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ANTIOXIDANT POTENTIALS OF DIFFERENT POTATO GENOTYPES

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AND M. MOHI-UD-DIN[4]

Abstract

The present investigation was undertaken to analyze the antioxidant potential of sixteen different potato genotypes. Eleven yellow fleshed potato genotypes namely Forza, Courage, Laura, Rosa Gold, Lady Rosetta, Cumbica, Asterix, Coronada, Granola, Cardinal and Diamant and five purple fleshed potato genotypes namely Jam Alu, KAC 10063, KAC 10064, KAC 10069, KAC 10097 were used as experimental materials. Total carotenoids, anthocyanin, phenolics, flavonoids, ascorbic acid and antioxidant activity in the above mentioned genotypes were determined to compare the antioxidant potentials of the genotypes. Analysis of above mentioned parameters resulted significant variation in their contents in both yellow and purple fleshed genotypes. The results indicate the purple fleshed genotypes showed significantly higher carotenoids, anthocyanin, flavonoids and total antioxidant activity than those of yellow fleshed genotypes. The findings also suggested the antioxidant activity of the genotypes positively correlates to the total content of carotenoids, anthocyanin and flavonoids. Since, purple fleshed genotypes showed higher antioxidant properties, the results of this study claim that the purple fleshed genotypes would be suitable for direct consumption as vegetables which might increase the health and food security of human beings.

Keywords: Potato, anthocyanin, phenolics, carotenoids and flavonoids.

Introduction

Potato, the fourth most producing (376 million tons) important food crop after maize, wheat and rice (FAOSTAT, 2016), is primarily considered as a source of carbohydrate, but recent studies propose that it has high nutritional value due to the presence of natural bioactive compounds including cellular antioxidants. Potato is consumed as the major vegetable in developing country like Bangladesh where annual demand of potato is greater than 7.0 million tons against its production of 9.4 million tons (BBS, 2016). The people of Bangladesh mostly consume white fleshed potatoes though very few people are interested to coloured fleshed genotypes due to having their good nutritional value. A lot of investigations concerning growth, yield, nutritional and physiological properties of potato genotypes throughout the world have been found, but very few claims

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have been reported on the crucial biochemical properties such as antioxidant potentials of the genotypes. Moreover, very little efforts are made with coloured potatoes which likely to be the good source of antioxidants and good for human health. Studies have indicated that antioxidants have high free-radical scavenging activity, which helps reduce the risk of chronic diseases including cancer and age-related neuronal degeneration (Teow *et al*., 2007). Investigations suggest that antioxidant activity in coloured potatoes is associated with the presence of different phytochemicals such as polyphenols, anthocyanins, flavonoids, carotenoids, ascorbic acid, tocopherols, alpha-lipoic acid and selenium (Kosieradzka *et al.*, 2004; Lachman *et al.*, 2009). Several findings also suggest that purple potatoes contain anthocyanin and phenolics and show high antioxidant activity than that of red, yellow and white potato cultivars indicating the potentials of coloured potato genotypes in human health security (Jansen and Flamme, 2006). Investigations on the above issues have been reported throughout the world, but very few claims are made so far in the country like Bangladesh where potato is consumed as the major vegetable crop. Hence, along with carbohydrate, the antioxidant rich coloured genotypes should be explored to meet the additional health security. Considering the facts, in the present efforts, sixteen potato genotypes comprising both yellow and purple fleshes were taken into consideration to analyze them to find out antioxidant rich genotypes which might fulfill the basic requirements as direct consumption and food security regarding to health concern issue.

Materials and Methods

Plant materials

Sixteen potato genotypes namely Forza, Courage, Laura, Rosa Gold, Lady Rosetta, Cumbica, Asterix, Coronada, Granola, Cardinal and Diamant of yellow flesh and Jam Alu, KAC 10063, KAC 10064, KAC 10069, KAC 10097 of purple flesh were used as experimental material. The materials were collected from Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural Development Corporation (BADC) and local areas of Gazipur. Randomized Complete Block Design with three replications was used as experimental design Potato genotypes were planted in the experiment field on 25 November 2015 and the tubers were harvested at 90 DAP (Days after Planting) and kept in room temperature for curing. Chemical analyses were performed in the Crop Botany laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University.

Total carotenoids

Total carotenoid content was determined spectrophotometrically according to the procedure of Lachman *et al*. (2003) with slide modifications. Briefly, 1 g of potato sample was taken into a glass vial and 5 ml of acetone was added and kept at 4°C in the dark for 24 hours. Using the supernatant absorbance was measured at 444 nm and total carotenoid content was expressed as micrograms of lutein equivalent per gram of fresh weight sample (µg LE g^{-1} FW) for three replications from the lutein standard curve.

Anthocyanin content

Anthocyanin content was determined spectrophotometrically as described by Hughes and Smith (2007) with slide modifications. For preparing the extraction solution, 6M HCL was added into a volumetric flask where methanol and distilled water were taken earlier. Fresh potato sample was taken into an ice cold vial and extraction solution was added here. After keeping the vial at 4°C for 24 hours, 2 ml of the solution was centrifuged with distilled water and chloroform. The aliquot was taken into a cuvette and absorbance was measured at 530 nm. The anthocyanin content was expressed as micrograms of cynadin-3-glucoside equivalent per gram of fresh potato sample.

Extraction and determination of polyphenol, flavonoid content and antioxidant activity

The extraction was done by following the procedure of Nayak *et al*. (2011). Peeled and chopped potato flesh was homogenized with methanol (HPLC grade) to a uniform consistency by mortar and pestle. The samples were centrifuged at 30,000× g at 4°C for 20 min and the supernatants stored at -20°C for further analysis of total phenolics, flavonoids and total antioxidant activity.

The content of total phenolic compounds was determined spectrophotometrically according to the Folin-Ciocalteu method (Singleton *et al*., 1999). 1.0 ml of methanolic extract sample was taken into test tubes and 0.5 ml 10% (0.2 N) Folin–Ciocalteu's reagent was added here. After a 15 minutes of incubation period, 2.5 ml (700 mM) Na_2CO_3 solution was mixed and incubated at room temperature for 2 hours. The absorbance of reaction solutions was measured at 765 nm against a blank sample. The measurements were compared to a standard curve of gallic acid solutions and expressed as micrograms of gallic acid equivalents per gram fresh weight (µg GAE g^{-1} FW).

Total flavonoid content was determined according to the procedure of Zhuang *et a*l. (1992) with slide modification. Briefly, 1 ml methanol was added to potato extracts into a test tube. Following that, 1 ml of distilled water, 5% sodium nitrite and 10% $AlCl_3.6H_2O$ were added to the mixture. 2 ml of 1M NaOH was added into the test tube at 6^{th} minute. The volume was made 10 ml using distilled water and absorbance was measured at 510 nm against the blank. Total flavonoid content was expressed as micrograms of quarcetin equivalent per gram of fresh weight sample (µg QE g^{-1} FW) for three replications from the quarcetin standard curve.

The antioxidant activity of potato samples was determined using the DPPH$^{\bullet}$ radical-scavenging assay based on the ability of antioxidants to block the 2, 2-Diphenyl-1picrylhydrazyl radical (Brand-Williams *et al*., 1995). Plant extract and standard were taken into a test tube. After adding DPPH$^{\bullet}$ solution into the test tubes, they were incubated for 5 min at 25°C and finally the absorbance was measured at 517 nm. The antioxidant activity was expressed as DPPH$^{\bullet}$ scavenging percentage (%).

Extraction and determination of ascorbic acid

From tuber sample, ascorbic acid was extracted by using 4% Trichloro Acetic Acid and the supernatant of the potato extract was treated with a pinch of activated charcoal and kept for 5 minutes. Charcoal particles were removed by centrifugation (2,000 rpm for 10 min) again and aliquots were used for Ascorbic acid estimation. Extraction was added with 4% TCA, DNPH (Dinitrophenyl hydrazine) reagent and thiourea by following the method of Kapur *et al*. (2012). After incubation (37ºC, 3 hrs), 85% sulphuric acid was added to the cooled sample. Absorbance was read at 540 nm against blank.

Data Analysis

Statistical analysis was performed using MSTAT-C software and data were subjected to analysis of variance for mean comparison using Randomized Complete Block Design with three replications. Significant differences were calculated according to Duncan's multiple range test (DMRT) at $p<0.05$ and data were reported as mean ± standard error.

Results and Discussion

Total carotenoids (µg g^{-1} FW)

Carotenoids act as essential component to increase antioxidant potentials of any vegetable. We determined total carotenoids in different potato genotypes and found a great variation among them (Fig.1). The carotenoid content ranged between 0.47 to 3.00 µg g^{-1} of fresh tuber sample. The purple fleshed genotypes contained higher amount of carotenoids compared to the yellow fleshed genotypes. Among all the genotypes, KAC 10097 showed the highest amount (3.00 µg g^{-1} FW) of total carotenoids. KAC 10063, KAC 10064, KAC 10069 and Jam Alu were found to gain 2.56, 2.51, 2.09 and 1.34 µg g^{-1} FW, respectively. Among the yellow fleshed potato genotypes, Rosa Gold contained 2.78 µg g^{-1} FW and performance of which was very similar to purple fleshed genotypes. Coronada and Cumbica are statistically similar and contained 1.88 and

1.79 µg g^{-1} FW, respectively and significantly different from Courage, Forza, Laura and Granola. Some findings also made consistency to our results such as Brown *et al*. (2005) reported that the light yellow potato cultivars contained 1.01 to 2.71 µg g^{-1} FW total carotenoids. The total quantity of the carotenoids was found to be between 0.38 and 1.75 µg g^{-1} FW in eight commercial potato varieties (Breithaupt and Bamedi, 2002). Several investigations showed higher content of total carotenoids in yellow fleshed potatoes than that of white or creamy fleshed potatoes (Andre *et al*., 2007b, Burgos *et al*., 2009). From the above result, the findings suggest that the purple fleshed potatoes contain higher amount of carotenoids than that of the yellow color genotypes except the golden yellow coloured Rosa Gold (Fig. 1).

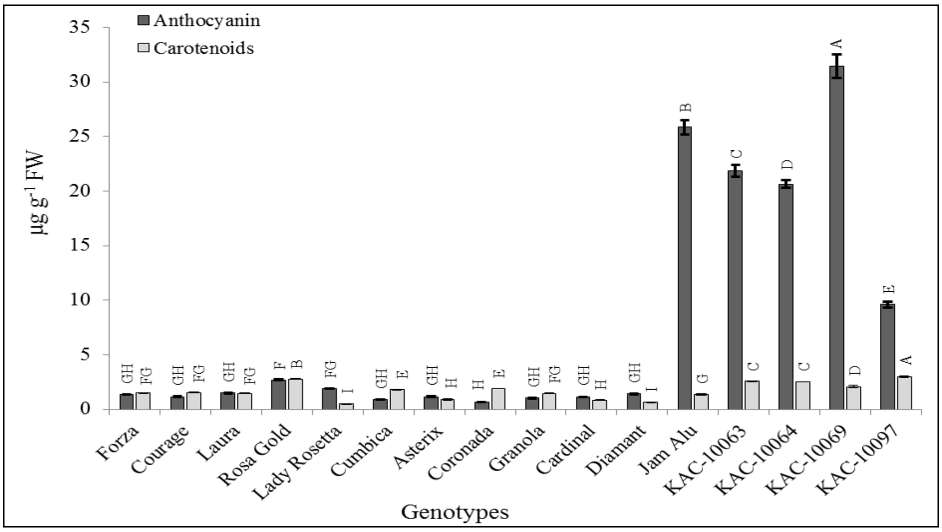

Fig. 1. Anthocynin and carotenoids of sisteen potato genotypes. Vertical bars represent ±SE values calculated from three replications; values in the same coloured columns with different letters(s) are significantly different at $p<0.05$ by DMRT.

Anthocyanin (µg g^{-1} FW)

Anthocyanin, a valuable component which have the ability to trigger the antioxidant potential of plant materials. Hence, we compared the anthocyanin content in different potato genotypes. In this finding, the anthocyanin content of potatoes ranged from 0.65 to 31.45 µg g^{-1} of fresh weight sample. Like carotenoids, anthocyanin content is also higher in the purple fleshed potato genotypes (Fig. 1). The highest amount 31.45 µg g^{-1} was found in KAC 10069 followed by Jam Alu, 25.83; KAC 10063, 221.84; KAC 10064, 20.63 and KAC 10097, 9.60 µg g^{-1} FW (Fig. 1). Yellow fleshed genotypes comprised with lower amount of anthocyanin compared to the purple fleshed potatoes and ranged from

0.65 to 2.69 µg g^{-1} FW. Rosa Gold and Lady Rosetta are statistically similar and contained 2.69 and 1.19 µg g^{-1} FW. There was no significant difference found among the content of Laura, Diamant, Forza, Courage, Asterix, Cardinal, Granola, Cumbica and Coronada (Fig. 1). According to Kita *et al*. (2015), the anthocyanin content of potatoes ranged from 6.7 to 13.0 mg 100 g^{-1} FW (67 – 130 µg g^{-1}) in purple fleshed tubers. In the present study, almost all genotypes exhibited decreased anthocyanin content which might be the effect of different genotypic and growing conditions. Leszczynski (2000) stated that the most important factor responsible for variation in anthocyanin content is genotype, along with the climate, location and storage conditions.

Flavonoids (µg g^{-1} FW)

We also determined flavonoids content which is also considered as valuable components for increasing antioxidant activity. Likewise carotenoids, anthocyanin content in the studied genotypes, flavonoid content of purple fleshed potato genotypes were much higher than those of yellow fleshed potatoes (Table 1). Flavonoid content of purple fleshed genotype ranged from 49.59 to 175.70 µg g^{-1} FW. The highest amount was found in KAC 10069 (175.70 µg g^{-1}FW). KAC 10063, KAC 10097, KAC 10064 and Jam Alu contained 167.10, 160.20, 158.30 and 49.59 µg g^{-1} FW, respectively, and they are statistically different from each other. Brown (2006) found up to 30µg 100 g^{-1} FW of flavonoids present in the white-flesh potatoes with roughly twice the amount present in purple-flesh potatoes that supports the findings of the present study. In this study, yellow fleshed genotypes showed lower performance in respect to flavonoid content than purple fleshed potatoes. Among yellow fleshed genotypes, highest amount of flavonoids accumulation was found in Rosa Gold (50.87 µg g^{-1} FW) followed by Asterix (40.55 µg g^{-1} FW), Cardinal (36.82 µg g^{-1} FW) and Diamant (32.77 µg g^{-1} FW) which are statistically different (Table 1).

Ascorbic acid content (Vitamin - C) (µg g^{-1} FW)

Ascorbic acid has antioxidant potential which is necessary for scavenging activities against the free radical produced within the human body. So it has a high nutritive value in our daily foods and estimation of ascorbic acid is very crucial in popular vegetable potato. In this experiment, range of ascorbic acid content was found from 37.42 to 164.70 µg g^{-1} fresh potato sample for yellow fleshed genotypes (Table 1). The highest value; 164.70 µg g^{-1} FW, was found in Coronada, following Diamant; 140.30 µg g^{-1}, and Granola; 100.30 µg g^{-1} fresh potato which were statistically different from each other. Rosa Gold contained ascorbic acid 63.62 µg g^{-1}FW and, the lowest amount (48.58 µg g^{-1}) was found for Lady Rosetta (Table 1). Purple fleshed potatoes gained comparatively lower amount of ascorbic acid ranges between 37.42 – 67.37 µg g^{-1} FW. KAC 10064 and KAC 10069 contained 67.73 and 67.07μg g^{-1} FW without any statistical difference. Other three genotypes Jam Alu, KAC 10097, KAC 10063 showed 50.56; 40.73 and 37.42 μg ascorbic acid content g^{-1} fresh potato respectively (Table 1). Kaur and Aggarwal (2014) described in their findings that ascorbic acid content in Indian and exotic potato genotypes ranged 110 – 190 μg g^{-1} fresh weight that clearly justifies the result of this research finding.

Table 1. Estimation of flavonoid, ascorbic acid and phenolics of sixteen potato genotypes

Genotypes	Flavonoid (μg g^{-1} FW)	Ascorbic Acid (μg g^{-1} FW)	Phenolics (μg g^{-1} FW)
Yellow Fleshed Genotypes			
Forza	10.96 ± 0.65 $^{i-k}$	85.79 ± 0.51^{d}	155.1 ± 4.26^{hi}
Courage	24.86 ± 0.98 ^{g}	59.88 ± 2.21^{ef}	304.5 ± 5.92^{c}
Laura	16.38 ± 0.57 ^{hi}	68.39 ± 1.46^{e}	277.7 ± 7.08^{d}
Rosa Gold	50.87 ± 2.23 ^{d}	63.62 ± 3.08^{e}	60.18 ± 5.02^{k}
Lady Rosetta	5.08 ± 0.40 ^{k}	48.58 ± 1.55^{gh}	267.5 ± 2.68^{d}
Cumbica	11.86 ± 1.00 ^{ij}	87.11 ± 2.22^{d}	168.0 ± 6.30^{gh}
Asterix	40.55 ± 1.03 ^{e}	80.87 ± 1.08^{d}	367.0 ± 8.06^{b}
Coronada	18.64 ± 1.20 ^{h}	164.70 ± 6.56^{a}	212.4 ±8.06^{f}
Granola	9.04 ± 0.93 ^{jk}	100.30 ± 6.96^{c}	305.3 ±7.01^{c}
Cardinal	36.82 ± 1.46 ^{ef}	52.76 ± 1.30^{fg}	241.9 ± 4.44^{e}
Diamant	32.77 ± 1.68 ^{f}	140.30 ± 2.19^{b}	270.8 ± 6.03^{d}
Purple fleshed Genotypes			
Jam Alu	49.59 ± 0.69 ^{d}	50.56 ± 0.64^{f-h}	397.2 ± 6.76^{a}
KAC 10063	167.10 ± 5.33 ^{b}	37.42 ± 6.11^{i}	163.6 ± 6.80^{gh}
KAC 10064	158.30 ± 3.86 ^{c}	67.73 ± 2.13^{e}	136.2 ± 12.68^{ij}
KAC 10069	175.70 ± 1.96 ^{a}	67.07 ± 3.39^{e}	132.8 ± 14.68^{j}
KAC 10097	160.20 ± 1.19 ^{c}	40.73 ± 2.65^{hi}	182.5 ± 6.15^{g}

SE value(s) included with the mean was calculated from three replications and letter(s) next to values in a column indicates statistical difference at $p<0.05$ level of significance by DMRT.

Total phenolic content (μg g^{-1} FW)

Fruits and vegetables contain phenolic compound and this phenolics along with anthocyanin content show good antioxidant properties (Wojdylo *et al.*, 2007) which could improve the quality of different ready potato products. Total phenolic content of the yellow fleshed potato samples ranged from 60.18 to 367.0 µg g^{-1} FW. Asterix attained the highest value (367.0 µg g^{-1} FW) for phenolic content followed by Granola (305.3 µg g^{-1} FW), Courage (304.5 µg g^{-1} FW), Laura (277.7 µg g^{-1} FW), Diamant (270.8 µg g^{-1} FW) and Lady Rosetta (267.5 µg g^{-1} FW) (Table 1). Among the purple fleshed genotypes Jam Alu obtained the highest value; 397.20 µg g^{-1} FW followed by KAC 10097, KAC 10063, KAC 10064 and KAC 10063 which were 182.5, 163.6, 136.2 and 132.8 µg g^{-1} fresh weight, respectively (Table 1). Kita *et al*. (2015) observed in his study that, purple potato cultivars are richer source of polyphenols. American purple fleshed potato tubers also contained higher amount of polyphenols, 76-181 mg of chlorogenic acid 100 g^{-1} FW (Reyes *et al*., 2005) and Andean purple fleshed Guincho Negra variety contained 285 mg 100 g^{-1} FW, higher than presented herein (Andre *et al*., 2007a). The differences in phenolic content accumulation might be due to the variation of environmental conditions, harvesting date, location, genotypic variations etc. which have been shown to be involved in the accumulation of phenolic compounds in different potato varieties (Lachman *et al*., 2009; Reyes *et al.,* 2005). Specially, the growing environment might be the possible reason for this decreased accumulation of phenolics in potatoes because Hamouz *et al.* (1999) described in his findings that, higher level of phenolic content was found in the tubers grown where the intensity of coldness is more.

Total antioxidant activity (DPPH˙ radical scavenging %)

The DPPH˙ free radical scavenging activity of the potato extract was determined in the potato genotypes here. It is a discoloration assay, which is evaluated by the addition of the antioxidant to a DPPH˙ (2, 2-diphenyl-1-picrylhydrazyl, crystalline powder of stable free-radical molecules) solution in methanol and the ability to scavenge the stable free radical of DPPH˙. We found that the antioxidant potential of yellow and purple fleshed potato range remained between 23.90 to 94.63 %. KAC 10097 contained the high level of polyphenols and anthocyanins (Fig. 2) was characterized by highest antioxidant activity and that was 94.63 % followed by KAC 10064 (94.60%), KAC 10063 (93.93%) and KAC 10069 (93.33%), respectively. Jam Alu showed antioxidant activity 64.74 %, which differs significantly from four other purple fleshed potato genotypes (Fig. 2). Antioxidant potential of yellow fleshed genotype ranges from 23.90 to 51.83 % of fresh weight. Rosa Gold, Asterix showed antioxidant potential 51.83 and 51.01 % respectively, which are significantly different from Granola (42.96 %) and other genotypes. Several efforts were also made to determine antioxidant activity in potato genotypes by various ways and found a great variation in respect to genotypes (Hesam *et al*., 2012; Reddivari *et al.,* 2007). Research findings of Kaur and Aggarwal (2014) exhibited that the range of DPPH˙ radical scavenging activity in three potato cultivars is 28.80-67.30% which is more or less justifiable to our investigations although the results of present study showed better performance than that.

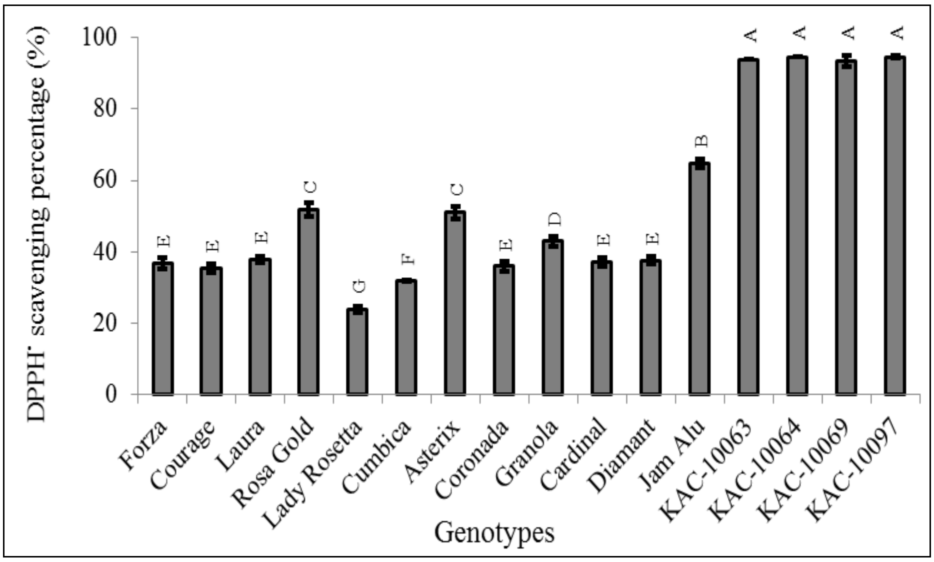

Fig. 2. Total antioxidant activity (DPPH scavenging %) in sixteen potato genotypes. Vertical bars represent ±SE values calculated from three replications; values in the columns with different letter(s) are significantly different at p≤0.05 by DMRT.

Correlation analysis

Our statistical analysis suggests antioxidant activity of the genotypes positively correlates to the content of carotenoids (R^2=0.50), anthocyanins (R^2=0.68) and flavonoids (R^2=0.68) suggesting that presence of these organic components have the great role to increase the antioxidant activity of potato genotypes (Fig. 3; a, b, c). In contrast, the antioxidant activity negatively correlates to the phenolics and ascorbic acid content of the genotypes (data not shown) although some demonstrations found positive relationship in that respect (Reyes *et al,* 2005). Moreover, our investigation found negative correlation between phenolics and carotenoids content (Fig. 3; d) supporting the higher carotenoids accumulation is responsible for lower phenolics content in the genotypes used in this study. The trend of this result is supported by the findings of Reddivari *et al.* (2007). This variation may be due to the lower accumulation of these two organic components in the genotypes used in this study (Table 1). The positive correlation between anthocyanin content and carotenoids was found in our experiment (Fig. 3; e), although Brown *et al.* (2007) found that as negative. The varied relationship among these organic components should be occurred due to the variation of genotypes and environment as well.

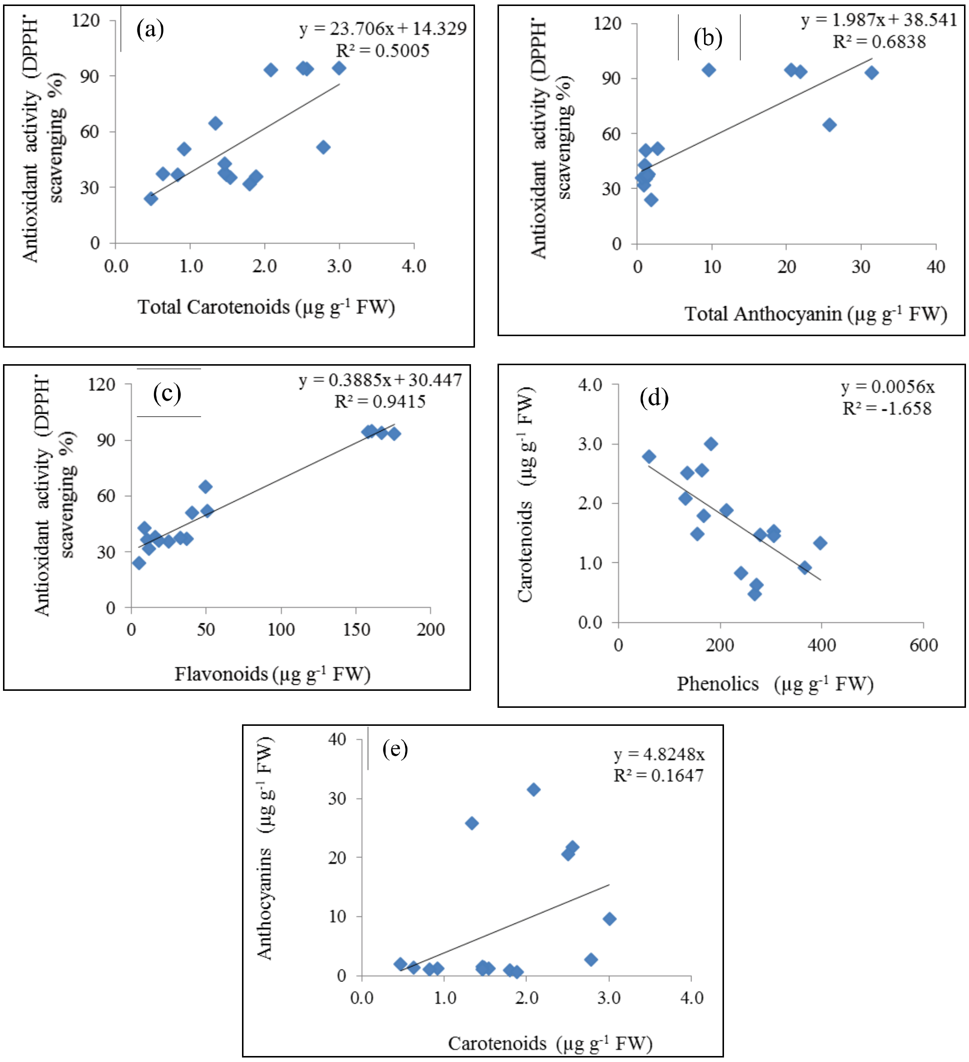

Fig. 3 Correlation of total (a) carotenoids, (b) anthocyanin, (c) flavonoids with DPPH˙ radical scavenging activity (%), and carotenoids content with (d) phenolics and (e) anthocyanin.

Conclusion

Based on the comparative biochemical analyses, it can be concluded that the purple fleshed genotypes KAC 10097, KAC 10063, KAC 10064, KAC 10069 and Jam Alu exhibited very high antioxidant potential that might be suitable for direct consumption as vegetables. Among the yellow fleshed genotypes, only Rosa gold should be as good candidate in terms of showing more or less better antioxidant potentials. However, the correlation analysis suggests that the antioxidant activity of the genotypes greatly depends on total carotenoids, anthocyanins and flavonoids content.

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PERFORMANCE OF HYBRID LINES OF POINTED GOURD (*Trichosanthes dioica* Roxb) FOR YIELD AND YIELD ATTRIBUTES

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Abstract

A field experiment was conducted at the Regional Agricultural Research Station, Ishurdi, Pabna during the growing season of 2013-14 with eighteen hybrid lines of pointed gourd and BARI Hybrid Patal -1 as check to observe their performances for yield, yield attributes and other morphological characters. The experiment was laid out in randomized complete block design with three replications. The maximum vine length (242.00 cm) and nodes/plant (18.30) was recorded from PG018×M_2. Shoots/plant ranged from 12.50 (PG027×M_2) to 4.66 (PG008 M_1). The maximum number of fruits/plant (160.00) was obtained from PG009×M_2 followed by PG012×M_1 (154.66). Individual fruit weight was recorded highest (50.10 g) in PG027×M_2, which was very close to PG008×M_2 (48.00) and PG018×M_2 (47.00 g). Weight of fruits/plant ranged from PG009×M_2 (6.86 kg) to PG022×M_1 (3.01 kg). The highest pulp weight was recorded in PG027×M_2 (44.20 g) which was statistically similar to PG008×M_2 (42.20 g). Three different leaf colour (light green, green and deep green), two types of leaf tip (pointed and blunt) and four types of leaf margin (slightly serrated, serrated, entire and undulated) were found among the hybrid lines. Four fruit colour (whitish, light green, green and dark green), four fruit stripes (no stripe, white, green white and light green) and three types of fruit curvature (slightly curved, curved and straight) were observed in different lines. The line PG009×M_2 showed better performance in respect of fruits/plant and weight of fruits/plant and thus gave the highest yield (45.74 t/ha). The lines PG008×M_2, PG007×M_2, PG017×M_2, PG027×M_2 and PG014×M_1 also produced better yield (39.23 - 35.58 t/ha). Therefore, the lines PG014×M_1, PG007×M_2, PG008×M_2, PG009×M_2 and PG017×M_2 should be subjected for further evaluation to release as variety.

Keywords: Hybrid lines, pointed gourd, *Trichosanthes dioica* and yield.

Introduction

Pointed gourd (*Trichosanthes dioica* Roxb.) locally known as 'Patal' is a popular cucurbitaceous vegetable in Bangladesh. The Bengal and Assam region of India

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are the primary centre of its origion (Singh *et al*., 1992). It is cultivated almost in all districts of Bangladesh, especially in Rajshahi, Pabna, Jessore, Bogra, Rangpur and Kushtia in summer and rainy season (Rashid, 1993). It is morphologically distinct from the other cucurbitaceous species due to its well established dioecious vegetative means of propagation (Awal *et al.,* 2005). In Bangladesh, pointed gourd is cultivated in an area of around 10006.5 ha with total production of 84096 metric tons and national average yield is 8.40 t/ha during 2014-15 (Anon., 2016). It is seen that average yield of pointed gourd (8.40 t/ha) is low compared to other countries like India (FAO, 1981) due to lack of enough high yielding varieties.

Besides carbohydrates, it provides considerable amounts of minerals. 100 g edible portion of pointed gourd contains 83.0 mg Cu, 17.0 mg S, 9.0 mg Mg and 2.6 mg Na (Singh, 1989). Scarcity of vegetables prevails in the market at the end of winter and beginning of summer seasons. During the months of May to October, only a few vegetables are available in the market and the quantity is very low against the demand. Pointed gourd becomes available in the market from March to the end of October. At this juncture, pointed gourd can fulfill the demand of vegetables to some extent.

There are three released pointed gourd varieties, two open pollinated and one hybrid in Bangladesh, which are not enough for the farmers. Farmers need more number of high yielding varieties including hybrid for cultivation. Pointed gourd is dioecious in nature and propagated vegetatively through root suckers and vines. Therefore, development and maintenance of hybrid is easier than other crops. Some hybrid lines have been developed at the Regional Agricultural Research Station, Ishurdi, Pabna. Among those lines, one line (PG027×M_2) has been released as BARI Hybrid Patal-1 after evaluation and other lines need to be evaluated. The study was, therefore, undertaken to evaluate different hybrid lines for selection of superior hybrid varieties of pointed gourd.

Materials and Method

The experiment was conducted at the Regional Agricultural Research Station of Bangladesh Agricultural Research Institute (BARI), Ishurdi, Pabna, during the growing period of October 2013 to October 2014. The experimental site was at 24.03^0 N Latitude and 89.05^0 E Longitude with an elevation of 16 m above from the sea level. The soil of the experimental field was clay loam with pH value of 8.5 belonging to the High Ganges River Floodplain under AEZ -11 (BARC, 2005). The crop received 1175 mm annual rainfall during the whole growing season. The treatment consisted of 18 hybrid lines of pointed gourd viz., PG002×M_1, PG003×M_1, PG004×M_1, PG005×M_1, PG006×M_1, PG008×M_1, PG012×M_1, PG014×M_1, PG022×M_1, PG002×M_2, PG005×M_2, PG006×M_2, PG007×M_2, PG008×M_2, PG009×M_2, PG017×M_2, PG018×M_2 and PG025×M_2

with BARI Hybrid Patal-1 as check. The fresh vines of male lines were planted on 10 October 2013 in some plots where female plants were not planted. The male and female population was maintained at 1:10 ratio. The hybrid lines of pointed gourd were evaluated in randomized complete block design with three replications. The land was ploughed well with the help of tractor followed by harrowing. Unit plot size was 4.5 m × 1.0 m. The fresh vines of different female lines were planted on 10 October 2013 maintaining the spacing of 1.5 m × 1.0 m. Watering was done in the morning for establishment of the vines. Manure and fertilizers were applied @ 10 tons of cowdung, 500 kg of Urea, 360 kg of Triple Super Phosphate, 330 kg of Muriate of Potash and 200 kg of Gypsum per hectare (Khan *et al*., 2007). Full doses of cowdung, Triple Super Phosphate and gypsum were applied as basal during pit preparation. Urea and Muriate of Potash were top dressed in three equal installments at 20, 60 and 90 days after emergence (Khan *et al*., 2007). Irrigation and other intercultural operations were done as and when necessary. Bamboo branches were used to support the plants and the plants were allowed to trail on the trellises made of bamboo slices. Vines emerged out from the plants near the soil level were pruned during the growing period. Fruits were harvested regularly when attained maturity or immediately before hardness of seeds (about 12 days after anthesis). Harvesting of fruit was started on 23 March 2014 and continued upto 28 October 2014 in different lines. Data on various morphological and yield characters were recorded from three plants of each plot following Plant Genetic Resources Descriptor (IBPGR, 1983). Fresh fruits were harvested from the field treatment wise in the month of July 2014 and brought them to the laboratory. Then ten fruits were randomly selected and kept treatment wise in white polybag (25 cm ×20 cm) having some holes in ambient condition. Days counted from first day (on harvest day) to the day at which fruits became shriveled, pale in colour and unsuitable for consumption were considered for shelf life.

Collected data were subjected to statistical analysis through MSTAT C Software and means were compared by DMRT at 5% level of probability.

Results and Discussion

A) Days to 1st female flowering, vine length, number of node and shoot

The pointed gourd lines showed wide variation in days to first female flowering (Table 1). Appearance of first female flower ranged from 151 (PG005×M_2) to 170 (PG008×M_2) days. Variation in flowing period in pointed gourd was also observed by Shanmugavelu (1989). The line PG018×M_2 produced the highest vine length (242.00 cm) which was statistically similar to PG025×M_2 (234.00 cm) and PG027×M_2 (233.00 cm). The line PG007×M_2 produced the lowest vine length (90.00 cm). Significant variation in vine length of pointed gourd was also reported by Kumar *et al*. (1995) and Kabir (2007). Kumar *et al*. (1995) found the vine length ranging from 180.00 cm to 267 cm; whereas, Kabir (2007) found vine length with a range of 95 cm to 470 cm. The maximum number of nodes/plant was found in PG018×M_2 (18.30) followed by PG006×M_1 (17.30), PG025×M_2 (16.60), PG027×M_2 (16.33), PG017×M_2 (16.00), PG002×M_1 (15.00), PG012×M_1 (15.00), PG008×M_2 (14.30), PG002×M_2 (14.00) and PG007×M_2 (14.00). Number of nodes/vine increased with the increasing vine length. Singh and Prasad (1989) also observed a wide range of variation for number of nodes/vine in pointed gourd. Number of shoots/plant ranged from 4.66 to 12.50 (Table 1). BARI Hybrid Patal 1 produced the maximum shoots/plant (12.50) which was identical to PG006×M_1 (12.00), PG012×M_1 (11.00), PG003×M_1 (10.66), PG002×M_1 (10.33) and PG014×M_1 (10.33), while the minimum in PG008×M_1 (4.66).

Table 1. Days to first female flowering, vine length, number of nodes per plant and shoots per plant of nineteen hybrid pointed gourd lines

Hybrid lines	Days to 1st female flowering	Length of vine (cm)	Nodes/plant (no.)	Shoots/plant (no.)
PG002×M_1	164def	172.00c	15.00a-f	10.33ab
PG003×M_1	164def	114.00f-h	10.00g-i	10.66ab
PG004×M_1	168abc	183.00j	8.30h-i	8.00d
PG005×M_1	161f	109.00gh	15.30a-e	9.66bc
PG006×M_1	164def	218.00b	17.30ab	12.00a
PG008×M_1	153gh	113.00f-h	11.33d-i	4.66f
PG012×M_1	156g	214.00b	15.00a-f	11.00ab
PG014×M_1	166bcd	101.00hi	10.33f-i	10.33ab
PG022×M_1	166bcd	139.00d	11.00e-i	6.33d-f
PG002×M_2	162ef	143.06d	14.00a-g	7.30de
PG005×M_2	151h	121.00fg	12.60b-h	8.00cd
PG006×M_2	163ef	92.00ij	7.30i	5.66ef
PG007×M_2	166bcd	90.00ij	14.00a-g	5.60ef
PG008×M_2	170a	136.00e	14.30a-g	7.33de
PG009×M_2	166bcd	125.00ef	11.6c-i	8.00cd
PG017×M_2	169ab	219.00b	16.00a-d	7.00de
PG018×M_2	163ef	242.00a	18.30a	8.00cd
PG025×M_2	165cde	234.30a	16.60ab	7.33de
BARI Hybrid Patal -1	157g	233.00a	16.33a-c	12.50a
CV (%)_	6.70	4.95	18.17	11.45

Means with uncommon letter(s) in a column are significantly different at 5% level by DMRT.

Table 2. Number of fruits per plant, fruit size, individual fruit weight, weight of fruits per plant of nineteen hybrid pointed gourd lines

Hybrid lines	Days to 1st fruit harvest	Fruits/plant (no.)	Individual fruit weight (g)	Length of fruit (cm)	Width of fruit (cm)	Weight of fruits/plant (kg)
PG002×M_1	176bc	107.33ij	40.24d-f	10.00c	3.30ef	4.32d
PG003×M_1	175c	98.00k	45.61a-d	11.56b	3.53d-f	4.47cd
PG004×M_1	179abc	115.66e	44.49a-d	11.50b	3.50d-f	5.14c
PG005×M_1	175c	114.00g-i	38.00e-h	10.06c	3.60c-f	4.38d
PG006×M_1	175c	121.66d-f	37.00e-h	8.36fg	3.53d-f	5.25c
PG008×M_1	176c	117.66e-g	43.66b-e	9.83cd	3.20f	4.38d
PG012×M_1	165c	154.66a	34.14gh	9.40c-e	3.63c-e	5.26c
PG014×M_1	168c	117.33e-g	45.62a-d	11.33b	3.70b-e	5.33c
PG022×M_1	178abc	135.00b	22.92i	7.83g	3.60c-f	3.01f
PG002×M_2	178abc	107.35ij	32.40h	9.50c-e	3.30ef	3.46e
PG005×M_2	176bc	115.00f-h	44.40a-d	9.53c-e	3.46d-f	5.10c
PG006×M_2	167d	125.66cd	39.60d-g	9.16de	3.53d-f	4.95c
PG007×M_2	177bc	129.00bc	41.27c-f	8.90ef	3.66c-e	5.32c
PG008×M_2	178abc	120.00d-g	48.00ab	12.67a	3.96a-c	5.88b
PG009×M_2	182a	160.00a	43.00b-f	10.16c	3.76a-d	6.86a
PG017×M_2	178abc	129.00bc	42.00b-f	9.56c-e	4.10ab	5.43c
PG018×M_2	181ab	109.66h-j	47.00a-c	9.93cd	4.16a	5.15c
PG025×M_2	175c	123.00c-e	41.24c-f	9.13de	3.56c-f	5.07c
BARI Hybrid Patal -1	178abc	104.00ij	50.10a	13.23a	4.10ab	5.39c
CV (%)	5.29	3.24	7.76	4.19	6.03	5.06

Means with uncommon letter (s) in a column are significantly different at 5%level by DMRT.

