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C O N T E N T S

Short Communication

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INFLUENCE OF PACLOBUTRAZOL ON GROWTH, YIELD AND QUALITY OF MANGO

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Abstract

A study on the effect of paclobutrazol on vegetative growth, harvest time, yield and quality of mango cv. BARI Mango-3 (Amrapali) was conducted at the Germplasm Centre, Department of Horticulture, Bangladesh Agricultural University, Mymensingh. Paclobutrazol @ 7500 ppm, 10000 ppm and control (water application) along with two application times; 15 July and 15 October were used with three replications following RCBD design. Paclobutrazol soil drenched @ 7500 ppm or 10000 ppm on 15 July distinctly advanced panicle emergence and fruit harvest by 23 and 22 days, respectively. Application of paclobutrazol @ 7500 ppm on 15 July produced the highest number of fruits (185) as well as yield (55.05 kg) per plant and the biggest fruit (303.67 g). Paclobutrazol @ 7500 ppm applied on 15 July or 15 October also resulted in higher edible portion, lower stone pulp ratio, longer shelf life, higher TSS, increased vitamin C, lower titratable acidity, higher dry matter, reducing, non-reducing and total sugar contents.

Keywords: Paclobutrazol, panicle emergence, fruit retention, edible portion, yield and quality.

Introduction

Mango (*Mangifera indica* L.), the king of fruits, predominantly grows in a short harvest period from May to June in Bangladesh. Irregular flowering, low fruit set as well as retention leading to low yield and fruits of poor quality are also the prevalent problems in mango production. The availability of fresh fruits after the normal fruiting season for a longer period, in addition to increasing yield and quality can be extended by using paclobutrazol. Soil application of paclobutrazol induces precocious flowering in young trees and promotes early flowering in bearing trees (Kulkarni, 1988). Inflorescence becomes visible within 2.5 to 4 months after the application of paclobutrazol depending on cultivar (Junthasri *et al.*, 2000). PP333 (paclobutrazol) enhances the flower and fruit production in mango (Anbu *et al.*, 2002). Improvement of fruit set and fruit retention in mango cv. Gulab Khas as well as the highest yield had been noticed under soil application of paclobutrazol (Singh and Singh, 2006). Paclobutrazol exhibits the pronounced effect on increasing the parameters like ascorbic acid, total sugar,

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reducing sugar and TSS, except for acidity in fruits of Alphonso mangoes at Coimbatore, India (Vijayalakshmi and Srinivasan, 2000). Mango trees treated with paclobutrazol had higher results for number of panicles produced, yield as well as quality of fruit compared to control (Yeshitela *et al.*, 2004). Information regarding regulation of flowering and harvesting time, increasing yield and quality of mango using paclobutrazol is little or nil in Bangladesh. In order to extend the availability period as well as increasing yield and quality by adopting soil drench application of paclobutrazol in mango cv. BARI Aam-3 (Amrapali), the present study was undertaken.

Materials and Methods

The experiment was conducted at the Germplasm Centre, Department of Horticulture, Bangladesh Agricultural University, Mymensingh which is located at 24^0 $26^/$ latitude and 90^0 $15^/$ longitude with an altitude of 8.3 m above the sea level. Investigations related to bio-chemical analysis were carried out in the Department of Biochemistry of Bangladesh Agricultural University, Mymensingh. Ten years old BARI Aam-3 (Amrapali) plants with a plant spacing of 5 x 5 m were included in the study. The factorial experiment was laid out in a Randomized Complete Block Design with three replications. Paclobutrazol (2*RS*,3*RS*)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl) pentan-3-ol @ 7500 and 10000 ppm and control (water application) and two times of application (15 July and 15 October) were included in the study. By dissolving 30 and 40 ml of 25 % paclobutrazol (Syngenta Chem. Co. Ltd., India) into one litre of fresh water each, the solutions of 7500 and 10000 ppm were prepared, respectively. Paclobutrazol solutions, each of 1 litre were soil drenched according to Burondkar & Gunjate (1993), where 10 small holes (10–15 cm depth) were prepared in the soil around the collar region of the plants just inside the fertilizer ring. The prepared solutions of paclobutrazol as per treatment uniformly drenched into the holes and the soil was reworked after application of paclobutrazol. Only water (1 litre/plant) was applied in the control plants. The data of the following parameters were recorded: length of terminal shoot, number of leaves per terminal shoot, leaf area, length of panicle, number of secondary branches per panicle, date of first panicle emergence, total number of panicles, fruit set per panicle, number of fruits retained per panicle at 10 days interval starting from pea stage to harvest, date of harvest, number of fruits per plant, fruit weight, yield, edible portion, stone pulp ratio, peel pulp ratio, shelf-life, TSS, titratable acidity, vitamin C, dry matter, reducing sugar, non reducing sugar and total sugar content. The length and number of leaves of ten randomly selected terminal shoots at flowering stage were measured and the average was worked out. Leaf area was measured for all the 50 leaves taking 5 from each of ten above selected shoots by a leaf area meter and expressed as square centimeter. The length and number of secondary branches per panicle of 10 randomly tagged panicles covering the whole tree was recorded and the average was worked out.

Ten panicles were randomly selected from each treatment. The initial number of fruits of each panicle and the fruits retained per panicle at 10 day intervals starting from pea stage up to harvest were recorded and the average was worked out. After harvest, ten randomly selected fruits were allowed to ripen at room temperature and fruit quality was determined using 10 fruits per tree. Total Soluble Solid (TSS) of 10 fully ripened fruits for each treatment was estimated by a hand refractometer and the average was worked out. The titratable acidity (Ranganna, 1979), vitamin C (Plummer, 1971), reducing sugar (Miller, 1972) and total sugar content (Jayaraman, 1981) in mango pulp were determined. Data on different parameters of the experiment were tabulated and analyzed and the treatment means were separated by Least Significant Difference (LSD) test at 5 % level of significance.

Results and Discussion

1. Combined effect on leaf, shoot and panicle characters of mango

Date of first panicle emergence in different treatment combinations of paclobutrazol and time of application ranged from 09.12.06 to 01.01.07. Paclobutrazol applied either @ 7500 ppm or 10000 ppm on 15 July exhibited earlier panicle emergence compared to the delayed emergence in control. Regardless of concentration, paclobutrazol had earlier panicle emergence. Combined effect of paclobutrazol and time of application exhibited significant effect on terminal shoot length, number of leaves per terminal shoot, leaf area, panicle length, panicle breadth, number of secondary branches per panicle and number of panicles per plant (Table 1). Control plants had the longest terminal shoot (21.00 cm) treated on 15 October as against the shortest shoot (6.43 cm) from the plants treated with paclobutrazol @ 10000 ppm on 15 July. Control plants also exhibited maximum number of leaves (12.30) and leaf area (65.58 cm^2) compared to minimum leaves per terminal shoot (9.10) and leaf area (44.51 cm^2) in 10000 ppm paclobutrazol applied on 15 July. Paclobutrazol @ 7500 ppm on 15 July application resulted in maximum panicle length (28.41 cm) and panicle breadth (26.92 cm) and the control exhibited minimum panicle length (22.63 cm) and breadth (20.92 cm). Maximum secondary branches per panicle was obtained from the treatment combination of paclobutrazol @ 7500 ppm and 15 July application (36.30) followed by the combined effect of paclobutrazol @ 7500 ppm and 15 October application (34.30), whereas the lowest value (26.25) was recorded in control. Maximum number of panicles per plant was obtained from the treatment combination of paclobutrazol @ 7500 ppm and 15 July (412.00), while it was noticed minimum in control (232.33). Regardless of application time and concentration, paclobutrazol suppressed vegetative growth compared to control. Paclobutrazol can enhance the total phenolic content of terminal buds that alter the phloem to xylem ratio of the stem, which is important in restricting the vegetative growth and enhancing flowering by altering assimilate partitioning and patterns of nutrient supply for new growth (Kurian

Table 1. Combined effect of paclobutrazol and time of application on leaf, shoot and panicle characters

Paclobutrazol Concentration	Time of application	Date of first appearance of panicle	Length of terminal shoot (cm)	No. of leaves per terminal shoot	Leaf area (cm^2)	Length of panicle (cm)	Breadth of panicle (cm)	Number of secondary branch / panicle	Number of panicles / plant
Paclobutrazol at 7500 ppm	15 July	9.12.06	7.04	9.43	47.62	28.41	26.92	36.30	412.00
	15 October	12.12.06	8.10	9.77	52.20	26.62	25.60	34.30	326.33
Paclobutrazol at 10000 ppm	15 July	9.12.06	6.43	9.10	44.51	24.33	24.62	32.27	400.33
	15 October	12.12.06	7.15	9.30	49.79	23.25	24.20	29.80	296.67
Control (water application)	15 July	01.01.07	19.30	11.83	65.58	22.63	20.92	26.25	232.33
	15 October	01.01.07	21.00	12.30	65.16	22.90	21.67	26.78	242.66
CV (%)		-	7.68	6.88	5.49	5.06	3.50	7.11	6.20
LSD (0.05)		-	1.61	1.29	5.40	2.27	1.53	4.01	35.91

and Iyer, 1992). Soil drench applications of Cultar (Paclobutrazol) to mango cv. Dashehari at Ludhiana prior to flower bud differentiation during the first week of October affected the vegetative growth (Zora *et al*., 2000). The superior performances in terms of higher panicle length, panicle breadth and number of secondary branches per panicle in plants soil drenched with 7500 ppm paclobutrazol on 15 July might be due to the optimum concentration and time of application of paclobutrazol. It is also probable that the application of paclobutrazol caused an early reduction of endogenous gibberellins levels within the shoots as also observed by Anon. (1984), causing them to reach maturity earlier than those of untreated trees. The total activity of auxin-like substances increased the higher starch reserve, total carbohydrates and higher C: N ratio in the shoots favoured flower bud initiation in mango. High level of auxins are necessary for flower bud differentiation in mango and this manipulation by sprays of synthetic substances at appropriate intervals may be helpful to induce flowering (Jogdande and Choudhari, 2001). In mango, it was found that PP333 exhibited auxin like activity and influenced the auxin synthesis. Regular, profuse and early bearing was also reported to be found due to paclobutrazol application in mango cv. Banganapalli grown in India (Singh and Ranganath, 2006). Paclobutrazol in general produced higher number of inflorescences per plant compared to control. Burondkar *et al.* (1997) also noted profuse flowering in paclobutrazol treated trees, when applied once during the month of July than untreated ones. A significant positive correlation between shoot total non-structural carbohydrates (TNC) and number of flowers developed was observed by Phavaphutanon *et al.* (2000). Yeshitela *et al.* (2004) reported the increased number of panicles for paclobutrazol treated plants is due to lower expenditure of tree reserves to the vegetative growth parameters and consequently no assimilates limitations, compared with an excessive vegetative growth in the control trees. The application of paclobutrazol to soil antagonized gibberellin production in new shoots and induced flowering and fruiting (Ram, 1999).

2. Combined effect on fruit set as well as fruit retention

Among the treatment combinations, paclobutrazol applying @ 7500 ppm on 15 July manifested maximum fruit set per panicle (17.73), followed by paclobutrazol @ 7500 ppm on 15 October (16.60) and 10000 ppm and 15 July application (16.40) (Table 2). The control plants exhibited minimum fruit set (5.73). From 13 March 2007 to harvest, plants treated with paclobutrazol @ 7500 ppm on 15 July demonstrated maximum number of fruits per panicle and it was recorded 2.00 at harvest, which was followed by the combined effect of 10000 ppm paclobutrazol and 15 July (1.70). The control plants always recorded the least number of fruits per panicle and it was noted 0.60 at harvest. Trees Paclobutrazol treated trees had higher food reserves enhanced the highest fruit set compared to the lowest fruit set in the untreated tree with low reserves because of excessive vegetative growth (Yeshitela *et al.*, 2004) corroborate the present result. Zora *et al*. (2000) revealed that cultar was the best treatment to promote flowering as well as fruit set in mango cv. Dashehari at Ludhiana, when applied in October.

Table 2. Combined effects of paclobutrazol and time of application on fruit set and fruit retention per panicle

Paclobutrazol Concentration	Time of application	Fruit set per panicle	Number of fruits retained per panicle at			
			13.03.07	23.03.07	02.04.07	12.04.07
Paclobutrazol at 7500 ppm (P_1)	15 July	17.73	6.03	4.40	2.93	2.70
	15 October	16.60	5.10	3.80	2.33	1.82
Paclobutrazol at 10000 ppm (P_2)	15 July	16.40	4.80	3.70	2.83	2.30
	15 October	13.65	4.00	3.05	2.10	1.30
Control (water application) (P_3)	15 July	5.73	2.79	2.80	1.93	1.25
	15 October	6.63	1.80	2.83	2.03	1.27
CV (%)		5.57	8.86	11.16	11.04	5.80
LSD (0.05)		1.30	0.66	0.69	0.27	0.19

Table 2 contd.

Paclobutrazol concentration	Time of application	Number of fruits retained per panicle at					
		22.04.07	02.05.07	12.05.07	22.05.07	01.06.07	Harvest
Paclobutrazol at 7500 ppm (P_1)	15 July	2.30	2.10	2.00	2.00	2.00	2.00
	15 October	1.73	1.47	1.47	1.47	1.44	1.44
Paclobutrazol at 10000 ppm (P_2)	15 July	2.10	2.00	1.80	1.77	1.73	1.70
	15 October	1.23	1.03	1.00	1.00	1.00	1.00
Control (water application) (P_3)	15 July	1.17	0.77	0.70	0.67	0.67	0.60
	15 October	1.20	0.80	0.70	0.67	0.67	0.67
CV (%)		9.39	9.81	7.84	8.70	7.39	7.78
LSD (0.05)		0.27	0.24	0.18	0.20	0.17	0.17

3. Combined effect on date of harvest, number of fruits, fruit characters, yield and shelf life

Paclobutrazol in general exhibited earlier harvest than that of the control. Induction of early flowering may also advance fruit maturity (Burondkar & Gunjate 1993). Spraying of paclobutrazol in late August/early September in the southwestern part of Hainan province, China promoted flowering and ripening date (Xie *et al*., 1999). The advancement of harvesting time in case of paclobutrazol application in mango cv. Banganapalli has been reported in India (Singh and Ranganath, 2006). The combined effect of paclobutrazol and time of application was found significant in respect of number of fruits per plant, fruit weight, fruit length, fruit breadth, fruit thickness, stone pulp ratio, yield and shelf-life but edible portion and peel pulp ratio did not exhibit significant variation (Table 3 and Fig. 1). The number of fruits per plant was noticed to be the highest (185.33) in the treatment combination of 7500 ppm paclobutrazol and 15 July application and the second highest number of fruits was manifested from

10000 ppm paclobutrazol when applied on 15 July (157.12), whereas the control produced the lowest fruits (66.99). Paclobutrazol when soil drenched @ 7500 ppm on 15 July resulted in the highest fruit weight (303.67 g), which was statistically identical to that of the combination of 7500 ppm and 15 October application (293.33 g), as compared to the lowest fruit weight (177.00 g) in the control. The paclobutrazol treated plants @ 7500 ppm on 15 July resulted in the highest fruit length (11.10 cm) while the control plants had the least fruit length (8.89 cm). The highest fruit breadth (7.41 cm) was recorded from the treatment combination of 7500 ppm paclobutrazol and 15 July application as against minimum value with 6.37 cm in control. Fruit thickness was recorded the highest (6.84 cm) in the combination of paclobutrazol @ 7500 ppm and 15 July application as against the lowest thickness (5.85 cm) in control. The plants soil drenched with paclobutrazol @ 7500 ppm combined with 15 July or 15 October application registered the lowest and same stone pulp ratio of 0.22 as compared to the highest ratio (0.29) in control. The increased fruit weight in paclobutrazol treated plants might be due to the increased rate of photosynthesis and an increase in chlorophyll content. Quinlan (1981) opined that paclobutrazol increased the water use efficiency in photosynthesis of leaves by increasing the rate of photosynthesis for a given level of leaf stomatal conductance or transpiration. Paclobutrazol in general caused an increase in fruit number as well as yield per plant compared to control. A significantly higher fruit set and fruit retention in the paclobutrazol treated plants had a favourable impact on culminating higher final fruit number and yield per plant. Paclobutrazol has been reported to exert influence on partitioning the photosynthates to the sites of flowering and fruit production consequent to the reduction of vegetative growth. In this context, Kurian *et al.* (2001) reported that paclobutrazol appeared to favourably alter the source sink relationship of mango to support fruit growth with a reduction in vegetative growth.

