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MOLECULAR ASSESSMENT OF MAIZE INBRED LINES (*Zea Mays* L.) USING MICROSATELLITE MARKERS

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Abstract

Genetic diversity analysis and germplasm characterization are essential steps in plant breeding and molecular markers are proved tool to accomplish. The present study was undertaken at the Molecular Breeding Lab of Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI) to determine the genetic relatedness and molecular characterization of 15 maize inbred lines of BARI. In present study, genetic diversity analysis was performed by using 10 SSR primers to evaluate the polymorphisms, among them six primers showed distinct polymorphism between the maize inbred lines. The maize genotypes E81, E144, E08, E167, E102, E142 and E121 were found more diverged (0.9003) compared to other inbred lines. On the other hand, the lowest genetic distance values (0.1501) were found between the genotype E140 and genotype E80 followed by genotype E126 and genotype E140; genotype E140 and genotype E65; genotype E65 and genotype E80 values were identical (0.4502). The genotypes viz. E81, E144, E08, E167, E102, E142 and E121 were found far away from centroid of the cluster and rest of the genotypes were placed around the centroid. The Principal Coordinate Analysis (PCO) helped to visualize four major clusters and showed that seven maize inbred lines (E81, E58, E08, E167, E102, E142 and E121) were far away from the other genotypes. In conclusion, SSR markers enabled discrimination among accessions and provided valuable information for future use in improvement of these genomic resources.

Keywords: Molecular Diversity, Microsatellite Marker and Inbred Maize

Introduction

Diversity of maize (*Zea mays* L.) inbreds has major importance in the process of maize improvement. The narrow genetic base of the modern highly yielding maize hybrids is problematic in breeding for adaptation to biotic and abiotic stresses, including chilling, drought, heat or salt tolerance. Knowledge on the genetic diversity and relationships among maize inbred lines is helpful in identifying promising combinations for exploitation of heterosis and establishment of heterotic groups for use as source materials in a breeding program. Morphological characteristics are often influenced by the environment

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and therefore, they do not always express genetic relationships. Besides, these traits reveal differences that are not comprehensible in terms of genetic distances. Molecular markers have proven valuable for genetic diversity analysis of many crop species. Their expression, unlike morphological markers, is not influenced by environmental factors; hence reflect the actual level of genetic difference existing between genotypes (Smith and Smith 1992, Westman and Kresovich 1997). In maize, microsatellites have proved to be a valuable tool for genome mapping (Taramino and Tingey 1996). Microsatellites or simple sequence repeats (SSRs) are DNA markers with short stretches of tandemly repeated di-, tri- or tetra-nucleotide motifs (Weber 1990). SSRs are characterized by a great abundance (Matsuoka *et al.* 2002), high variability (Tautz 1989, Schug *et al*. 1998) and even distribution throughout a wide range of genomic regions (Liu *et al.* 1996, Senior *et al.* 1996). They are codominant, highly polymorphic, multi-allelic and have become the marker of choice for genetic analysis in crops (Gupta and Varshney 2000). The objective of the present study was to use microsatellite markers for assessment of genetic diversity among the maize variety and inbred lines.

Materials and Methods

A total of 15 inbred lines of maize were randomly selected from BARI maize inbred lines. Seeds were grown in plastic pots. Then the pots were kept in the net house. After fifteen to twenty days (3 or 4 leaf stage) the fresh leaf was used for DNA isolation. Total DNA was isolated by CTAB method with slight modifications according to Maaß and Klass (1995). After treatment with 10µg/ml RNase A for half an hour at 37ºC, the DNA was purified with propanol. The purified DNA was dissolved in TE buffer and stored at -20ºC and the concentration was determined fluorometrically (Nano drop).

Ten SSR primer pairs were chosen (p-umc1354,p-umc1566,p-umc1292,p-bnlg1124,p-bnlg1179,phi002,phi037,phi038, phi039and bnlg565) to evaluate the polymorphism among the inbred lines. PCR conditions were optimized according to Hoxha *et al.* (2003). Here amplifications were performed in 20µl volumes containing 100ng genomic DNA, 2.5 mMdNTPs, 1.5mM MgCl2 , 10 pmol each forward and reverse primers, 3U TaqDNA polymerase and 10X PCR buffer (Genei). Thermal cycling consisted of initial denaturation at 95ºC for 3min, 30 cycles of 95ºC for 1 min, annealing temperature 55ºC for 1 min and 72ºC for 1 min, followed by a final extension at 72ºC for 5 min. PCR products were stored at 4ºC until use. The PCR products were visualized in Polyacrylamide gel electrophoresis (PAGE).

Molecular weight for each amplified allele was measured in base pair using Alpha-Ease FC 5.0 software. The allele frequency data from Power Marker version 3.25 (Liu and Muse, 2005) was used to export the data in binary format (allele presence="I" and allele absence = "0") for analysis with NTSYS-pc version 2.2 (Rohlf, 2002).

The summary statistics including the number of alleles per locus, major allele frequency, gene diversity, polymorphism information content (PIC) values were determined using Power Marker version 3.25 (Liu and Muse, 2005). A similarity matrix was calculated with the Simqual subprogram using the Dice coefficient, followed by cluster analysis with the SAHN subprogram using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) clustering method as implemented in NTSYS-pc was used to construct a dendrogram showing relationship among the genotypes. The similarity matrix was also used for principal coordinate analysis (PCA) with the D Center, Output, and MXPlot subprograms in computer program Numerical Taxonomy and Multivariate Analysis System (NTSYS-pc).

Results and Discussions

Microstallites displayed a high level of polymorphism.Out of 10 SSR markers employed to investigate the polymorphism, six markers (p-umc1354, p-umc1566, p-umc1292, phi037, phi039 and bnlg565) revealed clear and consistent amplification profiles. Among these, four markers (phi038, bnlg1179, bnlg1124, phi002) showed monomorphic pattern and hence were not included in further analysis.

A total of 48 alleles were detected at 10 SSR markers among 15 maize inbred lines with an average of 8 alleles per-microsatellite/genotypes locus (Table 1).The highest number of alleles per locus/genotype was detected using SSR primer set bnlg565, showing 12 alleles with an average of 0.8 alleles per genotype (Table 1). The lowest allele number per locus among the homologous chromosomes was observed using SSR primer set p-umc1566, showing a total of 4 with an average of 0.27 alleles per genotype (Table 1). The average number of alleles obtained in the present study was higher than those reported in previous maize diversity studies (Lu and Bernardo, 2001, Enoki *et al.* 2002, VazPatto *et al.* 2004). Lu and Bernardo (2001) reported 4.9 alleles per SSR locus for a sample of 40 US inbreds analyzed by 83 SSR markers; Warburton *et al.* (2002) investigating 57 CML lines with 85 SSR markers reported 4.9 alleles per marker; Senior *et al.* (1998) found 5.0 alleles/locus in a study of 94 elite US maize inbreds with 70 SSR markers, and Vaz Patto *et al.* (2004) reported 5.33 alleles per locus in 104 Portuguese and inbreds using 15 SSRs. In addition, Pejic *et al.* (1998) reported 6.8alleles/locus in 33 inbreds from US corn belt using 27 SSRs; Enoki *et al.* (2002), studying 65 inbred lines adapted to cold regions of Japan and imported American materials with 60 SSRs reported 7.3 alleles per locus and Xia *et al.* (2004) reported 7.4 alleles per locus in 155 tropical lowland inbreds using 79 SSRs. On the other hand, Liu *et al.* (2003) reported average 21.7 alleles per locus in a study including 260 US inbreds analyzed at 94 SSR loci. It is important to note that the total number of alleles reported in diversity studies is usually proportional to sample size, and some differences seen here may be attributable to sampling differences. However, another factor influencing the number of alleles is the use of di-nucleotide repeat SSRs, which can produce large number of alleles. However the more diverse set of inbreds from the gene bank collections included in the study may also contribute to the observed higher allelic richness. Range of allele size (bp) was from 4 (p-umc1566) to 12 (bngl565) (Table 1). The highest allele size difference in phi039 followed by bnlg565 and lowest in p-umc1566. According to Nei's (1973) the highest level of gene diversity value (0.8991) was observed in loci bnlg565 and the lowest of gene diversity value (0.6234) was observed in loci p-umc1566 with a mean diversity of 0.7773 (Table 2). It was observed that marker detecting the lower number of alleles showed lower gene diversity than those detected the higher number of alleles showed higher gene diversity. This result is consistent with previous work done by Herrera *et al.* (2008).

Table 1. Number of alleles, range of allele (bp) and gene diversity (GD) found in 15 maize inbred lines for 6 SSR markers.

Sl. No.	Markers	Chro[a] No.	Repeat type	Allele number	Range of allele size (bp)	Diff[b] (bp)	Gene diversity
1	p-umc1354	1.01	(CCG)5	6	36-62	26	0.7556
2	p-umc1566	1.01	(GCC)6	4	65-68	3	0.6756
3	p-umc1292	1.01	(TGG)6	8	68-100	32	0.8356
4	phi037	1.08	(AG)	8	131-164	33	0.8356
5	phi039	1.08	(ATT)	10	78-129	51	0.8000
6	bnlg565	3	(CT)21	12	47-92	45	0.9067
	Mean			8			0.8015

The frequency of the most common allele at each locus ranged from 13.33 % (bnlg565) to 46.66% (p-umc1566). On an average, 32.22% of the 15 maize inbred lines shared common major allele at any given locus (Table 2).

The polymorphic information content (PIC) values ranged from 0.6234 to 0.8991 with an average *of* 0.7733. The highest PIC value (0.8991) was obtained for bnlg565 followed by p-umc1292 (0.8159), phi37 (0.8159) respectively. The lowest PIC value (0.6234) was obtained for p-umc1566 (Table 2). PIC value revealed that bnlg565 was considered as the best marker for 15 maize inbred lines followed by p-umc1292 and phi37. P-umc1566 could be considered as least powerful marker.

The average PIC value determined in our investigation agreed well with the earlier findings reported based on SSR marker in maize inbred lines (Senior *et al.* 1998, Heckenberger *et al.* 2002 and VazPatto *et al.* 2004). Dinucleotide SSR loci (phi 037, nc003, bnlg619, phi054) identified the largest mean number of alleles (4.8) and mean PIC (0.67) as compared to tri, tetra and penta nucleotide repeats in this study, which is also in close agreement with previous observations for maize (Smith *et al.* 1997, Senior *et al.* 1998 and Enoki *et al.* 2002).

Table 2. Data on sample size, No. of observation, major alleles frequencies and Polymorphism information content (PIC) found among 15 maize inbred lines.

Sl. No.	Locus	No. of observation	Major allele frequencies (%)	PIC	Mean PIC
1	p-umc1354	15	0.40	0.7237	
2	p-umc1566	15	0.47	0.6234	
3	p-umc1292	15	0.27	0.8159	0.7773
4	phi037	15	0.27	0.8159	
5	phi039	15	0.40	0.7858	
6	bnlg565	15	0.13	0.8991	

The UPGMA clustering system also generated four genetic clusters with similarity coefficient of 15%. Maize inbred line E58 alone formed a single cluster named cluster III which showed 88% dissimilarity with the cluster IV (E121, E144, E142, E132, E139, and E89) and 79% dissimilarity with cluster II (E102, E126, E140, E80, E65 and E81).

Two inbred lines form a single cluster I where E08 and E167 are closed to each other. In cluster II inbred lines E140 and E80 showed maximum similarity 83% followed by E132, E139; E121, E144 (34% similar and 66% dissimilar). Cluster IV and Cluster II had maximum six inbred lines. In cluster IV all inbred were closed to each other by about 26%.

The pair-wise genetic dissimilarity coefficients based on 6 SSR marker indicated that the maximum genetic distance values (0.9003) was recognized between genotype E08 and genotype E121, genotype E08 and genotype E102, genotype E102 and genotype E121, genotype 139 and genotype E65, genotype E140 and genotype E132, genotype E58 and genotype E126, genotype E80 and genotype E144, genotype E81 and genotype E142, genotype E89 and genotype E81 and so on (Table 3). These results were in agreement with findings of Principal

Coordinate Analysis and suggested that these genotypes were diversed. The lowest genetic distance values (0.1501) were found between the genotype E140 and genotype E80 followed by genotype E126 and genotype E140; genotype E140 and genotype E65; genotype E65 and genotype E80 values were identical (0.4502).

Each lower and higher intergenotypic distances between pairs of maize inbred lines based on 6 SSR markers were given in the (Table 3) on the basis of Nei distance (Nei, 1973). Future breeding program for crop improvement could choose these genetically diversed parents for crossing program to create genetic variability and transgressive segregants.

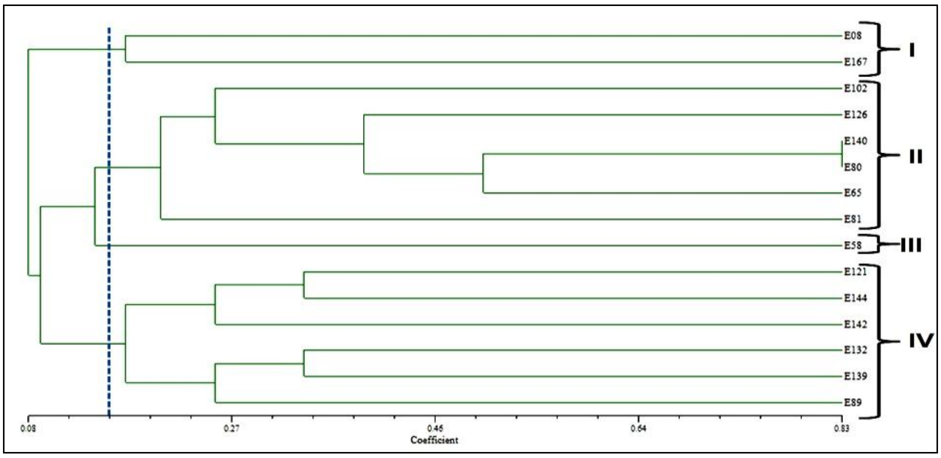

Fig. 1. Associations among maize inbred lines revealed by cluster analysis of SSR distance databased on the alleles detected by 6 SSR markers.

The two dimensional graphical view of Principal Coordinate Analysis (PCO) showed the spatial distribution of the 15 maize inbred lines along the two principal axes. The genotypes viz. E81, E144, E08, E167, E102, E142 and E121 were found far away from centroid of the cluster and rest of the genotypes were placed around the centroid (Fig.2). The genotypes were placed far away from the centriod were more genetically diverged compared to the genotypes placed near the centriod were likely to be genetically more similar. However, centriod may be defined as the vector representing the middle point of the cluster which contained at least one number for each variable. The connecting line between the each genotype and the centriod represented eigen vectors for the respective genotypes.

Table 3. Lower and higher inter genotypic distances (Nei, 1973) between pairs of Maize inbred lines based on 6 SSR markers

	E08	E102	E121	E126	E132	E139	E140	E142	E144	E167	E58	E65	E80	E81	E89
E08															
E102	0.9003														
E121	0.9003	0.9003													
E126	0.7503	0.7503	0.6002												
E132	0.7503	0.7503	0.7503	0.6002											
E139	0.9003	0.9003	0.7503	0.7503	0.6002										
E140	0.9003	0.6002	0.7503	0.4502	0.9003	0.7503									
E142	0.7503	0.9003	0.7503	0.7503	0.7503	0.7503	0.9003								
E144	0.9003	0.9003	0.6002	0.7503	0.7503	0.7503	0.9003	0.6002							
E167	0.7503	0.7503	0.9003	0.7503	0.9003	0.7503	0.7503	0.7503	0.9003						
E58	0.9003	0.9003	0.7503	0.9003	0.7503	0.7503	0.7503	0.9003	0.9003	0.9003					
E65	0.7503	0.7503	0.7503	0.6002	0.9003	0.9003	0.4502	0.7503	0.9003	0.7503	0.6002				
E80	0.9003	0.6002	0.6002	0.6002	0.9003	0.7503	0.1501	0.9003	0.9003	0.7503	0.7503	0.4502			
E81	0.9003	0.7503	0.7503	0.9003	0.9003	0.9003	0.6002	0.9003	0.9003	0.9003	0.7503	0.7503	0.6002		
E89	0.7503	0.9003	0.7503	0.7503	0.7503	0.6002	0.7503	0.7503	0.7503	0.9003	0.9003	0.9003	0.7503	0.9003	

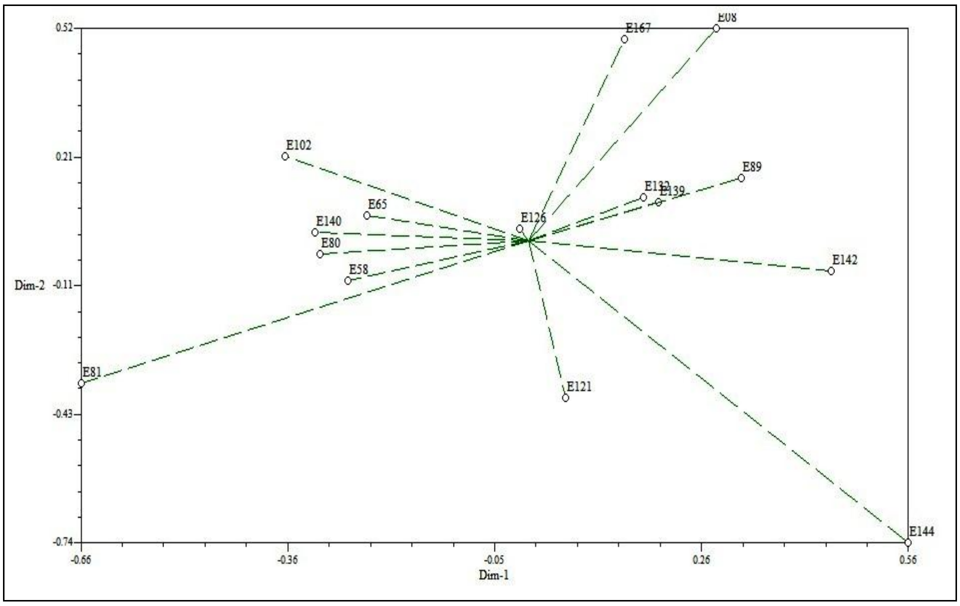

Fig. 2. Two-dimensional view of principal coordinate analysis (PCO) with 6 SSR markers over 15 maize inbred lines.

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RESPONSE OF CHICKPEA VARIETIES TO BORON APPLICATION IN CALCAREOUS AND TERRACE SOILS OF BANGLADESH

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Abstract

An experiment was conducted at Madaripur and Gazipur during *rabi* (winter) season of 2012-13 and 2013-14 to determine the optimum dose of B for different varieties of chickpea (*Cicer arietinum* L.). There were 12 treatment combinations comprising three varieties (BARI Chola-5, BARI Chola-8 and BARI Chola-9) and four levels of boron (0, 1, 1.5 and 2 kg ha^{-1}) along with a blanket dose of $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1}. Boron was applied as H_3BO_3. Results showed BARI Chola-9 with 1.5 kg B ha^{-1} produced the highest seed yield of 1338 kg ha^{-1} at Madaripur and 2218 kg ha^{-1} at Gazipur. Nodulation, nitrogen (N) and protein contents were also found highest for the same variety and B treatment. The other two varieties (BARI Chola-5 and BARI Chola-8) also performed higher yield in the plot receiving 1.5 kg B ha^{-1} compared to 1 kg B ha^{-1} or 2 kg B ha^{-1} at both locations. The results suggest that BARI Chola-9 and 1.5 kg B ha^{-1} along with $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1} could be used for achieving higher yield of chickpea in calcareous and terrace soils of Bangladesh.

Keywords: Chickpea, boron, yield, nodulation, protein content

Introduction

Chickpea (*Cicer arietinum* L.) commonly known as gram, is the third most important pulse crop in the world and stands 5th in respect of area (8250 ha) and production (6488 tons) in Bangladesh, with an average yield of 786 kg ha^{-1} (BBS, 2012). It is an important source of protein and is rich in fiber, minerals (phosphorus, calcium, magnesium, iron and zinc) and β-carotene (Legesse Hidoto *et al.*, 2017). Chickpea as a legume crop plays a significant role in improving soil fertility by fixing the atmospheric nitrogen (Kuldeep Balai, 2017). It leaves substantial amount of residual nitrogen for subsequent crops and adds huge amount of organic matter to improve soil health. Due to deep tap root system, chickpea can withstand drought conditions by extracting water from deeper layers in the soil profile.

The soils of different parts of Bangladesh are deficient in B and nitrogen fixing bacteria (*Rhizobium* sp.) which causes low yield of crops (Quddus *et al.*, 2014).

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Boron deficiency is more common in winter crops (Jahiruddin, 2015). General fertility levels of calcareous soils are low to medium. Terrace soils are acidic in reaction with low organic matter, moisture holding capacity and fertility level. The soils are mainly phosphate fixing, and low in P, K, S, Zn and B levels (FRG, 2012). Boron plays a vital role for chickpea growth especially flowering, fruit and seed set and yields (Ahlawat *et al.*, 2007). Boron influences the absorption of N, P, K and its deficiency affects the optimum levels of these three macronutrients (Raj, 1985). So, use of suitable variety and B dose can ensure higher yield of chickpea.

The present study was undertaken to evaluate the response of chickpea varieties to boron application and to find out the suitable dose of boron for yield maximization of chickpea in calcareous and terrace soils of Bangladesh.

Materials and Methods

Field experiments were conducted in two locations for two consecutive years (winter season of 2012-13 and 2013-14): (i) research field of Regional Pulses Research Station, Bangladesh Agricultural Research Institute (BARI), Madaripur and (ii) Pulses Research Sub-Station, BARI, Gazipur. Madaripur is medium high land with loamy textured calcareous soils. It belongs to Gopalpur series (Soil taxonomy: Aquic Eutrochrepts) under the agro-ecological zone of Low Ganges River Floodplain (AEZ-12). Gazipur is medium high land with fine-textured (clay loam) terrace soils. It belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agro ecological zone - Madhupur Tract (AEZ-28). The Madaripur area got average rainfall from 7.6 to 80.2 mm during November to April. The mean minimum and maximum air temperatures during November to March of the experiment were 10.3 and 34.8°C, respectively. Gazipur area received average rainfall from 1.2 to 34.8 mm during November to April. The mean minimum and maximum air temperatures during November to March of the experiment were 9.23 and 34.2°C, respectively. Before starting the experiment initial soil (0-15 cm) samples of both locations were analyzed. The chemical properties are shown in Table 1.

There were 12 treatment combinations comprising three varieties of chickpea (V_1= BARI Chola-5, V_2= BARI Chola-8 and V_3= BARI Chola-9) and four levels of boron (0, 1, 1.5 and 2 kg ha^{-1}) along with a blanket dose of $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1}. Treatment combinations were arranged as T_1= V_1B_0; T_2= V_1B_1; T_3= $V_1B_{1.5}$; T_4= V_1B_2; T_5= V_2B_0; T_6= V_2B_1; T_7= $V_2B_{1.5}$; T_8= V_2B_2; T_9= V_3B_0; T_{10}= V_3B_1; T_{11}= $V_3B_{1.5}$; and T_{12}= V_3B_2. The experiment was laid out in a split-plot design with three replicates. The main plot was considered as variety factor and sub-plot was as B factor. Each sub-plot size was 4 m × 3 m. The land was first opened by a tractor and prepared thoroughly by ploughing with a power tiller followed by laddering and leveling. Boron was applied as boric acid (17% B). Each plot received an equal amount of fertilizers $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1} as urea, TSP,

Table 1. Soil fertility status of experimental field at Madaripur and Gazipur

Location	pH	OM (%)	Total N (%)	Ca	K	P	S	Zn	B
				meq. 100 g^{-1}		µg g^{-1}			
Madaripur (result)	7.3	1.22	0.058	11.4	0.13	16	14	0.50	0.12
Critical level	-	-	0.12	2.0	0.12	10	10	0.60	0.20
Interpretation	slightly alkaline	low	very low	high	low	medium	medium	low	low
Gazipur (result)	6.2	1.28	0.061	6.55	0.11	13	13.5	0.65	0.16
Critical level	-	-	0.12	2.0	0.12	7	10	0.60	0.20
Interpretation	acidic	low	very low	high	low	medium	medium	low	low

(Interpretation source: FRG 2012)

MoP, gypsum and zinc sulphate, respectively during final plot preparation. Two types of chickpea like Desi chickpea (brown to yellow brown seed coat with various shaped- generally small or medium small and angular with a rough surface) e.g. BARI Chola-5 and BARI Chola-9, and Kabuli chickpea (white thin seed coat with bigger round shape and smooth surface) e.g. BARI Chola-8 were used. Seeds of chickpeas were sown @ 40-45 kg ha^{-1} with a spacing of 50 cm × 10 cm in mid-November in both locations. Two hand weedings were done at 25 and 50 days after sowing. The disease (BGM) was controlled by spraying Secure fungicide @ 0.2% two times at an interval of 10 days. The first at flowering stage and insects (pod borer and aphid) were controlled by spraying Karate @ 0.2% two times at 10 day intervals during podding stage. Crop was harvested at maturity. Maturity refers to chickpea pods to be brown or yellow brown coloured as well as the seed become hard containing 12-16% moisture. The data of nodules per plant was recorded at flowering stage in each plot by selecting 5 plants randomly. The chickpea plants were smoothly uprooted and the soil was carefully removed from roots by water. Then the roots were washed with distilled water, blotted with tissue paper and the number of nodules was counted. For measuring yield attributes viz. plant height, pods per plant and seeds per pod, mature ten plants of chickpea were randomly selected and uprooted from each plot at the harvest time. Plant height was recorded from above ground part and averaged. Pods were detached from every plant and the number of pods per plant was counted and averaged. Ten pods were separated randomly from composite pods of 10 plants from each plot. The number of seeds per pod was counted on ten pods and averaged. For stover yield (kg ha^{-1}), mature plants were collected from 1-m^2 in each plot at harvest time. The harvested plants were sun dried and seeds were separated. The dry stovers were weighed and the weight was converted to kg ha^{-1}. The seed yield (kg ha^{-1}) was measured based on whole plot (4 m× 3 m) technique. The 100- seed weight (g) was determined by randomly counting of 100- seed from the whole seeds from each plot and weighed. Initial soil samples (0-15 cm depth) of two locations were collected and brought to the laboratory and spread on a brown paper for air drying. The air-dry soil samples were ground and passed through a 2-mm sieve. After sieving, the prepared soil samples were kept into plastic containers with proper label for chemical analysis. Soil pH was measured by glass electrode pH meter using soil: water ratio of 1:2.5 (Page et al., 1982) and organic matter by Nelson and Sommers (1982) method; total N by Microkjeldahl method (Bremner and Mulvaney, 1982); exchangeable K by 1N NH_4OAc method (Jackson, 1973); exchangeable Ca by 1N NH_4OAc method (Gupta, 2004); available P by Olsen and Sommers (1982) method for calcareous soil and Bray and Kurtz (1945) method for terrace soil; available S by turbidity method using $BaCl_2$ (Fox *et al.*, 1964); available Zn by DTPA method (Lindsay and Norvell, 1978); available B by azomethine-H method (Page *et al.*, 1982). Plant samples (stover and seed) against each treatment were oven-dried at 70°C for 48 h and were finely ground using Cyclotec™ 1093 sample Mill (Made in Sweden). An amount of 0.1 g ground sample (stover and seeds) was analyzed for N using the Kjeldahl method FOSS (Persson et al., 2008). Protein content in chickpea seed was calculated by considering the pulses food factor 5.30 (FAO, 2018). The protein content was estimated by multiplying the %N content of seed with pulses food factor 5.30 that means (%N × 5.30). Analysis of variance (ANOVA) for the yield, yield attributes, nodulation and N and protein contents were done following the Statistix 10 package (Statistix 10., 1985). Data of yield attributes, nodules per plant, N and protein content were computed averaged of two study years in each location. Averaged data of all parameter were also statistical analyzed through ANOVA procedure using a split-plot design with three replicates considering main-plot factor variety and sub-plot for factor B. Then multiple comparisons like all-pairwise comparisons i.e. the means of treatment tested by LSD method at 5% (LSD 0.05) and level of significance (Statistix 10., 1985).

Results and Discussion

Effects of varieties and boron

The interaction between variety and boron showed significant variation in seed yield of chickpea over the years and locations (Table 2). The mean seed yield varied from 865 kg ha^{-1} to 1338 kg ha^{-1} at Madaripur and 1121 kg ha^{-1} to 2218 kg ha^{-1} at Gazipur across the treatments. The highest seed yield (1649 kg ha^{-1} in the 1^{st} year and 1026 kg ha^{-1} in the 2^{nd} year) at Madaripur was found in the treatment $V_3B_{1.5}$ which was statistically similar to $V_1B_{1.5}$ and V_1B_2 in the 1^{st} year and V_3B_2 & V_3B_1 in the 2^{nd} year. At Gazipur, the highest seed yield of 1965 kg ha^{-1} in the 1^{st} year and 2471 kg ha^{-1} in the 2^{nd} year was found in the treatment $V_3B_{1.5}$ followed by V_3B_2 in the 1^{st} year. Positive response of pulse crops to B application

Table 2. Effects of boron rates on the seed and stover yields of chickpea varieties

Treatment	Seed yield (kg ha^{-1})						Stover yield (kg ha^{-1})					
	Madaripur			Gazipur			Madaripur			Gazipur		
	1st yr	2nd yr	Mean	1st yr	2nd yr	Mean	1st yr	2nd yr	Mean	1st yr	2nd yr	Mean
v_1B_0	1256cde	774c-f	1015	1172fg	1352cd	1262	2989de	1654c	2322	2850c	3114fg	2982
v_1B_1	1385bcd	777b-f	1081	1329def	1508c	1419	3125cd	1745bc	2435	3521a	3745d	3633
$v_1B_{1.5}$	1641a	792b-e	1217	1457de	1782b	1620	3468a	1812bc	2640	3656a	3824cd	3740
v_1B_2	1543ab	812bcd	1178	1404de	1766b	1585	3314abc	1964b	2639	3612a	3678de	3645
v_2B_0	1122e	608g	865	1034g	1208d	1121	2745f	1610c	2178	2910c	3045g	2978
v_2B_1	1181e	625fg	903	1158fg	1269d	1214	2879ef	1798bc	2339	3123bc	3258fg	3191
$v_2B_{1.5}$	1374bcd	657d-g	1016	1286def	1347cd	1317	3254bc	1800bc	2527	3489a	3415ef	3452
v_2B_2	1244cde	650efg	947	1275def	1319cd	1297	3124cd	1697c	2411	3425ab	3356fg	3391
v_3B_0	1223de	891abc	1057	1486cd	1800b	1643	2833ef	2702a	2723	3124bc	3845cd	3485
v_3B_1	1417bc	938ab	1178	1674bc	1874b	1774	2845ef	2789a	2817	3547a	4056bc	3802
$v_3B_{1.5}$	1649a	1026a	1338	1965a	2471a	2218	3421ab	2941a	3181	3614a	4456a	4035
v_3B_2	1454b	989a	1222	1788ab	1892b	1840	3310abc	2812a	3061	3589a	4267ab	3928
CV (%)	8.14	12.8	-	8.73	8.87	-	3.58	6.61	-	5.88	5.44	-
$LSD_{0.05}$	192	175	-	212	248	-	191	239	-	340	342	-

Values within the same column with a common letter do not differ significantly ($P<0.05$).

(0.5 to 2.5 kg B ha^{-1}) was reported by Ceyhan and Onder (2007). Among the treatments, the lowest seed yield was observed in V_2B_0 in both years and locations. The stover yield (mean of two years) of chickpea ranged from 2178 to 3181 kg ha^{-1} at Madaripur and 2978 to 4035 kg ha^{-1} at Gazipur. The $V_3B_{1.5}$ treatment showed the highest stover yield across the years and locations (Table 2). The results indicate that every variety at 1.5 kg ha^{-1} B rate demonstrated positive effect on the yields of chickpea. The seed yield of chickpea was found comparatively lower in the 2^{nd} year at Madaripur. This variation might be due to infestation of chickpea plants by *Fusarium* wilt in the 2^{nd} year.

Table 3. Effects boron rates on the yield attributes (pooled data of two years) of chickpea varieties

Treatment	Plant height (cm)		Pods $plant^{-1}$		Seeds pod^{-1}		100 seed weight (g)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
v_1B_0	32.1e	43.6e	27.9de	37.1fg	1.12bcd	1.13	13.0e	13.2c
v_1B_1	33.0de	46.1de	29.1cd	42.2cd	1.15a-d	1.21	13.4e	13.6c
$v_1B_{1.5}$	35.7cde	49.4abc	31.7b	43.1cd	1.24ab	1.26	13.3e	13.8c
v_1B_2	34.7cde	47.9bcd	30.7bc	43.4c	1.21a-d	1.23	13.0e	13.4c
v_2B_0	34.9cde	45.4de	21.2i	36.5g	1.06d	1.09	24.5b	25.6a
v_2B_1	36.2cd	47.6bcd	22.2hi	38.0fg	1.08cd	1.11	25.0ab	26.2a
$v_2B_{1.5}$	37.4bc	49.5abc	25.0fg	39.3ef	1.17a-d	1.13	25.3a	26.8a
v_2B_2	36.7cd	46.7cd	24.0gh	38.4efg	1.12bcd	1.11	24.9ab	26.2a
v_3B_0	36.8c	47.2bcd	26.5ef	40.7de	1.19a-d	1.19	20.7cd	20.7b
v_3B_1	37.9bc	50.0ab	28.6d	48.5b	1.23abc	1.22	21.0cd	21.4b
$v_3B_{1.5}$	41.6a	51.0a	33.6a	51.9a	1.30a	1.27	21.2c	21.7b
v_3B_2	40.8ab	49.4abc	30.9bc	49.0b	1.24ab	1.23	20.6d	20.9b
CV (%)	5.79	3.86	4.38	3.00	7.26	10.8	1.51	4.31
$LSD_{0.05}$	3.6	3.2	2.1	2.2	0.15	ns	0.5	1.5

Values within the same column with a common letter do not differ significantly ($P<0.05$)

Yield attributes of chickpea viz. plant height, number of pods per plant, number of seeds per pod and 100-seed weight were influenced significantly by the treatments of varieties and B rates in both locations except number of seeds per pod at Gazipur. The tallest plant was found in the treatment $V_3B_{1.5}$ followed by V_3B_2 and dwarf plant was observed in the treatment V_1B_0 in both Madaripur and Gazipur (Table 3). The maximum number of pods per plant (33.6 at Madaripur and 51.9 at Gazipur) was recorded in the treatment $V_3B_{1.5}$ which was significantly different from the other treatments at Madaripur and Gazipur. The highest number of seeds per pod was counted in the treatment $V_3B_{1.5}$ which showed significant variation between the treatments but not at Gazipur. Ceyhan and Onder (2007) reported significant variation in varietal response to different B rates. The highest 100-seed weight was observed in $V_2B_{1.5}$ which was significantly different from other treatments, however, statistically similar for V_2B_2 and V_2B_1 (Table 3). Among the three varieties of chickpea, BARI Chola-8 under Kabuli type and the seed size was inherently bigger than other two varieties. Every variety at 1.5 kg B ha^{-1} gave better contribution compared to 1 kg B ha^{-1} or 2 kg B ha^{-1}.

Table 4. Effects of varieties and B rates on the number of nodules per plant, nitrogen (N) and protein contents of chickpea (pooled data of two years)

Treatment	No. of nodules plant^{-1}		N content (%)		Protein content (%)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
v_1B_0	22.5de	23.4d	3.25c	3.12b	17.2c	16.5b
v_1B_1	24.3cde	27.8c	3.67abc	3.45ab	19.5abc	18.3ab
$v_1B_{1.5}$	25.6abc	29.4bc	3.85abc	3.50ab	20.4abc	18.6ab
v_1B_2	25.0bcd	28.1c	3.69abc	3.46ab	19.6abc	18.3ab
v_2B_0	22.3e	24.3d	3.26c	3.06b	17.3c	16.2b
v_2B_1	23.0de	27.6c	3.45abc	3.25ab	18.3abc	17.2ab
$v_2B_{1.5}$	27.4ab	30.2b	3.99ab	3.78ab	21.1ab	20.0ab
v_2B_2	24.9b-e	28.7bc	3.76abc	3.55ab	19.9abc	18.8ab
v_3B_0	23.4cde	25.1d	3.33bc	3.18ab	17.7bc	16.9ab
v_3B_1	25.9abc	29.3bc	3.67abc	3.56ab	19.5abc	18.9ab
$v_3B_{1.5}$	27.8a	32.4a	4.05a	3.98a	21.5a	21.1a
v_3B_2	26.1abc	30.5ab	3.66abc	3.65ab	19.4abc	19.3ab
CV (%)	6.79	4.33	10.8	13.9	10.7	14.0
$LSD_{0.05}$	2.9	2.1	0.68	0.83	3.56	4.41

Values within the same column with a common letter do not differ significantly ($P<0.05$)

Presence of favorable soil environment and B nutrient along with other macro and micro nutrients might have promoted the nodule formation of chickpea varieties. Chickpea varieties and B rates demonstrated significantly a good number of active nodules per plant (Table 4). The number of nodules per plant ranged from 22.3 to 27.8 across the treatments. The maximum number of nodules per plant was counted from the treatment $V_3B_{1.5}$ which was significantly different from other treatments. The minimum number of nodules per plant was counted in V_2B_0 (Table 4). Alam *et al.* (2017) reported that the interaction between variety and boron level created significant variation in respect of number of nodules plant^{-1}. In contrast with our result, Alam *et al.* (2017) found the maximum number of nodules plant^{-1} (30.8) in BARI Chola-8 with 3 kg B ha^{-1}. The variation in the number of nodules per plant over the varieties might be due to variation in microbes and edhaphic condition of that area. The whole nodulation process is regulated by highly complex chemical communications between the plant and the bacteria. The protein content varied between 17.2 to 21.5% at Madaripur and 16.2 to 21.1% at Gazipur across the varieties and B rates. The highest protein content (21.5% at Madaripur and 21.1 at Gazipur) was measured from the treatment $V_3B_{1.5}$ which showed in most cases significantly similar with the other treatments. The lowest protein content in seed (17.2% at Madaripur and 16.2% at Gazipur) was measured from V_1B_0 treatment.

Effects of varieties

Chickpea yield in both locations was significantly different between the varieties (Table 5). The mean seed yield (mean of two years) ranged from 933 to 1198 kg ha^{-1} in Madaripur and 1237 to 1869 kg ha^{-1} in Gazipur across the varieties. The highest seed yield (1435 kg ha^{-1} in the 1st year and 961 kg ha^{-1} in the 2nd year at Madaripur and 1728 kg ha^{-1} in the 1st year and 2009 kg ha^{-1} in the 2nd year at Gazipur) was obtained from V_3 (BARI Chola-9) which was significantly higher than other varieties. The lowest mean seed yield of 933 kg ha^{-1} at Madaripur and 1237 kg ha^{-1} at Gazipur were recorded with the variety BARI Chola-8 (Table 5).The stover yield showed significant variation during two consecutive years in both the locations due to different chickpea varieties. The highest mean stover yield (2957 kg ha^{-1} in Madaripur and 3813 kg ha^{-1} in Gazipur) was recorded from BARI Chola-9 and the lowest stover yield of 2364 kg ha^{-1} at Madaripur and 3252 kg ha^{-1} at Gazipur was found in BARI Chola-8 (Table 5). This variation might be due to varietal characters; as a result BARI Chola-9 gave the highest yield. Boron doses exerted significant influence on the seed yield of chickpea. This result is supported by Alam et al. (2017) conducted in Rajshahi region of Bangladesh that BARI Chola-8 produced the highest seed yield. Plants must adapt their growth by sensing and responding to surrounding conditions like availability of nutrients in the soil for ensuring successful reproduction and yield.

Yield attributes showed significant variation due to chickpea varieties at the locations of Madaripur and Gazipur (Table 6). The highest plant height (39.3 cm at Madaripur and 49.4 cm at Gazipur) was recorded from V_3 (BARI Chola-9) which was significantly different from other varieties. The maximum number of pods per plant (29.9 at Madaripur and 47.5 at Gazipur) was found in V_3 which was significantly different to other, but statistically similar to BARI Chola-5 at Madaripur. The maximum number of seeds per pod (1.24 at Madaripur and 1.23 at Gazipur) was recorded from BARI Chola-9 followed by BARI Chola-5. The highest seed weight (24.9 g at Madaripur and 26.2 g at Gazipur) was obtained in BARI Chola-8 which was significantly different over other varieties (Table 6).

Table 5. Effects of chickpea varieties on yields

Chickpea variety	Seed yield (kg ha^{-1})						Stover yield (kg ha^{-1})					
	Madaripur			Gazipur			Madaripur			Gazipur		
	1st yr	2nd yr	mean	1st yr	2nd yr	mean	1st yr	2nd yr	mean	1st yr	2nd yr	mean
V_1	1456a	789b	1123	1341b	1602b	1472	3224a	1794b	2509	3410a	3590b	3500
V_2	1230b	635c	933	1188c	1286c	1237	3001b	1726b	2364	3237b	3267c	3252
V_3	1435a	961a	1198	1728a	2009a	1869	3102b	2811a	2957	3469a	4156a	3813
CV (%)	5.09	6.52	-	6.52	5.04	-	3.17	3.63	-	2.63	1.69	-
$LSD_{0.05}$	79.2	58.7	-	104	93.2	-	111	86.8	-	100	70.4	-

Values within the same column with a common letter do not differ significantly ($P<0.05$)

V_1=BARI Chola-5, V_3=BARI Chola-9, V_2=BARI Chola-8

Table 6. Effects of chickpea varieties on the yield attributes (pooled data of two years)

Chickpea variety	Plant height (cm)		No. of pods plant^{-1}		No. of seeds pod^{-1}		100 seed weight (g)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
V_1	33.9c	46.7b	29.8a	41.5b	1.18ab	1.21a	13.2c	13.5c
V_2	36.3b	47.3b	23.1b	38.1c	1.11b	1.11b	24.9a	26.2a
V_3	39.3a	49.4a	29.9a	47.5a	1.24a	1.23a	20.9b	21.2b
CV (%)	4.98	1.83	1.27	3.72	6.54	6.46	2.26	2.96
$LSD_{0.05}$	2.1	0.99	0.40	1.78	0.09	0.09	0.50	0.68

Values within the same column with a common letter do not differ significantly ($P<0.05$)

V_1=BARI Chola-5, V_3=BARI Chola-9, V_2=BARI Chola-8

Chickpea varieties influenced significantly on the number of nodules per plant. The highest number of nodules per plant (25.8 at Madaripur and 29.3 at Gazipur) was counted in BARI Chola-9. This variation might be inherent characters of BARI Chola-9. Nitrogen and protein contents showed non-significant variation across chickpea varieties. BARI Chola-9 assimilated the highest protein content (19.9% at Madaripur and 19.0% at Gazipur) than the rest of the varieties (Table 7).

Table 7. Effects of chickpea varieties on the number of nodules plant^{-1}, N and protein content (pooled data of two years)

Chickpea variety	No. of Nodules plant^{-1}		N content (%)		Protein content (%)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
V_1	24.3b	27.2b	3.62	3.38	19.2	17.9
V_2	24.4b	27.7b	3.61	3.41	19.2	18.1
V_3	25.8a	29.3a	3.68	3.59	19.5	19.0
CV (%)	2.90	3.41	8.84	10.2	8.80	10.3
$LSD_{0.05}$	0.8	1.1	ns	ns	ns	ns

Values within the same column with a common letter do not differ significantly (P<0.05)
V_1=BARI Chola-5, V_3=BARI Chola-9, V_2=BARI Chola-8

Table 8. Effects of different levels of boron on the yields of chickpea

Boron levels (kg ha^{-1})	Seed yield (kg ha^{-1})						Stover yield (kg ha^{-1})					
	Madaripur			Gazipur			Madaripur			Gazipur		
	1st yr	2nd yr	mean	1st yr	2nd yr	mean	1st yr	2nd yr	mean	1st yr	2nd yr	mean
0	1200c	758	979	1231c	1453c	1342	2856c	1989b	2423	2961b	3335c	3148
1	1328b	780	1054	1387b	1550bc	1469	2950c	2111ab	2531	3397a	3686b	3542
1.5	1555a	825	1190	1569a	1867a	1718	3382a	2184a	2783	3586a	3898a	3742
2	1414b	817	1116	1489ab	1659b	1574	3249b	2158a	2704	3542a	3767ab	3655
CV (%)	5.09	6.52	-	6.52	5.04	-	3.17	3.63	-	2.63	1.69	-
$LSD_{0.05}$	110	ns	-	122	143	-	110	138	-	196	198	-

Values within the same column with a common letter do not differ significantly (P<0.05)

Effects of boron application

Yields of chickpea varieties increased markedly due to application of boron. The mean seed yield at Madaripur ranged from 979 to 1190 kg ha^{-1} and at Gazipur ranged from 1342 to 1718 kg ha^{-1} due to application of different rates of B. The highest seed yield (1555 kg ha^{-1} in the 1st year & 825 kg ha^{-1} in the 2nd year at

Madaripur and 1569 kg ha^{-1} in the 1st year & 1867 kg ha^{-1} in the 2nd year at Gazipur) obtained in the plot receiving of 1.5 kg B ha^{-1} which was significantly different with the other plot receiving of 2.0 kg B ha^{-1} or 1.0 kg B ha^{-1} except the 2nd year at Madaripur that was showed non-significant (Table 8). Khanam et al. (2000) reported that the seed yield of chickpea was affected significantly due to different rates of boron application. The stover yield of chickpea varieties across the rates of boron showed in some exception almost similar trend of seed yield (Table 8).The seed yield (mean of two years) of chickpea in Gazipur was observed higher over the yield of Madaripur. Because chickpea plants in the 2nd year were infested by the disease *Fusarium* wilt in Madaripur. The weather of 2nd year and soil condition might be favoured for the disease *Fusarium* wilt.

Different boron fertilization showed significant effect on yield attributes of chickpea varieties except seeds per pod at Gazipur (Table 9). The highest plant height (38.2 cm at Madaripur and 49.9 cm at Gazipur) was noted from the rate of B 1.5 kg ha^{-1} followed by 2.0 kg ha^{-1} in both locations. The maximum number of pods per plant (30.1 at Madaripur and 44.8 at Gazipur) was counted from application of 1.5 kg B ha^{-1} followed by 2.0 kg B ha^{-1}. The maximum number of seeds per pod was recorded from application of 1.5 kg B ha^{-1} in both locations (Table 9). Similar results were also reported by Alam et al. (2017). The highest 100-seed weight (19.9 g at Madaripur and 20.8 g at Gazipur) was obtained from application of 1.5 kg B ha^{-1}. In most of the cases, the lowest yield attributes of chickpea varieties were found in B_0 treatment (Table 9).