B) Days to 1st fruit harvest, number of fruits/plant, individual fruit weight, fruit length and width and weight of fruits/plant

Days to 1st fruit harvest, fruits/plant, fruit length, fruit width, individual fruit weight and weight of fruits/plant showed significant variation in hybrid pointed gourd lines (Table 2). Days to 1st fruit harvest ranged from 165 to 182 days. Maximum days were required to 1st fruit harvest of PG009×M_2 (182 days) followed by PG018×M_2 (181 days), PG004×M_1 (179 days), PG002×M_2 (178 days), PG017×M_2 (178 days), BARI Hybrid Patal 1 (178 days) and PG022 × M_1 (178 days), and the minimum time required for PG012×M_1(165 days). The number of fruits/plant ranged from 98.00 to 160.00. Maximum number of fruits /plant was recorded from PG009×M_2 (160.00) followed by PG012×M_1 (154.66) and the minimum from PG003×M_1 (98.00). The variation in number of fruits/plant among the pointed gourd genotypes was also reported by Prasad and Singh (1990) and Alam *et al*. (2008). Alam *et al*. (2008) found the fruit number/plant with a range of 13.67 to 180.67. Individual fruit weight varied significantly among the lines and it ranged from 22.92 g to 50.10 g. The largest fruit was obtained from BARI Hybrid Patal-1 (50.10 g) followed by PG008×M_2 (48.00 g), PG018×M_2 (47.00 g), PG003×M_1 (45.61 g), PG014×M_1 (45.62 g), PG004×M_1 (44.49 g) and PG005 × M_2 (44.40g); whereas, the smallest fruit was produced by PG022×M_1 (22.92 g). The fruit length ranged from 7.83 to 13.23 cm. The highest fruit length was in BARI Hybrid Patal-1 (13.23 cm) which was closely followed by PG008 × M_2 (12.67 cm) and the smallest from PG022×M_1 (7.83 cm). These results are almost similar to Khan *et al*. (2007) and Alam *et al*. (2008). The widest fruit was produced by PG018×M_2 (4.16 cm) followed by PG017×M_2 and Bari hybrid Patal 1 (4.10 cm) but the narrowest in PG008 × M_1 (3.20 cm). Weight of fruits/plant varied significantly among the lines (Table 2). The maximum weight of fruits/plant was recorded in PG009×M_2 (6.86 kg) which differed significantly from others but the minimum was found in PG022×M_1 (3.01kg). The better fruit weight/plant was also recorded in PG008×M_2 (5.88 kg), PG027×M_2 (5.39 kg) and PG014×M_1 (5.33kg). Similar results were also reported by Singh *et al*. (1985), Alam *et al*. (2008) and Khan *et al*. (2007).

C) Pulp weight, number of seeds/fruit, weight of seeds/fruit, duration of fruit harvest, fruit yield and shelf life

Pulp weight/fruit, number of seeds/fruit, weight of seeds/fruit, duration of fruit harvest, fruit yield and shelf life are presented in Table 3. Pulp weight in the lines ranged from 17.20 g to 44.20 g. The maximum pulp weight was obtained from the fruit of BARI Hybrid Patal 1 (44.20 g) followed by PG008×M_2 (42.20 g). On the other hand, the minimum pulp weight was produced by PG022×M_1 (17.20 g). These results are in conformity with the findings of Kabir (2007), Khan *et al.* (2007) and Alam *et al*. (2008). Number of seeds/fruit ranged from 16.66 to 27.33. The maximum number of seeds/fruit was recorded in PG014×M_1 (27.33) closely followed by PG018×M_2, PG007×M_2, PG025×M_2, PG008×M_2, and PG012 × M_1, while the minimum in PG005×M_1 (16.66). This corroborates the findings of other investigators (Khan *et al.*, 2007; Alam *et al.*, 2008; Prasad and Singh, 1990). The maximum weight of seeds/fruits was found in PG018 × M_2 (7.20 g) which was closely followed by PG006×M_2 (7.10 g) while the lowest in PG005×M_1 (4.13 g). Significant variation was also found in the lines with regard to duration of fruit harvest which ranged from 212 days to 223 days. The maximum harvest duration was found in PG017×M_2 (223 days) followed by PG009×M_2 (222 days) and the minimum duration was recorded in PG002×M_2 (212 days) and PG005×M_2 (212 days). Yield of pointed gourd significantly varied among the lines (Table 3). The maximum yield was obtained from PG009×M_2 (45.74 t/ha) followed by PG008×M_2 (39.23 t/ha), BARI Hybrid Patal-1 (36.85 t/ha), PG017×M_2 (36.19 t/ha) and PG027×M_2 (35.94 t/ha) and the minimum was recorded in PG0022×M_1 (20.10 t/ha). These results are almost similar with the findings of Khan *et al.* (2007) and Alam *et al*. (2008). Maximum shelf life was found in BARI Hybrid Patal-1 (15.0 days) followed by PG014×M_1 (14.33 days), PG007×M_2 (14 days) and PG017×M_2 (12.50 days) while the lowest shelf life was found in PG005×M_1 (6.23 days).

Table 3. Pulp weight, number of seeds per fruit, weight of seeds per fruit, duration of fruit harvest, fruit yield and shelf life of nineteen hybrid pointed gourd lines

Hybrid lines	Pulp weight (g)	Number of seeds/fruit	Weight of seeds/fruit (g)	Duration of fruit harvest (days)	Fruit yield (t/ha)	Shelf life (days)
PG002×M_1	34.00d-h	22.33b-d	5.20c	218c-f	28.84h	6.25j
PG003×M_1	38.00c	22.66b-d	5.56bc	219b-e	29.80h	7.25ij
PG004×M_1	38.10c	22.67b-d	5.40bc	214gh	34.30e-g	11.23c-e
PG005×M_1	33.00e-i	16.66f	4.13d	216d-g	29.23h	6.23j
PG006×M_1	31.00g-j	23.00b-d	5.30bc	215fgh	35.04d-f	10.50d-f
PG008×M_1	37.00c-e	22.23b-d	5.43bc	214gh	29.20h	12.00c
PG012×M_1	29.00ij	24.00a-d	4.16d	216d-g	35.06b-f	9.66fg
PG014×M_1	39.10b-d	27.33a	5.33bc	215fgh	35.58c-e	14.33b
PG022×M_1	17.20k	23.00bc	5.20c	213gh	20.10j	9.00gh
PG002×M_2	26.50j	21.66cd	5.40bc	212h	23.10i	8.00hi
PG005×M_2	38.50b-d	21.00de	5.41bc	212h	34.03e-g	11.3c-e
PG006×M_2	32.00f-i	18.00ef	7.10a	218c-f	33.01g	9.03gh
PG007×M_2	35.60c-g	25.33ab	5.30bc	220bc	36.85c	14.00b
PG008×M_2	42.20ab	24.66a-c	5.20c	219bd	39.23b	8.66gh
PG009×M_2	37.40c-e	20.66de	5.56bc	222ab	45.74a	11.50cd
PG017×M_2	36.20c-f	23.00b-d	5.40bc	223a	36.19cd	12.50c
PG018×M_2	39.50bc	25.66ab	7.20a	216efg	34.35e-g	9.36h
PG025×M_2	35.00c-g	25.00a-c	5.73b	218c-f	33.81fg	10.00e-g
BARI Hybrid Patal -1	44.20a	23.00b-d	5.40bc	218c-f	35.94cd	15.00a
CV (%)	7.32	8.14	4.94	4.58	2.50	7.32

Means with uncommon letter (s) are significantly different at 5% level by DMRT.

D) Leaf colour, leaf tip and leaf margin

The leaves of pointed gourd lines showed wide variation in different leaf characteristics (Table 4). The colour of leaves was light green, green and deep green. The leaves of the lines, PG017×M_2, PG018×M_2, and PG025×M_2 were deep green while PG003×M_1, PG004×M_1, PG005×M_1, PG006×M_1, PG008×M_1, PG014×M_1, PG005×M_2 and PG006×M_2 were green. The rest of the lines had light green leaves. The two lines PG005×M_1 and PG018×M_2, and the variety BARI Hybrid Patal 1 produced blunt leaves, while the rest of the lines produced pointed leaves. The leaf margin of PG002×M_1 and PG009×M_2 were slightly serrated, while PG003×M_1, PG004×M_1, PG012×M_1, PG005×M_2 and PG017×M_2 and PG004×M_1 were serrated. The leaf margin of the lines PG005×M_1, PG008×M_1, PG014×M_1, PG022×M_1, PG002×M_2, PG006×M_2, PG007×M_2, PG008×M_2 were entire and the remaining had undulated margin. These results are in agreement with the findings of Khan *et al*. (2007) who reported to have variation in type of margin of pointed gourd.

Table 4. Leaf characteristics of nineteen hybrid pointed gourd lines

Hybrid lines	Leaf colour	Leaf tip	Leaf margin
PG002×M_1	Light green	Pointed	Slightly serrated
PG003×M_1	Green	Pointed	Serrated
PG004×M_1	Green	Pointed	Serrated
PG005×M_1	Green	Blunt	Entire
PG006×M_1	Green	Pointed	Undulated
PG008×M_1	Green	Pointed	Entire
PG012×M_1	Light Green	Pointed	Serrated
PG014×M_1	Green	Pointed	Entire
PG022×M_1	Light green	Pointed	Entire
PG002×M_2	Light green	Pointed	Entire
PG005×M_2	Green	Pointed	Serrated
PG006×M_2	Green	Pointed	Entire
PG007×M_2	Light green	Pointed	Entire
PG008×M_2	Light green	Pointed	Entire
PG009×M_2	Light green	Pointed	Slightly serrated
PG017×M_2	Deep Green	Pointed	Serrated
PG018×M_2	Deep Green	Blunt	Undulated
PG025×M_2	Deep Green	Pointed	Undulated
BARI Hybrid Patal-1	Light green	Blunt	Undulated

Table 5. Fruit characteristics of nineteen hybrid pointed gourd lines at marketable stage

Hybrid lines	Fruit colour	Stripes of fruit	Shape of fruit	Curvature of fruit
PG002×M_1	Dark green	Green white stripe	Spindle	Slightly curved
PG003×M_1	Whitish	No stripe	Spindle	Curved
PG004×M_1	Dark green	White stripe	Spindle	Curved
PG005×M_1	Light green	No stripe	Cylindrical	Slightly curved
PG006×M_1	light green	Light green stripe	Cylindrical	Straight
PG008×M_1	Dark green	White stripe	Cylindrical	Slightly curved
PG012×M_1	Green	White stripe	Oval	Straight
PG014×M_1	Green	Green white stripe	Cylindrical	Straight
PG022×M_1	Dark green	Green white stripe	Oval	Straight
PG002×M_2	Light green	White stripe	Spindle	Curved
PG005×M_2	Whitish	No stripe	Spindle	Curved
PG006×M_2	Dark green	Green white stripe	Cylindrical	Straight
PG007×M_2	Dark green	Green white stripe	Cylindrical	Slightly curved
PG008×M_2	Dark green	Green white stripe	Cylindrical	Curved
PG009×M_2	Dark green	Green white stripe	Spindle	Curved
PG017×M_2	Dark green	Green white stripe	Oval	Straight
PG018×M_2	Green	Green white stripe	Spindle	Slightly curved
PG025×M_2	Light green	Green white stripe	Oval	Slightly curved
BARI Hybrid Patal -1	Dark green	Green white stripe	Cylindrical	Slightly curved

E) Colour, shape, stripe and curvature of fruit

The fruits of hybrid pointed gourd lines showed variation in colour, shape, stripes and curvature (Table 5). The colour of fruit was dark green in PG002×M_1, PG004×M_1, PG008×M_1, PG022×M_1, PG006×M_2, PG007×M_2, PG008×M_2, PG009×M_2, PG017×M_2, and BARI Hybrid Patal. The fruit colour of PG003×M_1 and PG005×M_2 was whitish; whereas, PG005×M_1, PG006×M_1, PG002×M_2 and PG025×M_2 was light green. Variation in colour of pointed gourd has also been observed by Ram (2001) and Khan *et al*. (2007). The fruits of PG004×M_1, PG008×M_1, PG012×M_1 and PG002×M_2 showed white stripes and PG006×M_1 showed light green stripes. On the other hand, the fruits of PG003×M_1, PG005×M_1 and PG005×M_2 had no stripe. The rest of the lines produced fruits with green white stripes. The lines PG005×M_1, PG006×M_1, PG008×M_1, PG014×M_1, PG006×M_2, PG007×M_2, PG008×M_2 and PG027×M_2 produced cylindrical fruits, while PG002×M_1, PG003×M_1, PG004×M_1, PG002×M_2, PG005×M_2, PG009×M_2 and PG018×M_2 produced spindle shaped fruits, but the rest of the lines produced oval shaped fruits. Variation in shape of pointed gourd was also reported by Khan *et al*. (2007). Slightly curved fruits were found in PG002×M_1, PG005×M_1, PG008×M_1, PG007×M_2, PG018×M_2, PG025×M_2 and BARi Hybrid Patal 1. On the contrary, curved fruits were produced by PG003×M_1, PG004×M_1, PG002×M_2, PG005×M_2, PG008×M_2 and PG009×M_2 but the rest produced straight fruits. The results are in conformity with the report of Prasad and Singh (1990).

Conclusion

Based on the above result, it can be concluded that the hybrid pointed gourd lines PG014×M_1, PG007×M_2, PG008×M_2, PG009×M_2 and PG017×M_2 performed better in respect of yield and yield attributes. These five hybrid lines should be subjected for further evaluation to release as hybrid variety (ies).

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EFFECT OF FOLIAR APPLICATION OF IRON AND ZINC ON NUTRIENT UPTAKE AND GRAIN YIELD OF WHEAT UNDER DIFFERENT IRRIGATION REGIMES

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Abstract

A field experiment was carried out to study the zinc-iron relationship in wheat (BARI Gom-26) plant grown under water stress condition in the field near net house of Soil Science Division, BARI, Joydebpur, Gazipur, during November 2015 to March 2016. The experiment was designed in a split plot on sixteen treatments comprising four irrigation treatments (regular irrigation, stopping irrigation at crown root initiation, stopping irrigation at booting stage and stopping irrigation at grain filling stage) and four foliar application of zinc and iron (control, 0.05% of zinc, 0.05% of iron and 0.05% of zinc +0.05% of iron). Zinc sulphate monohydrate ($ZnSO_4$. H_2O) and ferrous sulphate ($FeSO_4$. H_2O) were used as a source of Zn and Fe. The highest yield (4.01 t ha^{-1}) was recorded in stopping irrigation at grain filling stage which was identical with regular irrigation. Water stress at crown root initiation stage had the most negative effect on growth and yield. Foliar application of zinc and iron played a major role on yield and yield components of wheat at later stages of growth. The results obtained from the present research showed that iron and zinc spray increased grain yield and quality of wheat and improved the effects caused by drought stress.

Keywords: Wheat, foliar application, iron, zinc, yield.

Introduction

Increasing the zinc and iron concentration in food crop plants, resulting in better crop production and improved human health is an important global challenge. Micronutrient malnutrition, particularly Zn and Fe deficiency, affects over three billion people worldwide (Bouis, 2007). Producing micronutrient enriched cereals via biofortification, either agronomically or genetically, and improving Fe and Zn bioavailability are considered promising and cost effective approaches for diminishing malnutrition (Distelfeld *et al.*, 2007). Foliar fertilizer sprays have

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proved to be a sustainable, effective and low cost strategy to improve Fe and Zn levels in edible portions of staple food crops (Ling *et al.*, 2013).

Foliar spraying is a new method for crop feeding in which micronutrients in form of liquid are sprayed on leaves (Nasiri *et al.,* 2010). Foliar application of microelements is more beneficial than soil application. Since application rates are lesser as compared to soil application, same application could be obtained easily and crop reacts to nutrient application immediately (Zayed *et al.,* 2011). Foliar spraying of microelements is very helpful when the roots cannot provide necessary nutrients (Babaeian *et al.,* 2011). Moreover, soil pollution would be a major problem by micronutrients through soil application. Narimani *et al.* (2010) reported that microelements foliar applications improve the effectiveness of macronutrients. It has been found that microelements foliar application is in the same level and even more influential as compared to soil application. Resistance to different stresses will be increased by foliar application of micronutrients (Ghasemian *et al.*, 2010).

Plant nutrition has an important role in raising level of plants tolerance against a variety of environmental stresses and in this regard, iron and zinc are the most important essential micronutrients in plant nutrition (Baybordy and Mamedov, 2010). Metal ions such as iron, zinc, copper, manganese and magnesium as a cofactor participate in construction of many antioxidant enzymes and results of Cakmak *et al.* (2010) studies showed that under micronutrients deficiency conditions, antioxidant enzyme activities decrease and thus increases the sensitivity of plants to environmental stresses. Thalooth *et al.* (2006) reported that foliar application of zinc sulfate in water stress conditions had a positive effect on growth, yield and yield component of mungbean plant. Experimental result of Odeley and Animashaun (2007) also showed that foliar application of micronutrients increased the soybean yield, quality, resistance to pests and diseases and drought stress. Therefore, the micronutrients such as iron, copper, boron, zinc and manganese have many contributions in cell wall formation and plant resistance to pests and diseases and environmental stresses.

The micronutrients play an important role in increasing crop yield. Micronutrients have prominent effects on dry matter, grain yield and straw yield in wheat (Asad and Rafique, 2000). Zinc and Fe are involved in detoxification of reactive oxygen specious (ROS) and they are also important for reducing the production of free radicals by superoxide radical producing enzymes (Cakmak, 2000). Iron plays a key role in biological redox system, enzyme activation and oxygen carrier in nitrogen fixation (Weisany *et al.,* 2013). Previously, many reports have evaluated the response of wheat to micronutrients (soil or foliage) application but little information is available regarding combined application of micronutrients. This experiment was conducted to evaluate the role of mixed application of micronutrients in improving wheat performance under water different irrigation regimes.

Materials and Methods

A field experiment was carried out in the field near net house of Soil Science Division of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during November, 2015 to March, 2016 with a view to studying zinc-iron relationship in wheat plant grown under water stress condition. The experiment was arranged as split plot based on randomized complete block design with three replications. Main plots included irrigation period with three levels (irrigation at CRI stage, booting stage and grain filling stage) and sub-plots were treatments of Zn, Fe and Zn+Fe foliar application and control (water foliar application). BARI Gom-26 variety was tested. Each split plot was 2 m^2 in size with 0.5 m border distance.

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	Texture	pH	OM	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Zn
			(%)	meq 100g^{-1}			%	µg g^{-1}					
Result	Sandy clay loam	7.7	1.06	6.5	2.2	0.21	0.056	3.6	29.7	0.20	2.4	24.6	3.46
Critical level	-	Alkaline	-	2.0	0.5	0.12	-	10.0	10	0.2	0.2	4.0	0.6

Table 2. Moisture status of soil at different days during the study

Treatment	Moisture status (%) of 0-15 cm depth of soil						
	Initial	18 DAS	40 DAS	55 DAS	70 DAS	85 DAS	100 DAS
T_1 = Control (regular irrigation)	17	15.3	18.1	15.1	18.3	20.5	10.6
T_2 = Skipping irrigation at CRI stage	17	13.4	15.5	12.5	10.3	15.1	9.50
T_3 = Skipping irrigation at booting stage	17	15.5	13.3	11.7	13.2	14.6	8.40
T_4 = Skipping irrigation at heading & flowering stage	17	14.3	15.6	13.5	13.5	11.0	6.50

There were sixteen treatment combinations comprising four irrigation treatments, i.e T_1: full irrigation (unstressed); irrigation at crown root initiation stage, booting stage and grain filling stage, T_2: stressed by stopping one irrigation at crown root initiation stage, T_3: stressed by stopping one irrigation at booting stage, T_4: stressed by stopping one irrigation at grain filling stage and four levels of foliar sprays are F_1: control (foliar application of distilled water), F_2: foliar application of 0.05% of Zn, F_3: foliar application 0.05% of Fe and F_4: foliar application of 0.05% of Zn and 0.05% of Fe. Foliar application of zinc and iron was done during the stopping irrigation at respective days. Zinc sulphate monohydrate ($ZnSO_4$. H_2O) and ferrous sulphate ($FeSO_4$. H_2O) were used as a source of zinc and iron. Urea, TSP, MP, gypsum and boric acid were used as a source of N, P, K, S and B, respectively. Fertilizers were applied based on BARC fertilizer recommendation guide-2012. All PKSB and half of N were applied at the final land preparation and the remaining half of N was applied before booting stage. The crops were harvested on 04 March 2016 at full maturity. Ten plants from each plot were sampled randomly for collection of different plant characters and yield attributes. Data on yield and yield contributing characters such as plant height (cm), spike length (cm), grain spike^{-1}, 100 grain wgt, yield (t ha^{-1}) were recorded. Plants of 1 m^2 area from each plot were selected for data collection. Soil moisture data collected at different growth stages of wheat are shown in Table 2. Weather data during the crop growth period are presented on Fig 1. Data on yield and yield contributing parameters were recorded and statistically analyzed with the help of statistical package MSTAT-C and mean separation was tested by Duncan's Multiple Range Test (DMRT). Moisture content in soil was calculated by using the following formula.

$$\text{Soil Moisture (\%)} = \frac{\text{Wet soil (g) - Dry soil (g)}}{\text{Dry soil (g)}} \times 100$$

Methods of chemical analysis

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). The soil was found to be Alkaline. Standard methods were used in these determinations. Soil pH was measured by a combined glass calomel electrode. Organic carbon was determined by the wet oxidation method. Total N was determined by a modified Kjeldahl method. Calcium (Ca), magnesium (Mg) and K were determined by NH_4OAc extractable method, copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were determined by DTPA extraction followed by AAS reading. Boron (B) was determined by $CaCl_2$ extraction method. Available P was determined by the Bray and Kurtz method while S was determined using the turbidimetric method with $BaCl_2$.

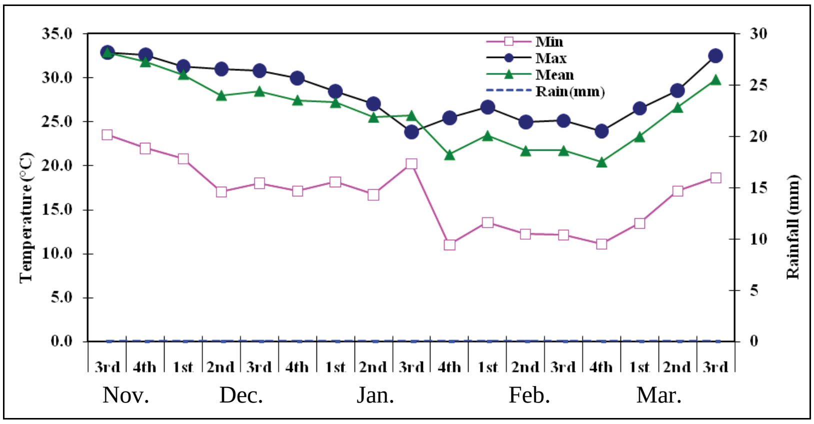

Figure 1. Rainfall, minimum, maximum and mean air temperature during growing period.

Results and Discussion

Effect of irrigation

The effect of irrigation on the grain yield and yield components of wheat has been shown in Table 3. The highest grain yield (4.01 t ha^{-1}) was obtained in T_4 treatment (stopping irrigation at grain filling stage) which was identical with T_1 treatment (regular treatment). The lowest yield (3.02t ha^{-1}) was obtained from stopping irrigation at crown root initiation stage (T_2) which was significantly lower than other treatments. This finding revealed that crown root initiation was the most critical stage for irrigation and its omission at this stage reduced the grain yield. CRI stage is the most critical stage for irrigation in wheat, because any shortage of moisture at this stage results in less tillering and great reduction in yield. Bajwa *et al.*, (1993) reported that number of tillers improved with irrigation at crown root stage and better grain yield was recorded with irrigation at crown root and booting stage.

Effect of foliar application of zinc and iron

The effect of foliar application of zinc and iron on the grain yield and yield components of wheat has been shown in (Table 3). Foliar application of zinc and iron played a significant role on the yield and yield components of wheat. The highest grain yield (4.02 t ha^{-1}) was obtained by using (Fe+Zn) treatment. Due to the enzymatic activity enhancement, microelements effectively increased photosynthesis and translocation of assimilates to the seed. Foliar application of Fe and Zn increased grain yield and protein content (Seilsepour, 2007). Chaudry *et al.* (2007) reported that micronutrients (Zn, Fe, B) significantly increased the wheat yield over control when applied in single and in combination, along with basal dose of NPK, whilst Mandal *et al.* (2007) noticed significant optimistic

Table 3. Main effect of irrigation and foliar application of Zn and Fe on yield and yield components of wheat

Treatment combination	Plant height (cm)	spike length (cm)	No of grain $spike^{-1}$	100 grains wt. (g)	Grain wt. m^{-2} (g)	Grain yield ($t\ ha^{-1}$)
Irrigation						
T_1 = Control (regular irrigation)	72.7	10.4	46.4	51.8	400a	4.00a
T_2 = Stopping irrigation at CRI stage	68.2	9.80	37.2	42.1	302b	3.02b
T_3 = Stopping irrigation at booting stage	69.7	10.3	43.2	45.6	343ab	3.43ab
T_4 = Stopping irrigation at Grain filling stage	73.9a	10.3a	46.0	51.8	401a	4.01a
Foliar application						
F_1 = Control	68.1c	9.5d	38.9	45.6	323c	3.23c
F_2 = 0.05% Zn	71.5b	10.5b	43.7	48.4	373ab	3.73ab
F_3 = 0.05% Fe	70.0bc	10.0c	41.7	45.8	348bc	3.48bc
F_4 = 0.05% Zn + 0.05% Fe	75.0a	10.9a	48.4	51.5	402a	4.02a

Mean values in the same column followed by the same letters are not significantly different ($P < 0.05$) by DMRT.

Table 4. Interaction effect of irrigation and foliar application of Zn and Fe on yield and yield components of wheat

Treatment combination		Plant height (cm)	Spike length (cm)	No of grain spike^{-1}	1000 grains wt. (g)	Grain wt. m^{-2} (g)	Grain yield (t ha^{-1})
Irrigation	Foliar application						
T_1 = Control (regular irrigation)	F_1 = Control	69.4	9.81	40.8	50abcd	373abc	3.73abc
	F_2 = 0.05% Zn	73.0	10.71	47.9	52abc	413ab	4.13ab
	F_3 = 0.05% Fe	70.7	10.41	45.4	49abcd	368abc	3.68abc
	F_4=0.05%Zn+0.05%Fe	77.6	10.82	51.4	56a	447a	4.47a
T_2 = Skipping irrigation at CRI stage	F_1 = Control	65.9	8.98	35.2	39d	267c	2.67c
	F_2 = 0.05% Zn	68.6	10.24	36.8	42cd	311bc	3.11bc
	F_3 = 0.05% Fe	65.7	9.83	36.1	43bcd	296bc	2.96bc
	F_4 = 0.05% Zn+0.05%Fe	72.7	10.34	40.5	44bcd	333bc	3.33bc
T_3 = Skipping irrigation at booting stage	F_1 = Control	65.7	9.56	39.8	43bcd	294bc	2.94bc
	F_2 = 0.05% Zn	70.4	10.68	43.0	46abcd	359abc	3.59abc
	F_3 = 0.05% Fe	70.1	9.97	41.8	43bcd	341abc	3.41abc
	F_4=0.05%Zn+0.05% Fe	72.4	11.13	48.1	50abcd	379abc	3.79abc
T_4 = Skipping irrigation at grain filling stage	F_1 = Control	71.3	9.60	39.6	50abcd	359abc	3.59abc
	F_2 = 0.05% Zn	73.8	10.40	47.0	53ab	410ab	4.10ab
	F_3=0.05%Fe	73.4	9.85	43.8	48abcd	387abc	3.87abc
	F_4 = 0.05% Zn+0.05%Fe	77.2	11.17	53.6	56a	449a	4.49a
CV%		2.93	2.88	3.83	5.83	7.42	7.42

Mean values in the same column followed by the same letters are not significantly different ($P < 0.05$) by DMRT.

Table 5. Concentration of Zn and Fe in wheat grain and their uptake as influenced by the interaction of irrigation and foliar application of Zn and Fe

Treatment combination		Grain yield	Concentration				Fe uptake by grain	Zn uptake by grain
			Fe	Zn	Fe	Zn		
Irrigation	Foliar application	(kg ha^{-1})	(ppm)		(%)		(kg ha^{-1})	
T_1 = Control (regular irrigation)	F_1= Control	3730	82.19	90.5	0.0082	0.0090	0.307	0.337
	F_2 = 0.05% Zn	4130	83.88	94.7	0.0084	0.0095	0.346	0.391
	F_3 = 0.05% Fe	3680	84.74	97.8	0.0085	0.0098	0.312	0.360
	F_4=0.05%Zn + 0.05%Fe	4470	87.12	112.9	0.0087	0.0113	0.389	0.505
T_2 = Skipping irrigation at CRI stage	F_1= Control	2670	76.21	89.5	0.0076	0.0090	0.203	0.239
	F_2= 0.05% Zn	3110	80.53	91.7	0.0081	0.0092	0.250	0.285
	F_3 = 0.05% Fe	2960	78.32	92.4	0.0078	0.0092	0.232	0.274
	F_4=0.05%Zn + 0.05%Fe	3330	82.13	99.5	0.0082	0.0100	0.273	0.331
T_3 = Skipping irrigation at booting stage	F_1= Control	2940	77.03	88.7	0.0077	0.0089	0.226	0.261
	F_2 = 0.05% Zn	3590	90.98	81.6	0.0091	0.0082	0.327	0.293
	F_3 = 0.05% Fe	3410	79.52	92.4	0.0080	0.0092	0.271	0.315
	F_4=0.05%Zn + 0.05%Fe	3790	89.93	95.5	0.0090	0.0096	0.341	0.362
T_4 = Skipping irrigation at grain filling stage	F_1= Control	3590	90.30	80.7	0.0090	0.0081	0.324	0.290
	F_2 = 0.05% Zn	4100	91.52	85.9	0.0092	0.0086	0.375	0.352
	F_3 = 0.05% Fe	3870	93.46	95.3	0.0093	0.0095	0.362	0.369
	F_4=0.05%Zn + 0.05% Fe	4490	101.80	116.2	0.0102	0.0116	0.457	0.522

interaction among physiological stages of wheat growth and fertilizer treatments. Bameri *et al.* (2012) showed that foliar micronutrient application (Fe, Zn, and Mn) significantly improved the plants height, number of spike per plant, number of grain per spike, 1000-grain weight, grain yield, biological yield and harvest index. Application of Fe and Zn alone or combination had positive effect on grain yield and its components. Zain *et al.* (2015) showed that the application of micronutrients (Fe, Zn and Mn) substantially improved plant height, spike length cm, spikelets per spike, grains per spike, 1000-grain weight, number of tillers square meter, grain yield, biological yield and harvest index of wheat. Zayed *et al.* (2011) announced that due to the synergistic effect, zinc + iron treatment as compared to Zn treatment and Fe treatment was more helpful in rice. Kobraee *et al.* (2011) claimed that zinc and iron application at the same time could be lead to higher dry matter and seed yield as compared to using them separately. Foliar application with micronutrients (Fe, B and Zn) might be due to their critical role in crop growth, involving in photosynthesis processes, respiration and other biochemical and physiological activates and thus their importance in achieving higher yields (Salih, 2013). Habib (2012) obtained significant increase in 1000-kernels weight when Zn and Zn+Fe supplied on foliage at grain filling period of wheat in comparison with Fe supplement without affecting grain numbers per spike. Zeidan *et al.* (2010) recorded significant increase in all grain yield parameters and straw yield when Zn and Fe were sprayed on foliage at tillering and booting stage.

Interaction effects of irrigation and foliar application of zinc and iron

The interaction effect between irrigation and foliar application of zinc and iron on the grain yield and yield components of wheat was statistically significant (Table 4). The highest weight of 1000 seed (56 g) was recorded in T_4 treatment (stopping irrigation in grain filling stage) with a mixture of zinc and iron which was statistically identical to T_1 treatment (regular irrigation). The highest yield (4.49 t/ha) was recorded on T_4 treatment (stopping irrigation at grain filling stage with foliar spray of zinc and iron), which was followed by T_1 treatment (regular irrigation with foliar spray of zinc and iron), but the variation was non-significant. Stopping irrigation at crown root initiation of growth caused the reduction in all yield components and grain yield. The lowest grain yield (2.67 t ha^{-1}) was recorded from T_2 treatment (stopping irrigation at crown root initiation stage). This might be due to disturbance of crown root development which decreased the grain yield significantly. Foliar application of zinc and iron at grain filling stage was more effective in alleviating the adverse effect of water deficit on grain yield. Many current and past researches pointed soil and/or foliage supplied Zn and Fe can increase the accumulation of Zn and Fe in wheat grain, respectively (Kutman *et al.,* 2010; Habib, 2012; Kutman *et al.,* 2012). Micronutrients fertilizer when applied at milking dough stage of grain increase the mineral contents of grain and improved its nutritional quality (Zhang *et al.*, 2010). Translocation of nutrients from the old to young leaves and leaves or stem to grains occur through phloem transport system and translocation ranges from utilization to storage sinks (Campbell and Reece, 2002). In case of wheat plant, grain resembles the storage sink and rest as utilization sink. Thus the availability of Zn and Fe at later stage of plant development particularly at grain filling period could increase the uptake as well as concentration of these elements in wheat grain (sink). The iron and zinc element in stress condition have an enhancing role on osmotic adjustment process (due to the increase of soluble carbohydrates). Under drought stress conditions the role of these elements can be seen as a contributor to osmotic regulation that with intervention in the synthesis of osmotic compounds for compatibility with stress and maintain turgor pressure performed their roles (Akbari *et al.*, 2013).

Iron and Zn content in wheat grain

The concentration of Zn in wheat grain ranged from 76.2 to 101.80 ppm (Table 5). Drought at grain filling stage treatment (T_4) showed significantly higher content of Zn in grain compared to other treatments. The concentration of Fe in wheat grain ranged from 80.7 to 116.2 ppm (Table 5). Drought at grain filling stage treatment (T_4) showed significantly higher content of Fe in grain compared to other treatment. Ling *et al.* (2013) demonstrated that foliar Fe amino acid and a relatively low concentration of $ZnSO_4$. $7H_2O$ significantly increase the Fe and Zn concentration in brown rice of different cultivars. Indeed, many previous studies have also reported a positive correlation between grain Zn and Fe concentrations in cereals (Cakmak *et al.*, 2004; Morgounov *et al.*, 2007).

Conclusion

It can be concluded that the foliar application of zinc and iron fertilizers have positive effect on growth, yield components and grain yield by wheat when plants are not able to absorb the iron and zinc from soil due to high soil pH. As a result, foliar application of zinc and iron develops plant growth, grain yield and enhances its quality. Under drought stress, foliar application of zinc and iron improved yield of wheat, grain filling stage being more responsive.

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GENETIC VARIABILITY, HERITABILITY AND CORRELATION PATH ANALYSIS IN MUNGBEAN (*Vigna radiata* L.WILCZEK)

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Abstract

The success of crop improvement program largely depends on the nature and magnitude of genetic variability, heritability and characters association. This experiment was undertaken to estimate the extent of genetic variability and relation between yield and related characters. Twenty eight mungbean genotypes were grown at Pulses Research Centre, Ishurdi, Pabna during *kharif-I* 2015 in a randomized complete block design with three replications to estimate the extent of genetic variability and association between yield and yield related traits. Analysis of variance revealed that all the traits showed highly significant difference among genotypes except seeds per pod. Pods per plant, plant height and 100 seed weight showed high genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV). High broadsense heritability coupled with moderate genetic advance as percent of mean was observed for 100 seed weight, days to flower and pods per plant suggesting preponderance of additive gene action for these characters and selection of such traits might be effective for the improvement of grain yield. Seeds per pod, plant height and pods per plant showed positive significant phenotypic and genotypic correlation with yield. The result of path analysis indicated that pods per plant had maximum direct effect on yield followed by plant height and 100 seed weight and they contribute 31% variation in yield.

Keywords: Mungbean (*Vigna radiata*), variability, correlation, path analysis and yield performance.

Introduction

Mungbean (*Vigna radiata* L.Wilczek) is one of the most important pulse crop in Bangladesh for its easy digestibility and contains high protein. In Bangladesh, the total pulse production as per BBS 2017 it is 0.377 million ton on 0.371 million hectares with an average productivity of 1000 kg/ha (BBS, 2017). During 2016-17 the total area under mungbean cultivation was 0.32 million hectare with an average productivity of 663 kg/ha (Krishi diary, 2018). Its ranks 3rd position in acreage among the pulse crops in our country. Low yield as well as poor stability remains one of the most important constraints in its expansion. Since, it is a short

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duration legume, it fits well in many cropping systems under rainfed and irrigated conditions and increase small farmer's income and improve soil fertility.

Estimation of genetic parameters of mungbean genotypes can act as a useful guide to suggest effective breeding procedures for improvement of quantitatively inherited characters. Hence, the information on the relative magnitude of genotypic and phenotypic coefficients of variability and character associations is of immense value in starting a scientific breeding program. The knowledge of heritability and genetic advance guide the breeders to select superior parents to initiate effective and fruitful crossing program. In mungbean large amount of genetic variability has been reported (Pandiyan *et al.,* 2006; Ghosh and Panda, 2006), which indicates the potential for genetic improvement. Correlation coefficient analysis is a handy technique, which elaborates the degree and extent of relationship among important plant characters and it provides basic criteria for selection which leads to directional model based on yield and its components in the field experiments. Path coefficient analysis is an efficient statistical technique specially designed to quantify the interrelationship of different components and their direct and indirect effects on yield.

Crop improvement through successful selection program is only achieved using valid information about the correlation and genetic variability of traits of interest and it knows that improvement in any crop is dependent on the amount of genetic variability in the population. Therefore the aim of this study is to assess genetic variability for yield and related traits and estimate the extent of correlation between pairs of characters at genotypic and phenotypic level.

Materials and Methods

The experiment was conducted at Pulses Research Centre, Ishurdi, Pabna during *kharif*-I 2015 in a randomized complete block design with three replications. Sowing was done in the field on 5 March 2015. Plant to plant and row to row distances were maintained at 5 cm and 40 cm, respectively. The unit plot size was 4 meter long with 4 crops. Intercultural operation (Weeding, thinning, pesticide spray) were done 20 days after seed sowing. Twenty eight genotypes were evaluated for variation in the study. Data were collected on days to flowering (DF), days to maturity (DM), pods per plant (PP), plant height (PH), number of seeds per pod (SPP), 100 seed weight (SW) and yield (Y).

Statistical Analysis: The analysis of variance, correlation and path coefficient analysis for each characteristic was performed using STAR 2.0.1(2014) software developed by IRRI and Microsoft Excel.

Estimation of variance components: The genotypic and phenotypic components of variance were computed according to formulae given by (Lush, 1949) and (Choudhary and Prasad, 1968) for the observed characteristics. The phenotypic and genotypic co-efficient of variations were estimated according to the formula suggested by (Burton and Devane, 1953).

