of female flowers/plant	4.67	1.00	4.78	3.67	2.67
Fruit length (cm)	74.40	40.06	54.18	57.27	47.95
Fruit breadth (cm)	35.00	18.03	27.65	30.11	26.35
Single fruit weight (kg)	3.58	0.85	2.05	2.54	1.71
Fruit yield/plant (kg)	7.15	0.85	6.10	3.63	2.70

Table 5.Ten of each higher and lower inter- genotypic distance (D^2) among the 21 pumpkin genotypes.

Sl No.	Genotypic Combination		Ten Maximum ($D^{2)}$ Values	Sl No.	Genotypic Combination		Ten Minimum ($D^{2)}$ Values
01	BD-2150-	BARI mistikumra-2	47.46	01	BD-2174	- BD-9489	0.75
02	BD-2151 -	BARI mistikumra-2	46.39	02	BD-2177	- BD-2214	1.42
03	BD-2150-	BARI mistikumra-1	46.04	03	BARI mistikumra-1	- BARI mistikumra-2	1.57
04	BD-2151 -	BARI mistikumra-1	44.82	04	BD-9489	- BD-9490	2.13
05	BD-266 -	BARI mistikumra-2	43.86	05	BD-2174	- BD-9490	2.41
06	BD-2229 -	BARI mistikumra-2	43.04	06	BD-264	- BD-9491	2.92
07	BD-266 -	BARI mistikumra-1	42.30	07	BD-9490	- BD-9491	3.45
08	BD-2229 -	BARI mistikumra-1	41.46	08	BD-2196	- BD-2214	3.60
09	BD-2196 -	BARI mistikumra-2	38.98	09	BD-2151	- BD-2229	3.71
10	BD-2196 -	BARI mistikumra-1	37.42	10	BD-2174	- BD-9491	3.74

The intra-cluster distances were computed by using the values of inter-genotypic distances from distant matrix according to Sing and Chaudhury (1985). The

magnitude of the intra cluster distances were not always proportional to the number of genotypes in the clusters (Huque *et al*, 2012), as the maximum intra cluster distance was noticed for the cluster V (0.261) followed by cluster III (0.177) and cluster IV (0.109). The minimum intra cluster distance was found in cluster I (0.00) followed by cluster II (0.01) (Table 6). This result supported by Gaffar (2008) and he reported that the genotypes were grouped into five clusters in which the highest intra cluster distance was noticed for the cluster II (0.999) and the lowest for the cluster IV (0.439).

Table 6. Intra (Bold) and inter cluster distances (D^2) for 21 pumpkin genotypes.

Cluster	I	II	III	IV	V
I	**00.00**	15.472	11.858	6.825	10.326
II		**00.01**	17.922	14.444	10.447
III			**0.177**	7.284	9.274
IV				**0.109**	6.450
V					**0.261**

Table 7. Eigenvalues and percentage of variation in respect of 13 principal components in 21 genotypes of pumpkin

Principal component axis	Eigen values	Percent variation	Cumulative % of Percent variation
1	5.735	44.12	44.12
2	2.066	15.89	60.12
3	1.684	12.95	72.96
4	1.176	9.05	82.01
5	0.812	6.24	88.25
6	0.558	4.29	92.54
7	0.328	2.53	95.07
8	0.233	1.80	96.87
9	0.185	1.42	98.29
10	0.137	1.06	99.35
11	0.035	0.27	99.62
12	0.033	0.25	99.88
13	0.018	0.13	100.00

Canonical Variate Analysis (CVA)

The inter-cluster distances were obtained from CVA. The inter cluster distances were larger than intra cluster distances which indicated that wider genetic diversity among the genotypes of different groups. The maximum inter cluster distance was observed between cluster II and III (17.922) followed by cluster I and II (15.472), cluster II and IV (14.444). The maximum inter cluster distance indicated that the genotypes belonging to cluster II were far away from those of cluster III. The minimum inter cluster distance was observed between cluster IV

and V (6.45) followed by I and IV (6.825) (Table 6). The results revealed that the crosses between the genotypes of cluster II and III would exhibit high heterosis and produce new recombinant with desirable traits.

Principal Component Analysis (PCA)

PCA is a statistical method which attempts to describe the total variation in multivariate sample using fewer variables than in the original data set (Bartolome *et al.*, 1999). The analysis results in the identification of the major attributes that are responsible for the observed variation within a given collection. From principal component analysis the values were found as 72.96% in the first three components and it was 82.01% in the four components of the total variance (Table 7). The two dimensional scatter diagram was prepared by using score component 1 in X axis and 2 in Y axis, showing the groups into five clusters among the genotypes which supported the result of cluster analysis (Fig 1).

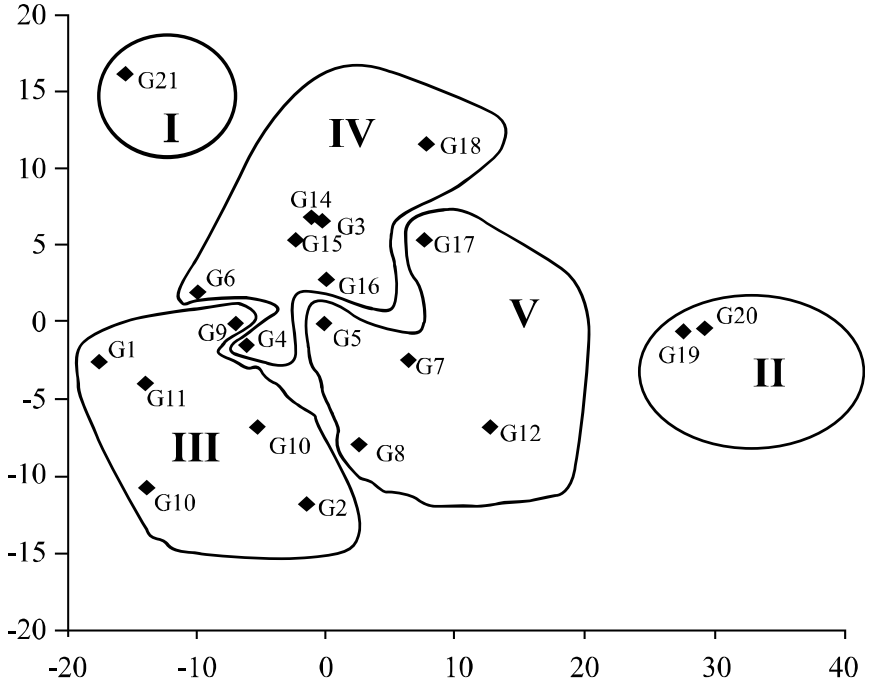

Fig. 1. Scattered diagram of 21 pumpkin genotypes of superimposed clusters

Contribution of characters towards divergence of the genotypes

Contribution of characters towards divergence of the genotypes is presented in table 8. The result of principal component analysis revealed that in vector I (Z_1), the important characters responsible for genetic divergence in the major axis of differentiation were leaf length, leaf breadth, days to first male flowering, pedicel

length of male flower, number of male flowers/plant, number of female flowers/plant, single fruit weight and fruits/plant which accounted for 44.12% of the total variation. In vector II (Z_2), which was the second axis of differentiation, leaf breadth, internodes distance, days to first female flowering, pedicel length of male flower, pedicel length of female flower, number of male flowers/plant and fruits/plant were important. Those characters contribute 15.89% of the total variation. The role of leaf breadth, pedicel length of male flower, number of male flowers/plant and fruit yield/plant in both the vectors was positive, which indicate the important components of genetic divergence in the collected materials. Divergence in the collected materials due to these four characters will offer a good scope for improvement of yield through rational selection of parents for producing hybrids. Banik (2003) reported that main vine length, first female flower node number, nodes on main vine, fruit length and number of seeds/fruit in snake gourd had the highest contribution towards the divergence.