Table 3. Combined effect of paclobutrazol and time of application on number of fruits and fruit characters

Paclobutrazol concentration	Time of application	Date of harvest	Number of fruits per plant	Fruit Weight (g)	Fruit Length (cm)	Fruit Breadth (cm)	Fruit Thickness (cm)
Paclobutrazol at 7500 ppm (P_1)	15 July	04.06.06	185.33	303.67	11.10	7.41	6.84
	15 October	04.06.06	140.78	293.33	10.99	7.29	6.68
Paclobutrazol at 10000 ppm (P_2)	15 July	04.06.06	157.12	260.67	10.22	7.17	6.39
	15 October	04.06.06	93.50	239.47	9.84	6.93	6.30
Control (water application) (P_3)	15 July	26.06.06	66.99	177.00	8.89	6.37	5.85
	15 October	26.06.06	68.25	178.33	8.95	6.38	5.88
CV (%)		-	4.29	3.69	5.04	4.51	5.02
LSD (0.05)		-	9.26	16.25	0.92	0.57	0.58

Table 3 contd.

Paclobutrazol Concentration	Time of application	Edible portion (%)	Stone pulp ratio	Peel pulp ratio	Shelf life (days)
Paclobutrazol at 7500 ppm (P_1)	15 July	69.55	0.22	0.23	9.67
	15 October	68.76	0.22	0.24	9.17
Paclobutrazol at 10000 ppm (P_2)	15 July	68.09	0.23	0.23	9.50
	15 October	66.80	0.25	0.24	9.33
Control (water application) (P_3)	15 July	65.82	0.28	0.23	7.67
	15 October	65.95	0.29	0.23	8.00
CV (%)		3.67	8.81	5.59	5.95
LSD (0.05)		-	0.04	-	3.23

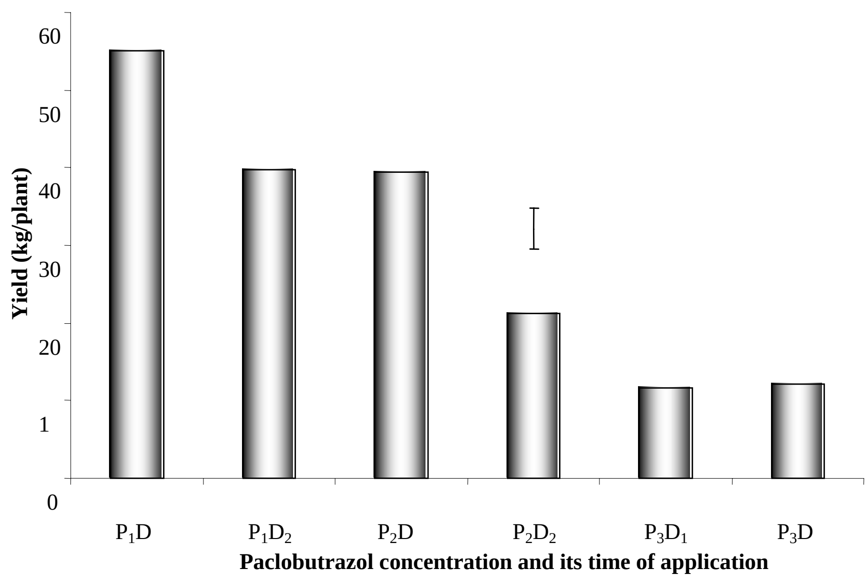

Figure 1. Effect of paclobutrazol and time of application on the yield per plant of mango Vertical bar represents LSD at 5% level

P_1 : Paclobutrazol @ 7500 ppm D_1 : 15 July application

P_2 : Paclobutrazol @ 10000 ppm D_2 : 15 October application

P_3 : Control (water application)

The treatment combination of 7500 ppm paclobutrazol and 15 July application exhibited maximum fruit yield (55.05 kg/plant). The next higher but statistically identical yield (39.77 and 39.40 kg/plant) were noticed from the treatment combinations of 7500 ppm and 15 October and 10000 ppm and 15 July, respectively. The control plants showed minimum (11.72 kg/plant) yield. Paclobutrazol @ 7500 ppm combined with 15 July application exhibited the highest shelf life (9.67 days) as compared to the lowest value with 7.67 days in control. Moreover, the effect of paclobutrazol on increasing the chlorophyll content of leaves, besides influencing the CO_2 assimilation might manifest higher photosynthetic efficiency leading to higher accumulation of carbohydrates, that might have influence on higher fruit bud initiation, flowering, fruit set and yield (Richardson and Quinlan, 1986). Plants treated with paclobutrazol in mango cv. Langra in India produced the highest number of fruits and yield (Karuna *et al.*, 2005; Karuna *et al.,* 2007).

4. Combined effect on fruit quality

There were profound variations in respect of TSS, titratable acidity, vitamin C, dry matter content; reducing, non reducing and total sugar due to the combined effect of paclobutrazol and time of application, while pH and moisture content did not exhibit significant differences (Table 4). Plants soil drenched with paclobutrazol @ 7500 ppm on 15 July recorded the highest TSS content (28.00%) compared to the lowest TSS in control (22.27%). The lowest value of the titratable acidity with 0.19 was exhibited when paclobutrazol @ 10000 ppm was applied to the plants on 15 July, whereas the highest value (0.24) appeared in the control. Paclobutrazol when applied @ 7500 ppm on 15 July resulted in maximum vitamin C content (35.02 mg/100g pulp), while control plants had minimum vitamin C content (28.73 mg/100g pulp).

Table 4. Combined effect of paclobutrazol and time of application on quality attributes

Paclobutrazol Concentration	Time of application	TSS (%)	pH	Titratable acidity (%)	Vitamin C (mg/100 g pulp)
Paclobutrazol at 7500 ppm	15 July	28.00	6.13	0.20	35.02
	15 October	26.53	6.30	0.22	34.73
Paclobutrazol at 10000 ppm	15 July	25.13	6.02	0.19	33.72
	15 October	24.57	6.09	0.20	32.96
Control (water application)	15 July	22.27	5.55	0.23	28.73
	15 October	22.47	5.79	0.24	28.90
CV (%)		6.56	4.73	5.87	3.82
LSD (0.05)		2.96	-	0.03	2.25

Table 4 contd.

Paclobutrazol concentration	Time of application	Moisture content (%)	Dry matter content (%)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)
Paclobutrazol at 7500 ppm	15 July	78.01	21.99	5.42	13.95	19.37
	15 October	79.78	20.22	5.35	13.87	19.22
Paclobutrazol at 10000 ppm	15 July	81.15	18.85	5.21	13.50	18.71
	15 October	81.93	18.07	5.15	13.44	18.59
Control (water application)	15 July	83.61	17.39	4.81	12.48	17.30
	15 October	81.56	17.44	4.76	12.43	17.19
CV (%)		2.61	4.67	3.00	2.93	2.91
LSD (0.05)		-	1.61	0.28	0.71	0.97

Paclobutrazol applied at 7500 ppm on 15 July exhibited maximum dry matter (21.99%) compared to the lowest value with 17.39% in control. Reducing sugar content was recorded the highest (5.42%) in the plants treated with paclobutrazol @ 7500 ppm on 15 July as against the lowest content (4.76%) in control. Paclobutrazol irrespective of concentration and time of application produced higher reducing sugar content compared to control. Fruits from the plants treated with paclobutrazol @ 7500 ppm on 15 July contained maximum non reducing sugar (13.95%), whereas control plants showed minimum sugar (12.43%). Soil drenched with paclobutrazol @ 7500 ppm on 15 July resulted in maximum total sugar content of 19.37% as against minimum sugar (17.19%) in control. All the treatment combinations except control were statistically identical and demonstrated higher total sugar. Improvement in fruit quality in respect of TSS, TSS to acid ratio, total sugar and reducing sugar in response to paclobutrazol can be related to assimilate partitioning of the plant. Due to higher suppression of vegetative growth, assimilates need to become unidirectional towards developing fruit, as a result paclobutrazol treated trees exhibited higher fruit quality attributes. With the same justification, the control trees had lower TSS and sugars but higher titratable acidity. Paclobutrazol improved fruit quality (Vijayalakshmi & Sirivasan, 1998; Hoda *et al*., 2001 and Yeshitela *et al.*, 2004). Vijayalakshmi and Srinivasan (2000) reported that paclobutrazol in Alphonso mangoes in India had the greatest effect enhancing all the qualitative parameters (ascorbic acid, total sugar, reducing sugar and TSS, except for acidity) in harvested fruits. Soil treatment with paclobutrazol improved the fruit quality attributes (Singh and Singh, 2006).

Conclusion

The result revealed that soil drenched with paclobutrazol either at 7500 ppm or 10000 ppm on 15 July advanced panicle emergence as well as harvest in mango cv. BARI Aam-3 (Amrapali) by 23 and 22 days, respectively, which will in turn help the growers in extending the availability period of mango. Paclobutrazol @ 7500 ppm on 15 July exhibited superior results pertaining to fruit yield and quality.

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INTEGRATED MANAGEMENT OF FUSARIUM WILT OF GLADIOLUS

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Abstract

Integrated management of Fusarium wilt of gladiolus was studied at Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during 2011-2013 following RCB design with four replications. Seven treatment such as (1) Corm treated with Bavistin @ 0.1% for 15 minutes, (2) Corm treated with hot water @ 54^{o}c for 5 minutes, (3) Corm treated with hot water @ 52^{o}c for 10 minutes, (4) Poultry refuse @ 5t/ha, (5) Mustard oil cake @ 600 kg/ha, (6) Bio-pesticide @ 64kg/ha, (7) Bavistin @ 0.1% as soil drenching were evaluated in nine different combinations against the Fusarium wilt of gladiolus (*Fusarium oxysporum* f. sp. g*ladioli*) under naturally infested field condition. Corm treated with Bavistin (0.1%) for 15 minutes + Poultry refuse @ 5t/ha in soil application 25 days before corm sowing + Bavistin @ 0.1% as soil drenching at 45 days after corm sowing gave best integrated management option for reducing Fusarium wilt of gladiolus and thereby resulting maximum germination, spike length, rachis length, florets spike^{-1}, flower sticks, corm and comel yield. Besides, integration of Bavistin (0.1%) as corm treatment for 15 minutes + Mustard oil cake @ 600 kg/ha in soil application 25 days before corm sowing + Bavistin (0.1%) as soil drenching at 45 days after corm sowing was also better option for combating Fusarium wilt of gladiolus. The alternate option was integration of Bavistin (0.1%) as corm treatment for 15 minutes + Bio-pesticide in soil application 7 days before corm sowing + Bavistin (0.1%) as soil drenching at 45 days after corm sowing was effective against the disease incidence as well as better spike length, rachis length, florets spike^{-1}, flower sticks, corm and cormel yield.

Keywords: Gladiolus, *Fusarium oxysporum* f. sp. g*ladioli*, Fusarium wilt, Bavistin, Poultry refuse, Mustard oil cake and Bio-pesticide.

Introduction

Gladiolus (*Gladiolus* sp) is one of the most popular commercial flower in Bangladesh. The agro-ecological conditions of the country are very much conducive for the survival and culture of gladiolus. The major production belts of this Sharsha flower are Jessore sadar, Sharsha, Jhikargacha, Kushtia, Chuadanga, Satkhira, Khulna, Chittagong, Mymensingh, Dhaka, Savar and Gazipur.

It has great economic value as a cut-flower and its cultivation is relatively easy. Income from gladiolus flower production is six times higher than that of rice in Bangladesh (Momin, 2006).

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The major obstacle of gladiolus cultivation in the Subtropical and Mediterranean regions is the diseases caused by fungi, bacteria and viruses of which Fusarium wilt disease caused by *F. oxysporum* f. sp. *gladioli* is a major one in all over the gladiolus growing areas causing 60-70% yield loss (Vlasova and Shitan, 1974) and the damage may reach upto 100% (Pathania and Misra, 2000). Crop loss of 30% in Germany and 60-80% in Russia was estimated due to Fusarium wilt of gladiolus (Bruhn, 1955). It is also a serious threat in India and reduced plant growth and flowering upto 15- 28% in the number of florets/spike (Misra *et al.*, 2003).

The pathogen is both seed and soil borne (Cohen and Hass, 1990; Mukhopadhyay, 1995). It causes curving, blending, arching, stunting, yellowing and drying of leaves associated with root and corm rot in the field as well as in the storage. *F. oxysporum* f. sp. *gladioli* causes three types of rot e.g. vascular corm rot, brown rot and basal rot (Partridge, 2003). Vascular rot is also called yellows and is characterized by a brown discoloration in the centre of the corm and extending into the flesh. The leaf symptoms start at the tip of the leaf blade and gradually spread all over the leaf blade. If the plant is infected at later stage, it produces weak or small florets. When the plant is infected at early stage and infection is severe, whole plant becomes dry and dies within few days (Misra and Singh, 1998). Fusarium wilt of gladiolus may be minimized by the integrated management approach under pot culture and polyhouse conditions (Sharma *et al.* 2005). The integrated approach using pots treated with neem cake, carbendazim and *Trichoderma harzianum* revealed the highest disease control and enhanced plant health and corm yield. Application of carbendazim (200 ppm), *T. harzianum* (P=0.001) and *Pseudomonas fluorescence* (P= 0.05) decreased corm rot, yellows and the pathogen population in soil resulting increased plant growth and flowering (Khan and Mustafa, 2005). Singh and Arora (1994) reported that Bavistin-HCl and Emisan as better fungicides in reducing disease severity (%) and enhancing corm and cormel yield.

Different workers practiced biological, cultural and chemicals means in controlling the disease. It is difficult to control Fusarium wilt of gladiolus with a single component. Considering the above situation the present work was under taken to find out an effective integrated approach for controlling Fusarium wilt disease (*Fusarium oxysporum* f. sp. g*ladioli*) of gladiolus.

Materials and methods

The experiment was conducted at the Floriculture Field under the Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur during the period from 2011-2013. The experiment was set in previously *Fusarium oxysporum* f. sp. g*ladioli* infested soil. It was laid out in the Randomized Complete Block Design (RCBD) with four replications. The management options were (1) Corm treated with hot water @ 54^{o}c for 5 minutes,

(2) Corm treated with hot water @ 52^{o}c for 10 minutes, (3) Corm treated with Bavistin @ 0.1% for 15 minutes, (4) Poultry refuse @ 5t/ha, (5) Mustard oil cake @ 600 kg/ha, (6) Bio-pesticide @ 64kg/ha, (7) Bavistin @ 0.1% as soil drenching and nine treatment combinations.

Corms were treated with hot water and dried in shade before 24 hours of seed sowing. The corms were treated by Bavistin just before seed sowing. Poultry refuse and mustard oil cake were applied before 25 days and bio-agents were applied before 7 days of seed sowing. Bavistin @ 0.1% was applied as soil drenching around the base of the plants at 45 days after sowing.

The recommended dose of fertilizers cowdung @ 10 t/ha, TSP @ 225 kg/ha and MoP 190 kg/ha were applied to the soil during land preparation and thoroughly mixed with the soil. Urea @ 200 kg/ha was top dressed in two equal splits, one at the four leaf stage and another at spike initiation stage (Woltz, 1976).

The unit plot size was 1.25 m × 1.6 m. Spacing was maintained at 25 cm between the rows and 20 cm between the plants. Depth of planting of the corms was 6 cm. The space between plots and block were 50 cm and 75 cm respectively. Germination (%), Plant height (cm) , Spike length (cm), Rachis length (cm), Florets spike^{-1}, Flower stick weight (g), Flower sticks plot^{-1}, Flower sticks ha^{-1}, Pre-germination corm rot (%), Wilted plant (%), Disease incidence (%), Percent disease index (PDI), Corms hill^{-1}, Corm yield, Cormels hill^{-1} and Cormels yield (g) were rcorded. The disease incidence, Percent disease index and wilted plant were calculated using following formula (Singh and Arora, 1994):

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants plot}^{-1}}{\text{Number of total plants plot}^{-1}} \times 100$$

$$\text{Percent disease index (\%)} = \frac{\text{Class frequency}}{\text{Total number of sample} \times \text{Maximum grade of scale}} \times 100$$

$$\text{Wilted plant (\%)} = \frac{\text{Number of wilted plants plot}^{-1}}{\text{Total number of plants plot}^{-1}} \times 100$$

Results and Discussion

Effect of integrated management option on vegetative growth of gladiolus was significantly different (Table 1). Higher germination was recorded in the treatment combination A_1 (99.98%) which was statistically identical with that of A_2, A_3 and A_4. The lowest germination was 93.75% in control (A_{10}). There was no significant difference among the treatment combinations A_5, A_6, A_7, A_8 and A_9 on corm germination.