Genotypic variance ($\sigma^2 g$) = $\frac{\text{Genotype Mean Square (GMS) - Error Mean Square (EMS)}}{\text{Number of Replication (r)}}$

Phenotypic Variance ($\sigma^2 p$) = $\sigma^2 g + \sigma^2 e$

Genotypic co-efficient of variation (GCV) = $\frac{\sqrt{\sigma^2 g}}{\bar{x}} \times 100$

Phenotypic co-efficient of variation (PCV) = $\frac{\sqrt{\sigma^2 p}}{\bar{x}} \times 100$

Estimation of heritability: Broad sense heritability measures the extent to which phenotypic variation is determined by genotypic variation. Heritability was estimated in broad sense by the formula suggested by Johnson *et al*. (1955) as:

Heritability (h^2_b) = $\frac{\sigma^2 g}{\sigma^2 p} \times 100$

Estimation of genetic advance: Estimation of genetic advance and percentage of the mean (GAM) was done following formula illustrated by Johnson *et al.,* (1955) as:

Genetic Advance (GA) = h^2_b. K. σp

Where,

$h^2 b$=Heritability

K=Selection differential, the value of which is 2.06 at 5% selection intensity and σp = Phenotypic standard deviation.

The genetic advance percentage of mean (GAM) was computed as:

GAM (%) = $\frac{GA}{\bar{x}} \times 100$

Estimation of correlation coefficients:

The Genotypic and phenotypic correlation coefficients between yield and different yield contributing characters were estimated as following Singh and Choudhury (1985) as:

Genotypic correlation (r_g)= $\frac{Cov(ph)xy}{\sqrt{\sigma^2 (ph)x \, \sigma^2 (ph)y}}$

Similarly,

Phenotypic correlation (r_p) = $\frac{Cov(ph)xy}{\sqrt{\sigma^2 (ph)x \, \sigma^2 (ph)y}}$

Estimation of direct and indirect effect of different characters on yield: The path coefficient analysis was done according to the method of Dewey and Lu (1959).

Calculation of residual effect: After calculating the direct and indirect effect of different traits, the Coefficient of determination (R^2) and residual effect (U) was calculated using the formula suggested by (Singh and Choudhury, 1985) as:

$$U = \sqrt{1-R^2}$$

Where, $R^2 = \sum r_{ij} p_{ij}$

Results and Discussion

Analysis of variance: The analysis of variance for all characters is presented in Table 1. It revealed highly significant (p<0.01) differences for all characters except for number of seeds per plant that had non-significant differences among the genotypes. This suggested adequate amount of genetic variability among genotypes that may be helpful for yield improvement by selection. Similar results have also been reported to have highly significant variations with regard in different sets of mungbean genotypes (Abbas *et al*., 2008; Abbas *et al*., 2010; Rahim *et al*., 2010; Mondal *et al*., 2011).

Table 1. Analysis of variance of seven yield contributing characters in respect of 28 mungbean genotypes

Sources of variation	DF	Mean sum of squares						
		DF	DM	PH	PP	100 SW	SPP	Y
Replication	2	1.2262	1.1071	51.9925	47.3787	0.2448	37.7976	699766.3
Genotype	27	49.906**	21.494**	296.078**	115.308**	2.357**	53.754^{ns}	477653.70**
Error	54	1.4237	1.4405	24.481	25.1578	0.0666	46.1433	137956.6
CV(%)	-	3.00	1.85	10.08	15.13	5.56	13.51	10.35

DF - Degree of freedom, * - Significant at p = 0.05, ** - Significant at p = 0.01, DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), PP= Number of Pods per plant, SPP= No. seed per pod, 100SW= Hundred seed wt. (g) and Y=Seed yield (Kg/ha)

Genetic components: Genotypic variance, genotypic coefficient of variance, phenotypic variance, phenotypic coefficient of variance, broad sense heritability and genetic advance for seven traits were shown in Table 2. The knowledge of nature and magnitude of the variability among the accessions for the traits is very important prerequisite for making simultaneous selection on more number of traits to make significant improvement in mungbean. The genotypic and phenotypic variance ranged from 0.58 and 0.64 for 100 seed weight and 84924.27 to 222880.84 for yield, respectively. Estimates of both genotypic and phenotypic variances were high for yield, plant height and pods per plant (Table 2). Coefficient of variation was estimated at phenotypic and genotypic levels. In general, phenotypic coefficient of variation was higher in magnitude than that of genotypic coefficient for all the characters. The highest values of coefficient of variation were recorded for pods per plant i.e., 23.79 and 34.61 in percent followed by yield (18.33 and 29.69), plant height (16.79 and 19.59) and 100 seed weight (16.42 and 17.35) at genotypic and phenotypic levels, respectively. The lowest value of coefficient of variation was found for days to maturity at both genotypic and phenotypic levels. The highest estimate of coefficient of variation was recorded for pods per plant followed by yield, plant height and 100 seed weight. The differences of phenotypic and genotypic variances were also found low for the characteristics of days to maturity, days to flower and 100 seed weight, indicated that these characteristics were less influenced by environment, while and rest of the traits were influenced by environment. Reddy *et al.,* (2003), Pandiyan *et al.,* (2006), Rahim *et al.,* (2010) and Rai *et al.,* (2014) also reported the similar results in their findings.

Heritability: Heritability estimates are classified by Burton (1952) as high (greater than 70%), moderate (50-70%) and low (less 50%). The magnitude of the estimated broad sense heritability in this study ranged from 37.74 for seeds per pods to 89.58 for 100 seed weight. 100 seed weight showed the highest (89.58) broadsense heritability followed by days to flower (89.49) pods per plant (81.25) and days to maturity (77.69), whereas, the lowest values of heritability were obtained for seeds per pods (37.74) and yield (38.11) and rest of the traits showed moderate heritability. Heritability estimates were high for pods per plant, 100 seed weight and seed yield per plant. The characters which exhibited high heritability suggests that the selection will be more effective whereas the traits showing low heritability indicates that the selection will be influenced by the environmental factors.

Genetic advance: The highest amount of genetic advance was observed for yield (370.56) followed by plant height (14.557), days to flower (6.79) and pods per plant (6.727). On the other hand, the lowest amount of genetic advance was recorded for seeds per pod (0.57) and 100 seed weight (1.48). Similar results were reported by Reddy *et al.*, (2003), Pandiyan *et al.*, (2006), Gul *et al.*, (2007) and Rahim *et al.,* (2010). High heritability coupled with high genetic advance for 100 seed weight, days to flower and pods per plant indicated the role of additive gene action in their expression; suggesting that these traits are responsive in early generation selection. High heritability coupled with low genetic advance for days to maturity indicating the presence of additive as well as non-additive gene action. For these traits improvement can be made opting the two to three cycles of recurrent selection followed by pedigree or single seed descent methods of breeding as also corroborated by the findings of Pandiyan *et al.* (2006); Dadepeer *et al*. (2009), Dhananjay *et al*. (2009) and Rahim *et al*. (2010).

Table 2. Genetic variability components for different quantitative traits in mungbean

Characters	Grand mean	σ^2g	σ^2p	GCV (%)	PCV (%)	h^2_b (%)	GA
Days to flower	39.73	12.120	13.55	8.76	9.26	89.49	6.79
Days to maturity	64.82	5.013	6.46	3.46	3.92	77.689	3.07
Plant height (cm)	49.07	67.89	92.38	16.796	19.59	68.51	14.557
Pods per plant No.)	19.96	22.54	47.69	23.79	34.61	81.25	6.727
100 seed weight (g)	4.61	0.58	0.64	16.42	17.35	89.58	1.48
Seeds per pod (No.)	50.27	1.91	48.05	3.75	13.79	37.74	0.57
Yield (Kg/ha)	1590.39	84924.27	222880.84	18.33	29.69	38.11	370.56

Genotypic and phenotypic correlations: The genotypic and phenotypic association of seed yield with other characters is presented in Table 3. The relationship among these characters and their association with seed yield is essential to establish selection criteria (Singh, 1990). Seed yield had positive and highly significant genotypic correlation with plant height (0.482), pods per plant (0.491) and seeds per pod (0.641). Plant height, pods per plant and seeds per pod showed significant and positive phenotypic correlation with yield. A highly significant positive association between days to flowering and days to maturity was observed both at genotypic (0.855) and phenotypic (0.713) levels. The result revealed that if days to flowering increased, then days to maturity and plant height also increased. Days to flowering showed a highly significant negative association with 100 seed weight both at genotypic (-0.596) and phenotypic (-0.534) level. Days to maturity also showed a highly significant negative association with 100 seed weight and seeds per pod both at genotypic and phenotypic levels. Plant height had a significant positive correlation with yield and number of seeds per pod at genotypic level and phenotypic level. Makeen *et al.* (2007), Islam *et al.*, (1999), Niazi *et al.*, (1999) also observed a significant positive correlation between plant height and seed yield. Pods per plant showed a significant positive correlation with seed per pod and seed yield both at genotypic and phenotypic levels as reported by Makeen *et al.* (2007), Rao *et al.* (2006), Islam *et al.* (1999). Seeds per pod showed significant positive correlation with seed yield both at genotypic (0.641) and at phenotypic (0.379) level. Similar results were obtained by Islam *et al.* (1999). Highly significant positive correlation was recorded between 100 seed weight and seeds per pod at genotypic (0.612) and phenotypic (0.576) levels.

Table 3. Estimates of genotypic (r_g) and phenotypic (r_p) correlation coefficients among different quantitative characters in mungbean.

Characters		DF	DM	PH (cm)	PP (No.)	100 SW (g)	SPP (No.)
Days to flower	r_g	-					
	r_p	-					
Days to maturity	r_g	0.855**					
	r_p	0.713**					
Plant height (cm)	r_g	0.227	0.399**				
	r_p	0.184	0.208				
Pods per plant (No.)	r_g	0.231	0.219	-0.359			
	r_p	0.150	0.133	-0.212			
100 seed weight (g)	r_g	-0.596**	-0.605**	-0.284	0.221		
	r_p	-0.534**	-0.505**	-0.231	0.144		
Seeds per pod (No.)	r_g	-0.004	-0.731**	0.618**	0.715**	0.612**	
	r_p	-0.001	-0.582**	0.538**	0.526**	0.576**	
Yield (Kg/ha)	r_g	0.251	0.013	0.482**	0.491**	-0.011	0.641**
	r_p	0.183	0.011	0.373*	0.394*	-0.015	0.379*

* - Significant at p = 0.05, ** - Significant at p = 0.01

Path analysis: The correlation values indicate only the nature and degree of association existing between pairs of characters. A character like seed yield is dependent on several mutually associated component characters and change in any one of the components is likely to affect the whole network of cause and effect relationship. This in turn might affect the true association of component characters, both in magnitude and direction and tend to vitiate association of yield and yield components.

Path coefficient analysis revealed that number of pods per plant, had the maximum direct effect (0.408) on seed yield followed by plant height and 100 seed weight. It indicated that a slight increase in any of these traits may directly contribute towards seed yield (Table 4). Pods per plant showed positive direct effect of on seed yield via indirect positive effect through days to flowering, days to maturity and plant height. Our findings are in accordance with previous reports (Rao *et al*., 2006; Makeen *et al*., 2007; Hakim, 2008; Tabasum *et al*., 2010 and Mondal *et al*., 2011). Positive direct effect of plant height on seed yield and indirect positive effects via days to maturity and 100 seed weight as observed in this study have also been reported by Solanki (2006) and Tyagi and Khan (2011). Moreover, 100 seed weight exhibited positive indirect effects through days to maturity, seeds per pod and plant height. Similar findings were also reported by Mondal *et al*., (2011) and Biradar (2007). The residual effect of 0.69 was observed under present study indicates the contribution of component characters was 31% and the rest 69% was the contribution of other factors. The present study suggests that seed yield, number of pods per plant and plant height are greatly influenced by the additive gene effect and greater proportion of variations are heritable.

Table 4. Direct (diagonal) and indirect effects (off-diagonal) of different characters on yield at genotypic level

	DF	DM	PH	PP	100 SW	SP	Y
DF	**-0.499**	-0.655	-0.461	0.164	0.012	0.612	0.251
DM	-0.655	**-0.098**	0.591	0.156	0.147	-0.423	0.013
PH	-0.461	0.591	**0.383**	0.275	0.14	-0.429	0.482**
PP	0.164	0.156	0.275	**0.408**	-0.228	-0.201	0.491**
100 SW	0.012	0.147	0.14	-0.228	**0.124**	0.144	-0.011
SP	0.612	-0.423	-0.429	-0.201	0.144	**-0.078**	0.641**

R^2=0.323

DF= Days to flowering, DM= days to maturity, PH= Plant height (cm), PP= Number of Pods per Plant, SPP= No. seed per pod, 100SW= Hundred seed wt. (g) and Y= yield.

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IMPACT OF SHARECROPPING ON RICE PRODUCTIVITY IN SOME AREAS OF KHULNA DISTRICT

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Abstract

The study reveals the effect of sharecropping on rice productivity in some selected areas of Khulna District in the South-West region of Bangladesh. Access to land for the landless farmer is governed by informal land tenure arrangement, which in turn affects the productivity of the rice farm. In exploring the debate on sharecropping and farm efficiency, the present study has been conducted to assess the effect of sharecropping on rice productivity. During June 2014, a field survey was conducted by using a semi-structured questionnaire in two villages of Khulna District where sharecropping is one of the dominant land tenure arrangements in rice farming. A Cobb-Douglas production function estimation showed that type of land ownership, use of fertilizers, human labor, and modern variety (MV) including hybrid seed and high yielding varieties (HYVs) of seed had the positive and significant influence on rice production. There was a significant mean difference between the sharecroppers and the owner farmers regarding their volume of rice production. The production volume of the owner farmers was significantly higher by around 781 kg ha^{-1}. The study result from the production function revealed that on an average owner farmers' output was significantly higher by 10% than that of the sharecroppers. The study also observed that higher land rent in form of a fixed amount of cash or a higher crop share demotivated the sharecroppers to supply the optimum level of input and to use the land intensively. The result implied that the sharecroppers are inefficient compared to the landowners. Therefore, it is recommended that sharing an equitable production cost and a justifiable crop sharing structure might be the better options to motivate the sharecropper to become more efficient concerning their volume of production.

Keywords: Sharecropping; Land tenancy; Rice productivity; Production function; South-West region of Bangladesh.

1. Introduction

Bangladesh is predominantly an agriculture based developing country and rice is the main agricultural product which is mostly contributing to the agriculture sector of Bangladesh. The area, production, and yield of rice have increased over the year (Table 1). It is seen that from 1990-1991 to 2016-2017 there is a positive growth rate (compound annual growth rate) regarding the area of overall rice cultivation, total production volume and rice yield in Bangladesh. The growth

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rate of the area, production, and yield of rice in Bangladesh were 0.2%, 2.39%, and 2.19% respectively during the period from 1990-91 to 2016-17 (Table 1). Among the different rice production seasons, Boro is the single largest crop in Bangladesh regarding the volume of production and it is persistently contributing more compared to the Aus and Aman over the year regarding the overall rice yield. To find the study objectives, the study concentrated on the Boro rice production. In this connection, the authors reported the information on Boro rice cultivation and it is seen that the area, production, and yield of Boro rice are increasing day by day. In 2016-2017, it is estimated that Boro rice occupied nearly 41% of the 11 million hectares (ha) of rice cultivated area, and contributed more than 53% of the 33.80 million tons of rice produced. The yield (ton/ha) of Boro rice is significantly higher than Aus and Aman. The estimated yield of this rice in 2016-2017 was 4.02 ton/ha (Table 1).

The agricultural sector in Bangladesh is largely dominated by rice sub-sector and sharecropping is a widespread system in rice cultivation. Usually, the land-rich farmers cultivate a small portion of their cultivable land and rest are rented out by either sharecropping or fixed rental basis (Akanda *et al*., 2008). The rural marginal as well as the landless farmers largely depend on the system of share tenancy and the number of household with no won land is increasing in rural areas of Bangladesh over the time period. However, farmers having own land may also depend on others land to raise their farm size. According to a report of Bangladesh Agricultural Census, the percentages of landless households in rural areas were 12.84% in 2008 which were 10.18% in 1996, and 8.67% in 1983-1984 (BBS, 2008). In Bangladesh, the percentages of the owner farmers, owner cum tenant, and tenant farmers were 65.28%, 21.88%, and 12.83%, respectively, while in Khulna District, the percentages of the owner farmers, owner cum tenant, and tenant farmers were 63.44%, 17.16%, and 19.40%, respectively (BBS, 2008). This indicates that the share tenancy is a significant cultivation practice in the study area. During the shortage of off-farm employment, agricultural tenancy systems are commonly found in Bangladesh, especially at the time of cropping seasons. The system of cash tenancy and sharecropping are commonly practiced in agriculture of Bangladesh. Despite the higher prevalence of contract based cropping system in many developing countries, the yields of the sharecroppers differ than that of a fixed rent contract (Laffont and Matoussi, 1995). They found that sharecroppers exert less effort than that of a fixed rent contract, thus, production is lower for the sharecroppers.

The theoretical debate on sharecropping and agricultural productivity is observed by the model of the principal-agent relationships (Pender and Fafchamps, 2005; Laffont and Matoussi, 1995; Marshall, 1920). Marshall (1920) considers share tenancy as an inefficient practice of cultivation where resources are sub-optimally utilized. The argument behind the inefficiency of sharecroppers is that the farmers are not interested in utilizing their effort optimally because a large portion of output goes to the landlord (Tesafa and Abera, 2014; Braido, 2008). In contrast to the Marshallian inefficiency argument, Johnson (1950) advocates that the tenant may induce to apply the efficient level of input if there is continuous monitoring of the landowners regarding the cultivation practice. If the sharecroppers are monitored then their productivity may alter. Jacoby and Mansuri (2009) found that productivity of the unmonitored sharecroppers is lower than that of the monitored sharecroppers.

Table 1. Rice Production in Bangladesh

Year	Production Statistics of Boro Rice				Statistics on Gross Rice Production			
	Area ('000 Ha)	Prod. (M. Ton)	Yield (Ton/ Ha)	Annual Growth rate	Area ('000 Ha)	Prod. (M. Ton)	Yield (Ton/ Ha)	Annual Growth rate
1990-91	2,548	6,357	2.49	-7.42%	10,435	17,852	1.71	-2.88%
1991-92	2,635	6,804	2.58	3.50%	10,244	18,252	1.78	4.15%
1992-93	2,599	6,586	2.53	-1.86%	10,178	18,341	1.80	1.14%
1993-94	2,581	6,572	2.55	0.48%	9,982	17,851	1.79	-0.76%
1994-95	2,664	6,544	2.46	-3.53%	9,889	16,839	1.70	-4.78%
1995-96	2,603	7,221	2.77	12.93%	9,917	17,687	1.78	4.74%
1996-97	2,783	7,460	2.68	-3.37%	10,178	18,883	1.86	4.02%
1997-98	2,887	8,145	2.82	5.25%	9,934	18,291	1.84	-0.76%
1998-99	3,474	10,275	2.96	4.84%	9,763	19,109	1.96	6.30%
1999-00	3,652	11,027	3.02	2.09%	10,708	23,067	2.15	10.06%
2000-01	3,762	11,921	3.17	4.95%	10,797	25,086	2.32	7.86%
2001-02	3,771	11,766	3.12	-1.54%	10,660	24,300	2.28	-1.89%
2002-03	3,845	12,222	3.18	1.88%	10,771	25,188	2.34	2.59%
2003-04	3,944	12,837	3.25	2.40%	10,825	26,190	2.42	3.46%
2004-05	4,064	13,837	3.40	4.61%	10,369	25,157	2.43	0.28%
2005-06	4,066	13,975	3.44	0.95%	10,529	26,530	2.52	3.86%
2006-07	4,258	14,965	3.51	2.26%	10,580	27,318	2.58	2.47%
2007-08	4,608	17,762	3.85	9.68%	10,575	28,931	2.74	5.95%
2008-09	4,716	17,809	3.78	-2.03%	11,280	31,317	2.78	1.48%
2009-10	4,778	18,341	3.84	1.65%	11,425	32,257	2.82	1.69%
2010-11	4,771	18,617	3.90	1.65%	11,530	33,541	2.91	3.03%
2011-12	4,810	18,759	3.90	-0.05%	11,528	33,889	2.94	1.06%
2012-13	4,760	18,778	3.94	1.15%	11,423	33,833	2.96	0.75%
2013-14	4,791	19,007	3.97	0.56%	11,372	34,356	3.02	2.00%

Table 1. Cont'd

Year	Production Statistics of Boro Rice				Statistics on Gross Rice Production			
	Area ('000 Ha)	Prod. (M. Ton)	Yield (Ton/ Ha)	Annual Growth rate	Area ('000 Ha)	Prod. (M. Ton)	Yield (Ton/ Ha)	Annual Growth rate
2014-15	4,840	19,192	3.97	-0.05%	11,415	34,710	3.04	0.65%
2015-16	4,773	18,938	3.97	0.07%	11,381	34,710	3.05	0.30%
2016-17	4,476	18,014	4.02	1.43%	11,001	33,803	3.07	0.75%
Mean	3,832	13,101	3.30		10,692	25,825	2.39	
Std. Dev.	871	4,889	0.58		573	6,551	0.49	
Growth Rate*	2.11%	3.93%	1.79%		0.20%	2.39%	2.19%	

Source: BBS (2018).

N.B.: * Growth rate = Compound annual growth rate; Prod. = Production; Ha = hectare; M. Ton = Metric Ton.

The sharecroppers share their crop with the landowners on the basis of a pre-determined contract. The existing sharing system is not always fairly balance the distribution of crop between tenants and landowners (Akanda *et al*., 2008; Zaman, 1973). Nasrin and Uddin (2011) concluded that the land tenancy structure significantly influences the use of inputs and production cost, which in turn affect the productivity. Banerjee *et al*. (2002) found that relatively more land rights that lead to improved crop shares and higher security of tenure for tenants may have a positive effect on productivity. Several studies (Braido, 2008; Dubois, 2002) found that the land leased out to the tenant might be of less fertile than that is cultivated by owner farmers, and thus, sharecropping is relatively inefficient. Goswami (2015) found that the sharecroppers do not consider the productivity enhancing strategy and they are reluctant to use the sufficient amount of input in agricultural production. Ray (2005) explored that the tenant farmers under-supply productivity improving investments in the land. In the context of Nepal, Acharya and Ekelund (1998) found that owner cum share tenants have more incentives to increase output by applying a significantly higher amount of family labor and other inputs in their own lands than in the shared lands they cultivate.

Several study findings revealed that there is always a debate on the performance of sharecropping in agriculture. In order to investigate the efficiency of share tenancy in agricultural productivity, an attempt has been made to highlight the tenancy structure in rice farming and its impacts on agricultural productivity in two selected rural areas of Khulna District in Bangladesh. Two categories of farmers - tenant farmers and owner farmers were considered to find the efficiency of sharecropping in rice production. In case of categorizing the type of farmers, the farmers who might have their own land, however, cultivated others land in a sharecropping system are considered as the sharecroppers and the farmers who cultivated rice only in their own land are considered as owner farmers. For the case of sharecroppers, the production data was collected from their land, which is in under sharecropping system and subsequently their productivity is compared with the owner farmers. The study tried to satisfy the following study objectives.

(i) To explore the existing cost and crop sharing structure under the sharecropping system in the study area;

(ii) To explore the impact of sharecropping on rice productivity in the study area.

2. Materials and Methods

2.1. Description of the Study Area

A field survey was conducted based on the multistage sampling technique in two purposively selected villages namely Raruli and Bhabanipur in Raruli Union of Paikgacha Upazila of Khulna District in Bangladesh. These two villages were known to both the authors as they were living in Khulna District at that time of the survey. For the convenience of surveying the farmers, purposively Khulna District among the Districts of the South-west region of Bangladesh then Paikgacha Upazila among the nine Upazilas was selected as the study Upazila. Then two villages namely Raruli and Bhabanipur among the two hundred and twelve villages from Paikgacha Upazila were chosen purposively. These two villages were adjacent to each other.

2.2. Sampling Technique, Data Collection Procedure and Period of Study

At that time of the survey, a village listing of rice cultivators (list of the farmers) was conducted in these two villages and it was found that there were about four hundred rice farmers in these two villages who were the concerned population of this study. As the objectives of this study were to find the role of sharecropping on rice productivity, two categories of farmers – sharecropper and owner farmer in rice cultivation were taken for this study to find out their production difference. To make a balance between these two groups, the primary data were collected from a total of 80 respondents randomly taking 40 from the owner farmers and 40 from the sharecroppers which were a mixture of pure sharecroppers and fixed rental based tenants. The pure sharecroppers share the output (crop amount) with the landowners in a pre-determined proportion, some cases 50:50 share and in other cases 65:35, whereas in a fixed rental system of cultivation, a fixed amount of money paid annually to the landowners by the cultivators ranged from BDT 4,000 to BDT 6,000 [1 US $ = 78.00 Bangladeshi Taka at the time of survey] per hectare of land depend ing on the land fertility and accessibility of land. The sharecroppers might have some amount of their own land. However, this study only considered the information on their cultivated land, which is in under sharecropping system. In order to find the role of sharecropping on rice productivity, the study collected the data on rice production and input use from the rice production plots of landowners and the production plots of sharecroppers.

A semi-structured questionnaire was used to collect the data from 80 samples of these two villages. A draft questionnaire was prepared and it was pre-tested through a pilot survey. The pilot survey was conducted during the middle of May 2014. After a careful scrutiny based on the observations from pilot survey and field visits, the final version of the questionnaire was prepared for the household survey, which was conducted in June 2014. The questionnaire covered - the socio-economic condition of the farmer, land holding, tenancy structure, farming type, use of inputs, output, existing crop sharing practice, etc. The information on rice cultivation covered the Boro rice which is usually cultivated during January to May in each year.

2.3. Analytical Technique

To determine the output differentials between the sharecropper and owner farmer, the hypotheses were tested by using the t-test. The study also used a kernel distribution curve to find the production structure between the sharecroppers and owner farmers. This curve showed the production distribution of both the group of farmers and the enveloped area represented the density of each group.

In order to assess the effect of sharecropping on rice productivity, a Cobb-Douglas form of production function was estimated (Equation 1). In the production function, land ownership pattern of the farm was used as a dummy (1 for owner farmer and 0 for sharecropper) along with several other explanatory variables such as land size, number of labor, use of seed, use of fertilizers, use of pesticides, cost of irrigation, cost of ploughing, nature of farming, farming experience, cropping pattern and crop rotation are used as the explanatory variables.

$$Ln\ \mathrm{Q} = \beta_{\mathrm{n}} + \beta_i LnX_i + \beta_i D_i + u_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

In equation 1, Q is yield of rice (kg ha^{-1}; ‘ha’ is refers to ‘hectare’), X_1 is land size (ha), X_2 is use of seed (kg ha^{-1}), X_3 is use of fertilizers (kg ha-1), X_4 is use of labor (man days ha^{-1}), X_5 is use of pesticides (kg ha^{-1}), X_6 is cost of ploughing (BDT ha^{-1}), X_7 is cost of irrigation (BDT ha^{-1}), X_8 is farming experience (years), X_9 is household size, D_1 is a dummy for type of seed (1 for modern variety and 0 for others), D_2 is a dummy for ownership pattern of the farm (1 for owner farm and 0 for sharecropper), D_3 is a dummy for training in farming (1 for having training in rice cultivation and 0 for having no training), D_4 is a dummy for nature of farming (1 for full-time farming and 0 for not doing rice cultivation as full time), D_5 is a dummy for crop rotation (1 for the same crop in each season and 0 for different crops in each alternate seasons), and D_6 is a dummy for cropping pattern (1 for single crop and 0 for more than single crop). The dummy for ownership pattern of the farm is used to find the production difference between the sharecroppers and owner farmers.

3. Results and Discussion

3.1. Patterns of Crop Sharing Under the Tenancy Contracts

There are three types of farming practice prevailed in rice cultivation in the study areas such as owner farming, owner cum tenant farming and tenant farming based on the crop sharing and rental system. The pattern of crop sharing depends on the cost sharing of inputs and other assistance. Traditionally, there was a proportion of crop sharing of 50 percent for the owner and the rest 50 percent for the cultivator. At present, the scenario of crop sharing has been changed because of increasing cost of production. The sharecroppers in the study area were unable to invest in crop production and seek financial assistance from the landowners.

In many cases, the landowners did not share the cost of production, thus, received less than 50 percent of output. In contrast, when a landowner shares the cost of production then he or she receives more than half or sometimes exactly half of the output. When a sharecropper bears all the cost of production then he or she gets 65 percent of output (Fig. 1). Nasrin and Uddin (2011) observed that a large number of sharing agreements under the pure share tenancy in Bangladesh mostly dependent on the proportion of cost sharing. Islam and Maharjan (2015) observed that in most of the cases the landowner takes 50 percent of the produced crops without sharing any portion of production costs and in less than 5 percent of the cases the sharing pattern was more than 50%.

The study result indicated that out of 20 pure sharecroppers, 60 percent (12 out of 20 pure sharecroppers) of them reported 50:50 share (Fig. 1) where both the farmers (landowner and tenant) got equal portion of output and the rest 40 percent of the sharecroppers (eight out of 20 pure sharecroppers) reported 65:35 share where the sharecroppers got 65 percent and the owner farmers got 35 percent of the output (Fig. 1). For the case of 50:50 share of output, the landowners shared half of the cost of irrigation and fertilizers, and for the case of 65:35 ratio of output, the sharecroppers bore all the cost of production. In this case, the landowners got the crop as the rent of land without sharing any cost of production. This finding revealed that there was a significant association between the crop share and the rate of production cost-sharing by the landowners. In a study on a North Indian village, Sharma and Drèze (1996) claimed that the relationship between landlord and tenant was often assumed to be inherently unequal and exploitative.

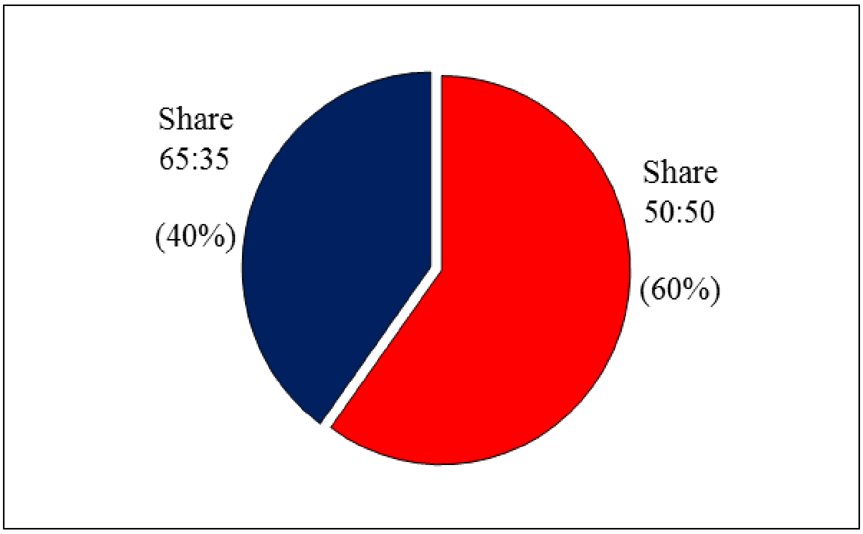

Fig. 1. Sharing Pattern of Output in the Study Area (Percent).
Source: Authors compilation based on field survey (2014)

3.2. Impact of Sharecropping on Rice Productivity

From the study findings, it was observed that there was a significant mean production difference between the owner farmers and sharecroppers (Table 2). During the Boro rice cultivation [January to May], the mean output of an owner farmer was ~6114 kg ha^{-1}, while the mean output of a sharecropper was ~5332 kg ha^{-1} which revealed a significant production difference between these two categories of farmer. The findings illustrated the farm's efficiency level under different tenancy structure by comparing their mean output per hectare of land. In addition, the study also observed that the owner farmers were more productive than their counterparts (sharecroppers). The kernel distribution curve showed that the distribution of the owner farmers enveloped a higher density in the range of the higher value of log of rice production (kg ha^{-1}) (Fig. 2). On the contrary, for the sharecroppers, a higher density was observed in the range of the lower value of log of rice production as compared to the owner farmers. The findings indicated that the sharecroppers suffered from the productive inefficiency, the while the landowners were mostly better off in terms of productive efficiency.

Fig. 2. Kernel Distribution of the Output by Land Tenancy Structure.

Source: Authors compilation based on field survey (2014)

According to the Marshallian inefficiency argument, it was assumed that sharecropping might influence the crop yields. In order to test the inefficiency hypothesis of sharecropping on rice production, a Cobb-Douglas form of production function (Equation 1) was used to estimate the relationship between ownership pattern of rice farm and volume of production. The farm specific characteristics and other explanatory variables of production function (Table 2) showed the use of factors of production and nature of farming of both the sharecropper and owner farmers.

In case of the mean difference in output as well as inputs between the owner farmers and sharecroppers, the former group of farmers outperformed the later one regarding the use of the quantity of seeds, fertilizers, labor, and use of modern variety including hybrid seeds and high yielding varieties (HYVs). In the context of the Northeast region of India, Goswami (2015) found that the sharecroppers did not intensively use the land and undersupplied labor in agriculture. In addition, the land size of the owner farmers was significantly higher than the sharecroppers (Table 2). The reason might be the lack of land ownership by the sharecroppers. Thus, they were dependent on the other’s land for rice cultivation. As the sharecroppers were dependent on the land of other landowners they might get less access to land for cultivation, and thus, their farm size is small compared to the owner farmers.

Table 2. Farm Specific Characteristics of the Sample Boro Rice Farmers

Particular	Owner Farmer (a)	Sharecropper (b)	Mean Difference [(a) – (b)]
	Mean	Mean	Mean
Yield (kg ha^{-1})	6113.653	5332.207	781.446***
Land size (ha)	0.460	0.364	0.095**
Seed (kg ha^{-1})	41.998	41.410	0.588
Fertilizers (kg ha^{-1})	448.660	440.572	8.088
Labor (No. ha^{-1})	197.167	187.132	10.035
Pesticides (kg ha^{-1})	8.252	8.273	-0.021
Ploughing (BDT ha^{-1})	6448.20	6275.00	173.2
Irrigation (BDT ha^{-1})	47.255	42.608	4.647
Type of seed (Modern variety = 1; otherwise = 0)	0.150	0.075	0.075
Nature of farming (full time= 1; Part time= 0)	0.525	0.400	0.125
Crop rotation (same crop= 1; different crop = 0	0.775	0.750	0.025
Cropping pattern (single crop=1, different =0)	0.675	0.825	-0.150

*N.B: ***, ** and * indicate the differences between owner farmer and sharecropper are significant at 1% (p<0.01), 5% (p <0.05) and 10% (p <0.10) level respectively.*

The cost structure of rice cultivation was mentioned in BDT ha^{-1} where 1 US $ = 78.00 Bangladeshi Taka (BDT) at the time of survey (June, 2014)

Source: Authors compilation based on field survey (2014)

Table 3. Estimation of Production Function

Explanatory variables	(1)	(2)	(3)
	Model 1	Model 2	Model 3
Land (X_1)	0.062	0.005	0.031
	(0.055)	(0.055)	(0.063)
Seed (X_2)	0.121	0.125	0.164
	(0.121)	(0.115)	(0.122)
Fertilizers (X_3)	0.468***	0.384***	0.414***
	(0.147)	(0.142)	(0.146)
Human labor (X_4)	0.284***	0.248**	0.236**
	(0.103)	(0.098)	(0.106)

Table 3. Cont'd

Explanatory variables	(1)	(2)	(3)
	Model 1	Model 2	Model 3
Pesticides (X_5)	0.046	0.054	0.046
	(0.095)	(0.090)	(0.093)
Ploughing (X_6)	0.007	0.020	0.022
	(0.045)	(0.042)	(0.046)
Irrigation (X_7)	0.039	0.034	0.030
	(0.029)	(0.027)	(0.030)
Type of seed (D_1)	0.141**	0.121*	0.116*
	(0.065)	(0.062)	(0.068)
Ownership pattern (D_2)		0.110***	0.112***
		(0.036)	(0.038)
Experience of farming in year (X_8)			0.001
			(0.003)
Having training in farming (D_3)			0.052
			(0.041)
Nature of farming (D_4)			-0.046
			(0.041)
Crop rotation (D_5)			0.031
			(0.046)
Cropping pattern (D_6)			-0.016
			(0.051)
Household size (X_9)			-0.005
			(0.018)
Constant	3.621***	4.152***	3.945***
	(0.828)	(0.801)	(0.852)
Observations	80	80	80
R-squared	0.418	0.488	0.517

N.B: Robust standard errors in the parentheses;

****, ** and * indicate the level of significance at 1% (p<0.01), 5% (p <0.05) and 10% (p<0.10), respectively*

Source: Authors compilation based on field survey (2014)

The production function estimation revealed the effect of sharecropping on rice productivity in the study area. The result showed that the extent of variations in output when the farm was operated under the sharecropping system. In order to explore the impact of farm specific characteristics, ownership of the farm, and other farmer's and household level characteristics on rice production, three separate production functions were estimated (Table 3). The first regression result (model 1) showed that the use of fertilizers, human labor, and modern variety (MV) had a positive and significant effect on rice production (Table 3).

The result implied that a one percent increase in fertilizers uses leads to an increase in output by an average of 0.40 percent. It could be inferred that as the marginal productivity of fertilizer was positive, there was an opportunity of using additional fertilizers to increase the volume of production. Land, seed, pesticides, ploughing irrigation, and crop rotation had also a positive impact on output, while they were not significant.

In model 2, the positive elasticity of land ownership indicated that owner farmers positively influenced the output as compared to the sharecroppers. The coefficient of the dummy variable D_2 (β = 0.11) indicated that holding other things constant, on an average owner farmers' output was 10% [= 1 – exp (–0.11)] higher than that of sharecroppers. It was observed that the sharecroppers had to share 35 percent to 50 percent of their output to the landowners as a rent of their land. Thus, higher rent demotivated the sharecroppers to supply the optimum level of input and also to use the land intensively. Some characteristics of the farmers were also added in model 3. None of them were found a significant influence on production volume.

Goswami (2015) noted the sharecroppers as the most inefficient group of farmers. Usually, the sharecroppers in this study were not monitored by the landowners. After getting the cultivation rights from the landowners, the sharecroppers took the decisions on production process and input use by themselves. In case of pure tenant, the landowners sometimes tried to intervene the output choice but they were not concerned about the input use and production process. However, in case of the cash tenant, the landowners are reluctant to intervene in production process, input use and even in output choice. Lack of monitoring by the landowners could be a reason of lower productivity by the sharecroppers. The study also found that around 60% of the pure sharecroppers did not share the cost of production while enjoyed a significant portion of output. In another case, it is mentioned earlier that the landowners enjoyed half of the output without sharing the cost of production. The existing cost sharing and output distribution between the sharecroppers and landowners might be a cause of lower productivity of sharecropping system. In the context of Pakistan, Jacoby and Mansuri (2009) found that there was no significant yield difference between the sharecroppers and owner farmers, while the owner farmers gained 18% more yield than the unmonitored sharecroppers. Therefore, monitoring could be an issue to make the farms more efficient and productive. The findings of this study indicated that compared to sharecropper the owner farmers were more efficient regarding the volume of rice production.

4. Conclusions

Among the several land tenure arrangements, the system of sharecropping is one of the usual systems of cultivation for the marginal as well as the landless farmers in the rural areas of Bangladesh. However, this system of cultivation is a concern in the present time regarding the productivity in rice cultivation because of the existence of the inefficiency hypothesis in sharecropping and rice production. The study findings revealed that the rice production of the owner farmer was significantly higher than the sharecropper. The owner farmers were more productive regarding the volume of output. The sharecroppers in the study areas used less amount of input such as seed, fertilizers, and human labor as well as spent less on ploughing and irrigation compared to the owner farmers. In addition, a lower percentage of sharecroppers used modern variety than the owner farmers.

The production difference between the sharecroppers and owner farmers revealed that the sharecroppers were less interested in providing their full effort in enhancing their farm productivity. The existing crop sharing ratio and cost sharing structure might be the reasons for less incentive of the sharecropper in applying the production enhancing inputs. Thus, the sharecroppers were more inefficient in rice productivity. In order to overcome the debate between sharecropping and agricultural productivity, the ratio of crop share should be favorable for the sharecropper, and that should be revised and uniform based on the cost sharing structure. In addition, the landowners should keep in touch with the use of their land by the tenant, which could motivate the sharecroppers to give full effort to apply the production enhancing inputs.