Table 9. Effect of different rates of boron on the yield attributes of chickpea (pooled data of two years)

Boron levels (kg ha^{-1})	Plant height (cm)		No. of pods plant^{-1}		No. of seeds pod^{-1}		100 seed weight (g)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
0	34.6c	45.4c	25.2d	38.1c	1.12b	1.14	19.4b	19.8b
1	35.7bc	47.9b	26.6c	42.9b	1.15ab	1.18	19.8a	20.4ab
1.5	38.2a	49.9a	30.1a	44.8a	1.24a	1.22	19.9a	20.8a
2	37.4ab	48.0b	28.5b	43.6ab	1.19ab	1.19	19.5b	20.2ab
CV (%)	4.98	1.83	1.27	3.72	6.54	6.46	2.26	2.96
$LSD_{0.05}$	2.09	1.83	1.20	1.26	0.08	ns	0.29	0.87

Values within the same column with a common letter do not differ significantly (P<0.05)

The number of nodules per plant increased with the increasing rates of boron application (Table 10). The highest number of nodules per plant (26.9 at Madaripur and 30.7 at Gazipur) was achieved by the application of 1.5 kg B ha^{-1}

which showed significant variation with other B application rates but statistically identical to application of 2 kg B ha^{-1} at Madaripur (Table 10).

Table 10. Effects of different levels of boron on the number of nodules plant^{-1}, N and protein content of chickpea (pooled data of two years)

Boron levels (kg ha^{-1})	No. of nodules plant^{-1}		N content (%)		Protein content (%)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
0	22.7c	24.3c	2.28b	3.12b	17.4b	16.5b
1	24.4bc	28.2b	3.60ab	3.42ab	19.1ab	18.1ab
1.5	26.9a	30.7a	3.96a	3.74a	21.0a	19.9a
2	25.3ab	29.1b	3.70a	3.55ab	19.6a	18.8ab
CV (%)	2.90	3.41	8.84	10.2	8.80	10.3
$LSD_{0.05}$	1.7	1.2	0.39	0.48	2.06	2.55

Values within the same column with a common letter do not differ significantly ($P<0.05$)

The N and protein content accumulations were influenced significantly by the rates of B application. The N and protein contents varied from 2.28 to 3.96% N and 17.4 to 21.0% protein across the rates of B application. The highest N and protein contents were recorded in the treatment of 1.5 kg B ha^{-1} followed by 2 kg B ha^{-1} and 1 kg B ha^{-1} at both Madaripur and Gazipur whereas the minimum contents (N and protein) were observed in control (B_0) treatment (Table 10). Boron influences the absorption of N, P, K and positive role on protein synthesis (Raj, 1985).

Conclusion

All varieties of chickpea were found responsive to boron, but BARI Chola-9 response to boron comparatively was higher than that of other two varieties by the trial of two consecutive years. BARI Chola-9 and boron @ 1.5 kg ha^{-1} along with a blanket dose of $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1} appeared as the best-suited combination on the basis of yield, quality (protein content) and yield components. All tested varieties like BARI Chola-5, BARI Chola-8 and BARI Chola-9 achieved higher yield in the plot receiving 1.5 kg B ha^{-1} than that of the plot receiving 1 kg B ha^{-1} or 2 kg B ha^{-1} at both Madaripur and Gazipur. Thus boron @ 1.5 kg ha^{-1} along with $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1} can be recommended for chickpea cultivation in calcareous and terrace soils of Bangladesh.

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RESPONSE OF BROCCOLI TO USG AND PRILLED UREA IN SHALLOW RED-BROWN TERRACE SOIL UNDER MADHUPUR TRACT

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Abstract

A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during the period from 2012-13 to verify the effectiveness of urea super granule (USG) and prilled urea (PU) on the yield and quality of broccoli, to assess the comparative performance of USG and PU on nutrient uptake and nitrogen use efficiency and to evaluate the effect of USG and PU on post-harvest nutrient status in Shallow Red-Brown Terrace Soil of Madhupur Tract (AEZ-28). The experiment was designed in a randomized complete block with three replications having 5 treatments as T_1: Control, T_2: USG-N_{140}, T_3: USG-N_{160}, T_4: USG-N_{180} and T_5: PU-N_{180}. Result showed that USG performed better than PU. The comparative performance of USG in relation to yield, head quality (ascorbic acid, β-carotene and chlorophyll content), SPAD value, nutrient (NPKS) uptake and N use efficiency was found higher as compared to PU. USG treated broccoli plants gave significantly higher yield where the highest yield (13.49 ton ha^{-1}) was recorded with USG-N_{160} kg ha^{-1}. Moreover, USG showed higher β-carotene and chlorophyll content over PU and those were increased with increasing levels of N. However, ascorbic acid content was slightly decreased with increasing rate of N fertilizer. Nitrogen, phosphorus and potassium uptake increased with increasing N rate upto USG-N_{180} but sulphur uptake was increased upto USG-N_{160}. Nitrogen use efficiency was higher in USG treated plots than that of PU having the highest value of 111.71% with USG-N_{160} kg ha^{-1}. Post-harvest soil nutrient status was not significantly influenced by the treatments although it was slightly higher in USG as compared to PU. Considering all, USG @ 160 kg N ha^{-1} (USG-N_{160}) with other recommended fertilizers (@ 53 kg P, 83 kg K, 20 kg S, 2.0 kg Zn, 1 kg B and 0.8 kg Mo ha^{-1}) could be the best USG based fertilizer dose for quality broccoli production in Shallow Red-Brown Terrace Soil of Madhupur Tract.

Keywords: Broccoli, USG, head quality, chlorophyll content, nitrogen use efficiency, soil nutrient status.

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Introduction

Broccoli (*Brassica oleracia* var. italica L.) is one of the winter vegetables belonging to the family Cruciferae. It is a beneficial and more nutritious vegetable than any other of the same genus (Yoldas *et al*., 2008). It is well known that, broccoli has enormous nutritional and medicinal values due to its high contents of vitamins (A, B_1, B_2, B_5, B_6 and E), minerals (Ca, Mg, Zn and Fe) and antioxidant substances which prevent the formation of cancer causing agents (Beecher, 1994). Broccoli contains a higher rate of sulforaphane that prevents *Helicobacter pylori* which are responsible for stomach cancer (Fahey *et al*., 2002). Nitrogen plays an important role in broccoli production and broccoli is highly dependent on N fertilization to achieve a good yield (Babik and Elkner, 2002). At present, different sources of N fertilizer are available in the market which may improve fertilizer use efficiency. Among these, USG is used by the farmers for upland vegetable crops like tomato, cabbage, broccoli, papaya, banana etc (Hussain *et al*., 2003; Nazrul *et al*., 2006). Total yield of broccoli is greatly influenced by the different doses of nitrogenous fertilizer (Bélec *et al.*, 2001). Zaman *et al*. (1993) reported that N is an important plant nutrient and is the most limiting one due to its high mobility and different types of losses. To control such losses, USG application may be a good practice to minimize production cost as well as to increase N use efficiency, yield and quality of the crop.

On the other hand, leaf greenness is closely related to chlorophyll contents which is related to leaf N and the SPAD values- that is proportional to the chlorophyll content of leaves (Kapotis *et al.*, 2003). Yoldas *et al.* (2008) reported that application of N increased N, P, K and Fe concentrations in broccoli head. Evaraarts and Willigen (1999) found that band placement of N influenced N uptake positively. The increase rate of N fertilizer induces increase of nitrate content in plant tissue of broccoli (Zebarth *et al.*, 1995). As nitrogen plays a major role in agriculture and is also responsible for a number of environmental problems, nitrogen management is indispensable for maximizing broccoli yield and minimizing N loss and cultivation cost. Therefore, it is essential to evaluate the different forms of N and levels of USG and PU application for sustainable crop cultivation. To attain this goal the present study was undertaken to verify the effectiveness of USG and PU on the yield and quality of broccoli, to assess the comparative performance of USG and prilled urea on nutrient uptake and N use efficiency and to evaluate the effect of USG and PU on post-harvest nutrient status in Shallow Red-Brown Terrace Soil under Madhupur Tract (AEZ-28).

Materials and Methods

A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University during *rabi* season of 2012 – 2013. The soil of the experimental field belongs to Salna series representing the Shallow Red-Brown

Terrace which falls under the order Inceptisols (FAO, 1988) representing Madhupur Tract (AEZ-28). Before setting up of the experiment, soil samples were collected from the experimental plots and different physico-chemical properties were analyzed as presented in Table 1a and 1b.

Table 1a. Physical properties of initial soil of the experimental plot

Soil properties (0-15 cm soil depth)	Analytical value
Particle size distribution of soil:	
Sand (%)	17.8
Silt (%)	45.6
Clay (%)	36.6
Texture	Silty clay loam
Bulk density (g cm^{-3})	1.34
Particle density (g cm^{-3})	2.61
Porosity (%)	47.47
Field capacity (%)	28.67

Table 1b. Chemical properties of initial soil of the experimental plot

Soil properties (0-15 cm soil depth)	Soil pH	Organic carbon	Total N	Exchangeable K	CEC	Available P	Available S	Available B
		%		meq/100g soil		µg g^{-1}		
Analytical value	5.97	0.96	0.10	0.32	12.67	14.18	13.78	0.21

The experiment was laid out in a randomized complete block design with three replications having 5 treatments comprised of different levels of USG and PU as- T_1: Control (0 kg N), T_2: USG-N_{140} (140 kg N as USG), T_3: USG-N_{160} (160 kg N as USG), T_4: USG-N_{180} (180 kg N as USG) and T_5: PU-N_{180} (180 kg N as PU). Besides these, a blanket dose of nutrients @ 53 kg P, 83 kg K, 20 kg S, 2.0 kg Zn, 1 kg B and 0.8 kg Mo ha^{-1} in the forms of TSP, MoP, gypsum, boric acid, zinc oxide and sodium molybdate, respectively were applied mostly on the basis of initial soil test value following FRG, 2012 to all plots except the control. Nitrogen was applied as per treatment in two forms as USG and PU. "Premium Crop" a high yielding variety of broccoli (*Brassica oleracea* var. italica L.) collected from Taki seed company, Japan was used as a test crop. The unit plot size was 2.4 m × 2.7 m (6.48 m^2) having plot to plot and block to block distances

0.75 m and 1.0 m, respectively. After proper land preparation, 25-day-old seedlings were transplanted in lines on November 20, 2012 maintaining a row to row and plant to plant distance 0.60 m and 0.45 m, respectively. Each plot was irrigated uniformly at every alternate day by watering can to bring the soil moisture at desired level. Weeding was done twice before first and second top dress. Earthing up was done to make a continuous line of ridges and furrows. For the establishment of crop, furrow irrigation was given at an interval of 7 days. MoP 50% and all other fertilizers except PU and USG were applied as broadcasting and incorporated in soil during final land preparation. Prilled urea was top-dressed in two equal splits at 15 and 35 DAT in a ring method. At 15 DAT, USG was placed at 7-8 cm below the surface and 9-10 cm apart from broccoli plant. The remaining 50% MoP was top-dressed at 15 DAT followed by irrigation. Harvesting was started on 25th January and continued up to 5th February, 2013. Data on yield and other parameters were collected as outlined by Liu *et al.* (1993). Initial and post-harvest soil samples were collected and analyzed for both physical and chemical properties. Plant samples were also collected and analyzed for N, P, K, S and B contents. SPAD reading using the instrument Minolta SPAD-502 meter were recorded at 5 days interval after the application of USG and PU. SPAD readings were taken on the tip of the leaf along with the midrib (mid-point) of the three youngest but fully expanded leaves of five randomly selected plants. Fifteen leaves were measured at random from each plot and a mean SPAD value was calculated according to Costa *et al.* (2003). Post-harvest soil analysis was done to assess soil nutrient status. Total N of soil was determined following the micro-Kjeldahl method according to Jackson *et al. (*1973). Available P was determined following the sodium bicarbonate extraction using Colorimetric method (Olsen *et al.*, 1954). Exchangeable potassium of soil was determined from ammonium acetate (1N NH_4OAC) extract as described by Jackson (1973) using flame-photometer. Available sulphur in soil was determined by extracting the samples with $CaCl_2$ (0.15%) solution **(**Page *et al.*, 1982) using spectrophotometer at 420 nm wave length followed by turbidimetrical method. Total B content was measured by colorimetric method (Hunter, 1980) measuring concentration using double beam spectrophotometer. (Model no. 200-20, Hitachi, Japan) at 555 nm wave length.

Ascorbic acid (vitamin C) was determined by the Iodate method described by Samotus *et al.* (1982) using the formula as stated below:

$$\text{Ascorbic acid (mg/100g FW)} = \frac{f \times V_1 \times V_2 \times 100}{W \times V_{13}}$$

Where,

V_2= Total volume of blended sample (100ml)

V_3= Volume of sample extract taken (5ml)

W= Weight of fresh head sample (20g)

V_1 =Titrated volume of KIO_3 (ml)

Chlorophyll a, Chlorophyll b and β-carotene were determined following acetone-haxen method as stated by Masayasu and Yamashita (1992). The chlorophyll a, chlorophyll b and β-carotene contents were estimated using the formula as follows:

Chlorophyll a (mg/100 ml) = $0.999A_{663} - 0.0989A_{645}$

Chlorophyll b (mg/100 ml) = $0.328A_{663} + 1.77A_{645}$

β-carotene (mg/100 ml) = $0.216A_{663} - 1.22A_{645} - 0.304A_{505} + 0.452A_{453}$

*A_{663}, A_{645}, A_{505}, A_{453} are absorbance at 663 nm, 645 nm, 505 nm and 453 nm, respectively.

Plant biomass was estimated by oven dry method. Samples were dried at 65°-70° C for 72 hours and weighted. The biomasses per plant, per plot and per hectare were calculated by the following formula:

a). Biomass per plant (g)= $\frac{\text{(Total above ground biological yield of 10 plants(g)}}{100}$

b). Biomass per hectare (kg)=Biomass yield per plant (kg) × Number of plants ha^{-1}

To evaluate leaf nutrient content, leaf samples were collected from matured leaf of five randomly selected plants at harvesting stage which were then oven dried and ground for analyses. To estimate the head quality, samples were collected from the head of five randomly selected plants from each treatment. Collected samples were analyzed for vitamin-C, β-carotene and chlorophyll content. Plant nitrogen in leaf, stem and head samples were determined following the Micro-Kjeldahl method and phosphorus was determined after digestion with HNO_3 and $HClO_4$ mixture followed by ammonium vana-molybdate method colorimetrically with the help of a spectrophotometer at 660 nm wavelength. Potassium contents were determined directly with the help of flame photometer after digesting the samples with di-acid mixture and sulphur content was measured by adding 6N HCl plant extract with $BaCl_2$ outlined by Black, 1965.

Nutrient uptake from the soil was calculated by using the formula:

Nutrient uptake (kg ha^{-1}) = $\frac{(\%\ \text{Nutrient} \times \text{Y (kg ha}^{-1}\text{)}}{100}$

Here,

% Nutrient = Average nutrient content (%) of plant or head biomass

Y (kg ha^{-1}) = Total dry matter production of plant or head biomass

Nitrogen use efficiency (NUE) was determined by the equation stated by Craswell and Godwin (1984):

$$\text{Nitrogen use efficiency (NUE)} = \frac{(\text{N uptake F - N uptake C})}{\text{Fertilizer N applied}} \times 100$$

Where,

F and C denote fertilized crop and unfertilized (control), respectively.

The collected data were then compiled and statistical analyses were done by using the statistical package, MSTATC. Mean separation was done by DMRT at 5% level of probability. Computation and preparation of graphs were made using Microsoft Excel 2003 program.

Results and Discussion

Effect of USG and PU on yield and yield attributes of broccoli

Plant height

Plant height was significantly influenced due to different forms and levels of nitrogen and it was increased with increasing rate of N fertilizer (Table 2). At harvest, the highest plant height (67.10 cm) was recorded from USG-N_{180} which was statistically identical with USG-N_{160} (65.28 cm) and PU-N_{180} (64.77 cm) (Table 2). This phenomenon might be due to continuous supply, higher availability and uptake rate of N from USG for its longer retention in soil than that of PU, which is vulnerable to loss in many ways. The minimum plant height (44.98 cm) was recorded from N-control. These results are similar to the findings of Hala and Nadia (2009) who observed the highest plant height and number of leaves plant^{-1} with the minimum dose of N along with P and K.

Number of leaves plant^{-1}

Number of leaves plant^{-1} significantly increased due to different forms and levels of N (Table 2). The maximum number of leaves (14.30 plant^{-1}) was recorded with USG-N_{180} followed by USG-N_{160} (14.10 plant^{-1}). The minimum number of leaves (11.63 plant^{-1}) was obtained from the control. These results are in accordance with the findings of Ouda and Mahadeen (2008). Such effect of N on number of leaves plant^{-1} was also reported by Nasreen *et al.* (1992) and Masson *et al.* (1991). Thakur *et al.* (1991) reported that increasing rate of N application delayed head maturity and increased the number of leaves plant^{-1}, leaf area, gross plant weight, stalk length, dry matter content and head yield of cauliflower.

Head length

The highest head length (14.07 cm) was recorded from USG-N_{140} followed by USG-N_{160} which was statistically identical with PU-N_{180} and USG-N_{180} (Table 2) but significantly higher over N-control. The head length recorded in PU-N_{180} was higher than that of USG-N_{180} which might be due to lower flow of translocates to cell development in comparison to cell elongation. The lowest head length (10.4 cm) was observed in N-control. Chao-Jiong *et al.* (2010) also reported similar result in case of broccoli.

Head diameter

Head diameter was significantly affected by the different levels of N where the maximum head diameter (19.47 cm) was recorded from USG_{160}, which was statistically similar to USG-N_{180} (18.67 cm) but significantly higher than all other treatments (Table 2). This might be due to continuous and balanced supply of assimilates from leaf to floret. The lowest diameter (9.83 cm) was recorded from N-control. This finding is in agreement with the findings of Yoldas *et al.* (2008) who reported that increased N rates significantly increased yield, average weight of main and lateral heads, and the diameter in broccoli compared to control.

Head weight

Individual head weight was also significantly influenced by the application of different N levels. It was increased with increasing level of N fertilizer upto 160 kg N ha^{-1} where the highest head weight (364.3 g $plant^{-1}$) was obtained from USG-N_{160} followed by USG-N_{180} which was statistically identical with PU_{180} (Table 2). This might be due to maximum translocation of carbohydrate from leaf to head which increased size, shape and head compactness with an optimum vegetative growth. The minimum head weight (131.8 g $plant^{-1}$) was recorded from N-control. Similar results were obtained by Chao-Jiong (2010) in broccoli. Rickard (2008) reported that N had a curvilinear effect on marketable yield and an increase was seen up to application of 165 kg N ha^{-1} which may justify the present findings.

Table 2. Effect of different forms and levels of N-fertilizer on yield components of broccoli

Treatment	Plant height (cm)	Number of leaves $plant^{-1}$	Head length (cm)	Head diameter (cm)	Head weight (g $plant^{-1}$)
Control	51.64 c	11.63 b	10.40 b	9.83 d	131.8 c
USG-N_{140}	62.14 b	13.56 a	14.07 a	17.43 bc	316.3 b
USG-N_{160}	65.28 ab	14.10 a	14.00 a	19.47 a	364.3 a
USG-N_{180}	67.10 a	14.30 a	13.07 a	18.67 ab	349.0 ab
PU-N_{180}	64.77 ab	13.93 a	13.47 a	17.20 c	325.3 ab
CV (%)	2.45	4.41	8.58	4.04	6.88
SE (±0.05)	0.8809	0.3440	0.6439	0.3851	11.82

Means followed by uncommon letters are statistically different from each other at 5% level of provability by DMRT.

Head yield

The head yield of broccoli was significantly influenced by the different forms and levels of N. It was increased with increasing rate of N up to USG-N_{160} kg ha^{-1} and then declined. The highest head yield (13.49 ton ha^{-1}) was obtained with USG-N_{160} followed by USG-N_{180} (12.93 ton ha^{-1}) (Fig.1). Prilled urea treated plot (PU-N_{180}) gave 12.05 ton ha^{-1} head yield which was statistically identical with USG-N_{140}. This might be due to maximum translocation of carbohydrate from leaf to head that increased size and head compactness optimizing vegetative growth for higher N supply. USG-N_{180} also produced more yield than that of PU-N_{180} which indicated the superiority of USG over PU. The minimum head yield (4.88 ton ha^{-1}) was recorded from N-control. This result is in agreement with the findings of Greenwood *et al.* (1980) where the maximum broccoli yield was obtained with the recommended doses from 175-252 kg N ha^{-1}. Zebarth *et al.* (1995) found that marketable yield of broccoli increased with increasing N rate in a curvilinear pattern. Similar results were reported by Goodlass *et al.* (1997) and Chao-Jiong (2010) in broccoli. The low crop yield from the control treatment is due to the insufficient supply of N in plants, leading to limit the carbon assimilation, resulting in reduction of plant productivity (Lawlor, 2002).

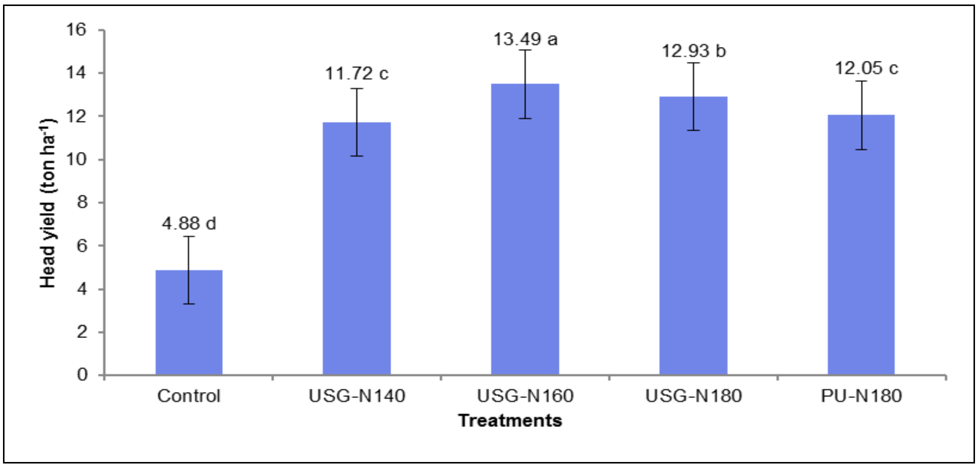

Fig. 1. Effect of different forms and levels of N-fertilizer on head yield of broccoli (Vertical bar showing the SE; CV: 6.88 %).

Effect of USG and PU on quality attributes of broccoli

SPAD value

Results on SPAD (Soil Plant Analysis Development) value was recorded to determine the leaf greenness and to compare leaf chlorophyll content as affected by different forms and levels of urea N and presented in Table 3. At initial stage up to 35 DAT, no significant variation was found with the SPAD values of the broccoli leaf (Table 3) although it was slightly higher in PU-N_{180}. However, at later stages from 40 DAT, a significant variation was observed among the treatments and it was increased with increasing levels of urea N. At these stages the highest SPAD values were recorded with USG-N_{180} which was slightly higher than that of PU-N_{180}. The maximum increase of SPAD values (11.59 %) was noted at 60 DAT over 25 DAT for the control. But it was 25.03 and 18.27 % at 60 DAT over 25 DAT for USG-N_{180} and USG-N_{180}, respectively. Perhaps this phenomenon was due to rapid availability of N at initial stage as it was closer and adjacent to the root zone in case of PU, but at later stages availability of N from USG increased over time and ensured a continuous supply upto harvest (70 DAT). On the other hand, supply of N from PU became limiting at later stages. Maximum SPAD values were recorded at 60 DAT and then decreased slightly. At 60 DAT, the maximum SPAD value (74.73) was recorded from USG-N_{180} followed by USG-N_{160} (73.10) and PU-N_{180} (Table 3). However, at harvest (70 DAT) the highest SPAD value (73.93) was recorded with USG-N_{180} followed by USG-N_{160} (72.23) but it was 72.07 for PU-N_{180} treatment (Table 3). Perhaps this was due to higher N content in leaf. The minimum SPAD value was recorded in N-control. Similar results were also reported by Bullock and Anderson (1998), Kantety *et al.* (1996) and Wang *et al.* (2004). Varvel *et al*. (1997) demonstrated that N fertilizer significantly increased both corn grain yield and SPAD readings.

Table 3. SPAD values as affected by different forms and levels of N-fertilizer at different days after transplanting

Treatment	25 DAT	30 DAT	35 DAT	40 DAT	45 DAT	50 DAT	55 DAT	60 DAT	65 DAT	70 DAT
Control	56.07	56.20	57.20	58.20 c	60.07 b	60.30 b	61.47 b	62.57 b	62.23 b	62.30 b
USG-N_{140}	56.90	56.93	57.13	59.93 bc	66.40 a	68.63 a	71.67 a	72.27 a	71.70 a	71.50 a
USG-N_{160}	59.27	59.57	60.53	64.47 ab	67.17 a	69.23 a	71.67 a	73.10 a	72.77 a	72.23 a
USG-N_{180}	59.77	60.67	61.30	65.80 a	68.77 a	71.10 a	73.00 a	74.73 a	74.10 a	73.93 a
PU-N_{180}	62.17	62.47	63.80	64.50 ab	67.33 a	70.53 a	72.97 a	73.53 a	72.37 a	72.07 a
CV (%)	4.82	6.18	3.94	3.82	3.43	3.33	2.19	3.56	3.59	4.02
SE (±0.05)	1.642	2.121	1.360	1.380	1.306	1.306	0.8884	1.464	1.462	1.632

Means followed by uncommon letters are statistically different from each other at 5% level of probability by DMRT

Compactness coefficient

The higher the head compactness the better the head quality of broccoli. Head compactness significantly increased with increasing levels of N and the highest compactness coefficient (18.91) was found from PU-N_{180} followed by USG-N_{160} (18.71) which were statistically similar to all other treatments except control with the lowest compactness coefficient (13.41) (Fig. 2). It was due to higher supply of translocates but lower cell elongation which might have caused maximum accumulation of assimilates as well as higher head compactness. This finding is in agreement with the result of Renata *et al*. (2005) in broccoli.

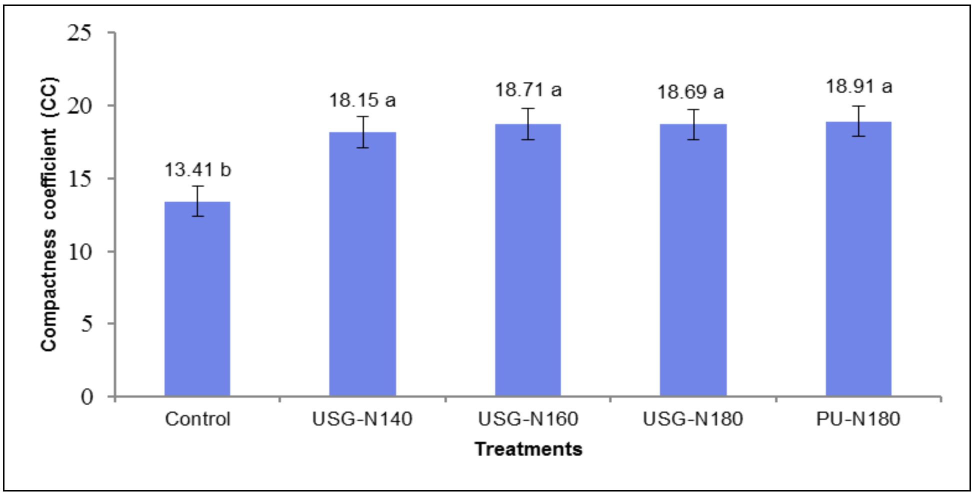

Fig. 2. Effect of different forms and levels of N-fertilizer on compactness coefficient of broccoli head (Vertical bar showing the SE; CV: 7.53 %).

Ascorbic acid and β-carotene content

A significant difference was observed with ascorbic acid (Vitamin C) content. The highest ascorbic acid content (84.28 mg $100g^{-1}$ FW) was found with USG-N_{140} which was followed by USG-N_{160} (83.60 mg $100g^{-1}$ FW) but identical with N-control (79.93 mg $100g^{-1}$ FW). The lowest ascorbic acid content (66.33 mg $100g^{-1}$ FW) was recorded with PU-N_{180} (Table 4). This might be due to the higher nitrogen doses produced higher fresh but reduced dry matter content which resulted in less ascorbic acid. Karitonas (2001) reported that an increased level of N supply slightly reduced the vitamin C content from 83 to 73 mg 100 g^{-1} FW in broccoli flowers. Similar result was also reported by Chao-Jiong *et al*. (2010). Beta-carotene content was significantly influenced by different treatments and the highest β-carotene content was recorded with USG-N_{160} (0.384 mg/100g FW) followed by USG-N_{180} (0.373 mg $100g^{-1}$ FW) but statistically identical with PU-N_{180} and USG-N_{140} (Table 4). The minimum and significantly different β-carotene content (0.312 mg $100g^{-1}$ FW) was recorded with control treatment.

Chlorophyll-a and chlorophyll-b content

Chlorophyll-a content was significantly higher at higher level of USG and 0.738 mg $100g^{-1}$ FW was recorded with USG-N_{180} which was statistically identical with USG-N_{160} (0.0.736 mg $100g^{-1}$ FW), PU-N_{180} (0.707 mg $100g^{-1}$ FW) and USG-N_{140} (0.685 mg $100g^{-1}$ FW) (Table 4). Statistically the lowest chlorophyll-a content (0.671 mg $100g^{-1}$ FW) was noted with control treatment. Chlorophyll-b content was also higher at higher levels of USG and the highest chlorophyll-b content (1.1154 mg $100g^{-1}$ FW) was observed with USG-N_{180}, which was statistically identical with USG-N_{160}. However, the statistically lowest chlorophyll-b content (0.7709 mg $100g^{-1}$ FW) was recorded in N control, which was significantly lower than USG treated plant but identical to PU-N_{180} (Table 4). The plants under PU-N_{180} always contained lower chlorophyll-b than that of USG-N_{180}. Ouda and Mahadeen (2008) reported that head number per plant, head diameter and chlorophyll content were higher when a combination of organic and inorganic fertilizers was added compared with their individual addition.

Table 4. Effect of different forms and levels of N-fertilizer on the head quality of broccoli

Treatment	Ascorbic acid (mg $100g^{-1}$ FW)	β-carotene (mg $100g^{-1}$ FW)	Chlorophyll-a (mg $100g^{-1}$ FW)	Chlorophyll-b (mg $100g^{-1}$ FW)
Control	79.93 ab	0.312 b	0.671 b	0.7709 c
USG-N_{140}	84.28 a	0.346 ab	0.685 ab	0.9743 bc
USG-N_{160}	83.60 a	0.384 a	0.736 a	1.0359 ab
USG-N_{180}	75.10 b	0.373 ab	0.738 a	1.1154 a
PU-N_{180}	66.33 c	0.346 ab	0.707 ab	0.9813 bc
CV (%)	5.39	6.81	3.68	7.36
SE (±0.05)	2.420	0.01826	0.01826	0.03873

Means followed by uncommon letters are statistically different from each other at 5% level of provability by DMRT

Effect of USG and PU on nutrient uptake by broccoli

Nitrogen uptake

Nitrogen uptake increased with the increasing levels of urea N and the highest N uptake (273.65 kg ha^{-1}) was found with USG-N_{180} followed by USG-N_{160} (267.02 kg ha^{-1}) and PU-N_{180} showed the third highest N uptake (235.70 kg ha^{-1}). However, the higher N uptake was found from USG treated plots as compared to PU (Table 5). This might be due to continuous supply, higher N retaining capacity in the soil and greater fertilizer-N recovery in case of USG than that of PU. The possible reason for higher uptake is that as USG placed at deeper zone the limited number of nitrifying bacteria present at the premise of USG and converts a limited portion of urea to NO_3^{-1} –N. Consequently, takes more time to convert whole USG to available N as compared to PU resulted in greater opportunity for plants to take up N from soil. This result is in agreement with the findings of Rashid *et al.* (1996). They reported that the use of N as USG was more effective than that of PU and they also stated that deep placement of USG was an effective means of increasing N use efficiency of rice as compared to the traditional split application of PU. Khalil *et al.* (2011), Zebarth *et al.* (1995) and Rickard (2008) also reported the similar findings.

Nitrogen use efficiency

From the study, it was found that the N use efficiency was increased with increasing levels of N upto USG-N_{160} (111.71%) and then decreased with the further increased rate of N fertilizer (Fig. 3). The lowest N use efficiency was found from PU-N_{180} (81.90%). Overall N use efficiency was higher with USG than that of PU. This result was more or less similar to that of the findings of Khalil *et al.* (2011). The apparent N recovery decreased with increasing rate of fertilizer N application for several vegetable crops (Greenwood and Draycott, 1988). Rashid *et al.* (1996) reported that the use of N as USG was more effective than that of PU and they also stated that the deep placement of USG was an effective means of increasing N use efficiency of rice as compared to the traditional split application of PU. Zebarth *et al.* (1995) reported that the apparent fertilizer-N recovery in the aboveground portion of the plant decreased linearly from between 46 and 93% at a N rate of 125 kg N ha-' to between 20 and 45 % at a N rate of 625 kg N ha^{-I}. Letey *et al.* (1983) reported 76 % N use efficiency and Thompson *et al.* (2002) found 87.4, 69.0 and 81.3 %, N use efficiency with 13.0, 18.9 and 11.5 ton yield ha^{-1} of broccoli for different years. Accordingly, N use efficiency (NUE) of broccoli decreased with increasing amount of fertilizer (Riley and Vagen, 2003; Tremblay and Beaudet, 2006). Lower N rates affected crop growth and reduced N uptake while the higher N rates caused losses through the root zone. Another fact to the higher NUE is the less root disturbance, since there was no lateral dressing in case of USG and it was placed only once at a cropping season. A larger root system, and possibly a stronger plant, could have contributed to better N uptake by USG treated plots.

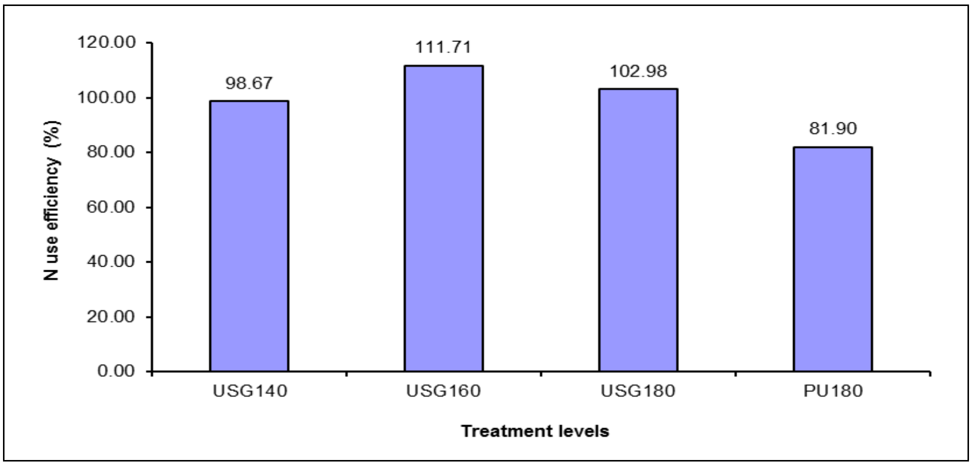

Fig. 3. Effect of different forms and levels of N-fertilizer on N use efficiency of broccoli.

Table 5. Effect of different forms and levels of N-fertilizer on N, P, K and S uptake by broccoli

Treatment	N uptake ($kgha^{-1}$)	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	S uptake (kg ha^{-1})
N-control	88.28 c	8.03 c	73.17 c	0.48 d
USG-N_{140}	226.42 b	25.22 b	186.09 b	1.48 c
USG-N_{160}	267.02 a	27.37 a	197.20 a	1.85 a
USG-N_{180}	273.65 a	29.08 a	207.19 a	1.77 a
PU-N_{180}	235.70 b	25.54 b	192.66 b	1.66 b
CV (%)	4.43	5.46	3.88	6.23
SE (±0.05)	5.575	0.7230	3.836	0.05164

Means followed by uncommon letters are statistically different from each other at 5% level of provability by DMRT

Phosphorus and potassium uptake

Phosphorus uptake increased significantly with increasing levels of urea N in the form of USG and the highest 29.08 kg ha^{-1} was found with USG-N_{180} which was followed by USG-N_{160} (27.37 kg ha^{-1}), but this was statistically identical (Table 5). Third highest P uptake 25.54 kg ha^{-1} was with PU-N_{180} and significantly identical with USG-N_{140}. USG performed better than PU. The highest K uptake (207.19 kg ha^{-1}) was noted with USG-N_{180} which was statistically identical with USG-N_{160} (197.20 kg ha^{-1}). Significantly lower K uptake was observed with PU-N_{180} (Table 5). This result was supported by Yoldas *et al.* (2008). They reported that the application of N increased N, P, K and Fe concentrations in broccoli head. Similar results were also reported by Abdelrazzag (2002) and Magnusson (2002) on several vegetable crops. The synergistic effect between N and K resulted in higher K uptake with increasing levels of N.

Sulphur uptake

Sulphur uptake also increased significantly with increasing levels of urea N upto USG-N_{160} and then it was decreased and showed a curvilinear fashion (Table 5). The highest S uptake 1.85 kg ha^{-1} was noted from USG-N_{160} followed by USG-N_{180} (1.77 kg ha^{-1}) but statistically identical. A lower S uptake (1.66 kg ha^{-1}) was obtained with PU-N_{180} than that of USG-N_{180}. Therefore, it was observed that a higher uptake of S from USG treated plots than that of PU (Table 5). This is due to continuous supply, higher S use efficiency and greater fertilizer S recovery in case of USG.

Effect of USG and PU on post-harvest soil nutrient status of broccoli field

Statistically significant variation was observed for post harvest nutrient status of soil due to different forms and levels of N (Table 6). The highest N content

(0.101%) was found in USG-N_{180} treated plant which was followed by PU-N_{180} (0.099%), but statistically identical with each other (Table 6). The lowest N content (0.077%) was found in N-control, which was significantly lower than USG-N_{180} and PU-N_{180}. This finding was supported by Evaraarts and Willigen (1999) who reported that the amount of mineral N in the soil at harvest generally increased with increasing amounts of N applied. Result revealed that USG addition exhibited more residual effect on soil-N content than that of PU. Phosphorus content did not follow any pattern although the highest P content (17.59 µg g-1) was found in control plot (Table 6). A significant variation was observed in post harvest soil K content and the highest K content (0.188 me/100g) was recorded from control which was followed by USG-N_{140} > USG-N_{160} > PU-N_{180} > USG-N_{180}, respectively (Table 6). The lowest K content (0.138 me/100g) was found with USG-N_{180}. It might be due to higher uptake and removal of K by the crop. Similarly a significant variation was observed in post harvest soil S content and the highest S content (10.06 µg g^{-1}) was recorded with USG-N_{140} which was followed by USG-N_{160}, PU-N_{180} and USG-$N_{180,}$ but statistically identical with USG-N_{160} (Table 6). This might be due to higher plant growth as well as higher nutrient uptake by the plant. The minimum S content (7.06 µg g^{-1}) was found in the control plot. Variation in B content in post harvest soil was also found significant and the highest B content (0.296 µg g^{-1}) was recorded in USG-N_{140}. This was also statistically similar to USG-N_{160} and was followed by and PU-N_{180} (Table 6). It may be due to higher absorption and higher growth of the plant as promoted by N. The minimum B content (0.115 µg g^{-1}) was found with N-control. The minimum S and B content in control plot may be due to no addition of those fertilizers.

Table 6. Effect of different levels of USG and PU on post-harvest soil nutrient status of broccoli field

Treatment	Total N	Exchangeable K	Available nutrient		
			P	S	B
	(%)	(me/100g)	(µg g^{-1})		
Control	0.077 b	0.188 a	17.59 a	7.06 c	0.115 c
USG-N_{140}	0.096 ab	0.172 ab	16.78 ab	10.06 a	0.296 a
USG-N_{160}	0.096 ab	0.156 bc	16.04 b	9.39 a	0.294 a
USG-N_{180}	0.101 a	0.138 c	14.10 c	7.89 bc	0.202 b
PU-N_{180}	0.099 a	0.157 bc	15.64 b	9.01 ab	0.207 b
CV (%)	5.93	9.63	4.61	7.50	7.38
SE (±0.05)	0.005774	0.005774	0.4270	0.0.3737	0.00577

Means followed by uncommon letters are statistically different from each other at 5% level of probability by DMRT

Conclusion

From the above study it appeared that USG-N is superior to PU-N in terms of yielding ability and quality parameters (Vitamin-C, β-carotene, and chlorophyll content) of broccoli. Nutrient uptake, nitrogen use efficiency and post harvest soil-N were also found to be higher with the use of USG-N. Such performance of USG-N was better with USG-N_{160}. Nitrogen application @ 160 kg-N ha^{-1} in the form of USG along with recommended dose of other fertilizers may be suggested as the best combination of N rate and form of application for maximizing the yield and quality of broccoli in Silty Clay Loam Soil under Madhupur Tract (AEZ-28).

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ADOPTION AND PROFITABILITY OF SUMMER TOMATO CULTIVATION IN JASHORE DISTRICT OF BANGLADESH

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Abstract

The study assessed the level of adoption and profitability of summer tomato varieties at farm level. Data were collected from 90 randomly selected tomato farmers of Bagherpara, Jashore Sadar and Jhikorgacha upazila of Jashore district. The results indicated that BARI Hybrid Tomato-4 was highly adopted summer tomato variety (75%) followed by BARI Hybrid Tomato-8 (16%) and ACI summer king tomato variety (9%). The adoption level of ploughing, manure and fertilizer use were low, whereas planting time and irrigation were high. Total cost of production of summer tomato was Tk 584822 per hectare whereas Tk 507355 per hectare was variable cost and fixed cost was Tk 77467 per hectare. Among the cost items mancha preparation cost was the highest (26.89 %) and 26.10 % cost was for labor. The average yield of summer tomato was 50.41 t/ha and gross return was 1542300 tk/ha. On the average, benefit cost ratio was found to be 2.64 on full cost basis and 3.04 on cash cost basis. MoP, zipsum and manure were significant effect on summer tomato cultivation. Attack by pest and disease, lack of seed at proper time, lack of agricultural credit and high cost of production were the major constraints for the adoption of summer tomato.

Keywords: Adoption, Profitability, Summer Tomato.

1. Introduction

Bangladesh is an agro-based country where agriculture is considered as backbone of her economy. About 45 percent of total labor force were engaged in agriculture (BBS, 2016). Agriculture plays a vital role through employment generation, poverty alleviation, food security, enhance standard of living by increasing income level of rural population. Many developing countries like Bangladesh benefited from the green revolution in cereal production in the past but were not able to substantially reduce poverty and malnutrition. Vegetable production can help farmers to generate income which eventually alleviate poverty.

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Among the vegetables tomato (*Solanum Lycopersicun*) is one of the most important vegetables in terms of acreage, production, yield, commercial use and consumption. It is the most consumable vegetable crop after potato and sweet potato occupying the top of the list of canned vegetable (Chowdhury, 1979). It is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmed, 1976). However, the yield of the crop is very low compared to those obtained in some advanced country (Sharfuddin and Siddique, 1985). In Bangladesh congenial atmosphere remains for tomato production during low temperature winter season that is early November is the best time for tomato planting in our country (Hossain *et al.,* 1999). It is a good source of vitamin C (31 mg per 100g), vitamin A, calcium, iron etc (Matin *et al.,* 1996). Although tomato plants can grow under a wide range of climatic conditions, they are extremely sensitive to hot and wet growing conditions, the weather which prevails in the summer to rainy season in Bangladesh. But limited efforts have been given so far to overcome the high temperature barrier preventing fruit set in summer-rainy (hot-humid) season. Its demand for both domestic and foreign markets has increased manifold due to its excellent nutritional and processing qualities (Hossain *et al.,* 1999).

Considering the growing demand and importance of tomato, Bangladesh Agricultural Research Institute (BARI) has taken initiative to develop off-season summer and rainy season tomatoes. So far BARI has developed and released 3 hybrid tomato varieties i.e. BARI Hybrid Tomato-3, BARI Hybrid Tomato-4 and BARI Hybrid Tomato-8 which can be grown during summer and rainy season under poly tunnel. The average yield of BARI Hybrid Tomato was 32.78 t/ha in the Jessore district (Karim *et al*, 2009). But very little information has been generated about the profitability and adoption of hybrid tomato cultivation technologies by the farmers in the country. Generalization from studies conducted in home and abroad (Mohiuddin *et al.*, 2007; Zaman *et al.*, 2006; Islam, 2005; Rahman *et al.,* 1998; Ali and Gupta, 1978; Gupta and Rao, 1978) regarding the tomato production may not be always applicable due to considerable variation in attributes of the technologies and for various others factors. Fortunately, the farmers of Bagharpara upazila under Jashore district started to adopt this technology as a pioneer farmer since 2005 (Karim *et al.,* 2009). It is recognized that in order to expand the area of this crop as well as to fit this crop in the farmers cropping system, studies are needed to ascertain its cost and return situation in relation to profitability, input use and farmer's resource use efficiency. Keeping all these factors in consideration, the present study was undertaken to provide information through fulfillment of the following objectives.

Objectives

i. To know the adoption status of summer tomato variety along with its cultivation technologies at farm level and to find out the factors affecting their adoptions.

ii. To estimate the input use pattern and profitability of summer tomato cultivation.

iii. To identify the constraints to summer tomato production at farm level.

2. Methodology

2.1 Sample size and sampling technique

The present study was conducted at three upazila namely Bagherpara, Sadar and Jhikorgacha upazila of Jashore district. The study area was purposively selected considering the higher concentration of BARI Hybrid Tomato cultivation during summer season. The study was carried out by using formal survey method. A total of 90 farmers taking 30 from each upazila was randomly selected for interview. Necessary information regarding this study was also collected on input costs, price, yields etc.

2.2 Method of data collection

Data were collected through pre-designed interview schedule during the summer season of 2014. Field investigators under the direct supervision of the researcher collected field level data using pre-tested interview schedule. The unit of data collection was a single hybrid tomato plot of each selected farmers where detailed information regarding this crop cultivation were taken and analysis was done on per hectare basis. Although some of the selected farmers continued to harvest the crop up to December but yield data and other information were taken up to last week of October considering summer period.

2.3 Analytical techniques

Both fixed cost and variable cost were taken into account in calculating cost of summer tomato cultivation. Land use cost was calculated on the basis of per year existing lease value of land. The profitability of tomato cultivation was examined on the basis of gross margin, net return and benefit cost ratio analysis. The adoption categories were developed based on the percentage of respondent farmers with respect to each technology. Adoption level was categories into three: 70-100% as high, 50-69% as medium and <50% as low level of adoption. Collected data were edited, summarized, tabulated and analyzed to fulfill the objectives of the study. Descriptive statistics using different statistical tools like averages, percentages and ratios were used in presenting the results of the study.