Table 1. Effect of integrated management option on vegetative growth of gladiolus

Treatment combinations	Germination (%)	Days to 50% germination	Plants/hill	plant height (cm)
$A_1 = T_1+T_4+T_7$	99.98 a (10.0)	11.50 b	1.74 a	42.77 a
$A_2 = T_1+T_5+T_7$	99.36 ab (9.97)	12.00 ab	1.68 ab	41.47 ab
$A_3 = T_1+T_6+T_7$	99.36 ab (9.97)	12.25 a	1.65 ab	42.26 ab
$A_4 = T_2+T_4+T_7$	98.74 abc (9.94)	11.50 b	1.60 ab	41.99 ab
$A_5 = T_2+T_5+T_7$	98.12 bcd (9.90)	11.50 b	1.55 ab	40.95 b
$A_6 = T_2+T_6+T_7$	98.12 bcd (9.90)	12.00 ab	1.53 ab	41.01 b
$A_7 = T_3+T_4+T_7$	97.50 cd (9.87)	12.50 a	1.48 b	41.70 ab
$A_8 = T_3+T_5+T_7$	96.88 d (9.84)	12.00 ab	1.48 b	42.48 a
$A_9 = T_3+T_6+T_7$	96.88 d (9.84)	12.25 a	1.45 bc	42.10 ab
A_{10} = Control	93.75 e (9.69)	12.50 a	1.23 c	40.86 b
CV%	0.43	3.74	10.25	2.11

Means followed by the same letter do not differ significantly at the 5% level by DMRT.

Values within paranthesis were square root transformation.

T_1= Corm treated with Bavistin @ 0.1% for 15 minutes, T_2= Corm treated with hot water @ 54^{o}c for 5 minutes, T_3= Corm treated with hot water @ 52^{o}c for 10 minutes, T_4= Poultry refuse @ 5t/ha, T_5= mustard oil cake @ 600 kg/ha, T_6= bio-pesticide @ 64kg/ha, T_7= Bavistin @ 0.1% as soil drenching.

The minimum days (11.50) required to reach 50% germination was observed in A_1, A_4 and A_5 which were followed by A_2, A_6 and A_8. The maximum days (12.50) required to reach 50% germination was noticed in A_{10} and A_7 which were statistically identical to A_3, A_9, A_2, A_6 and A_8. The maximum numbers of plants hill^{-1} was 1.74 recorded in A_1 which was statistically similar to A_2, A_3, A_4, A_5 and A_6 while minimum numbers of plants hill^{-1} was 1.23 recorded in A_{10}. The taller plant was 42.77 cm was recorded in case of poultry refuse, corm treated with Bavistin @ 0.1% for 15 minutes and soil drenching with Bavistin (A_1) which was followed by A_8, A_3, A_9, A_4, A_7 and A_2. The shorter plant (40.86 cm) was recorded from A_{10} which was followed by A_5 and A_6.

All the parameters of disease infestation showed significant variations due to various treatments combinations (Table 2). Corm and soil treatment showed significant effect on the pre germination corm rot. The highest pre germination corm rot was 6.75% recorded in A_{10} and the lowest was 0.50% recorded in A_1 which was followed by A_2 and A_3. There was no significant variation of pregermination among A_5, A_6, A_7, A_8 and A_9. The highest wilted plant (10.12%) was recorded in A_{10} and lowest (1.13%) was observed in A_1 which was statistically similar to A_2, A_3, A_4, A_5 and A_6. Incidence of plant infection was the highest in control (57.50%) whereas the minimum plant infection was 47.0% in A_1. There was no significant differences among the rest options with respect to disease incidence. Percent disease index (PDI) was minimum (21.25%) in A_1 and A_2 where rest of the options showed statistically similar. PDI ranging from 21.88 to 25.63%.

Table 2. Effect of integrated management options on disease infestation of gladiolus

Treatment combinations	Pre germination corm rot (%)	Wilted plant (%)	Incidence of plant infection (%)	Percent disease index (PDI)
$A_1 = T_1+T_4+T_7$	0.50 e	1.13 c	47.0 b	21.25 b
	(0.71)	(0.97)	(6.86)	(26.44)
$A_2 = T_1+T_5+T_7$	1.13 de	1.75 c	47.75 b	21.25 b
	(0.97)	(1.22)	(6.91)	(26.44)
$A_3 = T_1+T_6+T_7$	1.13 de	1.75 c	48.0 b	21.88 b
	(0.97)	(1.22)	(6.93)	(26.88)
$A_4 = T_2+T_4+T_7$	1.75 cd	1.13 c	49.50 b	23.75 b
	(1.22)	(0.97)	(7.04)	(28.10)
$A_5 = T_2+T_5+T_7$	2.38 bc	1.13 c	49.50 b	23.75 b
	(1.48)	(0.97)	(7.04)	(28.10)
$A_6 = T_2+T_6+T_7$	2.38 bc	1.77 c	50.0 b	24.38 b
	(1.48)	(1.23)	(7.07)	(28.51)
$A_7 = T_3+T_4+T_7$	3.00 b	4.35 b	51.0 b	25.63 b
	(1.73)	(2.06)	(7.14)	(29.28)
$A_8 = T_3+T_5+T_7$	3.63 b	4.36 b	52.0 b	25.63 b
	(1.89)	(2.07)	(7.21)	(29.28)
$A_9 = T_3+T_6+T_7$	3.63 b	4.36 b	52.25 b	25.63 b
	(1.89)	(2.07)	(7.23)	(29.28)
A_{10} = Control	6.75 a	10.12 a	57.50 a	31.25 a
	(2.59)	(3.18)	(7.58)	(32.77)
CV%	20.39	30.19	6.42	7.93

Means followed by the same letter do not differ significantly at the 5% level by DMRT. All values within paranthesis were square root transformation but PDI values within paranthesis were Arcsin transformation.

T_1= Corm treated with Bavistin @ 0.1% for 15 minutes, T_2= Corm treated with hot water @ 54^{o}c for 5 minutes, T_3= Corm treated with hot water @ 52^{o}c for 10 minutes, T_4= Poultry refuse @ 5t/ha, T_5= mustard oil cake @ 600 kg/ha, T_6= bio-pesticide @ 64kg/ha, T_7= Bavistin @ 0.1% as soil drenching.

Effect of integrated management options varied statistically with respect to different parameters on flower production of gladiolus (Table 3). The highest spike length (77.23 cm) was recorded in the treatment of A_1 which was statistically similar to A_2, A_3 and A_4. The minimum spike length (70.25 cm) was recorded in A_{10} which was followed by A_9, A_8 and A_7. The maximum rachis length (45.18 cm) was observed in A_1 which was followed by A_2 and A_3 and minimum rachis length (38.75 cm) was observed in A_{10}. The rachis length of the other options ranged from 41.63 cm to 43.50 cm. The highest number of florets (12.73) spike^{-1} was recorded in A_1 which was followed by A_5, A_4, A_8, A_2 and A_6 while the lowest number of florets (11.60) spike^{-1} was recorded in A_{10} which was statistically similar to A_9, A_7 and A_3.

Table 3. Effect of integrated management options on flower production of gladiolus

Treatment combinations	spike length (cm)	Rachis length (cm)	Florets spike^{-1}	Flower stick weight(g)	Flower sticks plot^{-1}	Flower sticks ha^{-1}
$A_1= T_1+T_4+T_7$	77.23 a	45.18 a	12.73 a	68.71 a	40.75 a	97000 a
$A_2= T_1+T_5+T_7$	76.00 ab	44.57 ab	12.25 ab	68.13 a	40.00 ab	95250 ab
$A_3= T_1+T_6+T_7$	75.40 ab	44.00 abc	12.11 bc	67.88 a	39.75 ab	94750 ab
$A_4= T_2+T_4+T_7$	75.25 ab	43.50 bc	12.36 ab	67.88 a	39.25 ab	93250 ab
$A_5= T_2+T_5+T_7$	74.54 bc	43.00 cd	12.40 ab	67.50 a	39.00 b	92750 b
$A_6= T_2+T_6+T_7$	74.25 bcd	42.75 cde	12.23 ab	67.00 a	38.75 b	92250 b
$A_7= T_3+T_4+T_7$	72.63 cde	42.13 de	11.93 bc	64.45 b	36.50 c	87000 c
$A_8= T_3+T_5+T_7$	72.25 cde	41.50 e	12.34 ab	64.13 b	36.25 c	86000 c
$A_9= T_3+T_6+T_7$	71.75 de	41.63 e	11.85 bc	63.88 b	36.00 c	85000 c
A_{10} = Control	70.25 e	38.75 f	11.60 c	61.00 c	33.00 d	78000 d
CV%	2.16	1.94	2.84	2.51	2.65	2.65

Means followed by the same letter do not differ significantly at the 5% level by DMRT.

T_1= Corm treated with Bavistin @ 0.1% for 15 minutes, T_2= Corm treated with hot water @ 54^{o}c for 5 minutes, T_3= Corm treated with hot water @ 52^{o}c for 10 minutes, T_4= Poultry refuse @ 5t/ha, T_5= mustard oil cake @ 600 kg/ha, T_6= bio-pesticide @ 64kg/ha, T_7= Bavistin @ 0.1% as soil drenching.

The heaviest flower stick (68.71 g) was produced by the treatment combination A_1 which was statistical similar to A_2, A_3, A_4, A_5, and A_6 (Table 3). On the other hand, the lightest flower stick (61.0 g) was produced by A_{10} where A_9, A_8 and A_7 showed statistically similar trend. The highest number of sticks plot-^{1} (40.75) was produced by A_1 which was statistically similar to A_2, A_3 and A_4. The lowest number of sticks plot-^{1} (33.0) was found in control plot (A_{10}). A_1 produced maximum number (97000/ha) flower sticks followed by the treatment combinations A_2, A_3 and A_4 while minimum number (79000/ha) flower sticks were recorded in A_{10}.

Effect of integrated management options on corm production of gladiolus varied significantly among the treatments (Table 4). The maximum number of corms (1.58) hill^{-1} was recorded in the treatment A_1 which was statistically similar to the treatments A_2, A_3, A_4, A_5, A_6 and A_7. The minimum number of corms (1.30) hill^{-1} was recorded from A_{10} which was followed by A_8, A_9 and A_7. The heaviest corm (20.0 g) was recorded by the treatment A_1 which was statistically identical to A_2, A_3, A_5, A_6, A_4, A_7 and A_8 and the lightest corm (16.25 g) was recorded from A_{10}. The largest corm (3.53 cm) was noticed in A_1 which was statistically similar to A_2, A_3, A_4, A_8 and A_{10} and the smallest corm (3.17 cm) was recorded in the treatment A_7 which was followed by A_6, A_9, A_5 and A_{10}. The maximum number of corms plot^{-1} (62.65) was produced by A_1 which was statistically identical to A_2, A_3, A_4, A_5 and A_6. The minimum corms plot^{-1} (43.88) was produced by A_{10} while no significant difference existed among A_6, A_7, A_8 and A_9. The treatment combination A_1 produced the highest number of corms ha^{-1} (149000) which was statistically similar A_2, A_3, A_4, A_5 and A_6 (Table 4). The lowest number of corms ha^{-1}(104000) was recorded in A_{10} which was followed by A_9, A_8 and A_7.

Table 4. Effect of integrated management options on corm production of gladiolus

Treatment combinations	Corms hill^{-1}	Corm weight (g)	Corm diameter (cm)	Corms plot^{-1}	Corms ha^{-1} (000)
A_1= T_1+T_4+T_7	1.58 a	20.00 a	20.00 a	62.65 a	149.0 a
A_2= T_1+T_5+T_7	1.55 ab	19.00ab	19.00ab	60.85 a	144.8 a
A_3= T_1+T_6+T_7	1.53 ab	18.88 ab	18.88 ab	59.88 a	142.5 a
A_4= T_2+T_4+T_7	1.50 ab	18.38 ab	18.38 ab	58.85 ab	140.0 ab
A_5= T_2+T_5+T_7	1.50 ab	18.88 ab	18.88 ab	58.50 ab	139.3 ab
A_6= T_2+T_6+T_7	1.48 ab	18.43 ab	18.43 ab	57.18 abc	136.3 abc
A_7= T_3+T_4+T_7	1.43 abc	18.25 ab	18.25 ab	53.43 bc	127.5 bc
A_8= T_3+T_5+T_7	1.40 bc	18.13 ab	18.13 ab	52.18 c	124.3 c
A_9= T_3+T_6+T_7	1.40 bc	17,75 bc	17,75 bc	52.18 c	124.3 c
A_{10} = Control	1.30 c	16.25 c	16.25 c	43.88 d	104.3 d
CV%	6.63	6.60	6.60	6.72	6.73

Means followed by the same letter do not differ significantly at the 5% level by DMRT.

T_1= Corm treated with Bavistin @ 0.1% for 15 minutes, T_2= Corm treated with hot water @ 54^{o}c for 5 minutes, T_3= Corm treated with hot water @ 52^{o}c for 10 minutes, T_4= Poultry refuse @ 5t/ha, T_5= mustard oil cake @ 600 kg/ha, T_6= bio-pesticide @ 64kg/ha, T_7= Bavistin @ 0.1% as soil drenching.

All the parameters of cormel production of gladiolus showed significant variations among the treatments (Table 5). The maximum number of cormels hill^{-1} (21.63) was recorded in A_1 which was statically identical to A_2 and A_3 while minimum number of cormels hill^{-1} (14.38) was produced by A_{10}.

Table 5. Effect of integrated management options on cormel production of gladiolus

Treatment combinations	Cormels hill^{-1}	Cormel weight hill^{-1} (g)	Cormel yield plot^{-1}(g)	Cormel yield ha^{-1}(t)
A_1= T_1+T_4+T_7	21.63 a	29.75 a	1183 a	2.82 a
A_2= T_1+T_5+T_7	21.25 a	29.00 a	1139 a	2.71 ab
A_3= T_1+T_6+T_7	20.40 ab	28.25 ab	1108 ab	2.64 abc
A_4= T_2+T_4+T_7	18.83 bc	27.85 abc	1092 ab	2.60 abc
A_5= T_2+T_5+T_7	17.13 cd	26.00 abcd	1014 abc	2.42 abcd
A_6= T_2+T_6+T_7	16.63 d	25.25 abcd	978 abcd	2.33 bcd
A_7= T_3+T_4+T_7	16.13 de	24.50 abcd	919 bcde	2.19 cde
A_8= T_3+T_5+T_7	15.50 de	23.25 bcd	866 cde	2.07 de
A_9= T_3+T_6+T_7	15.13 de	22.75 cd	849 de	2.02 de
A_{10} = Control	14.38 e	22.00 d	744 e	1.77 e
CV%	7.64	12.37	15.83	15.77

Means followed by the same letter do not differ significantly at the 5% level by DMRT.

T_1= Corm treated with Bavistin @ 0.1% for 15 minutes, T_2= Corm treated with hot water @ 54^{o}c for 5 minutes, T_3= Corm treated with hot water @ 52^{o}c for 10 minutes, T_4= Poultry refuse @ 5t/ha, T_5= mustard oil cake @ 600 kg/ha, T_6= bio-pesticide @ 64kg/ha, T_7= Bavistin @ 0.1% as soil drenching.

The highest cormel weight hill^{-1} (29.75 g) was recorded in A_1 followed by A_2, A_3 A_4, A_5, A_6 and A_7 and the lowest weight of cormel hill^{-1} (22.00 g) was found A_{10} followed by A_9, A_8, A_7, A_6 and A_5. The maximum cormel yield plot^{-1} (1183 g) was produced by the treatment option A_1 which was statistically identical to A_2, A_3 A_4, A_5 and A_6. The minimum cormel yield plot^{-1} (744g) was found in the treatment A_{10} followed by A_9, A_8 and A_7. Treatment A_1 produced the highest cormel yield ha^{-1} (2.82 t) which was statistically identical to A_2, A_3 A_4 and A_5 and the lowest yield (1.77 t ha^{-1}) was recorded A_{10} followed by A_9, A_8 and A_7.

Integrated management of Fusarium wilt of gladiolus was performed by incorporating the treatments and it appeared from the results that Poultry refuse @ 5t/ha in soil at 25 days before sowing in addition corm treated with Bavistin @ 0.1% for 15 minutes and soil drenching with Bavistin @ 0.1% at 45 days after sowing gave better control of the disease and increased germination, plants hill^{-1}, spike number and quality, corm and cormel production. Hossain *et al.* (2007) reported that use of poultry manures and seed treatment with Vitavax-200 and poultry manures and soil drenching with Bavistin showed better performance in reducing stem canker and black scurf disease of potato.