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MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER USING SELECTED BOTANICALS

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Abstract

The study was conducted to evaluate the effect of botanicals namely neem leaf extract, neem oil, mahogany oil, mahogany oil + mahogany cake, garlic extract, tobacco leaf extract along with an untreated control to manage brinjal shoot and fruit borer (BSFB). The percent shoot infestation reduction over control was the highest in mahogany oil + mahogany cake treated plot resulting 62.39%, 64.44%, 67.86% and 71.05% reduction at vegetative stage and early, mid and late fruiting stage, respectively. The same treatment provided the highest fruit infestation reduction over control resulting 86.70%, 85.08% and 85.50% reduction at early, mid and late fruiting stage, respectively. The lowest number of larvae per infested shoot was recorded 1.10 and 1.08 in the same treatment at early and mid fruiting stage, respectively but notat vegetative stage and late fruiting stages. The number of larvae per infested fruit was similarly lowest having 1.50, 1.06 and 1.07 at early, mid and late fruiting stage, respectively using the same approach. The maximum yield (35.82 t ha^{-1}) was achieved in the mahogany oil + mahogany cake treated plot with the highest benefit cost ratio (2.35).

Keywords: *Leucinodes orbonalis*, neem, mahogany, garlic, tobacco, extracts, oils, cake.

Introduction

Brinjal (*Solanum melongena* L.) is one of the most popular vegetables in South and South-East Asia (Thapa, 2010) having hot-wet climate (Hanson *et al.*, 2006) and other parts of the world (Nonnecke, 1989). The cultivation of brinjal is more than 16.00 lakh producing around 50 million tons throughout the world (FAO, 2012). The higher yield and longer fruiting and harvesting period lure the farmer on eggplant production (Ghimire *et al.*, 2007). In Bangladesh it covers about 15% of the total vegetable area of the country producing 1.6 million tons annually. The production of brinjal is 60-65 t ha^{-1}(BARI, 2005) which is not satisfactory to meet up the growing demand of vegetables. The production of brinjal is affected severely by different insect pests from seedling to fruiting stage (Latif *et al*., 2009). Brinjal shoot and fruit borer (*Leucinodes*

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orbonalis, Guenee) is the most destructive insect pest of brinjal in Bangladesh which caused 31-86% fruit damage (Alam *et al*., 2003) reaching up to 90% (Rahman, 1997). It also reduces the content of vitamin C in fruit up to 80 percent (Sharma, 2001). Farmers of Bangladesh as well as of other Asian countries in most cases solely depend on insecticides for the management of this pest. Such dependence on insecticides has created many problems such as very frequent application of insecticides (up to 140 times in a season in Jessore), excessive residues on marketed vegetables that concerns general consumer's health and the environment, pesticide resistance, trade implications, poisoning, hazards to non-target organisms, increased production costs etc. (Alam *et al*., 2003; Pedigo, 2002).

Now-a-days, emphasis is given on the use of plant extracts as biopesticides in insect control measures (Singh *et al.*, 2007; Gupta and Raghuraman, 2004; Oerke, 2006; Gokce, 2010). This is because that the use of plant based biopesticides in insect control is non-toxic and safe biodegradable alternatives to the conventional chemical control (Anil and Pandey, 2001; Dolui and Debnath, 2010). So, for ensuring food safety and minimization environmental hazards the present study was undertaken to determine the effectiveness of selected botanicals for the management of brinjal shoot and fruit borer (BSFB).

Materials and Methods

Experimental site and climatic condition

The experiment was conducted in the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna (22°47′57.84″N, 89°31′53.48″E), Bangladesh during December 2013 to June 2014. The experimental site was characterized by moderately high temperature and heavy rainfall during *kharif* season (April-October) and scantly rainfall with moderately low temperature during *rabi* season (November-March).

Raising of seedlings and transplanting

The seed of local brinjal variety named Makra was collected from local market Gollamari and raised as seedling in germplasm centre of Khulna University. Brinjal seedling was raised in seedbed of 3m×1m size. Weeding, mulching and irrigation were done when required. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The entire experimental plot was divided into 3 blocks each containing 7 units plots. Totally there were 21 unit plots. The treatments were randomly assigned to each unit plot so as to allot one treatment combination once in each block. The unit plots were 3m×2m in size with 75 cm distance between the blocks and 50 cm between the unit plots. Each plot was contained 16 plants. Organic amendments and chemical fertilizers were applied in the field as recommended by Bangladesh Agricultural Research Council (Anon., 2005). Healthy seedlings were uprooted from the seedbed and were transplanted in the experimental plots during late afternoon on December, 2013. Immediately after planting, the seedlings were watered. Seedlings were also planted around the experimental area for gap filling and to check the border effect.

Preparation of neem leaf extract

Fresh leaves of *Azadirachata indica* (Neem) were collected from the plants at the Khulna University campus. Then the collected leaves were dried in shade and were ground with a domestic grinder. Fifty grams (50g) of the ground leaves were added with water and left overnight to make 1000 ml solution. The mixture was then filtered and the filtrate poured into a flat bottom flask as stock for the field spraying five grams of wheel powder was added to increase its adhesiveness (Murugesam and Murugesh, 2009).

Preparation of garlic extract

Bulbs of garlic were brought from the market, 30 g of garlic bulbs were chopped into pieces using knife and such material was ground thoroughly, mixed with 50 ml of water and the ground mixture was soaked in little quantity of water over night and squeezed through muslin cloth and the volume was made up to 1 liter to get 3 per cent extract five grams of wheel powder was added to increase its adhesiveness (Murugesam and Murugesh, 2009).

Preparation of tobacco leaf extract

Tobacco leaves were brought from the market, 30 g of tobacco leaves were chopped into pieces and such material was ground thoroughly in mixed with 50 ml of water and the ground mixture was soaked in little quantity of water over night and squeezed through muslin cloth and the volume was made up to 1 liter to get 3 per cent extract five gram of wheel powder was added to increase its adhesiveness (Murugesam and Murugesh, 2009).

The neem oil, mahogany oil and mahogany cake were purchased from the local market of Khulna.

Treatment application

The treatments namely Untreated control (only water), Neem leaf extract (@ 50 gl^{-1} water), Neem oil (@ 40 ml l^{-1} water), Mahogany oil (@ 40 ml l^{-1} water), Mahogany oil + Mahogany cake (oil (@ 40 ml l^{-1} water + cake @ 250 kg ha^{-1}), Garlic extract (@ 50 g l^{-1} water) and Tobacco leaf extract (@ 50 g l^{-1} water) were applied as foliar sprays starting after 20 days of transplanting and repeated subsequently at 7 days interval and mahogany cake was applied in the plot and incorporated with soil. Care was taken to avoid drifting of treatment to neighbouring plots. No pest control technique was applied in untreated control plots. However, an equal volume of water, which was used for other plots, was sprayed at 7 days intervals. After transplanting of seedlings, various intercultural operations were accomplished for better growth and development of the plants.

Harvesting and data collection

Harvesting of fruits was started at 60 days after transplanting and continued up to 150 days after transplanting with an interval of 7 days. Harvesting was usually done manually. In order to know the effects of the treatments on controlling BSFB. Data were collected on total numbers of shoot, total numbers of infested shoot, percentage of shoots damage, percentage reduction of shoots infestation, numbers of larvae per infested shoot, total numbers of fruits, percentage of fruits damage, percentage reduction of fruits infestation, numbers of larvae per infested fruits, cost of production, gross return and benefit cost ratio (BCR).

Data analysis

Data were analyzed by using MSTAT-C software for analysis of variance. ANOVA was made by F variance test and the pair comparisons were performed by Duncan's Multiple Range Test (DMRT).

Results and Discussion

The percent shoot infestation reduction over control by brinjal shoot and fruit borer (BSFB) in different stages was statistically significant (Table 1). Among the seven treatments the highest percent shoot infestation reduction over control was observed in mahogany oil + mahogany cake (62.39%) treated plot and the lowest in the mahogany oil (25.93%) treated plot at vegetative stage. At early fruiting stage, the highest (64.44%) percent shoot infestation reduction over control was found in mahogany oil + mahogany cake and the lowest in the garlic extract treated plot (28.60%). Whereas, at the mid fruiting stage, the percent shoot infestation reduction over control was the highest (67.86%) in mahogany oil + mahogany cake and the lowest (31.82%) in garlic extract sprayed fields. Finally at late fruiting stage, the highest percent shoot infestation reduction over control (71.05%) was recorded from mahogany oil + mahogany cake and the lowest (27.63%) in the garlic extract applied plot.

From the result, it was revealed that at all the growth stages of brinjal percent shoot infestation reduction over control was the highest in mahogany oil + mahogany cake and the lowest in the garlic extract. Botanicals are more advantageous over insecticides (Prakash *et al.*, 2008), as they fit well in IPM.

The safer plant products are useful in developing sound pest management strategies (Gupta and Singh, 2002). Among the plant extract treatments, more protection of shoot over control was found from neem leaf extract (92.5%) followed by tobacco leaf extract (84.4%) and mahogony seed extract (60.40%) (Ashadul *et al.*, 2014). Dutta *et al.* (2011) found that simultaneous application of trap and neem extract afforded 79.24% protection against shoot damage.

Table 1. Percent shoot infestation reduction over control at different stages

Treatments	Vegetative stage (30-60 DAT) (%)	Early fruiting stage (60-90 DAT) (%)	Mid fruiting stage (90-120 DAT) (%)	Late fruiting stage (120-150 DAT) (%)
Control	0.00c	0.00f	0.00d	0.00e
Neem leaf extract	40.00ab	32.33de	42.00bc	42.11c
Neem oil	59.26a	55.67ab	65.38a	64.85ab
Mahogony oil	25.93b	40.37cd	39.58bc	37.28cd
Mahogany oil + Mahogany cake	62.39a	64.44a	67.86a	71.05a
Garlic extract	27.78b	28.60e	31.82c	27.63d
Tobacco leaf extract	40.74ab	46.97bc	45.00b	56.58b
Level of significance	**	**	**	**
CV (%)	26.74	10.05	9.97	13.33

DAT= Days After Transplanting; **= Significant at 1% level; CV= Coefficient of Variation.

Means followed by common letter(s) in a column do not differ significantly by DMRT.

The percent fruit infestation reduction over control at different stages was statistically significant (Table 2). Percent fruit infestation reduction over control was the highest inmahogany oil + mahogany cake (86.70%, 85.08% and 85.50%) at early, mid and late fruiting stage, respectively. The lowest percent of fruit infestation eduction over control was found in garlic extract (17.40%, 9.06% and 9.80%) at early, mid and late fruiting stage, respectively. It was recommended that innovative methods of application, proper timing and aqueous neem seed extract can be other alternative or supplement to synthetic insecticide for the management of vegetable pests by poor farmers (Owusu-Ansah *et al.*, 2001). Among the plant extract treatments, more protection of fruit over control was found from neem leaf extract (93.30%) followed by tobacco leaf extract (84.30%) and mahogony seed extract (73.00%) (Ashadul *et al.,* 2014). Application of trap and peak neem afforded 47.70% protection against fruit damage (Dutta *et al*., 2011).

Table 2. Percent fruit infestation reduction over control at different stages

Treatments	Early fruiting stage (60-90 DAT) (%)	Mid fruiting stage (90-120 DAT) (%)	Late fruiting stage (120-150 DAT) (%)
Control	0.00g	0.00e	0.00g
Neem leaf extract	43.90d	41.10bc	38.90d
Neem oil	71.90b	44.30b	69.50b
Mahogony oil	31.50e	25.60cd	25.90e
Mahogany oil + Mahogany cake	86.70a	85.80a	85.50a
Garlic extract	17.40f	9.06de	9.80f
Tobacco leaf extract	57.40c	58.20b	58.70c
Level of significance	**	**	**
CV (%)	5.45	16.29	7.73

DAT= Days After Transplanting; **= Significant at 1% level; CV= Coefficient of Variation.

Means followed by common letter(s) in a column do not differ significantly by DMRT.

Number of larvae in infested shoot and fruit atdifferent stages was statistically significant (Table 3). The highest number of larvae per infested shoot was recorded (3.10) in the control and the lowest (1.00) in neem oil which was statistically similar to mahogany oil + mahogany cake (1.09). Mean number of larvae per infested shoot at early fruiting stage was recorded the lowest in mahogany oil + mahogany cake (1.10) preceded by neem oil (1.40) and the highest was recorded from the control (2.50). The mean number of larvae per infested shoot at mid fruiting stage was the highest in control (2.50) and the lowest in mahogany oil + mahogany cake (1.08). Mean number of larvae per infested shoot at late fruiting stage was found the highest (2.30) in control and the lowest (1.07), in mahogany oil + mahogany cake. Mean number of larvae per infested fruit plant at early fruiting stage was observed the highest in the control (3.20) and the lowest in mahogany oil + mahogany cake (1.06). Mean number of larvae per infested fruit plant at mid fruiting stage was the highest in the control (3.20) and the lowest in mahogany oil + mahogany cake (1.06). Mean number of larvae per infested fruit plant at late fruiting stage was the highest in the control (3.20) and the lowest in mahogany oil + mahogany cake (1.07) followed by neem oil (1.10).

Table 3. Mean number of larvae per infested shoot and per infested fruit at different stages

Treatments	Mean number of larvae per infested shoot				Mean number of larvae per infested fruit		
	Vegetative stage (30-60DAT)	Early fruiting stage (60-90 DAT)	Mid fruiting stage (90-120 DAT)	Late fruiting stage (120-150 DAT)	Early fruiting stage (60-90 DAT)	Mid fruiting stage (90-120 DAT)	Late fruiting stage (120-150 DAT)
Control	3.10a	2.50a	2.50a	2.30a	3.80a	3.20a	3.20a
Neem leaf extract	1.70bc	2.10ab	2.00a	1.90a	1.90c	1.50bc	1.40bc
Neem oil	1.00c	1.40c	1.30b	1.20b	1.70c	1.30bc	1.10c
Mahogany oil	2.30b	2.40a	2.20a	2.10a	1.80c	1.90b	1.80b
Mahogany oil + Mahogany cake	1.09c	1.10c	1.08b	1.07b	1.50c	1.06c	1.07c
Garlic extract	2.20b	2.30a	2.10a	2.00a	2.40b	1.90b	1.60bc
Tobacco leaf extract	1.30c	1.50bc	1.30b	1.00b	1.50c	1.30bc	1.20bc
LS	**	**	**	**	**	**	**
CV (%)	14.46	12.04	10.51	10.59	10.28	15.010	13.52

DAT= Days After Transplanting; LS= Level of Significance; **= Significant at 1% level

CV= Coefficient of Variation.

Means followed by common letter(s) in a column do not differ significantly by DMRT.

The yield per plot showed significant variation among the treatments (Table 4). The yield was highest (35.82t ha^{-1}) when mahogany oil + mahogany cake was applied which was statistically identical with tobacco leaf extract (33.97t ha^{-1}) treated field plot. Increased yield over control was highest in mahogany oil + mahogany cake (19.34 t ha^{-1}) treatment and the lowest was in garlic extract treated plot (5.34 t ha^{-1}).

According to the procedure of Ramakrishna and Palled (2005), cost and return analysis in details was done and has been shown in Table 5. Material, non-material and overhead cost were recorded for all treatments on unit plot basis and calculated per hectare. The total cost of production ranged between 291666 Tk. and 491666 $Tkha^{-1}$. The highest cost of production was found in neem oil (491666 $Tkha^{-1}$) followed by tobacco leaf extract (411666) and the lowest was found in the control (291666$Tkha^{-1}$). The range between the gross return was

264000 Tk to 949700 Tkha^{-1}. The treatment mahogany oil + mahogany cake gave the highest net return of Tk. 949700 followed by tobacco leaf extract of Tk. 888200 and the lowest was found in control (264000 Tkha^{-1}). The maximum benefit cost ratio was found (2.35) in the mahogany oil + mahogany cake which was statistically similar with tobacco leaf extract (2.16) and the minimum was in untreated control (0.91) plot.

Considering the economic return per hectare, this experiment demonstrated that application of mahogany oil + mahogany cake was found more appropriate for brinjal production for controlling brinjal shoot and fruit borer.

Table 4. Effect of selected botanicals on brinjal yield

Treatments	Yield (t ha^{-1})	Increased yield over control (t ha^{-1})
Control	16.48d	0.00d
Neem leaf extract	25.32bc	8.84bc
Neem oil	30.85ab	14.37ab
Mahogony oil	23.32cd	6.84cd
Mahogony oil + Mahogony cake	35.82a	19.34a
Garlic extract	21.82cd	5.34cd
Tobacco leaf extract	33.97a	17.49a
Level of significance	**	**
CV (%)	11.17	22.18

**= Significant at 1% level; CV= Coefficient of Variation.

Means followed by common letter(s) in a column do not differ significantly by DMRT.

Table 5. Benefit Cost Ratio of brinjal production

Treatments	Gross return (Tkha^{-1})	Total cost of production (Tkha^{-1})	Benefit cost ratio(BCR)
Control	264000g	291666	0.910c
Neem leaf extract	573200d	341666	1.68b
Neem oil	808500c	491666	1.64b
Mahogany oil	448200e	391666	1.14c
Mahogany oil + Mahogany cake	949700a	403333	2.35a
Garlic extract	403200f	361666	1.11c
Tobacco leaf extract.	888200b	411666	2.16a
Level of significance	**	NS	**
CV (%)	11.47	-	12.19

**= Significant at 1% level; NS= Non Significant; CV= Coefficient of Variation.

Means followed by common letter(s) in a column do not differ significantly by DMRT

Conclusion

The findings of the present study revealed that mahogany oil + mahogany cake, was proved to be highly effective against BSFB and cost effective. So, brinjal growers may be motivated to apply mahogany (oil + cake) for better management of brinjal shoot and fruit borer (BSFB) to ensure maximum yield.

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EFFECTS OF ZINC AND BORON ON YIELD, NODULATION AND NUTRIENT CONTENTS OF FIELDPEA IN TERRACE SOILS

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Abstract

An experiment was conducted for two consecutive years (2014-15 and 2015-16) in the field of Pulses Research Sub-Station, BARI, Gazipur during *rabi* (winter) season to evaluate the effect of zinc (Zn) and boron (B) application on the yield, nodulation and nutrient content of fieldpea (*Pisum sativum* L.). There were 16 treatment combinations comprising four levels each of zinc (0, 1, 2 and 3 kg ha^{-1}) and boron (0, 1, 1.5 and 2 kg ha^{-1}) along with a blanket dose of N_{12} P_{18} K_{30} S_{10} kg ha^{-1} over the treatments. The experiment was laid out in a split-plot design with three replications. Zinc (Zn) as $ZnSO_4.7H_2O$ and boron (B) as H_3BO_3 were applied to the crop (cv. BARI Fieldpea-1). Results showed that the combination of $Zn_3B_{1.5}$ kg ha^{-1} produced the highest seed yield (1582 kg ha^{-1}) in the 1st year and the Zn_3B_2 kg ha^{-1} gave the highest yield (1702 kg ha^{-1}) in the 2nd year.The lowest seed yield was found in the control (Zn_0B_0). The Zn_3B_2 demonstrated the highest nodulation and nutrient and protein contents. The results suggest that the application of Zn_3B_2 kg ha^{-1} along with N_{12} P_{18} K_{30} S_{10} kg ha^{-1} can support the higher yield of fieldpea in terrace soils of Bangladesh.

Keywords: Zinc and boron, fieldpea, yield, nodulation, nutrient content

Introduction

Field pea (*Pisum sativum* L) is a popular legume crop worldwide. Fieldpea is rich in high-quality protein (20%), contains 4 mg pro-vitamin A, 300 mg vitamin C, 3 mg $B_{1,}$ 1.5 mg B_2 and 1.2 mg pantothenic acid per 1000g fresh seed weight and also it contains 1.1% fat, 2.2% minerals, 4.5% fiber and 56.5% carbohydrate (Dixit, 2002). Besides, fieldpea improves soil health through biological nitrogen fixation (about 30-50 kg N ha^{-1}) and addition of organic matter to the soil (Erman *et al*., 2009).

The yield of pulses including fieldpea in Bangladesh is low as because it is usually cultivated in less fertile soil. As a micronutrient, Zn and B are deficient in this country's soil. This crop (fieldpea) is less tested in terrace soils which exist in the Barind and Madhupur tracts. They 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 (Rashid, 2001; FRG, 2012).

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Zinc and B deficiency is widespread in the country; specifically B deficiency is more common in *rabi* crops (Jahiruddin, 2015). Zinc plays a vital role in metabolism and is known to be involved in N-fixation through nodule formation (Patel *et al*., 2011). Boron influences the absorption of N, P, K and its deficiency changed the equilibrium of optimum of those three macronutrients (Raj, 1985).

Hence, balance application of micronutrient along with macro nutrients may render good possibility to increase fieldpea production as well as improve soil fertility. The present study was therefore, undertaken (i) to evaluate the effect of Zn and B on yield, nodulation and nutrient content of fieldpea; and (ii) to find out the suitable combination of Zn and B for yield maximization of fieldpea.

Materials and Methods

A field experiment was conducted for two consecutive years (2014-15 and 2015-16 at winter) in the research field of Pulses Research Sub-Station (PRSS), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The terrace soils of Gazipur is medium high land with fine-textured (clay loam) and belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agroecological zone - Madhupur Tract (AEZ-28). Before beginning the experiment initial soil (0-15 cm) sample was collected from the field and analysed for chemical properties. The soil contains 6.6 pH, 1.26% organic matter, 0.057% N, 15.5 ppm P, 16 ppm S, 0.8 ppm Zn and 0.17 ppm B.

There were 16 treatment combinations comprising four levels each of Zn (0, 1, 2 and 3 kg ha^{-1}) and four levels of B (0, 1, 1.5 and 2 kg ha^{-1}). The blanket dose was N_{12} P_{18} K_{30} S_{10} kg ha^{-1}. The experiment was laid out in split-plot design with three replications. The unit plot size was 4 m × 3 m. Zinc and B were applied as zinc sulphate and boric acid, respectively. Every plot received an equal amount of fertilizers at N_{12} P_{18} K_{30} S_{10} kg ha^{-1} (FRG, 2012) as urea, TSP, MoP and gypsum during final plot preparation. Seeds of fieldpea cv BARI Fieldpea-1 were sown @ 30 kg ha^{-1} with a spacing of 40 cm × 05 cm on 12 November 2014 and 10 November 2015. Two hand weedings were done at 25 and 50 days after sowing. Diseases and insects were controlled properly. The crop was harvested after maturity. The data of nodule per plant was recorded from 5 randomly selected plants in each plot. Stover yield (kg ha^{-1}) was measured from two places in each plot over one square meter. Seed yield (kg ha^{-1}) was recorded from the whole plot technique.

Treatment-wise plant samples (stover and seed) against each treatment plot were oven-dried at 70° C for 48 h and finely ground.

The initial soil sample was analyzed for 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 (Bremner and Mulvaney, 1982); exchangeable K by 1N NH_4OAc method (Jackson, 1973); available P by Bray and Kurtz (1945) method; 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).

Ground plant sample (stover and seeds) was analysed for N using the Kjeldahl method FOSS (Persson *et al.,* 2008). Ground plant samples (seed and stover) were digested with di-acid mixture (HNO_3-$HClO_4$) (5: 1) as described by Piper (1966) for the determination- content of P (spectrophotometer method), K (atomic absorption spectrophotometer method), S (turbidity method using $BaCl_2$ by spectrophotometer), Zn (atomic absorption spectrophotometer method) and B (spectrophotometer following azomethine-H method).

Protein content in fieldpea seed was calculated on considering the pulses food factor 5.30 (FAO, 2018). Protein content was measured 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, nodulation, different nutrient and protein content was done following the Statistix 10 package (Statistix 10. 1985). The least significant difference (LSD) at 5% level was used to compare the treatments means.

Results and Discussion

Effects of zinc and boron on crop yields

The interaction effect of Zn and B on the yields of fieldpea was observed statistically significant during two consecutive years (Table 1). The crop responded to Zn and B application since the experimental soil was deficient zinc and boron. Similar findings were reported by Agrawal and Sharma (2005). Results showed that the mean seed yield varied from 920 kg ha^{-1} to 1631 kg ha^{-1} depending on the treatments. The highest seed yield of 1582 kg ha^{-1} in 1st year was obtained from $Zn_3B_{1.5}$ kg ha^{-1} and 1702 kg ha^{-1} in the 2nd year from Zn_3B_2 kg ha^{-1} treatment; however both the treatments were statistically similar to each other. The lowest seed yield was observed in control (Zn_0B_0) treatment. The stover yield (mean of two years) of fieldpea ranged from 2486 kg ha^{-1} to 4310 kg ha^{-1} over the treatments. The Zn_3B_2 treatment combination exhibited the highest stover yield in both years followed by the treatment of $Zn_3B_{1.5}$ kg ha^{-1} (Table 1). Micronutrient enhanced the survival and multiplication of microorganism, more nitrogen fixation, transport of sugars and better uptake and assimilation of available nutrients by the plants during the entire growth period for higher yields. Similar observations have been reported by Valenciano *et al.* (2010).

Table 1. Combined effect of zinc and boron on the yields of fieldpea

Treatment	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	1st yr	2nd yr	Mean	1st yr	2nd yr	Mean
Zn_0B_0	890e	949	920	2475	2497	2486
Zn_0B_1	1126	1187	1157	3263	2995	3129
$Zn_0B_{1.5}$	1196	1283	1240	3350	3224	3287
Zn_0B_2	1126	1384	1255	3021	3416	3219
Zn_1B_0	1085	1163	1124	2967	3011	2989
Zn_1B_1	1158	1421	1290	3249	3612	3431
$Zn_1B_{1.5}$	1248	1528	1388	3445	3745	3595
Zn_1B_2	1277	1544	1411	3491	3831	3661
Zn_2B_0	1126	1306	1216	3263	3323	3293
Zn_2B_1	1297	1468	1383	3578	3629	3629
$Zn_2B_{1.5}$	1417	1549	1483	3802	3756	3779
Zn_2B_2	1408	1607	1508	3778	4005	3892
Zn_3B_0	1155	1375	1265	3194	3511	3353
Zn_3B_1	1291	1597	1444	3544	3898	3721
$Zn_3B_{1.5}$	1582	1680	1631	4015	4253	4134
Zn_3B_2	1513	1702	1608	4233	4387	4310
CV (%)	4.61	3.66	-	5.71	4.39	-
LSD (0.05)	178	88	-	606	264	-

Effects of zinc and boron on nodulation

The Zn and B treatments along with macro nutrients promoted the nodule formation. Combined application of Zn and B influenced significantly to produce good numbers of active nodule per plant (Table 2). Similar observation made by Chatterjee and Bandyopadhyay (2015). The number of nodules per plant counted at 32 DAS ranged from 7.98 to 15.1 across the treatments. Nodulations per plant at 47 DAS varied from 19.8 to 30.2, at 62 DAS from 24.8 to 38.6 and 77 DAS, nodulations varied from 17.9 to 27.1. The maximum number of nodules per plant was counted on the treatment Zn_3B_2 in all the dates except 77 DAS. The minimum number of nodule per plant was counted in control treatment (Zn_0B_0) over the collection dates (Table 2). Nodule formation was less in 32 DAS and 77 DAS and was more at 47 and 62 DAS. It appears that the highest number of nodule formation occurred during early to mid flowering stage.

Table 2. Combined effect of zinc and boron on the number of nodules per plant of fieldpea at different dates (2-years pooled data)

Treatment	No. of nodules after 32 DAS	No. of nodules after 47 DAS	No. of nodules after 62 DAS	No. of nodules after 77 DAS
Zn_0B_0	7.98	19.8	24.8	17.9
Zn_0B_1	9.14	21.3	27.3	19.3
$Zn_0B_{1.5}$	9.25	22.4	27.1	20.5
Zn_0B_2	10.0	22.7	28.7	21.6
Zn_1B_0	9.39	21.6	27.1	22.1
Zn_1B_1	11.4	23.1	28.9	23.7
$Zn_1B_{1.5}$	12.1	23.9	30.1	25.6
Zn_1B_2	12.3	24.3	32.4	26.4
Zn_2B_0	10.6	23.7	29.8	23.3
Zn_2B_1	11.7	24.5	31.9	24.7
$Zn_2B_{1.5}$	12.4	25.7	33.7	27.1
Zn_2B_2	12.8	26.5	35.2	26.9
Zn_3B_0	11.4	23.4	31.6	25.7
Zn_3B_1	13.2	26.9	35.7	24.1
$Zn_3B_{1.5}$	14.3	28.7	37.9	25.1
Zn_3B_2	15.1	30.2	38.6	24.9
CV (%)	5.12	3.29	4.14	3.84
LSD (0.05)	0.99	1.35	2.18	1.53

Effects of zinc and boron on nutrient content

Application of Zn and B remarkedly influenced the N, protein, P, K, S, Zn and B contents of fieldpea seed (Table 3). The N content due to different treatments ranged from 3.85 to 4.56%, the highest N content being found in Zn_3B_2 which was statistically similar to $Zn_3B_{1.5}$, Zn_2B_2, $Zn_2B_{1.5}$, Zn_2B_1, and Zn_1B_2 treatments. Different combination of Zn and B had a significant effect on protein content (%) of fieldpea seed. The protein content varied between 20.4% and 24.1% over the treatments. The highest protein content (24.1%) was noted for the treatment Zn_3B_2 kg ha^{-1} which was significantly different with the others treatments. The lowest protein content in seed (20.4%) was calculated from Zn_0B_0 treatment (Table 3). Márquez-Quiroz *et al.* (2015) reported that micronutrient application may enhance nutrition security through improving the grain quality in addition its role in increasing productivity.The P content in seed varied from 0.22 to 0.29% with the highest record in Zn_3B_2 which was statistically identical to $Zn_3B_{1.5}$,

Zn_3B_1, Zn_2B_2, $Zn_2B_{1.5}$, Zn_3B_0 and Zn_1B_2 treatments. The K and S contents in different treatments ranged from 0.35 to 0.45% and 0.08 to 0.16%, respectively across the treatments. The maximum K content (0.45%) was recorded in Zn_3B_2 followed by $Zn_3B_{1.5}$, Zn_2B_2 and $Zn_2B_{1.5}$ and the lowest K content was in control. The highest S content (0.16%) was observed in Zn_3B_2 which was statistically similar at per $Zn_3B_{1.5}$, Zn_3B_1, Zn_2B_2, and $Zn_2B_{1.5}$ treatments. Regarding Zn and B contents in seed, it varied from 23.6 to 27.5 ppm and 25.9 to 31.2 ppm, respectively. The maximum Zn (27.5 ppm) and B (31.2 ppm) contents were observed in Zn_3B_2.The control (Zn_0B_0) gave the lowest nutrient contents (Table 3). Karim (2016) reported that combined application of Zn, B and Mo contributed to higher nutrient contens (5.04% N, 0.36% P, 0.86% K, 0.34% S, 72.4 ppm Zn and 41.5 ppm B) in lentil seed.

Table 3. Combined effects of zinc and boron on N, protein, P, K, S, Zn and B contents of fieldpea seed (2-years pooled data)

Treatment	Nutrient content in seed						
	N	Protein	P	K	S	Zn	B
	(%)					ppm	
Zn_0B_0	3.85	20.4	0.22	0.35	0.09	24.1	26.3
Zn_0B_1	3.93	20.8	0.23	0.36	0.08	24.3	26.2
$Zn_0B_{1.5}$	3.91	20.7	0.22	0.35	0.10	24.0	26.8
Zn_0B_2	3.98	21.1	0.24	0.34	0.09	24.5	27.1
Zn_1B_0	3.87	20.5	0.23	0.35	0.11	23.6	25.9
Zn_1B_1	4.03	21.4	0.24	0.38	0.12	25.1	27.3
$Zn_1B_{1.5}$	4.13	21.9	0.23	0.37	0.11	25.8	27.8
Zn_1B_2	4.25	22.5	0.26	0.39	0.13	26.1	27.9
Zn_2B_0	4.10	21.7	0.24	0.40	0.11	25.3	26.2
Zn_2B_1	4.31	22.8	0.25	0.41	0.13	24.9	26.9
$Zn_2B_{1.5}$	4.36	23.1	0.27	0.42	0.14	25.7	27.0
Zn_2B_2	4.41	23.4	0.28	0.43	0.15	26.1	25.9
Zn_3B_0	4.12	21.8	0.26	0.36	0.13	25.1	26.4
Zn_3B_1	4.06	21.5	0.27	0.37	0.14	25.5	28.3
$Zn_3B_{1.5}$	4.49	23.8	0.28	0.43	0.15	26.2	29.4
Zn_3B_2	4.56	24.1a	0.29	0.45	0.16	27.5	31.2
CV (%)	4.76	4.74	8.23	5.69	12.0	1.47	1.32
LSD (0.05)	0.33	1.75	0.04	0.04	0.025	0.62	0.61

Main effects of zinc

Different levels of zinc demonstrated significant variation in yields of fieldpea (Table 4). The seed yield increased with increasing Zn rates. The seed yields (mean of two years) in different Zn rates (0, 1, 2 and 3 kg ha^{-1}) were 1142, 1303, 1397 and 1488 kg ha^{-1}, respectively. Hence the seed yields due to 2 and 3 kg Zn ha^{-1} were found statistically similar particularly for the 1st year. The stover yields due to 2 and 3 kg Zn ha^{-1} were a similar trend of seed yield. It was observed that the yield increased with the increase of Zn level up to 3 kg ha^{-1}. Similar trend was also reported by Kasthurikrishna and Ahlawat (2000). The yield benefits in terms of percentage varied from 14.1 to 30.3% over the control treatment.

Table 4. Main effects of zinc on the yields of fieldpea

Zinc level (kg ha^{-1})	Seed yield (kg ha^{-1})			% Yield increment over control	Stover yield (kg ha^{-1})		
	1st yr	2nd yr	Mean		1st yr	2nd yr	Mean
Zn_0	1084	1200	1142	-	3028	3033	3031
Zn_1	1192	1414	1303	14.1	3288	3550	3419
Zn_2	1312	1482	1397	22.3	3605	3678	3642
Zn_3	1386	1589	1488	30.3	3747	4012	3880
CV (%)	5.58	3.82	-		6.94	4.52	-
LSD (0.05)	98	54	-		335	161	-

Zinc played encouraging role on nodulation of fieldpea. At 32 DAS, the number of active nodules per plant ranged from 9.09 to 13.5, at 47 DAS, 21.6 to 27.3 and at 62 DAS, it was 26.9 to 35.9, respectively. Furthermore, at 77 DAS, it varied from 19.8 to 25.5. The maximum number of nodules per plant was found with the application of Zn at 3 kg ha^{-1} for all the nodule collection dates. The minimumt number of nodules per plant was recorded from Zn control plot (Table 5).

Table 5. Main effect of zinc on nodulation of fieldpea (2- year's pooled data)

Zinc level (kg ha^{-1})	No. of nodules at 32 DAS	No. of nodules at 47 DAS	No. of nodules at 62 DAS	No. of nodules at 77 DAS
Zn_0	9.09	21.6	26.9	19.8
Zn_1	11.3	23.2	29.6	24.5
Zn_2	11.9	25.1	32.7	25.5
Zn_3	13.5	27.3	35.9	24.9
CV (%)	3.80	3.14	1.82	4.80
LSD (0.05)	0.44	0.76	0.57	1.13

In case of nutrients content, the highest N, protein, P, K, S, Zn and B contents 4.31%, 22.8%, 0.28%, 0.41%, 0.14%, 26.1 ppm and 28.8 ppm, respectively were recorded with 3 kg ha^{-1} Zn rate (Table 6). Proper doses of zinc application may enhance the synthesis of carbohydrates, nutrient and protein content and their transport to the site of seed formation (Mali *et al.*, 2003).

Table 6. Main effects of zinc and boron on N, protein, P, K, S, Zn and B contents of fieldpea seed (2-years pooled data)

Zinc levels (kg ha^{-1})	Nutrient content in seed						
	N	Protein	P	K	S	Zn	B
	(%)					ppm	
Zn_0	3.91	20.8	0.23	0.35	0.09	24.2	26.5
Zn_1	4.07	21.6	0.24	0.37	0.12	25.1	26.6
Zn_2	4.30	22.7	0.26	0.40	0.13	25.5	27.2
Zn_3	4.31	22.8	0.28	0.41	0.14	26.1	28.8
CV (%)	3.16	3.13	1.29	3.09	10	1.78	1.31
LSD (0.05)	0.13	0.69	3.22	0.02	0.02	0.45	0.36

Main effects of boron

The seed yield ranged from 1132 to 1446 kg ha^{-1}, the highest yield in the 2nd year being observed at 2 kg ha^{-1} B application. In the 1st year, the seed yield was found highest at B rate of 1.5 kg ha^{-1} was statistically similar to B rate of 2 kg ha^{-1}. The lowest yield was recorded in the control treatment (Table 7). The trend of stover yield showed the similar of seed yield. Boron influences reproductive growth of crop (Chatterjee and Bandyopadhyay, 2015).

Table 7. Main effects of boron on the yields of fieldpea

Boron level (kg ha^{-1})	Seed yield (kg ha^{-1})			% Yield increment over control	Stover yield (kg ha^{-1})		
	1st yr	2nd yr	Mean		1st yr	2nd yr	Mean
B_0	1065	1198	1132	-	2975	3086	3031
B_1	1218	1418	1318	16.4	3408	3533	3471
$B_{1.5}$	1361	1510	1436	26.6	3707	3744	3726
B_{2-}	1331	1560	1446	27.7	3577	3910	3744
CV (%)	5.58	3.82	-		6.94	4.52	-
LSD (0.05)	64.6	43.8	-		219	132	-

The number of nodules per plant increased with increasing the rates of B application. The number of nodules per plant at 32 DAS ranged from 9.84 to 14.6, at 47 DAS from 22.1 to 25.9, at 62 DAS from 28.3 to 33.7 and at 77 DAS, it varied from 22.2 to 24.9 over the treatments. The maximum number of nodules per plant was recorded from the application of 2 kg B ha^{-1} across the nodule collection dates (Table 8). Noor and Hossain (2007) reported that adequate boron application positively influenced effective nodulation and nitrogen fixation in legumes.

Table 8. Main effects of boron on nodulation of fieldpea (2- year's pooled data)

Boron level (kg ha^{-1})	No. of nodules at 32 DAS	No. of nodules at 47 DAS	No. of nodules at 62 DAS	No. of nodules at 77 DAS
B_0	9.84	22.1	28.3	22.2
B_1	11.4	23.9	30.9	22.9
$B_{1.5}$	12.0	25.2	32.2	24.5
B_2	12.6	25.9	33.7	24.9
CV (%)	3.80	3.14	1.82	4.80
LSD (0.05)	0.49	0.67	1.09	0.76

Different nutrient (N, P, K, S, Zn and B) and protein contents in seed of fieldpea was influenced significantly due to application of different rates of B (Table 9). The highest nutrient content (4.30% N, 0.27% P, 0.40% K, 0.13% S, 26 ppm Zn and 28 ppm B) in seed were obtained with application of 2 kg B ha^{-1} that was statistically identical to 1.5 kg B ha^{-1} except P and Zn contents. The lowest nutrient content in seed was noted for B control treatment (Table 9). Regarding protein content, the highest protein content in seed (22.8%) was obtained with 2 kg B ha^{-1} application that was statistically similar to application of 1.5 kg B ha^{-1}(Table 9).

Table 9. Main effects of zinc and boron on N, protein, P, K, S, Zn and B contents of fieldpea seed (2-years pooled data)

Boron levels (kg ha^{-1})	Nutrient content in seed						
	N	Protein	P	K	S	Zn	B
	(%)					ppm	
B_0	3.98	21.1	0.24	0.37	0.11	24.5	26.2
B_1	4.08	21.6	0.25	0.38	0.12	24.9	27.2
$B_{1.5}$	4.22	22.4	0.25	0.39	0.13	25.4	27.7
B_2	4.30	22.8	0.27	0.40	0.13	26.0	28.0
CV (%)	3.16	3.13	1.29	3.09	10	1.78	1.31
LSD (0.05)	0.17	0.87	0.02	0.02	0.02	0.31	0.30

Conclusion

This study indicates that application of Zn at 3 kg ha^{-1} and B at 1.5 or 2 kg ha^{-1} significantly increased the seed yield of fieldpea. The maximum nodulation and protein percentage was found in Zn_3B_2 treatment followed by $Zn_3B_{1.5}$ treatment. Similarly nutrient (N, P, K, S, Zn and B) contens were also higher in the treatment combination of Zn_3B_2 followed by $Zn_3B_{1.5.}$ Thus, results of the experiment suggest that the application of Zn_3B_2 along with N_{12} P_{18} K_{30} S_{10} kg ha^{-1} is needed for yield maximization of fieldpea.