Cobb-Douglas production function was used to estimate the contribution of factors to a tomato. The functional form of the Cobb-Douglas production function model was given below.

$$Y = AX_1^{b1}X_2^{2}....................X_n^{bn}e^{ui}$$

The production function was converted to logarithmic form so that it could be solved by least square method i.e.

$$\text{In } Y = a + b_1 \text{ In}X_1 + B_2 \text{ In}X_2 \text{ ....} + b_n \text{ In}X_n + U_i$$

The empirical function model is as follows:

$$\text{In } Y = a + b_1 \text{ In}X_1 + b_2 \text{ In}X_2 + b_3 \text{ In}X_3 + b_4 \text{ In}X_4 + b_5 \text{ In}X_5 + b_6 \text{ In}X_6 + b_7 \text{ In}X_7 + b_8 \text{ In}X_8 + U_i$$

Where, Y= Yield of tomato (ton/ha)

X_1 = Human labour (man-days/ha) ,

X_2 = Seed (kg/ha)

X_3 = Urea (kg/ha)

X_4 = TSP (kg/ha)

X_5 = MoP (kg/ha)

X_6 = Zipsum (kg/ha)

X_7 = Boron (kg/ha)

X_8 = Manure (kg/ha)

a = Intercept,

b_1, b_2 ... ... b_8 + Coefficients of the respective variables to be estimated,

U_i = Error term.

3. Results and Discussions

3.1 Adoption of summer tomato variety

An attempt was made to assess the level of adoption in terms of percent of farmers adopted summer tomato variety at farm level. The scientists of BARI developed some variety of tomato for summer season. But from the study it was appeared that BARI Hybrid Tomato-4 was mostly cultivated in the study area. About 75% farmer cultivates BARI Hybrid Tomato-4 (Table 1). After that BARI Hybrid Tomato-8 was 16% and ACI summer king was 9% also cultivated in the summer season.

Table 1. Percent of adoption of improved summer tomato varieties by the respondent farmers

Variety	Bagharpara	Jashore sadar	Jhikorgacha	All respondent
BARI Hybrid Tomato-4	25	24	26	75
BARI Hybrid Tomato-8	-	9	7	16
ACI Summer King	9	-	-	9

3.2 Adoption of crop management technology

The existing level of technology employed in the production of summer tomato and their adoption level were presented in Table 2. Land preparation includes ploughing, laddering and other operation needed to make the soil suitable for sowing seed. On the average, 28% of the total farmers ploughed their land 4-5 times which was recommended for tomato cultivation. The sowing time of summer tomato was started April and continue upto July. It was revealed that 78% farmers sowing at April to May which was the optimum time for summer tomato. The sowing time of summer tomato was high. All the farmers planting the seedling in line which adoption was high. Necessary inputs of a plant like manure used was high and high level of adoptions. On the other hand all fertilizer such as urea, TSP, MP, Zipsum and boron was highly used by farmer but low level of adoptions, that means farmer used these fertilizer of their recommended dose. All the farmers were used insecticide and hormone in tomato plant for getting higher yield. Again all the farmers making mancha for keeping the plant safe from rain water so that it cannot attack by disease and water stagnant.

Table 2. Percent of adoption of crop management technologies used in summer tomato cultivation

Technology	Bagharpara	Jashore sadar	Jhikorgacha	All respondent	Adoption level
1. Ploughing and laddering (No.)					
Up to 3 Nos.	60	70	40	57	
*4-5 Nos.	30	15	40	28	Low
Above 5 Nos.	10	15	20	15	
2. Seed sowing period					
*April-May	80	80	75	78	High
June-July	20	20	25	22	
3. Seed sowing method					
Broadcasting	0	0	0	0	
*Line sowing	100	100	100	100	High
4. Seed rate (gm/ha)					
*Up to 400	85	90	80	85	High

Technology	Bagharpara	Jashore sadar	Jhikorgacha	All respondent	Adoption level
Above 400	15	10	20	15	
6. Manure (kg/ha)					
*Up to 14000	76	82	85	81	High
Above 14000	24	18	15	19	
7. Urea (kg/ha)					
Below 550	90	87	95	91	
*Above 550	10	13	5	9	Low
8. TSP (kg/ha)					
*Up to 500	32	40	48	40	Low
Above 500	68	60	52	60	
9. MoP (kg/ha)					
*Up to 300	30	40	36	35	Low
Above 300	70	60	64	65	
10. Zipsum (kg/ha)`					
*Up to 70	12	15	10	12	Low
Above 70	88	85	90	88	
11. Boron (kg/ha)					
*Up to 7	42	45	43		Low
Above 7	58	55	57		
12. Pesticide					
Do not use pesticide	0	0	0	0	
*Used pesticides	100	100	100	100	High
13. Hormone					
Do not use hormone	0	0	0	0	
*Used hormone	100	100	100	100	High
*Mancha preparation	100	100	100	100	High

Note: Technology adoption was categorized by percentage of respondent farmers such as 70-100% as high; 50-69% as medium and <50% as low adoption.
* Recommended use or dose

3.3 Input use pattern

Input was the main elements for producing something. In tomato production there need different types of input for getting higher production. The human labor used for producing summer tomato was found to be 838 man-days per hectare (Table 3). Land preparation cost was 9183 Tk./ha. Seed was used 421 gm/ha for cultivating summer tomato. The total quantity of fertilizer required was

1977 kg/ha of which urea, TSP, MoP, Zipsum and Boron were 330 kg/ha, 646 kg/ha, 530 kg/ha, 454 kg/ha and 17 kg/ha respectively. These were equal to the recommended doses. Total cow dung used was 14804 kg per hectare when land was prepared. For better production farmers applied hormone and pesticide at the rate of 24742 Tk./ha and 36505 Tk./ha respectively. Its cultivation needs to prepare mancha which was most costly where bamboo, polithin, nylon rope and sutli incurred 75799 Tk./ha, 65227 Tk./ha, 5825 Tk./ha and 10421 Tk./ha respectively.

Table 3. Input use pattern for cultivating summer tomato

Items	Quantity
Human labour (man-day/ha)	813
Family	610
Hired	203
Land preparation cost (Tk./ha)	9183
Seed (gm/ha)	421
Cowdung (kg/ha)	14804
Fertilizer (kg/ha)	1977
Urea (kg/ha)	330
TSP (kg/ha)	646
MoP (kg/ha)	530
Zipsum (kg/ha)	454
Boron (kg/ha)	17
Hormone (Tk./ha)	24742
Pesticide (Tk./ha)	36505
Irrigation (Tk./ha)	8079
Bamboo (Tk./ha)	75799
Polythene (Tk./ha)	65227
Nylon rope (Tk./ha)	5825
Sutli (Tk./ha)	10421

3.4 Cost and return

For calculating the cost of cultivation of summer tomato, all variable costs like human labour, land preparation, seed, manures, fertilizers, pesticide, hormone, irrigation, mancha preparation were calculated on per hectare basis. The fixed cost of tomato cultivation included cost of land use and interest on operating capital. The total cost included fixed cost and variable cost. Total cost of production of summer tomato was 584822 Tk./ha where as 507355 Tk./ha was variable cost and fixed cost was 77467 Tk. per hectare (Table 4). The cost of family labour, hired labour, land preparation, seed, fertilizer, manures, hormone, pesticides, irrigation and mancha were 26.10%, 8.67%, 1.57%, 1.97%, 7.17%, 2.53%, 4.23%, 6.24%, 1.38% and 26.89% respectively. Among the cost items mancha preparation was the highest (26.89 %) followed by labour cost (26.10 %).

Table 4. Cost of summer tomato cultivation in the study area

Particular	Cost (Tk./ha)	% of cost
A. Variable cost		
Family labour	152624	26.10
Hired labour	50690	8.67
Land preparation	9183	1.57
Seed	11497	1.97
Fertilizer	41959	7.17
Manures	14804	2.53
Hormone	24742	4.23
Pesticides	36505	6.24
Irrigation	8079	1.38
Mancha preperation	157272	26.89
Total variable cost	507355	86.75
B. Fixed cost		
Land use	52734	9.02
Interest on operating capital	24733	4.23
Total fixed cost	77467	13.25
C. Total cost (A+B)	584822	100.00

3.5 Profitability of hybrid tomato cultivation

Return was calculated by multiplying yield with its price. Return per hectare of tomato cultivation was shown in Table 5. The average yield of summer tomato was 50.41 t/ha. The average gross return was calculated as Tk. 1542300 per hectare. The average price of hybrid tomato upto last week of October was Tk. 30 per kilogram. The average net return was observed to be Tk. 957478. On the average, benefit cost ratio was found to be 2.64.

Table 5: Profitability of summer tomato production

Particulars	Cost and return (Tk./ha)
Total Variable cost	507355
Total cost	584822
Yield (ton/ha)	50.41
Average selling price (Tk/kg)	30.00
Gross return	1542300
Gross margin	1034945
Net margin	957478
Benefit cost ratio	2.64

3.6 Contribution of different inputs to hybrid tomato production

For producing hybrid tomato different types of variable inputs were employed. Initially 8 variables were included in the model. Estimated values of coefficients and related statistics of Cobb-Douglas production function were presented in Table 6. The coefficient of determination (R^2) tells how well the sample regression line fits the data (Gujarati, 1995). Zipsum had positive and significant at 1% level, indicated that 1% increase in the use of zipsum, keeping all other factors remaining constant would increase the yield of tomato by 0.005%. Manure use had negative but significant impact on the yield of tomato. The coefficient of determination (R^2) was 0.58, which indicates that around 58 percent of the variations in gross return were explained by the independent variables included in the model. The F-value of the equation is significant at 1% level implying that the variation in return from summer tomato production mainly depends upon the independent variables included in the model.

Table 6. Estimated coefficients and their related statistics of production function for summer tomato

Explanatory variables	Co-efficient	t-values
Intercept	2.25***	5.65
Human labor (X_1)	0.011	1.55
Seed (X_2)	0.008	0.35
Urea (X_3)	0.002	0.65
TSP (X_4)	0.001	1.45
MoP (X_5)	0.004**	2.55
Zipsum (X_6)	0.005***	4.35
Boron (X_7)	0.015	0.25
Manure (X_8)	-0.005***	-3.25
R^2	0.58	
F value	12.25***	

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

3.7 Constraints to hybrid tomato cultivation

Although hybrid tomato cultivation was opined to be a profitable crop, there were several constraints to its higher production. It was observed from Table 8 that about one half of the farmers reported high price of mancha making materials which was increased their production cost. Most of the farmers (100%) reported that they faced attack of insect and diseases in the summer tomato field which hamper their production as well as their income. Eighty percent farmers opined that timely non-availability of seed, 60% opined on non-availability of agricultural credit, and 50 % farmer opined on high price of input materials.

Table 8: Constraints to summer tomato cultivation in different study areas

Particulars	Percent of responses
1.Attack of insect and disease infestation	100
2. Non-availability of seed in time	80
3. Non-availability of agriculture credit	60
4. High price of input	50
5. High cost of production	50

4. Conclusion

The study assessed the level of adoption and profitability of summer tomato varieties at farm level. Three summer tomato varieties namely BARI Hybrid Tomato-4, BARI Hybrid Tomato-8 and ACI Summer King were found to adopt by the farmers. The levels of adoption of most crop management technologies were found to be high. The productivity of summer tomato variety was high. The gross margin, net return and BCR are high. Attack by pest and disease, lack of seed at proper time, lack of agricultural credit and high cost of production were the major constraints for the adoption of summer tomato. The farmer had no marketing problem in the study area due to high demand of tomato at this season.

5. Recommendations

The following recommendations were forward to increase adoption of summer tomato variety at farmer's level:

- BARI has developed three summer tomato varieties, but its area coverage was very limited. Research organization should take initiatives to disseminate those varieties to the farmers.
- Farmers need proper training to increase summer tomato production. DAE should take initiative to motivate the farmers to cultivate BARI developed varieties and technology through providing training.

- Related organization should ensures supply of proper amount of seed to the farmer for increase cultivation.
- Government should ensure credit facilities through institutional sources for summer tomato cultivation.

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PRODUCTIVITY AND PROFITABILITY OF IMPROVED VERSUS EXISTING CROPPING PATTERN IN KUSHTIA REGION

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Abstract

The trial was conducted at Multi Location Testing (MLT) site under On-Farm Research Division, BARI, Kushtia during the last week of February, 2015 to second week of February, 2017 at farmers' field condition to cover two cropping cycle of four crops. The main objectives of the trial were to verify the feasibility of growing improved cropping pattern Mustard-Mungbean-T.Aus-T.Aman rice and to compare its productivity and profitability with existing cropping pattern Lentil-Sesame-T.Aman rice. The varieties BARI Sarisha-15, BARI Mung-6, BRRI dhan48 and Binadhan-7 were used for the crop Mustard, Mungbean, T.Aus and T.Aman rice, respectively in the improved cropping pattern, while in case of existing pattern, the varieties were BARI Masur-6, BARI Till-3 and Binadhan-7 for Lentil, Sesame and T.Aman rice, respectively. Findings revealed that the mean crop duration of 340 days were required for one cycle in a year in improved cropping pattern which implied that four crop based cropping pattern was agronomically feasible to replace existing cropping pattern. Total seed/grain yield in terms of REY of improved cropping pattern was 14.85 t ha^{-1} year^{-1} which was 44% higher than that of existing pattern (10.30 t ha^{-1} year^{-1}). Mean production efficiency (35.78 kg ha^{-1} day^{-1}), land use efficiency (93.15%) and labour employment (589 mandays ha^{-1} year^{-1}) of improved cropping pattern was 51%, 16% and 62%, higher, respectively than that of existing cropping pattern. The mean net economic advangaes of improved cropping pattern was Tk 12677 ha^{-1} year^{-1} which implied that the improved cropping pattern was economically viable. Moreover, the improved cropping pattern increased cropping intensity, farmers knowledge, skill, and income as well as employment. It also maintained soil health by incorporating mungbean stover and T.Aus rice straw in the soil. Therefore, farmers in Kushtia region of Bangladesh could follow the improved cropping pattern in their high and medium high land for higher productivity and profitability as well as employment generation over existing cropping pattern.

Keywords: Four crops, grain yield, production efficiency, rice equvalent yield, profitability

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Introduction

Bangladesh is the most densely populated (about 1033 persons per sq. km) country in the world with a population of 152.40 million, which is increasing annually at the rate of about 1.37 per cent (BBS, 2016). By the year 2030, the population will increase to about 186 million (United Nations, 2017). At present total cultivable land of the country is about 8.44 million hectares and it is shrinking day by day. Demographic pressures and increased urbanization have caused cultivated area to decline at a rate of about 1 percent per year. Food requirement of the country is estimated to be doubled in the next 25 years (Islam and Haq, 1999).The demand has to be met from our limited and shrinking land resources. There is very little scope of increasing cultivable land but there are some scopes of increasing cropping intensity from existing level of 192% by improving the existing cropping patterns by including short duration crops viz., mustard, potato, mungbean and T.Aus rice in the rice based cropping system (Mondal *et al.,* 2015).

Kushtia district is located under Agro Ecological Zone (AEZ) 11. The soil is calcareous under High Ganges River Floodplain. About 76% lands are under high and medium high land which has a great potential to produce four crops in a year. Total cultivable land of the district is 162125 ha in which 10835 ha were single cropped, 25960 ha was double cropped and 76375 ha was triple cropped land (47% of total cultivable land). The cropping intensity of this area is 263% and about 93% lands are under irrigation (DAE, 2016).It is possible to increase cropping intensity in this area by using short duration crop varieties which is developed by BARI and other research institutes. The lentil production hampers due to foot and root rot and stemphylium blight disease. Besides, the sesame production hampers due to early monsoon at harvesting stag. Moreover, the price of lentil fluctuates every year. So, the farmers in Kushtia face economic loss in the existing lentil and sesame based cropping patterns. Therefore, it is needed a better cropping pattern which is more benefitted to the farmers of Kushtia against.

Recently BARI has developed few four crop based cropping patterns which could give more benefit to the farmers. Mustard-Mungbean-T.Aus-T.Aman is one of them. This cropping pattern is needed to verify in farmers field of Kushtia against existing Lentil-Sesame-T.Aman cropping pattern.

Mondal *et al.* (2015) reported that T.Aman rice (var: Binadhan-7) - Mustard (var: BARI Sarisha-15) -Mungbean (var: BARI Mung-6) -T.Aus rice (var: Parija) cropping pattern gave higher benefit with less cost of production and could be easily fitted in the existing pattern. Hossain *et al.* (2014) also reported that T.Aman rice (var: Binadhan-7) - Mustard (var: BARI Sarisha-15) -Mungbean (var: BARI Mung-6) – T.Aus rice (var: Parija) are agronomically feasible and economically profitable compared to the existing pattern.Due to growing four crops in a year in the same piece of land more employment opportunity could be created and at the same time due to increased production of crops, food and nutritional security could be ascertained for the farmers and at the same time cropping intensity and productivity could be increased (Mondal *et al.*, 2015; Hossain *et al.*, 2014).

Nazrul *et al.* (2017) found that improved pattern (Mungbean-T.Aus -T.Aman rice) provided higher grain yield, contributed more REY, gave maximum sustainable index, production efficiency, land use efficiency and higher profit compared to farmers pattern (Fallow- T.Aus-T.Aman rice). Moreover, a number of reports on different cropping pattern are available in Bangladesh and India that an additional crop could be introduced without much changes or replacing the existing ones for considerable increases of productivity as well as profitability of the farmers (Azad *et al.*, 1982; Malavia *et al.*, 1986; Soni and Kaur, 1984; Khan *et al.*, 2005; Nazrul *et al.*, 2013; Kamrozzaman *et al*., 2015).

Farmers in Kushtia have been facing problem in existing patterns, whereas they have a great potential to conduct four crops in a same piece of land in a year because 76% lands are under high and medium high land and 93% lands are under irrigation. But, no attempt has been made for on-farm verification of four crops based improved cropping pattern Mustard-Mungbean-T.Aus-T.Aman rice in Kushtia. With this view in mind, the present study was therefore, undertaken in the following objectives.

Objectives:

i. to document the agronomic practices of growing Mustard-Mungbean-T.Aus-T.Aman rice cropping pattern;

ii. to verify the feasibility of growing Mustard-Mungbean-T.Aus-T.Aman rice cropping pattern in farmers field condition;

iii. to compare its productivity and profitability against farmer's existing cropping pattern Lentil- Sesame-T.Aman rice; and

iv. To determine the land use efficiency, production efficiency and labour employment generation of improved and existing cropping pattern.

Materials and Methods

The trial was conducted at Multi Location Testing (MLT) site under On-Farm Research Division (OFRD), BARI, Kushtia during the last week of February, 2015 to second week of February, 2017 at farmers' field condition to cover two cropping cycle of four crops. Before setting up and end of two cycle of the experiment, soil samples were taken separately over 0-15 cm depth to determine baseline and post soil properties, respectively. Soil samples were air-dried, crushed, and analyzed separately in SRDI laboratory.

The experiment was laid out in block approach for maintaining all activities one after another at a time. There were two blocks consisting of one hectare in each cropping pattern of 8 farmers. One block was under the improved cropping pattern and the other was farmer's existing pattern. In the improved cropping pattern, Mustard (var. BARI Sarisha-15) - Mungbean (var. BARI Mung-6) - T.Aus rice (var. BRRI dhan48) - T.Aman rice (var. Binadhan-7) was cultivated against existing pattern Lentil (var. BARI Masur-6) - Sesame (var. BARI Till-4) - T.Aman rice (var. Binadhan-7). The trial was started by mungbean cultivation in improved cropping pattern. Lentil, sesame, mustard and mungbean seed was sown in broadcasting method and the rice seedling was transplanted 20 x 15 cm. All fertilizers were applied as basal and top dressing by following improved management practices. The agronomic parameters and inter-cultural operation for crop production under improved and farmer's existing practices are presented in Table 2. In T.Aus and T.Aman rice, stem borer and sheath blight was observed in some plots. Folicur @ 0.5 ml/L was sprayed to control sheath blight and Virtako 40 WG @1.5g/10 L for stem borer. In Mustard, Rovral-50 wp @ 2 g/L was sprayed at early stage for controlling alternaria blight disease. In mungbean, Tafgor (2ml/L) and Imitaf 20 SL (0.5ml/L) were sprayed for controlling aphid and thrips. All field operation and management practices of both improved and farmer's pattern were closely monitored and the data were recorded for observing agro-economic performance. The yield data of product and by-product were recorded from 1 m^2 in 3 areas from each block.

Agronomic performance *viz.*, land use efficiency, production efficiency and rice equivalent yield of cropping patterns were calculated.

Land use efficiency: It is worked out by taking total duration of individual crop in a pattern divided by 365 days as Tomer and Tiwari, (1990) as follows:

$$\text{Land use efficiency} = \frac{\sum \text{di}}{365} \times 100$$

Where,

di = duration of the i^{th} crop i = 1, 2, 3 and 4

Production efficiency: Production efficiency in terms of Kg $ha^{-1}day^{-1}$was calculated by total production in a cropping pattern divided by total duration of crops in that pattern (Tomer and Tiwari. 1990).

$$\text{Production efficiency} = \frac{\sum \text{yi}}{\sum \text{di}}$$

Where,

Yi = Yield of the i^{th} crop

di = duration of the i^{th} crop

i = 1, 2, 3 and 4

Rice equivalent yield: For comparison between cropping patterns, the yield of all crops was converted into rice equivalent yield (REY) on the basis of prevailing market price of individual crop (Verma and Modgal, 1983).

$$\text{Rice equivalent yield (t ha}^{-1}) = \frac{\text{Yield of individual crop} \times \text{Market price of that crop}}{\text{Market price of rice}}$$

Profitability analysis: The economic indices like total variable cost and gross return were also calculated on the basis of prevailing market price of the produces. For economic evaluation of two tested cropping patterns, average data of two crop cycles were used. Gross return was calculated on the basis of taka per hectare of product and by-product. Total variable cost of different crops was calculated on the basis of taka per hectare of different operations performed and materials used for raising the crops. Partial budgeting was used to compare the advantage in between improved and existing cropping pattern. Net economic advantage was derived by subtracting of total economic disadvantage from total economic advantage.

Results and Discussion

Changes in soil properties: The result of nutrient status of initial and post soil is presented in Table 1. Initially, the soil was slightly alkaline (7.8-8.1), medium in organic matter and K content. The contents of S and B were also in medium level. Total N, P and Zn contents were found low. After completion of two cycles, soil was also tested. Post soil chemical analysis result revealed that the mean pH was slightly lower than initial value whereas OM increased due to incorporation of mungbean in the soil of improved cropping pattern. The contents of K, Zn and B increased in post soil compared to initial soil while the contents of P and S decreased in post soil than initial soil. Total N is same in post and initial soil. This result is supported by the result of Mondal *et al.*(2015).

Crop management: Crop management practices include date of sowing/transplanting, date of harvesting, fertilizer dose used, irrigation, weeding and application of pesticides etc. of improved and existing cropping pattern which is shown in Table 2. The crop (field) duration of improved cropping pattern (Mustard-Mungbean-T.Aus-T.Aman rice) took 339 and 341 days for completion of 1st and 2nd cycle, respectively. While, existing cropping pattern (Lentil-Sesame-T.Aman rice) required 290 and 296 days for completion of 1st and 2nd cycle, respectively. Turnaround time in four crops based improved cropping pattern for completion of 1st and 2nd cycle was 26 and 24 days, respectively whereas it was 75 and 69 days, respectively for completion of 1st and 2nd cycle in existing cropping pattern. This indicates that four crops based improved cropping pattern is easily fitted in a piece of land in a year instead of three crops existing pattern.

Table 1. Chemical properties of initial and post soil (0-15 cm depth) of the experimental field at Kushtia sadar, Kushtia during 2014-15 and 2016-17

Replication	pH	Organic matter (%)	K	Total N (%)	P	S	Zn	B
			meq/100 g soil		μg g^{-1}			
Initial:								
R_1	7.8	2.17	0.24	0.11	11.70	20.40	0.87	0.47
R_2	8.1	1.97	0.27	0.10	10.70	18.21	0.87	0.41
R_3	7.9	1.88	0.28	0.09	8.80	18.40	0.72	0.54
R_4	7.8	1.82	0.23	0.09	13.40	22.47	0.97	0.35
R_5	7.9	2.10	0.18	0.10	14.60	26.45	0.72	0.41
Mean/Range	7.8-8.1	1.99	0.24	0.10	11.84	21.19	0.83	0.44
Critical limit	-	-	0.12	0.12	10.00	10.00	0.60	0.20
Interpretation	Slightly Alkaline	Medium	Medium	Low	Low	Medium	Low	Medium
Post:								
R_1	7.7	1.92	0.25	0.09	8.45	15.24	0.75	0.58
R_2	7.2	2.28	0.22	0.11	11.25	22.48	0.92	0.58
R_3	8.0	1.97	0.32	0.10	9.17	14.57	0.85	0.58
R_4	7.2	1.97	0.27	0.10	14.21	20.24	0.95	0.58
Mean/Range	7.2-8.0	2.04	0.27	0.10	10.77	18.13	0.87	0.58
Critical limit	-	-	0.12	0.12	10.00	10.00	0.60	0.20
Interpretation	Slightly Alkaline	Medium	Medium	Low	Low	Medium	Low	Medium

Seed/Grain yield: The mean seed/grain yield of mustard, mungbean, T.Aus and T.Aman were 1.35, 1.14, 5.10 and 4.59 t ha^{-1}, respectively in improved cropping pattern while mean seed/grain yield of lentil, sesame and T.Aman were 0.78, 1.25 and 4.90 t ha^{-1}, respectively in the existing cropping pattern (Table 3). The stover/straw yield of the cited crops is presented in the Table 3. The yield of T.Aus rice was found to be very good which might be occurred due to residual effect of mungbean stover. The yield of lentil in existing cropping pattern was low due to attack of foot and root rot and stemphylium disease. In improved cropping pattern, seed/grain yield of mustard, mungbean, T.Aus and T.Aman were 1.20, 1.15, 4.97 and 4.59 t ha^{-1}, respectively for 1^{st} cycle while seed/grain yield of lentil, sesame and T.Aman were 0.75, 1.20 and 4.70 tha^{-1}, respectively in the existing pattern. In the 2^{nd} cycle of improved cropping pattern, seed/grain yield of mustard, mungbean, T.Aus and T.Aman were 1.49, 1.12, 5.22 and 4.59 tha^{-1}, respectively while in the existing pattern seed/grain yield of lentil, sesame and T.Aman were 0.80, 1.30 and 5.10 tha^{-1}, respectively. Similar findings were found in Mondal *et al.* (2015) and Hossain *et al.* (2014).

Table 2. Crop management practices of existing (Lentil-Sesame-T.Aman) and improved (Mustard-Mungbean-T.Aus-T.Aman) cropping pattern in the 1st and 2nd cycle at Kushtia sadar, Kushtia

Parameters	Existing Cropping Pattern			Improved Cropping Pattern			
Crop	Lentil	Sesame	T.Aman	Mustard	Mungbean	T.Aus	T.Aman
Variety	BARI Masur-6	BARI Til-3	Binadhan-7	BARI Sarisha-15	BARI Mung-6	BRRI dhan48	Binadhan-7
1st cycle:							
Fertilizer dose (CD tha^{-1}, $NPKSZnBkgha^{-1}$)	17.15-18.7-5-0-0	86.5-18-26-9.5-0	103.4-22.5-37.5-9.5-2.6	126-35-46-29.5-2.5-2.12	17-17-18-10-0-1	86-22.5-37.5-9.5-2.15-0.6	86-22.5-37.5-9.5-1.61-0
Date of sowing/ transplanting	18/11/15	18/3/15	2/8/15	14-15 /11/15	27-28 /02/15	13-14 /05/15	10-12 /08/15
Date of harvesting	03/03/16	11/6/15	07/11/15	7-9/2/16	1-10/5/15	6-8/08/15	11-12 /11/15
Irrigation (no.)	-	-	-	1	-	10	-
Weeding (no.)	-	1	2	1	1	1	1
Field duration(day)	106	86	98	86	73	86	94
Turnaround time (day)	10	14	51	18	02	4	2
2nd cycle:							
Fertilizer dose (CD tha^{-1}, $NPKSZnBkgha^{-1}$)	17.15-18.7-5-0-0	86.5-18-26-9.5-0	103.4-22.5-37.5-9.5-2.6	126-35-46-29.5-2.5-2.12	17-17-18-10-0-1	86-22.5-37.5-9.5-2.15-0.6	86-22.5-37.5-9.5-1.61-0
Date of sowing/ transplanting	15/11/16	15/03/16	04/08/16	12-14 /11/16	26-28 /02/16	12-14 /05/16	10-12 /08/16
Date of harvesting	5-7/03/17	14/06/16	04/11/16	08-10/02/17	01-08 /05/16	06-08 /08/16	11-12 /11/16
Irrigation (no.)	-	-	-	1	1	10	-
Weeding (no.)	-	1	2	1	1	1	1
Field duration (days)	111	92	93	89	72	87	93
Turnaround time	10	9	50	17	3	3	2

Table 3. Yield of existing (Lentil-Sesame-T.Aman*)* and improved (Mustard-Mungbean-T.Aus-T.Aman) cropping pattern at Kushtia sadar, Kushtia

Parameters	Existing Cropping Pattern			Improved Cropping Pattern			
Crop	Lentil	Sesame	T.Aman	Mustard	Mungbean	T.Aus	T.Aman
Variety	BARI Masur-6	BARI Til-3	Binadhan-7	BARI Sarisha-15	BARI Mung-6	BRRI dhan48	Binadhan-7
1st cycle							
Seed/grain yield (t ha^{-1})	0.75	1.20	4.70	1.20	1.15	4.97	4.59
Stover/straw yield (t ha^{-1})	1.10	2.30	4.20	2.00	1.24	4.16	4.12
2nd cycle							
Seed/grain yield (t ha^{-1})	0.80	1.30	5.10	1.49	1.12	5.22	4.59
Stover/straw yield (t ha^{-1})	1.11	2.15	4.03	1.92	1.22	3.54	3.08
Mean							
Seed/grain yield (t ha^{-1})	0.78	1.25	4.90	1.35	1.14	5.10	4.59
Stover/straw yield (t ha^{-1})	1.11	2.23	4.12	1.96	1.23	3.85	3.60

Rice Equivalent Yield: The mean rice equivalent yield (REY) of improved cropping pattern was 14.85 $tha^{-1}year^{-1}$ which was 44% higher over existing cropping pattern (10.30 $tha^{-1}year^{-1}$). The REY of improved cropping pattern was 15.15 $tha^{-1}year^{-1}$ which was 37% higher against existing cropping pattern (11.03 $tha^{-1}year^{-1}$) in 1st cycle. While REY of improved cropping pattern was 14.55 $tha^{-1}year^{-1}$, which was 52% higher over existing cropping pattern (9.57 $tha^{-1}year^{-1}$) in 2nd cycle. Higher rice equivalent yield was obtained in improved cropping pattern due to inclusion of new crops and varieties. It is evident from the above findings that improved cropping pattern gave higher yield compared to existing pattern (Table 4). This finding was supported by Mondal *et al.*,(2015); Hossain *et al.*(2014); Nazrul *et al.* (2017) and Nazrul *et al.* (2013).

Land use efficiency: Land use efficiency is the effective use of land in a cropping year, which mostly depends on crop duration. The mean land-use efficiency of improved cropping pattern was higher (93.15%) than that of existing pattern (80.28%). Improved cropping pattern utilized the land by 92.88% and 93.42% for 1st and 2nd cycle, respectively, whereas existing pattern utilized the land by 79.45% and 81.10% for 1st and 2nd cycle, respectively (Table 4). The land use efficiency was higher in improved cropping pattern due to cultivation of more component crops in the pattern. The similar trend of the findings was cited by Nazrul*et al.* (2017) and Nazrul *et al.* (2013).

Production efficiency: Maximum production efficiency was obtained from improved cropping pattern over existing cropping pattern (Table 4). The higher production efficiency of improved cropping pattern might be due to inclusion of four crops and new modern varieties as well as improved management practices. The mean production efficiency of improved cropping pattern was found to be 35.78 kg ha^{-1} day^{-1}which was 51% higher over existing cropping pattern (23.63 kg ha^{-1} day^{-1}). Production efficiency of improved cropping pattern and existing cropping pattern was found to be 35.13 and 22.93 kg ha^{-1} day^{-1}, respectively in 1st cycle, while it was found to be 36.42 and 24.32kg ha^{-1} day^{-1} for improved cropping pattern and existing cropping pattern, respectively in 2nd cycle (Table 4). Production efficiency of improved cropping pattern was 53% and 50% higher than that of existing pattern in 1st and 2nd cycles, respectively. Finding revealed that maximum production efficiency was found in improved cropping pattern against existing pattern in all the cycles. Similar findings were cited by Nazrul *et al.* (2017), Nazrul *et al.* (2013) and Khan *et al.* (2005) in case of improved cropping patterns.

Labour employment generation: Human labour was employed for land preparation, sowing/transplanting, fertilizing, weeding, pesticide application, harvesting, carrying, threshing, cleaning and drying. It is observed that the mean total number of human labour used for crops cultivation under improved cropping pattern was 589 man-days ha^{-1} year^{-1} (Table 4) which was generated 62% higher labour employment than that of existing cropping pattern (363 man-days ha^{-1} year^{-1}). It was also generated employment of women, children and aged people due to inclusion of mungbean.

Table 4. Rice equivalent yield, production efficiency, land use efficiency and labour employment of existing (Lentil-Sesame-T.Aman) and improved (Mustard-Mungbean-T.Aus-T.Aman) cropping pattern at Kushtia sadar, Kushtia

Cycles	Cropping pattern	Rice equivalent yield (tha^{-1})	Land use efficiency (%)	Production efficiency (Kg ha^{-1}day^{-1})	Labour employment (man-days ha^{-1} year^{-1})
1st	Existing	11.03	79.45	22.93	361
	Improved	15.15	92.88	35.13	586
2nd	Existing	9.57	81.10	24.32	364
	Improved	14.55	93.42	36.42	592
Mean	Existing	10.30	80.28	23.63	363
	Improved	14.85	93.15	35.78	589

Profitability analysis: The study revealed that the mean gross return of improved and existing cropping pattern was Tk. 282244 ha^{-1} and Tk. 200966 ha^{-1}, respectively (Table 5). The mean gross return of improved cropping pattern was 40% higher than that of existing cropping pattern. The higher gross return of improved cropping pattern might be due to inclusion of new crops and new high yielding varieties. The mean total variable cost of improved and existing cropping pattern was Tk. 174638 ha^{-1} and Tk. 106037 ha^{-1}, respectively (Table 5). The mean gross margin of alternate cropping pattern was 13% higher (Tk. 107607 ha^{-1}) than that of existing cropping pattern (Tk. 94929 ha^{-1}).

Table 5. Gross return, total variable cost and gross margin of existing (Lentil-Sesame-T.Aman) and alternate (Mustard-Mungbean-T.Aus-T.Aman) cropping pattern at Kushtia sadar, Kushtia

Cycles	Cropping pattern	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk.ha^{-1})
1st	Existing	188197	107478	80719
	Alternate	252619	175175	77444
2nd	Existing	213734	104595	109139
	Alternate	311869	174100	137769
Mean	Existing	200966	106037	94929
	Alternate	282244	174638	107607

Price of produce (1st cycle) (Tk. kg^{-1}): Lentil- 85.00, Stover-2.00, Mustard- 46.50, Straw-1.00, Mungbean- 47.50, T.Aman-15.75, Straw-2.91, T.Aus-11.25, Sesame-30.00.

Price of produce (2nd cycle) (Tk. kg^{-1}): Lentil-65.00, Stover-2.00, Mustard-42.50, Straw-1.00, Mungbean-50.00, T.Aman-20.50, Straw-3.80, T.Aus-16.25, Sesame-30.50.

Table 6. Partial budgeting of existing (Lentil-Sesame-T.Aman) and improved (Mustard-Mungbean-T.Aus-T.Aman) cropping pattern at Kushtia sadar, Kushtia

Cycles	Economic disadvantage	Tk. ha^{-1} $year^{-1}$	Economic Advantage	Tk. ha^{-1} $year^{-1}$
1st	(a) Gross return of existing cropping pattern	188197	(e) Gross return from improved cropping pattern	252619
	(b) Total variable cost of improved cropping pattern	175175	(f) Total variable cost of existing cropping pattern	107478
	(c) Total (a+b)	363372	(g) Total (e+f)	360097
	(d) Net disadvantage (g-c)	-3275		
2nd	(a) Gross return of existing cropping pattern	213734	(e) Gross return from improved cropping pattern	311869
	(b) Total variable cost of improved cropping pattern	174100	(f) Total variable cost of existing cropping pattern	104595
	(c) Total (a+b)	387834	(g) Total (e+f)	416464
	(d) Net disadvantage (g-c)	28630		
Mean	(a) Gross return of existing cropping pattern	200966	(e) Gross return from improved cropping pattern	282244
	(b) Total variable cost of improved cropping pattern	174638	(f) Total variable cost of existing cropping pattern	106037
	(c) Total (a+b)	375604	(g) Total (e+f)	388281
	(d) Net disadvantage (g-c)	12677		

Economic advantage: The mean net economic advantage was Tk. 12677 ha^{-1} $year^{-1}$ which implied that four crop based improved cropping was economically viable than that of existing cropping pattern (Table 6). Similar trend was found in 2^{nd} (Tk. 28630 ha^{-1} $year^{-1}$) cycle. But net economic disadvantage was found in 1^{st} cycle (Tk. 3275 ha^{-1} $year^{-1}$), because farm gate price of lentil in existing cropping pattern was high whereas T.Aus price in improved cropping pattern was lower. In the 2^{nd} cycle, lentil price became lower and T.Aus price became higher which increased net advantage in improved cropping pattern.

Conclusion

The trial was conducted to verify the feasibility of growing improved cropping pattern Mustard-Mungbean-T.Aus-T.Aman rice and to compare its productivity and profitability with existing cropping pattern Lentil-Sesame-T.Aman rice. After completion of two cycles, soil was also tested. Post soil chemical analysis result revealed that the mean pH was slightly lower than initial value whereas organic matter content increased due to incorporation of mungbean in the soil of improved cropping pattern. The contents of K, Zn and B increased in post soil compared to initial soil while the contents of P and S decreased in post soil than initial soil. Total N is same in post and initial soil. The mean crop duration was 340 days for improved cropping pattern which implied that four crop based improved pattern is agronomically feasible to replace existing cropping pattern. Total seed/grain yield in terms of REY of improved cropping pattern was 14.85 t ha^{-1} $year^{-1}$ which was 44% higher than that of existing pattern (10.30 t ha^{-1} $year^{-1}$). Mean production efficiency (35.78 kg ha^{-1} day^{-1}), land use efficiency (93.15%) and labour employment (589 mandays ha^{-1} $year^{-1}$) of improved cropping pattern was 51%, 16% and 62%, higher, respectively than that of existing cropping pattern. The mean net economic advangaes of improved cropping pattern was Tk 12677 ha^{-1} $year^{-1}$ which implied that the improved cropping pattern was economically viable. Moreover, the improved cropping pattern increased cropping intensity, farmers knowledge, skill, and income as well as employment. The food and nutritional security will be ensured for the farmers of Kushtia region due to increase production of crops. It also maintained soil health by incorporating mungbean stover and T.Aus straw in the soil of improved cropping pattern. Farmers in Kushtia region of Bangladesh could follow Mustard (var. BARI Sarisha-15) - Mungbean (var. BARI Mung-6) - T.Aus rice (var. BRRI dhan48) - T.Aman rice (var. Binadhan-7) cropping pattern in their high and medium high land for higher productivity and profitability against existing pattern Lentil (var. BARI Masur-6) – Sesame (var. BARI Till-4) - T.Aman rice (var. Binadhan-7).

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COMBINING ABILITY AND HETEROSIS STUDYIN MAIZE INBREDS THROUGHOUT DIALLEL MATING DESIGN

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Abstract

Combining ability effects were estimated for grain yield and some other important agronomic traits of maize in a 7×7 diallel analysis excluding reciprocals. The variances for general combining ability (GCA) were found significant for yield, days to pollen shedding, days to silking and ear height while it was found non-significant for plant height and number of kernels/ear. Non-significant general combining ability (GCA) variance for plant height and number of kernels/ear indicates that these two traits were predominantly controlled by non- additive type of gene action. Specific combining ability (SCA) was significant for all the characters except yield and days to silking. Non-significant specific combining ability (SCA) variance for yield and days to silking suggests that these two traits were predominantly controlled by additive type of gene action. Both GCA and SCA variances were found significant only in days to pollen shedding and ear height indicated the presence of additive as well as non additive gene effects for controlling the traits. However, relative magnitude of these variances indicated that additive gene effects were more prominent for all the characters studied except days to silking. Parent BIL95 was the best general combiner for both high yield and number of kernels/ear and parent BML4 for dwarf plant type. Two crosses (BML4× BML36 and BIL114× BIL31) exhibited significant and positive SCA effects for grain yield involved low × average and average × average general combining parents. The range of heterosis expressed by different crosses for grain yield and days to silking was from -65.83 to 21.26 percent and -17.85 to 8.22 percent, respectively.. The better performing three crosses (BIL114×BIL31, BIL138×BIL95 and BIL31×BIL95) can be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigour.

Keywords: Combining ability,heterosis, maize, GCA, SCA

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Introduction

Maize is one of the oldest and key cereal crops in the world. It is the highest yielding grain crop having multiple uses. A great combination of high market demand with comparatively low production cost, ready market and high yield has generated great interest among the farmers in maize cultivation. Day by day it is gaining popularity in the country due to vast demand, particularly for poultry industry. In Bangladesh it is the third most important crop after rice and wheat and it accounts for 4.8% of the total cropped land area and 3.5% of the value of agricultural output (Ahmad *et al.*, 2011). In 2014-15, maize was cultivated in 3.25 lac hectares of land and yielded 22.72 lac tons (BBS, 2016).

The effects of General Combining Abilities (GCA) and Specific Combining Abilities (SCA) are important indicators of potential value for inbred lines in hybrid combinations. Differences in GCA effects have been attributed to additive, the interaction of additive x additive, and the higher-order interactions of additive genetic effects in the base population, while differences in SCA effects have been attributed to non-additive genetic variance (Falconer, 1981). The concept of GCA and SCA has become increasingly important to plant breeders because of the widespread use of hybrid cultivars in many crops (Wilson *et al.,* 1978). The evaluation of crosses among inbred lines is an important step towards the development of hybrid varieties in maize (Hallauer, 1990). This process ideally should be through the evaluation of all possible crosses (diallel crosses), where the merits of each inbred line can be determined. A diallel analysis provides good information on the genetic identity of genotypes especially on dominance-recessive relations and some other genetic interactions. Diallel crosses have been used in genetic research to determinate the inheritance of a trait among a set of genotypes and to identify superior parents for hybrid or cultivar development (Yan and Manjit, 2003). The present study involving a 7×7 diallel analysis designed to find out the better general combining parents and for isolating good cross combinations in maize for developing suitable hybrid(s) locally.

Materials and Methods

Seven inbred lines of maize viz. P_1(BML4), P_2(BML36), P_3(BIL106), P_4(BIL114), P_5(BIL138), P_6(BIL31) and P_7(BIL95) collected from CIMMYT-Mexico, CIMMYT-ARMP, and locally developed were crossed in all possible combinations (excluding reciprocals) in the *rabi* season of 2012-2013 at Joydebpur. During *rabi* 2013-2014, crossed 21 F_1's and along with three commercial hybrids were grown following Randomized Complete Block Design (RCBD) with three replications were sown on 24 November 2013. Each plot involved of 2 rows 5.0 m long. The unit plot size was 5.0 m x 0.75 m. Spacing adopted was 75 cm × 20 cm between rows and hills, respectively. One healthy seedling per hill was kept after proper thinning. Fertilizers were applied @ 250, 55, 110, 40, 5 and 1.5 kg/ha of N, P, K, S, Zn, B, respectively. Standard agronomic practices were followed and plant protection measures were taken when required. Data on days to 50% pollen shedding and silking were recorded on whole plot basis. Ten randomly selected plants were used for recording observations on plant height and ear height. All the plants in 2 rows were considered for plot yield which was later converted to t/ha. The combining ability analysis was carried out following Model I (fixed effects) and Method IV (one set of F_1's but neither parents nor reciprocal F_1's is included) described by Griffing (1956) using a software 'diallel analysis' by Mark D. Burrow and James G. Coors, version 1.1.

Results and Discussion

Analysis of variances for combining ability (Table1) revealed that variances for general combining ability (GCA) were significant for yield, days to pollen shedding, days to silking and ear height while it was found non-significant for plant height and number of kernels/ear. Non-significant general combining ability (GCA) variance for plant height and number of kernels/ear suggested that these two traits were predominantly controlled by non- additive type of gene action. Specific combining ability (SCA) was significant for all the characters except yield and days to silking. Non-significant specific combining ability (SCA) variance for yield and days to silking suggested that these two traits were predominantly controlled by additive type of gene action.Both GCA and SCA variances were found significant in days to pollen shedding and ear height indicated the presence of additive as well as non additive gene effects for controlling the traits. Importance of both GCA and SCA variances for yield and yield contributing traits in maize was reported by Ahmed *et al.* (2008), Gurung *et al*. (2008) and Abdel-Moneam *et al*. (2009). However, in the present study variances due to GCA were much higher in magnitude than SCA for all the characters except days to silking indicating preponderance of additive gene effects for the inheritance of these traits. Malik *et al*. (2004) in their study also found higher GCA variances than SCA for days to pollen shedding, plant height, ear height, 1000-kernel weight and grain yield. Predominance of additive gene action for various quantitative traits in maize was reported by Muraya *et al*. (2006), Ahmed *et al.* (2008), Alam *et al.* (2008) and Amiruzzaman (2010). The current result was in contrast with Abdel-Moneam *et al*. (2009) who observed GCA/SCA ratio was less than unity for kernels/row, 100-kernels weight and ear yield/plant, indicating non additive gene action were controlling the traits. Kadir (2010) in his study showed that the non-additive effects (SCA) were more important than additive effects (GCA) for plant height, ear height, days to pollen shedding, days to silking, seeds/row, 100-seed weight and grain yield/plant.