Table 8. Relative contributions of the thirteen characters of 21 pumpkin genotypes to the total divergence.

Characters	Vector-1	Vector-2
Leaf length without petiole (cm)	0.5349	-0.1190
Leaf breadth (cm)	0.1333	0.0045
Internodes distance	-0.1342	0.1140
Days to first male flowering	0.9228	-0.3450
Days to first female flowering	-0.0185	0.1123
Pedicel length of male flower (cm)	0.1329	0.0509
Pedicel length of female flower (cm)	-0.5019	0.2415
Number of male flowers/plant	0.1079	0.2099
Number of female flowers/plant	0.3500	-1.9159
Fruit length (cm)	-0.0214	-0.2980
Fruit breadth (cm)	-0.4121	-0.1813
Single fruit weight (kg)	1.3447	-1.4068
Fruit yield/plant (kg)	0.0004	1.4252

Selection of genotypes

It is generally assumed that maximum amount of heterosis would be manifested in cross combinations involving the genotypes belonging to the most divergent clusters. Genotypes in cluster II if crossed with cluster I and cluster III might exhibit high heterosis as well as wide spectrum of genetic variation in F_2 generation. Based on inter cluster distance, inter genotypic distance and consideration of desirable characters for high yield potential, the genotypes G19

(BARI mistikumra-1) and G20 (BARI mistikumra-2) from cluster II; G21 (BD-2150) from cluster I and G1 (BD-2151) and G13 (BD-266) from cluster III may be considered better parents for future hybridization program.

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DEVELOPMENT OF UNION LEVEL DIGITAL DATABASES AND MAPS OF MAIZE GROWING AREAS AT PIRGONJ IN THAKURGAON DISTRICT

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Abstract

A study was conducted during 2012-13 to build union level digital databases and maps of maize growing areas using both primary and secondary data. Primary data were collected from maize growing areas of the upazilla namely Pirgonj of Thakurgaon district. For summer and winter maize; union, upazila, district and country level digitized maps were used in the study. Geographical Information System (GIS), Global Positioning System (GPS) and Management Information System (MIS) related Information Technology (IT) were also applied. Total cultivable land 28138 ha in Pirgonj upazila and area and production of maize were 5100 ha and 34508.75 t respectively. Sixteen (16) varieties were cultivated in the study areas and maximum area (74.09%) of maize was cultivated by the executive varieties NK40, Pacific 984, 900M Gold, 900M, 3396, and Supergold. Average maize yield of the study areas was 6.77 t/ha during 2012-13. A web site was developed for variety wise area coverage data collection of maize as well as for other crops. This web site can also be used in mobile phone.

Keywords: Maize, Area, Cultivation, Production, Variety, Union, ICT and Digital database.

Introduction

Agriculture is the backbone of the nation but agricultural land is the scarcest means of production in Bangladesh. To overcome this situation, agricultural lands should be utilized more efficiently through cultivating high yielding crops like maize. Maize is playing an important role in the economy of Bangladesh. The area under maize cultivation is increasing day by day due to high demand. Thakurgaon districtis the third highest maize production area (28315ha) in Bangladesh.We selected Pirgonj upazila which is maximum yield production of maize at all upazilas in Thakurgaon district. Besides, the genetic yield potential of maize is also very high. There is an important scope of increasing the current yield and production in the country. Maize can be used as food for ensuring food security presently as well as in future increasing population of the country.

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In terms of area, maize holds rank 3rd followed by rice and wheat. Because of higher nutritional status, it could be a good source of nutrients for mal-nourished people in Bangladesh. It is now widely used in the poultry farms as animal feed, as well as the people consume roasted and fried maize in Bangladesh. Moreover, as a food item, maize is used in different forms such as maize flour, maize flour mixed with wheat flour etc. (Roy, 2009).

Due to wide adaptability, maize is grown in the varied environmental conditions in Bangladesh, from sub-tropical low land at sea level to high elevation. Potentiality for growing maize is high in almost throughout Bangladesh. So, it is under cultivation both in winter and summer season and well suited to the existing agronomic conditions, particularly rain fed condition.

Bangladesh Agricultural Research Institute (BARI) has been conducting research activities for varietal development of maize since 1976. Initially, thrust was given for development of composite varieties. So far, BARI developed 19 varieties among them eight open pollinated and 11 hybrid varieties. The yield potentiality of the released composite varieties varies from 5.5 to 7.0 t/ha and that of the hybrid varieties ranges 7.4 - 12.0 t/ha. Status of those varieties in the farmers' field demands through investigation.

Now a day of ICT, it is necessary to build a IT based system for data collection of maize from root level. This system might be used for all other crops. It would be used for data collection of summer and winter maize from upazila, union even block level. By using ICT, collection, documentation of different information and preparation of maps can be done. So, the study was done with the following objectives:

(1) To determine the variety wise area coverage of maize in block, union, upazila and district.

(2) To develop a system for data collection, documentation and mapping of maize.

(3) To develop a database using GIS, GPS and MIS on the basis of IT.

Materials and method

Both primary and secondary data were used in the study. For primary data, two field surveys were done for summer and winter maize during 2012-13. Sites was selected purposively at Pirganj upazila of Thakorgaon district. Simple random sample procedure was followed for data collection and complete enumerations of different varieties of maize were taken for whole population.

Primary data were collected as follows:

1. Summer and winter maize data were collected from maize growers of different upazilas by Sub Assistant Agriculture Officers (SAAO) during 2012-13.
2. Collected data were recorded by the concerned researcher from SAAO as per prescribed database structure.
3. The data schedule was filled up by UAO/SAAO and passed through internet.
4. At the time of data collection, GPS technology was used.
5. A web site was developed which was used through mobile phone for data collection.