The another combination was mustard oil cake (600 kg/ha) applied in soil at 25 days before sowing including corm treated with Bavistin @ 0.1% for 15 minutes and soil drenching with Bavistin @ 0.1% at 45 days after sowing performed better in controlling disease infestation as well as increased yield. This findings is supported by Nikam *et al.* (2007) who reported chickpea wilt due to *Fusarium oxysporum* f. sp. *ciceri* being soil borne disease could be managed by integrating varoius practices like using resistant varieties, seed treatment with chemicals, seed and soil application of bio-agents and amendments of soils with oils seeds cake. Sharma *et al.* (2005) studied integrated approach using pots treated with neem cake, carbendazim and *Trichoderma harzianum* revealed the highest disease control (Fusarium yellows), enhanced corm yield and improved plant health of gladiolus. Sultana and Ghaffar (2010) reported Carbendazim and soil amendments with mustard oil cake as more effective to control *Fusarium solani* in other crops.

Another combination was bio-pesticide (64 kg/ha) incorporation in soil at 7 days before sowing, corm treated with Bavistin @ 0.1% for 15 minutes and soil drenching with Bavistin @ 0.1% at 45 days after sowing was also better in controlling disease infestation as well as increased yield. Khan and Mustafa (2005) reported application of carbendazim, *T. harzianum* and *Pseudomonas fluorescence* decreased the corm rot and yellows scores and the soil population of the pathogen and increased plant growth and flowering. Mishra *et al*. (2005) studied the effect of integration of chemicals and biological control agents against gladiolus corm rot. Mirsha *et al.* (2000) used *Trichoderma virens,* carboxin and a combination of both and found good for the control of gladiolus corm rot and wilt caused by *Fusarium oxysporum* f. sp. *gladioli* in glasshouse and field experiment.

Conclusion

Corm treated with Bavistin (0.1%) for 15 minutes + Poultry refuse @ 5t/ha in soil application 25 days before corm sowing + Bavistin @ 0.1% as soil drenching at 45 days after corm sowing gave best option for integrated management of Fusarium wilt of gladiolus and thereby resulting maximum germination, spike length, rachis length, florets spike^{-1}, flower sticks, corm and comel yield. On the other hand, integration of Bavistin (0.1%) as corm treatment for 15 minutes + Mustard oil cake @ 600 kg/ha in soil application 25 days before corm sowing + Bavistin (0.1%) as soil drenching at 45 days after corm sowing also reduced Fusarium wilt of gladiolus. Similarly, integration of Bavistin (0.1%) as corm treatment for 15 minutes + Bio-pesticide in soil application 7 days before corm sowing + Bavistin (0.1%) as soil drenching at 45 days after corm sowing also effective in inhibiting the disease incidence as well as better spike length, rachis length, florets spike^{-1}, flower sticks, corm and cormel yield.

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GENETIC DIVERSITY BASED ON AGRONOMIC AND FRUIT QUALITY TRAITS IN GBOMA EGGPLANT (*Solanum macrocarpon* L.)

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Abstract

Solanum macrocarpon L is a fruit and leaf vegetable in sub-Sahara Africa. The genetic diversity of the crop remains largely unexploited consequently there is a dearth of genetic information on agronomic and fruit quality traits. Agronomic and fruit quality variability and association among traits were evaluated. Twenty – six accessions were grown in a randomized complete block design with three replications. Measurements taken on agronomic and fruit quality traits were subjected to a combined analysis of variance, Principal Component Analysis and grouping using Unweighted Pair Group Method Arithmetic Average using option Ward's. There were significant differences ($P \leq 0.05$) among the accessions for all the traits, while Genotype by Year Interaction (GYI) showed insignificant effects for most traits except plant height at flowering and maturity and seed yield. High broad sense heritability suggested the preponderance of both additive and non-additive genetic action for agronomic and fruit quality traits. The percentage contribution of agronomic traits toward the genetic diversity was maximum in plant height at flowering and plant height at maturity. Positive correlation coefficients was recorded between days to 50% flowering and fruit infructescence/plant ($r = 0.45$, $P \leq 0.05$). Dendogram analysis revealed three distinct groups with overlap of traits and no relationship between geographic location and phenotypic diversity. Hybridization among MM 268, MM 10256, MM 150 and MM 10161 may bring together gene constellations for earliness, fruit yield and delayed time to fruit browning. Superior genotypes are recommended for use in hybridization schemes for variety development and the subsequent molecular characterization

Keywords: Diversity; Fruit infructescence per plant; Principal Component Analysis, Total Soluble Solids; Fruit browning; Fruit cluster: *Solanum macrocarpon*.

Introduction

Solanum macrocarpon L. (Gboma eggplant) (2n = 24) is classified in Solanum subgenus Leptostemonum; section Melongena and series Macrocarpa Bitter. It is cultivated throughout tropical Africa, especially in humid regions. The wild ancestor of *S. macrocarpon* L. is *Solanum dasyphyllum* Schum and Thon. The Gboma eggplant is distributed along the coast of West Africa (Ghana, Nigeria, Togo, Ivory Coast, Benin), East and South African countries (Malawi, Zambia,

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Zimbabwe and Mozambique) (Shippers, 2002). The species *Macrocarpon* comprised four cultigroups (*S. macrocarpon* L. complex in Uganda: *S. macrocarpon* L. 'semi wild', *S. macrocarpon* L. 'Mukono' and *S. macrocarpon* L. 'Nabingo') (Bukenya and Carasco, 1994; Bukenya, and Hall, 1987). *Solanum macrocarpon* L. is indigenous to Africa; its production, consumption and utilization are compatible with the norms, beliefs and food culture of communities in sub Sahara Africa. Both the fruits and leaves are consumed fresh or stewed with other vegetables like Amaranth and Cabbage. Production of fruits and leaves are mainly for domestic market and export is limited. It is a perennial shrub and robust, it grows up to 1.5 meters tall, with glabrous or prickly stems. The leaves are simple, alternate and blades are large (15 – 46 cm × 8 – 30 cm), stipules are absent; and the petiole grows up to 7 cm long (Shippers, 2002). The fruits are large (ranged from 3 to 12 cm in diameter and 2 to 6 cm long) spherical or depressed, usually cream, green, whitish or purple or with lighter markings at commercial harvest. At maturity, the fruits turn yellow or orange or brown in colour and the surface may crack (Daunay *et al.,* 2001a, b, Collonnier *et al.,* 2001; Adeniji, 2013).

Solanum macrocarpon L. has not attracted the interest of researchers compared to other *Solanum* species (Tomatoes and Peppers). As an important underutilized leaf and fruit vegetable in sub Sahara Africa, production is hindered by dearth of improved varieties, susceptibility to biotic and abiotic stresses. Genetic information on agronomic and fruit quality variation in Gboma eggplant from Africa is limited, yet agronomic variation and relatedness usually reveals important traits of interest to plant breeders and variety development (Thormann and Osborn, 1992). Prior to genetic improvement, evaluation of genetic resources was crucial for breeders to establish variation among individuals and selection of popular cultivars with reference to changes in consumer demand. Postharvest handling of fresh fruits is constrained by fruit flesh browning; this is associated with phenolic compounds in the fruit. Variation for fruit quality traits (fruit browning, fruit acidity and total soluble solids (Adeniji and Aloyce, 2012) usually depend on genetic and non-genetic factors (Bukenya and Carasco, 1994). Field evaluation of accessions from different geographical locations may provide information on traits associated with specific environment. In this study, we examined variability among accessions of *S. macrocarpon* L. based on agronomic and fruit quality traits, determine association among agronomic and fruit quality traits, and identify promising accessions for specific and multiple traits.

Material and Methods

Seeds of 26 genotypes of *S. macrocarpon* L. received from different parts of Africa and Asia conserved in the gene bank of The World Vegetable Center and French Institute for Agricultural Research (Table 1) were used for field and laboratory investigations. These accessions are landraces in their respective places of collection and posses agronomic and fruit quality traits that could be of importance for variety development in this species. The entries are homogeneous for phenotypic traits. Agronomic investigations took place at Horticultural Research and Training Institute, Tanzania (4.9°S latitude, 3.7°E longitude; altitude. 1290 meters), during two consecutive years between June to November, 2009 and 2010. The experimental site received annual rainfall of 700 to 1000 mm during trial periods; soil was a well drained clay loam and slightly acidic (pH of 6.0 and 6.4). Seeds were sown in multipot seedling trays and maintained for three weeks. A randomized complete block design with three replications was used for field evaluation, each plot comprised three rows (ridges) of 7 m long and 0.75m spacing between rows. Vigorous and healthy seedlings at 3 weeks old were transplanted to the sides of the ridges. Agronomic and fruit quality traits were measured at different stages of growth. The number of days to 50% flowering was counted as the number of days from transplanting to attainment of 50% flowering. Plant height (m) was measured at 50% flowering and at maturity by random sampling of 15 vigorous plants per replicate. At harvest, plants in each net plot (3 m x 3 m) were used to determine the number of fruits/plant, fruits/infructescence and fruit infructescence/plant. Harvested fruits from each net plot were used to determine fruits/plant and fruit yield (t/ha). Fruit weight was measured on three randomly picked fruit per plant in grams. Fruit taste was determined on a two point scale of 1= Bitter and 2= Tasty by panellist of 20 farmers and consumers. Fruit acidity (pH) at commercial ripeness and at physiological maturity was measured by pH meter (meq citric acid/100 ml). The time (seconds) to fruit browning after cut was determined using a stop watch. The Total Soluble Solids (TSS) was measured using hand held refractometer from ten randomly picked fruits per entry at commercial ripeness and maturity. Seed mass/plant (grams) and seed yield (t/ha) were measured using appropriate balances. A combined analysis of variance (PROC - GLM procedure of SAS, (1998) was performed using replication as a random variable to determine the level of significance and the percentage of contribution of each component to the total variation. The Genotype (G), Year (Y), and Genotype by Year Interaction (GYI) were considered to be fixed-effects. To estimate the magnitude of genotypic variability for traits measured, genetic variance ($\sigma^2 g$), phenotypic variance ($\sigma^2 p$), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and broad sense heritability were estimated using the formula described by Uguru (1995). To determine the relative importance of agronomic and fruit quality traits in diversity, the principal component analysis was done prior to cluster analysis. Relationships among agronomic and fruit quality traits were studied by Principal Component Analysis (referred hereafter as PCA) (SAS, 1998) and UPGMA (Unweighted Pair Group Method Arithmetic Average) using option Ward's (Ward, 1963; Sneath, and Sokal, 1973; Sokal and Michener, 1958) for grouping. Each accession was considered as one OTU. Prior to multivariate analysis, agronomic traits were transformed to standard units (log transformation).

Table 1. ***Solanum macrocarpon*** **L. accessions used in the study organized by country of collection**

Acc no	Acc Code	Country of collection	Source
1	S00052	Malaysia	AVRDC
2	S00013	Unknown	AVRDC
3	MM 10161	Burkina Faso	INRA
4	MM 12209	Democratic Republic of Congo	INRA
5	MM 1132	Togo	INRA
6	MM 150	Ivory coast	INRA
7	MM 872	Madagascar	INRA
8	MM 905	Chad	INRA
9	MM 714	Zimbabwe	INRA
10	MM 268	Mauritania	INRA
11	MM 10256	Ghana	INRA
12	CR001	Cameroon	AVRDC
13	MM 10181	Burkina Faso	INRA
14	CR006	Cameroon	AVRDC
15	CN 012	Cameroon	AVRDC
16	MM 1615	Unknown	INRA
17	MM 11044	Ivory coast	INRA
18	MM10351	Madagascar	INRA
19	MM 12302	Nigeria	INRA
20	MM 1127	Benin	INRA
21	MM 583	Benin	INRA
22	MM 1144	Nigeria	INRA
23	MM 10260	Ghana	INRA
24	MM 856	Togo	INRA
25	MM 10252	Mauritania	INRA
26	MM 10251	Nigeria	INRA

Legend: AVRDC = Asian Vegetable Research and Development Center.
INRA= French Institute for Agricultural Research.

Results and Discussion

Phenotypic Character Distribution

There were significant differences ($P \leq 0.05$) among the accessions for all the traits, while for Genotype by Year Interaction (GYI) significant ($P \leq 0.05$) and non-significant differences were found (Table 2) for traits. The accessions of *Solanum macrocarpon* L. showed large phenotypic variation (within and between years) in agronomic and fruit quality traits and mean performance. A similar trend of result was reported among *Solanum aethiopicum* sub groups (Adeniji, 2012) and *Solanum melongena* L. (Kumar and Arumugam, 2013). Insignificant Year and Genotype by Year (GY) interaction for all traits except plant height at flowering implied that environmental variables during trial periods were consistent over years of evaluation and did not influence the phenotype of the accessions. Analysis of the variance components (Table 2) showed that estimates of phenotypic variances are larger than their corresponding genotypic variances for all traits. High manifestation of phenotypic variance compared with genotypic variance indicated a larger manifestation of environmental influence on genotypes during the growing period compared to genetic factors. Similarly, phenotypic coefficients of variations were larger than the genetic coefficients of variations, except for days to 50% flowering, seed yield and fruit inflorescence per plant. High proportion of phenotypic coefficient of variation indicated that variation observed among accessions was mainly due to environmental factors rather than genetic factor. Broad-sense heritability estimates (Table 2) were high for all traits, this implied the importance of these traits for selection of promising accessions. Heritability and genetic variance obtained in this study are important for selection of potential parents from the population. The fruits/plant was highest in MM872 (33) followed by MM1144 (31), although the fruit size was small (fruit length of 1.2 cm and fruit diameter of 1.8 cm in MM 10260) and large (fruit length of 6.0 cm and fruit diameter of 6.1 cm in MM 10161) (Table 3). The fruit weight of three fruits per plant (g) ranged from 14 g (MM 714 and MM 10161) to 173 g (S00052) with an average of 94 g. Values for other accessions are intermediate between the two extremes. Four accessions (MM10161, MM11044, MM 12209 and MM1615) recorded high seed mass (g)/plant, on the other hand they recorded moderately low values for seed yield (t/ha). Fruit yield (t/ha) varied from 28 t/ha (S00052) to 77 t/ha (MM905, MM10260). The fruits of CR006 were long (6.73 cm on the average), while MM150 were wide (8.6 cm diameter). Among the entries, MM150 and MM10161 performed best for fruit size, fruit length and fruit diameter (cm). Fruit infructescence/plant was high (4) in CR005. MM10161 was best for multiple traits (fruits/plant, seed mass (g), fruit yield (t/ha), fruit length and fruits/infructescence). At commercial harvest fruits are slightly alkaline (p^H of 6.4) in MM1615 and acidic (low p^H of 5.3) in MM1132. At physiological maturity fruit p^H peaked (5.7) in MM10181, but low p^H reading of 4.2 in MM10181. Earliness varied among the accessions, for instance, there were accessions that flowered spanning 66 d (MM150) and 86 d (MM714 and CR005) after transplanting. The fruit browning time was early (two minutes) in CR006, S00052, MM10181 and late (five minutes) in MM1132, MM10260, MM714 and MM 1144.

Table 2. Means square value for agronomic and fruit quality traits of 26 accessions of *Solanum macrocarpon* L.