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EFFECTS OF DIFFERENT METHODS AND TIME OF BORON APPLICATION ON THE NUTRIENT CONCENTRATION AND UPTAKE BY WHEAT (*Triticumaestivum* L.)

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Abstract

At present, inclusion of Boron (B) in fertilizer management practice most often determines the yield performance of crops. Methods of supply of B to plants demands more research to come to a conclusion. The effect of different methods of boron application on the nutrient concentration and uptake of wheat (*Triticuma estivum* L.*cv.* Shatabdi) was studied through a field experiment at Bangladesh Agricultural University (BAU) farm, Mymensingh during *rabi* season of 2012-13. The experiment was laid out in a randomized complete block design (RCBD) with six treatments and three replications. The treatments were- (i) B–control (no addition of B), (ii) soil application @ 1.5 kg ha^{-1}, (iii) seed priming @ 0.4% boric acid solution, (iv) foliar spray @ 0.4% boric acid solution at primodia stage (37DAS), (v) foliar spray @ 0.4% boric acid solution at booting stage (55 DAS),and (vi) foliar spray at primodia stage (37DAS) and booting stages (55 DAS). Boric acid was used as a source of boron. Seed priming was done by soaking wheat seeds into 0.1% boric acid solution for 10 hours and then seeds were dried before sowing. Foliar spray of B at primodia and booting stage of crop (T_6) recorded the highest B concentration of grain (19.60 µg g^{-1}) and the control (T_1) treatment performed the lowest B concentration (6.75 µg g^{-1}). Similarly, the foliar spray of B at primodia and booting stages of crop (T_6) recorded the highest B uptake by both grain and straw that was statistically identical to foliar spray of B at booting stage of crop (T_5) in both cases. In view of cost-return analysis, foliar spray of B at primodia and booting stage treatment required the highest input cost but obtained the highest gross return, while control B required the lowest input cost along with lowest gross return.

Keywords: Bangladesh; Foliar application of B; Seed priming of B, Soil application of B; Wheat.

Introduction

Wheat growing soils were reported to be B deficient in different areas keeping in with the dissemination of semi-dwarf wheat varieties in the 1960s (Rerkasem

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and Jamjod, 2004). According to Shorrocks (1997), B deficiency in wheat soils were found in countries like India, Pakistan, Bangladesh, Nepal, China, Thailand, Brazil, Bulgaria, Sweden, Finland, Madagascar, South Africa, Tanzania, Zambia, USA and Yugoslavia. In Asia, the B deficiency prone soils were discovered in and around eastern Nepal, north-eastern India and north-western Bangladesh, through to south-western China (Bhatta and Ferrara, 2005). The growth and yield of wheat, a crop which is growing worldwide, responds significantly to B application (Chakraborti and Barman, 2003; Soylu and Topal, 2004). A study in Pakistan identified the response of wheat to B in non-irrigated fields (Chaudhry *et al.*, 2007). They also reported that wheat yield increasewith the application of B. Soils with low organic matter, coarse in texture, high pH, prolonged dry condition, soils under intensive cultivation, containing less micronutrients and nutrient mining can be turned into B deficient soils (Rashid *et al.*, 2005; Mengel and Kirkby, 2001; Niaz *et al.* 2007).As wheat is growing in every part of the world, the deficiency may also be found in new and new areas over time. How to correct these should be studied efficiently. Ahmad *et al.* (2012) reported that correcting B deficiency in soils by external application can result in increased yield of crops with quality. The crop yield on B deficient soils depends on sources, rates, formulations and timing and B application methods in soil/to plants. Soil and/or foliar application methods of B are effective in improving crop yield, quality, content and uptake of B (Ahmad *et al.*, 2012).

With the frequent application of B to soil, the chances of B toxicity is huge and a very thin difference in between deficiency and toxicity reported by (Cooke 1982). Thus, a careful and judicious application of boron is necessary. Efficiency of B application depends on the time and method of application. Mahler (2010) and Marphy and Walsh (1972)put emphasis on B application for several times over the crop growing season. The reason may be immobile B is essential to be available at all growth stages, mainly during fruit/seed development stages.

Boron may have influenced on the absorption of cations and anions and on carbohydrate and nitrogen metabolism (Batey, 1971, Bonilla *et al*. 1980, Pollard *et al*. 1977). There are many reports on the positive response of crops to B application (Ahmed *et al.*, 1991; Jahiruddin *et al.*, 1995; Haque *et al.*, 2000). Soil application is a common practice of B fertilizer supply for most of the crops. For micronutrients when plants receive small amount, other methods like foliar spray and seed priming might be equally effective as soil application. Further, the latter two methods would be more economic since they will require much smaller amount of boron. Foliar spray of boron could be better for two reasons – (i) the amount of B fertilizer would be at least five times less and (ii) T.aman rice generally does not respond to B application, so residual effect of soil applied B would be of no value.

With the above understanding, a study was made to evaluate the effect of different methods of B application on the nutrient concentration and uptake of wheat (*Triticum aestivum* L.) at (i) BAU farm, Mymensingh (ii) Agro-ecological Zone-9).The present investigation also aimedto determine the best time and method of foliar application of boron for overcoming B deficiency and obtaining higher crop yield.

Materials and Methods

Experimental site

The experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU) farm, Mymensingh during 2012-13. The experimental field is located at 24.75° N latitude and 90.50° E longitude at a height of 17 m above the mean sea level. It was a medium high land. The soil was Sonatala silt loam, a member of *Aeric Haplaquept*. It belongs to the order Inceptisol having only few horizons, developed under aquic moisture regime. General characteristics of the soil are presented in Table 1 (A, B and C).

Table 1. Morphological, physical and chemical characteristics of the soil

A. Morphological characteristics

AEZ	Old Brahmaputra Floodplain (AEZ-9)
General soil type	Non-calcareous Dark Grey Floodplain Soils
Parent materials	Brahmaputra river borne deposits
Drainage	Moderate
Topography	Medium high land
Flood level	Above flood level

B. Physical characteristics

% Sand	20.4
% Silt	68.0
% Clay	11.6
Textural class	Silt loam

C. Chemical characteristics

Characteristics	Content	Interpretation
pH (soil: water = 1:2:5)	7.30	Near neutral
Organic matter (%)	0.81	Very Low
Total N (%)	0.06	Low
Available P ($mgkg^{-1}$)	7.29	Low
Available K (c mol kg^{-1})	0.06	Low
Available S (mg kg^{-1})	10.0	Low
Available Zn (mg kg^{-1})	0.84	Low
Available B (mg kg^{-1})	0.15	Low

Climate

The experimental area has a sub-tropical humid climate, which is characterized by high temperature, high humidity and high rainfall with occasional gusty winds in the kharif season and low rainfall associated with moderately low temperature during rabi season (Table 2).

Table 2. Monthly recorded temperature, relative humidity, rainfall and sunshine during thecropping period from November 2012 to March 2013

Year	Months	Air temperature (°C)**			Relative humidity (%)**	Rainfall (mm)*	Sunshine (hrs)*
		Maximum	Minimum	Average			
2012	November	29.35	18.63	23.99	82.80	Trace	204.7
	December	25.44	13.26	19.35	85.45	00.0	174.6
	January	24.00	11.70	17.85	82.87	00.0	240.3
2013	February	27.71	14.88	21.30	75.11	04.1	196.8
	March	31.95	20.72	26.34	74.54	16.2	210.9

* Monthly total, ** Monthly average

Source: Weather Station, BAU, Mymensingh

Crop

The crop under study was wheat and the variety used was *Shatabdi* developed by Bangladesh Agricultural Research Institute (BARI), Gazipur. The seeds were collected from Wheat Research Centre (WRC), Dinajpur.

Experimental design

The experiment was laid out in a randomized complete block design (RCBD). There were six boron treatments, each replicated three times. The number of plots was 6×3 = 18. The unit plot size was 4 m×5m. The plot- to- plot distance was 0.5 m and block - to- block distance was 1 m.

Treatments

The six boron treatments were as follows:

T_1 = Control

T_2 = Soil application of B @ 1.5 kg ha^{-1} (designated as SA)

T_3 = Seed priming (wheat seed soaked in 0.1% boric acid solution for 10 hours before sowing (designated as SP)

T_4 = Foliar spray @ 0.4% boric acid solution at primodia stage (37 DAS) of crop growth (designated as FS-p)

T_5 = Foliar spray @ 0.4% boric acid solution at booting stage (55 DAS) of crop growth (designated as FS-b).

T_6= Foliar spray at primodia and booting stages (designated as FS-pb).

Fertilizer application

Fertilizers were applied to each plot as per treatments. Besides boron, every treatment received 115 kg N ha^{-1}, 25 kg P ha^{-1}, 75 kg K ha^{-1} and 15 kg S ha^{-1}. Fertilizers such as urea, TSP, MoP, gypsum and boric acid were used as sources for N, P, K, S, and B, respectively. One-third dose of urea and full dose of all other fertilizers were applied as basal to the individual plots during final land preparation. Fertilizers were incorporated into soil by hand. The second split of urea was applied after 30 days of sowing (crown root stage) and the third split after 55 days (booting stage). Boron was applied as per treatments. For foliar spray treatments, boric acid solution was sprayed at 37 and 55 days after sowing to represent primodia and booting stages of crop, respectively.

Intercultural operations

Topdressing of urea was done as per schedule and the normal cultural practices including weeding and insecticide spray were done as and when required. Two irrigations were provided after 25 and 55 days of sowing. Weeding was done twice during the whole growth period, the one after 21 days of sowing and the other after 50 days. The field was attacked by armyworm (*Mythumnaseparata*) which was successfully controlled by using Akonazol.

Data collection

At harvest of the crop, ten plants were randomly collected from each plot. The data were then converted to grain and straw yield per plot. After oven-drying overnight at 105ºC, the dry biomass of the grain and straw yields were recorded for chemical analysis and uptake calculation.

Chemical analysis

The total N content of wheat grain and straw was measured following the Kjeldahl method. The P concentration was determined colorimetrically at 660 nm wavelength by developing blue colour with ammonium molybdate reagent. The concentration of K was determined directly by a flame photometer. The S concentration in the digest was determined turbidimeterically and the turbid was measured by spectrophotometer at 420 nm wavelengths and the concentration of boron estimated colorimetrically after colour development by azomethine-H method.

Calculation of uptake

The uptake of N, P, K, S and B were determined by multiplying with dry biomass of straw and grain by their corresponding specific nutrient content in straw and grain, respectively.

Statistical analysis

The analysis of variance (ANOVA) for various crop characters and also for nutrient concentrations and uptake were done following the principle of F-statistics. Mean comparison of the treatments were adjudged by the Duncan's Multiple Range Test (Gomez and Gomez, 1984). Correlation statistics was performed to examine the interrelationship among the plant characters under study.

Results and Discussion

A. Results

Effects of different methods of boron application on the nutrient concentration of wheat

Nitrogen concentration

The N concentration of wheat grain was significantly influenced by B application ($p < 0.05$; Figure 1). This indicates that B helps in protein synthesis. The N concentration in grain varied from 1.23% to 1.79%; the lowest N concentration found with B control and the highest concentration by soil application @ 1.5 kg B ha^{-1}(T_2).Like grain N- concentration, the straw N concentration varied among B application treatments ($p > 0.05$). All the B treatments (T_2 to T_6) showed identical straw N concentration.

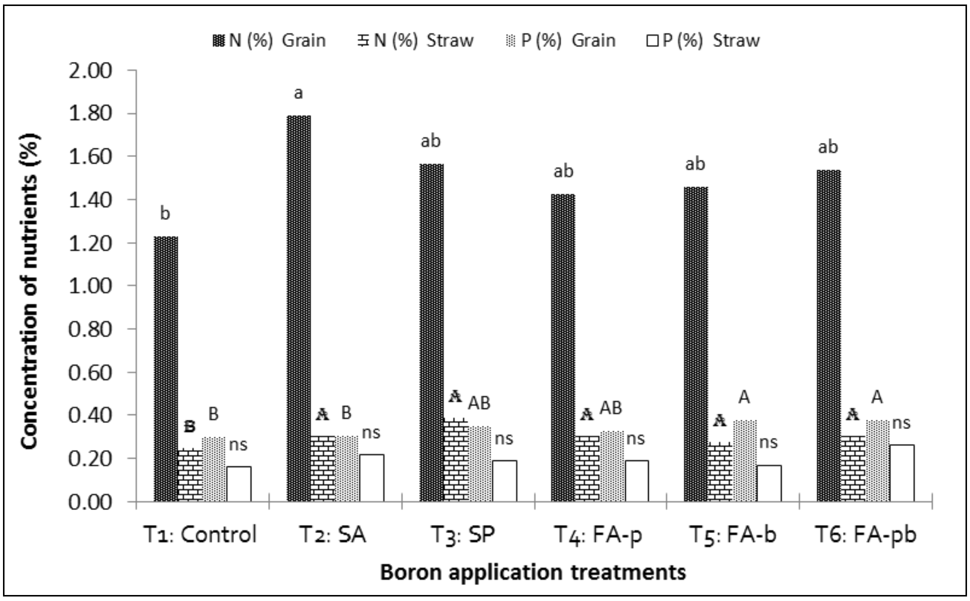

Fig. 1. Effects of different methods of applicationon the N and P concentrations of wheat grain and straw.

Standard error (SE±) for N in grain and straw and P in grain and straw were 0.03, 0.01, 0.001 and 0.001, respectively. Values in a column having same letter do not differ significantly at 5% level by DMRT

NS = Not significant

S.E = Standard error of means

SA = Soil application @ 1.5 kg B ha^{-1}

SP = Seed priming with 0.1% boric acid solution for 10 hours

FA-p= Foliar spray @ 0.4% boric acid solution at primodia stage (37 DAS) of crop.

FA-b=Foliar spray @ 0.4% boric acid solution at booting stage (55 DAS) of crop.

FS-pb = Foliar spray @ 0.4% boric acid solution at primodia and booting stage of crop.

Phosphorus concentration

Boron application had significant and positive effect on the grain P concentration of wheat ($p < 0.05$; Figure 1). The grain P concentration varied from 0.3 to 0.38%.The lowest value was noted in control treatment and the highest in foliar applied B at booting stage of the crop. The straw P concentration remained unaffected due to Bapplication ($p > 0.05$).

Potassium concentration

The K concentration of wheat grain was not significantly varied with B ($p > 0.05$; Figure 2). The grain K concentration over the treatments was 0.31% to 0.33%.

The highest grain-K concentration was recorded in soil application of B (T_2) and the lowest was observed in B control (T_1). The straw–K concentration significantly varied with B application method ($p < 0.05$; Figure 2). The maximum straw-K concentration was recorded with B applied as foliar spray at booting stage and the minimum was noted in control treatment.

Sulphur concentration

There was no significant effect of applied B on sulphur concentration of wheat grain (Figure 2).The grain S concentration was 0.12% - 0.16% over the six B treatments. The highest grain-S concentration (0.16%) was recorded with seed priming treatment (T_3) and the lowest grain S-concentration demonstrated by B control treatment. Unlike grain S, the S concentration significantly varied with B treatments (Figure 2). It ranged from 0.02% noted in control to 0.06% in foliar applied B at primodia and booting stages of crop.

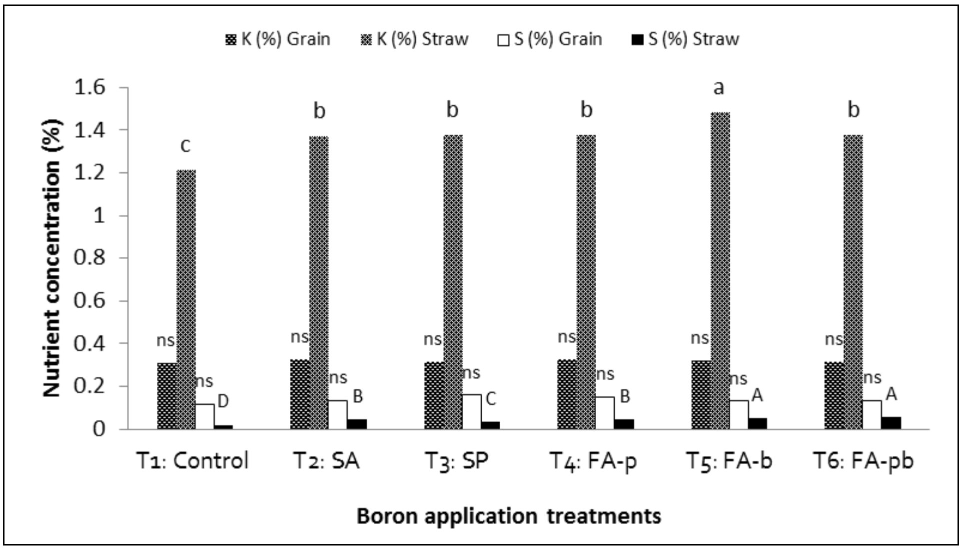

Fig. 2. Effects of different methods of applicationon the K and S concentrations of wheat grain and straw. SE(±)) for K in grain and straw and S in grain and straw were 0.0002, 0.004, 0.0001 and 0.0001, respectively.Values in a column having same letter do not differ significantly at 5% level by DMRT

NS = Not significant

SE = Standard error

SA = Soil application @ 1.5 kg B ha^{-1}

SP = Seed priming with 0.1% boric acid solution for 10 hours

FA-p= Foliar spray @ 0.4% boric acid solution at primodia stage (37 DAS) of crop.

FA-b=Foliar spray @ 0.4% boric acid solution at booting stage (55 DAS) of crop.

FS-pb = Foliar spray @ 0.4% boric acid solution at primodia and booting stages of crop.

Boron concentration

Boron concentration in grain varied with different methods of B application ($p < 0.05$; Figure 3). This result was expected because the soil was deficient in B. Comparing the methods of B application, foliar spray at primodia and booting stages of crop (T_6) showed the highest B concentration (19.6µg g^{-1}) that was` statistically identical with foliar spray at booting stage of crop (T_5). The grain-B concentration varied from 6.8 to 14.9 µg g^{-1}. The B control (T_1) treatment contained the lowest B concentration (6.8 µg g^{-1}). The straw-B concentration was also significantly affected due to different methods of B application ($p < 0.05$; Figure 3). The highest and lowest straw-concentrations were found by foliar spray at booting stage (15.7 µg g^{-1}) and with B control treatment (8.1 µg g^{-1}), respectively. The similar concentration was recorded with the treatment (T_5) and (T_6).

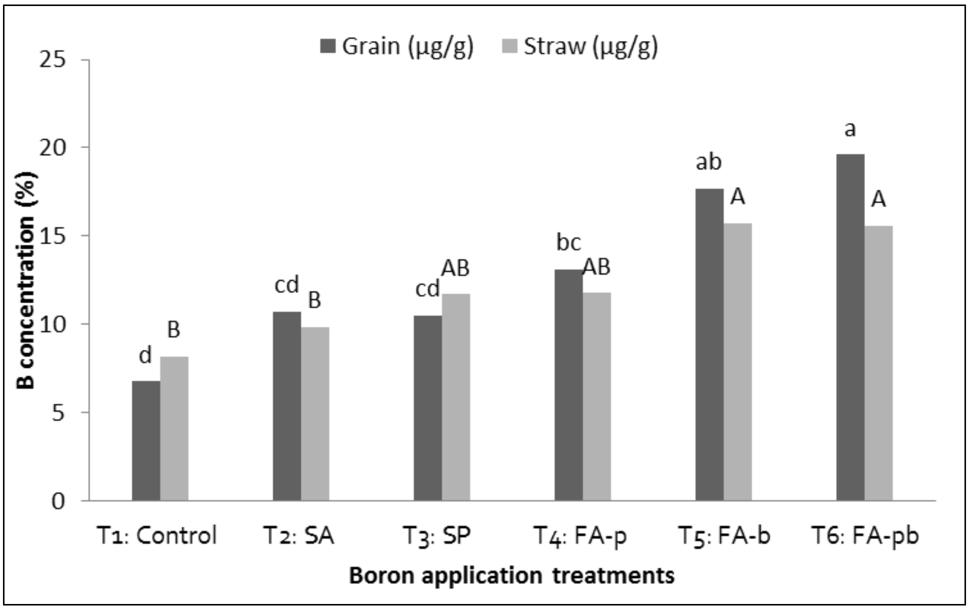

Fig. 3. Effects of different methods applicationon B concentration of wheat grain and straw. SE(±) for B in grain and straw were 3.16 and 6.29, respectively.Values in a column having same letter do not differ significantly at 5% level by DMRT

NS = Not significant

SE = Standard error of means

SA = Soil application @ 1.5 kg B ha^{-1}

SP = Seed priming with 0.1% boric acid solution for 10 hours

FA-p= Foliar spray @ 0.4% boric acid solution at primodia stage (37 DAS) of crop.

FA-b=Foliar spray @ 0.4% boric acid solution at booting stage (55 DAS) of crop.

FS-pb = Foliar spray @ 0.4% boric acid solution at primodia and booting stages of crop.

Effects of different methods of B application on the nutrient uptake by wheat

Nitrogen uptake

The N uptake by wheat grain varied due to the different B levels and methods of application ($p < 0.01$; Table 3). The N uptake by grain ranged from 46.5 to 56.09 kg ha^{-1}, the highest N uptake by grain being observed with foliar spray of B at primodia and booting stage**s** of crop (T_6) and was statistically identical with foliar spray of B at booting stage of crop (T_5) and foliar spray of B at primodia stage of crop (T_4).The lowest N uptake was observed with control treatment (T_1).Similar trend was also observed with straw(Table 3).

Phosphorus uptake

Significant effect was observed on grain P uptake of wheat ($p < 0.01$), where P uptake ranged from 8.7to14.3 kg ha^{-1} (Table 3). The highest P uptake by grain was observed with foliar spray of B at primodia and booting stage**s** (T_6) that was statistically identical with foliar spray of B at booting stage only. The lowest P uptake by grain was recorded with control treatment. The total P uptake was varied with different methods of B application (Table 3**),** being ranged from 11.0 to 15.8 kg ha^{-1}. The total P uptake was highest in foliar spray of B at primodia and booting stages (T_6) of crop, and was identical with T_5 treatment where B was sprayed on leaves at booting stage only.

Table 3. Effects of different methods ofB on N and P uptake by wheat grain and straw

Treatments	N (kg ha^{-1})			P (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
T_1: Control	46.5 b	17.1 b	63.6 b	8.70 d	2.27	11.0 c
T_2: SA	46.6 b	20.1 ab	66.8 b	11.2 c	1.29	12.5 b
T_3: SP	49.0 b	18.6 b	67.6 b	11.2c	1.30	12.5 b
T_4: FA-p	51.2ab	19.7ab	70.9ab	12.3bc	1.15	13.4 b
T_5: FA-b	51.5 ab	25.2 a	76.7 a	13.9 ab	1.35	15.2 a
T_6: FA-pb	56.09 a	18.9 b	75.0 a	14.3 a	1.49	15.8 a
Level of significance	***	**	**	**	NS	***
SE (±)	1.83	5.62	7.45	0.53	0.12	0.24

Values in a column having same letter do not differ significantly at 5% level by DMRT

* * = Significant at 1% level.

NS = Not significant, SE = Standard error of means, SA = Soil application @ 1.5 kg B ha^{-1}, SP = Seed priming with 0.1% boric acid solution for 10 hours, FA-p= Foliar spray @ 0.4% boric acid solution at primodia stage (37 DAS) of crop, FA-b=Foliar spray @ 0.4% boric acid solution at booting stage (55 DAS) of crop, FS-pb = Foliar spray @ 0.4% boric acid solution at primodia and booting stages of crop.

Potassium uptake

The K uptake by grain varied among different methods of B applications ($p < 0.01$; Table 4). The K uptake by grain varied from 9.04 to 13.1 kg ha^{-1}, where the highest K uptake by grain being recorded with foliar spray of B at primodia and booting stage of crop (T_6) that was statistically identical with the treatments T_2, T_4 and T_5.The lowest K uptake was with control treatment (T_1). On the other hand, the K uptake by straw and total K uptake (grain + straw) was significantly influenced by B application methods (Table 4). However, the K uptake by straw and total K uptake by wheat under different B treatments ranged from 72 to 101 kg $ha^{-1}$and 81 to 113 kg ha^{-1}, respectively. The lowest total K uptake by wheat was found in control treatment.

Sulphur uptake

The sulphur uptake by grain, straw and total grain + straw remained unaffected by B application ($p > 0.05$; Table 4). The highest grain- K uptake was found with foliar spray of B at primodia stage of crop (T_4) and the lowest K uptake found in control treatment (T_1). On the other hand, the highest and lowest straw S uptake were observed in foliar spray of B at primodia and booting stages (T_6) and control treatment (T_1), respectively. Finally, total S uptake was the highest in foliar spray of B at primodia and booting stage and the lowest was with control (T_1) treatment.

Table 4. Effect of different methods of B application on the K, S and B uptake by wheat grain and straw

B treatments	K (kg ha^{-1})			S (kg ha^{-1})			B (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1: Control	9.04 c	72 c	81 c	4.89	2.50	7.39	0.02 d	0.06b	0.08 b
T_2: SA	11.7ab	90ab	102	5.02	2.68	7.7	0.04c	0.05 b	0.09b
T_3: SP	10.5 bc	93 ab	103 b	5.13	2.36	7.49	0.03 cd	0.08 ab	0.11 ab
T_4: FA-p	12.0 ab	87 b	99 b	5.64	2.88	8.52	0.05 bc	0.07 ab	0.12 ab
T_5: FA-b	11.8 ab	93 b	105 b	5.06	2.83	7.89	0.06ab	0.08 ab	0.14 ab
T_6: FA-pb	13.1a	101 a	113 a	5.11	3.60	8.71	0.08a	0.11 a	0.18 a
SE (±)	0.55	16.3	11.7	1.4	1.6	2.9	0.0001	0.0002	0.001

Values in a column having same letter do not differ significantly at 5% level by DMRT.
* * = Significant at 1% level.
NS = Not significant.
SE = Standard error of means.
SA = Soil application @ 1.5 kg B ha^{-1}.
SP = Seed priming with 0.1% boric acid solution for 10 hours.
FA-p= Foliar spray @ 0.4% boric acid solution at primodia stage (37 DAS) of crop.
FA-b=Foliar spray @ 0.4% boric acid solution at booting stage (55 DAS) of crop.
FS-pb = Foliar spray @ 0.4% boric acid solution at primodia and booting stages of crop.

Boron uptake

There was a significant and positive effect of different methods of B application on the B uptake by wheat grain ($p < 0.01$; Table 4). The B uptake by grain varied from 0.02 to 0.08 kg ha^{-1}. It appeared that the foliar spray of B at primodia and booting stage**s** of crop (T_6) recorded the highest B uptake by both grain and straw that was statistically identical with foliar spray of B at booting stage of crop (T_5) in both cases. Again, in both the cases**,** the lowest B uptake was found in control treatment (T_1). Yet again, the B uptake by straw and also total B uptake (grain + straw) was not significantly influenced by the B treatments (Table 4).

Correlation among the different nutrient concentration and uptake in wheat plant

There was positive correlation among concentration (Table 5) and uptake of different nutrients by plants (Table 6). B concentration positively and significantly influenced P (r=0.85), K (r=0.75) and S content (r=0.64) of wheat plants, while B uptake had positively significantly correlated with uptake of all other nutrients. Positive correlations were also observed between nutrient concentration and nutrient uptake at harvesting stage of wheat plant (Table 5, 6 and 7). But uptake of nutrients was significantly correlated with B content in plants except N. As the correlation between B content and nutrient uptake in wheat plant was observed, it revealed that all correlation showed a strong positive relationship i.e. N (r=0.979), P(r=0.997), K (r=0.835), S (r= 0.715) and B (r= 0.939). This result indicates that the nutrient uptake in wheat may be interrupted by boron deficiency and it can be corrected by B application (Tables 5, 6 and 7).

Table 5.Correlation among concentration of different nutrientsin wheat

Concentration	N	P	K	S	B
N	1				
P	0.48	1			
K	0.49	0.55*	1		
S	0.63*	0.66*	0.77*	1	
B	0.18	0.85*	0.75*	0.64*	1

* denotes significant relationship

Table 6. Correlation among uptake of different nutrients by wheat

Correlation among different nutrient uptake					
	N	P	K	S	B
N	1				
P	0.973*	1			
K	0.755*	0.840*	1		
S	0.679*	0.747*	0.601*	1	
B	0.872*	0.935*	0.795*	0.804*	1

* denotes significant relationship.

Table 7. Correlation of different nutrient concentrations and their corresponding uptakes

	N	P	K	S	B
N	0.086	0.209	0.664*	0.062	0.103
P	0.728*	0.864*	0.924*	0.677*	0.898*
K	0.796*	0.744*	0.790*	0.368	0.537*
S	0.612*	0.637*	0.854*	0.598*	0.602*
B	0.979*	0.995*	0.839*	0.715*	0.95*

* denotes significant relationship.

Cost and return analysis

Cost and return analysis of wheat was shown in table 8.The highest gross return was obtained from T_6 whereas the lowest was from T_1. The highest cost was required in T_6 while lowest in T_1 might be due to least labour required in T_1 and B fertilizer and more labour required for premodia and booting stage.

Table 8. Cost and return analysis of wheat

Treatment	Total yield (t ha^{-1})		Gross return (Tk. ha^{-1})	Total input cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
	Grain	Straw				
T_1: Control	2.6	5.62	65637.5	53475.0	12161.5	1.23
T_2: SA	3.58	5.68	87340.0	56500.0	30840.0	1.55
T_3: SP	3.08	5.87	76631.0	57475.0	19156.0	1.33
T_4: FA-p	3.53	6.01	86742.5	57475.0	29267.5	1.51
T_5: FA-b	3.62	6.37	89312.5	57475.0	31837.5	1.55
T_6: FA-pb	3.63	6.39	89442.0	58375.0	31067.0	1.53

Price: Urea=17 Tk. Kg^{-1}, TSP=28 Tk. kg^{-1}, MOP=16 Tk. Kg^{-1}, Gypsum= 10 Tk. Kg^{-1}, Zinc sulphate (H_2O) = 150 Tk. Kg^{-1}, Boric acid=220 Tk. Kg^{-1}, Wheat grain=22 Tk. Kg^{-1}, Wheat straw=1.5 Tk. Kg^{-1}, Labour=250 Tk. Day^{-1} labour^{-1}, Irrigation= 1000 Tk. time^{-1} ha^{-1}

SA = Soil application @ 1.5 kg B ha^{-1}

SP = Seed priming with 0.1% boric acid solution for 10 hours

FA-p= Foliar spray @ 0.4% boric acid solution at primodia stage (37 DAS) of crop.

FA-b=Foliar spray @ 0.4% boric acid solution at booting stage (55 DAS) of crop.

FS-pb = Foliar spray @ 0.4% boric acid solution at primodia and booting stages of crop.

B. Discussion

Boron applied on wheat leaves or in soil increases nutrient uptake through increasing biomass at harvest. While boron requirement for optimum plant nutrition is low compared with those of primary nutrients, the need for boron is especially significant in branching, flowering and seed development. Schon and Blevins (1990) found increased branching; Reinbott and Blevins (1995) found increased pot setting and hence higher dry biomass yields and uptake of nutrients (Devi *et al*., 2012).According to Liebig (1955), Liebeg's Law of Minimum stated that crop used up all of the deficient nutrients in the soil making the yield directly proportional to the amount of the deficient nutrient present and the crop content of the nutrient. Growth of plants in any ecosystem is often limited by the availability of any essential nutrients irrespective of macro- or micro-nutrients. Liebig's law of the minimum stated that the nutrient in least supply relative to the plant's requirement will limit the plant's growth (Ågren *et al.*, 2012). The initial soil status showed that the soil was very low in B status. The B fertilizer applied in soil or foliar application of B helps correct the deficiency. Sakal (1991) and Devi *et al.* (2012) found B in deficiency or in excess affected the growth and yield of the soybean crop. They also put forward that B plays an important role in cell differentiation and development, translocation of photosynthates and growth regulators from source to sink and growth of pollen grains thereby marked increase in seed yield of crops. Ahmed Khan *et al*., (1990) found that dusting of 2 kg borax per hectare on sunflower heads during seed filling stage was effective in improving the seed yield by 25 %. Gormus (2005) reported significant response to foliar B treatment over the control on clay soil having 0.40 mg per kg B concentration in Adana, Turkey. Schon and Blevins (1987) at the University of Missouri demonstrated that foliar application of B could stimulate yield by increasing pod number on lateral branches, seed number, and overall seed yield. Boron is involved in the synthesis of protein (Sauchelli, 1969) and oil (Malewar *et al*., 2001). Earlier works mark the evidence that application of B influenced the yield components. Tripathy *et al*. (1999) conclusively suggested that application of B increased pod plant^{-1}. Havlin *et al*. (1999) also reported that the flowering and fruit development were restricted due to the shortage of B.

Application of B might have increased another nutrients uptake such as N, P, K and S resulting in higher biomass yield. A positive correlation observed between the B and other nutrient also proved that B application either in soil or on leaves accelerated overall nutrient uptake. Biswas *et al.* (2015) also reported similar results in a positive correlation was observed between the grain yield and the uptake of different nutrients. Boron has the favourable influence on the absorption of cations particularly calcium (Ca), to have retarding influence on the absorption of anions and to have an essential part in carbohydrate and N metabolism (Batey, 1971).This was also confirmed by Valmis and Ulrich (1971) who reported that with increasing B in the nutrient solution the concentrations of

N, P and S linearly decreased in the leaves of sugar beet. Rehim (1937), the pioneer, found that the addition of B to the nutrient medium increased the intake of cations and retarded the anions in plants as compared to culture lacking B. Bonilla *et al*. (1980) reported that both B deficiency and toxicity resulted in more NO_3-N accumulation in the sap of sugar beet due to the decrease in the activity of the N-Rase enzyme, suggesting a specific effect of B on N-Rase activity. Pollard *et al*. (1977) found that B deficiency in corn and broad beans reduced the capacity for the absorption of PO_4, due to the reduced ATPase activity, which could be rapidly restored by the addition of B. Gupta and Sanderson (1993) reported non-significant interactions between S and B in potato crop.

The increased uptake of nutrients by wheat can also be attributed to undisturbed roots for having adequate B during growing period. The B deficiency in soil can affect seedling emergence and cause an abnormal cellular development in young wheat plant (Snowball and Robson, 1983). Deficiency of B is known to inhibit the leaf expansion and reduction in photosynthesis. It also inhibits root elongation by limiting cell division in the growing zone of root tips (Dell and Huang, 1997).

Conclusions

Chemical analysis shows that the concentration of N, P, K, S and B significantly varied with the methods of B application. Foliar spray of B at primodia and booting stage recorded the highest B concentration of grain (19.6 µg g^{-1}) and reverse trend was observed with control treatment(T_1).Positive correlation was found with P. N concentration resulted in more protein synthesis. It also appeared that the foliar spray of B at primodia and booting stage recorded the highest B uptake with both grain and straw but statistically no difference was with the foliar spray at booting stage (T_5). The uptake of various nutrients by the crop showed the positive trend of wheat yield. T_5 treatment gave the highest gross margin though it input its input cost was less than T_6 treatment.

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PROFITABILITY OF MANGO MARKETING IN DIFFERENT SUPPLY CHAINS IN SELECTED AREAS OF CHAPAI NAWABGANJ DISTRICT

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Abstract

A plenty of mangoes are spoiled and damaged every year due to improper postharvest handling and inefficient supply chain. Sufficient information are lacking on these issues in Bangladesh. The study *assessed the postharvest handling of key actors in mango supply chains and estimated the post-harvest losses at different stakeholder level in Chapai Nawabganj district, Bangladesh. In total 83 respondents taking 30 mango growers and 53 mango traders were interviewed from Chapai Nawabganj and Dhaka districts. The* study identified eight marketing channels for mango marketing. The prominent channel was *Grower> Bepari> Urban Arathdar> Urban retailer> urban Consumer* since 85.1% mangos moved through this channel. *Bepari* incurred the highest marketing cost (Tk.7338/ton) due to long distance coverage followed by retailer (Tk.1218/ton) and *Faria* (Tk.738/ton). *Faria* received the highest net margin (Tk.8068/ton) due to lower marketing cost and spoilage followed by retailer (Tk. 6601/ton) and *Bepari* (Tk.5394/ton).*The results revealed that the estimated average postharvest losses were 14.11% and 9.61% at farm and traders' level respectively. At farm level,* these losses occurred during harvesting, sorting & grading, and transportation. *Harvesting losses were due to cracking, bruising, compression, and disease and insect infestation. T*he highest loss was recorded at retail level (4.64%) followed by *Bepari* (3.95%). Farmers and *Farias* used different local carriers, whereas trucks and pick up van were used by *Bepari* to transport mango from assemble markets to urban wholesale markets. Major marketing problems in the supply chain were delayed sale and lack of buyers.

Keywords: Mango, supply chain, postharvest loss, postharvest handling, marketing cost, marketing margin.

Introduction

The fruit nutrients are vital for maintaining good health. They are naturally low in calories, fat, sodium, and cholesterol. Fruits are rich in fiber, which is essential for the smooth movement of food in the body's digestive system. It can reduce the risk of many illnesses, including heart disease and stroke (www.healthyeating.org/Healthy-Eating). The per capita consumption of fruits in Bangladesh is 44.8 gm. However, sharp increase (58.02%) was taken place in the

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per capita consumption of fruits in the country over the period from 2000 to 2010 (HIES, 2010).

Mango (*Mangifera indica*) is one of the important fruits of Bangladesh. It occupies a total area of land 30.80 thousand hectares with a total production of 956.87 thousand tons having an average yield of 31.07 ton/ha (BBS, 2013). In the last couple of years, mango production is increasing due to the introduction of improved varieties and production techniques as well as increased market demand (Fig 1). The area and production of mango are increasing at the rate of 1.5% and 5.3% in the last ten years, respectively.

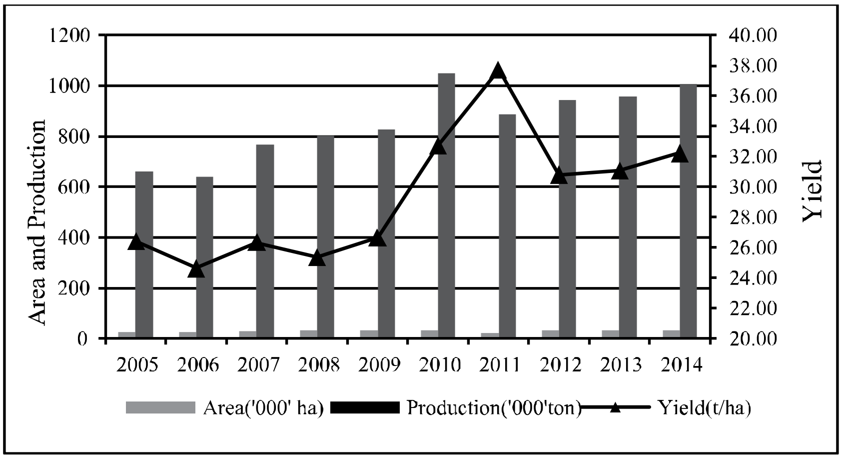


Fig 1. Area, production and yield of mango, 2005-2014.

Source: Various issues of BBS (2005-2014).

There are some intensive mango growing districts in Bangladesh, where mangoes are produced commercially and marketed in other areas of the country. Therefore, mango needs to be transported to a long distance to reach the ultimate consumers under the prevailing marketing system. Mangoes are bulky and perishable in nature and maintaining cool chain is not always possible due to higher cost involvement. In the peak season, there is an excess supply creating a glut in the market and causing a fall in the price and affecting the incomes of the farmers. However, both pre-harvest and postharvest factors are responsible for the postharvest losses of mango. A huge amount of mangoes are damaged every year due to their perishability, seasonality, bulkiness, poor infrastructure, and poor pre- and postharvest practices in Bangladesh that need to be taken into consideration. Due to inefficient marketing system, farmers are forced to sell their mangoes at lower price.