The online data collection system through dedicated web portal is **www.asictbari.net**

Secondary sources were NGOs and GOs such as Soil Resources Development Institute (SRDI), Bangladesh Bureau of Statistics (BBS) and Department of Agricultural Extension (DAE) as well as (FAO). Statistical package program SPSS and Excel were applied in addition to Arc View GIS program and digitized maps of union, upazila, district and country were utilized in this study.

Table-1. Indexing on area, production and yield of maize cultivation in Bangladesh.

Year		Area (ha)	Production (t)	Yield (t/ha)	Indexing on the basis of base year			Status (base year)		
1969-70 Base year line					**Area**	**Prod.**	**Yield**	**Area**	**Prod.**	**Yield**
1969-70		3239	3000	0.93	100	100	100	1	1	1
1974-75	1	2834	2000	0.71	87.5	66.7	76.2	0.9	0.7	0.8
1979-80	2	2024	1000	0.49	62.5	33.3	53.3	0.6	0.3	0.5
1984-85	3	3644	3000	0.82	112.5	100	88.9	1.1	1	0.9
1989-90	4	3239	3000	0.93	100	100	100	1	1	1
1994-95	5	2713	2680	0.99	83.8	89.3	106.7	0.8	0.9	1.1
1999-00	6	3162	4075	1.29	97.6	135.8	139.1	1	1.4	1.4
2005-06	7	98447	521525	5.3	3039.6	17384	571.9	30.4	173.8	5.7
2007-08	8	223886	1346000	6.0	6912.2	44866.7	646.5	69.1	448.7	6.5
2008-09	9	174000	1137000	6.53	5372.3	37900	705.5	53.7	379	7.1
2009-10	10	230000	1435000	6.24	7101.3	47833	673.6	71	478.3	6.7
2010-11	11	2,27060	15,52267	6.84	7010.2	51742	735.5	70	517.4	7.3
2011-12	12	2,87243	19,86879	6.92	8868.3	66229	744.1	88.7	662.3	7.4
2012-13	13	3,12566	21,83183	6.98	9650.08	72772.77	750.54	96.5	727.7	7.5

Source: B.B.S. and DAE.

In 1969-70, area of maize was 3239 ha and production was 3000 t pre-independence whereas in 2012-13 those were 312566 ha and 2183183 t, respectively. After 44 years, area, production and yield of maize were increased 96.5, 727.7 and 7.5 times respectively (Table-1).

Table- 2. Indexing on availability of maize crop in Bangladesh (base year1969-70).

Year	Sl. No	Population	Production (t)	Maize Availability		
				(kg/h/y)	(g/h/m)	(g/h/d)
1969-70		69882512	3000	0.04	3.58	0.12
1974-75	1	78328571	2000	0.03	2.13	0.07
1979-80	2	87981429	1000	0.01	0.95	0.03
1984-85	3	98529274	3000	0.03	2.54	0.08
1989-90	4	109300867	3000	0.03	2.29	0.08
1994-95	5	118885011	2680	0.02	1.88	0.06
1999-20	6	128172293	4075	0.03	2.65	0.09
2004-05	7	136314875	521525	3.83	318.82	10.63
2007-08	8	141028719	1343444	9.53	793.84	26.46
2008-09	9	142600000	1137000	7.97	664.45	22.15
2009-10	10	144171281	1435000	9.95	829.45	27.65
2010-11	11	145759875	1552267	10.65	887.45	29.58
2011-12	12	152518015	19,86879	13.03	1085.60	36.19
2012-13	13	156194958	2183183	13.98	1164.77	38.83

Source: Population census of Bangladesh, B.B.S. and DAE.

In 1969-70, maize crop availability was 0.12 g/h/d but in 2013 it was 38.83 g/h/d including seed and wastage (Table-2).

Table 3. Area and production of major maize growing districts of Bangladesh, 2012-13.

SL.No	District	Maize area (ha)	Percentage of area	Cumulative % of area	Production (t)	Percentage of prod.	Cumulative % of production	Yield
1	Dinajpur	56938	18.22	18.22	421710	19.32	19.32	
2	Chuadanga	41500	13.28	31.49	324750	14.88	34.19	
3	Thakurgao	28315	9.06	40.55	195957	8.98	43.17	
4	Lalmonirhat	25090	8.03	48.58	162995	7.47	50.63	
5	Rangpur	16670	5.33	53.91	101077	4.63	55.26	
6	Manikganj	16070	5.14	59.05	105263	4.82	60.08	
7	Panchagar	14945	4.78	63.84	95016	4.35	64.44	
8	Jhenaidah	13803	4.42	68.25	89525	4.10	68.54	
9	Rajshahi	12874	4.12	72.37	77104	3.53	72.07	
10	Bogra	9281	2.97	75.34	71752	3.29	75.36	
11	Gaibandha	8350	2.67	78.01	59467	2.72	78.08	
12	Nilphamari	7845	2.51	80.52	50377	2.31	80.39	
	Bangladesh	312566			2183183			6.98

Area and production of maize in Bangladesh were 312566 ha and 2183183 t respectively in 2012-13. Table-3 indicates the top 12 districts' coverage 80.52% area which contributes 80.39% of total production.

Results and discussion

In total, there were 20 blocks under 10 unions in the upazila Pirganj of Thakurgaon districts, (Table-4). Different agricultural information of maize production under the upazila was noted below:

Table 4. Blocks, unions and cultivable lands Pirganj upazila in Thakurgaon district, respectively in 2012-13.

Upazila	Pirganj (Thakurgaon)
Block	20
Union	10
Cultivable land (ha)	28,138

Source: Survey data of maize growers, 2012-13 collected by SAAO, DAE/Researcher, BARI.

Data were collected from the maize growers of the targeted upazila regarding cultivable land, area production, as well as yield of the crop. Databases of cultivable land, area, production and yield of maize in 2012-13 were prepared according to district, upazila and union**.**

Table 5. Union wise area (ha), production (t) and yield (t/ha) of maize at Pirganj, Thakurgaon, 2012-13

Union	Area (ha)	Production (t)	Yield(t/ha)
Bhamradeha	380	2806.25	7.38
Koharani ganj	660	4083	6.19
Khangaon	260	1680	6.46
Suaidpur	410	3050	7.44
Pirganj	320	2590	8.09
Hagipur	725	4705	6.49
Dalatpur	215	1585.5	7.37
Sengaon	330	3251	9.85
Jabarhat	350	2673	7.64
Burchuna	1450	8085	5.58
Total	5100	34508.75	6.77
Average	510	3450.87	-
Max	1450	8085	9.85
Min	215	1585.5	5.58
Std	368.60	1886.37	1.19
Cv%	72.27	54.66	16.45

Source: Survey data of maize growers, 2012-13 collected by SAAO, DAE/Researcher, BARI.

There were 20 blocks under 10 unions at Pirganj upazila. Total area, production and yield of maize at this upazila were 5100 ha, 34508.75 t and 6.77 t/ha, respectively during 2012-13 (Table5).

Table 6. Variety wise area coverage (ha) of maize at Pirganj, Thakurgaon, 2012-13.