	Df	Lvl (cm)	Lvw (cm)	Fr/pl	Frwt (g)	Sm/Pl	Frl (cm)	Frd (cm)	Fry (t/ha)	Fr/inf	TSS	Facom	Fapm	Frbr	Ht fl (m)	Htmt (m)	Sdy t/ha	D50 (d)	Frinf/pt
Acc	25	159.35***	35.61***	216.45***	7200.76***	563.56***	13.42***	17.08**	2339.42***	7.97***	4.74***	0.94***	1.44***	6.50**	0.09***	0.12***	0.36***	237.07***	7.97***
Rep	2	5.47**	6.98**	3.52	17.06	146.80	0.78	0.67	0.38***	1.21***	0.03	0.93***	0.02	0.33	0.004	0.03	0.07	18.30	0.72
Year	1	3.44	0.82	1.43	65.33	73.57	0.006	1.04**	3.91	0.001	0.06	0.007	0.11	0.06	0.02**	0.03	0.15	55.10	0.001
Acc x Year	25	1.42	0.88	5.66	82.94	32.36	0.006	2.09**	6.22	1.20	0.06	0.006	0.12	0.05	0.004***	0.06*	0.14**	10.43	1.20
Error	106	5.99	2.77	14.21	182.78	73.68	0.05	0.93	92.13	2.15	0.20	0.16	0.18	0.29	0.0001	0.02	0.09	13.00	2.15
σ g		51.12	10.95	62.67	2337.32	163.29	4.46	5.39	749.09	1.94	1.51	0.26	0.42	2.07	0.03	0.03	0.09	74.69	1.94
σ p		57.11	13.72	76.89	2522.11	236.97	4.51	6.31	841.22	4.09	1.71	0.42	0.60	2.36	0.03	0.05	0.18	87.69	4.09
σ e		5.99	2.77	14.21	182.78	73.68	0.05	0.93	92.13	2.15	0.20	0.16	0.18	0.29	0.0001	0.02	0.09	13.00	2.15
PCV		35.66	30.0	50.0	79.72	42.08	50.96	41.87	17.79	82.11	24.07	13.64	13.00	40.00	30.89	23.05	27.52	11.32	7.94
GCV		33.74	27.15	45.13	76.77	34.93	50.72	38.69	16.79	56.91	22.46	10.72	11.00	37.86	30.89	17.84	38.89	12.32	11.53
Hb (%)		86	82	94	97	86	98	82	97	87	96	93	82	95	90	63	51	91	67

***= indicate significant at 0.1% level of probability, Acc= Accessions, Rep= Replication, σ^2e = environmental variance, σ^2g = Genotypic variance, σ^2p = Phenotypic variance PCV = Phenotypic coefficient of Variation, GCV = Genotypic Coefficient of Variation, Hb = Broad Sense Heritability,

Lvl= leaf length, Lvw= leaf width, Fr/pl= Fruits/plant, Frwt/pl= Fruit weight of 3 fruits /plant, Sm/pl= Seed mass/plant, Fry= Fruit yield (tha^{-1}), Frl= Fruit length, Frd = Fruit diameter, Fr/inf = Fruits/infructescence, TSS = Total Soluble Solids, Facom= Fruit acidity at commercial ripeness, Fapm= Fruit acidity at physiological maturity, Syd t/ha= Seed yield ($t\ ha^{-1}$), Fbr= Fruit browning, Htfl= Height at flowering, Htmt= Height at maturity, Sdy = Seed yield (t/ha), D50= Days to 50% flowering, Frinf/pl= Fruit infructescence per plant.

Table 3. Mean values for agronomic and fruit quality traits of *Solanum macrocarpon* L. accessions investigated

	Lvl (cm)	Lvw (cm)	Fr/pl	Frwt (g)	Sm/pl (g)	Fry/pl (t/ha)	Frl (cm)	Frd (cm)	Fr/inf	TSS	Facm	Fapm	Fbr (minutes)	Htfl	Htmt	Sdy	Fr Inf/pl	D50F (d)	Finfpt
MM 150	35^{a}	17^{a-c}	12^{hg}	25^{h}	37^{b-e}	55^{d-h}	5.8^{b}	8.6^{a}	1^{e}	6.6^{cd}	5.6^{c-g}	4.4^{e-h}	4.6^{a-c}	0.39^{hi}	1.01^{c-f}	1.01^{c-f}	9.16^{f-h}	66^{l}	9.16^{f-h}
CR001	30b	11i-k	13gh	43g	64a-d	61cd	5.3b-d	2.9i	2a-c	5.3e-g	6.4ab	5.33ab	5.0ab	0.42f-h	0.88f-i	0.93d-g	10c-h	78d-f	
MM 12302	23d-f	13f-i	13gh	44g	24d-f	33l	2.0j-k	4.6fg	2a-c	5gh	5.6c-f	4.0eg	4.0cd	0.42c-i	0.85g-j	1.20a-d	10c-h	73g-j	
S00013	23d-f	19a	19d-f	136b	32b-f	48i-k	6.6a	5.3d-f	3a-b	6.3bc	6.1b-d	4.7b-f	4.6a-c	0.44c-f	1.04c-f	1.31a-c	11a-c	73g-j	
MM 10351	22d-f	11h-j	11i	57g-g	35c-f	46j-k	2.0j-k	3.6fg	2.6b-d	5.1f-h	5.4fg	3.6e	3.6de	0.64cd	0.87g-i	0.85d-g	11b-f	69j-l	
MM 583	32d-f	12g-j	15e-h	64d-f	31c-f	49h-k	3.1h-i	4.6fg	2.3c-e	6.5ab	5.5ef	4.3e-g	4.8ab	0.51e	0.92e-i	0.91d-g	10c-h	79b-e	
MM 1127	21fg	12g-j	15e-h	45g	36b-e	51e-k	2.6i-j	3.6hi	2de	4.6h	5.0g	5.0b-d	4.3b-d	0.46f	0.79ij	0.64fg	10d-g	73g-j	
MM 10181	31^{b}	18^{ab}	17^{e-g}	47^{fg}	45^{a-d}	47^{h-j}	6.6^{a}	3.5^{hi}	1^{e}	5.6^{d-f}	6.0^{b-e}	5.7^{a}	2.6^{g}	0.44^{f-g}	1.66^{b-e}	0.80^{e-g}	11^{b-g}	84^{a-c}	11^{b-g}
S00052	28^{c}	18^{ab}	15^{e-h}	173^{a}	41^{a-d}	28^{k}	5.5^{bc}	6.1^{cd}	1^{e}	6.1^{b-d}	6.0^{b-e}	4.7^{b-g}	2.0^{g}	0.45^{fg}	1.12^{a-c}	1.13^{b-e}	10.8^{b-g}	71^{i-k}	10.8^{b-g}
CR005	27^{cb}	14^{e-g}	12^{gh}	58^{d-g}	34^{b-f}	45^{j}	5.7^{f-h}	4.9^{f}	4^{a}	3.0^{j}	5.6^{c-g}	4.6^{c-g}	3.0^{ef}	0.70^{b}	1.00^{c-g}	1.00^{c-f}	11^{b-g}	86^{a}	11^{b-g}
MM 1144	26^{cb}	16^{cd}	31^{ab}	66^{de}	40^{a-e}	65^{bc}	4.3^{e-g}	5.0^{f}	2^{de}	4.6^{h}	5.6^{c-g}	5.0^{b-d}	5.3^{a}	0.60^{d}	0.82^{i-h}	0.71^{fg}	11.6^{a-c}	82^{a-d}	11.6^{a-c}
MM 11044	26^{cd}	12^{g-i}	14^{f-g}	60^{d-g}	54^{ab}	54^{d-h}	5.6^{bc}	4.8^{fg}	3^{b-d}	6.1^{b-d}	6.0^{b-e}	5.1^{a-c}	3.0^{ef}	0.66^{d}	0.95^{d-h}	0.85^{d-g}	0.67^{h}	71^{g-k}	0.67^{h}
MM 905	25^{cd}	16^{b-d}	14^{f-g}	22^{h}	32^{c-f}	77^{a}	3.6^{f-g}	6.6^{c}	2^{c-e}	4.7^{h}	5.7^{c-g}	5.1^{a-d}	4.3^{b-d}	0.41^{f-i}	1.23^{a}	0.67^{fg}	10.5^{b-h}	72^{g-j}	10.5^{b-h}
MM 1615	23^{d-f}	14^{e-g}	11^{h}	69^{d}	49^{a-c}	43^{j}	5.3^{b-d}	7.76^{ab}	2^{c-e}	6.2^{bc}	6.4^{ab}	5.3^{a-c}	3.0^{ef}	0.79^{a}	1.17^{ab}	0.93^{a-g}	10^{c-h}	83^{a-d}	10^{c-h}
MM 10260	23^{d-f}	15^{d-f}	22^{b-d}	68^{d}	44^{a-d}	76^{a}	1.2^{k}	1.38^{j}	2^{ce}	4.0^{i}	6.0^{b-e}	5.0^{b-d}	5.0^{ab}	0.70^{b}	1.0^{c-g}	0.98^{c-g}	10^{c-h}	77^{c-h}	10^{c-h}
MM 268	23^{d-f}	15^{d-f}	25^{b}	54^{d-g}	16^{f}	51^{g-j}	4.8^{c-e}	8.0^{ab}	1^{e}	6.0^{b-d}	5.7^{c-g}	4.9^{b-e}	5.3^{a}	0.42^{fi}	1.24^{a}	0.59^{g}	11.3^{a-e}	84^{ab}	11.3^{a-e}
MM 856	23^{d-f}	11^{i-k}	22^{b-d}	70^{d}	38^{b-e}	59^{de}	3.3^{hi}	4.03^{h}	2^{de}	5.6^{d-f}	6.0^{b-e}	4.9^{b-e}	4.6^{a-c}	0.61^{a}	0.71^{j}	0.76^{e-g}	9.16^{f-h}	78^{d-f}	9.16^{f-h}
CR006	23^{d-f}	14^{d-g}	13^{hg}	54^{d-g}	46^{a-c}	56^{d-g}	6.73^{a}	5.3^{d-f}	2^{c-e}	5.3^{e-g}	6.1^{bc}	5.2^{a-c}	2.0^{fg}	0.71^{b}	1.15^{a-c}	1.33^{a-c}	13^{a}	79^{c-e}	13^{a}

	Lvl (cm)	Lvw (cm)	Fr/pl	Frwt (g)	Sm/pl (g)	Fry/pl (t/ha)	Frl (cm)	Frd (cm)	Fr/inf	TSS	Facm	Fapm	Fbr (minutes)	Htfl	Htmt	Sdy	Fr Inf/pl	D50F (d)	Finfpt
MM 1132	22^{ef}	13^{efg}	17^{e-g}	49^{g-f}	46^{a-c}	59^{de}	4.5^{d-f}	6.00^{c-e}	2^{de}	5.8^{cd}	5.3^{gh}	4.2^{gh}	5^{ab}	0.45^{fg}	0.90^{f-i}	0.97^{c-g}	12^{ab}	71^{h-k}	12^{ab}
MM 714	21^{fg}	11^{i-k}	20^{c-e}	14^{h}	23^{ef}	58^{d-f}	2.9^{hi}	5.10^{ef}	2^{de}	4.0^{i}	5.8^{c-g}	5.0^{a-d}	5.3^{a}	0.39^{g-i}	0.91^{e-h}	0.65^{fg}	10.3^{c-h}	86^{a}	10.3^{c-h}
MM 10251	21^{fg}	13^{e-h}	13^{gh}	95^{c}	36^{b-e}	36^{k}	3.0^{hi}	5.33^{d-f}	3^{b-d}	6.0^{b-d}	6.8^{a}	4.6^{c-f}	4.6^{a-c}	0.67^{bc}	0.91^{e-h}	0.90^{d-g}	9.5^{d-h}	84^{a-c}	9.5^{d-h}
MM 10252	18^{gh}	11^{h-j}	13^{gh}	103^{c}	44^{a-d}	53^{e-h}	4.3^{e-g}	4.6^{fg}	3^{b-d}	7^{a}	5.8^{c-g}	4.3^{f-h}	4.6^{a-c}	0.60^{d}	1.00^{c-g}	$0.88d0^{g}$	9.3^{e-h}	78^{d-f}	9.3^{e-h}
MM 872	17^{hi}	12^{g-i}	33^{a}	21^{h}	23^{ef}	29^{k}	3.7^{f-h}	4.6^{fg}	3^{b-d}	5.1^{f-h}	5.8^{c-g}	4.3^{f-h}	3.6^{de}	0.38^{i}	0.81^{h-j}	0.83^{d-g}	9.3^{e-h}	71^{i-l}	9.3^{e-h}
MM 10161	15^{i}	12^{g-i}	24^{bc}	14^{h}	60^{a}	74^{ab}	6^{ab}	6.1^{cd}	4^{a}	5.3^{e-f}	5.6^{e-f}	4.3^{f-h}	4.6^{a-c}	0.45^{f}	0.96^{d-h}	1.53^{a}	10.3^{c-h}	74^{f-i}	10.3^{c-h}
MM 10256	14^{i}	9^{k}	15^{e-h}	57^{d-g}	38^{b-e}	59^{c-e}	3.10^{hi}	7.73^{b}	1^{e}	6.0^{b-d}	5.7^{c-g}	5.2^{a-c}	4.0^{ac}	0.41^{f-i}	1.12^{a-c}	0.81^{d-g}	9.0^{gh}	67^{kl}	9.0^{gh}
MM 12209	12^{j}	10^{jk}	15^{e-h}	23^{h}	50^{a-c}	73^{ab}	3.5^{g-i}	5.4^{d-f}	2^{c-e}	5.6^{d-f}	5.7^{c-g}	4.3^{e-h}	4.0^{ac}	0.45^{f-h}	0.93^{d-h}	1.47^{ab}	11.5^{a-d}	67^{j-l}	11.5^{a-d}

Lvl= Leaf length, Lvd= Leaf diameter, Fr/pl= Fruits per plant, Fr wt = Fruit weight, Sm/pl = Seed mass/plant, Fry/pl= Fruit yield Frl= Fruit length, Frd= Fruit diameter, Fr/inf= Fruits/infructescence, TSS = Total Soluble Solids, Facm= Fruit pH at commercial ripeness, Fapm = Fruit pH at physiological maturity, Fbr = Time to fruit browning, HtFl= Plant height at flowering, HtMt = Plant height at maturity, Sdy = seed yield(t/ha), D50F = Days to 50% flowerin.

Principal Component and Cluster Analysis

The relative discriminating power as shown by eigenvalues was high for the first three principal component axes with eigenvalues in excess of 2.20, altogether they explained 46% of the total variance (Table 4). The large number of PCs implied narrow genetic base in the population. In the pooled analysis, the percentage contribution of agronomic traits toward the genetic diversity was maximum (45%) in plant height at flowering, followed by days to 50% flowering (37%), plant height at maturity (36%), fruit infructescence (34%). This showed the discriminatory power of plant height and length of time to flowering for selection and breeding. The first PC axis demonstrated inverse relationship between plant height (m) and seed yield (t/ha). In contrast a positive association was recorded among fruit infructescence/plant, plant height and days to 50% flowering. The fruit browning time (seconds) recorded negative coefficient low in magnitude on the first principal component axis. The second PC axis accounted for additional 16% of the unexplained variation in first principal component axis; and demonstrated high discriminatory power and positive variation for fruit browning (seconds) and fruits/plant, both traits showed negative correlation coefficient. Traits that contributed most to the first PC (plant height at flowering, earliness, height at maturity and fruit infructescence/plant) displayed negative correlation coefficient with the major traits of the second PC axis.

The projection of accessions on the plot of PC 1 by 2 showed distance among the accessions and variables responsible for the variation. Accessions along principal component axes 1 and 2 displayed a spread of accessions into four quadrants (Figure 1). Seven accessions were projected in the first quadrant, they displayed geographic heterogeneity. The spread of accessions in this quadrant demonstrated high variation for earliness, leaf length and leaf width and fruits/plant. They recorded moderate though positive coefficients on PC axes 1 and 2. In this quadrant, MM 268 was moderately separated from other entries with maximum contribution to variability, although this variation was low compared to entries dispersed in the second quadrant. The grouping of accessions in the second quadrant showed consistence with high variability and relationship for plant height at flowering and maturity, fruits infructescence/plant and fruit acidity at commercial harvest and maturity. The accessions in the third quadrant displayed relationship for seed yield (t/ha) and fruit width (cm). MM12209 and MM10161 displayed large variation for earliness and fruit browning. The fourth quadrant displayed geographic heterogeneity and high variation for fruit browning (seconds), fruit yield (t/ha) and fruit taste. The multivariate techniques (PCA and dendrogram) detected phenotypic distinctness, similarities, and overlap of agronomic and fruit quality traits. Dispersion on the plot of PC 1 by 2 (Figure 1) is consistent with the range of variation and broad genetic base of the accessions. Plant height at flowering and length of time to flowering were attributed toward genetic distance among accessions and contributed largely to differentiation of all the genotypes into the four quadrants. The dendrogram drawn for 26 accessions

Table 4. Eigen values and vectors for seven principal component axes estimated for agronomic and fruit quality traits among 26 accessions of *Solanum macrocarpon* L.