Efficient marketing system usually ensures higher producer's share, reducing the number of middlemen in the supply chain, and restricting the marketing charges and mal-practices during marketing of farm products (Matin *et al.,* 2008). It is, therefore, essential to study the existing supply chain of mango in order to suggest suitable channel for the producers, appropriate technology for postharvest handling, and proper safety measures for the key stakeholders of the supply chain to ensure food quality and safety for the consumers.

The study was conducted with a view to developing capacity to reduce postharvest losses in Horticultural Chains in SAARC countries to promote, support and implement good practices in order to minimize postharvest losses and improve quality and safety in horticultural supply chains. Therefore, the study was conducted with the following objectives:

i. To investigate the supply chain of mango marketing;
ii. To estimate the marketing costs and margins at different stakeholders levels in mango supply chains;
iii. To assess the postharvest losses of mango at producers' and traders' level; and
iv. To identify the problems and constraints in mango supply chain.

Methodology

***Study area selection*:** Mango is an important fruit of Bangladesh. It grows more or less every parts of the country. However, Chapai Nawabganj, an intensive mango growing district, was purposively selected for this study. The district was selected in consultation with the personnel of Department of Agricultural Extension (DAE) and the fruits scientists of Bangladesh Agricultural Research Institute for administering field and market survey. Again, two suitable *Upazilas* Shibgonj and Bholahat were selected in terms of the availability of data, convenience of data collection, and easy accessibility.

***Sampling procedure and sample size*:** At first, a complete list of mango farmers was prepared with the help of DAE personnel. A total of 30 mango farmers (15 from each *Upazila*) were randomly selected from the list for interview to collect primary data. It was planned that in total 75 key actors in the mango supply chain (i.e. 15 each for *Faria*, *Bepari*, retailer, *Arathdar* and consumer) will be selected and interviewed, but due to the unavailability of some key actors the actual number of sample size was 68. All the actors were randomly selected and interviewed from different assemble, wholesale, and retail markets levels (i.e. *Upazila*/district/Dhaka City).

***Period of study*:** Primary data were collected by interviewing mango farmers and traders using two structured and pre-tested interview schedules during August-September, 2015. The researcher himself along with trained enumerators collected data and information for this study.

Analytical technique: The collected data were edited, tabulated and analyzed applying simple descriptive methods. However, marketing margins of the key actors were calculated by the following equations.

$$GM_i = PR_i - PP_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

Where,

GM_i= Gross margin (Tk/ton) for i^{th} intermediary
PR_i = Price received (Tk/ton) for i^{th} intermediary
PP_i = Price paid (Tk/ton) by i^{th} intermediary

$$NM_i = GM_i - MC_i - CPL_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

Where,

NM_i = Net margin (Tk/ton) for i^{th} intermediary
MC_i = Marketing cost incurred (Tk/ton) by i^{th} intermediary
CPL_i = Cost of postharvest loss incurred (Tk/ton) by i^{th} intermediary

$$CPL = (Q_{cd} + Q_{pdu}) \times P_p - Q_{pds} \times 0.5P_s \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (3)$$

Where,

CPL	=	Cost of postharvest loss (Tk/ton)
Q_{cd}	=	Quantity damaged completely (ton)
P_p	=	Average purchase price (Tk/ton)
Q_{pdu}	=	Quantity damaged partially that could not be sold (ton)
Q_{pds}	=	Quantity damaged partially that could be sold with less price (ton)
P_s	=	Average sell price (Tk/ton)

Results and Discussion

Mango Marketing System

The process of mango marketing started with the producers and continued through certain channels until the produce reached the final consumers. Selling mango garden in advance by its owner is a common and prominent system in the study areas. However, both direct and indirect transaction between the producers or advance buyer of mango garden and consumers were found in mango marketing system. The indirect transaction was found more prominent than the direct one. A number of intermediaries such as *Bepari*, *Faria*, *Arathdar*, and retailer were involved in the mango marketing channel (Fig 1). *Bepari* and *Faria* were the most important middlemen in the process of mango marketing. *Bepari* traded a large volume of mangoes in both peak and lean seasons covering a long distance. *Farias* traded volume was much lower than *Bepari*. Usually they do not store mangoes for even one night. *Arathdar* simply plays their role as a commission agent. Retailer traded in the consuming areas and their traded quantity was small. They purchase small quantity, hold long period and sell small quantity according to the consumer demand. Some institutional buyers such as PRAN Agro, Akij group, Agro Food Industries, Agro Food & Beverage, Technoprime Inc. BD. Ltd., Seazon, etc also good buyers (through *Bepari*) of mango in the study areas.

The following channels were identified in the study areas for mango marketing:

	Channel	%
1.	Farmer/advance buyer >Bepari>Urban Arathdar>Urban Retailer>Urban Consumer	85.1
2.	Farmer/ advance buyer >Faria>Local Arathdar>Bepari>Urban Arathdar>Urban Retailer>Urban consumer	4.8
3.	Farmer/ advance buyer >Faria>Bepari>Urban Arathdar>Urban Retailer>Urban Consumer	4.2
4.	Farmer/ advance buyer >Faria>Local Arathdar>Local Retailer>Local consumer	4.0
5.	Farmer/ advance buyer >Local Retailer>Local consumer	1.0
6.	Farmer/ advance buyer >Faria>Local Retailer>Local consumer	0.5
7.	Farmer/ advance buyer >Faria>Institutional buyer	0.2
8.	Farmer/ advance buyer >Bepari >Institutional buyer	0.2

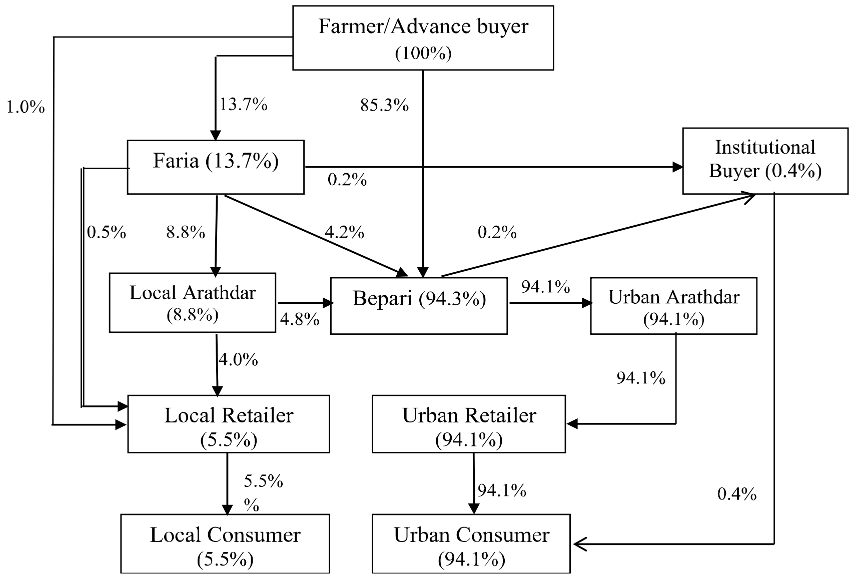


Fig 1: Flow diagram of mango supply chain.

Source: Field survey, 2015.

Volumes Traded and Seasonal Variations

The volume of mango traded by the traders varied according to seasons and due to many other factors. In the peak season* *Bepari*, *Faria* and retailers traded about four, three and five times higher quantities of mango compared to lean season respectively. On average, *Bepari* bought 62.1% mangoes from farmers and the rest from *Faria* (Table 1). On the other hand, they sold the lion share (99.8%) of mangoes to retailers through *Arathdar*. Some local *Beparis* also supplied a small percentage (0.2%) of mangoes to the local agent of the mango pulp factory situated in the study areas (Table 2). *Beparis* mainly supply low-quality sour variety of mango (*Ashina*) to the pulp factory in the lean season when the price and demand of mangoes both are low in the study areas.

Faria is an important trader in the mango supply chain. However, they purchased entire volume of mangoes from farmer and sold them to different buyers such as *Bepari*, local *Arathdar* and local agent of the mango pulp factory. *Faria* sold nearly 64.1% mangoes to local *Arathdar* followed by *Bepari* (30.5%) immediately after purchase. Retailer, an important trader in the mango supply chain, purchase mangoes from different types of traders where they get good products with lower price. However, retailer purchased the highest volume of mangoes (56.1%) directly from farmers followed by local *Arathdar* (39.7%) and *Faria* (4.2%). They sold their entire volume of mangoes to the final consumers (Table 2).

Table 1. Total volume of mangoes bought from different sellers at intermediaries' level

Key players	Peak season		Off season		Total	
	Quantity (ton)	Percent	Quantity (ton)	Percent	Quantity (ton)	Percent
A. Faria buys from:	832.36	100	258	100	1090.36	100
1. Farmer	832.36	100	258	100	1090.36	100
B. Bepari buys from:	8633	100	2249	100	10882	100
1. Farmer	5186	60.1	1576	70.1	6762	62.1
2. Faria	3447	39.9	673	29.9	4120	37.9
C. Retailer buys from:	121.44	100	14.92	100	136.36	100
1. Farmer	70.20	57.8	6.32	42.4	76.52	56.1
2. Local Arathdar	45.52	37.5	8.60	57.6	54.12	39.7
3. Faria	5.72	4.7	--	--	5.72	4.2

Source: Field survey, 2015.

* The peak and lean seasons are ranged from Mid June-Mid August and Mid August to Mid September for Chapai Nawabganj district

Table 2. Total volume of mangoes sold to different buyers at intermediaries' level

Key players	Peak season		Off season		Total	
	Quantity (ton)	Percent	Quantity (ton)	Percent	Quantity (ton)	Percent
B. Faria sold to:	823.72	100	257.96	100	1081.68	100
1. Bepari	159.00	19.3	171.00	66.3	330.00	30.5
2. Local Arathdar	609.46	74.0	83.26	32.3	692.72	64.1
3. Local retailer	38.90	4.7	2.50	0.9	41.40	3.8
4. Local agent of pulp centre	16.36	2.0	1.20	0.5	17.56	1.6
A. Bepari sold to:	8230.92	100	2302.24	100	10533.16	100
1. Arathdar	8214.32	99.8	2293.24	99.6	10507.56	99.8
2. Local agent of pulp centre	16.60	0.2	9.00	0.4	25.60	0.2
C. Retailer sold to:	117.52	100	13.16	100	130.68	100
1. Consumer	117.52	100	13.16	100	130.68	100

Source: Field survey, 2015.

Buying and Selling Price of Mango

The price of mango depends on its season, variety, size, colour, freshness, and nature of supply in the market. Irrespective of these factors, the average purchase price of mango in the peak season was estimated at Tk. 37202, Tk. 37810, and Tk. 41538 per ton respectively for *Faria*, *Bepari,* and retailer. However, the price of mango estimated at the lean season was higher compared to peak season. In the lean season, the average purchase price of mango was estimated at Tk. 52224, Tk. 43256, and Tk. 65920 per ton respectively for *Faria*, *Bepari,* and retailer. There is an inverse relationship between demand and supply of mango (i.e. low supply vs high demand) exists in the lean season for which the price remained high. More or less similar trend was observed in the selling price of mango in the study areas (Table 3).

Table 3. Buying and sell price of mango in the study areas

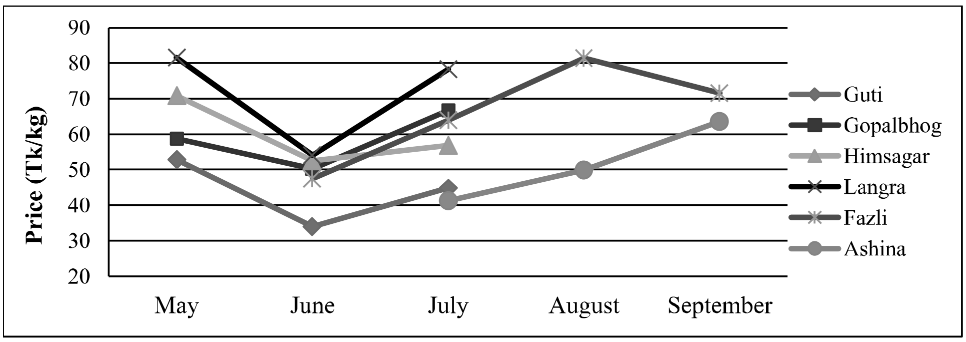
Cost headings	Purchase price (Tk/ton)			Sell price (Tk/ton)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
A. Peak season						
Faria	13435	51731	37202	34588	63654	46524
Bepari	32234	48745	37810	44583	59772	51027
Retailer	19500	75000	41538	35000	85000	51043
B. Lean season						
Faria	29688	75000	52224	37813	80833	59969
Bepari	37281	50500	43256	52000	62519	58881
Retailer	27500	105700	65920	33750	112500	73093

Source: Field survey, 2015.

Monthly Price Variation of Mango

The monthly price variations of different varieties of mango in Chapai Nawabganj district were recorded by Bangladesh Bureau of Statistics (BBS, 2013). The mango varieties Guti, Gopalbhog, Himsagar and Langra were found available in the market during May-July, and the price variation of these varieties ranged from Tk.33.97 to Tk.81.58 per kg. The variety Fazli remained available during June-September and its price ranged from Tk. 47.55-Tk.81.45 per kg. The late variety Ashina was found available during July in the market until September and its price ranged from Tk. 41.31-Tk.63.53 per kg. In the months of August and September, only two varieties namely Fazli and Ashina remained available in the market (Fig 2). The sale price of Ashina variety is significantly higher during these months only because of its late arrival in the market, although it is relatively a poor quality mango (i.e. less sweet, less taste, less nutrition, less customer appeal). This variety requires less care. Therefore, the number of Ashina orchard is increasing year after year since the growers receive more profit than other varieties that have more suppliers and market competition (Hassan *et al*., 2014).

Fig 2. Monthly price variation of different mango varieties, 2013



Month	Guti	Gopalbhog	Himsagar	Langra	Fazli	Ashina
May	52.84	58.69	70.85	81.58	--	--
June	33.97	50.28	52.55	54.10	47.55	--
July	44.81	66.75	56.86	78.25	63.99	41.31
August	--	--	--	--	81.45	49.94
September	--	--	--	--	71.56	63.53

Source: BBS, 2013.

Factors Influencing Mango Price

It has been stated earlier that mango price is depended on many factors. Mango size was one of the most important characters that highly influenced its price. On an average, about 87% traders mentioned this character that influence mango price. The second highest influencing factor was mango variety which was reported by 84.2% traders in the study areas. Most of the traders (71%) also mentioned that growing or harvesting season influenced mango price to some extent. The price remained very high during early season and late season when the supply of mango remained low, whereas the price remained low in the peak season. Product quality is also important to influence mango price. The other factors that influence price were reported to be bad weather and difficulties in transportation (Table 4).

Table 4. Factors influencing the price of mango

Influencing factors	% of responses by traders			
	Faria *(n=15)*	Bepari *(n=10)*	Retailer *(n=13)*	All trader *(n=38)*
1. Product size	93.3	70.0	92.3	86.8
2. Mango variety	86.7	80.0	84.6	84.2
3. Season	73.3	50.0	84.6	71.0
4. Product quality	26.7	40.0	53.8	39.5
5. Bad weather	13.3	40.0	--	15.8
6. Transportation defect	6.7	--	15.4	7.9

Source: Field survey, 2015.

Marketing Costs and Margins

The costs and margins in mango marketing for different traders are shown in Tables 5 and 6 respectively. Mango traders spent on various activities during mango marketing. Among different traders, *Bepari* incurred the highest average marketing cost of Tk. 7337.9 followed by retailer (Tk.1217.9) and *Faria* (Tk.738.2). *Beparis* incurred the highest costs due to higher *Arathdar* commission (Tk.4509.2/ton) and transportation (Tk.2083/ton). The table further reveals that transportation shared the highest cost to the total costs for retailer and *Faria* followed by personal expenses.

Table 5. Marketing cost of mango at traders level

Cost headings	Faria		Bepari		Retailer	
	Amount (Tk/ton)	Percent	Amount (Tk/ton)	Percent	Amount (Tk/ton)	Percent
1. Arathdar commission	--	--	4509.2	61.4	--	--
2. Transportation	431.3	58.3	2083.0*	28.4	738.7	60.7
3. Loading & unloading	5.6	0.8	401.4	5.5	--	--
4. Cleaning & grading	40.0	5.4	103.3	1.4	--	--
5. Basket/cartoon	16.3	2.2	65.2	0.9	--	--
6. Shop rent	--	--	76.1	1.0	181.0	14.8
7. Market toll	67.9	9.3	8.5	0.1	38.4	3.2
8. Electricity charge	--	--	7.6	0.1	62.4	5.1
9. Sweeping	1.7	0.2	5.1	0.1	9.5	0.8
10. Personal expenses	175.5	23.8	78.5	1.1	187.9	15.4
Total cost	**738.2**	**100**	**7337.9**	**100**	**1217.9**	**100**

* Transport mangos from Chapai Nawabganj to Dhaka for *Bepari.*

Source: Field survey, 2015.

The highest gross margin was estimated for *Bepari* (Tk. 13,549.23/ton) followed by retailer (Tk. 8,978.16/ton) and *Faria* (Tk. 8,961.49/ton). Again, *Faria* received the highest net margin (Tk. 8,067.76/ton) and *Bepari* received the lowest margin (Tk. 5,393.47/ton). The highest net margin for *Faria* was due to lower marketing cost and lower postharvest losses. Generally *Faria* performed both buying and selling activities in the same day and that's why their cost of transportation along with postharvest losses remained low. *Farias* purchase the entire volume of mango directly from farmers and sell it to *Bepari* and other customers immediately after purchase. On the contrary, the volume of transaction was the highest for *Beparis*, but their net margin was the lowest (Tk. 5,393.47/ton) due to higher marketing cost. Generally, retailers receive highest net margin in other business, but in mango marketing retailers were found to receive a reasonable net margin (Tk. 6,601.36/ton) due to higher postharvest loss (Table 6).

Table 6. Marketing margin and profit of different intermediaries

Trader type	Average purchase price (Tk/ton)	Average sale price (Tk/ton)	Gross margin (Tk/ton)	Average marketing cost (Tk/ton)	Average postharve st loss (Tk/ton)	Net profit (Tk/ton)
I	*II*	*III*	*IV=(III-II)*	*V*	*VI*	*VII=(IV-V-VI)*
Faria	37905.75	46867.24	8961.49	738.20	155.53	8067.76
Bepari	38303.92	51853.15	13549.23	7337.90	817.86	5393.47
Retailer	43146.83	52124.99	8978.16	1217.90	1158.90	6601.36

Source: Field survey, 2015.

Type of Packaging Used

Good packaging is very much important for maintaining product quality, transport to distant places, and reduce postharvest losses. Majority of the mango growers and traders agreed that good packaging has crucial role in maintaining product quality and attracting consumers. Currently, the use of conventional packaging has reduced to a great extent. On an average 69.1% key stakeholder in the mango supply chain used plastic crates with paper lining as packaging instrument. A good percentage of mango growers and local traders (*Faria*) used wooden box with tiny hole for packaging mango. Mango growers and *Faria* do not require transport mangoes to the distant places or markets. Generally, *Beparis* need transport mangoes carefully from assemble market to distant wholesale markets. That's why most of the *Beparis* (90%) used plastic crates for packaging mangos. Except *Faria*, some growers and traders also used thick/solid paper carton for packaging mangoes (Table 7).

Table 7. Type of packaging used for maintaining mango quality

Particulars	% of responses				
	Farmer *(n=30)*	Faria *(n=15)*	Bepari *(n=10)*	Retailer *(n=13)*	All *(n=68)*
1. Plastic crates with paper lining	76.7	20.0	90.0	92.3	69.1
2. Wooden box with tiny hole	56.7	53.3	--	15.4	39.7
3. Thick/solid paper carton	3.3	--	30.0	23.1	10.3

Source: Field survey, 2015.

Mode of Transportation

The key actors in the supply chain used different types of vehicles to transport mango. The use of vehicles varied from traders to traders and the length of destination markets. Farmers transported mango by using different local low-cost carriers like bicycle, rickshaw, van, and push cart. Trucks and vans were mostly used for mango transportation from the assemble markets to the destination wholesale markets. Majority of the *Farias* and retailers used rickshaw/van and *Nosimon* (5 wheeler local vehicle) to transport their mangoes. Table 8 revealed that 60% of *Farias* used rickshaw/van and the rest of them used bicycle to carry mangoes from garden to assemble markets. All the *Beparis* used truck to transport mangoes from assembles market to distant wholesale markets. *Beparis* also used rickshaw or van to transport purchased mangoes from assembles place to local *Arath* or near to truck. The highest percentage of retailers used rickshaw or van followed by bicycle for transporting mangoes from purchase place to their permanent shops.

Table 8. Mode of transportation of the traders

Mode of transport	% of responses by traders		
	Faria *(n=15)*	Bepari *(n=10)*	Retailer *(n=13)*
1. Truck/pick up	--	100.0	7.7
2. Rickshaw/van	60.0	--	76.9
3. Bicycle	40.0	--	15.4

Source: Field survey, 2015.

Disposal Pattern and losses of Mango at Farm Level

The highest quantity of mango was produced and sold in the peak season. The highest percentage (81.12%) of mango was sold by the growers at assemble market. About 3% of the total mangos were used for family consumption and 2.03% was gifted to their relatives or others (Table 9). On an average, the total postharvest loss of mango at farm level was 14.11% of the total production. Among the losses, 7.2% was completely spoiled which had no market value at all, whereas 6.91% were blemished (semi-spoiled) that could sell half of the price. The main postharvest losses occurred at farm level was due to cut, spotted, cracks, bruising, disease infected, and insect-pest damage found at harvest those were discarded from good ones during sorting and grading. Losses were also occurred due to improper packing and transportation system at farm level. Figure 3 reveals that the perceived damages during sorting & grading and transportation were estimated to be 6.16% and 1.04% respectively. Again, 6.75% of the total loss was semi-damaged during sorting & grading and 0.16% was due to improper transportation. However, the rate of damage in peak season was higher compared to lean season.

Table 9. Disposal pattern and postharvest losses of mango at farmers' level

Key players	Peak season		Lean season		All season	
	Quantity (ton)	% of total	Quantity (ton)	% of total	Quantity (ton)	% of total
Sale	161.68	81.25	14.48	79.74	176.16	81.12
Consumption	5.20	2.61	0.76	4.19	5.96	2.74
Gift	3.80	1.91	0.60	3.30	4.40	2.03
Damage	28.32	14.23	2.32	12.78	30.64	14.11
Rotten	14.52	7.30	1.12	6.17	15.64	7.20
Blemish	13.80	6.93	1.20	6.61	15.00	6.91
Total	**199.00**	**100**	**18.16**	**100**	**217.16**	**100**

Source: Field survey, 2015.

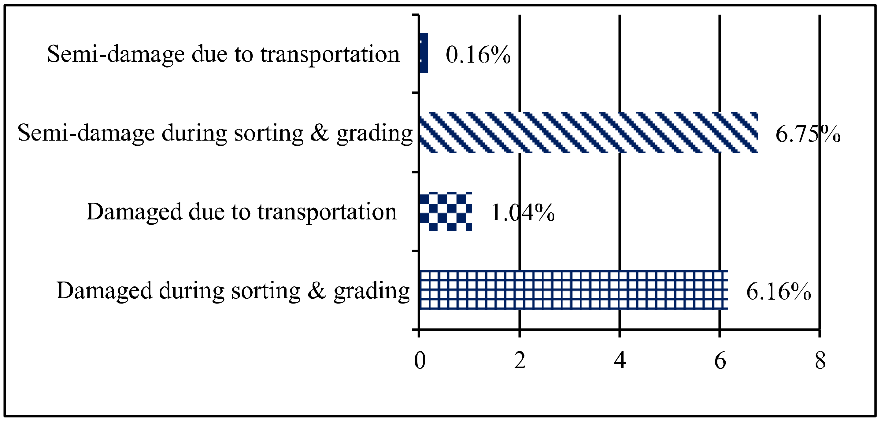


Fig 3: Percent of postharvest losses of mango at farm level.

Source: Field survey, 2015.

Postharvest Loss at Traders' Level

Table 10 showed that the total postharvest loss at trader's level was estimated at 9.61% which consisted of completely damaged mango (3.04%) and partial damaged mango (6.57%). Partial damaged mangoes could be sold at reduced price (e.g. in the study areas, it was sold at 50% of the selling price). Among intermediaries, the highest loss was recorded for retailer (4.64%) followed by *Bepari* (3.95%) and *Faria* (1.02%). The level of postharvest loss is dependent on various factors such as length of selling, type of transportation used, packaging system, etc. The volume of transaction of retailer is much lower, but the length of selling is higher compared to other intermediaries. Therefore, retailer's loss was reported to be the highest among intermediaries. Most of the *Beparis* currently used plastic crates to transport mango from assemble market to distant wholesale market that ensure lower transportation loss in the study areas.

Table 10. Total postharvest losses of mango at traders' level

Key players	Complete damage			Partial damage			Total damage		
	Total loss (ton)	Loss (kg/ ton)	% of total purchase	Total loss (ton)	Loss (kg/ ton)	% of total purchase	Total loss (ton)	Loss (kg/ ton)	% of total purchase
Faria	0.44	0.55	0.05	8.24	9.69	0.97	8.68	10.24	1.02
Bepari	131.12	13.00	1.30	217.72	26.54	2.65	348.84	39.54	3.95
Retailer	2.12	16.87	1.69	3.56	29.48	2.95	5.68	46.35	4.64
Total	133.68	30.42	3.04	229.52	65.71	6.57	363.2	96.13	9.61

Source: Field survey, 2015.

All the intermediaries stated that the loss incurred in the supply chain due to spoilage (not suitable for marketing) caused by short-time storage (1-2 days), improper handling during sorting & grading, transportation, and delayed sell. The percentage shares of postharvest losses at different stages in the supply chain are shown in Fig 4. It was revealed that *Faria* had no postharvest loss at storage level because they did not need storage at all. The highest loss at transportation level (2.91%) was incurred for *Bepari* due to unsuitable transportation. In the case of *Faria*, the highest loss (0.73%) incurred during sorting and grading due to inappropriate handling. The postharvest loss due to delayed sell (2.82%) was found to be the highest for retailer. Irrespective of traders, the highest loss was due to transportation (3.19%) followed by delayed sell (3.12%) and sorting & grading (1.85%).

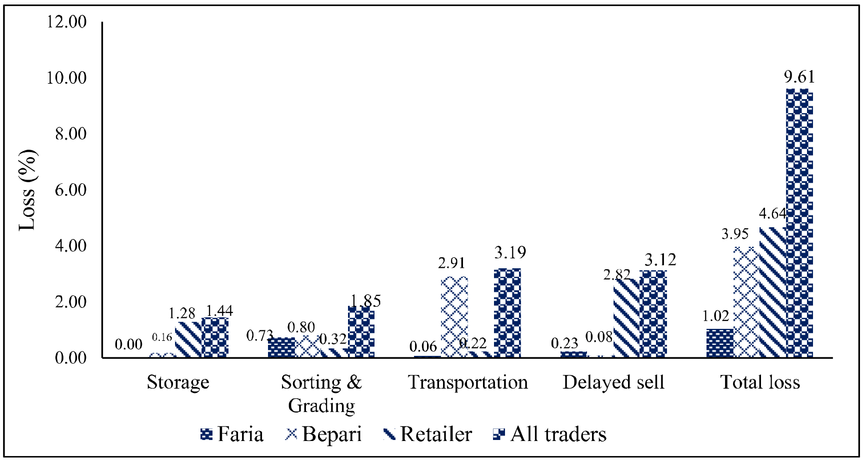


Fig 4. Postharvest losses at different stages of mango supply chain.

Source: Field survey, 2015.

Problems of Mango Marketing

The key actors in the supply chain encountered various problems with the produce on arrival at the market. The highest reported problem was delayed sale (57.9%) and lack of buyers (47.3%) for unstable supply. *Beparis* and retailers faced these two problems to a great extent compared to *Faria*. All the traders experienced partial damage of produces to some extent. Only 10% *Beparis* encountered mostly damage problem with their produce on arrival at the market (Table 11).

Table 11. Major problems encountered with the produce on arrival at the market

Major reason	% of responses by traders			
	Faria *(n=15)*	Bepari *(n=10)*	Retailer *(n=13)*	All trader (n=38)
1. Delayed sale	40.0	70.0	69.2	57.9
2. Lack of buyer	33.3	50.0	61.5	47.3
3. Partial decay/rotten	6.7	30.0	15.4	15.8
4. Mostly damage	--	10.0	--	2.6

Source: Field survey, 2015.

Conclusions and Recommendations

Conclusions

Mango is one of the popular fruits in Bangladesh. Due to the lack of appropriate pre- and postharvest measures, a plenty of mangoes are blemished every year. A number of middlemen are involved in the mango supply chain. Mango marketing in different chains is profitable, but it faces different problems in various stages of its marketing. However, this study identifies eight supply chains for mango marketing. The longest and dominant channel is *Farmer>Bepari>Urban Arathdar> Urban Retailer>Urban Consumer.* All the stakeholders in the mango supply chain added a good amount of net margin. *Faria* receives the highest net margin due to lower marketing cost and spoilage followed by retailer and *Bepari*. The marketing cost of mango for *Bepari* is the highest than the *Faria* and retailer due to transportation cost because they cover a long distance. Farmers and *Farias* use different local carriers like bicycle, rickshaw, and van (manual cart) to transport mango. Trucks and pick up van have been mostly used by *Bepari* to transport mango from assemble markets to urban wholesale markets. *The average postharvest losses are 14.11% and 9.61% at grower and traders' level respectively. These losses occurred due to cut, cracks, bruising, insect-pest infestation, which are discarded during* sorting & grading after harvest. *Transportation and delayed sale are the two main causes of losses at traders'* *level.* Major marketing problems in the supply chain are delayed sale and lack of buyers.

Recommendations

Based on the findings of the study, the following recommendations are required to reduce postharvest losses, increase profitability and improve marketing system of mango.

1. Donor agency and the government would make arrangement for funding to perform the pilot project establishing pack house and cool chain management system for fresh fruits in order to reduce postharvest spoilage.
2. Technical know-how and technology related to postharvest management and nutrition should be disseminated by Bangladesh Agricultural Research Institute (BARI) and other related agencies through TV, radio, billboard, video, brochure, and mobile phone apps etc., which would have much impact on the reduction of postharvest losses.
3. The concerned authority may undertake pilot projects to establish limited number of low temperature storage facilities in production catchment areas and wholesale markets for high-value crops including mango.
4. Entrepreneurs should come forward to establish more small-scale processing plants in the intensive growing areas to minimize wastage of mango.
5. BARI and Agricultural Universities in Bangladesh should strengthen their existing capacity in terms of postharvest research and development.

End Note:

Advance buyer: Selling mango garden in advance during flouring stage by its owner is a common and dominant system in the study areas. Sometimes first advance buyer hands over the garden to second buyer with desired profit just after one or two months later. Finally, advance buyer looks after the garden throughout the season.

Faria: *Faria* is a small scale businessman that purchases produces from the farmers at village or local assemble market, and offer the same to the *Bepari* or *Arathdar*. Sometimes, he sells his produces directly to the local retailers or consumers. Their volume of purchase is generally low and use small local vehicle for transporting produces from field to assemble market.

Bepari: *Bepari* is a professional wholesale trader who makes his purchase from producer or *Faria* at the local assemble market, bring their consignment to the urban wholesale market and sell them to *Paikar* and retailer through *Arathdar*. Their volume of purchase is generally high and use truck for transporting produces from assembles market to distant wholesale markets.

Arathdar: *Arathdar* is a commission agent who has a fixed establishment and operates between *Bepari* and retailer, or between *Bepari* and *Paiker*, or between *Faria* and *Bepari*. They take commission from both of the parties but generally they do not follow any standard rule to take commission. The rate of commission in the study areas varied from 8-10% of the total sell.

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EFFECT OF PLANTING DENSITY ON YIELD AND YIELD ATTRIBUTES OF LOCAL AROMATIC RICE VARIETIES

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Abstract

An experiment was conducted at the Agronomy Field of Patuakhali Science and Technology University, Dumki, Patuakhali from June to December, 2013 to find out the effect of variety and planting density on the yield and yield attributing characters of local aromatic rice. The experiment was laid out in a factorial randomized complete block design with three replications, which consisted of three local aromatic rice varieties (Chinigura, Shakhorkhora and Kalizira) and four planting densities were *viz.* S_1 (25 cm × 20 cm), S_2 (20 cm × 20 cm), S_3 (20 cm × 15 cm) and S_4 (20 cm × 10 cm). The results revealed that the local aromatic rice var. Shakhorkhora variety produced the highest number of grains per panicle (131) and 1000-grain weight (13.8 g), consequently higher grain (2.63 t ha^{-1}), followed by Kalizira (2.56 t ha^{-1}) and straw yield (4.21 t ha^{-1}). One the other hand, higher number of tillers per hill (14.8), number of grains per panicle (140 nos.) were found in 20 cm × 20 cm spacing with higher grain yield.

Keywords: Local aromatic rice, variety, planting density, rice yield.

Introduction

Rice (*Oryza sativa* L.) being the world's most widely consumed cereal grain play an unique role in satisfying global hunger (IRRI, 2004). Bangladesh, an agro-based country, depends on agriculture for most of her economic activities. The total area and production of rice in Bangladesh is about 11.75 million hectare and 34.4 million metric ton, respectively in the year 2013/14 (BBS, 2015). Although the geographical, climatic and ethnic conditions of Bangladesh are favorable for year-round rice cultivation, the national average of rice yield is low (2.91 ton ha^{-1}) compared to other rice growing countries (BBS, 2015). A dense population of crop may play the negative role to have the maximum yield from the limited resources. Optimum plant spacing ensures optimum number of plants per unit area which lead to yield contributing characters and ultimately grain yield. Optimum plant spacing facilitates plants to grow properly, utilizing more solar radiation and soil nutrients (Mia *et al.,* 1993; Bhowik *et al*., 2012). When the

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planting density exceeds the optimum level, competition among the plants for light and nutrients becomes severe. Consequently, the growth slows down and the grain yield decreases. The rice economy in Bangladesh can be changed by improving production technologies of aromatic fine rice. Among the rice varieties, scented or aromatic rice is popular in Asia and has gained wider acceptance in Europe and United States of America because of their good flavor and texture. Export of aromatic and fine rice from Bangladesh made a significant rise from 1100 tons in 2002 to 3300 tons in 2003, but the volume is still far below the potential demand of 4 million Bangladeshi living abroad. The demand of aromatic rice for internal consumption and also for export is increasing day by day (Das and Baqui, 2000). Plant spacing is one of the crop management activities which govern all of the components of plant need for their growth and yield. Plant spacing directly affects the normal physiological activities through intra-specific competition. Different crops and even different cultivars of a crop respond physiologically differently to plant spacing due to their differential requirement of light, space, oxygen, carbon dioxide, nutrients etc. (Oad *et al.*, 2001). Chinigura, Shakhorkhora and Kalizira are three popular aromatic rice varieties but there is not sufficient information regarding optimum spacing for these varieties. So, the present experiment was undertaken to find out the suitable local aromatic variety and optimum spacing for higher grain yield of rice varieties.

Materials and Methods

The experiment was conducted at the department of Agronomy field of Patuakhali Science and Technology University, Dumki, Patuakhali with geographical location of 22°26´N latitude and 90°22´E longitude at an elevation of 1.5 m above the sea level, during the period from June 2013 to December 2013 in the aman season. The field of the experimental site belonged to the Ganges Tidal Floodplain (AEZ- 13) which was characterized by non-calcareous Grey Floodplain soil with silty clay texture. The soil was mildly acidic and non-saline. The soil was loamy in texture and having soil pH ranges from 6.0 to 6.8. Organic matter content was low (1.1%).The experiment was laid out in a factorial Randomized Complete Block Design (RCBD) with three replications. The treatments were : Factor A: Variety- Chinigura (V_1), Shakhorkhora (V_2), Kalizira (V_3) and Factor B: Planting density- 25 cm × 20 cm (S_1), 20 cm × 20 cm (S_2), 20 cm × 15 cm (S_3), 20 cm × 10 cm (S_4). On July 1, 2013, 30-day-old rice seedlings were transplanted into the experimental plots. The recommended fertilizer dose was N_{90} P_{20} K_{50} $S_{7.5}$ B_2 and Zn_2 kg ha^{-1}, respectively. Urea was applied in three equal parts, whereby one-third of the urea and the entire amount of triple superphosphate (TSP), murate of potash (MOP), and gypsum were applied during final land preparation; one-third of the urea was applied at the maximum vegetative growth stage (30 days after transplanting [DAT]); and one-third of the urea was applied before the panicle initiation stage of Boro season rice (45 DAT). Though the season was monsoon, supplemental irrigation was used to keep the paddy field well flooded until the rice plants reached maturity. These were applied at 1, 15, 28, 40, 54, 63, and 78 DAT, with a total of 28 cm of irrigation water being applied during rice growth. Weeding was performed at 30 DAT. Precautionary measures were taken at every stage of crop production using natural methods of pest and disease management, such as light traps, the placement of sticks for birds to stand on, and the removal of disease-infected plants at an early stage of infection, removing any need for chemical and herbicide use. The T. aman rice was harvested on 3 November 2013. The data were collected from two 1 m^2 area selected randomly during transplanting of rice. All data regarding yield and yield attributes were collected from the quadrates, which then converted to yield in ton per hectare. Initial soil samples from plots of the experiment were collected from 0-15 cm soil depth and were analyzed in Soil Science laboratory of Patuakhali Science and Technology University, Dumki, Patuakhali. Right after collection of samples, soils were oven-dried and then sieved to clean off foreign materials. The soil samples were then analyzed for soil textural class, pH and organic carbon according to Black (1965), Ghosh (1983) and Jackson (1973), respectively. The collected data on growth parameters, yield contributing characters and yield of aromatic rice varieties under different spacing were analyzed statistically by using SPSS Inc. (Version 21, USA) and mean separation was done by LSD test.

Results and Discussion

The effect of variety on plant height of rice at 50 and 80 day after transplanting (DAT) along with at harvest stage was found significant (Table 1). At 50 DAT, Kalizira was the tallest (79.7 cm) which was statistically similar to Shakhorkhora (79.3 cm) and Chinigura was the shortest (77.4 cm) among the three varieties. At 80 DAT and harvest stage Shakhorkhora produced the tallest plant whereas Chinigura produced the shortest plant (Table 1). Number of tillers per hill was also significantly influenced by variety. Among the three varieties, Shakhorkhora produced the highest number of tillers per hill at 50 and 80 DAT (11.4 and 12.1, respectively) whereas the lowest number of tillers per hill was produced by Chinigura (10.1 at 50 DAT and 11.2 at 80 DAT), shown in Table 1. This confirms the report of Islam *et al*. (2013) and Sarkar *et al.* (2014), who reported the variable effect of variety on the number of effective tillers $hill^{-1}$. The variations in plant height and number of effective tillers $hill^{-1}$ among the varieties were probably due to heredity or varietal characters.

Plant height at different stages (50, 80 DAT and at harvest) was statistically different for planting density. The wider planting density S_1 (25 cm × 20 cm) produced the tallest plant (86.0 cm at 50 DAT and 134 cm at 80 DAT and 160 cm at harvest), which was statistically similar to 20 cm × 20 cm spacing (Table

1). The shortest plants were observed from closest planting density S_4 (20 cm × 10 cm). Number of tillers per hill differed significantly due to different planting densities. Planting density S_2 (20 cm × 20 cm) produced the highest number of tillers per hill (13.9 and 14.8, respectively) at 50 DAT and 80 DAT. The closest planting (20 cm × 10 cm) density produced the lowest number of tillers per hill (8.0 and 9.0, respectively) at 50 DAT and 80 DAT, shown in Table 1. The study of Tyeb *et al.* (2013) confirms the influence of planting density on plant height and number of tillers $hill^{-1}$.