Variety / Union	900M	900M Gold	NK -40	Pacific -11	Pacific-84	Pacific-999	224	9120	3396	Pioneer	Sunshine	Super Gold	Asta	827	962	GP-50	Total
Bhamradeha	0	35	160	0	30	0	0	10	0	30	40	75		0	0	0	380
Koharani ganj	5	75	260	0	43	80	45	0	0	10	0	59	80	0	3	0	660
Khangaon	35	0	80	0	30	10	0	20	0	35	35	0		15	0	0	260
Suaidpur	0	0	190	0	80	0	0	5	0	80	0	50		5	0	0	410
Pirganj	5	20	190	0	30	0	0	20	0	10	0	30		0	5	10	320
Hagipur	10		300	15	110	55	5	50	0	0	15	65	100	0	0	0	725
Dalatpur	0	20	90	15	30	0	0	5	0	12	0	5	10	10	8	10	215
Sengaon	10		159		35	40	15	0	0	0	18	35		0	18	0	330
Jabarhat	5	50	168	10	55	32	0	5	0	5	0	0	6	5	6	3	350
Burchuna	30	300	500	0	120	0	200	0	300	0	0	0		0	0	0	1450
Total	100	500	2097	40	563	217	265	115	300	182	108	319	196	35	40	23	5100
Percentage	1.96	9.80	41.12	0.78	11.04	4.25	5.20	2.25	5.88	3.57	2.12	6.25	3.84	0.69	0.78	0.45	100.00

Source: Survey data of maize growers, 2012-13 collected by SAAO, DAE/Researcher, BARI.

Varietal status of maize at Pirganj was presented in Table-6. Out of 5100 ha maize area at Pirganj; 2097 ha, 563 ha and 500 ha were occupied by NK40, pacific-984, and 900M Gold, respectively and the rest by varieties.

Table 7. Variety wise production(t) of maize at Pirganj, Thakurgaon, 2012-13

Variety / Union	900M	900M Gold	NK -40	Pacific -11	Pacific -984	Pacific-999	224	9120	3396	Pioneer	Sunshine	Super Gold	Asta	962	GP-50	Total
Bhamradeha	0	288.75	1150	0	220	0	0	90	0	210	300	547.5	0	0	0	2806.25
Koharani ganj	37	0	1781	0	338	355	208	0	0	83	0	863	400	18	0	4083
Khangaon	230	0	480	0	205	120	0	130	0	270	145	0	0	0	0	1580
Suaidpur	0	177	1626	0	380	0	0	55	0	482	0	280	0	0	0	3000
Pirganj	35	170	1670	0	219	0	0	155	0	0	0	237	0	34	70	2590
Hagipur	110	0	2045	255	545	347.5	40	350	0	0	150	362.5	500	0	0	4705
Dalatpur	0	160	720	127.5	183.5	0	0	37.5	0	94	0	26	60	52	70	1530.5
Sengaon	110	0	1490	45	333	400	133	0	0	0	210	350	0	180	0	3251
Jabarhat	75	470	1295	42.5	380	165	45	37.5	0	40	0	0	42	37	16.5	2645.5
Burchuna	120	1610	3650	0	465	0	950	0	1290	0	0	0	0	0	0	8085
Total	717	2875.75	15907	470	3268.5	1387.5	1376	855	1290	1179	805	2666	1002	321	156.5	34276.25
Percentage	2.09	8.39	46.41	1.37	9.54	4.05	4.01	2.49	3.76	3.44	2.35	7.78	2.92	0.94	0.46	100.00

Source: Survey data of maize growers, 2012-13 collected by SAAO, DAE/Researcher, BARI.

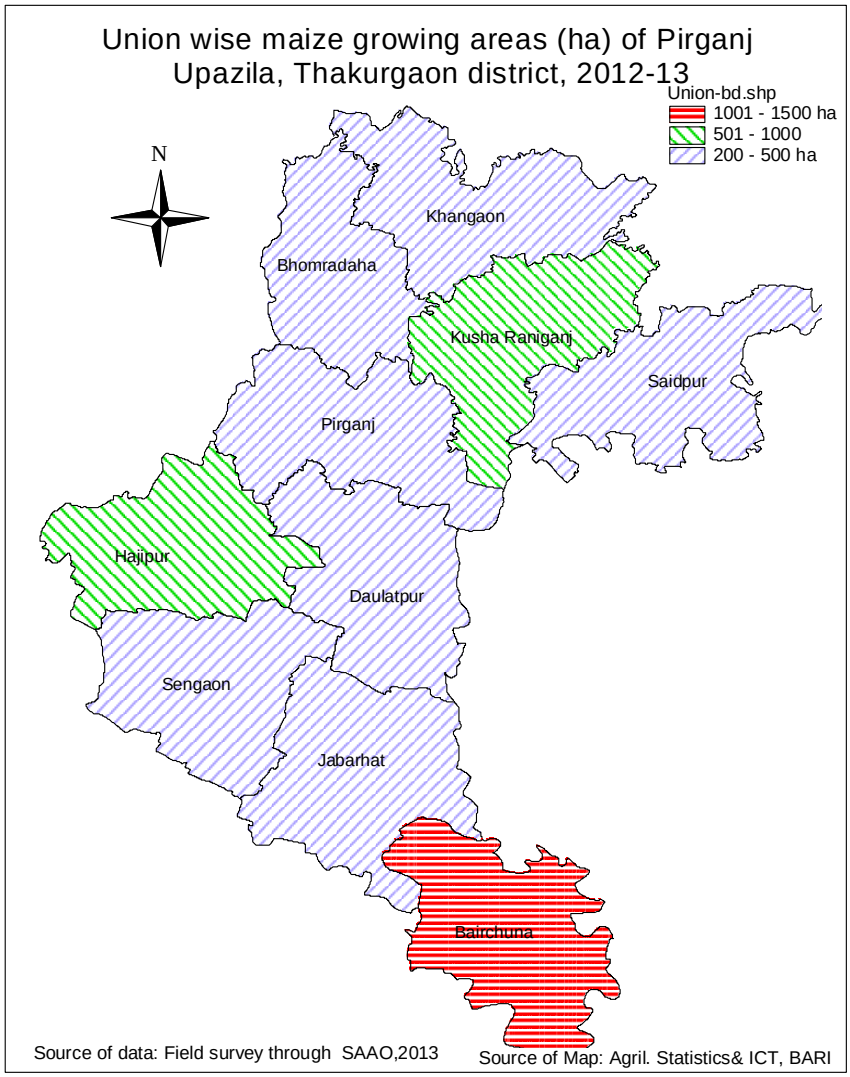
Out of 34276.25 t maize production at Pirganj in 2012-13; 15907 t (46.14%), 3268.5 t (9.54%) and 2875.75t (8.39%) were contributed by three varieties NK40, Pacific -984 and 900M Gold and the rest by varieties (Table -7).