Traits	Prin 1	Prin 2	Prin 3	Mean±SD	Min – Max
Days to 50% flowering	**0.37**	0.14	-0.05	75.8 ±6.49	64-90
Number of filaments	0.24	0.29	**-0.30**	6.34±1.05	5-9
Fruit diameter	-0.15	-0.02	0.04	6.00±1.68	1.38-7.00
Fruit length	0.17	-0.08	0.07	4.16±1.40	1.20-7.89
Leaf length	0.21	0.31	-0.16	21.19±5.20	1—37
Leaf width	0.13	0.28	-0.04	12.19±2.25	7-21
Fruits/plant	0.11	**0.37**	0.27	17.54±6.99	9-44
Seed mass/plant	0.11	-0.21	0.17	36.58±11.06	11-134
Fruits yield (t/ha)	-0.05	0.21	**0.42**	54.96±15.00	27-88
Fruit weight	0.02	0.11	**0.48**	163.0±0.20	111-185
Fruits/infructescence	0.20	**-0.32**	-0.29	2.46±0.50	1.0-5.0
Total Soluble Solids	0.02	-0.03	-0.12	5.43±0.97	3.0-7.0
Fruit acidity at commercial harvest	0.27	-0.18	0.003	5.99±0.24	4.0 7.00
Fruit acidity at physiological maturity	0.29	-0.04	0.11	4.75±0.51	4.0-6.00
Fruit taste	-0.15	0.07	**-0.42**	1.96 ±0.20	1-2
Time to fruit browning after cut	-0.07	**0.42**	-0.14	3.88±1.07	2-6
Plant height at flowering	**0.45**	-0.12	0.0001	0.56±0.12	0.34-0.80
Plant height at maturity	**0.36**	-0.09	0.14	0.97±0.20	0.60-2.12
Fruits infructescence/plant	**0.34**	-0.08	0.04	4.88±1.88	5-16
Seed yield (t/ha)	-0.17	-0.21	0.14	1.09±0.56	0.16-3.57
Eigen value	3.89	3.32	2.36		
Proportion (%)	19	16	11		
Cumulative (%)	19	34	46		

(Figure 2) based on agronomic and fruit quality traits showed similarity with the ordination of the accessions on the plot of principal component axes 1 and 2. (Figure 1). The dendrogram showed three distinct groups with overlap of agronomic and fruit quality traits within cluster and between clusters. The 26 accessions were ordered into three clusters at 15% level of phenotypic distance. The first cluster was divided into two sub - clusters 'a' and 'b', MM1144, MM856 and MM10260 to sub cluster 'a' while MM268, 10256 and MM 150 to sub-cluster 'b'. Eleven accessions starting from MM905 to MM1132 were grouped in second cluster, which was divided into 3 sub clusters. MM905, MM 1127, MM12209 to MM714 were ordered into sub cluster 'a', while MM10351, MM 12302 and

MM872 to sub cluster 'b' and MM10161 and MM1132 were grouped in to sub cluster 'c'. The third cluster was divided into two groups, CR006, MM11044, MM10252, MM1615, MM10251 and S00052 to group 'a' and CN012 and CR001 to group 'b'. MM11044 and CR005, MM1615 and MM10251, CN012 and CR001 are most related at 2%, 4% and 6% distance respectively. The study showed that within and between clusters accessions from different ecogeographic regions with high level of agronomic similarities and overlap were grouped, this indicated geographic heterogeneity. Similarly agronomic and fruit quality traits were not restricted to a specific geographic location. Dispersion and overlap among accessions of *Solanum macrocarpon* for agronomic and fruit quality traits mirrored phenotypic variation reported in this species (Shippers, 2002). The magnitude of genetic dissimilarity found among the accessions indicated that genetic improvement of earliness, fruit yield (t/ha), seed yield (t/ha), fruit taste, fruits/infructescence, fruit infructescence/plant and fruit browning will be feasible. Inter cluster hybridization will help to develop desirable segregants, for example, accessions belonging to clusters 1'b' and 2 'c' may aggregate genes for earliness, fruit length, fruit diameter, fruits/plant, seed yield (kg), fruit browning and fruit yield (t/ha). Similarly, inter cluster hybridization among members of cluster 1 'b' and cluster 3 may probably develop hybrids with superior fruit diameter (cm), seed yield (kg), fruit yield (t/ha) and fruit browning. Plant height, fruits/ infructescence and earliness contributed most to cluster constellation and variation among accessions, these traits and are not restricted to provenance. Hybridization among clusters may evolve desirable variations upon which selection can be made for variety development.

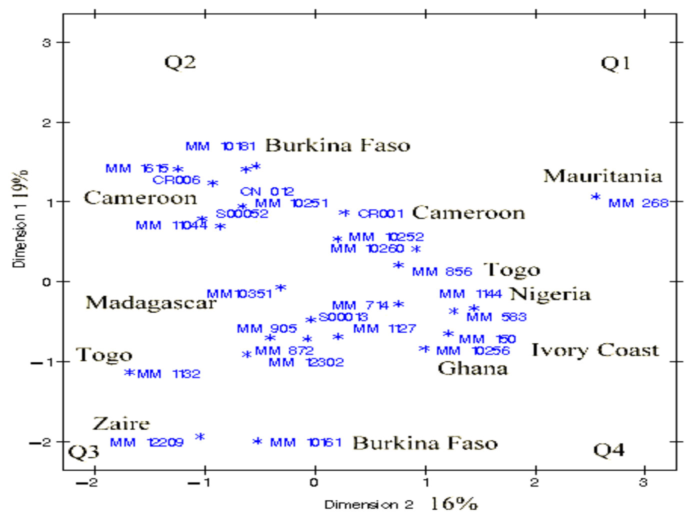

Fig. 1. Plot of the first two principal components axes showing spatial distribution of 26 accessions belonging to *Solanum macrocarpon* L. based on agronomic and fruit quality descriptors.

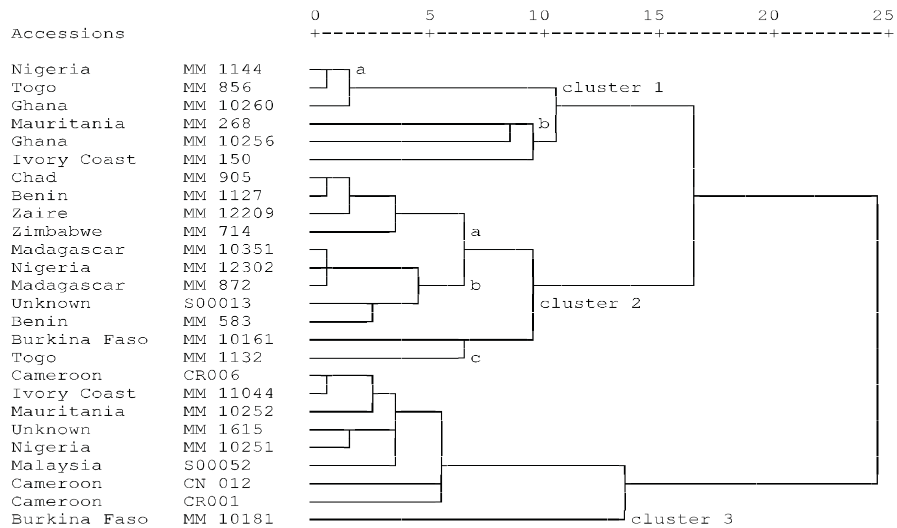

Fig. 2. Dendrogram constructed from agronomic and fruit quality data using UPGMA clustering option Ward (1963).

For genetic improvement in fruit yield, it is worthwhile to select accessions grouped in cluster 1 'a' as donor parents. Members of cluster 1 'b' and cluster 3 are superior for plant height; the former showed greater potential for fruit length (cm), fruit diameter (cm) and fruits/plant. Considering fruit infructescence/plant and plant height (m), members of cluster 3 are potential donor parents. If genetic improvement was in favour of fruit taste (sweet) and high sugars (high pH value), accessions grouped in clusters 1 'a' and 2 'b' may be considered as donor parents. Accessions ordered in cluster 1'b' constituted early maturing group, and are donor parent for earliness, fruit length and diameter. Specific use of MM150, MM10256 (cluster 1'b') and MM12209 (cluster 2'a') as source of gene for earliness, may evolve segregating population upon which selection of maturity groups can be advanced. Members of cluster 1 'a' and 3 are potential donor parent for delayed maturity, fruit and seed yield and direct commercialization. Distinctively MM10260 performed best for fruit yield (t/ha) compared to other accessions. The absence of duplicates provided evidence that these accessions are distinct and could be conserved for future genetic studies, specifically for molecular analysis of diversity.

Conclusion

The overall importance of the investigation was related to quantification of agronomic and fruit quality diversity, identification of promising traits and accessions for genetic improvement. Both type of analyses i.e., variance component and multivariate diversity provided good insight on the magnitude of variation, similarities and distinctness among the accessions. Agronomic and fruit quality traits investigated showed ample variation among the accessions. The best performing accessions for single and multiple traits i.e. earliness, fruit number, fruit yield and fruit infructescence in this population evaluated were identified and potential donor parents for further genetic improvement of Gboma eggplant through hybridization.

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HEAVY METAL ACCUMULATION IN LEAFY VEGETABLES GROWN IN INDUSTRIAL AREAS UNDER VARYING LEVELS OF POLLUTION

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Abstract

The concentration of lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co) and chromium (Cr) in three popular leafy vegetables such as spinach (*Spinacia oleracea*), red amaranth (*Amaranthus tricolor*) and amaranth (*Amaranthus oleraseus*) and that in the respective soils were assessed. These crops and soils were collected from two industrial areas (Kalakoir and Zorun, Konabari, Gazipur), and one non-industrial area (Bangladesh Agricultural Research Institute-BARI) under Gazipur district. The concentration of heavy metal in different parts of plant followed the roots>leaves>stem and in soils the order was Kalakoir (pollution)> Zorun (medium pollution) > BARI (low/non-pollution). In all three leafy vegetables similar trend of metal contents was observed i.e. Ni>Cr>Pb>Co>Cd. In the highly pollution area (Kalakoir) the Pb and Ni concentration was found in the order of amaranth>spinach>red amaranth. The Cd concentration was in the order of spinach>amaranth>red amaranth whereas for Cd it was amaranth>red amaranth>spinach and for Cr it was red amaranth>amaranth>spinach. The Pb, Cd, Ni, Co and Cr concentrations in the studied vegetables grown in the low polluted area were below the maximum acceptable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives, except, Cd in spinach and amaranth. However, the higher concentrations of Pb, Cd, Ni, Co and Cr in vegetables grown in the industrial areas indicates that industrial discharge causes heavy metals contamination of soil and eventually their accumulation in plants.

Keywords: Leafy vegetables, heavy metal, industrial areas.

Introduction

Anthropogenic activities have altered the environment significantly throughout the world including mining, industry and agriculture as well as increase of the urbanization level (Wang *et al.,* 2008). Disposal of sewage water and industrial wastes is a great problem. Often it is drained to the agricultural lands where it is used for growing crops including vegetables. These sewage effluents are considered not only a rich source of organic matter and some nutrients, but these

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also elevate the level of heavy metals like iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd), and cobalt (Co) in soils (Singh *et al.,* 2004).

In the low concentrations, many metals are essential to life (Kashif *et al.,* 2009). Trace quantities of certain heavy elements such as Co, Cu, Mn and Zn are essential micronutrients for higher animals and for plants (Somers, 1974). However, excessive accumulation of trace elements in agricultural soils through wastewater irrigation may not only result in soil contamination, but it also affects food quality and safety (Muchuweti *et al.,* 2006; Sharma *et al.,* 2007). Some trace elements are essential in plant nutrition, but plants growing in the nearby zone of industrial areas accumulate increased concentration of heavy metals, serving in many cases as bio monitors of pollution loads (Mingorance *et al.,* 2007).

Vegetables are an important part of human's diet. It is potential source of nutrients which have marked health effects (Arai, 2002). Vegetables are plants that are eaten raw or cooked. It is described as shrubs or herbaceous annual or perennial plants that are eaten by man (Longman, 2005). There are different kinds of vegetables ranging from edible roots, stems, leaves, fruits or seeds. Each group contributes to diet in its own way (Hanif *et al.,* 2006). Vegetables cultivated in soils polluted with toxic metals due to industrial activities take up heavy metals and accumulate them in their edible and non-edible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants because there is no good mechanism for their elimination from the human body (Alam *et al.,* 2003; Arora *et al.,* 2008). Trace elements are harmful because of their nonbiodegradable nature, long biological half-lives, and their potential to accumulate in different body parts.

Vegetables, especially those of leafy vegetables grown in heavy metals contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils (Al Jassir *et al.,* 2005). Previous study revealed that the concentrations of metal in vegetables varied with the locations, showing the trend: high-level of pollution> medium-level of pollution> low-level of pollution (Naser *et al.,* 2009). The present study was carried out in industrial areas of Turag River vicinity, Gazipur, Bangladesh, where irrigation of vegetable crops with polluted river water is a common practice. Knowledge about contamination of vegetables with heavy metals from industrial areas of Turag River vicinity is yet to be obtained. In this context, the present study was undertaken to investigate the concentration of heavy metals (Pb, Cd, Ni, Co and Cr) in commonly grown leafy vegetables and their level in respective crop-soils.

Materials and Methods

Soil and plant sampling

Soil and leafy vegetables samples were taken from three cropping areas exposed to different degrees of pollution. Area 1– high-level of pollution: Pollution by irrigation water (Kalakoir, Konabari, Gazipur- 23°59′32.65″N, 90°19′43.43″E), the vegetable samples in this area were taken from the site irrigated with the Turag river water. The river Turag is highly polluted by industrial effluents, sewage sludge, municipal waste water and urban pollution (Islam *et al.,* 2012b). Area 2– medium-level of pollution: Pollution by pond and kennel's water (Zorun, Konabari, Gazipur- 23°59′53.38″N, 90°19′21.77″E), which is polluted by industrial effluents, sewage sludge, municipal waste water and urban pollution. During rainy season pond and canals are over flown by rain water and submerse the adjacent cultivable land where the farmers grow their vegetables in winter. Area 3– low-level of pollution: The same vegetables samples and soils were collected from BARI (Bangladesh Agricultural Research Institute- 23°59′31.15″N, 90°24′50.95″E), experimental field, regarded as low-level pollution area. The collected plant samples included spinach (*Spinacia oleracea*), red amaranth (*Amaranthus tricolor*) and amaranth (*Amaranthus oleraseus*). Plant samples were collected from 6 week olds plants. Soil and vegetable samples were collected from different sites of each location. The plant samples represented different parts of plant roots, stem and leaves. Soil samples of 0–15 cm depth were collected by a stainless steel auger at the same time when vegetable samples were collected, and samples were taken to the laboratory.

Preparation and preservation

In the laboratory, all vegetables were washed with fresh running water to remove dust, dirty materials, possible parasites or their eggs and then were again washed with deionized water. The clean vegetable samples were air-dried and placed in an electric oven at 65 °C for 72–96 h depending on the sample size. The samples were homogenized by grinding using a ceramic coated grinder. All soil samples were spread on plastic trays and allowed to dry at ambient temperature for one week. Soil pH was determined by glass electrode pH meter and electricity conductivity (EC) was measured by conductivity meter in 1:5 ratio of soilwater suspension (Yong *et al.,* 2011). The dry samples of soils were ground with a ceramic coated grinder and sieved through a nylon sieve. The final samples were kept in labeled polypropylene containers at ambient temperature before analysis.

Digestion and determination

The samples were digested with HNO_3 and $HClO_4$ (5:1 volume) for total metal estimation, as described by Misra and Chaturvedi (2007). One gram of each sample was weighed into 50-ml beaker, followed by the addition of 10 ml mixture of analytical grade acids HNO_3: $HCIO_4$ in the ratio 5:1, and left overnight for complete contact of material. Next day, the digestion was performed at a temperature of about 190 ºC for 1.5 h. After cooling, the samples were transferred into 50 ml volumetric flask and solution was made up to a final volume raised up to the mark with distilled water. The metal concentrations were determined by atomic absorption spectrometry using a VARIAN model AA2407

Atomic Absorption Spectrophotometer (AAS). Analysis of each sample was carried out three times to obtain representative results and the data reported in µg g^{-1} (on a dry matter basis). Statistical differences were judged by Tukey's multiple comparisons test by using Excel Statistics version 4.0 (Esumi Co. Ltd., Tokyo, Japan).

Results and Discussion

Chemical properties of soils

The pH of soil samples from high-level and medium-level pollution area was 6.58 and 6.60, respectively, which indicates that the soils were slightly acidic to neutral. On the other hand pH from low-level pollution area was slightly alkaline in reaction pH (7.43). These pH values from polluted area (either high-level or medium-level) were within the range of the pH of the surface soils (ranged from 6.10 to 6.98) from the solid waste dumping site near to the present study area (Islam *et al.,* 2012a). The study revealed that the EC of the high-level polluted soils receiving irrigation with industrial effluents was higher (3.26 deciSiemens per meter – dS m^{-1}) than the soils of medium-level polluted (1.15 dS m^{-1}), and the value of EC was lowest in low-level polluted area (0.61 dS m^{-1}). The presence of large amount of ionic substance and soluble salts have resulted in increased value of EC in the industrial effluents contaminated irrigated soil samples in comparison to the others (Islam *et al.,* 2012a).