Table 1. Effect of variety and spacing on yield and yield attributes of aromatic rice

Treatments	Plant height (cm)			No of tiller/hill		Lodging (%)	
	50 DAT	80 DAT	At harvest	50 DAT	80 DAT	Milking stage	Harvest
Effect of variety							
V_1	77.4	127	153	10.1	11.2	36.3	40.0
V_2	79.3	131	155	11.4	12.1	28.7	30.3
V_3	79.7	129	154	10.9	11.7	21.5	24.3
$LSD_{0.05}$	1.03	1.08	1.43	0.82	0.85	3.02	5.77
CV %	1.54	0.98	1.10	8.92	8.57	12.0	8.39
Effect of spacing							
Spacing	Plant height (cm)			No of tiller/hill		Lodging (%)	
	50 DAT	80 DAT	At harvest	50 DAT	80 DAT	Milking stage	Harvest
S_1	86.0	134	160	13.0	13.8	47.2	49.6
S_2	85.2	134	160	13.9	14.8	29.3	38.8
S_3	73.2	125	150	9.4	10.4	23.9	25.0
S_4	70.8	126	146	8.0	9.00	22.8	24.6
$LSD_{0.05}$	1.18	1.24	1.65	0.94	0.98	3.49	6.66
CV (%)	1.54	0.98	1.10	8.92	8.57	12.0	8.39

Legend: V_1 = Chinigura; V_2 = Shakhorkhora and V_3 = Kalizira; S_1 = 25 cm × 20 cm; S_2 = 20 cm × 20 cm; S_3 = 20 cm × 15 cm; S_4 = 20 cm × 10 cm. LSD=Least significant difference; CV = Co-efficient of variance; DAT = Days after transplanting.

The results showed that yield and yield attributes of aromatic rice by interaction effect of variety and planting density was not significantly varied.

The effect of variety on lodging percentage was found significant. The lodging percentage was significant at milking stage as well as harvest stage among different varieties. The highest lodging was recorded in case of Chinigura for both of the stages and the lowest lodging was found in Kalizira (Table 1). That varietal difference has influence on lodging of rice was also found by Ookawa and Ishihara (1993) who found that difference in cell wall components of different varieties affect bending stress of the culm in relation to lodging resistance in rice.

Plant density also showed significant influence on the lodging percentage of local aromatic rice. The highest lodging percentage (47.2%) was recorded in wider spacing 25 cm × 20 cm spacing at milking stage, which continued up to harvest stage (49.6%). The lowest lodging percentage (22.8% at milking stage and 24.6% at harvest stage) was in narrower spacing (20 cm × 10 cm), which was statistically similar to 20 cm × 15 cm, respectively both at milking stage (23.9% at milking stage and harvest stage (25.0%) as presented in Table 1. Islam and Hossain (2002) found similar result of lodging. They found higher lodging with plants transplanted with wider spacing.

The panicle length varied significantly among varieties. It was observed that Shakhorkhora produced the longest panicle (25.5 cm) which was statistically similar to Kalizira (25.1 cm) and the shortest panicle was observed in the variety Chinigura (24.7 cm), shown in Table 2. The result also showed that variety had significant effect on number of grains per panicle. Variety Shakhorkhora gave significantly the highest number of grains per panicle (131) and the lowest grains per panicle (114) were produced by Kalizira (Table 2). Likewise, variety had significant effect on 1000-grain weight. Shakhorkhora produced the highest 1000-grain weight (13.8 g) and the lowest 1000-grain weight was produced by Chinigura (12.6 g), shown in Table 2. Islam *et al*. (2013) and Sarkar *et al*. (2014) confirm our results of the variable effect of variety on panicle length, grains per panicle and 1000-grain weight.

The panicle length was affected significantly under different planting densities. It was observed that the panicle length was the longest (26.8 cm) at 20 cm × 20 cm spacing, which was statistically similar to 25 cm × 20 cm spacing (26.4 cm) and the shortest panicle (22.4 cm) was found at 20 cm × 10 cm spacing (Table 2). Planting density also showed significant effect on number of grains per panicle. It was observed that the planting density S_1 (20 cm × 20 cm) produced the highest number of grains per panicle (140). The lowest number of grains per panicle (107) was produced by the closer planting density S_4 (20 cm × 10 cm), as displayed in Table 2. The result revealed that planting density had also significant effect on 1000-grain weight. It was observed that 25 cm × 20 cm spacing produced the highest 1000-grain weight (14.9 g) and the lowest 1000-grain weight (11.3 g) was recorded from the closest spacing (20 cm × 10 cm), shown in Table 2. Similar result was found by Lu *et al*. (2008). The result has also similarity with the result of Ao *et al*. (2008) and Gopal *et al*., (1999) who found that yield contributing characters of rice like panicle length, grains per panicle and 1000-grain yield were very much influenced by densities of planting of rice seedlings.

Table 2 Effect of variety and spacing on yield and yield attributes of aromatic rice

Treatments	Length of panicle (cm)	Grains/ panicle	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Effect of variety						
V_1	24.7	124	12.6	2.25 b	3.92	36.5
V_2	25.5	131	13.8	2.63 a	4.21	38.5
V_3	25.1	114	12.9	2.56 a	4.05	38.7
$LSD_{0.05\%}$	0.74	4.43	0.49	0.12	0.17	2.4
CV %	3.49	4.26	4.46	5.50	5.57	4.43
Effect of spacing						
Spacing	Panicle length (cm)	Grains/ panicle	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
S_1	26.4	132	14.9	2.40	4.19	36.4
S_2	26.8	140	14.6	2.87	4.38	39.6
S_3	24.7	112	11.5	2.38	3.95	37.6
S_4	22.4	107	11.3	1.92	3.72	34.0
$LSD_{0.05\%}$	0.86	5.12	0.57	0.44	0.33	2.6
CV (%)	3.49	4.26	4.46	5.50	5.57	4.43

Legend: V_1 = Chinigura; V_2 = Shakhorkhora and V_3 = Kalizira; S_1 = 25 cm × 20 cm; S_2 = 20 cm × 20 cm; S_3 = 20 cm × 15 cm; S_4 = 20 cm × 10 cm. LSD=Least significant difference; CV = Co-efficient of variance; DAT = Days after transplanting.

Variety had significant effects on grain yield of local aromatic rice (Table 2). It was observed that Shakhorkhora produced significantly the highest grain yield (2.63 t ha^{-1}), which was statistically similar to Kalizira (2.56 t ha^{-1}). The lowest grain yield was obtained from Chinigura (2.25 t ha^{-1}). Straw yield was not differed significantly among the local aromatic rice varieties (Table 2). However, the highest straw yield (4.21 t ha^{-1}) was observed in Shakhorkhora which was statistically identical with Kalizira (4.05 t ha^{-1}) and the lowest straw yield was found in Chinigura (3.92 t ha^{-1}).

It was found that planting density had significant effect on grain yield of local aromatic rice varieties. It was observed that 20 cm × 20 cm spacing produced the highest grain yield (2.87 t ha^{-1}) which was statistically different from other three planting densities. The lowest grain yield (1.92 t ha^{-1}) was recorded from the closest spacing (20 cm × 10 cm). Other two planting densities (25 × 20 cm and

20 × 15 cm) gave the intermediate values between S_1 and S_4 treatments (Table 2). Significant variation in straw yield was observed in local aromatic rice in respect of planting density (Table 2). The planting density S_2 (20 cm × 20 cm) produced the highest amount of straw yield (4.38 t ha^{-1}) followed by S_1 (20 cm × 25 cm, 4.19 t ha^{-1}) and 20 cm × 15 cm spacing (3.95 t ha^{-1}). The lowest straw yield was recorded in 20 cm × 10 cm spacing (3.72 t ha^{-1}).

Variety had no significant effect on harvest index (Table 2). However, it was found that Kalizira produced the highest harvest index (38.7%) followed by Shakhorkhora (38.5%) and the lowest harvest index (36.5%) was obtained from Chinigura. The variation due to the planting density was significant in terms of harvest index (Table 2). It was observed that the highest harvest index (39.6%) was recorded from S_2 (20 cm × 20 cm) spacing and the lowest harvest index (34.0%) was obtained from S_4 (20 cm × 10 cm), whereas S_1 (25 cm × 20 cm) and S_3 (20 cm × 15 cm) gave second highest harvest index (36.4% and 37.6%, respectively).

The local aromatic rice variety, Shakhorkhora performs better than other local varieties (Chinigura and Kalizira) in terms of yields (Table 2). The closest spacing 20 cm × 20 cm showed the best yield than other three plant densities (Table 2) due to highest plant population per unit area. Again, Shakhorkhora and 20 cm × 20 cm spacing produced the highest number of tillers $hill^{-1}$, the longest panicle, the highest number of grains $panicle^{-1}$ which may ultimately be behind the highest grain yield. Optimum spacing produced maximum number of tillers per plant which results in higher tillers number per area (Baloch *et al*. 2002; Quddus and Huda 1995).

The var. Shakhorkhora had found increased panicle length as well as increased grain with planting density management. Among the planting densities, the highest grains per panicle were recorded with 20 cm × 20 cm spacing. This observation was in agreement with the findings of Quddus and Huda (1995) and Rao *et al.* (2003) who stated that optimum planting density produced higher number of grains per panicle. The higher grain and straw yields with 20 cm × 20 cm spacing might be attributed due to higher number of plant per unit area.

The increased plant height with 25 × 20 cm and 20 × 20 cm planting can be attributed to the fact that widely spaced crop get more light, air and soil nutrients which facilitated the plant for proper development (Mia *et al.*, 1990). Again, the lodging percentage increased in close spacing might be due to slender and weak plant in closer spacing resulting from malnutrition.

Based on above results, it indicates that among the three local aromatic rice varieties, Shakhorkhora and Kalizira showed higher grain yield with closer spacing 20 cm × 20 cm.

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CHARACTERIZATION AND GENETIC DIVERSITY OF BRINJAL GERMPLASM

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Abstract

The experiment was carried out in a non replicated design with 40 accessions of brinjal (*Solanum melongena* L.) at Plant Genetic Resources Centre (PGRC), BARI Gazipur to characterize and study the genetic diversity and identify the useful traits. Each accession of nine plants was grown in a 3 X 2 m size plot. The accessions were collected from 16 districts of Bangladesh. Two to four classes were found for plant growth habit, leaf blade lobing, leaf prickles, flower colour, fruit shape, fruit apex shape and fruit colour distribution. The accessions exhibited 64% straight, 13% both slightly curved and curved, and 10% snaked shaped edible fruit along with 55% purple and 45% green fruit. Fruit length of accessions ranged from 5 to 31.23 cm, breadth 2.4 to 10.6 cm, weight 13 to 95.2 g and 3 to 30 fruits per plant. The accessions were grouped into five clusters. The inter and intra cluster distances ranged from 4.01 to 8.32 and 0.94 to 1.36, respectively. Accessions collected from the same districts felt into different clusters. The results obtained by D^2 analysis were also confirmed by canonical analysis. Crosses BD-7327 (Rangpur) of cluster II with BD-9954 (Chittagong) of Cluster-III and BD-7319 (Panchagarh) of Cluster-I with BD-11732 (Bandarban) of cluster V, could be performed for obtaining wider variability in the segregating generations. The breeders could use the selected accessions for varietal improvement of brinjal.

Keywords: *Solanum melongena,* cluster, characterization, diversity and Bangladesh.

Introduction

Brinjal (*Solanum melongena* L.) is the second important vegetable in Bangladesh. It is a good source of minerals and vitamins. The consumption of fruits and vegetables is important from the nutritional point of view and many consumers are now conscious about the health benefits of foods. The current nutritional condition of third world and some emerging countries like Bangladesh is a matter of concern as many people are suffering from malnutrition (Begum *et al.,* 2017). Brinjal can play a significant role in this case and can mitigate the nutritional shortage to some extent. Considering the potentiality of this crop, there is a need for improvement and to develop varieties for specific agro-

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ecological conditions and also for specific end use. It is grown on approximately 46,566 hectares of land across the country both in winter and summer season, yielding an average of 7.30 ton per hectare and a total production of about 3, 39,874 ton (BBS, 2011). The crop is highly diverse for fruit shape, size and colour in Bangladesh due to the Indian gene centre (Hawks, 1983). BARI released 20 varieties of brinjal including two hybrid and four transgenic varieties for cultivation in Bangladesh. The fruit and shoot borer resistant, trangeneic varieties are 'BARI Bt Bagun-1', 'BARI Bt Bagun-2', 'BARI Bt Bagun-3' and 'BARI Bt Bagun-4' (Azad *et al.,* 2017). Bangladesh Agricultural University released two brinjal varieties. Different seed companies released more than 60 varieties including hybrid (SCA, 2018). In addition, a lot of landraces are cultivated all over the country. PGRC of BARI conserved 282 accessions in the genebank. Systematic research such as collection, conservation, characterization and evaluation, and utilization of brinjal germplasm has been done at PGRC of BARI. Few studies on both morpho-genetic and molecular level have been done in different countries but few or none reports included accessions from Bangladesh (Murali *et al.,* 2017; Sunseri *et al.,* 2010; Demir *et al.,* 2010; Islam and Uddin 2009, Khorsheduzzaman *et al.,* 2008; Kumer *et al.,* 2008). Characterization and evaluation of plant germplasm is imperative for categorization of germplasm and identification of desirable genotypes carried out in precision fields under sufficient growth and plant protection conditions for utilization in breeding programs (Upadhyaya *et al.,* 2008). Before these resources can be exploited, they should be systematically evaluated to assess genetic diversity. Until a collection has been properly evaluated and its attributes become known to breeders, it has little practical use (Thomas and Mathur, 1991). Such a situation is just like a library where none of the books are catalogued. Therefore, the current piece of research will help to identify suitable germplasm of brinjal which can be used to develop desirable varieties. The specific purpose of this study was to characterize and to study the genetic diversity and identify the potential accessions for varietal improvement of brinjal in Bangladesh.

Materials and Methods

The experiment was conducted at PGRC of BARI, Joydebpur, Gazipur during September 2013 to May 2014 at 24.00^0 N latitude, 90.26^0 E longitudes and 8.40 m above sea level. The soil of the experimental field was silty clay having a pH of 6.5. Forty accessions including BARI Bagun-1 (Uttara) was used as check variety. The accessions were collected from 16 districts such as Panchagarh (3 accessions), Thakurgaon (2), Dinajpur (1), Rangpur (7), Pabna (3), Rajshahi (6), Chapai Nawabganj (1), Magura (1), Barisal (1), Tangail (1), Jamalpur (2), Sherpur (1), Chittagong (3), Bandarban (4), Rangamati (3) and Moulvibazar (1) of Bangladesh from 20º35' to 26º75' N latitude and 88º03' to 92º75' E longitude. Seedlings were raised in the seed bed containing a mixture of sandy-loamy soil and decomposed cowdung on 27 September 2013. Main field was prepared 10 days before transplanting the seedlings. The recommended doses of manure and fertilizers such as 5 ton/ha cowdung, 120 kg N, 36 kg P, 90 Kg K, 15 kg S and 2.0.kg/ha Zn in the form of urea, triple super phosphate, murate of potash, gypsum and zincsulphate (monohydrate), respectively were applied in the experimental field (FRG, 2012). The full doses of cowdung, TSP, gypsum and zincsulphate were applied during land preparation before one week of transplanting. Urea and MP were applied in the three equal splits at 21, 35 and 50 days after transplanting as ring method around the plant followed by irrigation (10-15 days interval during dry season). The experiment was conducted in a non replicated design. The unit plot size was 3 X 2 m and nine plants were accommodated in a plot with a plant spacing of 75 cm apart and row to row distance of 100 cm. The seedlings at the age of 52 days were transplanted on 18 November 2013. The insecticide admire (0.5 ml per litre) was applied for controlling aphids. Twenty-four observations on qualitative (12) and quantitative (12) characters were classified into descriptor states (Table 1) as per Descriptors for Eggplant (IBPGR, 1990). Range, mean, standard deviation and coefficient of variation of quantitative characters were calculated (Table 2). Principal Component Analysis, Principal Coordinate Analysis, Canonical Vector analysis and Cluster analysis were performed with Genstat 5 software.

Results and Discussion

(i) Characterization of brinjal

Sixty percent green and 20% both light violet and violet cotyledon were found among the 40 accessions of brinjal (Table 1). Plant growth habit, 48% intermediate, 45% upright and 7% prostrate were exhibited at vegetative stage. Begum *et al.* (2017) found erect, semi-erect and spreading growth habit in genetic variability study of brinjal. Leaf blade lobing, 60% weak, 37% intermediate and 3% strong along with 62% acute, 33% very acute and 5% intermediate leaf blade tip angle were observed among the accessions. Solaimana *et al.* (2015) reported three types of leaf blade lobing and leaf blade tip angle. Leaf prickles were absent in 25% accessions. The remaining accessions produced 40% very few, 25% few and 5% both intermediate and many prickles. Very few (<20) to few (20-50) number of leaf hairs were noted. The accessions exhibited 53% light violet, 37% bluish violet and 10% pale violet flowers. Hassan *et al.* (2015) found light purple and purple flower among 22 brinjal accessions. The maximum, 64% accessions produced straight edible fruit followed by 13% both slightly curved and curved, and the minimum, 10% accessions showed snake shaped fruit curvature. About half way from base to tip (77% accessions) and about three quarter from base to tip (23%) for fruit shape were found. Fruit apex shape, 38% depressed, 34% rounded and 28% protruded was found. Edible fruit colour, 55% purple and 45% green along with 47% uniform, 30% stripped and

23% mottled fruit colour distribution were exhibited (Table 1, Fig.1). Similar types of fruit curvature and fruit apex shape were reported by Solaimana *et al.* (2015). But more fruit colour variation was noted by Hassan *et al.* (2015) and Begum *et al.* (2017). Solaimana *et al.* (2015) found uniform and stripped fruit colour distribution. Different qualitative variations were found due to the different types of descriptor used in data recording, different growing region and diverse type of accessions were used in the experiments.

Fig. 1. Diversity of brinjal accessions at PGRC of BARI Bangladesh.

(ii) Descriptive statistics of quantitative character

The extent of diversity in respect to 12 characters in different accessions of brinjal are measured in terms of range, mean, standard deviation and co-efficient of variations (Table 2). A wide variation was observed among the different characters studied. The highest number of primary branches per plant was exhibited in BD-10154 (9.8) while the lowest 4.9 was observed in BD-7327. The accessions exhibited 50.8 to 96.2 cm plant height, 64.3 to 119.7 cm plant breadth, 11.7 to 23.4 cm leaf blade length and 7.8 to 13.3 cm leaf blade width. This indicated that the range of five characters were approximately two times larger than their minimum limit. Solaimana *et al.* (2015) found 4 to 7 branches, 45.6 to 87.4 cm plant height, 7.05 to 22.06 cm leaf blade length among the brinjal genotypes. The accessions produced first flower on 86 days (BD-9766) to 115 days (BD-11730) and days to 1st edible fruiting stage on 107 (BD-9766) to 139 (BD-11733) days. Earlier fruit harvest (45 to 128 days) was found by Solaimana *et al.* (2015). The accessions exhibited fruit length from 5 cm (BD-11738) to 31.2 cm (BD-10158). Among them, 54% long, 23% intermediate, 18% very long and 5% short fruits were found. Fruit breadth ranged from 2.40 (BD-7320) to 10.60 cm (BD-11726) where 42% intermediate, 33% long and 25% short were noted. The accessions produced 40% medium, 35% low and 25% high fruit weight ranging from 13 (BD-7321) to 95.20 g (BD-7319) (Table 2 and Table 3). The highest number of fruits per plant was obtained from BD-9955 (30) and the lowest from BD-11737 (3). Hasan *et al.* (2015) found 1.8 to 22.9 cm fruit length, 1.3 to 12.4 cm fruit breadth and 12.1 to 214.0 g fruit weight and Solaimana *et al.* (2015) found 7.15 to 31.56 cm fruit length, 2.6 to 9.0 cm fruit breadth and 35.5 to 313.30 g fruit weight in their study. 100-seed weight ranged from 0.19 to 0.48 g. More or less similar results were observed by Hassan *et al.* (2015) and Begum *et al.* (2017). The quantitative descriptors for individual accessions are presented in Table 2. The maximum co-efficient of variation was found in number of fruits per plant (57.99%) followed by 47.23% fruit length, 47.21% fruit weight, 43.71% fruit breadth, 16.67% plant breadth, 15.50% plant height, 15.10% number of primary branches and the lowest, 5.48% was found in days to first edible fruiting stage.

Table 1. Qualitative variation of different characters in brinjal

Name of descriptor	Descriptor state	Number of accession	Percent of accession
Cotyledon colour	Green	24	60
	Light violet	8	20
	Violet	8	20
Plant growth habit	Intermediate	19	48
	Upright	18	45
	Prostrate	3	7
Leaf blade lobing	Weak	24	60
	Intermediate	15	37
	Strong	1	3
Leaf blade tip angle	Acute	25	62
	Very acute	13	33
	Intermediate	2	5
No. of leaf prickles	Very few	16	40
	None	10	25
	Few	10	25
	Intermediate	2	5
	Many	2	5

Name of descriptor	Descriptor state	Number of accession	Percent of accession
No. of leaf hairs	Very few	35	87
	Few	5	13
Flower colour	Light violet	21	53
	Bluish violet	15	37
	Pale violet	4	10
Fruit curvature	Straight	26	64
	Curved	5	13
	Slightly curved	5	13
	Snake shaped	4	10
Fruit shape	About half way from base to tip	31	77
	About three quarter from base to tip	9	23
Fruit apex shape	Depressed	15	38
	Rounded	14	34
	Protruded	11	28
Fruit colour	Purple	22	55
	Green	18	45
Fruit colour distribution	Uniform	19	47
	Stripped	12	30
	Mottled	9	23

(iii) Genetic diversity in brinjal

The 40 accessions collected from 16 districts were arranged into 5 clusters on the basis of genetic diversity (Table 4). Number of accessions in each cluster ranged from 5 (Clusters-III) to 10 (Cluster-II and Cluster-IV). Cluster I contained 7 accessions of district Panchagarh, Thakurgoan, Sherpur, Chittagong, Bandarban and Rangamati. Cluster II was composed of the 10 accessions from Rangpur, Pabna, Rajshahi and Tangail. Cluster III formed with the 5 accessions of Rangpur, Pabna, Chittagong, Rangamati and Bandarban. Cluster IV was composed of the 10 accessions from Panchagarh, Dinajpur, Rangpur, Barisal, Jamalpur, Moulvibazar and Rangamati. Cluster V consisted of 8 accessions from Thakurgoan, Rajshahi, Chapai nawabganj, Pabna, Magura, Chittagong and Bandarban. 'BARI Bagun-1' (Uttara, BD-7781) was grouped in cluster V. Accessions collected from the same geographic origin (districts) were distributed into different clusters. In many cases, the accessions from different districts were grouped in the same cluster indicating their close affinity. This result suggested

Table 2. Yield and yield contributing descriptors in brinjal with range, mean, SD and CV%

Serial number	Accession number	Plant height (cm)	Plant breadth (cm)	No. of primary branches per plant	Leaf blade length (cm)	Leaf blade width (cm)	Days to 1st flowering	Days to 1st edible frutting stage	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	No. of fruits/ plant	100-seed wt (g)
1	2	15	16	17	18	19	20	21	22	23	24	25	26
1	BD-7314	65.8	89.0	5.3	16.3	11.1	98	122	15.0	4.9	33.75	7	0.37
2	BD-7315	73.0	89.5	7.0	16.9	11.6	103	126	28.8	2.8	67.65	12	0.33
3	BD-7319	77.7	87.3	7.5	16.8	12.4	104	122	13.0	4.0	95.20	7	0.45
4	BD-7320	63.3	69.0	6.3	16.2	10.3	109	132	23.6	2.4	40.00	18	0.3
5	BD-7321	75.5	90.8	7.2	15.2	11.1	104	127	17.2	4.7	13.00	8	0.31
6	BD-7323	71.0	81.2	6.3	16.6	10.7	106	122	18.8	4.0	70.15	6	0.37
7	BD-7324	75.5	81.5	7.5	16.6	9.5	109	132	16.0	6.0	43.83	9	0.32
8	BD-7327	55.0	66.7	4.9	19.8	11.9	100	122	9.5	8.1	18.13	4	0.39
9	BD-11726	53.7	64.3	6.7	18.7	10.3	95	119	11.1	10.6	32.40	5	0.45
10	BD-7328	66.2	76.2	6.0	16.6	10.2	100	123	8.5	2.6	27.00	6	0.29
11	BD-7332	55.2	82.4	6.2	13.9	9.0	102	125	13.9	2.9	42.64	9	0.39
12	BD-7333	59.2	79.7	5.5	19.5	10.9	93	116	11.6	4.0	53.88	6	0.32
13	BD-7335	72.0	75.0	7.0	23.4	13.0	109	137	28.5	3.6	72.00	9	0.43
14	BD-7781	73.8	106.1	7.7	14.5	9.6	93	120	13.9	6.2	28.97	13	0.37
15	BD-9766	74.0	79.6	6.3	15.4	10.7	86	107	27.6	6.6	41.92	6	0.38
16	BD-9838	71.0	108.3	8.0	16.2	12.3	97	123	15.0	5.0	42.83	7	0.32
17	BD-11727	83.4	108.3	7.9	16.4	10.8	93	121	14.3	5.3	61.26	17	0.35
18	BD-9952	60.9	94.6	8.3	14.4	9.8	105	125	9.4	7.9	24.51	11	0.37
19	BD-9953	57.3	76.7	8.3	14.5	9.7	100	125	11.0	10.2	35.95	6	0.44
20	BD-9954	88.1	119.7	9.5	20.1	13.0	109	137	18.9	8.0	49.60	6	0.42
21	BD-9955	76.6	104.3	7.8	11.7	8.1	88	117	5.5	5.1	63.01	30	0.41
22	BD-10151	71.3	81.3	8.2	12.7	8.7	105	130	19.4	3.6	52.64	21	0.34

Serial number	Accession number	Plant height (cm)	Plant breadth (cm)	No. of primary branches per plant	Leaf blade length (cm)	Leaf blade width (cm)	Days to 1st flowering	Days to 1st edible frutting stage	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	No. of fruits/ plant	100-seed wt (g)
23	BD-10154	89.4	98.9	9.8	14.1	9.8	102	127	30.7	2.9	56.53	22	0.37
24	BD-10156	67.4	85.2	7.8	14.9	9.8	108	134	19.1	3.7	52.25	19	0.38
25	BD-10157	65.5	66.5	7.7	15.2	10.7	110	124	20.0	3.8	42.55	12	0.4
26	BD-10158	66.1	76.4	6.9	14.8	9.0	99	128	31.2	3.4	16.90	10	0.42
27	BD-10312	51.7	69.7	8.0	13.0	8.1	87	108	8.4	8.2	21.80	8	0.48
28	BD-11728	96.2	102.0	8.0	21.0	13.3	98	121	21.4	2.6	22.22	7	0.34
29	BD-11729	67.0	98.0	6.5	18.4	11.0	96	119	5.1	3.2	33.82	5	0.36
30	BD-11730	84.0	118.3	8.3	20.0	12.9	115	131	12.5	3.5	66.57	7	0.19
31	BD-11731	80.1	105.2	7.8	18.2	12.3	105	131	11.5	2.6	26.38	10	0.33
32	BD-11732	86.3	112.0	8.7	17.8	11.4	110	135	12.5	3.5	28.19	7	0.31
33	BD-11733	80.0	93.6	8.3	16.4	11.4	110	139	9.4	4.6	82.80	9	0.27
34	BD-11734	65.2	88.9	7.3	15.1	9.2	96	122	11.2	7.4	20.63	6	0.37
35	BD-11735	69.1	87.1	7.4	15.5	10.5	99	119	8.1	7.9	18.73	6	0.39
36	BD-11736	50.8	65.4	7.2	15.8	9.4	100	122	13.8	5.8	22.26	6	0.31
37	BD-11737	58.1	78.2	5.0	18.6	12.3	107	125	8.8	8.2	19.93	3	0.35
38	BD-11738	65.2	85.4	7.0	12.7	7.8	104	127	5.0	4.5	62.11	9	0.26
39	BD-11739	69.1	92.1	8.3	16.2	9.9	102	125	6.5	4.1	44.40	14	0.28
40	BD-11740	64.5	91.0	7.0	16.7	11.8	101	124	16.0	3.2	66.00	4	0.44
Range		4.89 - 9.78	50.8 - 96.2	64.3 - 119.7	11.7 - 23.4	7.8 - 13.3	86 – 115	107 – 139	5.0 - 31.2	2.4 - 10.7	13 – 95	3 – 30	0.19 – 0.48
Mean		**7.3**	**69.9**	**88.1**	**16.4**	**10.6**	**101**	**125**	**15.0**	**5.0**	**0.43**	**9.65**	**0.36**
SD		1.1	10.8	14.7	2.4	1.4	6.77	6.84	7.1	2.2	0.20	5.59	0.06
CV (%)		15.1	15.5	16.7	14.8	13.5	6.68	5.48	47.2	43.7	47.21	57.99	16.79

that the accessions within a cluster might have some degree of ancestral relationship. Similar findings were obtained in previous study by Solaimana *et al.* (2015). The absence of relationship between genetic and geographic diversity suggests that forces other than geographic origin, such as exchange of breeding material, genetic drift, variation, natural and artificial selection are responsible for diversity (Murty and Arunachhalam 1966). The clustering pattern followed their respective geographic origin and variation between clusters might have resulted from the possible genetic drifts and selection. Hassan *et al.* (2015), Begum *et al.* (2017) and Solaimana *et al.* (2015) observed 3, 5 and 6 clusters, respectively.

Table 3. Number of brinjal accessions under different classes

Name of descriptor	Descriptor state	Number of accession	Percent of accession
No. of primary branches per plant	Intermediate (6-10)	37	92
	Weak (3-5)	3	8
Plant height (cm)	Tall (61-100)	32	80
	Intermediate (31-60 cm)	8	20
Plant breadth (cm)	Broad (61-90 cm)	24	60
	Very broad (91-150 cm)	16	40
Leaf blade Length (cm)	Intermediate (11-20 cm)	38	95
	Long (21-30 cm)	2	5
Leaf blade width (cm)	Wide (11-15 cm)	22	55
	Intermediate (5-10 cm)	18	45
Days to 1st flowering	Optimum (91-105 days)	26	65
	Late (>105 days)	11	27
	Early (<90 days)	3	8
Days to 1st edible fruiting stage	Optimum (121-130 days)	23	57
	Late (>130 days)	9	23
	Early (<121 days)	8	20
Fruit length (cm)	Long (11-20 cm)	22	54
	Intermediate (6-10 cm)	9	23
	Very long (>20 cm)	7	18
	Short (3-5 cm)	2	5
Fruit breadth (cm)	Intermediate (4-5 cm)	17	42
	Large (6-10 cm)	13	33
	Short (2-3 cm)	10	25
Fruit weight (g)	Medium (30-60 g)	16	40
	Low (<30 g)	14	35
	High (>60 g)	10	25
Number. of fruits/plant	Low (7-12)	18	44
	Very low (<7)	14	35
	Intermediate (13-18)	4	10
	High (19-24)	3	8
	Very high (>24)	1	3
100-seed weight (g)	Medium (0.31-0.40 g)	25	62
	High (>0.40 g)	9	23
	Low (<0.31 g)	6	15

Table 4. Distribution of accessions in five clusters of brinjal

Cluster	No. of accession	Accessions with their place of collection
Cluster-I	7	**Panchagarh-**BD-7319 and BD-11740; **Thakurgaon-**BD-7323; **Sherpur-**BD-7335; **Chittagong-**BD-7315; **Bandarban-**BD-11733; **Rangamati-**BD-11738
Cluster-II	10	**Rangpur**-BD-7327, BD-11726 and BD-10158; **Pabna**-BD-9953;**Rajshahi-**BD-10312, BD-11734, BD-11735, BD-11736 and BD-11737; **Tangail-**BD-7328
Cluster-III	5	**Rangpur-**BD-10154; **Chittagong**-BD-9954; **Rangamati-**BD-9955; **Bandarban**-BD-11730; **Pabna-**BD-11727
Cluster-IV	10	**Panchagarh-**BD-7320; **Dinajpur-**BD-7324; **Rangpur-**BD-10151, BD-10156 and BD-10157; **Barisal-**BD-7314; **Jamalpur-**BD-7332 and BD-7333; **Maulovibazar**-BD-9766; **Rangamati-**BD-11739
Cluster-V	8	**Thakurgaon-**BD-7321; **Rajshahi-**BD-7781; **Chapai Nawabganj-**BD-9952; **Magura**-BD-11728; **Chittagong-**BD-11729; **Bandarban-**BD-11731 and BD-11732; **Pabna-** BD-9838
Total	**40**	

Table 5. Intra-and Inter cluster distance of different accessions in brinjal

Name of character	Cluster-I	Cluster-II	Cluster-III	Cluster-IV	Cluster-V
Cluster-I	**0.98**				
Cluster-II	7.91	**0.94**			
Cluster-III	6.18	8.32	**1.36**		
Cluster-IV	4.16	4.01	5.23	**0.94**	
Cluster-V	8.12	4.34	5.20	4.31	**0.98**

Where, Diagonal and bold indicate intra cluster distance

The intra-cluster distance ranged from 0.94 (Clusters II and IV) to 1.36 (Cluster III) (Table 5). This showed cluster III was more heterogeneous than any other clusters. Maximum inter cluster distance was estimated between clusters II and III (8.32) followed by clusters I and V (8.13), suggesting wide diversity between the accessions of these groups. On the contrary, the minimum inter-cluster distance was observed between clusters II and IV (4.01) indicated close relationship (Table 5).

Table 6. Cluster mean of different characters in brinjal

Name of character	Cluster-I	Cluster-II	Cluster-III	Cluster-IV	Cluster-V
Plant height (cm)	71.91	59.32*	84.3**	66.63	76.35
Plant breadth (cm)	86.14	74.96*	109.9**	80.63	102.12
No. of primary branches per plant	7.16	6.77*	8.66**	6.91	7.78
Leaf blade Length (cm)	17.07**	16.24	16.46	15.69*	16.96
Leaf blade width (cm)	11.24	10.06*	10.92	10.06	11.35**
Days to 1st flowering	105**	98*	101	102	101
Days to 1st edible frutting stage	128**	121*	127	125	125
Fruit length (cm)	17.07	12.16*	16.38	17.27**	13.25
Fruit breadth (cm)	3.81*	7.24**	4.96	4.2	4.46
Fruit weight (g)	73.7**	23.37*	59.39	44.79	27.49
No. of fruits/plant	8	6*	16**	12	9
100-seed wt (g)	0.36	0.39**	0.35	0.35	0.34*

Within rows, * and ** indicate minimum and maximum cluster mean values, respectively.

The cluster means of different characters are presented in Table 6. Accessions belong to Cluster I had showed the highest leaf blade length, days to first flowering and days to edible fruiting stage, and fruit weight. This cluster showed the lowest fruit breadth. Accessions of Cluster II produced the lowest plant height, plant breadth, number of primary branches, leaf blade length and width, days to first flowering and first edible fruiting stage, fruit length and weight, and number of fruits per plant. This cluster showed the highest mean values for fruit breadth and 100-seed weight. Cluster III had the highest cluster mean values for plant height, plant breadth, number of primary branches per plant and number of fruits per plant. The highest fruit length and the lowest leaf blade length were obtained from cluster-IV. Cluster V exhibited the highest leaf blade width and the lowest of 100- seed weight. The cluster constellations obtained by D^2 analysis were confirmed by canonical analysis. Cluster constellations were also independently derived by using principal component analysis (PCA) to verify grouping obtained through D^2 statistic in a two-dimensional chart (PC1-PC2). In principal component analysis PC1, PC2 and PC3 were observed to contribute 60.68%, 34.06% and 3.42%, respectively of the total divergence. Accession scores obtained for the first two components were plotted on two main axis and then superimposed on the clustering found from D^2 analysis (Fig. 2), showed the similar results. The maximum distance was observed between accessions BD-7327 (Rangpur) from Cluster II with BD-9954 (Chittagong) from Cluster III, and BD-7319 (Panchagarh) from Cluster I with BD-11732 (Bandarban) from Cluster-V (Fig.2). The accessions were comparatively close to each other in cluster II and

IV, and those in cluster III were most heterogeneous through scatter diagram. The results obtained by principal component analysis were reconfirmed by D^2 analysis. Plant populations restricted to small geographic areas or subjected to identical environmental pressures help to evolve adaptive gene complexes. These gene complexes are conserved by genetic linkages or stringent natural or human selections. The clustering of accessions from different ecographic locations into one cluster could be attributed to the free exchange of breeding materials between regions (Solaimana *et al.* 2015). The magnitude of heterosis and potential for transgressive segregation largely depend on the degree of genetic diversity in the parental lines. The greater the distance between two clusters, the wider the scope of genetic diversity between their accessions. This suggested that selection of parents for hybridization should be done from two clusters having wider intercluster distances to get more variability among the segregants. But while considering genetic diversity among the parents to be included in a hybridization programme their yield potentiality should not be ignored.

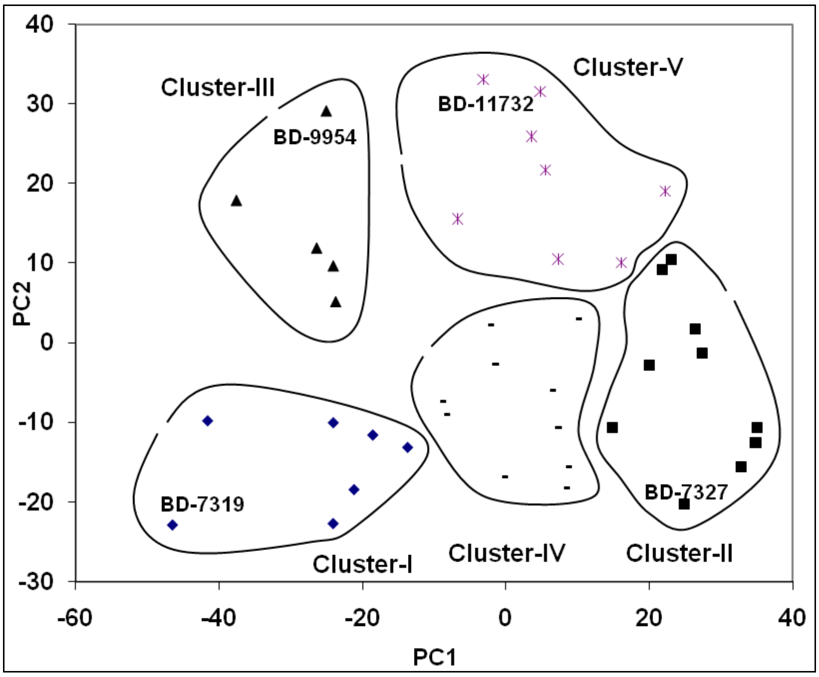

Fig. 2 Principal component analysis of the genetic diversity of 40 brinjal accessions with 5 clusters, where PC1 and PC2 principal component1 and principal conponent2, respectively.

On the basis of cluster analysis and different qualitative characters, the accessions could be selected, BD-7315, BD-7335, BD-9766, BD-10154 and BD-10158 as elongate fruit; BD-11726, BD-7327, BD-9953, BD-9954, BD-10312 and BD-11737 as broad fruit; BD-7319, BD-11733, BD-7335, BD-7323, BD-

7315, BD-11730 and BD-11740 as maximum fruit weight; BD-9955, BD-10154, BD-10151, BD-10156, BD-7320 and BD-11727 as maximum number of fruits.

Conclusion

Variations were found among the qualitative characters like plant growth habit, leaf blade lobing, leaf prickles, flower colour, fruit curvature, fruit shape, fruit apex shape, fruit colour, fruit colour distribution. A good range of variations were found among the 12 quantitative characters. The maximum coefficient of variations was found in number of fruits per plant (57.99%) and minimum in days to first edible fruiting stage (6.68%). The 40 accessions were grouped into five clusters. Genetic diversity of the accessions did not show clear relationship with their place of collection. The crosses should be made between the accessions in cluster II with accessions in cluster III, and accessions in cluster I with accessions in cluster V. The selected accessions could be used for varietal development of brinjal.