Table 1. Analysis of variance for combining ability of seven characters of maize in a 7×7 diallel cross

Source of variation	df	Yield (t/ha)	Pollen shedding (Days)	Silking (Days)	Plant Height (cm)	Ear height (cm)	No. of kernels/ ear	1000-kernel wt.(g)
GCA	6	30.70**	50.86**	47.86*	4869.71	2422.31*	18406.89	6314.28
SCA	14	7.38	6.38**	68.10	2529.84**	804.60**	7937.64**	2744.44**
Error	40	4.17	1.73	56.11	412.00	145.03	2664.03	880.39
GCA/SCA	-	4.16	7.97	0.70	1.92	3.01	2.32	2.30

**P=0.01,*P=0.05

General combining ability (GCA) effects

The GCA effects are shown in Table 2. None of the parents were found to be a good general combiner for all the characters under consideration. A wide range of variability of GCA effects was observed among the parents. In the present study, for days to pollen shedding, silking, plant height and ear height the inbred lines with significant and negative GCA effects were considered as good general combiners. Significant and negative GCA for days to pollen shedding and use of these parents might be useful in developing early hybrid variety(s). On the other hand, for yield and other yield components those with significant and positive GCA effects were considered as good general combiners.

For grain yield, parent BIL95 showed significant and positive GCA effect. In addition to grain yield, parent BIL95 was also good general combiner for days to pollen shedding and no. of kernels/ear. Sharma *et al.* (1982) reported that parents with good general combiners for grain yield generally shows good performance for various yield components. Similar views have been given by Malik *et al*. (2004), Uddin *et al.*(2006), Ahmed *et al*. (2008) and Abdel-Moneam *et al*. (2009). So, parent BIL95 could be used extensively in hybrid breeding program with a view to increase the yield level. Parent BML4, BML36 andBIL95 showed significant and negative GCA for days to pollen shedding though they did not posses significant for days to silking but they showed negative values. So, these parents might be useful in developing early hybrid variety(s). Parent BML4 exhibited significant and negative GCA effect both for plant and ear height. Uddin *et al.* (2006) and Ahmed *et al.* (2008) also found inbred line(s) as good general combiner for short plant type in their study. Significant and negative GCA for ear height was observed by Roy *et al.*(1998), Malik *et al.* (2004), Alam *et al.* (2008) and Amiruzzaman (2010) in their study.

Regarding number of kernels/ear, two parents viz. BIL138 and BIL95showed significant and positive GCA effect for this trait. These two parents are expected to produce more number of grains per ear. Similar observation was also noticed by Alam *et al.* (2008) and Amiruzzaman (2010).

For 1000-kernel weight, the gca effect was found significant for the parents BML36 and BIL31. These two parents are anticipated to contribute towards increasing the kernel size. Highly significant and positive gca effects for 1000-kernel weight was observed by Uddin *et al.*(2006), Alam *et al.* (2008) and Abdel-Moneam *et al*. (2009).

Table 2. Estimates of general combining ability effects (GCA) of the parents for different characters in maize

Parents	Yield (t/ha)	Pollen shedding (Days)	Silking (Days)	Plant ht (cm)	Ear ht (cm)	No. of kernels/ ear	1000-kernel wt.(g)
BML4 (P1)	-2.74**	-1.24**	-0.40	-34.98**	-25.61**	-47.01*	-18.76*
BML36 (P2)	0.73	-1.70**	-0.73	-1.57	-2.31	0.06	21.24*
BIL106 (P3)	-0.35	-0.70	0.60	5.74	4.45	7.06	-2.10
BIL114 (P4)	-0.65	3.43**	0.27	-3.18	0.75	-38.88*	-21.43*
BIL138 (P5)	0.88	1.63**	2.80	16.70*	12.07**	34.32*	-10.10
BIL31 (P6)	0.50	-0.64	0.60	-2.55	-1.19	-4.48	33.90**
BIL95 (P7)	1.63*	-0.77*	-3.13	19.83**	11.85**	48.92**	-2.76
SE (gi)	0.49	0.31	1.79	4.85	2.88	12.34	7.09
LSD(5%)	1.20	0.76	4.38	11.87	7.05	30.20	17.34
LSD(1%)	1.82	1.15	6.63	17.97	10.68	45.74	26.28

*P=0.05, **P=0.01

Specific combining ability effects (SCA)

Generally the crosses showing significant and positive SCA effects also possessed high mean performance and significant negative sca effects possessed low mean performance (Table 3 and 5). This reflected that high *per se* value of the crosses indicated their potentiality.

For grain yield two crosses (BML4×BML36and BIL114×BIL31) exhibited significant and positive SCA effects for grain yield. These crosses involved low x average and average × average general combining parents. Although the cross BML4 × BML36involved low × average general combiners, exhibited the highest significant and positive SCA effect but produced low grain yield. The cross BIL114×BIL31 involved average x average general combining parents but showed the second highest SCA effects and possessed third highest mean value (Table 3 and 5).Two crosses (BIL138×BIL95and BIL31×BIL95) both involved average × high general combiners, exhibited non significant SCA effects but showed high mean performance and high heterosis. Ivy and Hawlader (2000) also reported that good general combining parents do not always show high SCA effects in their hybrid combinations. On the contrary, Paul and Duara (1991) reported that the parents with high GCA always produce hybrids with high estimates of SCA. Thus the SCA effect of the crosses was not reflected through the GCA effects of the parents. Roy *et al.*(1998) and Ivy and Hawlader (2000) also found the similar result.

Table 3. Specific combining ability effects (SCA) of the crosses for different characters in maize

Crosses	Yield (t/ha)	Pollen shedding (Days)	Silking (Days)	Plant ht. (cm)	Ear ht. (cm)	No. of kernels/ ear	1000-kernel wt.(g)
P_1XP_2	2.57*	1.24	0.80	36.22**	20.58**	54.44*	9.11
P_1XP_3	0.52	-1.42*	-2.87	20.58*	11.16	44.78	12.44
P_1XP_4	-2.63*	-1.89**	1.13	-59.44**	-38.42**	-90.62**	-64.89**
P_1XP_5	1.04	-0.76	-2.40	7.95	4.53	13.18	30.44*
P_1XP_6	-2.12*	1.51*	0.13	-14.13	-2.74	-26.69	6.44
P_1XP_7	0.61	1.31	3.20	8.82	4.89	4.91	6.44
P_2XP_3	-0.52	1.71*	-0.20	-21.50*	-6.14	-36.62	-34.22*
P_2XP_4	0.24	0.24	2.80	22.42*	10.22	35.98	1.78
P_2XP_5	0.06	-1.96**	-3.40	-24.66*	-3.56	18.11	3.78
P_2XP_6	-1.12	-0.36	-1.87	-8.54	-9.90	2.58	19.78
P_2XP_7	-1.24	-0.89	1.87	-3.93	-11.20	-74.49**	-0.22
P_3XP_4	0.21	1.24	4.47	26.44*	20.13**	-29.02	58.44**
P_3XP_5	0.30	-0.29	-1.40	-23.77*	-20.52**	7.11	7.11
P_3XP_6	0.69	-0.69	-1.87	7.02	0.54	12.58	-33.56*
P_3XP_7	-1.20	-0.56	1.87	-8.77	-5.16	1.18	-10.22
P_4XP_5	-0.57	2.24**	4.60	-15.18	-4.76	5.04	-6.89
P_4XP_6	2.49*	-1.49	0.80	19.07	6.44	69.84*	2.44
P_4XP_7	0.26	-0.36	-13.80**	6.68	6.40	8.78	9.11
P_5XP_6	-1.16	0.64	-0.73	27.52*	12.45*	-80.69**	-12.22
P_5XP_7	0.34	0.11	3.33	28.14	11.88	37.24	-22.22
P_6XP_7	1.23	0.38	3.53	-30.94**	-6.79	22.38	17.11
SE (ij)	0.96	0.63	3.53	9.56	5.68	24.33	13.99
LSD(5%)	2.06	1.35	7.57	20.51	12.18	52.19	30.01
LSD(1%)	2.86	1.88	10.51	28.46	16.91	72.43	41.65

*P=0.05, **P=0.01

P1=BML4, P2=BML36, P3=BIL106, P4=BIL114, P5=BIL138, P6=BIL31 and P7=BIL95

Significant and negative SCA effects for days to pollen shedding and silking are desirable for selection of early maturing hybrids. Three crosses ($P_1 \times P_3$, $P_1 \times P_4$and $P_2\times P_5$) exhibited significant and negative sca effects for days to pollen shedding and one cross ($P_4 \times P_7$) for days to silking. These crosses mostly involved high × average, high × low and average × average general combining parents. These findings are consistent with the results of Ahmed *et al.(*2008).

Five crosses exhibited significant and negative SCA effects for plant height and two crosses for ear height indicating short statured plant. These two crosses ($P_1 \times P_4$, $P_3 \times P_5$) exhibited significant and negative SCA effects both for plant and ear height and are desirable for exploiting non additive gene. These crosses involved high × average, average × average, average × low general combining parents (Table 2 and 3). In this study, the cross BML4 × BIL114 showed significant and negative SCA effect both for plant and ear height and also possessed the lowest mean value. Although the cross BIL106 × BIL138 showed significant and high negative SCA effect both for plant and ear height but possessed high mean value (Table 3 and 5).

In case of number of kernels ear^{-1}, two crosses expressed significant and positive SCA effect involving average × low general combining parents. Two crosses (BIL36 × BIL95,BIL138 × BIL31) involved high × average combiners and exhibited significant and negative SCA effects but possessed high mean value. On the other hand, cross (BML4 × BIL114) involved low × low general combiners and simultaneously possessed the lowest significant and negative sca effects and the lowest number of kernels/ear (Tables 3 and 5).

For 1000-kernel weight, two crosses showed significant and positive SCA effects involved low × average combining parents. The SCA values for this character ranged from -64.89 (for BML4×BIL114)to 58.44 (for BIL106×BIL114).

Heterosis

The standard/economic heterosis expressed by the F_1 hybrids over the commercial check variety NK 40 for yield and yield related traits are shown in Table 4. All the traits showed significant heterosis in different crosses.

For grain yield/plant only three crosses showed significant and positive heterosis over the standard check variety NK-40 which was found in the range of -65.83 to 21.26 % (Table 4). It appears that among the 21 F_1s, only three crosses exhibited significant and positive heterosis and the others showed significant and negative heterosis for this trait. Amiruzzaman (2010) and Kadir (2010) foundstandard heterosis for karnel yield were -17.60 to 9.71 % and -15.21 to 27.97 % , respectively.

Significant and negative heterosis was exhibited by six crosses for days to pollen shedding and four crosses for days to silking indicating earliness (Table 4). Malik *et al*. (2004) also observed crosses with significant and negative heterosis in their study. None of the crosses showed significant and positive heterosis for grain yield coupled with significant and negative heterosis for days to silking. Ahmed *et al*. (2008) reported significant and negative heterosis for days to silking in maize.

Table 4.Heterosis of the crosses over NK-40 for different characters in maize

Cross	Yield (t/ha)	Pollen shedding (Days)	Silking (Days)	Plant ht (cm)	Ear ht (cm)	No. of kernels/ear	1000-kernel wt.(g)
P_1X P_2	-4.64	-0.74	-0.35	18.89**	13.66**	29.62**	-10.83**
P_1X P_3	-33.80**	-2.58**	-2.85**	13.52**	10.20*	28.84**	-15.83**
P_1X P_4	-65.83**	1.47**	1.07*	-43.73**	-58.86**	-19.07**	-40.00**
P_1X P_5	-17.55**	0.73	0.00	12.45**	11.50**	27.74**	-13.33**
P_1X P_6	-50.42**	0.73	0.36	-14.16**	-15.12**	6.92**	-8.33**
P_1X P_7	-14.58**	0.36	-0.35	15.03**	11.67**	29.41**	-17.50**
P_2X P_3	-11.14**	0.36	-0.35	7.94*	17.98**	19.79**	-17.50**
P_2X P_4	-6.87	3.31**	2.51*	30.48**	34.40**	26.88**	-13.33**
P_2X P_5	5.57	-1.10*	-1.43	12.97**	31.20**	41.50**	-10.00**
P_2X P_6	-8.82*	-1.84**	-2.14*	10.94**	5.79	27.13**	5.00*
P_2XP_7	0.46	-2.58	-2.14*	28.33**	21.00**	20.85**	-9.17**
P_3XP_4	-17.27**	5.51**	5.72**	37.77**	56.00**	11.46**	-5.00*
P_3X P_5	-2.23	1.83**	2.14*	18.25**	17.98**	40.46**	-15.00**
P_3X P_6	-2.14	-1.10*	-0.71	25.67**	28.09**	31.58**	-14.17**
P_3X P_7	-9.19*	-1.10*	-0.71	29.92**	37.59**	42.70**	-17.50**
P_4X P_5	-13.00**	9.19**	8.22**	18.03**	33.63**	27.76**	-23.33**
P_4X P_6	11.79**	2.57**	1.79	27.68**	30.94**	34.61**	-10.00**
P_4X P_7	1.58	3.67**	-17.85**	34.12**	47.80**	32.54**	-17.50**
P_5X P_6	-7.80*	2.93**	2.86**	45.93**	53.41**	14.18**	-10.83**
P_5X P_7	16.53**	2.21**	3.21**	60.74**	69.58**	59.48**	-22.50**
P_6X P_7	21.26**	0.00	1.07	10.30**	28.18**	45.28**	-1.67
Mean	15.36	2.19	2.75	24.61	30.22	29.42	12.54
LSD(5%)	7.46	0.95	1.81	6.33	8.24	5.57	4.82
LSD(1%)	10.18	1.29	2.47	8.64	11.24	7.60	6.58

*P=0.05, **P=0.01

P1=BML4, P2=BML36, P3=BIL106, P4=BIL114, P5=BIL138, P6=BIL31 and P7=BIL95

Negative heterosis is desirable for plant height which helps to develop short stature plant leading to tolerant to lodging. Heterosis for different crosses ranged from -43.73 to 60.74 percent and -58.86 to 69.58 percent, respectively, for plant and ear height. Two crosses exhibited significant and negative heterosis both for plant and ear height and except one cross (BML36 x BIL31) in respect to ear height, rest of the crosses showed significant and positive heterosis. Significant and negative heterosis for both these traits were reported by Uddin*et al*. (2006), Alam *et al*. (2008) and Amiruzzaman (2010).

Except one cross (BML4 × BIL114), rest of the crosses showed significant and positive heterosis for number of kernels ear^{-1}. The value of heterosis ranged from -19.07 to 59.48 % in the cross BML4 × BIL114and BIL138× BIL95, respectively.

Out of 21 F_1's, only one cross (BML36 × BIL31) expressed significant and positive heterosis for 1000-kernel wt. (Table 4). This finding was similar with Shewangizaw (1983) and Nigussie and Zelleke (2001) who observed heterosis only in few crosses.

Table 5. Mean performance of the single crosses evaluated at Joydebpur during *rabi* 2013-2014.

Genotypes	Yield/ plant (g)	Pollen shedding (Days)	Silking (Days)	Plant ht (cm)	Ear ht (cm)	Number of kernels/ ear	1000- kernel wt.(g)
$P_1X P_2$	10.27	90	93	185	88	490	357
$P_1X P_3$	7.13	88	91	176	85	487	337
$P_1X P_4$	3.68	92	94	87	31	306	240
$P_1X P_5$	8.88	91	93	175	86	483	347
$P_1X P_6$	5.34	91	94	133	65	404	367
$P_1X P_7$	9.20	91	93	179	86	489	330
$P_2X P_3$	9.57	91	93	168	91	453	330
$P_2X P_4$	10.03	94	96	203	104	479	347
$P_2X P_5$	11.37	90	92	175	101	535	360
$P_2X P_6$	9.82	89	91	172	82	480	420
P_2XP_7	10.82	88	91	199	93	457	363
P_3XP_4	8.91	96	99	214	120	421	380
$P_3X P_5$	10.53	92	95	184	91	531	340
$P_3X P_6$	10.54	90	93	195	99	497	343
$P_3X P_7$	9.78	90	93	202	106	539	330
$P_4X P_5$	9.37	99	101	183	103	483	307
$P_4X P_6$	12.04	93	95	198	101	509	360
$P_4X P_7$	10.94	94	77	208	114	501	330
$P_5X P_6$	9.93	93	96	227	118	431	357
$P_5X P_7$	12.55	93	96	250	131	603	310
$P_6X P_7$	13.06	91	94	171	99	549.	393
NK40	10.77	91	93	155	77	378	400
Pioneer	10.46	91	95	193	84	439	347
BHM9	10.69	91	934	215	116	484	327
Mean	9.82	91	93	185	94.66	476	346
LSD(5%)	0.87	1.02	1.79	13.46	8.57	25.77	14.92
LSD(1%)	1.18	1.38	2.43	18.26	11.62	34.98	20.25
F-test	**	**	ns	**	**	**	**
CV	19.82	1.66	7.55	10.48	12.34	10.82	8.72

*P=0.05, **P=0.01, ns= non significant

Conclusion

Parents with good positive gca for yield (BIL95), number of kernels/ear(BIL138and BIL95) and 1000- kernel wt. (BML36andBIL31) and negative gca for days to pollen shedding (BIL95), plant height and ear height (BML4) may be extensively used in hybridization program as a donor. The better performing three crosses (BIL114 × BIL31, BIL138 × BIL95 and BIL31 × BIL95) can be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigour.

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INFESTATION LEVEL AND POPULATION DYNAMICS OF APHID ON MUSTARD

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Abstract

Mustard *(Brassica juncea)* variety BARI Shorisha-11 was cultivated during September 2016 to March 2017 in Gazipur, Bangladesh to find out the population dynamics of aphid and its infestation level on mustard. The aphid *Lipaphis erysimi* (Homoptera: Aphididae) was abundant in the field and caused infestation. The population of aphid in the mustard field showed fluctuation and reached to the peak at 22 December which was 289 per plant. Inflorescence had significantly higher level of infestation compared to individual siliqua and leaf. The daily mean temperature had significant negative, light intensity had insignificant negative and relative humidity had insignificant positive correlation with the abundance of aphid. The multiple linear regression analysis showed that the weather parameters namely temperature, light intensity and relative humidity individually as well as combindly contributed on the abundance of aphid, but the temperature had greater effect than other factors.

Keywords: Abundance, *Brassica juncea,* infestation, *Lipaphis erysimi.*

Introduction

Mustard (*Brassica* spp.) is one of the first domesticated crops which has wide dispersal, and has been grown as herb in Asia, North Africa and Europe for thousands of years (Oplinger *et al.,* 2016). It ranks world's third important oil crop in terms of production and area, and in Bangladesh, it is the first in ranking. Among the three species of brassica, *Brassica napus* and *Brassica campestris* are regarded as rape seed and *Brassica juncea* is regarded as mustard. Mustard oil is one of the healthiest edible oils as it has no trans fat, has low saturated fats, high mono-unsaturated and poly-unsaturated fats like omega-3 (Das *et al.,* 2009).

Many insect pests like aphid, sawfly and leaf hopper damage the crop by feeding on leaves, stems, flowers and fruits causing serious yield loss. Aphid *Lipaphis erysimi* Kalt. (Homoptera: Aphididae) is the most destructive insect pest of mustard (Das, 2002). It is a cosmopolitan insect and found on both the leaf surfaces and in leaf folds of developing heads, on leaf stalks, and on leaf axles. They are found primarily on the growing points of the host plants, including tips, flowers and developing pods and cover the whole plant with high density (Nelson and Rosenheim, 2006). They suck sap from the hosts and infested plants become stunted and distorted. Their infestation causes wilting, yellowing and stunting of

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plants (Khan *et al.*, 2015). The avoidable yield losses at anywhere due to aphid infestation may be 20 to 50%, and it could be as high as 78% (Prasad and Phadke, 1983). Vekaria and Patel (2000) reported that weather plays an important role on the appearance, multiplication and disappearance of aphid.

Two model studies indicated that temperature was highly linked with the density of aphid or other sucking insects (Zhou *et al.*, 1997; Whittaker and Tribe, 1998). Bale *et al.* (2002) reported that increased temperature could decrease growth of some aphid species depending on their thermal requirements and host specificity. Though aphid has been identified as a major pest of mustard in Bangladesh but information on its infestation and population dynamics in respect of weather factors are very scanty. In this study infestation level of aphid *L. erysimi* on different parts of the mustard (*B. juncea*) plant BARI Shorisha-11, and the population dynamics of aphid in relation to weather factors namely temperature, humidity and rainfall were studied under field condition.

Materials and Method

The study was conducted during September 2016 to January 2017 in the Experimental Field of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur. The study site is located at 25°25′ North latitude and 89°5′ East longitude, which is in the middle of Bangladesh. The study area has subtropical climate having annual mean maximum and minimum temperatures, relative humidity and rainfall of 36.0 and 12.7 ^{o}C, 65.8% and 237.6 cm, respectively. The mustard *Brassica juncea* variety BARI Shorisha11 seeds were collected from Oil Seed Research Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The crop was cultivated following randomized complete block design comprising 4.0 m × 4.0 m plots. The distance between block to block and plot to plot was 60 cm. Mustard seeds were sown on 30 October 2016 in rows. The distance from row to row was 45 cm and plant to plant was 5 cm. Intercultural operations such as irrigation and weeding were done whenever necessary. Fertilizers were applied according to Fertilizer Recommendation Guide (N- 40 kg, P- 12 kg, K- 30 kg, S- 9 kg per hectare). After emergence of seedlings, weekly field inspection was carried out to record the data of aphid abundance. At each inspection, three plants from each plot were randomly selected and the numbers of aphid nymphs and adults per plant were counted. The population of aphid was counted with the help of a magnifying glass (FD75, Ballon Brand, China). The data of the abundance of aphid were recorded from 28 November to 28 December 2016. During inspection, the total number of leaves, inflorescence and silique as well as the number of infested leaves, inflorescence and silique of the plants were counted and percent infestations were calculated. Light intensity in the field during insect collection was measured with a digital light meter (Model 401025, Extech Instruments Corporation, USA). Data were collected weekly and in between 10.0 and 13.00 h at the canopy area of the plots. Mean daily temperature and relative humidity data were collected from the weather station of BSMRAU. Aphid abundance during the crop growth stages and their infestation levels on leaf, inflorescence and siliqua were analyzed by Chai statistics. The mean infestation level on leaf, inflorescence and siliqua were analyzed by analysis of variance (ANOVA) followed by Tukey HSD posthoc statistics. Correlation coefficients were calculated for aphid abundance with meteorological parameters. All the analyses were performed using IBM SPSS 21.1 software.

Results and Discussion

Aphid population in mustard field showed significant variations ($\chi^2 = 506.1$, df = 5, $p < 0.001$) during the crop growth stages (Fig. 1). The population showed an increasing trend from 20 November and reached the peak on 22 December and again declined on 28 December. The highest mean abundance of aphid per plant was found on 22 December which was 289 per plant.

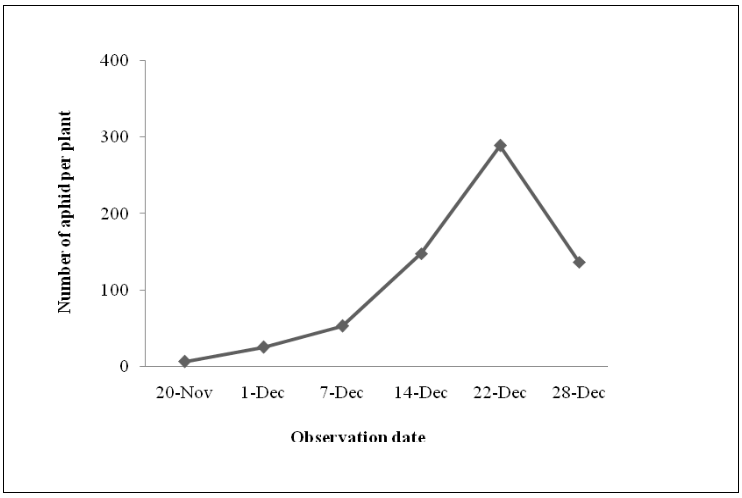

Fig. 1. Population dynamics of aphid in mustard field in Gazipur, Bangladesh during November to December 2016.

The abundance of aphid on mustard crop varies with geographic location and climatic condition of the cropping season. In this study, aphid appearance was first recorded on 20 November but Shahoo (2012) observed the appearance of aphid in the mustard field of West Bengal, India from last week of December and 1st week of January in the year 2009-10 and 2011-12, respectively, but the aphid abundance reached the peak on 6th week of crop cultivation in both the years.

Infestation of aphid on mustard leaf during the growth stages of the crop showed significant difference ($\chi^2 = 13.3$, df = 5, $p < 0.001$, Fig. 2). Aphid started leaf infestation from 20 November and it was highest on 14 December. The inflorescence and siliqua infestation was noticed during 01 December to 28 December and in both cases infestation was highest on 7 December. However, the inflorescence infestation did not show significant difference ($\chi^2 = 5.0$, df = 4, p = 0.29) but siliqua infestation differed significantly ($\chi^2 = 18.2$, df = 4, p < 0.01). The mean infestation level of leaf, inflorescence and siliqua ranged from 34.1 to 59.3% and the results differed significantly (Fig. 3, $F_{2,13} = 8.4$, $p < 0.01$). Among the plant parts, inflorescence revealed significantly higher level of infestation compared to leaf and siliqua. In India aphids alone attribute 30-70% losses in rape seed yield in different agro climatic conditions with an average loss of 52.2% (Roy and Baral, 2002). Under favorable circumstances, aphid population increase very rapidly by making dense colonies on all parts of plants. In India, aphid has attained the key pest status in mustard because of its prolific multiplication and severe damage, resulting curling of the leaf, stunting and drying up of the plants (Rana *et al*., 2007). In Pakistan, cabbage aphid and mustard aphid are important pests of *Brassica* (Razaq *et al.*, 2011).

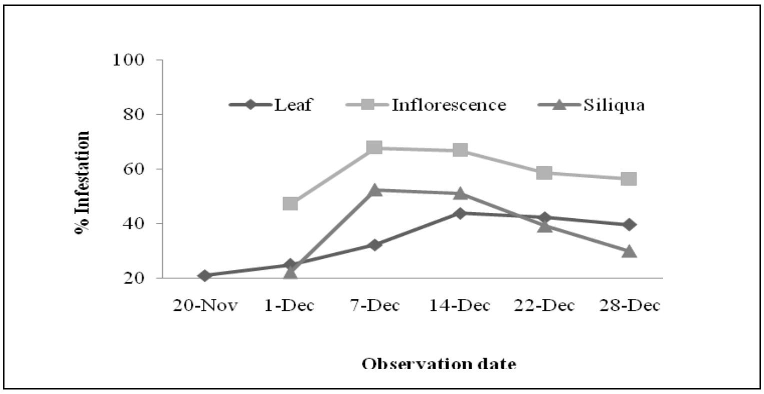

Fig. 2. Infestation level of aphid on different plant parts of mustard during November to December 2016.

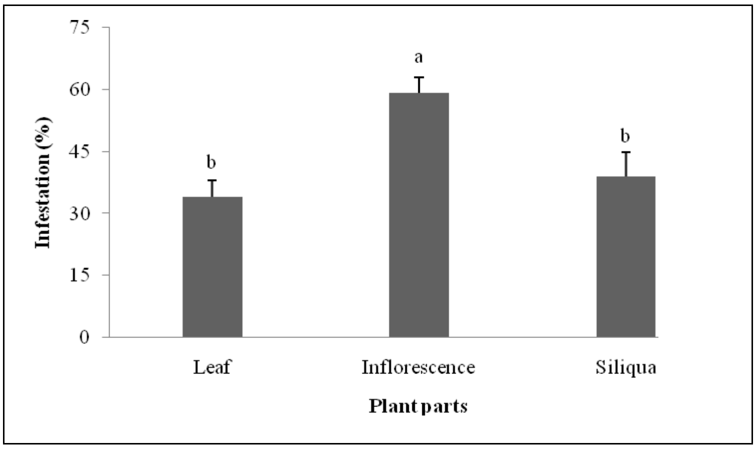

Fig. 3. Mean infestation level of aphid (%mean ± SE) on different plant parts of mustard. Bars with common letter are not significantly different by Tukey HSD posthoc statistic at p≤ 0.05.

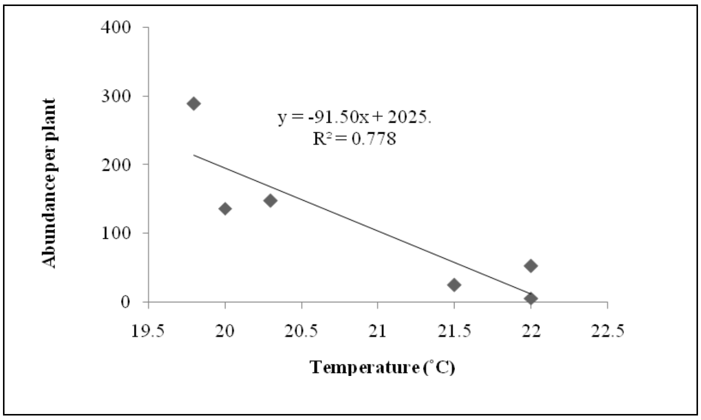

Fig. 4. Relationship between temperature and aphid abundance in mustard field during November to December 2016.

Seasonal variations of the weather factors play a vital role in multiplication, growth, development and distribution of insects, and influence on their population dynamics (Dhaliwal and Arora, 2001). Aphid population build up was regulated by temperature and time and population was relatively short in warm humid climates than in cool climates (Rao *et al.,* 2013). The present study showed that the daily mean temperature had significant negative correlation (Fig. 4: y = 2025 – 91.503x, r = 0.882, $F_{1, 4}$ = 14.1, $p < 0.05$), light intensity had insignificant negative correlation (Fig. 5: y = 142.12 - 0.065x, r = 0.055, $F_{1, 4}$ = 0.012, p = 0.92), relative humidity had insignificant positive correlation (Fig. 6: y = -576.01 + 7.7912x, r = 0.473, $F_{1, 4}$ = 1.2, p = 0.34) with abundance of aphid. Amin *et al.* (2017) showed that weather parameters had insignificant effect on the population abundance of aphid on cotton plant in Bangladesh. They also reported that the aphid population started to build up at the end of October when the maximum and minimum temperatures decreased, the relative humidity slightly declined, and there was little rainfall.

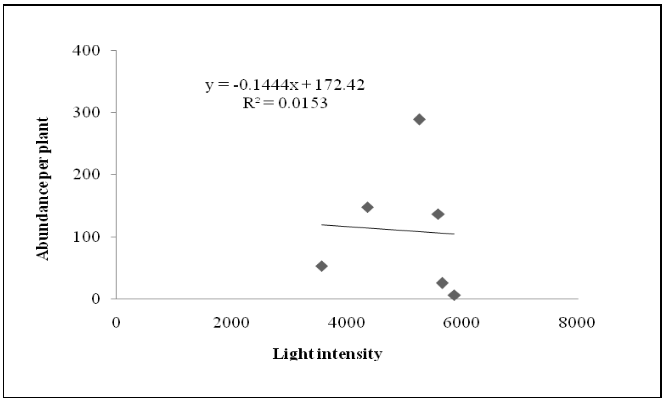

Fig. 5. Relationship between light intensity and aphid abundance in mustard field during November to December 2016.

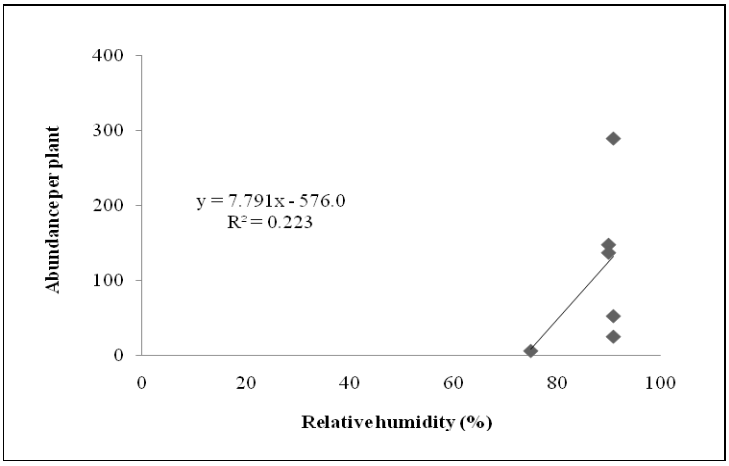

Fig. 6. Relationship between relative humidity and aphid abundance in mustard field during November to December 2016.

Table 1 showed that temperature individually exerted 77.9 % effect on population abundance of aphid on mustard and the effect was significant. The temperature with combination of light intensity provided 81.3% abundance, which was not statistically significant. The individual effect of light intensity demonstrated 3.4% abundance. The combination effect of temperature, light intensity and relative humidity depicted 81.7% abundance and the result was not statistically significant. The individual effect of humidity was 0.4%. The multiple linear regression analysis showed that the three weather parameters together contributed on the abundance of mustard aphid, but the temperature had the greater effect than others.

Table 1. Multiple regression models along with coefficients of determination (R^2) regarding the impact of weather parameters on abundance of aphid in mustard field

Regression equation	R^2	100 R^2	%Role of individual factor	F statistic	
$Y = 2025.07 – 91.50\ X_1$	0.779	77.9	77.9	$F_{1,4}$= 14.1	$P < 0.05$
$Y = 2194.6 – 94.324\ X_1 – 0.219X_2$	0.813	81.3	3.4	$F_{2,3}$= 6.5	$P = 0.08$
$Y = 2473.2 – 99.71X_1 – 0.277X_2 – 1.546X_3$	0.817	81.7	0.4	$F_{3,2}$= 2.98	$P = 0.26$

Y, insect population /plant; X_1, temperature (°C); X_2, light intensity(lux); X_3, relative humidity (%).

Weather factors greatly influenced the population dynamics of insects. A study by Namni *et al.* (2016) showed that weather parameters contributed 61.7% abundance of hopper on mango plant. Dhaliwal *et al*. (2007) stated that the incidence, growth and multiplication of mustard aphid are largely influenced by meteorological parameters like temperature, relative humidity, rainfall, wind speed and cloudiness.

Ansari *et al.* (2007) observed that the appearance of mustard aphid on *Brassica* germplasm occurred on 11th January at 60 days after sowing and disappeared after 2nd March at 110 days after sowing. Ansari *et al.* (2007) also reported that the peak aphid population was found at a maximum, minimum and average temperature of 23.37°, 6.87° and 15.76°C, respectively and mean relative humidity of 54.75% on 10th February at 90 days after sowing. The present findings showed that the weather factors during November to December remained conducive for the rapid multiplication of aphid. Moreover, the aphid population reached peak level coinciding with the flowering stage of the crop which was similar to those found by Shahoo (2012). However, the present findings provide information on the seasonal abundance of aphid as well as its level of infestation on different parts of mustard plant, which might be helpful to growers to escape the possible time of infestation.

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INTEGRATED MANAGEMENT OF TOBACCO CATERPILLAR AND CABBAGE BUTTERFLY WITH HOST PLANT RESISTANT AND ORGANIC AMENDMENT

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Abstract

Field study was conducted at Patuakhali Science and Technology University, Patuakhali during 2013-2014 to know the effect of cabbage variety and organic agriculture on the damage potential of *Spodoptera litura* F. and *Pieris brassicae* L. Two cabbage varieties viz., Atlas-70 (V_1) and Super tropic (V_2), and organic agriculture like, M_0 = control, M_1 = cowdung @ 6 kgplot^{-1}, M_2 = mustard oilcake @ 750gplot^{-1}, M_3 = Vermicompost @ 3 kgplot^{-1} and M_4 = Trichoderma @ 3 kgplot^{-1} were included in this study. Treatment combinations were V_1M_0, V_1M_1, V_1M_2, V_1M_3, V_1M_4, V_2M_0, V_2M_1, V_2M_2, V_2M_3 and V_2M_4. Results revealed that the lowest number of infested plants/plot and percent infested leavesplant^{-1} were found in variety Super tropic and trichoderma (V_2M_4) applied plots followed by variety Atlas-70 and vermicompost (V_1M_3) applied plots on different dates of observation while the highest number of infested plantsplot^{-1} and percent infested leaves plant^{-1} were in variety Super tropic and mustard oil cake (V_2M_2) applied plots followed by variety Atlas-70 and control (V_1M_0) applied plots. The highest number and percent (4.00 plot^{-1}) and (20.00% plot^{-1}) of infested heads were found in variety Super tropic and mustard oil cake (V_2M_2) applied plots followed by variety Atlas-70 and control plots (V_1M_0) (16.65%). The highest number of healthy heads plot^{-1} (19.67), healthy head yield (71.47 t ha^{-1}) and total head yield (72.14 t ha^{-1}) were recorded in variety Super tropic and Tricoderma (V_2M_4) applied plots followed by variety Atlas-70 and vermicompost (V_1M_3) (70.53 t ha^{-1}) applied plots while the lowest number of healthy heads per plot, healthy head yield and total head yield were recorded in in variety Super tropic and mustard oil cake (V_2M_2) applied plots followed by variety Atlas-70 and control plots (V_1M_0).

Keywords: Atlas-70, organic materials, trichoderma, Super tropic, vermicompost.

Introduction

Cabbage (*Brassica oleracea* L. var. *capitata*) is one of the most popular vegetables in the world. It is mostly grown in winter throughout Bangladesh. In Bangladesh, the annual production of cabbage is 217 thousand tons (BBS, 2014). The production and yield of cabbage is greatly hampered by many insect pests. Cabbage is also known to be infested by several insect pests *viz*., tobacco caterpillar, *Spodoptera litura* (Fab.), cabbage butterfly (*Pieris brassicae*),

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diamond back moth (*Plutella xylostella* Linnaeus) and cabbage aphid (*Brevicoryne brassicae* L.). Out of these, cabbage butterfly, diamond back moth and tobacco caterpillar are the most destructive pests causing severe yield loss to cabbage every year (Rao and Lal, 2005; Mahla *et al*., 2005; Kumar *et al*., 2007). Tobacco caterpillar is the most destructive insect pest sometimes cause complete failure of the crop. After hatching, the caterpillars start feeding on the under surface of the leaves. Leaves of heavily damaged plants have many feeding holes and sometimes the leaves take a 'sieve-like' appearance. It also destroys the leaves of cabbage by making holes in the head and greatly reduces its market value. As a result of feeding, the plants either fail to form compact cabbage heads or produce deformed heads (Uddin *et al*., 2007).

The indirect effects of fertilization practices acting through changes in the nutrient composition of the crop have been reported to influence plant resistance to many insect pests. Vermicompost are produced through the interactions between earthworms and microorganism in the breakdown of organic wastes and to convert into nutritional rich humus (Sinha *et al*., 2010). The vermicompost promote growth from 50-100% over conventional compost and 30-40% over chemical fertilizers (Sinha *et al*., 2010). Crop losses due to insects and diseases are reduced with organic farming (Merrill, 1983). Vermicomposts are rich in humic acid and phenolic compounds. Phenolic compounds act as feeding deterrents and hence significantly influence pest infestation (Mahanil *et al*., 2008; Bhonwong *et al*., 2009). Stevenson *et al.* (1993) reported that inhibition of *S. litura* development by phenolic compound from the wild groundnut. Meyer (2000) argues that soil nutrient availability not only affects the amount of damage that plants receive from herbivores but also increase the ability of plants to recover from herbivory; however, these two factors are rarely considered together. Describing the effects of soil fertility on both the degree of defoliation and compensation for herbivory for *Brassica nigra* plants damaged by *Pieris rapae* caterpillars (Meyer, 2000). Keeping these views in mind, the present study was conducted to evaluate the combine effect of varieties of cabbage and organic agriculture on the damage potential of *S. litura* and *P. brassicae* infesting cabbage.

Materials and Methods

The study was conducted at the agricultural farm of Patuakhali Science and Technology University, Dumki, Patuakhali during *rabi* season of 2013-2014. Two cabbage varieties *viz*., Atlas-70 (V_1) and Super tropic (V_2) were included in this study. Organic agricultural components were used as treatments were M_0 = control, M_1 = cowdung @ 6 kgplot^{-1}, M_2 = mustard oilcake @ 750gplot^{-1}, M_3 = Vermicompost @ 3 kgplot^{-1} and M_4 = Trichoderma @ 3 kgplot^{-1}. Treatment combinations were V_1M_0, V_1M_1, V_1M_2, V_1M_3, V_1M_4, V_2M_0, V_2M_1, V_2M_2, V_2M_3 and V_2M_4. Experiment was laid out in randomized complete block design (RCBD) with three replications. The entire field was divided into three blocks and each block was again divided into ten plots. The distance between both blocks and plots was 1.0 m. The area of each experimental plot was 9 m^2. Seeds of the selected cabbage cultivars were sown in the month of November and were transplanted in December. Thirty day-old cabbage seedlings were transplanted in the plot of 9 m^2 area with 45cm × 45cm spacing on 29 December, 2013. The chemical fertilizers viz., urea, TSP and MP were applied at the rate of 285, 145 and 218 $kgha^{-1}$. Fertilizer, irrigation and all other agronomic practices were carried out in the experimental field whenever necessary. Harvesting of cabbage heads were started on 02 February and continued till 28 February 2014. Weekly observations were done since one week of transplanting till maturity of the crop. The number of infested plants $plot^{-1}$, the number infested leaves $plant^{-1}$ and infested head were separated carefully and healthy and infested leaves were counted and recorded. After each harvest, the number of healthy and infested heads were sorted, counted and recorded separately. The weight of healthy and infested heads per plot was recorded separately for each treatment replicates. Treatment wise percent head infestation was calculated from the pooled data of ten observations. The total yield of cabbage ha^{-1} for each treatment was calculated in tons from cucmulative head harvested from a plot. Data were analyzed after appropriate transformation following RCBD using computer MSTAT C and MS excel programs. Means were compared by DMRT.

Results and Discussion

Combined effects of cabbage varieties and organic agriculture on the number of infested plants $plot^{-1}$ varied significantly on different dates of observations (Table 1). On 8^{th} January, the number of infested plants $plot^{-1}$ ranged from 1.50 -3.50. The lowest number of infested plants $plot^{-1}$ was 1.50 for the treatment combination of V_2M_4 (Super tropic + trichoderma) which was statistically identical to V_1M_1 (1.50) and V_2M_1 (1.50). The highest number of infested plant $plot^{-1}$ was 3.50 for the treatment combination of V_2M_2 (Super tropic + mustard oil cake) which was statistically similar to V_2M_0 (Super tropic + control).

On 15 January, the number of infested plants $plot^{-1}$ ranged from 1.00 to 3.50. The lowest number of infested plants $plot^{-1}$ was recorded for the treatment combination of V_1M_3 (var. Atlas + vermicompost) which were statistically similar to V_2M_4 (Super tropic + trichoderma). The highest number of infested plant $plot^{-1}$ was for variety Super tropic and mustard oil cake (V_2M_2) applied plots which were statistically similar to V_2M_0 (Super tropic and control).

On day 22 June 2014, the number of infested plants $plot^{-1}$ ranged from 0.50 to 3.00. Significantly the lowest number of infested plants $plot^{-1}$ was for the treatment combination of V_1M_3 (Atlas + vermicompost). The higher number of infested plants $plot^{-1}$ was recorded in V_2M_1 (Super tropic + cowdung) which was statistically similar to remaining all other treatment combinations.

On 29 January 2014, no significant differences were observed among different treatment combinations in respect of the number of infested plants $plot^{-1}$ (Table 1).

On 5 February 2014, number of infested plants $plot^{-1}$ ranged from 0.0 to 3.00. No plant was infested in treatment combinations of V_2M_4 (Super tropic +

trichoderma) and the lowest number was recorded in V_1M_4 (0.50) (Atlas + trichoderma) applied plots. The higher number of infested plants/plot was in V_1M_0 applied plots which was statistically identical to V_1M_1 (Atlas + cowdung) (3.00) but statistically similar to treatment combinations of V_1M_0 V_1M_2 on the same date.

On 12 February 2014, the number of infested plants plot^{-1} ranged from 2.00 to 6.50. The lowest number of infested plants plot^{-1} was observed in variety supertropic and trichoderma (V_2M_4) applied plots which was statistically identical to V_1M_4 (2.00) and V_2M_0 (2.00) applied plots. The higher number of infested plants/plot was found in variety Atlas-70 and mustard oil cake (V_1M_2) applied plots which was statistically similar to V_1M_1 (5.50) i.e., variety Atlas -70 and cowdung plot followed by V_1M_0 (5.00) i.e., variety Atlas-70 and untreated control plot (Table 1).

Table 1. Combined effects of cabbage varieties and organic manures on the number of infested plants plot^{-1} by *S. litura* and *P. brassicae* on different dates of observations

Treatment combinations	Number of infested plants plot^{-1} observed on						Average number of infested plants plot^{-1}
	8 Jan.	15 Jan.	22 Jan.	29 Jan.	05 Feb.	12 Feb.	
V_1M_0	2.50ab	2.50b	1.50b	2.00	3.00a	5.00b	2.75
V_1M_1	1.50c	2.50b	2.50a	2.50	3.00a	5.50ab	2.92
V_1M_2	2.00b	2.00c	2.50a	2.00	2.50a	6.50a	2.92
V_1M_3	2.50ab	1.00d	0.50c	0.50	0.00d	2.50de	1.67
V_1M_4	2.00b	2.50b	2.50a	1.50	0.50cd	2.00e	1.83
V_2M_0	3.00a	3.00a	1.50b	1.00	1.00c	2.00e	1.92
V_2M_1	1.50c	2.50b	3.00a	1.00	2.00b	3.00d	2.17
V_2M_2	3.50a	3.50a	3.00a	1.50	2.50a	4.00c	3.00
V_2M_3	2.50ab	2.00c	3.00a	2.00	1.50bc	3.50cd	2.42
V_2M_4	1.50c	1.50cd	1.00b	0.50	0.00d	2.00e	1.08
LSD	0.502	0.499	0.610	-	0.562	0.611	-
Level of significance	**	**	**	NS	**	**	-
CV (%)	4.75	3.80	3.76	6.48	1.65	5.40	-

Values are averages of 3 replications

Means within a column followed by different letters are significantly different from each other at 5% (*) and 1% (**) level of probability by DMRT

V_1=var. Atlas-70; V_2 = Super tropic;

M_0 = control, M_1 = cowdung @ 6 kg plot^{-1}, M_2 = mustard oilcake @ 750g plot^{-1}, M_3 = Vermicompost @ 3 kg plot^{-1} and M_4 = Trichoderma @ 3 kg plot^{-1}

On day 8 January 2014, the percentage of infested leaves plant^{-1} varied from 7.79% to 58.69% but significantly the lowest percenatge of infested leaves plant^{-1} was recorded in variety Super tropic and trichoderma (V_2M_4) applied plots and the highest percentage of infested leaves plant^{-1} was observed in variety Super tropic and mustard oil cake (V_2M_2) applied plots (Table 2).

On 15 January 2014, significantly the lowest percenatge of infested leaves plant^{-1} (4.17%) was recorded in variety Super tropic and trichoderma (V_2M_4) applied plots and the highest percentage of infested leaves plant^{-1} (66.67%) was observed in variety Atlas-70 and untreated control plot (V_1M_0)

On 22 January 2014, the lowest percenatge of infested leaves plant^{-1} (3.34%) was recorded in variety Super tropic and trichoderma (V_2M_4) applied plots which was statistically similar to V_2M_3 (3.57%) applied plots. The highest percentage of infested leaves plant^{-1} (61.61%) was observed in variety Super tropic and mustard oil cake (V_2M_2) applied plots which was statistically similar to V_1M_0 (58.93%) (Atlas-70 + untreated control plot).