Heavy metal contents in plant parts

The mean concentrations of Pb, Cd, Ni, Co, and Cr in different parts (roots, stem, and leaves) of vegetables studied were given in Tables 1–3. The concentrations of heavy metals in these samples were quite variable such as 0.64−5.97 µg $g^{-1}$for Pb, 0.22–1.28 µg g^{-1} for Cd, 4.02–46.5 µg g^{-1} for Ni, 0.39–2.62 µg g^{-1} for Co, and 1.71–6.99 µg g^{-1} for Cr. It was observed that high contents of Cd, Ni and Cr were accumulated in roots of spinach (1.28, 46.5 and 2.62 µg g^{-1}, respectively) grown on high-level polluted area. The spinach exhibited higher levels of Pb (5.97 µg g^{-1}) in leaves followed by red amaranth, while stem of red amaranth in low-level polluted area showed low concentration of Pb (0.64 µg g^{-1}). The lowest concentration of Co (0.39 µg g^{-1}) was observed in spinach stem. On the other hand, amaranth roots showed the highest concentration of Co (2.62 µg g^{-1}). Present study revealed that all the heavy metal content was found greater in spinach grown in polluted areas (either high-level or medium-level), only Co was found greater in roots of amaranth in the same location. With few exceptions, the magnitude of heavy metals detected in various plant components particularly in roots, stems and leaves was found as roots>leaves>stem. Content of heavy metal in different parts of vegetables followed the trend as high-level of pollution> medium-level of pollution> low-level of pollution.

The mean concentrations of Pb, Cd, Ni, Co and Cr in whole plant (roots, stem and leaves) of three leafy vegetables were shown in Table 4. The concentrations of heavy metals (μg g^{-1} of dry wt.) in those vegetables quite varied, such as Pb (0.76 to 5.73 μg g^{-1}), Cd (0.29 to 1.14 μg g^{-1}), Ni (4.94 to 33.8 μg g^{-1}), Co (0.49 to 2.38 μg g^{-1}) and Cr (2.23 to 6.67 μg g^{-1}). The levels of heavy metal in all the three vegetable samples from the polluted area (either high-level or medium-level) were higher than those from the low-level polluted (BARI) area. Several studies have indicated that vegetables grown in heavy metals contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soils (Al Jassir *et al.,* 2005; Farooqet *et al.,* 2008).

Statistically significant difference (P<0.01) in heavy metal (Pb, Cd, Ni, Co, and Cr) contents was found between polluted (either high-level or medium-level) and non-polluted areas in both vegetables and soils. For all the three vegetables and for all locations a similar trend in metal contents was observed i.e. Ni>Cr>Pb>Co>Cd and the magnitude of heavy metal contamination was high-level of pollution> medium-level of pollution> non-pollution. However, their values in all vegetables were different. In high-level polluted area the extent of heavy metal content in vegetables can be regarded in the order of amaranth>spinach>red amaranth for Pb, spinach>amaranth>red amaranth for Cd, amaranth>spinach>red amaranth for Ni, amaranth>red amaranth>spinach for Co and red amaranth>amaranth>spinach for Cr.

Proportion of heavy metal contents increased (%) in spinach, red amaranth and amaranth in high-level polluted and medium-level polluted areas in comparison to non-polluted area showing a range from 253 to 451%, 489 to 507% and 394 to 429% for Pb; 27 to 139%, 176 to 197% and 61 to 128% for Cd; 461 to 553%, 466 to 528% and 349 to 567% for Ni, it was 188 to 227%, 134 to 177% and 65 to 95% for Co; and was 115 to 142%, 165 to 174% and 185 to 198% for Cr, respectively.

In our previous study (Naser *et al.,* 2009), we determined the levels of Pb, Cd and Ni in samples of spinach, tomato and cauliflower 0.767-1.440 μg g^{-1}, 1.027-1.968 μg g^{-1}, 0.486-1.119 μg g^{-1}, respectively for Pb; 0.559-1.40 μg g^{-1}, 0.630-1.303 μg g^{-1}, 0.506-0.782 μg g^{-1}, respectively for Cd and 1.265-5.369 μg g^{-1}, 2.031-4.957 μg g^{-1}, 1.698-4.447 μg g^{-1}, respectively for Ni, grown in industrially (Konabari, Gazipur; Keranigonj, Dhaka), and non-industrial (Bangladesh Agricultural Research Institute-BARI, Gazipur) areas. The reported Cd concentrations were found similar to the current levels but the Pb and Ni concentrations were higher than the reported values. The higher concentrations of Pb and Ni might be due to the differences in location. On the other hand, concentrations of Pb and Ni in spinach from BARI were higher than those from previous study (Naser *et al.,* 2009). It might be due to the experimental field, which was top-dressed by foreign soil near about couple of years before. So, it is not representing the previous tested soils.

The Pb levels in vegetables in this study were higher than the reported values (Alegria *et al.,* 1991; Jamali *et al.,* 2007). For example, the levels of Pb in spinach grown in the waste water irrigation area (TVS) was 0.12 µg g^{-1} dry wt., while the cannel water irrigation area (CVS) showed 0.33 0.12 µg g^{-1} dry wt. (Jamali *et al.,* 2007). The Pb concentration in all the vegetables from polluted areas (either high-level or medium-level) was above the permissible levels (Table 4) of India (Awashthi, 2000) and was lower or similar with the maximum level as per FAO/WHO standard (FAO/WHO - Codex Alimentarious Commission, 1984), except, Pb content in amaranth from polluted area. On the other hand, the Pb levels in this study were lower than the concentrations of Pb (17.5–25.0 µg g^{-1}) in vegetables grown in wastewater treated areas of Varanasi, India (Sharma *et al.,* 2006) and the levels of Pb (6.77 µg g^{-1}) in vegetables irrigated with mixtures of wastewater and sewage from Zimbabwe (Muchuweti *et al.,* 2006).

Table1. Concentration (±, standard deviation) of Pb, Cd, Ni, Co and Cr in the roots of three leafy vegetables grown in areas with different levels of pollution by heavy metals

Vegetable	Level of pollution in the growing area	Concentration (µg $g^{-1}$of dry wt.)				
		Pb	Cd	Ni	Co	Cr
Spinach	High	4.87±0.35	1.28±0.54	46.5±2.63	1.78±0.25	6.99±0.78
	Medium	3.08±0.35	0.66±0.06	40.8±3.11	1.54±0.19	5.64±0.16
	Low	0.90±0.11	0.51±0.09	5.23±0.88	0.61±0.08	2.73±0.34
Red Amaranth	High	3.71±0.53	1.02±0.18	46.3±2.38	2.37±0.23	6.90±0.64
	Medium	3.67±0.75	0.86±0.21	40.0±2.87	2.10±0.22	6.58±0.58
	Low	0.79±0.19	0.40±0.03	5.75±0.90	1.01±0.13	3.02±0.39
Amaranth	High	5.94±0.45	1.20±0.47	37.8±2.20	2.62±0.27	6.55±0.46
	Medium	6.08±1.06	0.80±0.13	24.9±1.89	2.02±0.09	6.45±0.29
	Low	1.65±0.18	0.61±0.10	5.15±0.47	1.56±0.19	2.61±0.29

Vegetables from the polluted (either high-level or medium-level) area showed higher levels of Cd than those from the low-level polluted area (Table 1–3). In fact, significant differences ($P<0.01$) were found in the level of Cd in all tested vegetables between polluted (either high-level or medium-level) and low-level polluted areas. The above results obtained are in line with Lone *et al.,* (2003), who studied the effect of sewage and tubewell water on heavy metal content of spinach in Pakistan, they found considerably higher concentration of Cd than those soils irrigated with tubewell water. Our study also showed that the average Cd levels measured in vegetables were higher than that in leafy and non-leafy vegetables in India (Tripathi *et al.,* 1997). Similar to Pb as reported by the group of researchers (Jamali *et al.,* 2007), the concentration of Cd in vegetables sampled from TVS was high 0.14 µg g^{-1} (spinach) on a dry wt. basis, whereas in CVS showed 0.01 µg g^{-1}. The Cd concentration was below the Indian standard (Awashthi, 2000) but above the safe levels of FAO/WHO and China (SEPA, 2005). The Ni concentrations in vegetables in this study were higher compared to the Pb and Cd concentrations, and the heavy metal concentration from industrial area was higher than that from non-industrial area (Yusuf *et al.,* 2003). The Ni concentration was below the safe level as demonstrated by FAO/WHO and it was above the safe levels of Indian standard (Awashthi, 2000) and China (SEPA, 2005). The maximum Co concentration (2.38 µg g^{-1} dry wt.) was found in amaranth whereas the mean value was 2.27 and 1.60 µg g^{-1} dry wt. for red amaranth and spinach, respectively, which was lower than the mean value 9.2 to 11.3 µg g^{-1} dry wt., for garden spinach in India (Farooq *et al.,* 1999). Cobalt concentration was below the safe levels of FAO/WHO. The mean levels of Cr in vegetables in the present study were significantly lower than the concentrations of other reported studies (Gupta *et al.,* 2008; Sharma *et al.,* 2007) in India. However, it was close to the result obtained from past study in Bangladesh (Ahmad and Goni, 2009) and in China (Liu *et al.,* 2006). Chromium concentration in all the vegetables from polluted areas (either high-level or medium-level) examined in the present study was above the permissible levels recommended by FAO/WHO and China (SEPA, 2005) but below the maximum limit for India (Awashthi, 2000).

Table 2. Concentration (±, standard deviation) of Pb, Cd, Ni, Co and Cr in the stem of three leafy vegetables grown in areas with different levels of pollution by heavy metals

Vegetable	Level of pollution in the growing area	Concentration (µg g^{-1} of dry wt.)				
		Pb	Cd	Ni	Co	Cr
Spinach	High	4.37±0.49	1.11±0.16	21.3±2.25	1.40±0.27	5.57±0.57
	Medium	3.06±0.22	0.64±0.09	20.0±2.76	1.28±0.12	5.02±0.92
	Low	0.70±0.12	0.49±0.16	4.55±0.70	0.39±0.06	2.15±0.53
Red Amaranth	High	4.53±0.47	0.74±0.15	24.1±3.33	2.14±0.20	6.34±0.77
	Medium	4.39±0.43	0.80±0.18	21.9±1.64	1.63±0.29	6.92±0.15
	Low	0.64±0.12	0.22±0.06	4.02±0.58	0.64±0.09	2.50±0.30
Amaranth	High	5.50±0.42	1.02±0.33	34.3±2.26	2.23±0.16	6.45±0.29
	Medium	4.26±0.27	0.67±0.18	22.2±3.58	1.98±0.16	6.07±0.81
	Low	0.71±0.22	0.43±0.06	5.04±0.59	0.83±0.07	2.37±0.19

Table 3. Concentration (±, standard deviation) of Pb, Cd, Ni, Co and Cr in the leaves of three leafy vegetables grown in areas with different levels of pollution by heavy metals

Vegetable	Level of pollution in the growing area	Concentration (µg g^{-1} of dry wt.)				
		Pb	Cd	Ni	Co	Cr
Spinach	High	5.97±0.30	1.02±0.15	31.9±3.38	1.63±0.24	5.70±0.36
	Medium	3.61±0.18	0.52±0.03	24.6±2.23	1.41±0.17	5.62±0.23
	Low	1.16±0.16	0.43±0.07	5.48±0.47	0.47±0.09	2.69±0.24
Red Amaranth	High	5.51±0.35	0.85±0.14	22.5±3.68	2.31±0.15	6.76±0.12
	Medium	5.29±0.65	0.77±0.12	22.1±1.79	2.02±0.30	5.82±0.51
	Low	0.85±0.15	0.23±0.02	5.04±0.62	0.80±0.07	1.77±0.22
Amaranth	High	5.75±0.38	0.78±0.22	29.3±2.48	2.30±0.15	6.93±0.40
	Medium	5.70±1.07	0.68±0.15	21.1±3.54	2.02±0.03	6.52±0.43
	Low	0.89±0.03	0.30±0.08	4.99±0.61	1.27±0.16	1.71±0.33

Table 4. Concentration (±, standard deviation) of Pb, Cd, Ni, Co and Cr in whole plant (roots, stem and leaves) of three leafy vegetables grown in areas with different levels of pollution by heavy metals

Vegetable	Level of pollution in the growing area	Concentration (µg g^{-1} of dry wt.)				
		Pb	Cd	Ni	Co	Cr
Spinach	High	5.07±0.79c	1.14±0.31c	33.2±11.2 b	1.60±0.27b	6.09±0.85b
	Medium	3.25±0.35b	0.61±0.09b	28.5±9.74b	1.41±0.18b	5.43±0.57b
	Low	0.92±0.23a	0.48±0.10a	5.09±0.74a	0.49±0.12a	2.52±0.44a
Red Amaranth	High	4.59±0.87b	0.87±0.18b	31.0±11.8b	2.27±0.20b	6.67±0.56b
	Medium	4.45±0.89b	0.81±0.16b	28.0±9.21b	1.92±0.32b	6.44±0.63b
	Low	0.76±0.16a	0.29±0.09a	4.94±0.97a	0.82±0.18a	2.43±0.61a
Amaranth	High	5.73±0.41c	1.00±0.35c	33.8±4.20c	2.38±0.25b	6.64±0.40b
	Medium	5.35±1.13b	0.71±0.15b	22.7±3.19b	2.01±0.10b	6.35±0.52b
	Low	1.08±0.45a	0.44±0.15a	5.06±0.49a	1.22±0.35a	2.23±0.47a
Safe Limit (µg g^{-1}) [a]		5	0.3	20	50	5

Mean values in the same column followed by the same letters are not significantly different ($P < 0.01$).

[a] FAO/WHO-Codex Alimentarious Commission (1984).

Heavy metal contents in soils

Lead, Cd, Ni, Co and Cr concentrations in soil samples (Table 5) followed a trend similar to vegetables heavy metals concentrations of vegetables. Thus, the increase of metal contents (µg g^{-1}) in soils of medium-level and high-level polluted areas were 109 to 274%, 104 to 173% and 112 to 269% for Pb; 126 to 187%, 162 to 164% and 119 to 157% for Cd; 132 to 185%, 169 to 189% and 102 to 171% for Ni; it was 151 to 212%, 171 to 250% and 269 to 286% for Co; and was 142 to 174%, 151 to 178% and 154 to 159% for Cr, respectively. Comparing the metal concentration in soil with guidelines for soils showed that all metal concentration was below the safe limits for soils (Table 5).

Table 5. Concentration (±, standard deviation) of Pb, Cd, Ni, Co and Cr in soils of three leafy vegetables from areas with different levels of pollution by heavy metals

Vegetable	Level of pollution in the growing area	Concentration (µg g^{-1} of dry wt.)				
		Pb	Cd	Ni	Co	Cr
Spinach	High	17.5±0.55c	2.03±0.08c	39.9±1.10c	14.3±1.28b	32.3±1.40b
	Medium	9.75±1.23b	1.60±0.16b	32.5±1.60b	11.5±1.45b	28.6±1.71b
	Low	4.67±0.58a	0.71±0.03a	14.0±0.26a	4.59±0.84a	11.8±1.33a
Red Amaranth	High	13.5±1.87b	1.86±0.12b	38.5±0.92b	14.6±1.78b	33.4±0.17b
	Medium	10.1±0.35b	1.84±0.09b	35.7±3.62b	11.3±1.22b	30.1±1.05b
	Low	4.95±0.17a	0.70±0.03a	13.3±0.62a	4.17±1.50a	12.0±1.46a
Amaranth	High	18.7±1.20c	2.01±0.19b	41.0±2.40c	15.6±2.19b	31.9±1.91b
	Medium	10.8±0.59b	1.71±0.16b	30.7±1.79b	14.9±1.31b	31.3±1.06b
	Low	5.07±0.24a	0.78±0.17a	15.2±2.05a	4.04±0.63a	12.3±0.82a
Safe Limit (µg g^{-1}) [b]		100	3	50	50	100

Mean values in the same column followed by the same letters are not significantly different ($P < 0.01$).

[b][Ewers U (1991).

Relationship between soil and plant metal concentrations

The correlation between the heavy metal contents in soils and their corresponding contents in vegetables indicated positive correlation, the *r* values ranged from 0.599 to 0.999 (Table 6). The higher correlation between soil and plant corresponded to Cr in amaranth. On the other hand, comparatively lower correlation between soil-plant corresponded to Cr in spinach. However, the degree of relationship between soil and plant in respect of three locations was irregular.