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GENETIC VARIATION AND HERITABILITY FOR FOLIAGE YIELD AND YIELD COMPONENT TRAITS IN EDIBLE *Amaranthus cruentus* [L.] GENOTYPES

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Abstract

The field experiment with nine *Amaranthus cruentus* genotype was conducted, to estimate the magnitude of genetic variability, heritability and genetic advance for leaf yield and contributing traits of amaranth genotypes during 2013 and 2014 cropping seasons. Field experiment was carried out in a randomized complete block design with three replications between 2013 and 2014 cropping season in Jalingo Taraba state. Data were collected on branches/plant, leaves/plant, leaf length, lead width, leaf fresh weight, leaf dry weight, marketable foliage yield, non- marketable foliage yield and plant height. Analysis of variance revealed highly significant mean squares (P< 0.01) among the genotypes tested for all the traits investigated. Thus indicating presence of high variability for foliage yield and yield traits. The PCV value was greater than GCV for all traits; however, GCV values were near to PCV values for the traits like leaf width, plant height branches/plant indicating high contribution of genotypic effect for phenotypic expression of such characters. High heritability coupled with high genetic advance per percent of mean reflect the presence of additive gene action in the expression of these traits, and improving of these traits could be done through simple selection.For multiple traits, AM 45 outperformed other genotypes for leaves/plant, fresh weight of leaves, plant height, and branches/plant.While AM 42 performed best for foliage yield (t/ha) and branches/plant.

Keywords: *Amaranth cruentus*, Genotypic and phenotypic coefficient of variation, genetic variation, heritability, and marketable foliage yield.

Introduction

Amaranth belongs to the family Amarantheaceae, which include 650 genera and 850 species which are widely distributed in the tropical and temperate regions of the world. The genus Amaranthus, is a native to different parts of North, Central, and South America. It is mostly monoecious inflorescences bearing both male and female flowers (Trucco and Tranel, 2011). *A. cruentus* [L.] is diploids with chromosome number 2n = 32, but occasionally it can be 34 (Chan and Sun, 1997). Amaranth is an important high value indigenous vegetable in sub Saharan Africa, particularly important crop for developing countries (Smith and

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Eyzaguirre 2007). It is characterized by a high protein content of 12.5%–18% with a well-balanced amino acid composition and high lysine and methionine contents (Pospišil *et al.,* 2006). One cup of amaranth leaves that are cooked, boiled, and drained contains 90 % vitamin C daily value requirement, 73 % vitamin A, 28 % calcium and 17 % iron (Smith and Eyzaguirre 2007). The vitamin composition of the plant is higher than those reported for *Aspilia africana*, *Bryophyllum pinnatum* (Lam.) Oken, *Vernonia amygdalina, Eucalyptus globulus* L. and *Ocimum gratissimum* L. (Alabi *et al*., 2005). Amaranths leaves and stems are used as food in Southeast Asia and Equatorial Africa and can compete with spinach leaves in terms of protein content (van Le *et al.,* 1998). The particularity of amino acid profile of *A. cruentus* leaves is its methionine and lysine levels, which are the limiting amino acids in most plant proteins (Fasuyi 2007). Amaranth exhibit C_4 photosynthetic pathway, great amount of genetic diversity and phenotypic plasticity. It is a quantitative short-day plant, which is an advantage in the subtropics, where the generative stage is delayed during summer. Amaranths performed best on fertile, well-drained alkaline soils (pH 6) with a loose structure. Vegetable amaranth is cultivated anytime provided water is not limiting. Its cultivation for leaf is profitable during dry season compared to rain fed conditions. Vegetable amaranths grow well at day temperatures above 25 ^{0}C and night temperatures not lower than 15 ^{0}C. Shade is disadvantageous except in cases of drought stress. The mineral uptake in*Amaranthus cruentus* is very high (Grubben, 2004).

In *Amaranthus cruentus* there is an urgent need for genetic improvement to enhance foliage leaf yield and quality characters. Improvement in foliage yield requires knowledge of the magnitude of variation in available germplasm, interdependence of quantitative traits on leaf yield, extent of environmental influences, heritability and genetic gain. Genetic variability is important for selection of parents with transgressive segregation (Patro and Ravisankar, 2004). Information on genetic variability and availability of commercial varieties of *Amaranthus cruentus* genotypes is limited. Therefore, there is a need to generate information on genetic variability, heritability, and genetic advance to estimate the progress of breeding program in future. Progress and gain from selection in any breeding programme depend upon the magnitude of useful variability present in the population and the degree to which the desired traits are heritable. Heritability estimate of a character is important for plant breeder, because it provides information on the extent to which a particular character can be transmitted from the parent to the progeny (Allard, 1960; Poehlman and Sleper, 1995; Syukur *et al.,* 2012). Similarly, genetic advance is important because it shows the degree of the gain obtained in a character from one cycle of selection. High genetic advance coupled with high heritability estimates offers the most suitable condition to decide the criteria of selection (Allard, 1960; Poehlman and

Sleper, 1995; Syukur *et al.,* 2012). Efficiency of selection in breeding programme relies upon association between traits. Correlation between leaf yield and its related traits could improve the efficiency of selection in amaranth breeding. Leaf yield is a complex quantitative character and controlled by several genes interacting with the environment. The extent of genetic variation and genotypes agronomic performance of *Amaranthus cruentus* remains largely rudimentary indicating untapped potential for research. Currently, there are few commercial varieties of *Amaranth cruentus* released into the cropping systems in Nigeria.

The objectives of this study are to evaluate the magnitude of variation for leaf yield and yield component traits under short cycle harvest, estimate genetic variation and heritability for leaf yield and yield component traits and determine association between leaf yield and yield component characters.

Materials and Methods

Location, Site characteristics and Germplasm

This research was conducted at the research farm, National Open University of Nigeria, Jalingo, Nigeria (Lat 8°47'S and Lon 11^{0} 09'E,altitude of masl) in May, 2013 and 2014. Jalingo is characterized by monomodal rainfall regime. The rainfall season starts in April/May, thereafter the cold and dry season (November to January). The hottest month is between February to March/April. The soil type is clay loam with pH between 6.0 and 6.5. Eight amaranth genotypes (AM 42, AM 38-2, AMTZ 01, AM 40, AM 50, Ex-Zimbabwe, AM 25, AM 45 and a popular local cultivar (AM local) received from the gene bank of The World Vegetable Center were used for field investigations.The entries are homogeneous for phenotypic traits.

Experimental design and Data collection

Field experiments were established in July, 2013 and 2014. Nine amaranth genotypes were grown in a randomized complete blocks design with three replications. Sunken beds were made at 1 m x 2 m, each bed was separated by alley of 1m. A total of 9 beds constituted a replicates. Each bed was treated with 4 Kg of matured farmyard manure. Prior to field establishment seeds were tested for viability. Thereafter 10 g of viable seeds was uniformly spread on each vegetable bed. The experiment was rain fed with occasional manual irrigation. Weeding was carried out manually and frequently to maintain a weed free plots. Harvesting was done by uprooting at 4 weeks after sowing. Amaranth plants in each net plot (1 m x 1 m) were used to determine leaf yield and yield contributing traits. Branches/plant, leaves/plant was estimated by counting branches or leaves on ten randomly picked amaranth plants. The leaf length and width were measured with a meter rule on five randomly picked leaves per plant. Plant height (cm) was measured with a meter rule on ten randomly picked plants per entry. Foliage yield was separated into marketable foliage yield and non-marketable yield. The non-marketable foliage yield comprised weak and yellowish green plants, and portion of the lower stem and roots. The marketable foliage yield (t/ha) and non-marketable yield (t/ha) were estimated from marketable foliage yield/plot and non-marketable foliage yield/plot measured on weigh balance (Kg). At harvest three plants were randomly picked per plot, thereafter all leaves/plant were excised, counted and weighed on electronic weigh balance to obtain the fresh weight of leaves. The fresh leaves were oven dried at 32^0C, until a constant weight was obtained. Dried leaves were weighed on sensitive electronic weight balance to obtain leaf dry weight.

Data analysis

Homogeneity of residual variances was tested prior to a combined analysis over years using Bartlet's test (Bartlett, 1937). The data collected were homogenous and showed normal distribution. The Genotype (G) and Year (Y) were considered to be fixed-effects, while replications was considered as random effect. The combined analysis of variance was performed using a mixed model on plot means combined across years for all traits using PROC - GLM procedure of Statistical Analysis System (SAS) software version 9.2 (SAS, 2008). Thereafter treatment means were tested with Duncan multiple range testing (DMRT) at 5% probability levels (SAS, 2008). Correlation coefficients between traits was computed using PROC CORR procedure of SAS (2008).

Estimates of variance components

The variability present in genotypes on *A. cruentus* was estimated by phenotypic and genotypic variance and coefficient of variation. The phenotypic and genotypic variance, genotypic and phenotypic coefficients of variation were estimated based on formula Syukur *et al.* (2012) as follow:

$\sigma^2G = [(MSG) – (MSE)]/r$

$\sigma^2P = [\sigma^2G + (\sigma^2E/r)]$,

Where: σ^2G = Genotypic variance; σ^2P = Phenotypic variance; σ^2E = environmental variance (error mean square from the analysis of variance); MSG = mean square of genotypes; MSE = error mean square; r = number of replications.

Genotypic coefficient of variation (GCV) was calculated as = $[(\sigma^2G)^{½}X] \times 100$;

While Phenotypic coefficient of variation (PCV) was computed as = $[(\sigma^2P)^{½}/X] \times 100$, Where: σ^2G = Genotypic variance; σ^2P = Phenotypic variance; is grand mean of a character.

Estimation of heritability in broad sense heritability (h^2) of the all traits were calculated according to the formula as described by Allard (1960) as follow:

$h^2_{bs} = [(\sigma^2G) / (\sigma^2P)] \times 100$

Where: h^2b = heritability in broad sense; σ^2G =Genotypic variance; σ^2P = Phenotypic variance.

Genetic advance (GA) was determined as described by Johnson *et al.* (1955): GA = K (σP) h^2, where: K = the selection differential (K = 2.06 at 5% selection intensity); σP = the phenotypic standard deviation of the character; h^2 = broad sense heritability. The genetic advance as percentage of the mean (GAM) was calculated as: GAM (%) = GM/X × 100, where: GAM = genetic advance as percentage of the mean, GA = genetic advance, and X = grand mean of a character.

Results and Discussion

The analysis of variance for foliage yield and component traits combined across years (Table 1) showed significant ($P \leq 0.05$) mean squares for branches/plant, marketable foliage yield (t/ha), non-marketable foliage yield (tha^{-1}), fresh weight of leaves/plant, leaf dry weight/plant, plant height, leaf length and leaf width. The year effect recorded statistically significant ($P \leq 0.05$) mean squares (leaves/plant, marketable foliage yield (tha^{-1}), non-marketable foliage yield (tha^{-1}), leaf fresh weight, leaf dry weight and plant height) and insignificant ($P \geq 0.05$) mean squares for branches/plant). The genotype by year interaction had significant ($P \leq 0.05$) mean squares for leaves/plant, marketable foliage yield (tha^{-1}), fresh weight of leaves/plant, dry weight of leaves/plant, plant height and leaf length, and insignificant mean squares for branches/plant, non-marketable leaf weight and leaf width.

The number of branches/plant ranged from 5 to 7, AM 25and AMTZ 01 outperformed other genotypes for this trait (Table 2). Leaves/plant was low (5) in AM 38-2, but high (8.60-8.68) in AM 25 andAM 45 respectively. Other genotypes recorded values intermediate between the two extremes. Over years marketable foliage yield (t/ha) ranged from 11.50 t/ha and 22.67 tha^{-1}(Table 2). AM 42, AMTZ 01 performed best (22.67 tha^{-1} and 22.37 t/ha) followed by AMLOC. High and consistent leaf yield over years indicated that these genotypes are promising for leaf yield and further testing in other locations. Non-marketable foliage yield was high in AM 42 followed by AMTZ 01 and AM 45. High proportion of non-marketable foliage yield may be associated overcrowding associated with broadcasting of seeds, competition for available nutrients and insect pests attack. Marketable foliage yield recorded in this study was low compared to those reported for vegetable amaranth accessions harvested by uprooting in East Africa (AVRDC, 2002, 2008; Oluoch *et al.* 2009). The weight of fresh leaves/plant was high (38.2 g) in AM 45, while AMTZ 01 recorded 36.33 g, and 36.1 g in AM 25. In contrast, entries with high estimates for fresh weight of leaves recorded low values for leaf dry weight. This suggests high proportion of water compared to dry matter. Best genotypes for leaf dry weight are AM 25, AM 38-2 and AM LOC. Plant height is short (10.33 cm) in AM 38-2, on the other hand AM 45 and AM 42 are tall (28 cm and 25 cm at 4 weeks, respectively). The leaves of AM 42 are long (9.00 cm), followed by AM 45 (8.37 cm) and AMLOC (7.70 cm)(Table 2). The leaves of Ex-Zimbabwe are narrow (1.55 cm).In contrast AM 42, AM 45 and AMTZ 01 had wider leaves (range from 6.16 cm to 6.83 cm). AM 42 recorded high leaf yield, and also exhibited highest mean performance for leaf length and width (Table 2). For multiple traits, AM 45 was best for leaves/plant, fresh weight of leaves, plant height. While AM 42 performed best for leaf yield (t/ha) and branches/plant (Table 2).

Variability played an important role in crop breeding program, it is prerequisite to understand variability in the population and partitioning into genotypic, phenotypic and environmental effects. Variability is also important for the selection of superior genotypes in crop improvement programs. Agronomic traits are quantitative in nature, and interact with environment under study, so partitioning the traits into genotypic, phenotypic, and environmental effects is essential to find out the additive or heritable portion of variability. The estimates of genetic components and heritability are presented in Table 3. For all leaf yield and yield components traits estimates of genotypic variance are low in magnitude compared to their corresponding phenotypic variance. Similarly the estimates of phenotypic coefficient of variation (referred hereafter as PCV) were in most cases greater than their respective genotypic coefficient of variation (referred hereafter as GCV) for all the traits indicating the impact of the environmental factors towards expression of traits. Similar results were also reported by Syukur and Rosidah (2014) in pepper. Moderate estimate of PCV was recorded for plant height, fresh weight of leaves, leaf length, leaf width and non-marketable foliage yield, and moderate GCV was recorded for leaf dry weight. This implies that improvement in this trait under selection may be achieved up to a reasonable extent. Low PCV (branches/plant, leaves/plant and leaf length) and GCV (branches/plant, marketable foliage yield, fresh weight of leaves, leaves/plant) for traits implies that chances of getting substantial gain under selection are likely to be less for these traits. Environmental coefficient of variation ranged between from 0.10 (leaf dry weight) and 0.21 (non-marketable leaf weight t/ha). High PCV (marketable foliage yield, non-marketable foliage yield and dry leaf weight and leaf width) indicates the magnitude of improvement in these traits through selection to enhance the potentiality of leaf yield. Similar result were also observed in *Amaranth tricolor* (Shukla and Singh, 2000). However, GCV was

Table 1. Mean squares for foliage yield and yield component traits in *Amaranthus cruentus* [L] harvested at 4 weeks after sowing during 2013 and 2014 seasons

Source of variation	Df	Br/Pl	Lvs/Pl	Nmkt FY(t/ha	Mkt FY (t ha^{-1})	Lv Fwt (g)	Lv Dwt (g)	Plt Ht	Lvl (cm)	Lvw (cm)
Genotypes	8	17.70**	90.74***	2.13***	21.17***	5460.17***	0.21	44.46*	0.11	0.15
Year	1	3.93	8.20***	2.87***	133.28***	246.65***	4.09**	173.54***	11.19***	15.04**
Replications	2	2.79	0.50	0.14	42.39**	36.35	0.02	14.35	0.82	0.81
Genotypes x Year	8	1.37	5.03***	0.82	118.42**	195.67***	2.04***	21.12*	2.91**	0.98
Error	34	1.65	0.93	0.07	6.37	16.02	0.13	9.54	0.55	0.52
CV (%)		20	13	21.73	14.61	13.39	19.35	15.78	10.84	17.42
Mean		6.35	7.55	1.27	17.27	29.87	1.88	19.57	6.89	4.16

***= Significant at 0.1% level of probability

**= Significant at 1% level of probability

*= Significant at 5% level of probability

Br/plt= Branches/plant, Lvs/pl = leaves/plant, Nmkt FY (t/ha) = non marketable foliage yield, Nmkt FY= Non marketable foliage yield, Lv Fwt = Leaf fresh weight, Lv Dwt = Leaf fresh weight, Pht= Plant height, Lvl= Leaf length, Lvw= Leaf width.

Table 2. Mean values for foliage and leaf quality traits in 9 genotypes of *Amaranthus cruentus* during 2013 and 2014 cropping seasons

Genotypes	Br/Pl	Lvs/Pl	Mkt LvY (t ha^{-1})	Nmkt LvY(t ha^{-1})	Lv Fwt (g)	Lv Dwt (g)	Plt Ht	Lvl (cm)	Lvw (cm)
AM 25	7.17a	8.60a	16.56b	13.17bc	36.1ab	2.65a	17.56de	6.00de	4.30b
AM 42	7.00a	8.00ab	22.30a	17.83a	23.5de	1.48d	25.67ab	9.00a	6.83a
AM TZ 01	7.03a	7.00bc	22.67a	17.83a	36.33ab	1.35d	19.17dc	7.50bc	4.33b
AM 45	7.00	8.68a	20.67a	17.67a	38.20a	2.10bc	28.0a	8.37ab	6.16a
AM 40	6.83a	8.16ab	14.83bc	13.50bc	23.50de	1.80cd	22.17bc	7.70bc	4.11b
AM local	5.83ab	7.67abc	21.00a	14.67ab	32.33bc	2.37ab	17.83de	6.83cd	3.00c
AM 50	5.83ab	6.67c	13.83bcd	14.17ab	28.17cd	1.73cd	20.67cd	4.83f	3.50bc
AM 38-2	5.50ab	5.00a	11.50d	10.00c	21.50e	2.60a	10.33e	6.33de	3.56bc
EX ZIM	5.00b	8.33a	12.17cd	11.17bc	30.16c	0.91e	14.83c	5.50ef	1.55d

Br/plt= Branches/plant, Lvs/pl = leaves/plant, Nmkt FY (t/ha) = non marketable foliage yield, Nmkt FY= Non marketable foliage yield, Lv Fwt = Leaf fresh weight, Lv Dwt = Leaf fresh weight, Pht= Plant height, Lvl= Leaf length, Lvw= Leaf width

Table 3. Estimates of Genotypic variation (σ^2G), phenotypic variation (σ^2P), Genotype by Year variation (σ^2GY) Genotypic coefficient of variation (GCV), Phenotypic coefficient of variation (PCV), Environment Coefficient of Variation (ECV), heritability in broad sense (H_2b), Genetic advance (GA), genetic advance as percentage of the mean (GAM) for 9 traits of *Amaranthus cruentus*

Genetic variation	Br/Pl	Lv/Pl	Mkt FY (t ha^{-1})	Nmkt FY (t ha^{-1})	Fr Lwt (g)	Lv Dwt (g)	Plt Ht	Lvl (cm)	Lvw (cm)
σ^2G	0.43	0.52	2.31	7.45	8.49	0.36	28.57	1.38	2.34
σ^2PH	0.74	3.52	62.51	33.94	109.0	1.38	40.72	2.93	2.92
σ^2GY	0.07	1.38	37.35	13.53	59.88	0.64	3.86	0.79	0.15
PCV	18.10	24.84	45.78	40.34	34.95	63.10	32.61	28.24	41.08
GCV	10.33	9.55	8.80	19.90	9.75	31.60	27.31	17.05	36.77
ECV	0.20	0.13	0.17	0.21	0.13	0.10	0.15	0.11	0.17
Hb	41	15	3.69	23	7	26	70	47	80
GA	1.03	0.60	0.60	0.81	2.72	0.63	9.18	1.65	1.65
GAM (%)	16.22	7.95	3.47	63.77	9.11	33.51	46.81	23.94	39.66
PCV - GCV	7.77	15.29	36.98	20.44	25.20	31.50	5.30	11.19	4.31

Br/plt= Branches/plant, Lvs/pl = leaves/plant, Nmkt FY = non marketable foliage yield, Nmkt FY= Non marketable foliage yield, Lv Fwt = Leaf fresh weight, Lv Dwt = Leaf fresh weight, Pht= Plant height, Lvl= Leaf length, Lvw= Leaf width.

not near to PCV for all traits except leaf width, plant height and branches/plant. This indicates a high contribution of environmental effects compared to genotypic effect for phenotypic expression of these traits. A large difference between GCV and PCV was observed for marketable foliage yield (t/ha) and leaf dry weight, this indicates a large contribution of environmental factors, in addition to genetic effects in the expression of these traits. Findings reported in this investigation are similar to previous reports by Sharma *et al.* (2010) in bell pepper. Preponderance of genetic variability among the tested genotypes showed that yield improvement through selection was possible in A*maranth cruentus*. The efficiency of selection depends on the magnitude of genetic variability and inherent heritability of the traits.

Singh (2001) had noted that heritability values greater than 80% were very high, values from 60–79% were moderately high, values from 40–59% were medium, and values less than 40% were low. Accordingly, heritability estimates was low for leaves/plant, marketable yield, non-marketable foliage yield, fresh weight of leaves and leaf dry weight (Table 3). High heritability estimates were recorded for leaf width (70%) and plant height (60%). Findings in this study are consistent with previous report of Sharma *et al.* (2010) in *Amaranth tricolor.*Phenotypic traits having very high heritability indicates relative small contribution of the environment factors to the phenotype, and selection for such characters could be fairly easy due to high additive effect. In addition, medium heritability estimates wererecorded for branches/plant and plant height. While leaves/plant, marketable foliage yield, non-marketable foliage yield, fresh weight of leaves and leaf dry weight had low heritability estimates. In contrast, Shukla *et al.* (2004) reported that high heritability for foliage yield, branches/plant and plant height in *Amaranthus tricolor* harvested by cutting fresh leaves at 3 weeks after planting, and at 15 days thereafter. In this investigation it was observed that some traits recorded moderate to high heritability, with low genetic advance. These traits may be governed by non-additive gene action, which limits the scope for phenotypic improvement through selection

Branches/plant recorded negative and significant correlation coefficient with leaf width (Table 4). This indicated that phenotypic improvement in the number of branches will not complement leaf width among the genotypes. The leaves/plant recorded positive and significant correlation coefficient with marketable foliage yield (t/ha), non-marketable foliage yield (t/ha) and leaf fresh weight (g). This implied interdependency among these traits as more leaves are produced per plant, a corresponding increase in marketable foliage yield is expected. Interdependency associated with non-marketable foliage yield can be reduced through uniform distribution of seeds, use of organic fertilizers and adoption of good agricultural practices designed for vegetables. The marketable foliage yield showed positive and significant correlation coefficient with non-marketable leaf yield, and positive though insignificant correlation coefficients with leaf length, leaf width and leaf dry weight. Further, weight of fresh leaves recorded positive and significant correlation coefficient with leaves/plant. These result suggest that selection and improvement of leaves/plant will enhance leaf fresh weight. Significantly negative correlation coefficient in the association between leaf dry weight and branches/plant showed that improvement in leaf dry weight will not enhance branches/plant. Considering high genotypic and phenotypic variances along with GCV and PCV values, high heritability coupled with GA five traits (branches/plant, plant height, leaf width and leaf length) could be selected.

Conclusion

The study showed considerable magnitude of variation for foliage yield and yield traits in *Amaranthus cruentus* genotypes. The magnitude of phenotypic and genotypic variation, phenotypic and genotypic coefficient of variation recorded implied the scope on which improvement can be achieved in this species. Leaf width, plant height and branches/plantare highly heritable. These traits could be used as good criteria for selection in the amaranth improvement because these traits had moderate genotypic coefficient of variation, high heritability and genetic advance as percent of the mean. AM 25, AM 42, AMTZ 01 and AM 45 performed best for individual and multiple traits and are recommended for evaluation in multiple environment.

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REACTION OF GRASSPEA GERMPLASM RESISTANT TO RUST AND POWDERY MILDEW DISEASES

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Keywords: Grasspea, germplasm, rust and powdery mildew.

Grasspea (*Lathyrus sativas L.*) is popular as fodder crop as well as highest protein containing pulse in Bangladesh. It has a high potential compared to other grain legumes both as food and fodder crops, due to their high nutritional value and aptitude to withstand drought and excessive soil moisture, salinity and low soil fertility (Hanbury *et al.*, 2000). It is also the hardiest crop among the pulses and can survive where extreme environmental conditions prevail (Palmer *et al.*, 1989). It improves the fertility status of soil through atmospheric nitrogen fixation and can fixes approximate 40-46 kg N/ha/yr (Brahmaprakash *et al.*, 2004). It occupies the first position in area and production, it contributes about one third of the total pulses in Bangladesh (Krishi Diary, 2017). Though grasspea can survive under different adverse conditions, disease like rust and powdery mildew can affect badly on yield in field.

In an agricultural setting, the pathogen can be controlled using chemical methods, genetic resistance, and careful farming methods. Among them resistance is the cheapest and environmentally safe method. So, the study was performed to search for resistant germplasm against rust and powdery mildew among the genotypes of grasspea having higher yield potential.

The experiment was conducted at Regional Pulses Research Station (RPRS), BARI, Madaripur during *rabi* season of 2013-14 under natural condition. Seventy five entries of grasspea including a check BARI Kheshari-3 were collected from Pulses Research Center, BARI, Ishwardi, Pabna were included in the trial. The experiment was laid out in Randomized Complete Block Design (RCBD) and the plot size was 8m x 3m per ten entries and each entry was in two rows with the spacing 40cm from row to row with two replications. Seeds were sown on 18 November 2013. All recommended fertilizers were applied as basal dose during final land preparation. Intercultural operations were done as per requirement. Powdery mildew of grasspea was recorded on a 0-5 scoring scale (Bhatia and Thakur, 1989). The scale described as 0= no disease incidence and 5= above 50% leaf area covered by powdery mildew disease. Rust of grasspea was graded on a 1-9 scoring scale as modified by Morall and McKenzie (1974). The scale described as 1= no pustules visible, 3= few scattered pustules, usually

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seen after careful searching, 5= pustules common on leaves and easily observed, but causing no apparent damage, 7= pustules very common and damaging but no pustules on petioles and stems, 9= pustules extensive on leaves, petioles and stems, causing death of leaves and other plant parts. The crop was harvested after maturity. Data on yield contributing characters were recorded from 10 randomly selected plants from each plot. Grain yield (kg/ha) were recorded from the two rows. Mean comparisons for treatment parameters were made by LSD at 5% level of significance.

The tested grasspea genotypes/variety showed substantial variation in disease reaction for both rust and powdery mildew. Rust score among the test entries/varieties ranged from 3-7. None of the genotypes could exhibit complete resistance or immune to rust. Among 75 lines, 27 were graded as resistant which bear the score 3, 32 including check variety BARI Kheshari-3 graded as moderately resistant which took the score 5 and rest 16 lines graded as susceptible which bear the score 7 (Table 1).

Table 1. Distribution of grasspea lines in various infection categories of rust at RPRS, Madaripur during 2013-14.

Infection category	Grade	No. of genotypes	Lines involved
Highly resistant	1	-	-
Resistant	3	27	BGP-3, BGP-5, BGP-7, BGP-11, BGP-46, BGP-48, BGP-53, BGP-58, BGP-64, BGP-66, BGP-80, BGP-95, BGP-101, BGP-108, BGP-121, BGP-128, BGP-159, BGP-189, BGP-190, BGP-198, BGP-199, BGP-202, BGP-204, BGP-205, BGP-206, BGP-230 and BGP-255
Moderately resistant	5	32	BGP-4, BGP-6, BGP-9, BGP-13, BGP-14, BGP-15, BGP-19, BGP-51, BGP-54, BGP-71, BGP-78, BGP-88, BGP-98, BGP-105, BGP-115, BGP-122, BGP-131, BGP-136, BGP-156, BGP-157, BGP-158, BGP-169, BGP-170, BGP-186, BGP-188, BGP-209, BGP-216, BGP-218, BGP-220, BGP-221, BGP-222 and BARI Kheshari-3
Susceptible	7	16	BGP-21, BGP-24, BGP-25, BGP-31, BGP-40, BGP-43, BGP-140, BGP-142, BGP-143, BGP-148, BGP-150, BGP-225, BGP-226, BGP-227, BGP-233 and BGP-244
Highly susceptible	9	-	-

Powdery mildew score among the test entries ranged from 0-5. Among 75 lines, 38 were graded as resistant which bear the score 0, 37 graded as susceptible which took the score 5 (Table 2).

Table 2. Distribution of grasspea lines in various infection categories of powdery mildew at RPRS, Madaripur during 2013-14.

Infection category	Grade	No. of genotypes	Lines involved
Resistant	0	38	BGP-3, BGP-4, BGP-5, BGP-6, BGP-7, BGP-9, BGP-11, BGP-13, BGP-14, BGP-15, BGP-19, BGP-21, BGP-24, BGP-25, BGP-46, BGP-64, BGP-80, BGP-105, BGP-108, BGP-115, BGP-121, BGP-122, BGP-128, BGP-131, BGP-136, BGP-140, BGP-142, BGP-143, BGP-148, BGP-150, BGP-156, BGP-157, BGP-158, BGP-159, BGP-169, BGP-230, BGP-255 and BARI Kheshari-3
Susceptible	5	37	BGP-31, BGP-40, BGP-43, BGP-48, BGP-51, BGP-53, BGP-54, BGP-58, BGP-66, BGP-71, BGP-78, BGP-88, BGP-95, BGP-98, BGP-101, BGP-170, BGP-186, BGP-188, BGP-189, BGP-190, BGP-198, BGP-199, BGP-202, BGP-204, BGP-205, BGP-206, BGP-209, BGP-216, BGP-218, BGP-220, BGP-221, BGP-222, BGP-225, BGP-226, BGP-227, BGP-233 and BGP-244

Results showed that there were significant differences among the entries of grasspea in yield and contributing characters (Table 3). Days to flowering of grasspea entries were varied from 66-92. The maximum days to flowering (92) observed in BGP-140 and minimum (66) in BGP-43. The ranges in days to maturity were varied from 112-130. The maximum days to harvest (130) were recorded in BGP-140 and minimum (112) was in BGP-43, BGP-218. The plant height ranged from 37.80-99.50 cm. The highest plant height was recorded in BGP-128 (99.50 cm) which was significantly different over other germplasm and lowest in BGP-15 (37.80 cm). Number of branches/plant was varied from 2.70-5.00. The maximum number of branches/plant (5.00) was found in BGP-157 and minimum (2.70) in BGP-226. The number of pods/plant varied from 6.70 to 53.70. The maximum number/pods per plant (53.70) obtained from BGP-64 followed by (48.50) in BGP-108 and minimum (6.70) in BGP-227. The number of seeds/pod varied from 1.70 to 5.20. The maximum number of seeds/pod (5.20) obtained from BGP-115 and minimum (1.70) in BGP-13. 100 seeds weight varied from 5.00 to 16.00 g. The maximum 100 seeds weight (16 g) obtained from BGP-66 and minimum (5.00 g) from BGP-140, BGP-202, BGP-204, BGP-209, BGP-218 and BGP-226. The highest yield (1560 kg/ha) obtain from BGP-108 and lowest (120 kg/ha) from BGP-15. Among the genotypes, 8 lines viz. BGP-46 (1250 kg/ha), BGP-64 (1530 kg/ha), BGP-80 (1220 kg/ha), BGP-108 (1560 kg/ha), BGP-121(1130), BGP-128(1430), BGP-230 (1310 kg/ha) and BGP-255 (1320 kg/ha) yielded better than the check BARI Kheshari-3 (1020 kg/ha). All these eight lines showed resistant reaction to rust and powdery mildew.

Table 3. Yield and yield contributing characters of grasspea genotypes at Madaripur during Rabi season of 2013-14.

Entries	Days to flower	Days to harvest	Plant height (cm)	No. of branch / plant	No. of pods/ plant	No. of seed / pod	100 seeds wt (g)	Rust score (1-9 scale)	Powdery Mildew score (0-5 scale)	Yield (kg/ha)
BGP-3	79	123	59.70	3.10	22.00	2.50	6.50	3.00	0.00	370
BGP-4	88	126	48.30	4.30	13.90	3.10	11.00	5.00	0.00	270
BGP-5	78	121	59.00	3.50	17.60	4.10	6.50	3.00	0.00	130
BGP-6	69	119	58.10	3.90	12.90	3.30	6.00	5.00	0.00	631
BGP-7	75	126	85.10	3.30	40.70	3.00	7.00	3.00	0.00	1020
BGP-9	70	122	57.00	3.80	10.60	3.80	7.50	5.00	0.00	370
BGP-11	77	118	54.50	3.50	24.50	4.10	11.50	3.00	0.00	950
BGP-13	75	126	75.20	3.70	21.60	1.70	9.00	5.00	0.00	830
BGP-14	78	126	68.00	4.60	15.70	3.30	8.50	5.00	0.00	840
BGP-15	86	126	37.80	3.80	12.10	1.80	15.50	5.00	0.00	120
BGP-19	85	121	60.30	3.50	25.70	4.70	6.00	5.00	0.00	820
BGP-21	83	122	59.20	3.90	36.50	3.30	6.50	7.00	0.00	300
BGP-24	83	124	56.80	4.20	13.90	3.20	7.50	7.00	0.00	200
BGP-25	74	121	51.00	4.00	24.25	3.70	6.00	7.00	0.00	450
BGP-31	71	121	50.50	3.10	37.70	2.50	7.00	7.00	5.00	720
BGP-40	80	126	89.40	4.90	20.10	2.40	14.00	7.00	5.00	940
BGP-43	66	112	40.80	3.60	10.10	3.40	5.50	7.00	5.00	500
BGP-46	68	119	69.90	3.70	32.40	2.60	6.50	3.00	0.00	1250
BGP-48	81	126	60.20	3.30	32.80	2.70	8.00	3.00	5.00	340
BGP-51	86	122	56.40	3.20	23.20	3.80	6.00	5.00	5.00	210

Entries	Days to flower	Days to harvest	Plant height (cm)	No. of branch / plant	No. of pods/ plant	No. of seed / pod	100 seeds wt (g)	Rust score (1-9 scale)	Powdery Mildew score (0-5 scale)	Yield (kg/ha)
BGP-53	75	122	79.70	4.30	26.10	2.50	8.00	3.00	5.00	780
BGP-54	70	116	53.50	3.50	35.20	3.30	6.50	5.00	5.00	300
BGP-58	77	126	73.60	4.20	22.30	2.50	8.00	3.00	5.00	63l
BGP-64	72	121	67.40	3.80	53.70	3.20	8.50	3.00	0.00	1530
BGP-66	86	126	73.75	4.10	34.80	3.30	16.00	3.00	5.00	1010
BGP-71	81	124	56.65	3.70	39.70	4.00	7.00	5.00	5.00	730
BGP-78	80	126	86.10	3.90	37.30	3.10	8.00	5.00	5.00	930
BGP-80	80	120	66.35	3.05	32.57	3.00	12.50	3.00	0.00	1220
BGP-88	79	126	78.30	3.40	24.40	2.10	7.50	5.00	5.00	950
BGP-95	77	123	49.20	3.00	15.80	3.00	8.50	3.00	5.00	420
BGP-98	75	122	65.80	4.60	24.10	3.40	6.00	5.00	5.00	730
BGP-101	80	119	57.00	3.90	26.40	3.90	5.50	3.00	5.00	870
BGP-105	74	122	62.60	3.80	20.60	2.60	8.50	5.00	0.00	820
BGP-108	72	126	93.30	3.90	48.50	2.60	8.50	3.00	0.00	1560
BGP-115	86	119	57.50	3.40	21.80	5.20	6.50	5.00	0.00	530
BGP-121	80	126	90.10	3.60	35.80	2.80	8.00	3.00	0.00	1130
BGP-122	79	122	66.40	3.30	29.90	3.20	6.50	5.00	0.00	570
BGP-128	80	126	99.50	2.90	30.30	1.90	7.00	3.00	1.67	1430
BGP-131	84	122	66.40	3.50	10.20	3.40	5.50h	5.00	0.00	280
BGP-136	75	119	40.25	3.05	29.20	3.00	6.00	5.00	0.00	1060
BGP-140	92	130	47.70	3.50	11.80	2.80	5.00	7.00	0.00	370
BGP-142	79	119	58.25	3.60	30.90	3.80	7.00	7.00	0.00	300

Entries	Days to flower	Days to harvest	Plant height (cm)	No. of branch / plant	No. of pods/ plant	No. of seed / pod	100 seeds wt (g)	Rust score (1-9 scale)	Powdery Mildew score (0-5 scale)	Yield (kg/ha)
BGP-143	88	121	59.90	3.90	35.10	4.30	6.00	7.00	0.00	220
BGP-148	82	123	61.70	3.90	24.90	3.90	7.50	7.00	0.00	631
BGP-150	74	126	72.40	3.20	32.20	2.70	7.50	7.00	0.00	980
BGP-156	69	124	67.20	3.50	11.30	2.20	6.50	5.00	1.67	920
BGP-157	85	122	65.70	5.00	18.10	4.20	6.00	5.00	0.00	450
BGP-158	80	123	53.40	3.00	9.10	2.30	6.00	5.00	0.00	150
BGP-159	81	124	52.25	4.90	19.10	3.20	7.50	3.67	1.67	170
BGP-169	77	122	59.20	3.50	25.30	4.30	7.50	5.00	0.00	520
BGP-170	80	119	52.80	3.90	19.60	3.70	5.50	5.00	5.00	570
BGP-186	77	121	54.70	3.70	32.30	4.10	6.50	5.00	5.00	1000
BGP-188	74	126	65.90	3.20	35.10	2.40	9.00	5.00	5.00	1000
BGP-189	89	122	49.60	3.50	8.80	4.00	6.00	3.00	5.00	150
BGP-190	78	126	63.20	3.70	38.30	1.90	7.00	3.00	5.00	651
BGP-198	75	126	61.40	3.70	16.80	2.20	7.50	3.00	5.00	450
BGP-199	74	121	61.80	4.00	20.20	2.90	6.50	3.00	5.00	970
BGP-202	69	116	48.40	3.20	18.10	3.90	5.00	3.00	5.00	500
BGP-204	89	121	59.80	4.20	17.20	3.80	5.00	3.00	5.00	440
BGP-205	78	119	61.10	3.70	16.50	3.50	7.00	3.00	5.00	780
BGP-206	84	123	85.10	4.10	19.10	3.80	7.50	3.00	5.00	580
BGP-209	80	122	58.00	3.90	25.90	4.10	5.00	5.00	5.00	700
BGP-216	76	126	95.80	3.20	21.40	2.20	8.00	5.00	5.00	950
BGP-218	69	112	59.50	3.70	26.80	3.50	5.00	5.00	5.00	380

Entries	Days to flower	Days to harvest	Plant height (cm)	No. of branch / plant	No. of pods/ plant	No. of seed / pod	100 seeds wt (g)	Rust score (1-9 scale)	Powdery Mildew score (0-5 scale)	Yield (kg/ha)
BGP-220	75	122	65.60	3.90	28.00	2.80	7.50	5.00	5.00	670
BGP-221	68	122	69.00	3.60	23.50	3.30	7.00	5.00	5.00	880
BGP-222	81	126	80.50	3.20	28.70	2.00	9.00	5.00	5.00	730
BGP-225	78	117	39.10	3.10	10.80	4.10	5.50	7.00	5.00	160
BGP-226	82	121	43.50	2.70	15.40	4.10	5.00	7.00	5.00	700
BGP-227	91	124	54.65	3.95	6.70	3.10	5.50	7.00	5.00	120
BGP-230	83	119	81.95	3.00	37.20	2.10	6.00	3.00	0.00	1310
BGP-233	85	116	73.00	3.70	26.60	4.80	6.00	7.00	5.00	890
BGP-244	79	121	54.50	3.50	20.90	3.60	7.00	7.00	5.00	660
BGP-255	86	118	72.00	3.68	38.55	3.05	5.50	3.00	0.00	1310
BARI Kheshari-3	78	117	39.10	3.10	34.80	4.10	5.50	5.00	0.00	1020
CV (%)	6.17	1.76	12.78	12.71	9.71	6.27	7.66	2.69	0.21	8.86
LSD (0.05)	9.65	4.27	16.14	0.93	19.69	1.04	1.70	20.14	0.92	209.4

With the findings of the study it could be concluded that under field condition the grasspea lines BGP-46, BGP-64, BGP-80, BGP-108, BGP-121, BGP-128, BGP-230 and BGP-255 showed resistant reaction in relating to rust and powdery mildew and produced better yields than the check BARI Kheshari-3, where BGP-108 was the best.

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