On 29 January 2014, significantly the lowest percenatge of infested leaves plant^{-1} (4.17%) was obtained in variety Atlas-70 and vermicompost applied plots and the highest (53.96%) was observed in variety Super tropic and mustard oil cake (V_2M_2) applied plots.

On 5 February 2014, significantly the highest percentage of infested leaves plant^{-1} (61.67%) was observed in variety super tropic and mustard oil cake (V_2M_2) applied plots which differed significantly from all other remaining treatments. The lowest percenatge of infested leaves plant^{-1} (3.57%) was recorded in variety Atlas-70 and trichoderma (V_1M_4) applied plots (Table 2). No leaf infestation was observed in variety Atlas-70 and vermicompost (V_1M_3) (0.00%) and variety Super tropic and trichoderma (V_2M_4) (0.00%) applied plots.

On 12 February 2014, the lowest percenatge of infested leaves plant^{-1} (18.18%) was recorded in variety Atlas-70 and vermicompost applied plots which was statistically similar to V_1M_1 (22.35%). The highest percentage of infested leaves plant^{-1} (76.93%) was observed in variety Super tropic and mustard oil cake (V_2M_2) applied plots followed by variety Super tropic and cowdung (V_2M_1) (62.15%) applied plots (Table 3). No significant differences were observed among variety Atlas-70 and control plots (V_1M_0) (55.77%), V_1M_2 (54.95%) and V_2M_0 (51.25%) applied plots (Table 2).

Table 2. Combined effects of cabbage varieties and organic manures on the percentage of infested leaves plant^{-1} caused by *S. litura* and *P. brassicae* on different dates of observations

Treatment combinations	Percentage of infested leaves plant^{-1} on						Mean percentage of infested leaves plant^{-1}
	8 Jan.	15 Jan.	22 Jan.	29 Jan.	05 Feb.	12 Feb.	
V_1M_0	51.12b	66.67a	58.93a	46.88b	36.64b	55.77c	52.05
V_1M_1	31.45d	36.67c	28.57d	36.36c	39.56b	22.35f	32.08
V_1M_2	40.41c	43.69b	34.88c	39.74c	29.12c	54.95c	40.45
V_1M_3	12.78f	25.00e	19.23e	4.17g	0.00e	18.18f	13.05
V_1M_4	17.45e	11.31g	15.11f	17.86e	3.57d	43.34d	17.85
V_2M_0	36.14c	31.22d	30.77d	34.38cd	36.36b	51.25c	36.47
V_2M_1	40.36c	42.86b	41.19b	20.83e	38.92b	62.15b	40.78
V_2M_2	58.69a	46.88b	61.61a	53.96a	61.67a	76.93a	59.45
V_2M_3	30.19d	17.86f	3.57g	27.09d	39.74b	41.67d	31.07
V_2M_4	7.79g	4.17h	3.34g	7.69f	0.00e	31.47e	8.59
LSD	4.40	3.84	2.62	3.61	3.12	4.30	-
Level of significance	**	**	*	**	*	*	-
CV (%)	8.52	7.31	4.80	5.90	6.74	5.12	-

Values are averages of 3 replications

Means within a column followed by different letters are significantly different from each other at 5% (*) and 1% (**) level of probability by DMRT

V_1=var. Atlas-70; V_2 = Supertropic;

M_0 = control, M_1 = cowdung @ 6 kg plot^{-1}, M_2 = mustard oilcake @ 750g plot^{-1}, M_3 = Vermicompost @ 3 kg plot^{-1} and M_4 = Trichoderma @ 3 kg plot^{-1}

Significantly the highest number of healthy heads plot^{-1} (19.67) was found in variety Super tropic and trichoderma (V_2M_4) applied plots which was statistically similar to V_1M_3 (19.33) (Atlas-70 + vermicompost). The lowest healthy heads (16.00) was in variety supertropic and mustard oil cake (V_2M_2) applied plots which was statistically similar to V_1M_0 (16.67) (Table 3). On the contrary, the lowest number of infested heads plot^{-1} (0.33) was observed in variety Super tropic and trichoderma (V_2M_4) applied plots which was statistically similar to V_1M_3 (0.67) (Atlas-70 + vermicompost) applied plots. The highest number of infested heads per plot (4.00) was found in variety Super tropic and mustard oil cake (V_2M_2) applied plots followed by variety Atlas-70 and control plots (V_1M_0) (3.33) and variety Atlas-70 and mustard oil cake (V_1M_2) (2.67) applied plots. No significant differences were observed among variety Atlas -70 and cowdung (V_1M_1) (2.33), variety Super tropic and control (V_2M_0) (2.00), variety Super tropic and cowdung (V_2M_1) (2.12) and variety supertropic and vermicompost (V_2M_3) (1.67) applied plots in respect of number of infested heads per plot. In case of percent head infestation by number, the lowest percent (1.65%) was recorded in variety Super tropic and trichoderma (V_2M_4) applied plots followed by V_1M_3 (3.35%) and V_1M_4 (6.65%) applied plots. The highest percent (20.00%) head infestation by number was recorded in variety Super tropic and mustard oil cake (V_2M_2) applied plots followed by variety Atlas-70 and control plots (V_1M_0) (16.65%). No significant difference was observed among variety Atlas -70 and cowdung (V_1M_1) (11.65%), variety Super tropic and cowdung (V_2M_1) (10.60%), variety Super tropic and control (V_2M_0) (10.00%) in respect of the percentage of infested heads by number (Table 3).

Table 3. Mean number of healthy and infested head plot^{-1} and percent head infestation (by number) caused by *S. litura* and *P. brassicae* as influenced by treatment combinations

Treatment combinations	No. of healthy heads plot^{-1}	No. of infested heads plot^{-1}	Percent head infestation by number
V_1M_0	16.67e	3.33ab	16.65ab
V_1M_1	17.67cd	2.33cd	11.65cd
V_1M_2	17.33d	2.67bc	13.35bc
V_1M_3	19.33ab	0.67f	3.35fg
V_1M_4	18.67b	1.33e	6.65ef
V_2M_0	18.00bc	2.00cde	10.00cde
V_2M_1	17.88bd	2.12cde	10.60cd
V_2M_2	16.00e	4.00a	20.00a
V_2M_3	18.33bc	1.67de	8.35de
V_2M_4	19.67a	0.33f	1.65g
LSD	0.874	0.854	4.472

V_1=var. Atlas-70; V_2 = Super tropic;

M_0 = control, M_1 = cowdung @ 6 kg plot^{-1}, M_2 = mustard oilcake @ 750g plot^{-1}, M_3 = Vermicompost @ 3 kg plot^{-1} and M_4 = Trichoderma @ 3 kg plot^{-1}

Head yield of cabbage varied significantly among different treatment combinations applied in cabbage field under the present trial. The highest healthy head yield (71.47 ton ha^{-1}) was recorded in variety Super tropic and trichoderma (V_2M_4) applied plots which was statistically similar to V_1M_3 (69.23 ton ha^{-1}) applied plots but significantly different from all other treatment combinations while the lowest head yield (50.40 ton ha^{-1}) was recorded in variety Super tropic and mustard oil cake (V_2M_2) treated plot. However, no significant difference was observed among variety Super tropic and untreated control (V_2M_0) (59.20 ton ha^{-1}) and variety Super tropic and cowdung (V_2M_1) (58.78 ton ha^{-1}) treated plots in respect of healthy head yield by weight (Table 4). In contrast, the highest infested head yield (8.11 ton ha^{-1}) was recorded in variety Super tropic plus mustard oil cake (V_2M_2) applied plots followed by variety Atlas-70 plus control plots (V_1M_0) (6.13 ton ha^{-1}). No significant differences were observed among variety Atlas -70 plus cowdung (V_1M_1) (4.22 ton ha^{-1}), variety Super tropic plus cowdung (V_2M_1) (4.21 ton ha^{-1}), variety super tropic plus control (V_2M_0) (4.10 ton ha^{-1}) and variety super tropic plus vermicompost (V_2M_3) applied plots in respect of infested head yield by weight.

Table 4. Mean healthy, infested and total yield of cabbage and percent head infestation (by weight) caused by *S. litura* and *P. brassicae* as influenced by treatment combinations

Treatment combinations	Head yield (t ha^{-1})			Percent head infestation by weight
	Healthy	Infested	Total	
V_1M_0	53.65ef	6.13b	59.78ef	10.25b
V_1M_1	57.60d	4.22cd	61.82def	6.83c
V_1M_2	56.30de	4.37bc	60.67ef	7.20c
V_1M_3	69.23a	1.30ef	70.53ab	1.84ef
V_1M_4	64.63b	2.63cde	67.26bc	3.91de
V_2M_0	59.20cd	4.10cd	63.30cde	6.48c
V_2M_1	58.78cd	4.21cd	62.99de	6.68c
V_2M_2	50.40f	8.11a	58.51f	13.86a
V_2M_3	62.13bc	3.17cd	65.30cd	4.85cd
V_2M_4	71.47a	0.67f	72.14a	0.93f
LSD	3.614	1.827	4.143	2.512

V_1=var. Atlas-70; V_2 = Super tropic;

M_0 = control, M_1 = cowdung @ 6 kg $plot^{-1}$, M_2 = mustard oilcake @ 750g $plot^{-1}$, M_3 = Vermicompost @ 3 kg $plot^{-1}$ and M_4 = Trichoderma @ 3 kg $plot^{-1}$

The total head yield was the highest (72.14 ton ha^{-1}) in variety Super tropic and trichoderma (V_2M_4) applied plots which was statistically similar to V_1M_3 (70.53 ton ha^{-1}) applied plots but significantly higher from all other treatment combinations. On the other hand the lowest total head yield (58.51 ton ha^{-1}) was recorded in variety Super tropic and mustard oil cake (V_2M_2) applied plots followed by variety Atlas-70 plus control plots (V_1M_0) (59.78 ton/ha) which was statistically similar to V_1M_2 (60.67 ton ha^{-1}) treated plots. In terms of percent head infestation by weight, the lowest percent (0.93%) was recorded in variety Super tropic plus trichoderma (V_2M_4) applied plots followed by V_1M_3 (1.84%) treated plots. The highest percent (13.86%) head infestation by weight was recorded in variety Super tropic plus mustard oil cake (V_2M_2) applied plots followed by variety Atlas-70 plus control plots (V_1M_0) (10.25%). No significant difference was observed among variet Atlas-70 plus mustard oil cake (V_1M_2) (7.20%), variety Atlas -70 plus cowdung (V_1M_1) (6.83%), variety Super tropic plus cowdung (V_2M_1) (6.68%), variety Super tropic plus control (V_2M_0) (6.48%) in respect of percent infested heads by weight (Table 4).

From the results of Table 4, it is evident that the healthy head weight and total head yield of cabbage was increased in variety Super tropic plus trichoderma (V_2M_4), and variety Atlas-70 plus vermicompost (V_1M_3) treated cabbage plots compared to control group and remaining other treatment combinations.

There are many reports highlights the improvement of crop yield by applying vermicompost. Getnet and Raja (2013) observed significant differences in the growth and development of cabbage and pest infestation level between vermicompost applied and control plants. Uptake of soluble phenolic compounds from vermicompost, by the plant tissues makes them unpalatable there by affecting the rates of reproduction and survival of pest (Edwards *et al.*, 2010a; Edwards *et al.*, 2010b). The integration of vermicompost, chemical fertilizer and biofertilizer increased the rice yield by 15.9% over the use of chemical fertilizer alone (Jeyabal and Kuppusamy, 2001). The garden pea (*Pisum sativum*) grown by using vermicompost produce higher green pods, higher green grain weight plant^{-1} (Meena *et al*., 2007). In the present study the cabbage plant grown in vermicompost applied plot received all the essential nutrients there by cabbage head weight was increased significantly compared to untreated control. From the results of the present study, it is evident that the lowest number of infested plant plot^{-1} and lowest percentage of infested leaves plant^{-1} were found in variety Atlas-70 plus varmicompost (V_1M_3), and variety Super tropic plus trichoderma (V_2M_4) applied plots. Likewise, the lowest number of infested heads plot^{-1} and lowest percentage of infested head by number and weight, respectively were recoreded for variety Super tropic plus trichoderma (V_2M_4), and variety Atlas-70 plus vermicompost (V_1M_3) applied plots. On the other hand, the highest number of healthy heads plot^{-1}, highest yield of healthy head were obtained from variety Super tropic plus trichoderma (V_2M_4) applied plots followed by variety Atlas-70 plus vermicompost (V_1M_3) applied plots. It is assumed that both varieties have the ability to withstand the infestation caused by *S. litura* and *P. brassicae* caterpillars. On the other hand, the levels of the infestation on cabbage and the yield of cabbage were also influenced by the application of organic fertilizers. Khan (2007) reported that the variety Atlas-70 showed higher susceptibility to common cutworm in respect of head infestation, it gave higher yield. Khan (2006) reported that the weight of infested and healthy heads varied insignificantly by the combined effect of variety and nitrogen fertilizer level. He obtained the highest yield from the treatment combination V_1N_1 (V_1= Variety Atlas-70; N_1 = 260kg N ha^{-1}). This might be due to addition of organic amendments that helped in suppressing various insect pests such as European corn borer (Phelan *et al*., 1996), other corn insect pests (Birader *et al*., 1998), aphids and scale insects (Huelsman *et al*., 2000) and brinjal shoot and fruit borer (Sudhakar *et al*., 1998). Several authors reported that the addition of vermicompost decreased the incidence of *S. litura*, *Helicoverpa armigera*, leaf miner (*Apoaerema modicella)*, jassids (*Empoasca kerri*), aphids (*Aphis craccivora)* and spider mites on groundnuts (Rao *et al*., 2001; Rao, 2002; 2003). Significantly resulted lower number of leaf hoppers and thrips in chilli (Ramesh, 2000) and their damage in field crops. Vermicompost substitution to soil reduced the damage to cabbage seedlings by *Myzus persicae* and cabbage white caterpillars (*P. brassicae*) (Arancon *et al.* 2005). Plant grown in inorganic fertilizers is more prone to pest attack than those grown on organic fertilizers (Yardim and Edwards, 2003). Phelan (2004) reported that plant grown with organic fertilizers usually attacked by fewer arthropod pests and can resist pest attack much better than plants received inorganic fertilizers.

Variety Super tropic of cabbage grown in trichoderma (V_2M_4), and var. Atlas-70 plus vermicompost (V_1M_3) applied plots were found to be less infested by *S. litura* and *P. brassicae* in respect of number of infested plants $plot^{-1}$, number and percent of infested leaves $plant^{-1}$ on different dates of observation. The highest healthy heads (by number), healthy head yield (by weight) and total head yield were obtained from combined effect of variety Super tropic plus trichoderma (V_2M_4) as well as variety Atlas-70 plus vermicompost (V_1M_3) applied plots while the lowest healthy heads (by number), healthy head yield (by weight) and total head yield were found from variety Super tropic plus mustard oil cake (V_2M_2) applied plots as well as variety Atlas-70 plus control plots (V_1M_0).

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DESIGN AND DEVELOPMENT OF A POWER GROUNDNUT SHELLER

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Abstract

In Bangladesh groundnut shelling is done manually which is laborious, time consuming and costly. Shelling of groundnut pod with the help of mechanical power can be a probable solution of this problem. A power groundnut sheller was designed and fabricated in Farm Machinery and Postharvest Process Engineering (FMPE) Division, Bangladesh Agricultural Research Institute (BARI), Gazipur during 2011-13. The sheller was made of Mild Steel (MS) angle bar, MS flat bar, MS rod, MS sheet, MS sieve, rubber pad etc. The shelling capacities of power groundnut sheller were 110 and 115 kg/h for Dhaka-1 and BARI Badam-8, respectively. Average breakage of groundnut kernel was 2% at 7.5% moisture content (wb). The maximum and minimum unshelled pods were about12.4% and 9.18% for Dhaka -1 and BARI Badam-8, respectively. The shelling efficiency of the power groundnut sheller for Dhaka-1 and BARI Badam-8 were 86.6 and 88.82% respectively at 11.5% moisture content (wb). Winnowing efficiency was found to be 99% in the power groundnut sheller. The use of power groundnut sheller can reduce the cost of shelling by 76% over the manual groundnut sheller. This power groundnut sheller is recommended for shelling of groundnut at farm level and small industry level in Bangladesh.

Keywords: Groundnut, Power Sheller, Design, Fabrication and Performance.

Introduction

In Bangladesh, groundnut (*Arachis hypogaea* L.) is one of the important crops which can be cultivated round the year. The total cultivated area of groundnut was 35,726 ha with the total production of 62,264 t (BBS, 2016). Groundnut is the sixth most important oilseed crop in the world (Naim *et al*., 2010). Its world-wide production is more than 10 million tons per year (Bano and Negi, 2017). Developing countries constitute 97% of the global area and 94% of the global production of this crop (FAO, 2011). Groundnut kernel is contained in the pod which usually grown underground. The pod is harvested by hand or by a hoe. Sometimes, they are harvested by country plough. Later the pod is washed, dried and shelled or stored.

Shelling of the pod is laborious, time consuming and cost involving operation. Traditionally groundnut pods are shelled through manual operation in

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Bangladesh. As a result, the shelling of groundnut pod has constituted a bottleneck to the large-scale production and processing of the crop. Shelling is one of the main constraints of groundnut production in Bangladesh. Shelling is the process of grains subtraction from pod, either by stripping, impact action and rubbing or any combination of these methods. In Bangladesh, shelling is usually done by pressing the pod between the thumb and the finger to break off the pods and release the seed. This method has low efficiency, time consuming, and has high demand of energy. In addition, the output per-man hour is very low.

Paramawati *et al.* (2006) noted that quick postharvest handling could reduce the contamination of aflatoxin on groundnut. When groundnuts are intended to be used as kernels, the peeling process needs to be conducted rapidly. They also stated that using machines in postharvest handling, processing of groundnut makes it free from aflatoxin contamination. Atiku *et al.* (2004) evaluated a groundnut sheller and reported that the moisture content, material feed and the interaction between them had significant effect on the quantity of shelled, unshelled and partially shelled pods as well as that of damaged seeds. Winnowed chaffs at 1% level of significance and winnowing efficiencies decreased while percentage of partially shelled and unshelled pods increased with increase in moisture content and feed rate. The maximum shelling and winnowing efficiencies were 80 and 79.5%, respectively at the moisture content of 5% (wb) over a feed rate of 93.6 kg/h. The Percentage of seed damage increased with increase in moisture content between 5 and 10% (wb) to a maximum value of 38% and decreased with further increase in moisture content. The broken pods are susceptible to aflatoxin contamination hence minimum breakage is desirable (Rahmianna *et al.*, 2015).

A good numbers of groundnut sheller machines are available in the market but they are large in size, costly and not suitable for domestic applications. They are suitable for industrial applications where mass production is required (Walke *et al.*, 2017). In most of the cases the postharvest manual shelling operation of groundnut is done by women in rural area. BARI has developed a manual groundnut sheller in 2010-11 (Hoque *et al.*, 2011). Power groundnut sheller was designed and fabricated executing the recommendation after development of manual sheller (Hoque *et al.*, 2011). Operation of manual groundnut sheller was generating human drudgery for which it required 5 minutes rest after every 10-15 minutes operation. The manual sheller was also unable to separate husk from the grain and also unable to clean the grain from the unshelled groundnut. At present, there is no power groundnut sheller at farm level in Bangladesh. The development of small, power sheller have a good scope for shelling of groundnut at farm level and small-scale processing level. Therefore, this study has been undertaken to develop a suitable power groundnut sheller for farm level and industrial uses. The machine was designed having the strength and stability of materials of construction in mind so as to meet up with the required standard. (Fadele and Aremu, 2016; Pradhan *et al.*, 2010). The main objectives of this study were to design and development of a power groundnut sheller and to test the performance of the sheller.

Materials and Methods

Design and fabrication

A power groundnut sheller was designed for shelling about 100 kg groundnut per hour. The engineering drawing of the sheller was drawn with SolidWorks Software 2013 (Fig. 1) and fabricated (as shown in Fig. 2) at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during 2011-2012. It was made of locally available materials. Mild Steel (MS) angle bar, MS flat bar, MS rod, MS sheet, MS shaft, rubber pad, ball-bearing, 0.37 kW electric motor and other small parts were used to fabricate the groundnut sheller. Design and drawing of various parts are necessary for fabrication of quality machine. Different parts of the power maize Sheller are described below. The detailed specification of the groundnut sheller is given in Table 1.

Table 1. Specifications of power groundnut sheller

Item	Specification
Length (mm)	1060
Width (mm)	410
Height (mm)	1010
Weight (kg)	74
Length of shelling arm (mm)	520
Concave inner length (mm)	460
Concave radius (mm)	260
Rubber pad size (mm)	220 x 60 x 37
Sieve size (mm)	10 x 24
Hopper capacity (kg)	8-10
Clearance (mm)	11-13
Mode of operation	Power operated
Source of power (kW)	0.37

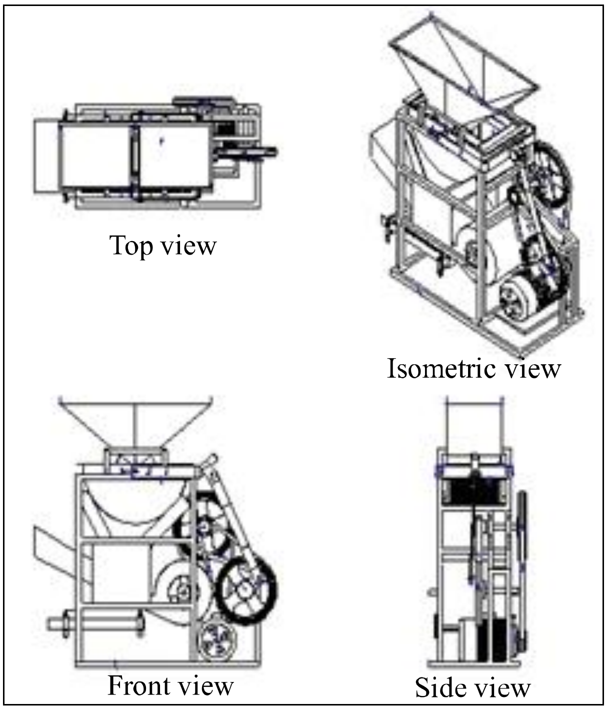

Fig. 1. Orthographic projections (OP) of power groundnut sheller.

3D isometric view Photographic view

Fig. 2. Isometric and photographic views of the power groundnut sheller.

1. **Hopper:** The hopper of the sheller was fabricated with MS sheet. The sheller hopper was designed to hold 8-10 kg groundnut. Overall dimension of the hopper is 676 x 260 x 235 mm as shown in Fig. 3.

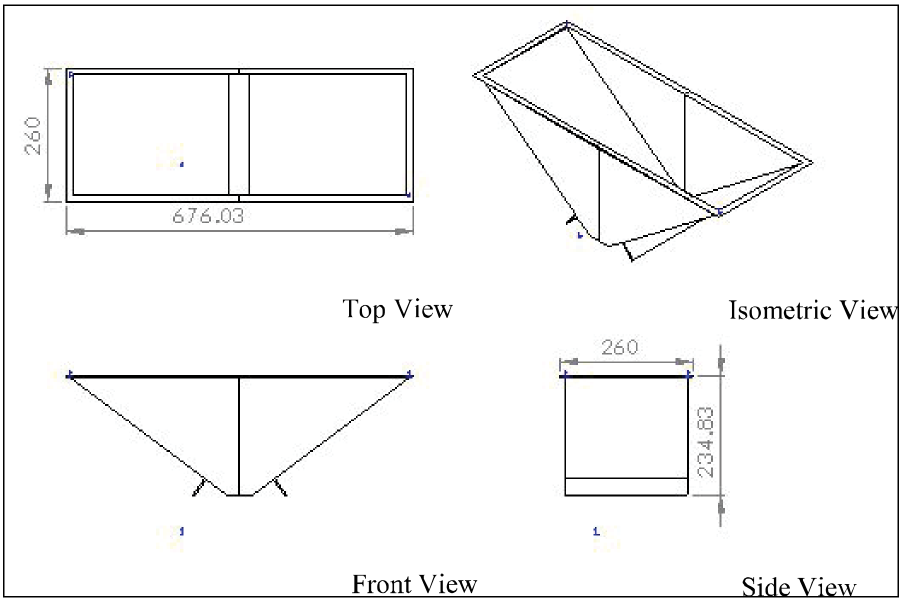

Fig.3. Orthographic projections (OP) of hopper.

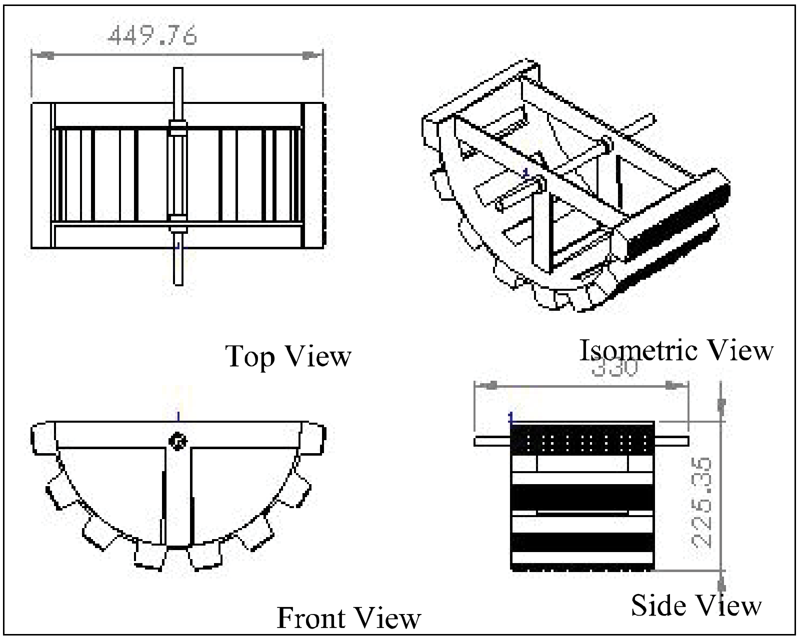

Fig.4. OP of pressing component.

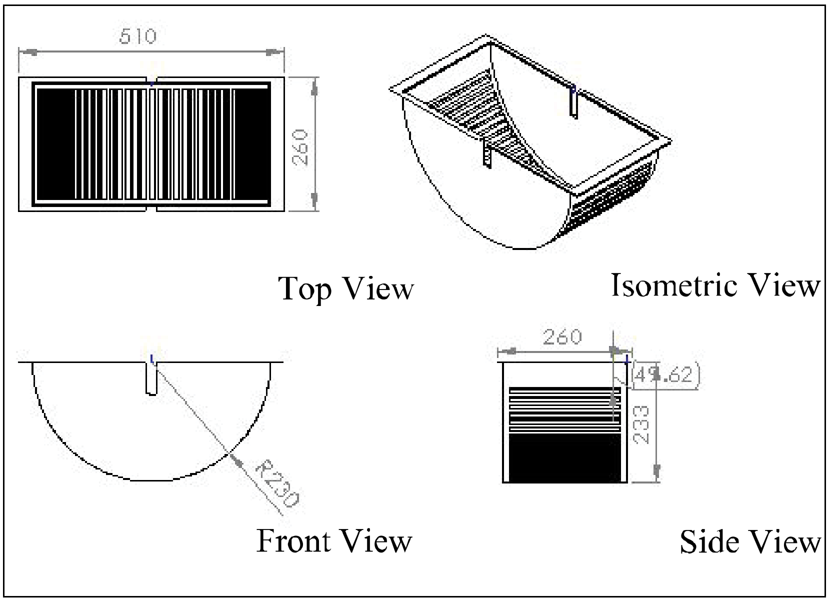

Fig.5. OP of shelling concave.

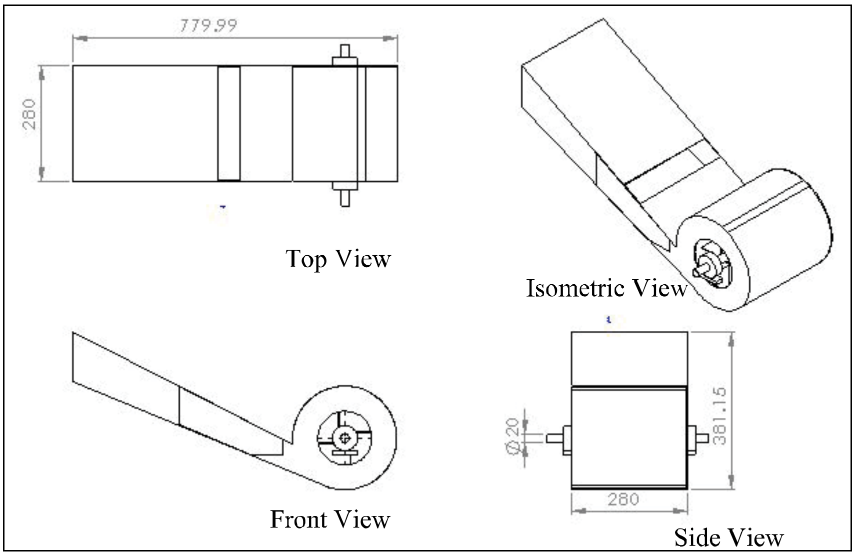

Fig.6. OP of blower.

2. **Pressing component:** A half cylinder rotating pressing component was fabricated (Fig. 4). Eight pressing arms was uniformly distributed on the peripheral diameter of the cylinder. Soft rubber sheet having zigzag bits were used for making rubber pad to press on the groundnut. This part

was reciprocating within the shelling concave powered by 0.37 kW electric motor. Clearance between rubber pad and shelling concave can be adjusted using screw.

3. **Shelling concave:** Half circular threshing concave with 230 mm radius was fabricated with MS sheet and flat bar (Fig. 5). Width of the concave was 260 mm. The flat bars were uniformly spaced at 11-13 mm interval over the peripheral diameter of the threshing cylinder. Selection of the opening depends on variety of groundnut.

4. **Blower:** A blower (Fig. 6) was fabricated with MS sheet which was operated with the same 0.37 kW electric motor. The speed of the fan was 450 rpm. Due to high velocity air flow, the shelled husk of the groundnut was separated from the kernel during falling from shelling concave.

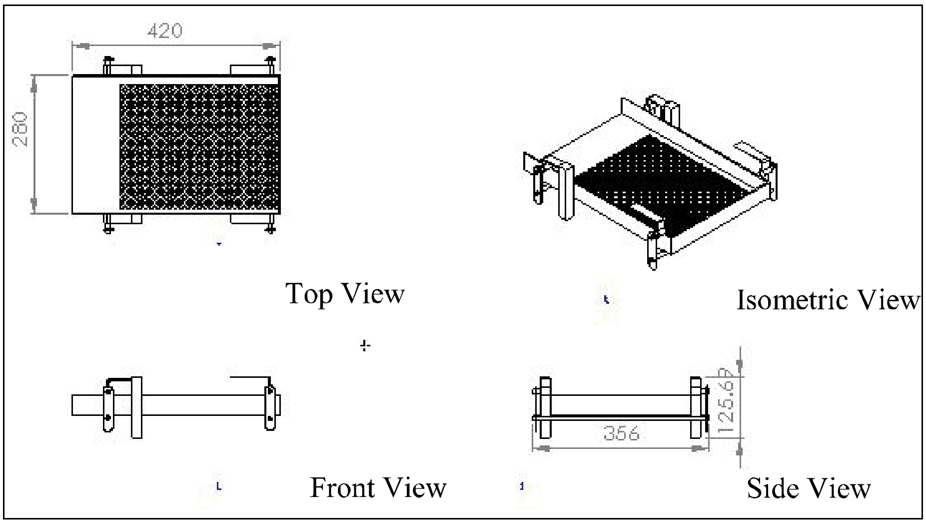

Fig.7. OP of cleaning sieve

5. **Cleaning sieve:** A sieve having 9 mm diameter hole was used for cleaning of the groundnut kernel. The sieve was operated with a cam to move in the horizontal motion. The dimension of the sieve was 420 x 280 mm as shown in Fig. 7.

Operation Principle

The machine was operated with a single phase electric motor. Unshelled groundnut pod was fed in the feeding hopper. The sheller was started with a switch after giving due connection of this sheller with domestic electric line of 220 V of AC power. With the electric motor, the movable threshing pad was operated within threshing cylinder. The groundnut was inserted in the threshing cylinder and after shelling fell into the sieving tray. The broken husk of groundnut was separated with air blow which was flown from the blower. The shelled grain was separated with the sieve by shaking with a rotating cam.

Experimental Procedure

The length, width and thickness of Dhaka-1 and BARI Badam-8 variety were measured with slide calipers of 0.02 mm accuracy. Randomly selected 50 samples from each variety were taken for the measurement. The length, width and thickness of whole groundnut and kernel were measured. Performance evaluation of the groundnut sheller was done with replicated experiments during 2012-13 in the laboratory of Farm Machinery and Postharvest Process Engineering Division, BARI, Gazipur. The performance of the power groundnut sheller and manual groundnut sheller (Fig. 8) was tested with Dhaka-1 and BARI Badam-8 collected from local market of Gazipur Sadar.

Fig.8. A photographic view of the manual groundnut sheller.

Moisture content of the groundnut was measured by oven dry method drying for 72 hours at 103ºC (Koushkaki *et al.* 2017). Initial moisture content of the groundnut was around 7% which was reduced by oven and then packet in poly bags. The moisture content of the groundnut during testing was maintained at around 7.50% (wb) since Kushwah *et al.* (2016) and Oluwole *et al.* (2007) found better dehulling efficiency and crackability of groundnut with similar moisture content. Sample size of each batch was 10 kg. The testing was replicated five times for each variety. The weight of shelled grain, weight of unshelled grain, weight of cracked grain, frequency of oscillation of the shelling pad, time of operation and moisture content of grain were recorded during testing of the groundnut sheller. Capacity, breakage and efficiency of the groundnut sheller were calculated. The power groundnut sheller was then tested at two upazilla (Nagarbari and Sujanagar) of Pabna district. The machine was evaluated with Dhaka-1 and BARI Badam-8 similarly. The following parameters were calculated using the standard formula as given below

i) Shelling capacity, $S_c = \frac{60W_2}{T}$

Where,

S_c = Shelling capacity, kg/h

W_s = Weight of shelled grain, kg

T = Operating time, minutes

ii) Breakage percentage, Br = $\frac{W_b}{W_s} \times 100$

Where,

B_r = Breakage percentage

W_b = Weight of broken grain, kg

iii) Unshelled grain, $U_{ng} = \frac{W_u}{W_g} \times 100$

Where,

U_{ng} = Unshelled grain, %

W_u = Weight of unshelled groundnut, kg

W_g = Weight of total feed, kg

iv) Shelling efficiency, $W_s = 100 - B_r - U_{ng}$

v) Winnowing efficiency, $E_s = \frac{W_c}{W_c - W_h}$

Where,

E_c = Winnowing efficiency, %

W_c = Weight of cleaned groundnut, kg

W_h = Weight of husk mixed with cleaned kernel, kg

vi) Separation efficiency, $E_s = \dfrac{W_f}{W_t - W_u}$

Where,

W_f = Weight of the fresh grain in pan, kg

W_t = Weight of total grain in pan, kg

W_u = Weight of unshelled grain in pan, kg

Results and Discussion

The length, width and thickness of pod of Dhaka-1 variety were 20.00±2.72, 11.20±1.24, 10.46±0.99 mm, respectively (Fig. 9). The pod length, width and thickness of BARI Badam-8 were 23.98±3.20, 12.44±1.09, 11.88±1.20 mm, respectively (Fig. 10). Kernel length, width and thickness of Dhaka-1 and BARI Badam-1 were 13.27±1.55, 8.59±1.02, 8.18±0.99 mm and 11.24±1.13, 8.02±1.09, 7.12±0.83 mm, respectively. Based on pod and kernel size, the opening of the threshing cylinder sieve was selected as 11mm for which most of the pod of the both variety were threshed with minimum breakage of grain.

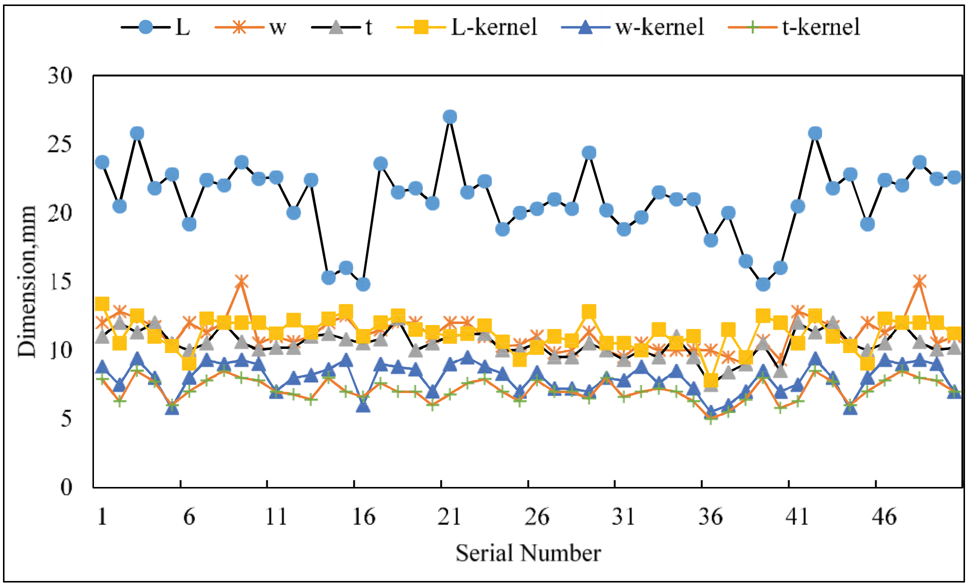

Fig.9. Length (L), width (W) and thickness (T) of some sample of Dhaka-1 groundnut.

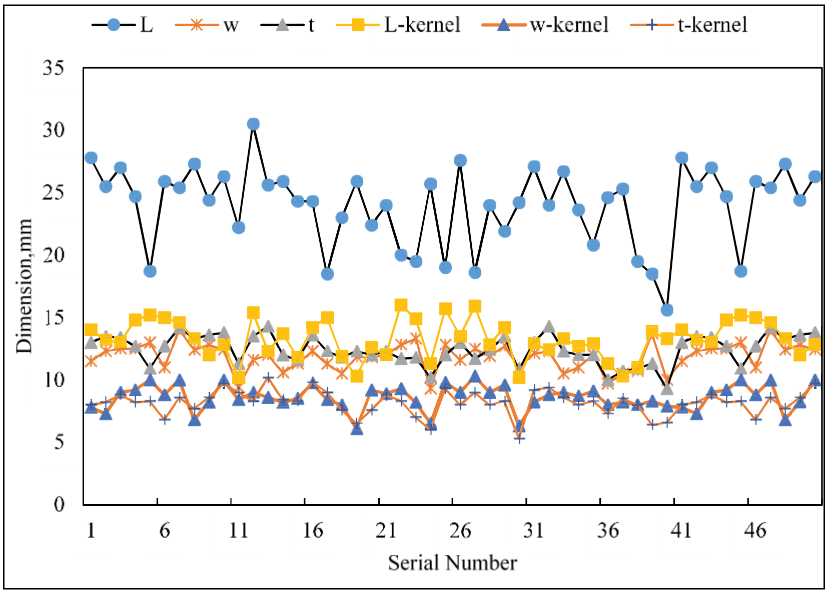

Fig.10. Length (L), width (W) and thickness (T) of some sample of BARI Badam-8 groundnut.

The developed groundnut sheller was capable to work continuously and facilitate winnowing. Moreover, this can separate unshelled groundnut from the shelled groundnut using same with simple 0.37 kW electric motor. Comparative performance of the power groundnut sheller and manual sheller for Dhaka-1 and BARI Badam-8 is shown in Table 2. It was observed from Table 2 that the shelling capacities of power groundnut sheller were 110 and 114.72 kg/h for Dhaka-1 and BARI Badam-8, respectively whereas 84.50 and 80 kg/h for manual sheller. Similar and even less capacity was found by Atiku *et al.* (2004). The shelling capacity of the manual sheller was lower than that of power groundnut sheller due to less stroke number per minute. Higher breakage percentages of the manual sheller were observed for both Dhaka-1 and BARI Badam-8 than those of power sheller. It might be due to longer stroke length in manual sheller. Average breakage of groundnut pod was found to be 2% at 11.5% moisture content (wb) in the lab test. The maximum and minimum unshelled percentage in power sheller was found to be12.4% for Dhaka-1 and 9.18% for BARI Badam-8, respectively. Unshelled nuts were found due to less diameters of groundnut than the opening of the shelling sieve (10 mm). Unshelled percentage of the tested power sheller was found more for Dhaka-1 since the diameter of the grain was less than opening of the shelling concave. This unshelling could be reduced by changing shelling concave with less opening. It was also found that the shelling efficiency of the power groundnut sheller for Dhaka-1 and BARI Badam- 8 were 86.6 and 88.82%, respectively at 11.5% moisture content (wb) which is similar with Ugwuoke *et al.* (2014). Winnowing efficiency of the power groundnut sheller was found to be 99% which was acceptable as reported by (Atiku *et al.*, 2004). Separation of fresh shelled kernel from unshelled groundnut was found from power groundnut sheller and separation efficiency was 97 and 98% for Dhaka-1 and BARI Badam-8 variety, respectively.

Table 2. Comparative performance of the power groundnut sheller and manual sheller for Dhaka-1 and BARI Badam-8 tested in the laboratory of FMPE Division, BARI, Gazipur

Parameters	Dhaka-1		BARI Badam-8	
	Power	Manual	Power	Manual
Moisture content (wb, %)	7.50	7.49	7.51	7.52
Weight of sample (kg)	10	10	10	10
Time required, minutes	5.5	7.1	5.23	7.5
Stroke (no/minutes)	100	50	98	43
Shelling capacity (kg/h)	110	84.50	114.72	80
Broken grain (%)	1.00	2.00	2.00	2.00
Unshelled grain (%)	12.40	13.00	9.18	10.85
Shelling efficiency (%)	86.6	85	88.82	87.15
Winnowing efficiency (%)	99	0	99	0
Separation efficiency (%)	97	0	98	0

Performance of power groundnut sheller at Pabna is given in Table 3. Shelling capacities of the groundnut sheller were found to be 124 and 128 kg/h at Nagarbari and Sujanagar of Pabna district, respectively. Broken grain (4 to 5%) and unshelled grain (13 to 15%) were more in the field test than those of the laboratory test due to uneven size, non-graded sample and high moisture content of groundnut samples. Thus, the shelling efficiencies were 83% and 80.0% in Nagarbari and Sujanagar, respectively. Winnowing efficiency was found 100% in both the locations. However, farmers showed their interest in power operated groundnut sheller for confectionary purposes.

Table 3. Performance of power groundnut sheller for shelling Dhaka-1 groundnut in Pabna

Parameters	Nagarbari	Sujanagar
Weight of sample (kg)	85	120
Moisture content, (wb, %)	9.50	9.75
Time required (minutes)	41	56
Stroke (no/minutes)	100	100
Shelling capacity (kg/h)	124	128
Broken grain (%)	04	05
Unshelled grain (%)	13	15
Shelling efficiency (%)	83	80
Winnowing efficiency (%)	100	100

Financial analysis

Cost analysis was done after the satisfactory performance evaluation of the power groundnut sheller. Different costs of the power and manual groundnut shellers are shown in Table 4. The price of the power and manual groundnut sheller was Tk. 25000 and Tk. 7500, respectively. The cost of the groundnut shelling was 590 Tk/t for power groundnut. On the other hand, shelling, cost by manual groundnut sheller was 2450 Tk/t. Therefore, the use of power groundnut sheller would reduce the cost of shelling by 76% over the manual groundnut sheller.

Table 4. Different costs of the power and manual groundnut shellers

Sl. No.	Cost factors and items	Costs	
		Power	Manual
1	Price of the groundnut sheller (Tk/unit)	25000	7500
2	Life of the groundnut sheller (Years)	5	5
3	Annual use (Hours)	240	240
4	Annual fixed cost		
	a) Depreciation (Tk/yr)	4500	1350
	b) Interest (12%) (Tk/yr)	1375	412.5
	c) Repair, maintenance and shelter (Tk/yr)	875	262.5
	Total fixed cost (Tk/yr)	6750	2025
	Total fixed cost (Tk/h)	28.13	8.44
5	Operating cost		
	a) Electricity (Tk/h)	2.16	
	b) Labour for shelling (Tk/h)	37.50	37.50
	c) labour for winnowing (Tk/h)	0	37.50
	d) labour for separation of unshelled pods (Tk/h)	0	112.50
	Total operating cost (Tk/h)	39.66	187.50
6	Total cost (Tk/h)	67.79	195.94
8	Shelling cost (Tk/t)	590	2450

Conclusion

The power groundnut sheller was operated without any trouble of the machine. The shelling capacities of power groundnut sheller were 110 and 115 kg/h for Dhaka-1 and BARI Badam-8, respectively. The maximum breakage of groundnut was found to be 2% at 11.5% moisture content (wb) in laboratory test at FMPE Division, BARI, Gazipur. The maximum and minimum unshelled percentage in power sheller was found to be 12.4% for Dhaka-1 and 9.18% for BARI Badam-8, respectively. The shelling efficiency of the power groundnut sheller for Dhaka-1 and BARI Badam-8 were 86.6 and 88.82%, respectively at 7.5% moisture content (wb). Winnowing efficiency was found to be 99% in the power groundnut sheller. Shelling capacities of the groundnut sheller were found to be 124 and 128 kg/h at Nagarbari and Sujanagar of Pabna district, respectively. Broken grain (4 to 5%) and unshelled grain (13 to 15%) were more in the field test than those of the laboratory test due to uneven size and high moisture content of groundnut samples. The performance of the groundnut could be improved by feeding uniform sized pods. The use of power groundnut sheller can reduce the cost of shelling by 76% over the manual groundnut sheller.

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FUNCTIONAL AND GROUP ABUNDANCE OF INSECTS ON EGGPLANT

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Abstract

The eggplants (*Solanum melongena* L.) were cultivated in the field to investigate the abundance and diversity of insects. In total 488 insects were collected from the eggplant field during May to August 2016, which belonged to 20 species in 21 families and 10 orders. Among the taxonomic orders, Hemiptera was the most dominant followed by Coleoptera, Hymenoptera, and Diptera. The order Thysanoptera revealed the lowest abundance. The abundance, richness and diversity of pest, predator, pollinator and other categories of insects differed significantly and the pest revealed the highest abundance and richness compared to others. In total 9 species of insects belonged to 7 families of 4 orders were found as pest and their abundance varied from 0.1±0.1 to 4.6±0.9 /30 sweeps. In total 8 species of insects belonged to 8 families of 7 orders were found as predator and their abundance varied from 0.3±0.1 to 2.0±0.3/30 sweeps. Among the predator insects, lady bird beetle showed the highest abundance. In eggplant field, insects were highest and lowest abundant at 11.00 and 13.00 h of the day, respectively.