Table 8. Area (ha), production (t) and yield (t/ha) of maize at Pirganj of Thakurgaon district, respectively, 2012-13.

Area	Area (ha)	Production (t)	Yield(t/ha)
Pirganj (Thakorganj)	5100	34508.75	6.77

Source: Survey data of maize growers, 2012-13 collected by SAAO, DAE/Researcher, BARI.

Cultivated area of maize in the study areas was 5100 ha. production was 34508.75 t and yield of maize was 6.77 t/ha (Table-8) at Pirganj, in Thakorganj.



Map-1. Union wise maize growing areas (ha) of Pirganj upazila, Thakurgaon district, 2012-13.

Table 9. Price (Tk/Kg), cost(Tk/Kg), benefit (Tk/Kg) and benefit cost ratio (BCR) of maize at Pirganj of Thakurgaon district, 2012-13.

Area	Price (Tk/Kg)	Cost(Tk/Kg)	Benefit/Profit (Tk/Kg)	BCR
Pirganj (Thakorganj)	13.68	7.15	6.53	1.91

Benefit Cost Ratio (BCR) of maize was 1.91 at Pirganj in Thakorganj district. (Table-9)

Conclusion

In this study, digital databases of different parameters such as area, production, yield and varietal information etc of maize were obtained. Union, upazila and district maps of maize were also developed. Sixteen (16) varieties were cultivated and Maximum area (74.09%) of maize was cultivated by the executive varieties NK-40, Pacific-984, 900M Gold, 900M, 3396 and Super gold. A web site was developed for variety wise area coverage data collection of maize as well as for other crops. This web site can be used through mobile phone. It is noted that BARI maize varieties were not cultivated in the study areas. However, it was found in some places of Manikganj, Kushtia, Dinajpur, Chuadanga, Jamalpur and Sherpur etc. Where germination capacity of BARI maize varieties needs improvement and their cultivation must be expanded rapidly in the farmers' fields. Furthermore dwarf type maize variety should be released. Besides adopting HYVs, management practices should be improved. Finally it was revealed that enhancement of maize production could be gained by vertical and horizontal expansion.

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DETERMINATION OF OPTIMUM SAMPLE SIZE FOR MEASURING THE CONTRIBUTING CHARACTERS OF BOTTLE GOURD

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M. M. RAHMAN[4] AND S. NASRIN[5]

Abstract

To improve efficiency in collecting data from field experiment on fruit attributes of bottle gourd (Lau), the sample size was studied for sample size at Olericulture Division, Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI) Gazipur during 2012-13. The treatments/varieties were LS 0026-5-3, LS 0012-5-3, LS 117-F-1, LS 117-A-2 and BARI Lau-3. Fruit length, breadth and weight of bottle gourd (Lau) data were collected from the experimental plot. The data were used to design optimum sampling plan from equal number of observations per cell. The observation on fruit length (cm), breadth (cm) and weight (kg) were taken from 5 plots/treatments at random. A randomized complete block design (RCBD) with 3 replications and five treatments/varieties was used in this experiment. Five (5) plants per plot and 2 fruits per plants (10 fruits per plot) were the original sampling plan for this experiment. A sampling plan of selecting 4 plants at random and measuring 2 fruits per selected plant (8 fruits per plot and plots were $25m^2$ i.e. 10m long and 2.5m wide) was found to be optimum and economical for taking measurements of fruit attributes in field experiments on bottle gourd.

Keywords: Measurement, Optimum sample size, Sampling technique and Bottle gourd.

Introduction

In any field experiments, it is necessary to determine the optimum sample size as well as optimum number of replications if researchers have to use sampling techniques for collecting data from such experiments (Islam *et al.* 2000). It is not possible to measure yield and yield contributing characteristics on the whole of each experimental unit. In any field experiment, the researcher has to face the problem in determines optimum (efficient) sample size for measuring plant characters (Federer, 1963). The researcher has to face the problem of optimum (efficient) sample size for measuring plant characters in the field experiment (Islam *et al.*2001). The optimum sampling technique depends on the variability associated with variable and the cost of reducing the variability (Kempthorne ,1952). Rigney and Nelson (1951) in cotton, Patel and Dalal (1992) in okra and Hossain *et al.* (2005) in Brinjal, Hossain *et al.* (2008) in Teasle gourd, Islam *et*

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al. (2012) in Sweet gourd and Islam *et al.* (2013) in Bitter gourd estimated the size of sample needed in taking measurements of plant characters. No such information is available in bottle gourd (*Lagenaria siceraria var.clavata*). This experiment deals with sample size study in bottle gourd particularly for taking measurements of fruit character like Length, Breadth and Weight. The investigation was carried out at Horticulture Research center (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2012-2013. The objective of the study is to find out optimum sample size for estimating yield contributing characters of the field experiment on bottle gourd.

Material and Method

Sample size depends on the variability associated with variable and the cost of reducing that variability. For such cases, it is necessary to choose optimum sample size and number of replications. Estimation of optimum sample size and number of replications are obtained by maximizing the information for a given cost.

There were five treatments/varieties used as treatment in this experiment. The treatments/varieties were LS 0026-5-3, LS 0012-5-3, LS 117-F-1, LS 117-A-2 and BARI Lau-3. Experimental plots were $25m^2$ (10m long and 2.5m wide). Fruit length, breadth and weight of bottle gourd (Lau) data were collected from the experimental plot. This data were used to calculate optimum sampling plan from equal observation per cell. The observation on fruit length (cm), breadth (cm) and weight (kg) were taken from 5 plots or treatments selected at random. The fruit length, breadth and weight of first two fruits from each selected plant utilized in this analysis. There were 10 fruits (5 plants per plot x 2 fruits per plant) per plot and 50 fruits per replication. Considering the time factor, the data of three replications were collected for deriving optimum sampling plan (Optimum in the sense of time involved in taking fruits measurements). A randomized complete block design (RCBD) with 3 replication was used for this experiment. The data were analyzed replication wise by analysis of variance (ANOVA) technique (Table 1) to estimate variance components associate with plots ($\hat{\sigma}_p^2$), plants ($\hat{\sigma}_q^2$) and fruits ($\hat{\sigma}_n^2$).

Analytical Model

We have an experiment in p treatments (plots) are taken at random, then q plants are randomly selected from each treatment. From each plant n random sampling unit is taken. The observations may be denoted by Y_{ijk} where i denote the treatments (i= 1, 2 ….. p), j the Plants (j = 1, 2, ……,q) and k the sampling unit (k = 1, 2, ….., n).

We also assume the following model:

$$Y_{ijk} = m + a_i + \beta_{ij} + \eta_{ijk} \quad (1)$$

Where

$m =$ the general mean

α_i=the treatments effect

$\beta_{ij} =$ the plants effect due to the (ij)th experimental unit.