Keywords: Abundance, richness, diversity, pest, predator, pollinator, *Solanum melongena.*

Introduction

Eggplant is one of the widely grown Solanaceous vegetables incredibly contains various constituents belonging to the category of the flavenoid, alkaloid, oleic, palmitic and linoleic acids (Yadav *et al.*, 2010). It is extensively cultivated in Bangladesh throughout the year. But the major constraint to sustainable productivity is the high incidence of insect pests.

Eggplants are infested by a number of pests such as brinjal shoot and fruit borer, aphid, jassid, whitefly, epilachna beetle, leaf hopper etc. Among them brinjal shoot and fruit borer is the most devastating pest in many parts of the world which may cause more than 60% loss of yield (Kapoor, 1993). Nayer *et al.* (1995) reported 53 species of insects pests cause damage to eggplant in India. Bhadauria *et al*. (1999) reported that shoot and fruit borer, jassid, aphids, leaf roller and stem borer were the most common pest of eggplant in Madhay Pradesh, India.

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Predator species play significant role in reducing pest population and they are free living organisms in both their immature and adult stages. About 167 families of 14 orders contain predatory insects. However, the orders Coleoptera, Neuroptera, Hymenoptera, Diptera and Hemiptera provide a very large number of individuals which frequently control the pest population. The lady bird beetles are well known beneficial arthropods found in many habitats (Ali and Rizvi, 2009). The adults and larvae of lady bird beetles found to be an effective predatory fauna in eggplant ecosystem (Ali *et al.,* 2009). El-Shafie (2001) reported that Coleoptera had occupied 60 % of the total plant dwelling predators in brinjal agroecosystem in Sudan.

Different categories or species of insects in certain habitat interact among them for food and shelter, and eventually influence on their abundance, richness and diversity. Vergara and Badano (2009) reported that 12 species of insects are found as pollinators in eggplant field and they are linked as the functional component of the eggplant ecosystem. Functional diversity is an important component of diversity which is a common approach to test the effects of diversity on ecosystem. In the present study insect pest, predator and pollinator abundance and diversity were investigated to find out their functional group status in eggplant ecosystem.

Materials and Method

The study was conducted during March to August 2016 in the Field Laboratory of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh.

Study location and climatic conditions: The study site is located at 25°25′ North latitude and 89°5′ East longitude, which is in the middle of Bangladesh. The study area has a subtropical *climate having* mean maximum and minimum temperatures 36.0 ºC and 12.7 ºC, respectively, and relative humidity and rainfall are 65.8% and 237.6 cm, respectively (Amin *et al.*, 2015).

Collection of eggplant seeds and cultivation of crop: Seeds of eggplant namely BARI begun 8 were collected from the Horticulture Research Center, Bangladesh Agricultural University, Gazipur, Bangladesh and were sown on 2 March 2016 in poly bags. For transplanting seedlings, plots having 4.0 m × 4.0 m followed by randomized complete block design were used. The spacing between block to block and plot to plot were 60 cm × 60 cm. Eggplant seedlings were transplanted 60 cm apart on 21 March 2016, in rows. The distance from row to row was 60 cm. Each plot has five rows and each row contained 5 plants. Fertilizers were applied according to Fertilizer Recommendation Guide (N- 78 kg, P- 36 kg, K- 66 kg, S- 17 kg per hectare). Intercultural operations such as irrigation and weeding were done whenever necessary.

Insect collection and identification: Free-living insects were collected from flower initiation to fruit maturation stage using a 30 cm diameter sweep net having 1.5 mm mesh, and attached with a 2 m long rod. Every week sweeping was done in between 09.00 to 11.00 am, and each sample was consisted of 30 sweeps covering an area from ground level to the top of the trees. The collected insects were brought to the Entomology Laboratory of BSMRAU for identification and counting. They were killed by storage in a freezer for a few hours, mounted on points, dried and morphotyped. Insects were identified to species or genus level and also was separated as pest, predator, pollinator and other categories. Identified specimens were deposited in the insect museum of BSMRAU.

Observation of insect abundance and foraging behavior of pollinators: Peak foraging time of the frequently abundant insect species was observed. To find out peak foraging time, weekly collection was conducted at 7.0 h, 9.0 h, 11.0 h and 13.0 h in a day, and number of insects per sample were counted. The insects collected at 11.0 am were grouped as pest, predator, pollinator and other category. Landing duration of the pollinators on eggplant flowers were measured using a stop watch. Observations were done in between 10:00 to 11:30 am and data were recorded 7 times for each species.

Statistical analysis: One way analysis of variance (ANOVA) followed by Tukey HSD posthoc test was employed for analyzing richness (total number of species), abundance (total number of individuals), diversity (Simpson Index of Diversity), abundance of pest and predator, and distribution of the insects. Diversity was calculated following the formula of Simpson (1949). Chi statistics was applied to find out significant difference in percent of insects among various orders. All the analyses were performed using IBM SPSS 21.0. (IBM SPSS statistics 21, Georgia, USA).

Results and Discussion

In the present study, in total 488 insects were collected from the eggplant field. The collected insects belonged to 20 species of 21 families and 10 orders. The percent of insects in different taxonomic orders varied from 0.4 to 33.6 (Fig. 1). Among the taxonomic orders, Hemiptera(33.6) was the most dominant followed by Coleoptera (28.3%), Hymenoptera (12.7%), Diptera (8.8%), Lepidoptera (7.6%), Odonata (2.6%) and Dermaptera (2.5%). Other orders namely Orthoptera (2%), Dictyoptera (1.2%) and Thysanoptera (0.4%) showed very lower percentages of abundance.

Table 1 showed that the abundance, richness, and diversity of pest, predator, pollinator and other categories of insects varied from 5.2±0.6 to 14.4±1.1, 1.5±0.1 to 5.0±0.2, 0.2±0.03 to 5.0±0.2 /30 sweeps, respectively and the results differed significantly (abundance: $F_{3,80}$=39.1, P < 0.001; richness: $F_{3,80}$=43.3, P < 0.001; diversity: $F_{3,80}$= 3.9, P<0.01). The abundance and richness of insect pest was higher compared to predator, pollinator and other categories. The insects in other categories revealed the lowest abundance, richness but showed highest diversity.

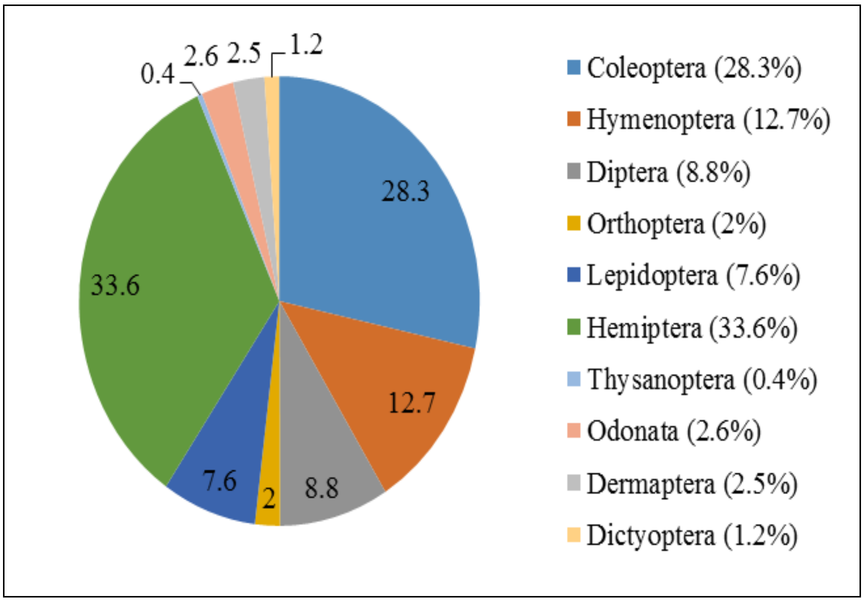

Fig. 1. Insects (%) belong to different taxonomic orders found in the eggplant field

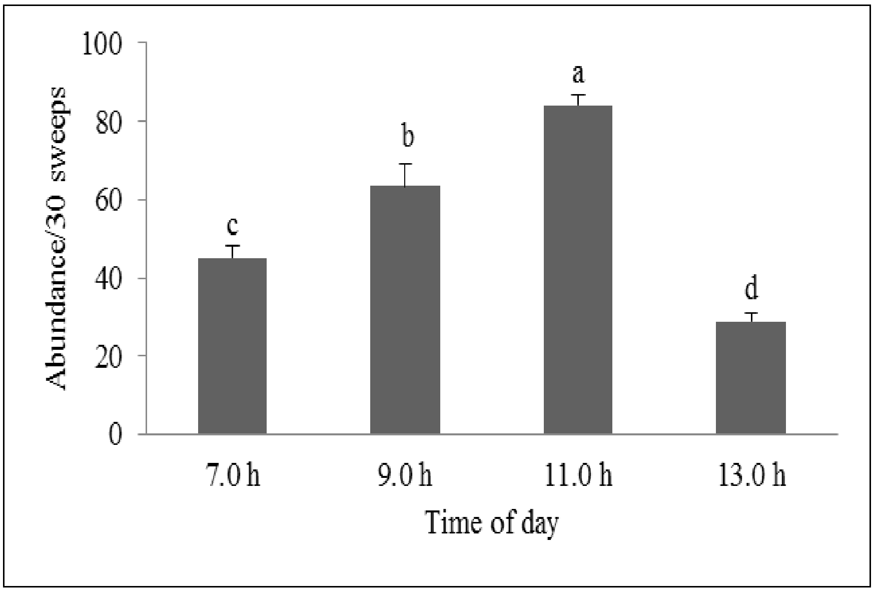

Fig. 2. Distribution of insect counts (mean ± SE) in eggplant field during full blooming period. Bars with common letter(s) are not significantly different by Tukey HSD posthoc statistic at P < 0.05.

Klein *et al.* (2007) reported the abundance, richness and diversity of insect pest, predator and pollinators and found significant variations. Insect species in eggplant field in different climatic and habitat conditions varied significantly. Vergara and Badano (2008) reported the richness of pollinator species in eggplant field and found the highest richness in rustic shaded site followed by commercial poly culture sites, and the lowest species richness was recorded in the specialized shaded plantations

Table 1. Average abundance, richness and diversity of insects in eggplant field

	Insect Pests	Predators	Pollinators	Others
Abundance	14.4±1.1 a	5.8±0.6 b	5.4±0.5 b	5.2±0.6b
Richness	5.0±0.2 a	3.4±0.3 b	3.7±0.3 b	1.5±0.1 c
Diversity	0.4±0.2 ab	0.2±0.04b	0.2±0.03 b	5.0±0.2 a

Data expressed as mean ± SE. Means per insect group are taken from 30 sweeps per total collection. Means within a row followed by same letter(s) are not significantly different by Tukey HSD posthoc statistic at < 0.05.

Table 2. Insect pests along with their abundance in eggplant field

Pest	Taxonomic profile	Abundance
Epilachna beetle	*Epilachna dodecastigma* (Coleoptera:Coccinellidae)	4.6±0.9 a
Jassid	*Amrasca biguttula* (Hemiptera:Cicadellidae)	4.6±0.4 a
White fly	*Bemisia tabaci* (Hemiptera:Aleurodidae)	2.6±0.2 b
Shoot and fruit borer	*Leucinodes orbonalis* (Lepidoptera: Pyralidae)	1.0±0.2 bc
Rice bug	*Leptocorisa acuta* (Hemiptera:Coriedae)	0.2±0.1c
Aphid	*Aphis gossypii* (Hemiptera: Aphididae)	0.9±0.2c
Thrips	*Thrips hawaiiensis* (Thysanoptera: Thripidae)	0.1±0.1 c
Leaf hopper	*Amrasca devastans* (Hemiptera: Cicadellidae)	0.3±0.1 c

Data expressed as mean ± SE. Mean of each pest was taken from 30 sweeps per total collection. Means in the column followed by same letter(s) are not significantly different by Tukey HSD posthoc statistic at < 0.05.

In total, 9 species of insects belonged to 7 families of 4 orders (Coleoptera, Lepidoptera, Hemiptera and Thysanoptera) were found as pest (Table 2). Their abundance varied from 0.1±0.1 to 4.6±0.9 /30 sweeps and the results differed significantly ($F_{7, 160} = 24.2$, $p < 0.001$). Among the pest insects, epilachna beetle showed the highest abundance while thrips showed the lowest abundance. In India, 53 species of insects were reported as pest of eggplant of which shoot and fruit borer was the most destructive (Nayer *et al.*, 1995). Aganon *et al*. (1997) reported that shoot and fruit borer, jassid (leaf hopper) and thrips (*Thrips tabaci*) were the common pests of brinjal in the field. Several researchers reported the severity of attack of jassid and white fly in brinjal (Bhadauria *et al.*, 1999, Alam *et al*., 2004).

Table 3. Insect predators along with their abundance in eggplant field

Predator	Taxonomic profile	Abundance
Preying mantid	*Mantis regiosa* (Dictyoptera:Mantidae)	0.3±0.1 c
Dragon fly	*Aeshna verticalis* (Odonata:Aeshnidae)	0. 3±0.1 c
Short horn grasshopper	*Oxya velox*(Orthoptera: Acrididae)	0.5±0.1 c
Ichneumonid wasp	*Megarhyssa macrurus*(Hymenoptera :Ichneumonidae)	0.4±0.2c
Ant	*Formica rubra* (Hymenoptera:Formicidae)	1.3±0.2 ab
Lady bird beetle	*Coccinella septempunctata* (Coleoptera:Coccinellidae)	2.0±0.3 a
	Coccinella transversalis (Coleoptera:Coccinellidae)	-
Earwig	*Forficula auricularia*(Dermaptera :Forficulidae)	0.6±0.1bc
Damselfly	*Coenagrion puella* (Odonata :Coenagrionidae)	0.3±0.1c

Data expressed as mean ± SE. Mean of each pest was taken from 30 sweeps per total collection. Means in the column followed by same letter(s) are not significantly different by Tukey HSD posthoc statistic at < 0.05.

In total, 8 species of insects belonged to 8 families of 7 orders (Dictyoptera, Odonata, Orthoptera, Hymenoptera, Coleoptera, Dermaptera, Odonata) were found as predator (Table 3). Their abundance varied from 0.3±0.1 to 2.0±0.3/30 sweeps and the results differed significantly ($F_{7, 160} = 12.1$, $p < 0.001$). Among the predator insects, lady bird beetle showed the highest abundance, while preying mantid, dragon fly, damselfly, short horned grasshopper and ichneumonid wasp showed the lowest and statistically similar abundance. Latif *et al*. (2009) reported that predaceous arthropods in brinjal field were grouped in 10 families under 7 taxonomic orders of which Coleoptera was the most important which occupied 42.4% of the total predators under 3 different families such as Coccinellidae, Carabidae and Staphylinidae. The plant dwelling insects in the brinjal field of Bangladesh other than Coleoptera were Hymenoptera, Hemiptera, Neuroptera, Diptera and Dictyoptera which contributed 27.3% of the total arthropods (Latif *et al.*, 2009).

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SOIL SALINITY MANAGEMENT FOR INCREASING POTATO YIELD IN THE COASTAL AREA OF SOUTHERN BANGLADESH

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Abstract

The study was conducted at farmers' field of Charfashion upazila in Bhola district under AEZ-18 during the *Rabi* season of 2015-2016 and 2016-2017 to find out suitable soil salinity management practice(s) for maximizing potato yield as well as farmers' income. Two planting systems viz. raised bed and flat land, and four management systems with fertilizers and mulching were considered in a factorial experiment. The rate of increase in soil salinity in raised beds was significantly lower than that of flat land. On an average, raised bed planting produced 13.04% higher tuber yield than flat land planting. The combination of raised bed + recommended fertilizer (RF) with cowdung @ 5 t ha^{-1} as IPNS+ straw mulch (@ 3.5 t ha^{-1}) produced the highest tuber yield in both the years (average 21.66 t ha^{-1}) and it was 75.10% higher than flat planting system with no mulch. This treatment combination also provided the highest average gross margin (Tk. 115945 ha^{-1}) and BCR (2.26). Besides, combination of raised bed + RF+25% K+ straw mulch provided average tuber yield (20.91 t ha^{-1}), gross margin (Tk. 110969 ha^{-1}) and BCR (2.25), which were very close to above treatment combination. The lowest average potato yield (12.51 t ha^{-1}), gross margin (Tk. 39835 ha^{-1}) and BCR (1.50) were obtained from combination of flat land planting + RF +no mulching. So, combination of raised bed + mulching+ RF along with IPNS basis cowdung @ 5 tha^{-1} or 25% extra K can help minimize soil salinity and produce significantly higher potato yield in the coastal areas.

Keywords: Coastal area, soil salinity, raised bed, flat land, mulching, potato

Introduction

Soil salinity is one of the major environmental hazards to global agriculture (Zhang *et al*., 2007).The saline area in Bangladesh is about 0.83 million hectares and presently estimated that it has increased up to 1.2 m ha (Islam *et al*., 2008).The coastal area of the country constitutes about 20% of the country of which about 53% are affected by different degrees of salinity (Haque, 2006). Soil salinity in Bangladesh is a seasonal problem that affects crop production severely in the saline belt during *rabi* season whereas in *Kharif-II* season soil salinity reaches about neutral and does not affect crop production (Khan *et al*.,

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2008). Soil salinity affects crop growth, yield and quality (Razzouk and Whittington, 1991; Dong *et al*., 2008). The salinity causes unfavorable environment and hydrological situation restricting the normal crop production throughout the year (Amin *et al*., 2008) and very few crops/cultivars could survive or produce economic yield in severe soil salinity environment (Shrivastava and Kumar, 2015). The severity of soil salinity problem in the coastal areas of Bangladesh increases with the desiccation of the soil (Haque, 2006). It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield loss (Rasel *et al*., 2013). The dominant crop grown in the saline areas is local T.Aman rice (Var. Sadamota, Rajashail, Kajalshail, Lalmota, etc.) and yield is comparatively lower than high yielding modern varieties. The main cropping pattern practiced in coastal areas is Fallow-Fallow-T.Aman rice. Late harvest of T.Aman rice (up to the first week of January) and delay receding of tidal flood water are the main causes of fallow land in this region. That is why about 40-45% and 30-35% of lands remain fallow in *rabi* and *kharif-1* seasons, respectively in southern region (Rafiquzzaman *et al*., 2010). The increasing pressure of growing population in the country demand more food. That is why it has become imperative to explore the possibilities of increasing productivity in saline areas through proper management practices.

Raised bed planting for row-spaced crops in many parts of the world is gaining importance (Sayre, 2007). It can save 25–30% irrigation water, increasing water use efficiency (Hassan *et al*., 2005; Malik *et al*., 2005; Choudhary *et al*., 2008; Ahmad *et al*., 2009) and providing better opportunities to leach salts from the furrows (Bakker *et al*., 2010). Under saline conditions, increased salt accumulation on top of the bed has also been reported by Choudhary *et al*. (2008) due to the upward movement of salts through capillary rise in response to evaporation gradients. Mulching is one the effective and promising management practices to reduce dry season salinity and conserve moisture in plant root zone, as it can decrease soil water evaporation, increase infiltration and regulate soil water and salt movement (Huang *et al*., 2001; Deng *et al*., 2003; Qiao *et al*., 2006; Devkota *et al*., 2015).It can reduce up to 30% salinity increase as compared to normal flat system with no mulch (BARI, 2008). Besides, potash fertilizer has an added advantage for controlling the soil salinity. It reduces sodium uptake by plants and of course increases potassium uptake. Thus potassium fertilization protects crops from harmful effects of sodium (Haque, 2006). Potato is mainly used as a vegetable in Bangladesh and grown all over the country. Bhola district is an important area for potato production among the coastal areas of Bangladesh. About 5660 ha land in Bhola district was under potato cultivation in 2014-2015, of which a major portion was under saline environment (DAE, 2014). As potato is cultivated in *Rabi* season, it provides very poor yields in saline coastal areas compared to its potential as soil salinity reaches to maximum during *rabi* season. Cultivation of potato in *Rabi* season with improved management practices including mulching could increase tuber yield significantly compared to traditional method under saline ecosystem. Thus the experiment was undertaken to find out improved management practices to reduce the adverse effect of soil salinity for maximizing yield of potato as well as farmers' income in coastal areas of Bhola district.

Materials and Methods

The experiment was conducted at farmers' field of Charfashion upazila under Bhola district under AEZ-18 in the *rabi* season of 2015-2016 and 2016-2017. The land type was medium highland with soil salinity 2.43 and 2.16 dSm^{-1} at the time of planting in 2015-2016 and 2016-2017, respectively. The treatments comprise of planting method P_1: Raised bed and P_2: Flat land and four management practices, viz., M_1: recommended fertilizer (RF) for potato production, M_2: RF + straw mulch (3.5 t ha^{-1}), M_3: RF + 25% K + straw mulch (3.5 t ha^{-1}) and M_4: RF with cowdung @ 5 t ha^{-1}in IPNS + straw mulch (3.5 t ha^{-1}). Potato variety was BARI Alu-7 (Diamant) and sowing date was 30 November 2015 and 05 December 2016, respectively. The experiment was laid out in factorial randomized complete block (RCB) design with six replications. Unit plot size was 4 m × 5 m. Recommended fertilizers (RF) for potato was 115-30-125-19-3.5-1.7 N-P-K-S-Zn-B $kgha^{-1}$ (FRG, 2012). Raised beds were made at the time of potato planting and beds were covered with rice straw (3.5 t ha^{-1}) mulch just after planting. Whole tuber of 'A' grade was planted at a spacing of 60 cm × 25 cm. Hand weeding was done twice at 20 and 45 days after planting. Furadan (Carbofuran) 5G @ 20 kg ha^{-1} was applied at the time of final land preparation for controlling cut warm. Single light irrigation was done at 38 days after planting. Secure @ 2g Lit^{-1} water was sprayed twice at 52 and 63 days after planting as a preventive measure against late blight infestation due to foggy weather. Soil salinity of the experimental plots was recorded at 15 days interval from planting to harvest of potato. It started on 30 November and ended on 01 March both the years. Soil samples were also collected before planting and after harvest of potato to determine the nutrient status of the experimental plots' soil. Harvesting was done on 20 March 2016 and 23 March 2017. Yield and yield components data of potato and cost of all inputs and operations were recorded. Economic performance was also calculated. Data were analyzed following the computer program MSTAT-C (Freed, 1985).

Results and Discussion

Effect of planting systems

Tubers $plant^{-1}$ and tuber yield differed significantly due to different planting system in both the years (Table 1). Though all yield contributing characters did not differ significantly, their cumulative effect contributed higher tuber yield in raised bed system than normal flat system potato planting. The highest tuber yield of 18.28 t ha^{-1} in 2015-2016 and 19.19 t ha^{-1} in 2016-2017 was found in raised bed planting system. Raised bed and at the same time mulching reduced soil salinity considerably (BARI, 2008; Bashar *et al*., 2014). Similar results were also reported by Muromota *et al*. (1991). The lowest tuber yield (15.98 t/ha and 17.16 t/ha, respectively in 2015-16 and 2016-17) was obtained from flat land planting because of lower number of tubers per plant and lower number of plants per sq. meter. Higher level of soil salinity in flat land system compared to raise bed system might have affected plant growth and yield of potato. On an average, raised bed increased potato yield by 13.04% compared to flat system.

Table 1. Tuber yield and yield attributes of potato under different planting systems in saline soil at Charfashion, Bhola during 2015-2016 and 2016-2017

Treatment	Plant height (cm)	Plants m^{-2} (No.)	Tubers plant^{-1} (No.)	Individual tuber wt. (g)	Tuber yield (t ha^{-1})
2015-2016					
Raised bed (P_1)	40.95	6.91	5.92	45.15	18.28
Flat land (P_2)	39.9	6.72	5.31	46.37	15.98
T-test	NS	NS	3.86	NS	4.39
2016-2017					
Raised bed (P_1)	42.9	7.01	6.00	45.22	19.19
Flat land (P_2)	42.3	6.65	5.60	47.13	17.16
T-test	NS	NS	2.82	NS	5.14
Mean					
Raised bed (P_1)	41.9	6.96	5.96	45.19	18.73
Flat land (P_2)	41.1	6.69	5.46	46.75	16.57

P_1: Raised bed, P_2: Flat system, NS= non-significant

Effect of management practices

Management practices i.e. fertilizers and mulching influenced plant height, individual tuber weight and tuber yield significantly in both the years while number of tubers plant^{-1} only in 2015-2016 (Table 2). The highest plant height (42.5 cm) in 2015-2016 was recorded in M_4 (recommended fertilizers + cowdung 5.0 t ha^{-1} in IPNS + straw mulch) and similar trend was recorded in 2016-2017 but M_4 and M_3 treatments at par in 2016-2017. Individual tuber weight was maximum in M_3 that was statistically identical to M_4 in 2015-2016 but insignificant in 2016-2017. Numerically higher number of plants m^{-2} was observed in all treatments having mulch than that of non-mulched treatment (M_1). Mulching reduced increase in soil salinity (Table 6, Table 7 and Table 8) that might have facilitated better crop stands establishment. Thus mulching along with 25% extra K or cowdung @5 t ha^{-1} contributed to higher no. of tubers $plant^{-1}$ and individual tuber weight in treatment M_3 and M_4, respectively. Although all yield contributing characters did not differ significantly, their cumulative effect made difference in tuber yield in different management practices. The maximum tuber yield (19.92 and 21.22 t ha^{-1} in 2015-2016 and 2016-2017, respectively) was obtained from Recommended fertilizer + cowdung 5 t ha^{-1}in IPNS + straw mulch (M_4 treatment) which was statistically similar to M_3: Recommended fertilizer + 25% extra K + straw mulch practices (19.39 and 20.39 t ha^{-1} in 2015-2016 and 2016-2017, respectively). These results were obtained might be due to the cumulative effect of higher number of tubers $plant^{-1}$ and individual tuber wt. Moreover, reason might be such that cowdung retained moisture in the soil for longer period that reduced soil salinity and ultimately increased tuber yield. Bezborodov *et al*. (2010) reported an approximately 20% increase in surface soil salinity of the non-mulch treatments compared to a surface mulching with 1.5 t ha^{1} wheat residues under conventional tillage. Maintaining a higher K^+/Na^+ ratio by applying potassium in saline soils helps in plant growth and yield (Tanji and Kielen, 2002; Takahashi *et al*., 2007; Peter *et al*., 2010; Yue *et al*., 2012).

Table 2. Tuber yield and yield attributes of potato under different management practices in saline soil condition at Charfashion, Bhola in 2015-2016 and 2016-17

Treatment	Plant height (cm)	Plants m^{-2} (No.)	Tubers $plant^{-1}$ (No.)	Individual tuber wt. (g)	Tuber yield (t ha^{-1})
2015-2016					
M_1	37.7c	6.56	5.14c	40.96c	13.06c
M_2	40.5b	6.84	5.48b	44.20b	16.15b
M_3	41.3b	6.84	5.82a	49.28a	19.39a
M_4	45.2a	7.02	6.02a	48.62a	19.92a
CV (%)	7.44	6.19	7.69	10.12	11.03
$LSD_{0.05}$	3.6	NS	0.31	3.28	1.92
2016-2017					
M_1	38.2c	6.50	5.72	40.48c	14.09c
M_2	42.4b	6.94	5.57	45.06b	17.00b
M_3	43.3ab	6.83	5.85	49.56a	20.39a
M_4	46.5a	7.06	6.07	49.61a	21.22a

CV (%)	9.08	8.65	10.04	5.74	10.76
$LSD_{0.05}$	4.0	NS	NS	4.46	2.08
Mean (Pooled)					
M_1	38.0c	6.53	5.43	40.72b	13.58c
M_2	41.4b	6.89	5.52	44.63b	16.58b
M_3	42.3ab	6.84	5.83	49.42a	19.89a
M_4	45.8a	7.04	6.05	49.12a	20.57a
CV (%)	8.20	7.54	11.36	6.53	11.52
$LSD_{0.05}$	4.19	NS	NS	4.38	2.13

M_1: Recommended Fertilizers (RF): @ 115-30-125-19-3.5-1.7 N-P-K-S-Zn-B kg ha^{-1}, M_2: RF + Straw mulch, M_3: RF + 25% extra K + Straw mulch, M_4: RF with cowdung @ 5t ha^{-1} in IPNS + Straw mulch

Interaction effect of planting systems and different management practices

Plant height, number of tubers $plant^{-1}$, individual tuber weight and tuber yield differed significantly due to the interaction effect of planting systems (raised bed and flat system) and different management practices (fertilizers and mulching) in both the years (Table 3, Table 4 and Table 5). The highest plant height was observed in P_2M_4 which was statistically identical with P_1M_4 in both the years (average 47.0 cm and 44.7 cm in P_2M_4 and P_1M_4, respectively). The highest number of tubers $plant^{-1}$ was observed in P_1M_4 in both the years (average 6.14) that was statistically identical to P_1M_3 and P_2M_4. The maximum individual tuber weight was found in P_1M_3 followed by P_1M_4, P_2M_3 and P_2M_4 in 2015-2016. In 2016-2017, the maximum individual tuber weight was found in P_1M_4 (50.17 g) and it was statistically identical to P_1M_3, P_2M_4, P_2M_3 and P_2M_2. Though all yield attributes did not differed significantly due to the interaction effect but their cumulative effect made difference in tuber yield in both the years. In 2015-2016, the highest tuber yield (21.13 t ha^{-1}) was obtained in P_1M_4 which was statistically identical with P_1M_3. But in 2016-2017, P_1M_4, P_1M_3 and P_2M_4 gave statistically identical tuber yield. In 2016-2017, tuber yield in all the treatments was slightly higher compared to 2015-16 due to lower soil salinity in 2016-2017. The highest average tuber yield was obtained in P_1M_4 (21.66 t ha^{-1}). Treatment combinations having raised bed with straw mulch + cowdung or extra K might have conserved soil moisture for longer period and thus reduced soil salinity to some extent that favoured better growth and yield. This finding is in agreement with Muromota *et. al*. (1991) and Mahmood *et al*. (2002). Application of potassium and different mulches had positive effect on growth characters and yield and economic analysis of potato (Pulok *et al*., 2016). In both the years all yield attributes and tuber yield (average 12.37 t ha^{-1}) was lowest in P_2M_1 (flat system planting and no mulch).

Table 3. Tuber yield and yield attributes of potato as influenced by interaction of planting systems and management practices in saline soil of Charfashion, Bhola in 2015-2016

Treatment		Plant height (cm)	Plants m^{-2} (No.)	Tubersplant^{-1} (No.)	Individual tuber wt. (g)	Tuber yield (t ha^{-1})
P_1	M_1	36.8d	6.65	5.74c	37.78e	14.04c
	M_2	40.8c	7.00	5.88b	42.98d	17.28b
	M_3	42.2bc	6.92	6.00a	49.95a	20.65a
	M_4	44.0ab	7.06	6.12a	49.90a	21.13a
P_2	M_1	32.6c	6.07	5.54c	42.13d	12.08d
	M_2	40.2c	6.68	5.16d	45.41bcd	15.01c
	M_3	40.4c	6.76	5.63c	48.61ab	18.12b
	M_4	46.4a	6.98	5.91ab	47.33abc	18.70b
CV (%)		9.3	7.16	8.32	11.54	9.58
$LSD_{0.05}$		3.1	NS	0.28	3.42	1.63

P_1: Raised bed, P_2: Flat bed, M_1: Recommended Fertilizers (RF): @ 115-30-125-19-3.5-1.7 N-P-K-S-Zn-B kg ha^{-1}, M_2: RF + Straw mulch, M_3: RF + 25% Extra K + Straw mulch, M_4: IPNS with cowdung @ 5 t ha^{-1} + Straw mulch

Table 4. Tuber yield and yield attributes of potato as influenced by interaction of planting systems and management practices in saline soil of Charfashion, Bhola in 2016-2017

Treatment		Plant height (cm)	Plants m^{-2} (No.)	Tubers plant^{-1} (No.)	Individual tuber wt. (g)	Tuber yield (t ha^{-1})
P_1	M_1	38.9cd	6.91	5.81bc	37.8d	15.53de
	M_2	42.9b	7.14	5.93ab	42.79c	17.87cd
	M_3	44.3bb	6.89	6.09a	50.13a	21.16ab
	M_4	45.4ab	7.11	6.16a	50.17a	22.19a
P_2	M_1	37.5d	6.09	5.62c	43.16bs	12.65f
	M_2	41.8c	6.74	5.20d	47.32ab	16.13de
	M_3	42.3bc	6.77	5.60c	48.98a	19.61bc
	M_4	47.5a	7.01	5.98ab	49.05a	20.24ab
CV (%)		7.9	8.12	6.65	8.67	10.08
$LSD_{0.05}$		3.6	NS	0.25	4.21	2.08

Table 5. Mean tuber yield and yield attributes of potato as influenced by interaction of planting systems and management practices in saline soil of Charfashion, Bhola in 2015-2016 and 2016-2017 (Pooled)

Treatment		Plant height (cm)	Plants m^{-2} (No.)	Tubers $plant^{-1}$ (No.)	Individual tuber wt. (g)	Tuber yield (t ha^{-1})
P_1	M_1	37.9de	6.78	5.78bc	37.79c	14.79e
	M_2	41.9bc	7.07	5.91abc	42.89b	17.58cd
	M_3	43.3bc	6.91	6.05a	50.04a	20.91ab
	M_4	44.7ab	7.09	6.14a	50.04a	21.66a
P_2	M_1	35.1e	6.08	5.58c	42.65b	12.37f
	M_2	41.0cd	6.71	5.18d	46.37ab	15.57de
	M_3	41.4c	6.77	5.62bc	48.80a	18.87bc
	M_4	47.0a	7.00	5.95ab	48.19a	19.47abc
CV (%)		7.86	8.35	7.97	10.32	10.64
$LSD_{0.05}$		3.28	NS	0.32	4.09	2.20

Soil Salinity

There was no significant difference in soil salinity level of different treatments on 15 December in both the years (Table 6, Table 7 and Table 8).Increase in soil salinity started from 31 December (i.e. about one month after planting) in both the years and the rate of increase was significant. Significantly the highest salinity level was observed in flat system planting with no mulch (P_2M_1) (average salinity level was 4.15, 5.42, 6.64, 7.44 and 8.07 dSm^{-1} on 31 December, 15 January, 31 January, 15 February and 01 March, respectively). Soil salinity increase in raised bed with mulching was very close to flat system with mulching. It indicates that mulching in saline soils is more important than planting in raised bed. This might be due to capillary movement of soil water that was higher in open land than mulched land (Devkota *et al*., 2015). Raised bed also reduced soil salinity increase than plain or flat land (Choudhary *et al*., 2008). In raised bed capillary movement of water increases in the furrow than top of the bed. Rahman *et. al.* (2006) observed that salinity was higher in no mulch treatment than treatments with different mulch materials. So, potato could be cultivated in coastal saline area minimizing soil salinity through raised bed with mulching.

Table 6. Salinity levels (dSm^{-1}) at potato experimental plots under different management practices at Charfashion, Bhola during 2015-2016

Treatments		Soil salinity monitoring dates						
		30 Nov'15	15 Dec'15	31 Dec'15	15 Jan'16	31 Jan'16	15 Feb'16	01 Mar'16
P_1	M_1	2.43	2.91	3.33bc	3.96bc	4.32bc	5.06b	5.82b
	M_2	2.43	2.68	2.96c	3.46c	3.93c	4.15c	4.56c
	M_3	2.43	2.65	2.92c	3.41c	3.88c	4.07c	4.50c
	M_4	2.43	2.64	2.92c	3.40c	3.87c	4.00c	4.31c
P_2	M_1	2.43	3.06	4.55a	5.98a	6.83a	7.75a	8.24a
	M_2	2.43	3.12	3.98ab	4.56b	4.98b	5.13b	5.28bc
	M_3	2.43	2.76	3.10c	3.68c	4.12bc	4.69bc	5.12bc
	M_4	2.43	2.80	3.17c	3.65c	4.07c	4.68bc	5.03bc
CV(%)		-	4.23	8.51	6.37	7.12	8.00	6.17
$LSD_{0.05}$		-	NS	0.68	0.71	0.87	0.95	0.97

P_1: Raised bed, P_2: Flat bed, M_1: Recommended Fertilizers (RF): @ 115-30-125-19-3.5-1.7 N-P-K-S-Zn-B kg ha^{-1}, M_2: RF + Straw mulch, M_3: RF + 25% Extra K + Straw mulch, M_4: IPNS with cowdung @ 5 t ha^{-1} + Straw mulch

Table 7. Salinity levels (dSm^{-1}) at potato experimental plots under different management practices at Charfashion, Bhola duirng 2016-2017

Treatments		Soil salinity monitoring dates						
		30 Nov'16	15 Dec'16	31 Dec'16	15 Jan'17	31 Jan'17	15 Feb'17	01 Mar'17
P_1	M_1	2.16	2.88	3.23abc	3.76bc	4.22b	4.89b	5.40b
	M_2	2.16	2.51	2.96c	3.26bc	3.63b	4.10bc	4.37bc
	M_3	2.16	2.40	2.82c	3.20c	3.55b	4.01bc	4.26c
	M_4	2.16	2.41	2.78c	3.12c	3.42b	3.83c	4.15c
P_2	M_1	2.16	3.14	3.75a	4.86a	6.44a	7.12a	7.90a
	M_2	2.16	3.09	3.65ab	3.96b	4.00b	4.78b	5.07bc
	M_3	2.16	2.78	3.11abc	3.56bc	3.94b	4.62bc	4.93bc
	M_4	2.16	2.76	3.05bc	3.58bc	3.91b	4.47bc	4.82bc
CV(%)		-	3.88	7.12	5.43	7.84	6.92	8.31
$LSD_{0.05}$		-	NS	0.66	0.75	0.82	0.92	1.06

Table 8. Average salinity levels (dSm^{-1}) at potato experimental plots under different management practices at Charfashion, Bhola during 2015-2016 and 2016-17

Treatments		Soil salinity monitoring dates						
		30 Nov	15 Dec	31 Dec	15 Jan	31 Jan	15 Feb	01 Mar
P_1	M_1	2.30	2.90	3.28	3.55	4.27	4.98	5.61
	M_2	2.30	2.60	2.96	3.36	3.78	4.13	4.47
	M_3	2.30	2.53	2.87	3.31	3.72	4.04	4.38
	M_4	2.30	2.53	2.85	3.26	3.65	3.92	4.23
P_2	M_1	2.30	3.10	4.15	5.42	6.64	7.44	8.07
	M_2	2.30	3.11	3.82	4.26	4.49	4.96	5.18
	M_3	2.30	2.77	3.11	3.62	4.03	4.66	5.03
	M_4	2.30	2.78	3.11	3.62	3.99	4.58	4.93

Soil Nutrient Status

Analysis of soil samples (composite) taken across the experimental plots before planting and after harvest of the crop did not show significant variation in soil nutrient status (Table 9). However, slight increase in organic matter, total N (%) and K while slight decrease in soil pH, P, S and B was found in soils after harvest (Table 9). Increase of organic matter might be due to addition of mulch materials. Negative balance of K is common in Bangladesh soils (Hossain *et al.*, 2016). Proper dose of K and 25% extra K in two plots might have influenced this slightly positive K balance. Application of recommended fertilizer in proper method can help in soil nutrient status degradation.

Table 9. Initial and post-harvest soil nutrient status of the experimental plots (average of 2015-2016 and 2016-2017)

	pH	OM (%)	Total N (%)	K (meq/ 100 g soil)	P	S	Zn	B
					(µg/g soil)			
Initial status	7.94	1.25	0.072	0.17	5.84	34.15	0.65	0.47
Interpretation	SA	L	VL	L	VL	H	L	Opt
Post-harvest statu	7.95	1.26	0.073	0.18	5.81	34.08	0.65	0.45
Interpretation	SA	L	VL	L	VL	H	L	Opt
Increase (+)/ decrease (-)	(+)0.01	(+)0.01	(+)0.001	(+)0.01	(-)0.03	(-)0.07	-	(-)0.02

Cost and Return analysis

Cost and return of potato was influenced by planting systems and management practices in saline soil condition (Table 10). Gross return (GR) varied due to variation of tuber yield as farm gate price of potato from different treatments was same. On an average, the highest GR (Tk. 208288 ha^{-1}) was obtained from the treatment raised bed + RF with 5 t ha^{-1} cowdung in IPNS + mulching (P_1M_4). Total variable cost (TVC) varied due to different management practices and the lowest average TVC (Tk. 79010 ha^{-1}) was found in flat land with no mulch system (P_2M_1). TVC increased mainly due to mulch material and additional labour for preparing raised bed and spreading of rice straw (mulch). The highest average TVC (Tk. 92343 ha^{-1}) was recorded in the treatment P_1M_4 due to cost of cowdung and transport and application in the field. Although TVC was highest in P_1M_4, gross margin (GM) was also the highest (Tk. 115945 ha^{-1}) in the same treatment as it provided the highest tuber yield. GM produced by P_1M_3 (Tk. 110969 ha^{-1}) was very close to P_1M_4 whereas GM was the lowest in P_2M_1 (Tk. 39835 ha^{-1}) due to the lowest tuber yield. Benefit cost ratio (BCR) is an indicator of profitability of a production activity. BCR was the highest (2.26) in P_1M_4 and it was very close to P_1M_3 (2.25). Other treatments such as P_2M_3, P_2M_4 and P_1M_2 also produced a considerable BCR. Treatment P_2M_1 (Flat land and no mulch) provided the lowest BCR 1.50 which indicated that flat land with no mulch is not suitable for potato cultivation in saline area.

Table 10. Average cost and return of potato as influenced by planting systems and management practices at saline area of Charfashion, Bhola during 2015-2016 and 2016-2017

Treatment		Yield (t ha^{-1})	Gross return (Tkha^{-1})	Total variable cost (Tkha^{-1})	Gross margin (Tkha^{-1})	BCR
P_1	M_1	15.16	144020	84503	59518	1.70
	M_2	17.73	168388	87890	80498	1.92
	M_3	21.04	199833	88864	110969	2.25
	M_4	21.93	208288	92343	115945	2.26
P_2	M_1	12.51	118845	79010	39835	1.50
	M_2	15.85	150575	82635	67940	1.82
	M_3	19.24	182780	83626	99155	2.19
	M_4	19.47	184965	86935	98030	2.13

P_1: Raised bed, P_2: Flat bed, M_1: Recommended Fertilizers (RF): @ 115-30-125-19-3.5-1.7 N-P-K-S-Zn-B kg ha^{-1}, M_2: RF + Straw mulch, M_3: RF + 25% Extra K + Straw mulch, M_4: IPNS with cowdung @ 5 t ha^{-1} + Straw mulch

Conclusion

Crop production in the coastal saline areas particularly during *Rabi* season (dry season) is very limited due to rise in soil salinity. From this study it is revealed that, raised bed and mulching (with rice straw) both minimizes rise in soil salinity significantly. Besides, use of cowdung or extra amount of potassium (K) with recommended fertilizers along with raised bed and mulching helps to reduce soil salinity and increased crop yield. Thus treatment comprised of raised bed + mulching + recommended fertilizers with cowdung (5 tha^{-1} as IPNS) or 25% additional K produced higher yield of potato in coastal saline environment. Farmers of coastal saline areas of Bhola district can adopt the technology for higher yield and economic return from potato.

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ASSESSMENT OF TRAINING NEEDS ON CROP PRODUCTION FOR FARMERS IN SOME SELECTED AREAS OF BANGLADESH

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Abstract

The study attempts to determine the training needs of the farmers emphasizing nine selected major thematic areas. Under each major component, specific and relevant training needs item were collected and systematically incorporated into an interview schedule and administered in terms of frequency of training imparted. Four districts were purposively selected for the study and a total of eighty farmers were randomly selected from four districts. Primary data were analyzed using descriptive statistics. The study revealed that more male was involved in farming and 45% farmers were middle age category (30-39 years). Majority of the farmers completed primary level of education compared to other categories and family size of more than half (60 %) of the respondents was three. Majority number of respondents (57%) had more than 10 years farming experience. A small number of farmers (8.75%) had owned agricultural land and 45% had land between 0.50- 1 hectare. More than 75% of annual gross income of 57.50% farmers came from agricultural activities. More than half (55%) of the respondents collected information on crop and its varieties by own attempt while about 34% was informed from seed seller or dealer. Farmers in Chattogram district had first priority to get training on integrated pest and diseases management, production of bio control agents and bio pesticides, marketing and transportation. Water management, integrated pest and disease management, vermi-compost production, marketing and transportation ranked first in Khagrachori district. The areas of priority for training in Rajshahi district were production and management technology, processing and value addition, marketing and transportation, integrated pest and disease management, water management and vermi-compost production. Training on integrated pest and disease management, bio-control of pests and diseases, production of bio control agents and bio pesticides, production of off-season vegetables, vermi-compost production, marketing and transportation were most emphasized by the respondents in Rangpur district. Respondents defined identification of adulterated fertilizer, insecticide and pesticide application, disease and insects of mango varieties and fruit bagging system of mango as very good type of training. The study concluded that there is an urgent need to design regular training programs in identified thematic areas to fulfill the knowledge gap among the farmers of Bangladesh.

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Introduction

Training is a process of acquisition of new skills, attitude and knowledge in the context of preparing for entry into a vocation or improving one's productivity in an organization or enterprise. Effective training requires a clear picture of how the trainees will need to use information after training in place of local practices what they have adopted before in their situation. Training does not mean knowing more but behaving differently. Again training is acquisition of the best way of utilizing knowledge and skill (Sajeev and Singha, 2010; Ajayi, 1995). Training of farmers essentially contributes to human resource development in agriculture. The basic needs of farmers are crop wise information *viz*., improved seed, inter cultural operation, fertilizers, soil testing, irrigation, new implements, plant protection measures, mushroom cultivation, poultry, animal husbandry and credit information (Babu and Singh, 1986). Majority of the farmers had low extension contact, poor credit orientation and medium farming knowledge. The farmers had high need for training in agronomical practices for 2 to 4 days just before the Kharif and *rabi* season (Chauhan and Kokate, 1986).

Bangladesh is an agro-based developing country and sustainability of agricultural production is prerequisite for attaining the rate of overall growth of the economy. Now, the question is how to increase the production. There can be two possible approaches to enhance the production either by increasing the area under the crop and by increasing the productivity per unit area per unit time. Since the crop area expansion is not feasible anymore the only alternative is to adopt the better management practices and use certain modern agricultural technologies which include better seed technology, better fertilizer application, better pest control measure and irrigation management through imparting need based training. Training is an integral part of any development activity (Pandey *et al.*, 2015). Knowledge and skills of the farmers in agricultural technologies are important factors for increased agricultural production. The factors like hard working, dignity of labour and affection for the land are genetically prevailing among them which are considered to be the fundamental assets of farmer. However, in spite of high social values prevailing in these communities, they have remained backward, underdeveloped or neglected due to the factor like lack of ambition, lack of initiative, inadequate land holding, limited needs and orthodox behavior (Barman *et al.*, 2013). Most of the farmers do not possess adequate knowledge about the methods of modern agriculture. They often become frustrated with new practices in agriculture due to lack of proper understanding of the relevant factors. As a result, they are often skeptical towards new ideas and practices in agriculture.

National Agriculture Policy -2013 has asserted on the necessity of trained and efficient farmer in order to assure crop production and food security issues of Bangladesh. It also gave forces to facilitate training of farmers on modern crop production techniques. It identified the paucities of farmers training as a strong weakness of agriculture sector in Bangladesh. One of the mandates of Bangladesh Agricultural Research Institute is to provide farmers with information necessary for carrying out their farming business efficiently and profitably. In this respect farmers training has no alternative. Different divisions of BARI are providing a lot of training to farmers in each year in order to disseminate new varieties and technologies at field level. The Department of Agriculture Extension (DAE) has been working with a view to providing agricultural knowledge and skills to the farmers in Bangladesh.

Training needs assessment is one of the crucial steps towards identifying the area of farmers' interest, design and development of curriculum that can best suit to the existing real conditions of farmers. Pholonngoe and Richard (1995) underscored the necessity of need assessment while stating that if non-formal education trainers hope to foster meaningful development, they should bear in mind that the needs of adults constantly change. Thus, training assessment has to be carried out to design relevant and need based training programs that can accommodate changes over time. Barbazett (2006) noted that before any actual training is conducted, the training institution must determine who, what, when, where, why and how of training. Training needs assessment process helps determine the priority of changes in knowledge, skill, attitude and behavior that will provide the greatest impact on achieving organizational or individual goals. Caffarela (2002) noted that a systematic process of farmers' training must include needs assessment, goal and objectives setting, organizing instructional methods and techniques, monitoring and evaluation. Meenambigai and Seetharaman (2003) asserted that training is the most singular factor affecting individuals' attitude, productivity, improvement, minimization of risks. So, adequate training is essential for farmers to acquire necessary knowledge and skills in different aspects of farming.

But very little research has been conducted regarding training need assessment of farmers in Bangladesh. In view of the above discussion, the study attempted to achieve the following specific objectives-

i. To examine the socio-demographic characteristics of farmers and

ii. To determine the extent of training needs of farmers' in relation to agriculture

Methodology

Description of the study area

The study had covered 4 districts of Bangladesh namely Rangpur, Rajshahi, Chattogram and Khagrachori. These were purposively selected based on the agro-ecological zones, and production potentials in diversified farming. Rangpur is known as major vegetable growing district situated in northern part of Bangladesh. The district is renowned in crop production for a number of reasons viz., high cropping intensity (251%), acceptance of hybrid crop variety, skilled farmer and availability of modern crop production techniques. Rajshahi is located within Barind Tract, 23 m (75 ft) above sea level and has been built on the alluvial planes of the Padma River. Apart from the usual agricultural products of Bangladesh, such as rice, wheat, potatoes and lentils, Rajshahi is specially suited for various crops such as mangoes, litchis, sugarcane, tomatoes and watermelons. It's cropping intensity is 190%. Chattogram is a major coastal city and financial center in southeastern Bangladesh. It is situated on the banks of the Karnaphuli River between the Chittagong Hill Tracts and the Bay of Bengal. Though the economy of Chittagong district is predominantly non-agricultural but it is also enriched with a number of crops such as paddy, betel leaf, potato, corn, turmeric, tea, peanut, mustard, pointed gourd, brinjal, ginger, cucumber and vegetables. Khagrachori is a hilly area and includes a number of ethnic communities such as Tripura, Chakma, Marma and Tanchangya. Most of the people live on Jhum cultivation and 59.92% income come from agriculture (Wikipedia).

Sampling procedure

A multi stage stratified random sampling technique was followed to collect farm level data. From each district one upazila and from each selected upazila one village based on production potential of the different farming system was drawn up purposively for inclusion in the present study. Farmers were selected based on their intimacy with the DAE and BARI to ensure the farmers of this area well exposed about various agricultural development and latest technologies. On consultation with DAE and BARI personnel, a list of farmers representing different categories was prepared for each village. From the individual list of farmers from selected village, five farmers were randomly selected which made twenty farmers from each district. They were different in farming activities, land holding size and also in different socioeconomic attributes. Thus a total of 80 farmers were finally selected for data collection from 4 districts. The identified districts were coming from six agro-climatic zones of Bangladesh (Table 1).

Table 1. Agro-ecological zone wise coverage of the selected districts

Agro-ecological zone (AEZ)	AEZ No.	Districts
Active Tista Floodplain	AEZ 2	Rangpur
North Eastern Barind Tract	AEZ 27	
Lower Atrai Basin	AEZ 5	Rajshahi
High Barind Tract	AEZ 26	
Chittagong Coastal Plains	AEZ 23	Chattogram
Northern and Eastern Hill	AEZ 29	Khagrachori

Source: BBS, 2017

Analytical procedure

Data collection from randomly selected respondents was done by using pre-tested structured schedule through personal interview method. The duration of data collection was February to March 2016. For analyzing the data, descriptive statistics such as percentages, rank order and scoring techniques were used to achieve the objectives and to get meaningful results. In most cases, tabular method of analysis supported with appropriate statistical parameters was used to present the results of the study. A list of thematic areas and specific and relevant training need items under each area was prepared and collected through different review of literature, discussion with DAE and BARI staff as well as own field experiences

In this study, the farmer's responses were collected in a 3– point continuum scale as Very Important (VI), Important (I) and Not Important (NI) by assigning scores 3, 2 and 1 respectively. The results were calculated as weighted score for each of the thrust area identified for the training.

$$\text{Weighted score (WS)} = \frac{(\text{No.of VI} \times 3) + (\text{No.of I} \times 2) + (\text{No.of NI} \times 1)}{\text{TotalNo.of VI} + \text{I} + \text{NI}}$$

Where,

VI = Very Important, I = Important and NI = Not Important

Weighted Score ranged from 1 to 6.

Results and Discussions

Socio-demographic characteristics of the respondents

Table 2 shows that majority of respondents (97.50%) were male. The age distribution of respondents was fairly evenly spread over the various age groups, with the highest (45%) representation found in the 30 to 39 categories. Table 2 also shows that only 8.75% were above 50 years. It revealed that most of the farmers belonged to active age group.

About 16.25% of the respondents had no formal education, 36.25% had not completed primary school, 45% had completed primary school and 2.50% had completed secondary school. No respondents reported having tertiary education. These findings suggest that many farmers in the target groups were illiterate or have low literacy levels, which will impact on their ability to access different types of crop production training and information. This should be important to consider when developing training modules for farmers. The Table 2 also revealed that 60% of the farmers had three family members which is lower than average size of households (4.06) in Bangladesh (HIES, 2016). The reduction in the household size indicates that respondents prefer smaller families.

Table 2. Profile of the respondent farmers in the survey areas

Characteristics	Frequency	% of respondents
Sex		
Male	78	97.50
Female	2	2.50
Age (years)		
Less than 30	11	13.75
30-39	36	45.00
40-49	26	32.50
Above 50	07	8.75
Education		
No formal education	13	16.25
Not finished primary school	29	36.25
Completed primary school	36	45.00
Completed secondary school	2	2.50
Household size (No. of members)		
2	17	21.25
3	48	60.00
4 or more	15	18.75

Source: Field survey 2016

Farming experience varied among the sample respondents. About 40% had been farming for 10-20 years and 31.25% had more than 20 years farming experience (Table 3).Majority of the respondents (45%) had 0.5 to 1 hectares of agricultural land while 36.25% of the respondents were having less than half hectares' agricultural land in the survey area. In terms of ownership status, 8.75% of respondents owned their agricultural land, while 71.25% part own and part lease basis (Table 3). This clearly shows that a large proportion of respondents are smallholders and lease farmers, thus they would not be likely to invest in training and technology if other conditions are right.

The survey revealed a significant difference in the percentage of annual income gained from agricultural activities by the respondents. About 3.75% of respondents obtained less than 25% of their income from agriculture, 12.50 % obtained between 25 to 50 %, 26.25 % acquired between 51 to 75 %, and 57.50 % gained more than 75 % of their annual income from agriculture (Table 3).

Sources of other means of income were not explored in the survey, but during focus group discussions participants shared that the other source of income in the survey areas was mainly business. The proportion of income coming from other off-farm sources remains limited. Households diversified their income and were less reliant on agriculture day by day for economic development. While this is perhaps positive, it also means that farmers whose total household income is less reliant on agriculture may be less likely to invest time and money in training and technology. Most of the respondents (55%) gathered information by their own attempts and 27 % got information from seed dealer and only 3% from officials of BARI. Department of Agricultural Extension is working relentlessly for the overall agricultural development of Bangladesh. It is also an important source to get a wide variety of knowledge by farmers while the figure for the present study was only 7.5%.

Training needs of the sample households

The major training needs components identified for the study were field crop production, crop protection, soil health and fertility management, vegetable production, plantation crops, tuber crops, on farm production of inputs, agricultural engineering, marketing and transportation etc. The district-wise training needs of the farmers are presented in the form of weighted scores in the Tables 4-7. Weighted Scores in the range of 1 – 3 were ranked within each discipline and the first six rankings were identified as training needs of the farmers of the area. The areas which got 1, 2 and 3 rank orders were considered as main important areas of training. The following are the thematic areas where there are high training needs among the farmers of Chattogram, Khagrachori, Rajshahi and Rangpur district of Bangladesh.

Field Crop Production: It refers to acquire knowledge and skill about principals and practice of crop production, protecting from weeds and field management. Training on seed production was the most sought after by farmers in Chattogram district followed by water management of the field crops and training on crop diversification (Table 4). Training on weed management in field crops, nursery management practice, integrated farming and cropping systems also closely followed. In Khagrachori district water management and integrated farming were the most important need in crop production area (Table 5) which was also burning issue in Rajshahi district (Table 6). Integrated farming was regarded as the most important training area under crop production in Rangpur district (Table7). Development of quality training on integrated farming system is, therefore, a prerequisite for profitable farming in these regions.

Table 3. Distribution of respondents according to selected farming characteristics

Characteristics	Frequency	%
Farming experience (years)		
Less than 10 years	23	28.75
10-20 years	32	40.00
Above 20 years	25	31.25
Size of agricultural land (hectares)		
No land	-	0.00
Less than half	29	36.25
0.5 to 1	36	45.00
More than 1	15	18.75
Land ownership status		
Own all	7	8.75
Lease all	16	20.00
Part own/part lease	57	71.25
Percentage of yearly income from agricultural activities		
Less than 25 per cent	3	3.75
25 to 50 per cent	10	12.50
51 to 75 per cent	21	26.25
More than 75 per cent	46	57.50
Ways of information about crops and varieties		
Own Attempts	44	55.00
Seed Seller or dealer in the area	27	33.75
DAE through SAAO	6	7.50
Officials of BARI	3	3.75

Source: Field survey 2016

Crop Protection: It refers to one's need for gaining understanding and skill about the different aspects of insect control, namely, name of insect and disease, symptoms of attack, and nature of damage and control measures against each insect and disease pest (Alam, 2006). Training on integrated pest and disease management of the crops was the most important training need in plant protection followed by control of pest and disease by use of biological agents among the respondents of four districts (Table 4, 5, 6 & 7). This is attributed to the fact that farmers resort to over usage of fertilizers and pesticides/fungicides. Impact of excess application of those chemicals in the long run is ignored by them. But the farmers in the study area have realized the importance of integrated pest management in agriculture for sustainable production and development.

Soil Health and Fertility Management: The term refers to one's need for gaining understanding and skill about the different aspects of soil and fertilizer, namely, soil and water conservation, use of fertilizers, functions of different fertilizers, doses of fertilizers and procedure for applying fertilizers which are necessary for successful cultivation (Alam, 2006). Under Soil health and fertility management in Chattogram district, technologies for soil and water conservation and management of problematic soils were the most needed followed by technology for soil fertility management (Table 4). In Khagrachori district soil fertility management and management of problematic soils were regarded very important. On the other hand, respondents of Rajshahi and Rangpur districts select soil and water conservation as their training need in this area of interest. This isdue to continuous practice of unscientific methods of farming coupled with injudicious use of chemical fertilizers that led to soil degradation. This calls for immediate control measures and proper management practices against further degradation of soil fertility.

Vegetable Production: In vegetables sector of Chattogram and Khagrachori district, production of off-season vegetables and vegetables grading and standardization topped the list whereas in Rajshahi and Rangpur the important training need were producing off season vegetables and production of low volume and high value crops (Table 4, 5, 6 & 7). The identified training needs of farmers under vegetable sector in these areas shouldfind a place in planning and designing training programmes.

Plantation Crops: Processing and value addition was the most desired training rather production and management technology of plantation crops in Chattogram district followed by Rangpur district (Table 4&7). But this is totally ignored by the respondents of other two districts.

Tuber crops: Training on tuber crop production technology and it’s processing and value addition were regarded important among the respondents of all the districts (Table 4, 5, 6 & 7).

On farm production of agricultural inputs: Training on production of Vermi-compost, bio fertilizers and bio pesticides were still hot topics among the farmers. These reflect that farmers are so much reluctant to use chemical fertilizers, insecticides and pesticides in farming. So they demanded more and more training on these areas as day by day they are informed about the bad effects of these chemicals.

Agricultural engineering: Training on post-harvest technology of vegetables and fruits was the most important need under agricultural engineering in Rangpur district.

Besides these, curiosities to learn how to make efficient marketing was also very high among the respondents of all the four districts (Table 4, 5,6 & 7). Every respondent wants a suitable market in which they can sell their product safely and free from the middlemen.

Table 4. Training needs of farmers in Chattogram district

Thematic Area	Chittagong district (n = 20)			
	VI	I	NI	WS
Field Crop Production				
Weed Management	0	3	17	1.15
Cropping system	4	6	10	1.70
Water management	10	6	4	2.30
Integrated farming	6	9	5	2.05
Seed production	12	5	3	2.45
Crop diversification	8	7	5	2.15
Nursery management practice	0	9	11	1.45
Crop Protection				
Integrated pest management	20	0	0	3.00
Integrated disease management	20	0	0	3.00
Bio-control of pests and diseases	19	1	0	2.95
Production of bio control agents and bio pesticides	20	0	0	3.00
Soil health and fertility management				
Soil fertility management	16	4	0	2.80
Soil and Water conservation	20	0	0	3.00
Management of problematic soils	18	2	0	2.90
Soil and water testing	2	7	11	1.55
Integrated nutrient management	6	3	11	1.75

Thematic Area	Chittagong district (n = 20)			
	VI	I	NI	WS
Fertilizer Application	16	4	0	2.80
Vegetable production				
Production of low volume and high value crops	5	8	7	1.90
Production of off-season vegetables	16	4	-	2.80
Exotic vegetables production	2	6	12	1.50
Seedling raising	0	5	12	1.10
Export potential vegetables	12	5	3	2.45
Vegetables grading and standardization	16	4	0	2.80
Protective cultivation(green house, shade house)	0	7	13	1.35
Training and pruning	0	5	15	1.25
Plantation crops				
Production and management technology	4	11	5	1.95
Processing and value addition	18	2	0	2.90
Tuber crops				
Production and management technology	19	1	0	2.95
Processing and value addition	19	1	0	2.95
On farm production of inputs				
Bio-agents production	13	6	1	2.60
Bio-pesticides production	14	5	1	2.65
Bio-fertilizer production	15	5	0	2.75
Vermi-compost production	18	2	0	2.90
Agricultural Engineering				
Repair and maintenance of farm machinery and implements	0	2	18	1.10
Post-harvest technology of vegetables and fruits	0	12	8	1.60
Marketing and Transportation	20	0	0	3.00

Source: Field survey 2016

(-) indicates not under ranking

Table 5. Training Needs of farmers in Khagrachori district

Thematic Area	Khagrachori district (n =20)			
	VI	I	NI	WS
Crop Production				
Weed Management	0	0	20	1.00
Cropping system	13	5	2	2.55
Water management	20	0	0	3.00
Integrated farming	14	6	0	2.70
Seed production	1	14	5	1.80
Crop diversification	0	9	11	1.45
Nursery management practice	0	4	16	1.20
Crop Protection				
Integrated pest management	20	0	0	3.00
Integrated disease management	20	0	0	3.00
Bio-control of pests and diseases	13	7	0	2.65
Production of bio control agents and bio pesticides	16	4	0	2.80
Soil health and fertility management				
Soil fertility management	17	3	0	2.85
Soil and Water conservation	5	12	3	2.10
Management of problematic soils	20	0	0	3.00
Soil and water testing	0	0	20	1.00
Integrated nutrient management	0	13	7	1.65
Fertilizer application	19	1	0	2.95
Vegetable production				
Production of low volume and high value crops	0	5	15	1.25
Production of off-season vegetables	12	4	4	2.40
Exotic vegetables production	0	0	20	1.00
Seedling raising	0	9	11	1.45
Export potential vegetables	0	0	20	1.00
Vegetables grading and standardization	10	3	7	2.15
Protective cultivation(green house, shade house)	0	7	13	1.35
Training and pruning	0	5	15	1.25
Plantation crop				

Thematic Area	Khagrachori district (n =20)			
	VI	I	NI	WS
Production and management technology	0	0	20	1.00
Processing and value addition	0	0	20	1.00
Tuber crops				
Production and management technology	14	6	0	2.70
Processing and value addition	11	3	6	2.25
On farm production of inputs				
Bio-agents production	14	2	4	2.50
Bio-pesticides production	15	2	3	2.60
Bio-fertilizer production	15	5	0	2.75
Vermi-compost production	20	0	0	3.00
Agricultural Engineering				
Repair and maintenance of farm machinery and implements	0	6	14	1.30
Post-harvest technology of vegetables and fruits	8	0	12	1.80
Marketing and Transportation	20	0	0	3.00

Source: Field survey 2016

(-) indicates not under ranking

Table 6. Training needs of farmers in Rajshahi District

Thematic Area	Rajshahi district (n = 20)			
	VI	I	NI	WS
Crop Production				
Weed Management	0	0	20	1.00
Cropping system	0	11	9	1.55
Water management	16	4	0	2.80
Integrated farming	13	4	3	2.50
Seed production	0	8	12	1.40
Crop diversification	0	13	7	1.65
Nursery management practice	0	0	20	1.00
Crop Protection				
Integrated pest management	16	4	0	2.80
Integrated disease management	19	1	0	2.95

Thematic Area	Rajshahi district (n = 20)			
	VI	I	NI	WS
Bio-control of pests and diseases	8	11	1	2.35
Production of bio control agents and bio pesticides	9	7	4	2.25
Soil health and fertility management				
Soil fertility management	0	10	10	1.50
Soil and Water conservation	12	4	4	2.40
Management of problematic soils	9	11	0	2.45
Soil and water testing	0	0	20	1.00
Integrated nutrient management	0	7	13	1.35
Fertilizer application	7	13	0	2.35
Vegetable production				
Production of low volume and high value crops	15	5	0	2.75
Production of off-season vegetables	11	4	5	2.30
Exotic vegetables production	0	0	20	1.00
Seedling raising	0	0	20	1.00
Export potential vegetables	0	0	20	1.00
Vegetables grading and standardization	0	7	13	1.35
Protective cultivation(green house, shade house)	0	13	7	1.65
Training and pruning	0	0	20	1.00
Plantation crop				
Production and management technology	0	0	20	1.00
Processing and value addition	0	0	20	1.00
Tuber crops				
Production and management technology	20	0	0	3.00
Processing and value addition	20	0	0	3.00
On farm production of inputs				
Bio-agents production	5	7	8	1.85
Bio-pesticides production	12	5	3	2.45
Bio-fertilizer production	3	11	6	1.85
Vermi-compost production	16	4	0	2.80
Agricultural Engineering				

Thematic Area	Rajshahi district (n = 20)			
	VI	I	NI	WS
Repair and maintenance of farm machinery and implements	0	6	14	1.30
Post-harvest technology of vegetables and fruits	4	13	3	2.05
Marketing and Transportation	20	0	0	3.00

Source: Field survey 2016

(-) indicates not under ranking

Table 7. Training needs of farmers in Rangpur district

Thematic Area	Rangpur district (n = 20)			
	VI	I	NI	WS
Crop Production				
Weed Management	0	3	17	1.15
Cropping system	12	8	0	2.60
Water management	0	14	6	1.70
Integrated farming	16	4	0	2.80
Seed production	11	9	0	2.55
Crop diversification	0	13	7	1.65
Nursery management practice	0	9	11	1.45
Crop Protection				
Integrated pest management	20	0	0	3.0
Integrated disease management	20	0	0	3.0
Bio-control of pests and diseases	20	0	0	3.0
Production of bio control agents and bio pesticides	20	0	0	3.0
Soil health and fertility management				
Soil fertility management	4	16	0	2.20
Soil and Water conservation	11	9	0	2.55
Management of problematic soils	3	14	3	2.00
Soil and water testing	0	0	20	1.00
Integrated nutrient management	0	11	9	1.55
Fertilizer Application	16	4	0	2.80
Vegetable production				
Production of low volume and high value crops	9	8	3	2.30

Thematic Area	Rangpur district (n = 20)			
	VI	I	NI	WS
Production of off-season vegetables	20	0	0	3.00
Exotic vegetables production	0	0	20	1.00
Seedling raising	0	8	12	1.40
Export potential vegetables	7	6	7	2.00
Vegetables grading and standardization	7	8	5	2.10
Protective cultivation(green house, shade house)	0	0	20	1.00
Training and pruning	0	0	20	1.00
Plantation crop				
Production and management technology	0	11	9	1.55
Processing and value addition	8	5	7	2.05
Tuber crops				
Production and management technology	13	7	0	2.65
Processing and value addition	13	7	0	2.65
On farm production of inputs				
Bio-agents production	8	8	4	2.20
Bio-pesticides production	6	5	9	1.85
Bio-fertilizer production	18	2	0	2.90
Vermi-compost production	20	0	0	3.00
Agricultural Engineering				
Repair and maintenance of farm machinery and implements	0	2	18	1.10
Post-harvest technology of vegetables and fruits	17	3	0	2.85
Marketing and Transportation	20	0	0	3.00

Source: Field survey 2016

(-) indicates not under ranking

Comparative evaluation of training needs of farmers

Training needs on integrated pest and diseases management, production of bio control agents and bio pesticides, marketing and transportation ranked top followed by bio-control of pests and diseases, production and management technology, processing and value addition, vermi-compost production while soil fertility management, fertilizer application, production of off-season vegetables, vegetables grading and standardization come last on the ranking list in

Chattogram district (Table 9).One the other hand water management, integrated pest and disease management, vermi-compost production, marketing and transportation were main training areas in Khagrachori district as it is apparent from the weighted score values likewise, the training needs areas ranked in descending order were fertilizer application, soil fertility management, production of bio control agents and bio pesticides respectively (Table 9).

Besides areas of training needs indicated by the respondents of Rajshahi district in order of preference were production and management technology, processing and value addition, marketing and transportation, integrated disease management, water management, integrated pest management, vermi-compost production and production of low volume and high value crops in descending order (Table 8). In Rangpur district, integrated pest and disease management, bio-control of pests and diseases, production of bio control agents and bio pesticides, production of off-season vegetables, vermi-compost production, marketing and transportation were topped the list while training on bio-fertilizer production was the most sought after one (Table 8). Comparing training needs of four districts, integrated pest and diseases management, vermi-compost production, marketing and transportation areas emerged as important ones. Similar finding was observed in Barman *et al.* (2013) who reported fertilizer management, seed treatment, pest and disease management, water management and marketing were the important training need area where majority farmers had high level of training need.

Table 8. Comparative evaluation of training needs of farmers in four districts

Thematic Area	Chattogram		Khagrachori		Rajshahi		Rangpur	
	WS	Rank	WS	Rank	WS	Rank	WS	Rank
Field Crop Production								
Weed Management	1.15	-	1.00	-	1.00	-	1.15	-
Cropping system	1.70	-	2.55	-	1.55	-	2.60	6
Water management	2.30	-	3.00	1	2.80	3	1.70	-
Integrated farming	2.05	-	2.70	6	2.50	5	2.80	4
Seed production	2.45	-	1.80	-	1.40	-	2.55	-
Crop diversification	2.15	-	1.45	-	1.65	-	1.65	-
Nursery management practice	1.45	-	1.20	-	1.00	-	1.45	-
Crop Protection		-						
Integrated pest management	3.00	1	3.00	1	2.80	3	3.0	1
Integrated disease management	3.00	1	3.00	1	2.95	2	3.0	1
Bio-control of pests and diseases	2.95	2	2.65	-	2.35	-	3.0	1
Production of bio control agents and bio pesticides	3.00	1	2.80	4	2.25	-	3.0	1
Soil health and fertility management								
Soil fertility management	2.80	4	2.85	3	1.50	-	2.20	-

Thematic Area	Chattogram		Khagrachori		Rajshahi		Rangpur	
	WS	Rank	WS	Rank	WS	Rank	WS	Rank
Soil and Water conservation	3.00	-	2.10	-	2.40	-	2.55	-
Management of problematic soils	2.90	3	3.00	1	2.45	6	2.00	-
Soil and water testing	1.55	-	1.00	-	1.00	-	1.00	-
Integrated nutrient management	1.75	-	1.65	-	1.35	-	1.55	-
Fertilizer Application	2.80	4	2.95	2	2.35	-	2.80	4
Vegetable production								
Production of low volume and high value crops	1.90	-	1.25	-	2.75	4	2.30	-
Production of off-season vegetables	2.80	4	2.40	-	2.30	-	3.00	1
Exotic vegetables production	1.50	-	1.00	-	1.00	-	1.00	-
Seedling raising	1.10	-	1.45	-	1.00	-	1.40	-
Export potential vegetables	2.45	-	1.00	-	1.00	-	2.00	-
Vegetables grading and standardization	2.80	4	2.15	-	1.35	-	2.10	-
Protective cultivation (green house, shade house)	1.35	-	1.35	-	1.65	-	1.00	-
Training and pruning	1.25	-	1.25	-	1.00	-	1.00	-
Plantation crops								
Production and management technology	1.95	-	1.00	-	1.00	-	1.55	-
Processing and value addition	2.90	3	1.00	-	1.00	-	2.05	-
Tuber crops								
Production and management technology	2.95	2	2.70	-	3.00	1	2.65	5
Processing and value addition	2.95	2	2.25	-	3.00	1	2.65	5
On farm production of inputs								
Bio-agents production	2.60	-	2.50	-	1.85	-	2.20	-
Bio-pesticides production	2.65	6	2.60	-	2.45	6	1.85	-
Bio-fertilizer production	2.75	5	2.75	5	1.85	-	2.90	2
Vermi-compost production	2.90	3	3.00	1	2.80	3	3.00	1
Agricultural Engineering								
Repair and maintenance of farm machinery and implements	1.10	-	1.30	-	1.30	-	1.10	-
Post-harvest technology of vegetables and fruits	1.60	-	1.80	-	2.05	-	2.85	3
Marketing and Transportation	3.00	1	3.00	1	3.00	1	3.00	1

Source: Field survey 2016. (-) indicates not under ranking

Training received by the respondents

A limited number of training was provided by the Department of Agricultural Extension and Bangladesh Agricultural Research Institute (BARI). The present study was identified randomly some of the training that was provided by the DAE and BARI among the respondents of four districts. Duration of most of the training was one day mainly. In Rangpur district, the number of respondents received training was highest. Out of 20 respondents in Rajshahi district, only 9 received training whereas it is only 4 to the other two districts out of 20 respondents (Table 9). But the current study found their deep interest on receiving training on different crops. Respondents of Rajshahi district wanted training on papaya, wheat, eggplant and chili production practices. Training on tomato, bitter gourd, cauliflower, felon, coriander was demanded by the respondents of Chittagong region. At the same time respondents of Khagrachori district demanded training on turmeric, zinger, mango cultivation following by litchi, mango, zinger, turmeric, and groundnut and potato production practices in Rangpur district (Table 9).

Table 9. Training received and demand for training by the sample farmers

Name of District	Total no. of respondents	No. of respondents received training	Crops on which training should be delivered
Rajshahi	20	9	Papaya, Wheat, Eggplant, Chili, Potato
Chittagong	20	4	Tomato, Bitter gourd, Cauliflower, Felon, Coriander
Khagrachori	20	4	Turmeric, Zinger, Eggplant, Mango, Rice, Bitter gourd
Rangpur	20	13	Litchi, Mango, Zinger, Turmeric, Groundnut and Potato

Source: Field survey 2016

Respondents of the present study received a number of training from DAE and BARI. Table 10 shows a list of different training programs received by the sample farmers and their ranking as very good, good and poor. Identification of adulterated fertilizer, insecticide and pesticide, disease and insects of mango varieties, bagging system of mango, insecticide and pesticide application, vegetables production techniques as very good type of training (Table 10). Beside this, production technology of potato and pumpkin and seedlings preparation considered as poor type of training among the survey respondents.

Table 10. Training received by the sample farmer

Subject matter of Training	Organizing Agency	Duration (Days)	Grade
Seed conservation	DAE	3	Good
Modern rice cultivation	DAE	2	Good
Identification of adulterated fertilizer, insecticide and pesticide	DAE	1	Very Good
Disease and insects of mango varieties	BARI	2	Very Good
ToT on rice	DAE	3	Good
Rice cultivation technique	DAE	1	Good
Production technology of mango	BARI	1	Good
Fruit bagging system of mango	BARI	1	Very Good
Fertilizer application to mango	BARI	1	Good
Pulse crop production technology	DAE	5	Good
Insecticide and pesticide application	BARI	3	Very Good
Production technology of potato and pumpkin	DAE	1	Poor
Seed production and preservation	DAE	1	Good
Fertilizer application and weed management	DAE	1	Poor
Seed production of BRRI dhan 28	DAE	1	Good
Rice production technology	DAE	1	Good
Seedlings preparation	DAE	1	Poor
Turmeric and zinger production	DAE	1	Good
Seedlings of fruits preparation	BARI	1	Good
Insect and pest management	DAE	1	Good
Disease, insect and pest management	DAE	1	Good
Vegetables production techniques	DAE	1	Very good
Rearing mango orchard	DAE	1	Good

Source: Field survey 2016

Conclusion

All the sample respondents of the present study opined that training is very essential for making their crop production more efficient and profitable. But inadequacy of training is very common even in most crop intensive districts of Bangladesh. Farmers emphasized to get training on integrated farming systems and water management for field crop production. Integrated disease management attained the top most priority followed by integrated pest management under training on crop protection. Management of problematic soils and fertilizer application were most needed training under soil health and fertility management while training with respect to production of off-season vegetables was the most important one under vegetable production. Training on tuber crops cultivation was also in high demand for areas of production and management technology, processing and value addition of tuber crops. Vermi-compost production secured the top most position in the list under on- farm production of inputs followed by bio-pesticides and bio-fertilizers production. Marketing and transportation accorded highest response from the farmers in four districts in the assessment of training needs. A number of training in the survey area was identified as very useful for the farmer while some were regarded as poor in quality and necessity. It indicates a gap in farmer's knowhow and actual information which needs to be addressed through designing and developing a training module. The BARI and DAE can reorient their training schedule and subject matter based on these findings to enrich farmer's knowledge on improved crop production techniques.

Recommendations

Based on the findings of the study, the following recommendations are suggested:

- An extensive research programme should be conducted covering all the intensive crop growing areas of Bangladesh to identify the appropriate crop production needs of farmers.
- DAE should arrange training progrmme based on the necessity of the farmers. Otherwise, it will not bring any positive outcome in the crop production systems of Bangladesh. Training identified as not very good should be discarded and good one should be developed with current information and knowledge.
- Much emphasis should be paid on integrated farming systems, integrated pest and disease management and technologies for soil and water conservation while planning and designing training programmes for farmers.
- Both extensive and intensive hand on-training programmes should be emphasized for farmers through proper assessment of their training needs.
- The concerned different centers and divisions of BARI should pay relatively higher emphasis and care on those specific most important needs, as identified by this study through concerted efforts while formulating different training module for the farmers in hills and plain areas as well as different agro-climatic and farming system areas of Bangladesh.
- Farmers regular contact with BARI avail themselves with latest crop production techniques and information. So, BARI should increase their farmers training and field day workshops in different agro ecological zone of Bangladesh.

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INTERCROPPING GARDENPEA (*Pisium sativum*) WITH MAIZE (*Zea mays*) AT FARMERS' FIELD

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Abstract

An experiment was conducted at the farmers' field of Phulpur MLT site of On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Mymensingh during 2015-16 and 2016-17 to find out a suitable intercrop combination of garden pea with maize for higher productivity and profitability. Five treatments, viz. T_1= Maize (100%) + one row garden pea (33%) in between maize lines, T_2= Maize (100%) + two row garden pea (66%) in between maize lines, T_3= Maize (100%) + garden pea broadcast (100%) in between maize lines, T_4= Sole maize and T_5= Sole garden pea were tested following RCB design with six dispersed replications. Maize var. BARI Hybrid Maize-9 and garden pea var. BARI Motorshuti-3 were used in monoculture as well as in intercropping situations. Intercropping of garden pea improved the yield components of maize and offered some additional yield. The highest maize grain yield (8.62 t ha^{-1}) and maize equivalent yield (20.22 t ha^{-1} yr^{-1}) were recorded with maize (100 %) + two rows of garden pea (66 %) in between maize lines (T_2). The values of all the competition functions were greater than unity and maize (100 %)+ two rows of garden pea (66 %) in between maize lines (T_2) showed higher values of land equivalent ratio (1.56), gross return (Tk. 311920 ha^{-1}), gross margin (Tk. 175697 ha^{-1}) and BCR (2.29) as compared to other treatments.

Keywords: Maize, gardenpea, intercropping, land equvalent ratio, benfit-cost

Introduction

Bangladesh is an agricultural country and about 14.22 % of the gross domestic product (GDP) comes from agriculture (BBS, 2017). But the cultivable land area is decreasing with the increase in population and subsequent urbanization and industrialization in Bangladesh. Increasing food demand for additional population is creating challenge to the country for increasing productivity of the limited land. Intercropping system is one of the most common practice used more than one crop together in sustainable agricultural system to increase the productivity and stability of yield in order to improve resource utilization and environmental factors (Alizadeh *et al.*, 2010). The main concept of intercropping is to get increased total productivity per unit area and time, besides equitable and judicious utilization of land resource. Intercropping brings an increase in

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production or yield benefits, more efficient use of water, land, nutrients and labors reduction in problems caused by pests, diseases and weeds (Awal *et al*., 2006).

Maize is ranked third after rice and wheat among the most important cereal crops in Bangladesh. Maize is normally grown in wider row spacing (60 cm) and inter row space can profitably be utilized for higher returns. So, farmers can easily grow a short duration crop as intercrop with maize at early growth stage. Garden pea is an important legume crop as well as a primary source of plant protein for human and animals. Garden pea is a short duration (60-70 days), high value *rabi* crop suitable for the farmers' to earn quick return as well as cropping intensity will be increased without hampering the growth and yield of maize.

Hybrid maize covers a vast area of Mymensingh district as a single crop in *rabi* season. Moreover, garden pea as a leguminous crop, incorporation of green biomass of garden pea into soil after harvest of pods may increase soil fertility and soil organic matter. Legume in an intercropping system not only provides nitrogen to the associated crops but also increase the amount of humus in the soil due to decaying crop remains. Legumes as intercrop with maize instead of showing any adverse effect on maize increase its yield (Singh and Bajpai, 1991 and Mucheru *et al*., 2010). Better intercrop production could be achieved with the choice of appropriate crops, population density and planting geometry of component crops (Santalla *et al*., 2001). In this context, the experiment was undertaken to find out the suitable intercrop combination of garden pea with maize for increasing total productivity and profitability.

Materials and Methods

The experiment was conducted at the farmers' field of Phulpur MLT site, On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Mymensingh during 2015-16 and 2016-17. The experimental site was situated at approximately $24^0 38^{/}$N and $90^0 16^{/}$E with the altitude of 19 m above sea level. Mean annual precipitation was 2212 mm, most of which (90 %) was received during May to September due to monsoon. The soil was typical Dark Grey Floodplain with sandy loam to silty loam in texture of the medium highland having pH 6.2 to 6.5 under the Agro-ecological Zone-9 (AEZ-9). The experiment consisted of five treatments, *viz*. T_1= Maize (100%) + one row garden pea (33%) in between maize lines, T_2= Maize (100%) + two row garden pea (66%) in between maize lines, T_3= Maize (100%) + garden pea broadcast (100%) in between maize lines, T_4= Sole maize and T_5= Sole garden pea. The maize var. BARI Hybrid Maize-9 and garden pea var. BARI Motorshuti-3 were used in the experiment. The experiment was laid out in randomized complete block design with six dispersed replications. The unit plot size was 8.0 m × 5.0 m. Maize was the main crop and garden pea was grown as intercrop in the study. Garden pea was intercropped in between maize row @ 33, 66 and 100% plant population. Maize seeds were sown at 60 cm × 20 cm spacing both in sole and intercrop situation. Except broadcasting, garden pea seeds were sown maintaining 25 cm row to row and 12 cm plant to plant spacing both in sole and intercrop. The crops maize and garden pea were sown on 20 November, 2015 and 12 November, 2016. The recommended doses of fertilizers such as, 250-55-120-50-5-1 kg NPKSZnB ha^{-1} and 45-30-45 kg NPK ha^{-1} for sole crop of maize and garden pea, respectively were applied separately in sole crop. In intercropping maize was fertilized with 250-55-120-50-5-1 kg NPKSZnB ha^{-1} in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively. One third of N and all other fertilizers were applied as basal during final land preparation by broadcasting method. Remaining two-third of N was split equally and applied at 8-10 leaves stage after harvesting of garden pea and tasseling stage beside maize rows. Mulching and hand weeding were done as and when required to keep the field reasonable weed free. Drasban was sprayed at 15-20 days intervals as precautionary measure against insects attack. Garden pea was harvested on 23 January 2016 and 15 January 2017 and maize was also harvested on 17 April 2016 and 05 April 2017, respectively. The yield contributing characters of garden pea and maize were recorded from 10 randomly selected plants in both the years. Harvest index (HI) was calculated as per following equation:

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Yield of individual crop was converted into equivalent yield on the basis of the prevailing market price of individual crop (Prasad and Srivastava, 1991).

$$\text{Maize equivalent yield (MEY)} = \text{Yim} + \frac{\text{Yig} \times \text{Pg}}{\text{Pm}}, \text{ and}$$

$$\text{Garden pea equivalent yield (GEY)} = \text{Yig} + \frac{\text{Yim} \times \text{Pm}}{\text{Pg}}$$

Where, Yim= Yield of intercrop maize, Pg= Price of garden pea, Pm= Price of maize and Yig= Yield of intercrop garden pea

Various competition functions viz., land equivalent ratio (LER), area time equivalent ratio (ATER), system productivity index (SPI), replacement value of intercropping (RVI), monetary advantage index (MAI), aggressivity index (A), competitive ratio (CR) and relative crowding coefficient (RCC) were worked out by using following formula to find out the benefit of intercropping and the effect of competition between the treatments used in this experiment.

ATER= $\left[\frac{\text{Yim}}{\text{Ysm}} \times \text{Tm} + \frac{\text{Yig}}{\text{Ysg}} \times \text{Tg}\right] \div \text{T}$, Where Y_{im}= Yield of maize in intercropping, Y_{sm}=yield of maize in sole cropping, Y_{ig}= yield of garden pea in intercropping, Y_{sg}= yield of garden pea in sole cropping, T_m= Duration of maize, T_g= Duration of garden pea and T= Total duration of intercropping system.

RVI $= \frac{Yim \times Pm + Yig \times Pg}{Ysm \times Pm - Csm}$ Where Y_{im} & Y_{ig} are the yield of intercrops, P_m & P_g are the respective market price of these crops, Y_{sm} & C_{sm} are the yield and input cost of the main crop in sole stand.

$$MAI = \frac{\text{Monetary value of combined intercrops yield}}{LER} \times (LER - 1)$$

Relative crowding coefficient (RCC): $RCC_{maize} \times$, $RCC_{garden\ pea}$,

Where, $RCC_{maize} = \frac{Yim \times Zgi}{(Ysm - Yim) \times Zmp}$, and

$RCC_{garden\ pea} = \frac{Yig \times Zmp}{(Ysg - Yig) \times Zgp}$ where Z_{mp} and Z_{gp} are the proportion of maize and garden pea in the mixture, respectively.

Aggressivity (A) index:

$$A_{maize} = \frac{Yim}{Ysm \times Zmp} - \frac{Yig}{Ysg \times Zgp} \text{ and } A_{gardenpea} = \frac{Yig}{Ysg \times Zgp} - \frac{Yim}{Ysm \times Zmp}.$$

Competitive Ratio (CR):

$$CR_{maize} = \frac{LER_{maize}}{LER_{garden\ pea}} \times \frac{Zgp}{Zmp} \text{ and } CR_{garden\ pea} = \frac{LER_{garden\ pea}}{LER_{maize}} \times \frac{Zmp}{Zgp}$$

SPI= $\frac{Ysm}{Ysg} \times Yig + Yim$, Where Ysm and Ysg= Mean yield of maize and garden pea in sole cropping, Yim and Yig= Mean yield of maize and garden pea in intercropping.

Data on yield and yield contributing characters were collected properly. Data were statistically analyzed using analysis of variance technique with the help of computer package MSTAT-C and mean comparison among the treatments were made by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984). Pooled analysis was done as because there was no significant variation in yield and yield parameters between the years. Finally, benefit cost ratio was calculated based on prevailing local market price.

Results and Discussion

Yield attributes of maize

Number of grains cob^{-1} and grain yield of maize were significantly influenced by maize+garden pea intercropping systems (Table 1). The number of cobs plant^{-1} was not influenced significantly and similar trend was followed in case of plant height. There was trend to increase grains cob^{-1} in intercropping situation than sloe crop. Increased number of grains cob^{-1} of maize was also reported in maize-soybean intercropping system by Zhang and Li (1987) and Rana *et al*. (2001). Thousand grains weight of maize was not significantly influenced due to intercropping but there was an increasing trend when garden pea was intercropped with maize. Increased thousand grains weight was also noticed by Zhang and Li (1987) when maize was intercropped with leguminous crop like soybean. Singh *et al*. (2000) also reported that inclusion of legumes as intercrops increased the yield attributes viz., number of cobs plant^{-1}, grains cob^{-1} and thousand grains weight of maize.

Grain yield of maize

Grain yield of maize was influenced when intercropped with garden pea. Maize gained yield advantage of 1.83 to 5.12 % due to legume association as compared to sole maize (Table 1). The highest maize grain yield (8.62 tha^{-1}) was recorded when maize (100 %) + two rows of garden pea (66 %) intercropped in between maize lines (T_2) with 5.12 % increment in yield as compared to sole maize. The yield advantage of maize in intercropping systems might be resulted from maize-legume association due to symbiotic nitrogen fixation by garden pea and current transfer of nitrogen to the associated maize plants. This result corroborates with the findings of Rana *et al.* (2001) who reported that grain yield of maize was increased 2.32 to 7.50 % over sole cropping when it was intercropped with grain legumes (soybean, urdbean and cowpea). Kheroar and Patra (2013) also reported that the highest maize grain yield was recorded with maize + green gram intercropping system. The harvest index (HI) of maize did not differ by the intercropping systems. The harvest index of maize had higher value in $T_3>T_2>T_1>T_4$.

Yield and yield attributes of garden pea

Yield and yield contributing characters of garden pea were significantly influenced by maize+garden pea intercropping systems (Table 2). All the intercrops grown with maize were shorter in height than sole crop. Garden pea in association with maize decreased 25.89 to 31.33 % pods plant^{-1} and 3.94 to 12.11 % seeds pod^{-1}. Sole garden pea (T_5) produced higher number of pods (16.34) plant^{-1} as well as seeds (3.55) pod^{-1}. Significant differences in thousand seeds weight and harvest index were noticed. The entire intercrops garden pea was recorded lower 1000-seeds weight than sole crop. The higher pod yield (6.45 tha^{-}

[1]) was produced in sole garden pea (T_5) which was statistically different with intercrops yield due to cumulative effect of yield attributes. Lower yield was obtained from all the intercrops than sole crop might be due to lower plant population and yield attributes.

Table1. Yield attributes, grain yield and harvest index of maize as influenced by different intercropping systems at Mymensingh during 2015-16 and 2016-17 (pooled)

Treatment	Plant height (cm)	Cob plant^{-1} (no.)	Grains cob^{-1} (no.)	1000-grains weight (g)	Grain yield (t ha^{-1})	Harvest index (%)
T_1	202.11	1.43	616	325.40	8.35	41.47
T_2	200.40	1.44	629	322.10	8.62	41.52
T_3	198.35	1.39	612	325.50	8.40	41.76
T_4	202.30	1.35	609	320.90	8.20	39.50
LSD(0.05)	NS	NS	8.49	NS	0.31	-
CV (%)	8.52	7.29	4.99	5.41	6.59	-

T_1= Maize (100%) + one row garden pea (33%) in between maize lines, T_2= Maize (100%) + two row garden pea (66%) in between maize lines, T_3= Maize (100%) + garden pea broadcast (100%) in between maize lines and T_4= Sole maize

Yield of garden pea was reduced due to reduction in plant population in intercropping situations. Garden pea yield was decreased by 32.59 to 54.41 % than sole crop due to receipt lower amount of incoming solar radiation as well as lower number of plants in intercropping systems. Yield was mostly affected due to tall maize plants shaded the short statured garden pea plants which affected the rate of photosynthesis and thereby translocation of photosynthates from source to sink. Patra *et al*. (2000) also recorded lower number of pods plant^{-1}, seeds pod^{-1} and decreased in yield of soybean, green gram, groundnut and black gram due to intercropping legumes with maize as compared to their monoculture which corroborated the present findings. Sole crop of garden pea recorded the highest harvest index (31.80 %) among the treatments. The harvest index of garden pea had higher value in $T_5>T_2>T_3>T_1$.

Maize and garden pea equivalent yield

Maize and garden pea equivalent yield were recorded to be higher in all intercropping systems with respect to pure stand yield of their corresponding sole crops yields (Table 3). The highest maize equivalent yield (20.22 t ha^{-1}yr^{-1}) as well as garden pea equivalent yield (7.58 t ha^{-1}yr^{-1}) were recorded from maize (100 %) + two rows of garden pea (66 %) in between maize lines (T_2) which covered the yield advantages of 147 and 18 % over their respective sole crops. Such yield advantage might be due to combined yield of both the crops. Similarly, Chalka and Nepalia (2005) also observed that introduction of different legume crops did not affect yield attributes and yield of maize but significantly increased maize equivalent yield.