η_{ijk} = the sampling effect due to the (ijk)th observation

For the study we suppose that the η_{ijk}'s are normally and independently distributed with variance σ_n^2, β_{ij}'s are normally and independently distributed with variance σ_q^2 and α_i's are normally and independently distributed. The η_{ijk}'s will be independent of the β_{ij}'s and α_i's if the sampling random.

The least square estimates are obtained as follows:

$$\hat{m} = \bar{y}\ldots$$

$$\hat{a}_i = (\bar{y}_{i\ldots} - \bar{y}\ldots)$$

$$\hat{\beta}_{ij} = (\bar{y}_{ij} - \bar{y}_{i-})$$

$$\hat{\pi}_{ijk} = (\bar{y}_{ijk} - \bar{y}_{ij.})$$

Also

$$\bar{y}_{i\ldots} = \frac{\sum_{i=1}^{p}\sum_{j=1}^{q}\sum_{k=1}^{n} y_{ijk}}{pqn}$$

$$\bar{y}_{i=} = \frac{\sum_{j=1}^{q}\sum_{k=1}^{n} y_{ijk}}{qn}$$

$$\bar{y}_{ij.} = \frac{\sum_{k=1}^{n} y_{ijk}}{n}$$

Putting these values in equation (l) and squaring and summing on both sides. Then the total sum of squares can be partitioned as:

$$\sum_{i=1}^{p}\sum_{j=1}^{q}\sum_{k=1}^{n}(y_{ijk} - \bar{y}_{\ldots})^2 = nq\sum_{i=1}^{p}(\bar{y}_{ijk} - \bar{y}_{\ldots})^2 + \sum_{i=1}^{p}\sum_{j=1}^{q}(\bar{y}_{jk} - \bar{y}_{i=})^2 + \sum_{i=1}^{p}\sum_{j=1}^{q}\sum_{k=1}^{n}(y_{ijn} - \bar{y}_{ij})^2$$

+ producttern

But product terms are usually zero.

Thus, Total (SS)= Treatment (SS) + Plant (SS)+ Sampling (SS)

With their degrees of freedom (npq-1) = (p-1) + p (q-1) + pq (n-1)

Table 1. The analysis of variance

Sources of Variation (SV)	Degrees of Freedom (D.F.)	Sum of Squares (S.S)	Mean Sum of Squares (MSS)	Expected Mean Sum of Squares (EMSS)
Plots/Treatment (Levels A)	(p-1)	$nq\sum_i \left(\overline{y_{i..}} - \overline{y_{...}}\right)^2 = S_p^2$	$\frac{S_p^2}{(p-1)} = T$	$\sigma_n^2 + n\sigma_q^2 + nq\sigma_r^2$
Plants/Plot(Level B within A)	p(q-1)	$n\sum_i\sum_j \left(\overline{y_{i..}} - \overline{y_{...}}\right) = S_q^2$	$\frac{S_q^2}{p(q-1)} = p$	$\sigma_n^2 + n\sigma_q^2$
Fruits/Plant/Plot Sampling	pq(n-1)	$\sum_i\sum_j\sum_k (y_{ijk} - \bar{y}_{ij.})^2 = S_n^2$	$\frac{S_n^2}{pq(n-1)} = S$	σ_n^2
Total	pqn-1	$\sum_i\sum_j\sum_k \left(\overline{y_{ijk}} - \overline{y_{...}}\right)^2$		

Where, p = number of plot or treatment, q = number of plants/plot and, n = number of fruits/plant/plot. Also T= The mean sum of square of Treatment, P= The mean sum of square of Plant, S= The mean sum of square of Sampling respectively.

According to estimation of optimum sampling plan, Snedacor and Cochran (1967), the variance component may be estimated as.

The components of variance $\sigma_n^2, \sigma_q^2 and \sigma_p^2$ estimated by $\hat{\sigma}_n^2 = S, P = \sigma_q^2 + n\sigma_p^2 and T = \sigma_n^2 + n\sigma_q^2 + nq\sigma_q^2$ i.e

$$\hat{\sigma}_q^2 = \frac{P-S}{n} and \hat{\sigma}_q^2 = \frac{T-P}{nq}$$

Thus variance of mean is

$$S_y^2 \frac{\hat{\sigma}_p^2}{P} + \frac{\hat{\sigma}_q^2}{pq} + \frac{\hat{\sigma}_n^2}{npq} \qquad (2)$$

$\hat{\sigma}_p^2, \hat{\sigma}_q^2$ and σ_n^2 for the character were obtained from the analysis of variance table.

The same variance of mean can be altered for the mean by using various combinations of q and n in equation (2)

$$S'^2_{\bar{y}} = \frac{\hat{\sigma}_p^2}{P} + \frac{\hat{\sigma}_q^2}{pq} + \frac{\hat{\sigma}_n^2}{n' p' q} \quad (3)$$

Where q′ and n′ are the altered values of q and n respectively.

The component $\hat{\sigma}_q^2$ was assumed as constant, as it represented variation due to treatments.

Efficiency of new sampling plan,

$$E = \frac{S^2_{\bar{y}}}{S'^2_{\bar{y}}} \hat{\sigma}_q^2 \quad (4)$$

The formula of saving the work/time load i.e time factor (TF) without sacrificing precision as compared with original plan i.e 10 fruits (5plant/plot x 2fruits/plant) per plot is defined as

$$TF (\%) = \frac{q'n' - qn}{q'n'} \text{ x } 100 \quad (5)$$

Where, q′=5, n′=2, q=1,2,------,5 and n=1,2,-------,5. Since 10 fruits per plot is the original plan or control.

Results and discussion

The results of the study were utilized in arriving alternate sampling plans (i.e., altering the value of q from 1 to 5 plant per plot and from 1 to 5 fruits per plant, making total 25 sampling plants per plot) (Table-2). The relative efficiency of each plant was worded out in relation to original plan (5 plants per plot and 2 fruits per plants). Using equation-4 the relative efficiency of new alternate sampling plans is given in Table-3. The results (Table-3) indicated that the relative efficiency with the number of plants per plot and number of fruits per plant.

The other alternate plan with 4 plant per plot and 2 fruits per plant (total 8 fruits per plot) had also 99.62 percent efficiency in comparison to original plan but had 20 percent less amount field work (Using equation 5). The other plan which can be employed with same efficiency is to select 3 plants at random per plot and

measure 3 fruits each selected plant (9 fruits per plot) had 94.21 but work load will be about 10 percent less than the plan with 5 plants x 2 fruits per plot.

The results revealed that work load for field operation like lagging of flowers, harvesting and measurement of individual fruit could be reduced effectively without sacrificing efficiency by selecting proper sampling plan.

Table 2. The estimated variance components for plots ($\hat{\sigma}_q^2$), plants ($\hat{\sigma}_q^2$) and fruits ($\hat{\sigma}_q^2$).