Table 2. Yield attributes, pod yield and harvest index of garden pea as influenced by different intercropping systems at Mymensingh during 2015-16 and 2016-17 (pooled)

Treatment	Plant heigh (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000-seeds weight (g)	Pod yield (t ha^{-1})	Harvest index (%)
T_1	43.33	12.11	3.41	284.35	2.94	23.35
T_2	38.39	11.98	3.24	296.57	4.35	27.43
T_3	37.43	11.22	3.12	284.31	3.86	26.10
T_5	56.68	16.34	3.55	322.18	6.45	31.80
LSD(0.05)	5.38	1.18	0.68	3.14	0.83	-
CV (%)	7.12	5.46	6.68	6.12	6.84	-

T_1= Maize (100%) + one row garden pea (33%) in between maize lines, T_2= Maize (100%) + two row garden pea (66%) in between maize lines, T_3= Maize (100%) + garden pea broadcast (100%) in between maize lines and T_5= Sole garden pea

Cost-benefit analysis

An increase in gross return and gross margin was found due to intercropping of garden pea with maize as compared with sole crop. Maize (100 %) + two rows of garden pea (66 %) in between maize lines (T_2) was recorded the highest monetary advantage Tk. 175697 ha^{-1} which gave an additional income of Tk. 1,21,648 ha^{-1} over sole maize and Tk. 50,448 ha^{-1} over sole garden pea (Table 3). Total cultivation cost was lower in sole crop and higher in intercropping treatments might be due to inclusion of component crop. Intercropping of garden pea brought about an increase in return per taka investment. It was evident that intercropping was always beneficial and recorded higher benefit cost ratio (BCR) with respect to monoculture of maize and garden pea. Among the intercropping systems, maize (100 %) + two rows of garden pea (66 %) in between maize lines (T_2) obtained the highest benefit cost ratio of 2.29 which further indicated the superiority to T_2 over other treatments. These results are in agreement with the findings of Bharati *et al*. (2007) who stated that maize based intercropping gave higher net return than sole crop of maize. Similarly, Maize+legume intercropping was more productive and remunerative as compared to sole cropping stated by Kamanga *et al*. (2010), which was in close agreement with the present findings.

Land Equivalent Ratio (LER): The values of land equivalent ratio (LER) in different intercropping systems were found to be greater than unity indicating higher land use efficiency of intercropping systems over the respective monoculture (Table 4). Yield advantages occurred in intercropping was mainly due to the development of both temporal and spatial complementarities.

However, the total LER value (1.56) was highest in maize (100 %) + two rows of garden pea (66%) in between maize lines (T_2), where maize and garden pea achieved 89 and 67 % of their sole yields, respectively indicating higher biological and economic efficiency. It also expressed that by intercropping maize with garden pea, a farmer can produce 8.62 tons maize and 4.35 tons garden pea in one hectare of land instead of growing them separately as sole crop. Nurbaksh *et al*. (2013) also found similar results in intercropping of sesame and bean.

Table 3. Equivalent yield and cost benefit analysis of maize + garden pea intercropping systems at Mymensingh (average 2015-16 and 2016-17)

Treatment	Equivalent Yield (t ha^{-1} yr^{-1})		Gross return (Tk. ha^{-1})	Total cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
	Maize	Garden pea				
T_1	16.19	6.07	251200	126869	124331	1.98
T_2	20.22	7.58	311920	136223	175697	2.29
T_3	18.69	7.01	288800	135660	153140	2.13
T_4	8.20	-	131200	77151	54049	1.70
T_5	-	6.45	258000	132751	125249	1.94

Input and output Price: Urea=Tk.16.00 kg^{-1}, TSP= Tk. 23.00 kg^{-1}, MoP= Tk. 16.00 kg^{-1}, Gypsum = Tk. 10.00 kg^{-1}, Zinc sulphate= Tk. 180.00kg^{-1}, Boric acid= Tk. 220.00 kg^{-1}, Maize grain= Tk. 15.00 kg^{-1} and Garden pea (green pod) = Tk. 40.00 kg^{-1}

Area Time Equivalent Ratio (ATER): The area time equivalent ratio (ATER) included the duration of the intercrops in intercropping systems in the field and also evaluated the crop yield per day basis. ATER values were found greater than unity in all the intercropping systems. Maize (100%) + garden pea (66 %) in between two lines of maize intercropping system (T_2) showed higher ATER value (1.28) which was about 8.0 and 6.0 % higher than that of ATER values obtained from T_1 and T_3 which indicating higher yield per day (Table 4). So, the intercropping system was found to be advantageous in comparison to sole crop. This was achieved due to the development of temporal as well as spatial complementary. Mohan *et al*. (2005) also reported that the LER and ATER were higher in maize + legume in 1:2 proportion than in 1:1 proportion.

System Productivity Index (SPI): The system productivity index (SPI) which standardized the yield of the secondary crop (garden pea) in terms of the primary crop (maize) and also identified the combinations that utilized the growth resources most effectively and maintained a stable yield performance (Tajudeen, 2010). The results showed that maize 100% + two rows of garden pea (66 %) in between two maize lines (T_2) intercropping system gave the highest SPI value (14.21) than other intercropping systems (Table 4). The values of SPI were higher and largely determined by maize intercrop yields which were not much reduced by intercropping with garden pea.

Replacement Value of Intercropping (RVI): Replacement value of intercropping (RVI) is one of the better measures of economic advantage of intercropping. Maximum value (6.62) of RVI was observed in maize (100 %) + two rows of garden pea (66 %) in between maize lines (T_2) intercropping system (Table 4). This implies that, farmers who practice intercropping of two rows of garden pea in between maize lines (T_2) could make 562% more profit than the farmers who are involved in maize or garden pea monoculture.

Monetary Advantage Index (MAI): The monetary advantage index (MAI) values were positive in all intercropping systems (Table 4). The result also gives an indication of the yield and economic advantages in maize-garden pea intercropping systems over their sole cropping. The highest MAI (Tk. 1,11,971 ha^{-1}) was obtained in maize (100 %) + two rows of garden pea (66 %) in between maize lines (T_2), which implied that the planting pattern was highly economical and advantageous for the mixtures. The results are in agreement with the finding of Islam *et al*. (2016) who reported that higher MAI values found in turmeric-sesame intercropping systems compared to sole cropping system. Dhima *et al*. (2007) reported that if LER and relative crowding coefficient (RCC) values were higher than there was an economic benefit expressed with MAI values such as obtained in the present study.

Table 4. Competition functions as influenced by maize + garden pea intercropping systems at Mymensingh (average of 2015-16 and 2016-17)

Treatment	LER values			ATER	SPI	RVI	MAI ($Tk. ha^{-1}$)
	Maize	Garden pea	Total				
T_1	0.93	0.46	1.39	1.18	12.09	5.30	70,481
T_2	0.89	0.67	1.56	1.28	14.21	6.62	1,11,971
T_3	0.86	0.60	1.46	1.21	13.31	6.12	90,992
T_4	1.00	00	1.00	-	-	-	-
T_5	00	1.00	1.00	-	-	-	-

Aggressivity (A): The competitive ability of the component crops in an intercropping system is determined by its aggressivity value. Regardless of the intercropping system, there was a positive sign for maize and a negative sign for garden pea indicating that maize was dominant crop (+ve) while garden pea appeared as dominated crop (-ve). Higher aggressivity value (0.426) was calculated with maize (100 %) + broadcast of garden pea (100%) in between maize lines (Table 5). Results showed positive aggressivity for maize at (100%) + two rows of garden pea (66%) in between maize lines and maize (100%) + broadcast of garden pea (100%) in between maize lines planting pattern while it proved less competitive and was dominated by garden pea at maize (100 %) + one line garden pea (33%) in between maize lines.

Competitive Ratio (CR): The competitive ratio values showed variation among the intercropping indicating differential competitive ability of component crop as influenced by intercrops of garden pea (Table 5). Garden pea showed higher value of CR (0.70-1.50) than maize (0.67-1.43) indicating garden pea as the best competitor than maize. Consequently, maize (100%) + one row of garden pea (33%) in between two maize lines (T_1) intercropping system with higher difference of CR (0.83) exhibited dissimilarities in competitiveness between the component crops. However, Maize (100%) + two rows of garden pea (66%) in between maize lines (T_2) intercropping system with lower difference of CR (0.56) showed merely similar competitiveness between the component crops. The results expressed that similar competitiveness with minimum CR between component crops provided complementary utilization of growth resources for better performance of intercropping with higher productivity. These results are in agreement with the findings of Islam *et al*. (2016).

Table 5. Aggressivity index (A), competitive ratio (CR) and relative crowding coefficient (RCC) of maize and garden pea in maize + garden pea intercropping systems at Mymensingh (average of 2015-16 and 2016-17)

Treatment	Aggressivity index (A)		Competitive ratio (CR)			Relative Crowding Coefficient (RCC)		
	Maize	Garden pea	Maize	Garden pea	Differences	Maize	Garden pea	Total
T_1	-0.024	0.024	0.67	1.50	0.83	-18.37	2.54	46.66
T_2	0.003	-0.003	0.88	1.14	0.56	-13.55	3.14	42.55
T_3	0.420	-0.420	1.43	0.70	0.73	-42.00	1.49	62.58
T_4	-	-	-	-	-	-	-	-
T_5	-	-	-	-	-	-	-	-

T_1= Maize (100%) + one row garden pea (33%) in between maize lines, T_2= Maize (100%) + two row garden pea (66%) in between maize lines, T_3= Maize (100%) + garden pea broadcast (100%) in between maize lines and T_5= Sole garden pea

Relative Crowding Coefficient (RCC): Relative crowding coefficient (RCC) of maize and garden pea was more than unity indicating greater non-competitive interference than the competitive one. The intercropped garden pea had higher relative crowding coefficient values than the intercropped maize. Negative relative crowding coefficient values for maize were obtained in all intercropping systems (Table 5). In this study, 100 % maize + 100 % garden pea (T_3) had the maximum RCC value (62.58) and after that 100% maize + 33% garden pea (T_1) and100% maize + 66 % garden pea (T_2) with 46.66 and 42.55, respectively.

Conclusion

From the experimental findings it can be concluded that the productivity of unit land area is increased by intercropping rather than monocultures. Maize intercropped with garden pea produced higher grain yield than maize sole crop. The competitive functions also showed that intercropping had a major advantage over sole cropping. So, for optimum and sustainable productivity and profitability of maize-garden pea intercrop combinations, a planting pattern comprising of maize (100 %) + two rows of garden pea (66%) in between maize lines (T_2) could be suitable combination in Old Brahmaputra Floodplain (AEZ-9) to increase land use efficiency and maximum profit.

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IN VITRO SHOOT REGENERATION OF MINT (*Mentha sp.* L.) USING DIFFERENT TYPES OF EXPLANTS AND LEVELS OF BENZYLAMINOPURINE

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Abstract

An experiment was conducted in the Tissue Culture Laboratory of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur-1706 from March 2013 to February 2014 for *in vitro* shoot regeneration of mint using different *explant*s and levels of benzylaminopurine (BAP) in full strength MS media. Three different types of *explant*s *viz*. nodal segment, shoot tip and leaf were evaluated using three levels of BAP (1.0, 2.0 and 3.0 mg/l) along with control for shoot regeneration. Results revealed that shoot tip and nodal segments performed better than leaf as *explant*s in almost all the characters studied. Shoot tip and nodal segments initiated shoot within the shortest time of 9.6 and 10.6 days, respectively with 1.0 mg/l of BAP. Regarding number of shoot per *explant* and number of node/shoot, shoot tip and nodal segments along with 1.0 mg/l of BAP performed superior at almost all days after inoculation. In case of interaction of *explants* and BAP, better performance was recorded in most of the studied parameters from shoot tip and nodal segments alongwith 1.0 mg/l BAP. Therefore, for *in vitro* shoot regeneration of mint, shoot tip or nodal segment may be used with 1.0 mg/l of BAP.

Keywords: *In vitro* shoot, BAP, *Explants***,** Mint., *Mentha*.

Introduction

Mint (M*entha sp*) is an aromatic plant that contains volatile essential oils, used fresh or dried as flavoring agent in a wide variety of foods. Mint oils are used in making different dental and medicinal products as well as in cosmetic industries. It is commonly known as *pudina* having dark green leaves and is usually found near ponds and other humid places of homestead. This perennial plant belongs to the family Lamiaceae and has approximately 25 species (Bhat *et al.*, 2002). Mint cultivation is widely distributed around the world. The United States of America is the main producer of peppermint and spearmint followed by India. The average yield range of mint is 5.35-11.40 MT/ha where maximum yield is 13.75 MT/ha in some cultivars (Anon., 2008).

Mints are mainly propagated vegetatively rather than by seeds (Safaeikhorram *et al*., 2008). Programs for crop improvement via conventional breeding have been

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unsuccessful in mint because commercial cultivars are pollen-sterile and have a high ploidy number. Only some mints, such as *M. arvensis* L., *M. pulegonium* L. and *M. spicata* L., are propagated by seed (Heidari *et al*., 2012). In our climatic conditions, poor overwintering may occasionally produce an insufficient number of seedlings. However, this conventional process of vegetative propagation through stolon is a slow process and they are susceptible to many diseases (Safaeikhorram *et al.*, 2008). To overcome these problems, *in vitro* propagation of mint may be beneficial. It also offers year-round production, precise crop production scheduling and reduce stock plant space of crops. The main advantage of *in vitro* propagation lies not only in the mass scale production but also in the production of high quality and uniform planting material that can be multiplied on a year-round basis under disease-free conditions anywhere irrespective of the season and weather.

As an important medicinal plant, mint may be a source of income for domestic use as well as for export. Therefore, attempt was made to develop protocols for large-scale *in vitro* propagation of locally available *Mentha sp*. So far, several works have been done in Bangladesh scatteredly on *in vitro* propagation of this plant. Considering the above facts, the present investigation has been undertaken to find out the performance of different *explant*s with the optimum level of BAP for *in vitro* shoot regeneration of mint.

Materials and Methods

The experiment was conducted in the Tissue Culture Laboratory of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur-1706, from March 2013 to February 2014. *Explant*s of mint were taken from previously collected genotype (MP-12) grown in the Research Field of Department of Horticulture, BSMRAU, Gazipur. The genotype was collected from Mymensingh under a completed project of Ministry of Science and Technology, GoB. Tender and actively growing nodal segments (E_1), shoot tips (E_2) and leaves (E_3) were used as *explant*s. Three levels of BAP (mg/l) viz. B_2-1.0, B_3-2.0 and B_4-3.0 alongwith control (B_1- no BAP), were included in the experiment. Two factors experiment was laid out in Completely Randomized Design (CRD) with ten replications, where one (1) culture tube represented one replication**.**

Preparation of stock solution of BAP (6- Benzyl-aminopurine)

For preparing stock solution, 10 mg of BAP was weighed by an electric balance and placed on a clean beaker and then dissolved by few drops of 0.1 N HCl. The mixture was then collected in a 100 ml measuring cylinder and volume was made up to 100 ml by addition of distilled water. The strength of prepared stock solution was 100.0 mg/l. The prepared solution was then poured into a glass bottle, labeled properly and then stored in a refrigerator at 4°C.

Preparation of culture media

The medium contained full strength (4405.19 mg/l) Murashige and Skoog's (MS) inorganic salts and vitamins. To prepare 400 ml of the MS medium; 1.76 g MS powder was weighed and dissolved in 300 ml of distilled water in a 1.0 L beaker. Therefore, 24 g sucrose along with treatment wise different concentrations of hormonal supplements of BAP were added to the solution in the beaker and the mixture was mixed properly by using magnetic stirrer. The pH of the medium was adjusted to 5.7±1 with a pH meter by using 0.1 N sodium hydroxide (NaOH) or 0.1 N HCl and finally the volume of the solution was made to 400 ml with further addition of distilled water. In order to solidify the media, high brand agar of 2.8 g (@ 7%) was added to the solution and then thoroughly mixed and gently boiled in a microwave oven for 10–12 min. until the agar was dissolved completely. After that, about 10 ml prepared melted media was dispensed into each culture tube while the medium was still hot. The culture tubes were sealed with aluminum foil and marked with glass marker pen to indicate specific treatment. The culture tubes were then sterilized at 1.06 kg/cm^2 pressure at 121°C for 25 min. in an autoclave. After autoclaving, the culture media was left overnight within the autoclave to become cool and solid and were taken out. Inoculation was done in the following day.

Preparation of *explants* and inoculation

For establishing the plant in media, the tender actively growing mint shoots were collected and used in this study. The collected *explant*s were taken in a beaker and washed in running tap water for 15 min. The *explant*s were the sterilized with 1% osbam for 15 min and were again washed with tap water three times. Finally, sterilization was carried out in the aseptic condition under a laminar flow cabinet. Previously prepared materials were taken in a sterile pot and suspended in 0.1% $HgCl_2$ solution for 10 min. to ensure contamination free *explant*s. Then the *explants* were washed for 3–4 times with double distilled water to remove all traces of $HgCl_2$. Therefore, the leaves around the shoot tips were carefully removed and shoot tips were placed inside the test tubes carefully. After placing the *explant*s in the test tubes, they were kept inside the growth chamber where, physical condition for growth and development of cultures were maintained. The temperature was set to 22±1°C with a light intensity of 2000–3000 lux from fluorescent tubular lamps and the photoperiod maintained generally 16 h light and 8 h dark (16L/8D) with 60–70% relative humidity.

Successful shoot formation becomes evident when small green fresh leaves began to emerge. It was the first sign of regeneration. So, each test tube was observed regularly and the days to shoot initiation was recorded for the respective test tube. Other data were collected from 25 to 65 days after inoculation (DAI) at 10 days interval on number of shoot per *explant*, length of the longest shoot and number of node per shoot. Collected data were analyzed using MSTAT-C statistical package programme. Differences among the means were compared following Duncan's Multiple Range Tests (DMRT) at 1% level of significance.

Results and Discussion

Results regarding response of types of *explant*s, levels of BAP and their interaction on different aspects of *in vitro* shoot regeneration of mint are presented in the following heads.

Days to shoot initiation

Response of *explants* regarding days required for *in vitro* regeneration of shoot showed significant variation in mint. The highest number of days (46.15) required for shoot initiation in leaf whereas, shoot tip and node required relatively shorter period of 18.85 and 17.10 days, respectively (Fig. 1.) which were statistically similar. This finding corroborated with Ghanti *et al*. (2004) who also reported a non-significant difference regarding days required for shoot initiation in mint from shoot tip and nodal segment *in vitro*. The lowest number of days required for *in vitro* shoot regeneration in shoot tip and node might be due to higher totipotency of shoot tip and node having dormant bud which is absent in leaf, or might be due to different cytokinin complements of the shoot tip, nodal segment and leaves (Van, 2009). Heidari *et al.* (2012) opined that shoot meristems and nodes were more potent for shoot regeneration compared to leaf disk *explant*s which agreed the present findings. Range of days required for shoot initiation from shoot tip, nodal segment and leaf was 17.10- 46.15 in the present study which differed from the findings of Samantaray *et al.* (2012) who reported a range of 22.6-26.0 days required for shoot initiation in mint.

Different concentration of BAP showed significant variation in mint regarding days required for *in vitro* shoot initiation (Fig. 2). The highest days (35.53) required in control followed by BAP at 3.0 (27.33 days), 2.0 (24.73 days) and 1.0 mg/l (21.87 days) (Fig. 2). It was observed that days required for shoot initiation increased with the increase of BAP concentration. It might be due to inhibition characteristic of BAP on shoot initiation (Van, 2009). The highest days required in control reflected the positive effect of BAP on shoot initiation.

The interaction effect of *explant*s and levels of BAP on days required for shoot regeneration *in vitro* also showed significant variation (Fig. 3). The highest number of days required (47.80 days) in the combination of leaf without BAP (E_1B_1) followed by E_3B_4 (46.80 days), E_3B_2 (45.40 days) and E_3B_3 (44.60 days). The lowest number of days required for *in vitro* shoot regeneration was in E_2B_2 (9.60 days) followed by E_1B_2 (10.60 days) where shoot tip and nodal segments were used with 1.0 mg/l of BAP, respectively. It might be due to higher rate of growth and regeneration of shoot tip and nodal segment and best performance of BAP at 1.0 mg/l in mint. Present findings provide evidence that a further increase in concentration of BAP showed some adverse effect and subsequently increased number of days required for shoot development which corroborated with the findings of Samantary *et al.* (2012), Xiao *et al.* (2007), Shawl *et al.* (2006) and Godoy *et al.* (2005). It is also revealed from Fig. 3 that days required for *in vitro* shoot regeneration increased with the increased concentration of BAP. Inhibiting criteria of cytokinin at higher concentration on shoot initiation and shoot elongation might be the reason behind this (Van, 2009).

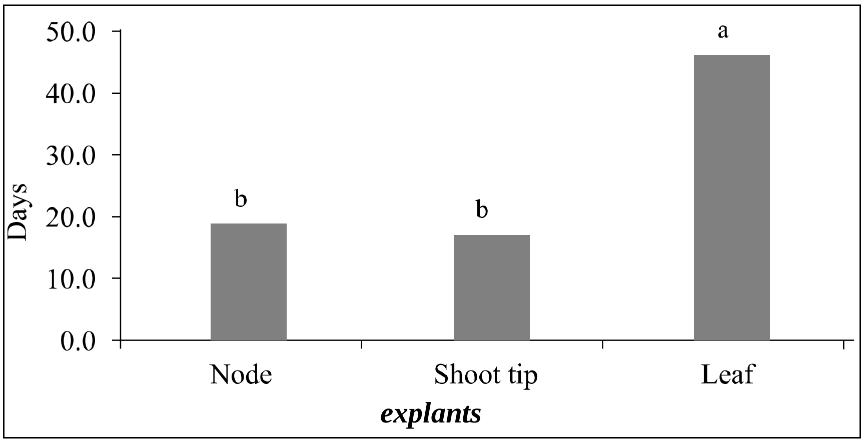

Fig. 1. Response of *explants* on days required for shoot initiation in mint after inoculation. Significant differences (p<0.01) among the *explants* are indicated by different letters according to DMRT.

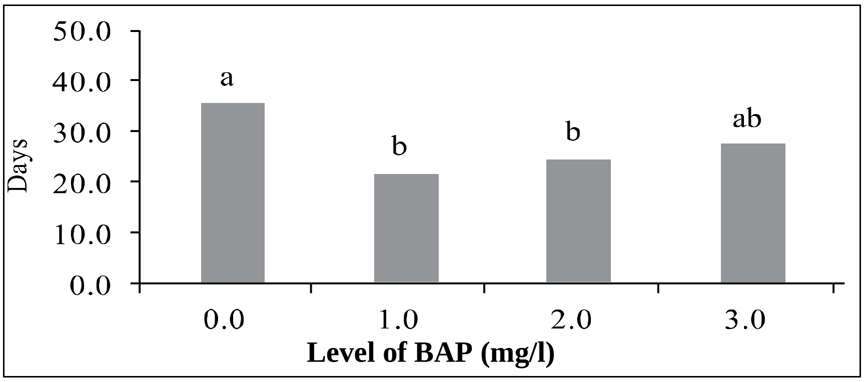

Fig. 2. Fig. 2. Effect of BAP on days required for shoot initiation in mint after inoculation. Significant differences (p <0.01) among the *explants* are indicated by different letters according to DMRT.

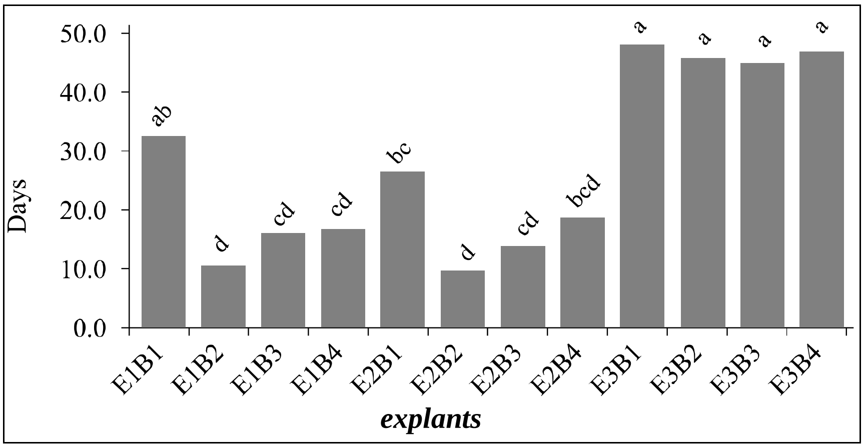

Fig. 3. Effect of BAP on days required for shoot initiation in mint after inoculation. Significant differences (p<0.01) among the *explants* are indicated by different letters according to DMRT.

E_1= Node, E_2= Shoot tip and E_3= Leaf; B_1= 0.0, B_2= 1.0, B_3= 2.0 and B_4= 3.0 mg/l of BAP.

Number of shoots per *explant*

Results presented in Fig. 4 revealed that the number of shoots increased among the *explant*s with the increase of days after inoculation (DAI). Shoot tip was found to be more responsive regarding number of shoots followed by node and leaf. At 25 days after inoculation, number of shoots produced by shoot tip and node were 0.95 and 0.80, respectively produced shoot but leaf started to produce shoot (0.10) at 45 DAI. Statistically similar numbers of shoots were produced by shoot tip and nodal segment of mint till 55 DAI in *in vitro* condition. However, at 65 DAI, shoot tip produced the highest number of shoots (3.35) per *explant* and this was statistically different from other two *explant*s. Node produced the second highest number of shoots (2.45) per *explant,* which differed significantly from the leaf (Fig. 4). The better performance of shoot tip and node in producing the highest number of shoots might be due to presence of apical bud in those *explant*s. Dhawan *et al.* (2003), Chaturvedi *et al*. (2007), Sujana and Naidu (2011a, 2011b) and Heidari *et al.* (2012) also reported the better performance of node and shoot tip as *explant* for *in vitro* shoot regeneration in mint. On the other hand, Eck and Kitto (1992) successfully regenerated shoots from peppermint and orange mint using leaf as *explant*s which differed from the present findings.

BAP exhibited significant influence on *in vitro* shoot regeneration in mint in respect of number of shoots/*explant* at different DAI (Fig. 5). At 25 DAI, the highest number of shoots (1.27) was recorded from BAP at 1.0 mg/l followed by 0.67 and 0.40 at 2.0 and 3.0 mg/l, respectively. Similar trend was also observed at 35, 45, 55 and 65 DAI. No shoot was found upto 35 DAI in control.

Number of shoots was found to be decreased with the increase of BAP concentration at all the studied days after inoculation. However, the best performance was observed with the BAP at 1.0 mg/l concentration in all the studied days after inoculation. This result is consistent with the findings of Ghanti *et al.* (2004) who reported that the highest number of shoots per *explant* in mint using 1.0 mg/l of BAP. They also found the number of shoots to be decreased with the increase of BAP concentration from 1.0 mg/l. This indicated the upper limit of the concentration of BAP for mint. This result slightly differed from Heidari *et al.* (2012), who recorded the highest number of shoots with 1.5 mg/l of BAP in *Mentha longifolia explant*s under 24 hours photoperiod in culture condition. This discrepancy might be due to the difference between *explant*s and culture condition. Many other researchers also documented the response of BAP in shoot regeneration of mint (Chishti *et al.*, 2006; Bolouk *et al*., 2013; Bariya and Pandya, 2014 and Shasany *et al*., 1998). George (1993) stated that cytokinins, especially BAP are reported to overcome apical dominance, release lateral buds from dormancy and promote shoot formation. The result differed from Bolouk *et al*. (2013) who reported that using *Mentha piperita explant*s produced the highest number of shoots in those receiving a treatment of 2.0 mg/l of BAP. This disparity might be due to species or *explant* or culture condition differences between two experiments.

Regarding interaction effect of *explant*s and different concentrations of BAP, it was observed that shoot number per *explant* was increased gradually from 25 to 65 DAI in all the treatment combinations. However, no shoot was found to be produced upto 35 DAI in the treatment combinations E_1B_1, E_2B_1, E_3B_1, E_3B_2, E_3B_3 and E_3B_4 (Table 1). No shoot formation in E_1B_1, E_2B_1 and E_3B_1 treatment combinations might be due to the absence of BAP in the medium, as BAP have effective role in DNA synthesis and mitosis (Sujana and Naidu, 2011b). While, no shoot in E_3B_2, E_3B_3 and E_3B_4 treatment combinations might be due to the absence of any apical buds in leaves. Shoot tip with 1.0 mg/l of BAP (E_2B_2) produced the highest number of shoots in all the recorded DAI, which were statistically similar with E_1B_2 upto 55 DAI. At 65 DAI, although, the treatment combination E_2B_2 produced significantly the highest number of shoot per *explant* (5.20) but the treatment combination E_1B_2 produced the 2nd highest number of shoots (3.80) per *explant*. This results authenticated the superiority of shoot tip and node as *explant* with 1.0 mg/l of BAP for *in vitro* regeneration of shoot in mint, which corroborate the findings of Ghanti *et al.* (2004) and Heidari *et al.* (2012), who recorded the highest number of shoots using 1.0 mg/l of BAP in both shoot tip and nodal *explant* of mint *in vitro.*

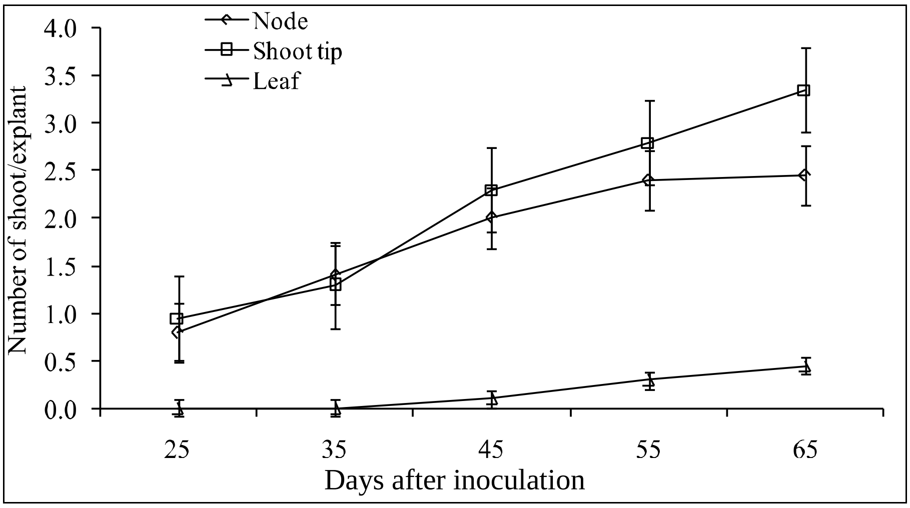

Fig. 4. Response of explants on number of shoot regeneration in mint at different days after inoculation. Vertical bars indicate ± SE.

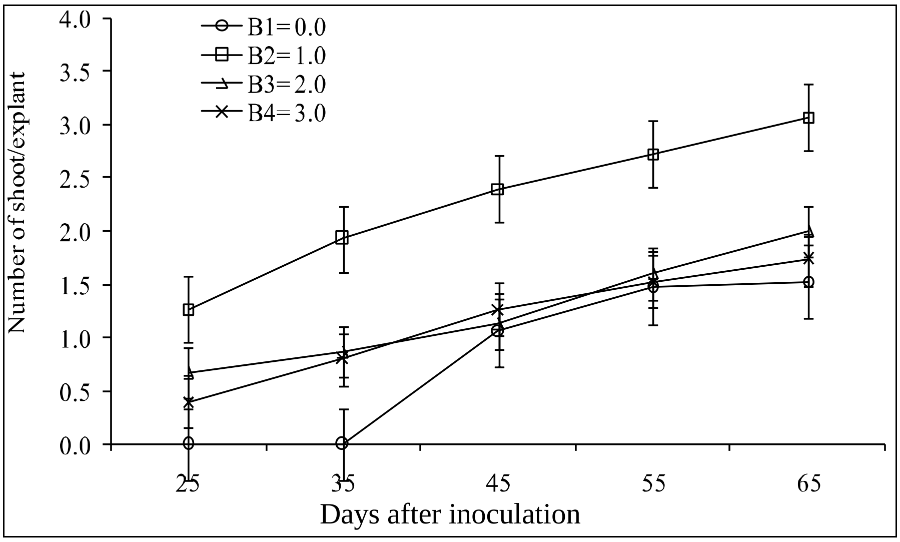

Fig. 5. Effect of BAP on number of shoot regeneration in mint at different days after inoculation. Vertical bars indicate ± SE.

Number of node per shoot

While studying the effect of *explant* on number of node, it was found that the number of node increased among the *explant*s with the increase of days after inoculation (Fig. 8). Shoot tip performed better regarding the number of node per shoot followed by nodal segment and leaf. At 25 DAI, shoot tip (1.85) and nodal segment (1.25) produced node but leaf started to produce node at 45 DAI (0.20) as it started to produce shoot at 45 DAI. The highest number of node produced by shoot tip and nodal segment of mint showing statistically similar result from 25 to 65 DAI in *in vitro* condition. However, at 65 DAI, nodal segment produced the highest number of nodes (9.15) per shoot, which was statistically similar with shoot tip (8.90) and significantly different from leaf (1.30). More number of node is important for *in vitro* culture, as it may be used as *explant*s in further multiplication of plant through subculture, which is one of the main objectives of *in vitro* propagation from a single plant at the shortest time. So, from this point of view, shoot tip and node performed better.

Table 1. Interaction effect of *explant*s and BAP on number of shoot per *explant* in mint at different days after inoculation

Treatment combination	Number of shoots/*explant* at				
	25 DAI	35 DAI	45 DAI	55 DAI	65 DAI
E_1B_1	0.00 d	0.00 c	1.20 bcd	1.80 bc	1.80 de
E_1B_2	1.60 ab	2.80 a	3.40 a	3.80 a	3.80 b
E_1B_3	1.00 bc	1.40 b	1.80 bc	2.00 b	2.00 d
E_1B_4	0.60 cd	1.40 b	1.60 bc	2.00 b	2.20 d
E_2B_1	0.00 d	0.00 c	2.00 b	2.40 b	2.60 cd
E_2B_2	2.20 a	3.00 a	3.80 a	4.40 a	5.20 a
E_2B_3	1.00 bc	1.20 b	1.60 bc	2.40 b	3.40 bc
E_2B_4	0.60 cd	1.00 bc	1.80 bc	2.00 b	2.20 d
E_3B_1	0.00 d	0.00 c	0.00 d	0.20 d	0.20 f
E_3B_2	0.00 d	0.00 c	0.00 d	0.00 d	0.20 f
E_3B_3	0.00 d	0.00 c	0.00 d	0.40 d	0.60 f
E_3B_4	0.00 d	0.00 c	0.40 d	0.60 cd	0.80 ef
Mean	0.58	0.90	1.47	1.83	2.08

Means followed by same letter(s) in a column do not differ significantly at 1% level by DMRT.

E_1= Node, E_2= Shoot tip and E_3= Leaf; B_1= 0.0, B_2= 1.0, B_3= 2.0 and B_4= 3.0 mg/l of BAP.

Results presented in Fig. 9 revealed that the effect of BAP on *in vitro* regeneration of mint regarding the number of node was significant in different concentrations at each day of data recorded (25, 35, 45, 55 and 65 DAI). While studying the effect of BAP on *in vitro* regenerated mint at 25 DAI statistically similar rank was found regarding the number of node per shoot at 1.0 mg/l (1.80) and 2.0 mg/l (1.40) which was significantly different from 0.93 at 3.0 mg/l of BAP. However, no node was produced at 25 DAI without BAP. Similar trend was observed at 35, 45, 55 and 65 DAI where number of node per shoot produced using 1.0, 2.0 and 3.0 mg/l of BAP occupied the statistically similar rank and that was significantly different from control. However, the highest number of node per shoot produced when BAP was used @ 1.0 mg/l at all the studied days.

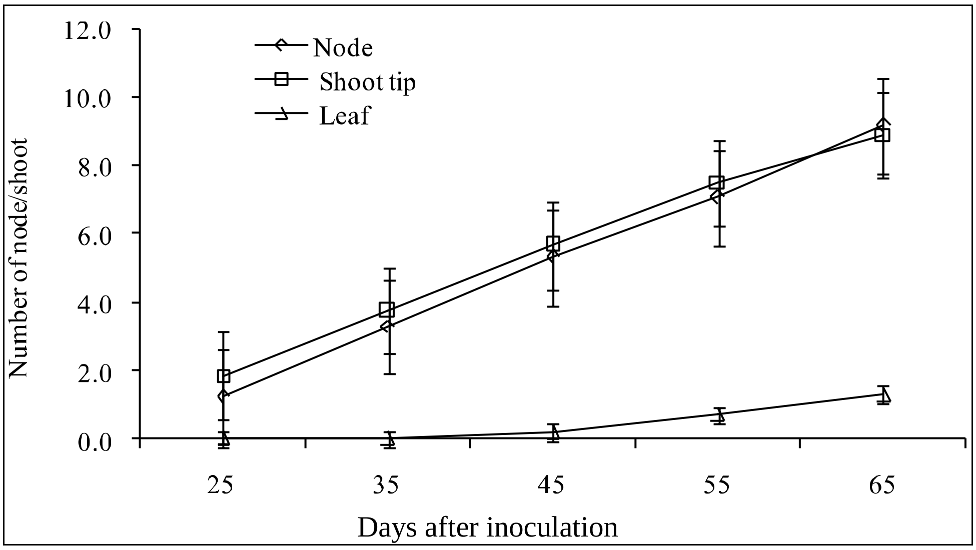

Fig. 8. Response of *explant* on number of node in mint at different days after inoculation. Vertical bars indicate ± SE.

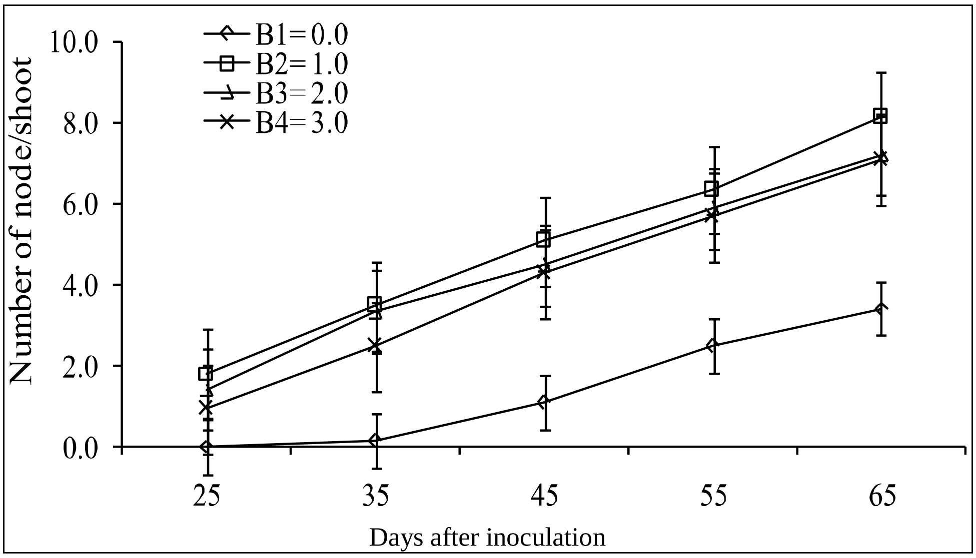

Fig. 9. Effect of BAP on number of node in mint at different days after inoculation. Vertical bars indicate ± SE.

In case of interaction of *explant*s with different concentrations of BAP on number of node per shoot, it was observed that node number increased gradually from 25 to 65 DAI in all the treatment combinations (Table 3). However, no nodes were found to be produced upto 25 DAI in the treatment combinations E_1B_1, E_2B_1, E_3B_1, E_3B_2, E_3B_3 and E_3B_4; upto 35 DAI in the treatment combinations E_2B_1, E_3B_1, E_3B_2, E_3B_3 and E_3B_4; upto 45 DAI in the treatments E_3B_1, E_3B_2 and E_3B_3; and upto 55 DAI in the treatment combination E_3B_2. As in these days, no shoot was produced and therefore, no node was observed in these treatments. Shoot tip with 1.0 mg/l of BAP (E_2B_2) produced the highest number of nodes per shoot at all recorded days (3.40 at 25 DAI, 5.60 at 35 DAI, 7.60 at 45 DAI, 9.60 at 55 DAI and 12.00 at 65 DAI), which were statistically similar with some other combinations of shoot tip and nodal segment with different concentrations of BAP. A similar trend of decreasing number of node with higher concentration of BAP (2.0 and 3.0 mg/l) than at 1.0 mg/l was observed in shoot tip and leaf. But in case of leaf, it performed better regarding number of node per shoot at higher concentration of BAP at 3.0 mg/l than other concentrations of BAP at each day of data recorded. It might be due to lack of cytokinin in leaf showing the higher requirement of BAP for better performance of leaf in *in vitro* condition.

Table 3. Interaction effect of *explant*s and BAP on number of node in mint at different days after inoculation

Treatment combination	Number of node/shoot at				
	25 DAI	35 DAI	45 DAI	55 DAI	65 DAI
E_1B_1	0.00 c	0.40 c	1.60 b	3.20 bc	5.00 b
E_1B_2	2.00 ab	4.80 ab	7.60 a	9.40 a	11.80 a
E_1B_3	1.80 b	4.80 ab	6.80 a	8.40 a	10.80 a
E_1B_4	1.20 bc	3.20 b	5.20 a	7.20 a	9.00 a
E_2B_1	0.00 c	0.00 c	1.60 b	3.80 b	4.60 b
E_2B_2	3.40 a	5.60 a	7.60 a	9.60 a	12.00 a
E_2B_3	2.40 ab	5.20 ab	6.60 a	8.40 a	9.20 a
E_2B_4	1.60 b	4.20 ab	6.80 a	8.20 a	9.80 a
E_3B_1	0.00 c	0.00 c	0.00 b	0.40 cd	0.60 c
E_3B_2	0.00 c	0.00 c	0.00 b	0.00 d	0.60 c
E_3B_3	0.00 c	0.00 c	0.00 b	0.80 bcd	1.60 bc
E_3B_4	0.00 c	0.00 c	0.80 b	1.60 bcd	2.40 bc
Mean	1.03	2.35	3.72	5.08	6.45

Means followed by same letter(s) in a column do not differ significantly at 1% level by DMRT.

E_1= Node, E_2= Shoot tip and E_3= Leaf; B_1= 0.0, B_2= 1.0, B_3= 2.0 and B_4= 3.0 mg/l of BAP.

Conclusions

Full strength MS media along with 1.0 mg/l of BAP can be used for *in vitro* shoot regeneration of mint; where, the *explant*s may be shoot tip or nodal segment.

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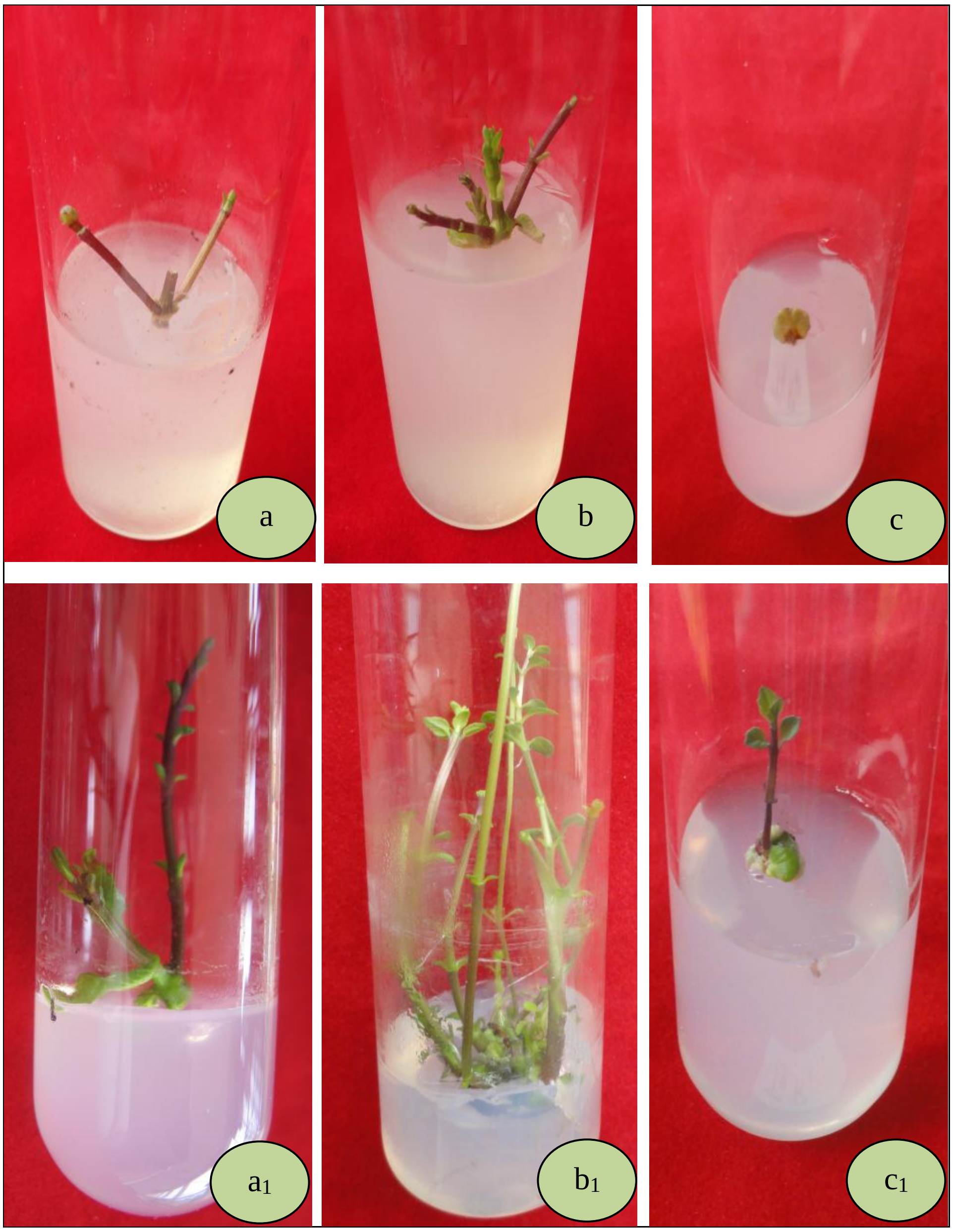

Fig. 10. *In vitro* regeneration of shoot in mint (a, b and c= *explant* from nodal segment, shoot tip and leaf, respectively; a_1, b_1 and c_1 is regenerated shoot from nodal segment, shoot tip and leaf, respectively).

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CONTENTS

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