Variance component	Fruit Length			Fruit Breadth			Fruit Weight		
	R-I	R-II	R-III	R-I	R-II	R-III	R-I	R-II	R-III
$\hat{\sigma}_p^2$	26.16	28.36	24.84	0.22	0.34	0.41	0.23	0.29	0.33
$\hat{\sigma}_q^2$	38.11	33.15	23.1	0.30	0.62	0.58	0.12	0.16	0.21
$\hat{\sigma}_n^{\ 2}$	1.59	2.17	1.84	0.69	0.85	0.91	0.47	0.37	0.41

Table 3. The relative efficiency for some of the alternative sampling plants.

Number of		Fruit Length			Fruit Breadth			Fruit Weight			Average over traits	Work/Time Load (%)
Plants /plot	Fruits /plant	R-I	R-II	R-III	R-I	R-II	R-III	R-I	R-II	R-III		
1	1	51.31	55.10	59.26	24.79	27.51	29.47	45.12	51.82	58.42	44.76	90
1	5	62.40	56.66	61.06	45.59	44.07	47.78	83.33	81.10	89.22	63.47	50
2	3	74.41	77.48	80.38	61.85	62.90	63.64	100.45	98.45	110.26	81.09	40
2	4	67.45	77.64	80.56	65.75	65.85	68.79	102.86	102.10	114.13	82.79	20
2	5	74.58	77.73	80.65	68.33	67.75	71.33	109.72	104.42	116.59	85.68	0
3	2	86.49	88.25	89.81	68.96	72.34	74.59	106.22	108.49	118.50	90.41	40
3	3	86.68	88.52	90.01	75.63	77.67	79.49	114.82	110.54	124.56	94.21	10
3	4	86.78	88.66	90.23	79.47	82.54	82.45	111.63	103.58	127.83	94.80	20
5	2	100	100	100	100	100	100	100	100	100	100	0
5	1	99.24	98.79	98.90	71.77	78.54	79.09	106.32	107.32	122.24	95.80	50
5	3	99.85	99.90	99.72	92.02	95.64	96.67	129.67	122.59	138.98	108.33	50
4	2	94.23	95.07	95.64	78.68	82.82	83.73	116.07	112.95	137.46	99.62	20
4	3	94.48	95.31	95.88	85.10	88.01	86.65	123.67	117.78	133.20	102.23	20
4	1	93.78	94.38	94.93	64.17	70.38	89.25	98.01	100.59	114.43	91.10	60
3	5	86.84	88.74	90.32	81.96	82.54	84.33	122.78	115.48	129.87	98.09	50

Conclusion

Among different sampling plans a plan with 5 plants per plot and 1 fruits (total 5 fruits per plot) had on an average 95.80 percent efficiency i.e., almost equal efficiency when compared with original sampling plan of 5 plants/plot and 2

fruits per plant (10 fruits per plot). By adopting this new plan 50 percent work load (time) could be saved without sacrificing precision.

Then we conclude that sampling of selecting 4 plants at random per plot and measuring 2 fruits each selected plant (total 8 fruits per plot) appeared optimum and efficient(closed to original sampling plan i.e. 10 fruits per plot).

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Bangladesh J. Agril. Res. 40(4): 711-715, December 2015 **Short Communication**

EFFICACY OF FUNGICIDES AND BOTANICALS IN CONTROLLING FOOT AND ROOT ROT OF LENTIL

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Lentil (*Lens culinaris* Medik) is the second most important pulse crop in terms of both area and production (Anon., 2014). In Bangladesh pulses constitute an integral part of the daily diet as a direct source of protein for human beings (Sattar *et al*., 1996). Consumption of lentils with small grains provides a balanced diet. It is a cheap source of protein for human beings and also for animals in Bangladesh (Sattar *et al*., 1996). Lentil is also important in crop diversification in the cropping systems of the country. As the price of animal protein is increasing day by day, the protein shortage in the diet system of the people in the country can be met up through lentil. The yield of lentil in Bangladesh is low which is associated with poor management practices, unavailability of quality seeds and especially lack of proper disease management options. Diseases play important role for yield reduction. Lentil is affected by a wide range of fungal diseases. Productivity of lentil is reduced by pathogens through infection and damage to leaves, stems, roots and pods. It also reduces marketability due to discoloration of the seeds. Lentil suffer from attack of a number of seed borne diseases such as vascular wilt, collar rot, root rot, stem rot, rust, powdery mildew and downy mildew, which are caused by *Fusarium oxysporum* f. sp. *lentis*, *Sclerotium rolfsii, Rhizoctonia solani, Uromyces fabae, Erysiphe polygoni* and *Peronospora lentis,* rspectively (Khare *et al*., 1979, Singh and Tripathy, 1999). The soil borne pathogens *Fusarium oxysporum* and *Sclerotium rolfsii* commonly occur in the tropics and sub-tropics of the world causing foot and root rot of many crops (Aycock, 1966).

Foot and root rot caused by *Fusarium oxysporum* and *Sclerotium rolfsii* is considered as an important and destructive disease of pulses in almost all legume-growing countries of the world including Bangladesh (Anon., 1986, Dey *et al*., 1993). In Bangladesh, about 44% lentil plants are infected by foot and root rot disease (Anon., 1986). It causes seedling death at early stage resulting very poor plant stand which ultimately produces very low yield.

Despite of the many achievements in modern agriculture, chemical control still holds a strong performance in combating certain destructive plant diseases. Farmers' use chemicals for controlling the diseases of crop plants in Bangladesh, but limited information on the efficacy of these chemicals exits in our country (Hoque *et al*., 2014). Considering the above facts the present study was undertaken to evaluate efficacy of fungicides and botanicals for controlling foot and root rot of lentil under field condition at Madaripur district of Bangladesh.

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The experiment was carried out at Regional Pulses Research Station of Bangladesh Agricultural Research Institute (BARI), Madaripur, in the cropping seasons of 2011-12 and 2012-13. Seeds of lentil variety BARI masur-1 susceptible to foot and root rot has been used in the study. The experiment plot was prepared mechanically. Weeds and other materials were removed. The soil was prepared into good tilth by four cross ploughings and ladderings. The soil of the field was leveled before seed sowing. Fertilizers such as Urea, TSP and MOP were applied @ 45, 85 and 35 kg/ha and Cowdung @ 5 ton/ha during final land preparation (Anonymous, 2005). The experiment was laid out in randomized complete block design with three replications. Each block was divided into seven experimental units. The size of each experimental unit was 4 m×3 m. The treatments were assigned in each block at random. Three fungicides and three botanicals were used as seed treatment with one untreated control. The lentil seeds were sown in furrows made with tine where distance between the furrows was 30 cm.

The fungicides and botanicals tested in the experiment were Provax 200 (Carboxin + Thiram), Bavistin 50 WP (Carbendazim), *Trichoderma* compost (3 t/ha), Neem leaf extract (1:4 w/v), Garlic clove extract (1:4 w/v), Allamanda leaf extract (1:4 w/v) and control (untreated seed). Garlic bulb, allmanda and neem leaf extracts were prepared separately by crushing the cloves and leaves with the help of a mortar and pestle. The crushed materials were blended in an electric blender for fresh extract, and required amount of sterile water was added at 1:1 for solution. The blend was filtered through sterile cheesecloth. The supernatant was mixed with carrier material (flour). The mixture was put into wooden pellet device, thus the tablets of Garlic (*Allium sativum*), allamanda (*Allamanda cathertica*) and neem (*Azadiracta indica*) were prepared separately. These tablets were melted in 1:4 (w/v) concentration before seed treatment. The required amounts of seeds for each sub plot were taken in ployethylene bags, mixed with fungicides or botanicals and then sown at a rate of 40 kg/ha in the furrows immediately. The *Trichoderma* compost was applied in the plot before seed sowing.

Intercultural operations were done whenever, necessary and weeding was performed two times during the growing period of the crop. One weeding was done at 20 days and another at 35 days after sowing. During the growing period the plots were inspected regularly to record the foot and root rot disease. Dead plants were removed from the field after counting. Infected 5 plants were collected to identify foot and root rot pathogens.

The incidence of foot and root rot of lentil was recorded at 10 days interval. The incidence of the disease was calculated by the following formula:

$$\text{Incidence (\%)} = \frac{\text{Number of infectedplants}}{\text{Totalnumber of plants}} \times 100$$

Data on growth parameters were recorded from 10 randomly selected plants in each plot. The crop was harvested on 10 March in 2012 and 09 March in 2013. Grain yield were determined based on the whole plot and expressed in kilogram per hectare. The recorded data were analyzed statistically. Analysis of Variance and LSD test were done to find out the significant difference among the treatment means (Zaman *et al*., 1982).

Plant mortality, number of pod per plant and yield ranged from 7.06-10.90%, 49.33-74.33 and 1063-1465 kg/ha, respectively under various treatments during 2011-2012 cropping seasons (Table 1). The highest mortality (10.90%) was recorded from the control plot. The lowest reduction was obtained with allamanda leaf extract followed by garlic clove extract and neem leaf extract. The reduction of disease severity under Bavistin 50WP and *Trichoderma* compost was similar. The maximum and significant reduction was achieved with only Provax 200 compared to control. The highest (74.33) number of pod was achieved from Provax 200 which was statistically similar to Bavistin 50WP (70.00) and the lowest (49.33) pod number was found under control plot (Table 1). The highest yield (1465 kg/ha) of lentil grain was recorded from Provax 200 and lowest yield (1063 kg/ha) form control. All treatments with fungicides as well as botanicals increased the crop yield significantly over control. The highest increase (37.82%) was achieved with Provax 200 followed by *Trichoderma* compost (30.10%) and Bavistin 50WP (23.89 %).

Table 1. Efficacy of fungicides and botanicals in controlling foot and root rot disease of lentil during rabi 2011-2012 at PRRS, Madaripur.

Treatment	Plant mortality (%)	No. of pods per plant	Yield (kg/ha)	Yield increase over control (%)
Provax 200 @ 2%	7.06	74.33 a	1465 a	37.82
Bavistin 50 WP @ 2%	8.23	70.00 ab	1317 bc	23.89
Trichoderma compost @ 3 t/ha	8.23	67.33 bc	1383 ab	30.10
Neem leaves extract (1:4 w/v)	8.86	63.67 bcd	1315 bc	23.70
Garlic clove extract (1:4 w/v)	9.16	61.00 cd	1256 cd	18.16
Allamanda leaf extract (1:4 w/v)	9.36	57.33 d	1195 d	12.42
Control	10.90	49.33 e	1063 e	-
CV(%)	5.32	5.94	3.99	-
LSD(0.05)	0.83	6.68	91.25	-

Values within a column having a common letter(s) do not differ significantly (P=0.05).

Plant mortality, number of pod per plant and yield also significantly varied among the treatments including control during 2012-2013. The highest % mortality was recorded from control (Table-2). Treatments with different fungicides reduced disease severity as compared to control. The lowest reduction was obtained with garlic clove extract followed by allamanda leaf extract and neem leaf extract. The reduction of disease severity under Bavistin 50WP and *Trichoderma* compost was identical. The maximum and significant disease reduction was achieved with Provax 200 compared to other treatments. The highest number (66.33) of pod was achieved from Provax 200 which was statistically similar with Bavistin 50WP (62.00) and *Trichoderma* compost (59.67) treated plot and the lowest (43.67) pod number was found under control (Table-2). The highest yield (1322 kg/ha) of lentil grain was recorded from Provax 200 and lowest yield (963.30 kg/ha) from control. The highest yield increase (37.24%) was achieved with Provax 200 followed by Bavistin 50WP (34.23%) and *Trichoderma* compost (29.24%). The effect of Provax 200 on crop yield was significantly higher over other treatments where Bavistin 50WP and *Trichoderma* compost are statistically identical (Table 2).

Table 2. Efficacy of fungicides and botanicals in controlling foot and root rot disease of lentil during rabi 2012-2013 at PRRS, Madaripur.

Treatment	Plant mortality (%)	No. of pods per plant	Yield (kg/ha)	Yield increase over control (%)
Provax 200 @ 2%	7.30	66.33 a	1322 a	37.24
Bavistin 50 WP @ 2%	9.33	62.00 ab	1293 ab	34.23
Trichoderma compost @ 3 t/ha	9.40	59.67 abc	1245ab	29.24
Neem leaves extract (1:4)	10.60	57.00 bc	1188 bc	23.33
Garlic clove extract (1:4)	11.00	54.33 cd	1123 c	16.58
Allamanda leaf extract(1:4)	11.60	50.00 de	1101 c	14.29
Control	12.90	43.67 e	963.30 d	-
CV(%)	6.48	6.60	4.93	-
LSD(0.05)	1.18	6.58	103.2	-

Values within a column having a common letter(s) do not differ significantly (P=0.05).

It was quite evident that foot and root rot of lentil caused by *Fusarium oxysporum* and *Sclerotium rolfsii* had immense impact on germination, disease incidence, seedling mortality and yield (Dey *et al*., 1993). From the result it was observed that seed treatment with all the tested fungicides/ botanicals reduced the disease severity and increased pod number and crop yield of lentil as compared to untreated control. Provax 200, Bavistin 50WP and *Trichoderma* compost showed better performance than other treatments in both the seasons. However,

in 2011-12 cropping season, Bavistin 50WP, *Trichoderma* compost and Neem leaf extract showed statistically identical mortality, pods per plant and yield while in 2012-13 cropping season, Bavistin 50WP and *Trichoderma* compost showed statistically similar results.

The result of the present study clearly indicated that, seed treatment with botanicals and fungicides promoted yield by reducing foot and root rot disease.

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