Bioconcentration factor

Bioconcentration factor (BCF) of different heavy metals from soil to vegetables are one of the key components of human exposure to metals through the food chain (Table 7). It is calculated as the ratio between the concentration of heavy metals in the vegetables and that in the corresponding soil (all based on dry weight) for each vegetable separately (Liu *et al.,* 2006). The TF values were below 1, and more TF values were obtained for Ni whereas it was less for Co as compared to Pb, Cd and Cr. The trend of TF for heavy metals in different leafy vegetables studied were in the order of Ni>Cd>Pb>Cr>Co. The TF values ranges were: Pb 0.153 – 0.500, Cd 0.383 – 0.675, Ni 0.340 – 0.878, Co 0.110 – 0.309, and Cr 0.181 – 0.215. These values were higher than those observed (Ahmad and Goni, 2009). The degree of TF showed irregular pattern in high-level polluted, medium-level polluted and low-level polluted areas, however the trend of TF for location were polluted (either high-level or medium-level)>low-level polluted.

Table 6. Correlations between heavy metal content§ in soils and in vegetables (§=μg g^{-1} of dry wt., *=*p* < 0.05, **=*p* < 0.01, ns=not significant)

Vegetable	Level of pollution in the growing area	Pb	Cd	Ni	Co	Cr
Spinach	High	0.8538ns	0.8350ns	0.9965**	0.9934*	9690*
	Medium	0.9944**	0.9087ns	0.9402ns	0.9794*	8039ns
	Low	0.6547ns	0.9920**	0.8232ns	0.8846ns	8975ns
Red Amaranth	High	0.9707*	0.9824*	0.9440ns	0.9665*	0.9381ns
	Medium	0.8496ns	0.9839*	0.9902**	0.8181ns	0.9709*
	Low	0.9041ns	0.6698ns	0.9868*	0.9687*	0.9992**
Amaranth	High	0.9983**	0.9278ns	0.9186ns	0.6833ns	0.9813*
	Medium	0.9498ns	0.9877*	0.9864*	0.9933**	0.9931**
	Low	0.8992ns	0.9317ns	0.5989ns	0.9331ns	0.9813*

Table 7. Bioconcentration factor (±, standard deviation) of Pb, Cd, Ni, Co and Cr for the soils to vegetables species

Vegetable	Level of pollution in the growing area	Pb	Cd	Ni	Co	Cr
Spinach	High	0.290±0.014	0.563±0.041	0.833±0.002	0.112±0.017	0.189±0.014
	Medium	0.337±0.046	0.383±0.043	0.878±0.072	0.124±0.020	0.190±0.013
	Low	0.200±0.033	0.675±0.033	0.363±0.032	0.110±0.032	0.215±0.087
Red Amaranth	High	0.345±0.054	0.466±0.005	0.806±0.053	0.156±0.007	0.200±0.006
	Medium	0.441±0.044	0.439±0.036	0.788±0.083	0.170±0.016	0.214±0.016
	Low	0.153±0.007	0.415±0.025	0.373±0.043	0.227±0.124	0.201±0.019
Amaranth	High	0.307±0.027	0.500±0.087	0.825±0.056	0.156±0.017	0.209±0.020
	Medium	0.500±0.049	0.412±0.016	0.742±0.032	0.135±0.003	0.203±0.007
	Low	0.213±0.020	0.575±0.067	0.340±0.073	0.309±0.075	0.181±0.035

The river Turag is highly polluted by industrial effluents, sewage sludge, municipal waste water and urban pollution. Vegetable lands irrigated with this water are contaminated, because more industrial effluents from various industrial sources enter into river. Additionally, little or no treatment is applied to the industrial discharges to detoxify the wastewater draining into rivers. However, the higher concentrations of Pb, Cd, Ni Co and Cr in the polluted (either high-level or medium-level) area indicates that industrial discharges add heavy metals into the soil.

Conclusions

Industrial effluents and urban pollution associated with sewage sludge, municipal waste water increased the levels of Pb, Cd, Ni, Co and Cr intake of the vegetables and soils. To avoid entrance of metals into the food chain, industrial discharges should not be drained into rivers and farmlands without prior treatment. Considering human health hazard, it is recommended that these types of plants should not be cultivated in farms and fields irrigated by industrial waste water or water contaminated by heavy metals. These findings suggest further work by more controlled experiment, which should take into consideration of variations in uptake between different plant species, cropping history, fertilization and the levels of metals present in the soils and atmosphere.

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EFFECT OF UREA SUPER GRANULE AND PRILLED UREA ON THE GROWTH AND YIELD OF BROCCOLI

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Abstract

A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during the period from 2012-13 to verify the effectiveness of urea super granule (USG) and prilled urea (PU)on growth, yield and yield attributes of broccoli in Shallow Red-Brown Terrace Soil under Madhupur Tract (AEZ-28). The experiment was laid out in a Randomized Complete Block Design with three replications having 5 treatments constituted with different levels of USG and PU as- T_1: Control, T_2: USG-N_{140} (140 kg N as USG), T_3: USG-N_{160} (160 kg N as USG), T_4: USG-N_{180} (180 kg N as USG), T_5: PU-N_{180} (180 kg N as PU). Performance of USG was better than PU and the treatment USG-N_{160} gave the highest yield (13.49 ton ha^{-1}) which was followed by USG-N_{180} (12.43 ton ha^{-1}) and PU-N_{180}(12.05 ton ha^{-1}) having significant difference among these. Higher but statistically identical number of lateral head 5.103 and 5.38 was produced by USG-N_{160} and USG-N_{180} treatments, respectively in comparison with PU-N_{180} (5.04). But higher lateral head yields (6.05 and 5.03 ton ha^{-1}) were found in USG-N_{180} treatments followed by PU-N_{180}. All the yield contributing characters and the economic profitability were favorably correlated with these high yield performing treatments with the highest MRR (3336.67%) obtained from USG-N_{160} which indicated that USG @ 160 kg N ha^{-1} (USG-N_{160}) is the most economically viable N dose in terms of yield and economics for broccoli production. Therefore, USG @ 160 kg N ha^{-1} (USG-N_{160}) with other recommended fertilizer could be suggested as USG based fertilizer recommendation for better broccoli production in terms of yield and economics in Silty Clay Loam Soil of Madhupur Tract.

Keywords: Broccoli, USG, head yield, lateral head, compactness coefficient, economic evaluation

Introduction

Broccoli (*Brassica oleracia* var italica L.) is one of the winter vegetables belonging to the family Cruciferae and it is a beneficial and more nutritious vegetable than any other of the same genus (Yoldas *et al*., 2008). It is well

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known that, broccoli has enormous nutritional and medicinal values due to its high contents of vitamins (A, B_1, B_2, B_5, B_6 and E), minerals (Ca, Mg, Zn and Fe) and antioxidant substances which prevent the formation of cancer causing agents. Broccoli contains a higher rate of sulforaphane that prevents against bacteria *Helicobacter pylori* which are responsible for stomach cancer (Fahey *et al*., 2002). Nitrogen plays an important role in broccoli production and broccoli is highly dependent on N fertilization to achieve a good yield (Babik & Elkner 2002). The total yield of broccoli is greatly influenced by different doses of nitrogenous fertilizer. The farmers of Bangladesh usually use PU for cultivation of crops. At present, different types of N fertilizer materials are available in the market to improve fertilizer use efficiency. Among those USG is used by the farmers in some parts of the country for upland vegetable crops like tomato, cabbage, broccoli, papaya, banana etc (Hussain *et al*., 2003; Nazrul *et al*., 2006). High yielding and high quality broccoli production requires careful nutrient management (Castellanos *et al*., 1999). Zaman *et al*. (1993) reported that N is an important plant nutrient and is the most limiting one due to its high mobility and different types of losses. To control this type of losses, USG application may be a good option to minimize production cost as well as to increase N use efficiency, yield and quality of the crop. As nitrogen plays a major role in agricultural production and is also responsible for a number of environmental problems N management is indispensable for maximizing broccoli yield and minimizing cost of production which may lead to increase farmer's income. Therefore it is essential to evaluate the effect of different forms and levels of urea as USG and PU application for sustainable crop production. To attain this goal the present study was undertaken to verify the effectiveness of USG and PU on crop growth, yield and yield attributes of broccoli; to assess the comparative performance of USG and PU on lateral head production of broccoli, to assess the economic performance of broccoli with USG and PU application and to develop an USG based fertilizer recommendation as compare to PU for broccoli production.

Materials and Methods

The field experiment was conducted at the research field and the analytical part of the experiments were done at the laboratory of the Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University during the period from 2012 to 2013 with a view to verifying the effectiveness of USG and PU on yield and quality of broccoli, to assess the comparative performance of USG and PU on nutrient uptake and uptake efficiency of broccoli, to evaluate the effect of USG and PU on post harvest soil nutrient status of broccoli field and to develop an USG based fertilizer recommendation as compared to PU with maximum yield and economic profitability. The soil of the experimental field belongs to Salna series representing the Shallow Red Brown Terrace soil in Bangladesh soil classification system, which falls under order Inceptisols in Soil Taxonomy (FAO, 1988). The soil of the study area is silty clay loam in texture having bulk density 1.34 g cm^{-3} and particle density 2.61%, porosity 47.47% and soil moisture at field capacity 28.67%. Chemical properties of soilwere analyzed in the BSMRAU laboratory of the Department of Soil Science and the results obtained were presented in Table 1.

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

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

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications having 5 treatments comprising different levels of N in the form of USG and PU.The treatments are- T_1: 0 kg N (Control), T_2: 140 kg N as USG (USG-N_{140}), T_3: 160 kg N as USG (USG-N_{160}), T_4: 180 kg N as USG (USG-N_{180}) and T_5: 180 kg N as PU (PU-N_{180}). Besides these a blanket dose of P, K, S, Zn, B, and Mo were applied for all treatments @ 53 kg P, 83 kg K, 20 kg S, 2.0 kg Zn, 1 kg B and 0.8 kg Mo ha^{-1} . Nitrogen,P, K, S, Zn, B, and Mo were applied in the form of USG, and PU, TSP, MoP, gypsum, boric acid, zinc oxide and sodium molybdate. The treatments were randomly assigned to each block. “Premium Crop” a high yielding variety of broccoli (*Brassica oleracea* var. *Italica* L.) collected from Taki seed company, Japan was used as a test crop in the experiment. The unit plot size was 2.4 m × 2.7 m (6.48 m^2) having plot to plot and block to block distances 0.75 m and 1.0 m, respectively. After proper land preparation, 25-day-old healthy broccoli seedlings were transplanted in lines on November 20, 2012 maintaining a row to row and plant to plant distance of 0.60 m and 0.45 m, respectively. Each plot was watered uniformly at every alternate day by watering can to bring the soil moisture at desired level and establishment of the crop. Weeding was done twice just before at first and second top dressing. Earthing up was done to make a continuous line of ridges and furrows. After stand establishment, furrow irrigation was given at an interval of 7 days. All the fertilizers with 50% MoP except PU and USG were applied as broadcast and incorporated during final land preparation. Prilled urea was top-dressed in two equal splits at 15 and 35 DAT as ring method round the plant mixing with the soil properly. At 15 DAT USG was placed at 7-8 cm below the surface and 9-10 cm apart from plant base. The rest 50% MoP was also top-top-dressed at 15 DAT followed by irrigation (depending on soil moisture status). Harvesting was started on 25th January and continued up to 5th February, 2013. Data on total weight, root weight, number of leaves per plant; head weight and other parameters and plant samples were recorded soon after harvesting. The crop was harvested when the head or inflorescence was at commercial maturity, just started to swell but before opening the flower bud. The entire plants including the head and roots were harvested very carefully with the help of a shovel and necessary data were recorded soon after harvesting. Before harvesting head diameter and after harvesting head length was measured using a centi-meter scale. The weight of individual head was taken including the stalk with three young leaves of the broccoli plant and the marketable portion of the plant was considered to the extent of about 15 cm from the top of the inflorescence along the stem according to Liu *et al.* (1993). The collected data were compiled and tabulated in proper form and statistical analysis was done by using the statistical package MSTATC. Computation and preparation of graphs were made using Microsoft Excel 2003 program. Economic evaluation of different fertilizer combinations was done through partial budgeting followed by marginal analysis of the cost-benefit as suggested by Perrin *et al.* (1979).

Initial soil samples were collected for analysis of both physical and chemical properties of soil. Plant height and number of leaves plant^{-1} were noted at 10 days interval and economic data were recorded for economic analysis and evaluation.

Compactness coefficient (CC) an indicator of the quality of a head was observed. Head compactness coefficient is the ratio of head yield (g plant^{-1}) to head diameter (cm) was estimated by the formula:

$$\text{Compactness coefficient (CC)} = \frac{\text{Head yield (g plant}^{-1}\text{)}}{\text{Head diameter (cm)}}$$

Plant biomass was estimated by oven drying the plant samples at 65°-70° C for 72 hours and weighing. The biomass per plant, biomass per plot and biomass per hectare were calculated by the following formulae:

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

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

Economic evaluation of different fertilizer combinations was done through partial budgeting and dominance analysis followed by marginal analysis of the cost undominated treatments was also done as suggested by Perrin *et al.*(1979). Gross return and variable costs were calculated considering the following price rate of the materials as- **Input cost:** Prilled urea @ Tk. 12.00 kg^{-1}, USG @ Tk. 12.30 kg^{-1}, TSP @ Tk. 22 kg^{-1}, MP @ Tk. 20 kg^{-1}, Gypsum @ Tk. 7 kg^{-1}, Zinc monohydrate @ Tk. 18 kg^{-1}, Borax @ Tk. 15 kg^{-1}, Cow dung @ Tk.1500 ton^{-1}, Poultry manure @ Tk.2000 ton^{-1}, Mustard oil cake @ Tk. 28 kg^{-1} (according to market rate during the year 2012-13). Fertilizer application and placement cost were considered as a variable cost which was estimated through labor requirement ha^{-1} according to treatments. These are: 56.58 labor ha^{-1} (2 times application) common for all the PU treatment; 27.86 labor for 80 kg; 30 labor for 100 kg, 2.29 labor for 120 kg, 34.29 labor for 140 kg, 39.86 labor for 160 kg, 41.58 labor for 180 kg, 49.29 labor for 200 kg and 54.01 labor for 220 kg USG treatment ha^{-1}. Labor cost=Tk.180 $diam^{-1}$. **Output cost:** Broccoli= @ Tk. 30 kg^{-1} (according to market rate during the year 2012-2013).

Benefit cost ratio (BCR), marginal benefit cost ratio (MBCR) and marginal rate of return (MRR) were calculated using the following formula:

$$\text{BCR} = \frac{\text{Gross return (Tk.ha}^{-1}\text{)}}{\text{Total variable cost (Tk.ha}^{-1}\text{)}}$$

$$\text{MBCR} = \frac{\text{Added return (Tk.ha}^{-1}\text{)}}{\text{Added cost of cultivation (Tk.ha}^{-1}\text{)}}$$

$$\text{MRR (\%)} = \frac{\text{Marginal gross margin (Tk.ha}^{-1}\text{)}}{\text{Marginal variable cost (Tk.ha}^{-1}\text{)}}$$

Results and Discussion

Plant height

From Fig.1 it was found that plant height was significantly influenced by the different forms and levels of urea and it was increased with increasing rate of N fertilizer and the higher plant height was observed in PU-N_{180} at initial stage from 10 to 20 DAT but in the later stages from 30-70 DAT the highest plant height was observed in the highest level of USG (USG-N_{180}). Growth pattern in relation to plant height at different DAT affected by different forms and levels of urea N is shown in Fig.1 and it is observed that plant height was increased rapidly in intermediate stage and maximum height was attained within 60 DAT and then it maintained a plateau. It reveals that higher plant height was achieved from USG treated plots as compared to that of PU. At harvesting the highest plant height (67.10 cm) was recorded from USG-N_{180} which was statistically identical with USG-N_{160} (65.28 cm) and PU-N_{180} (64.77 cm) (Fig.1). This phenomenon might be due to continuous supply, higher availability and uptake rate of N from USG for long time than that of PU. The minimum plant height (44.98 cm) was recorded from control. These results are similar to the findings of Hala and *Nadia* (2009) as they showed that different mineral fertilizers significantly influenced broccoli growth characters and the highest plant height and number of leaves $plant^{-1}$ were recorded by the plants with maximum N fertilizer along with P and K.

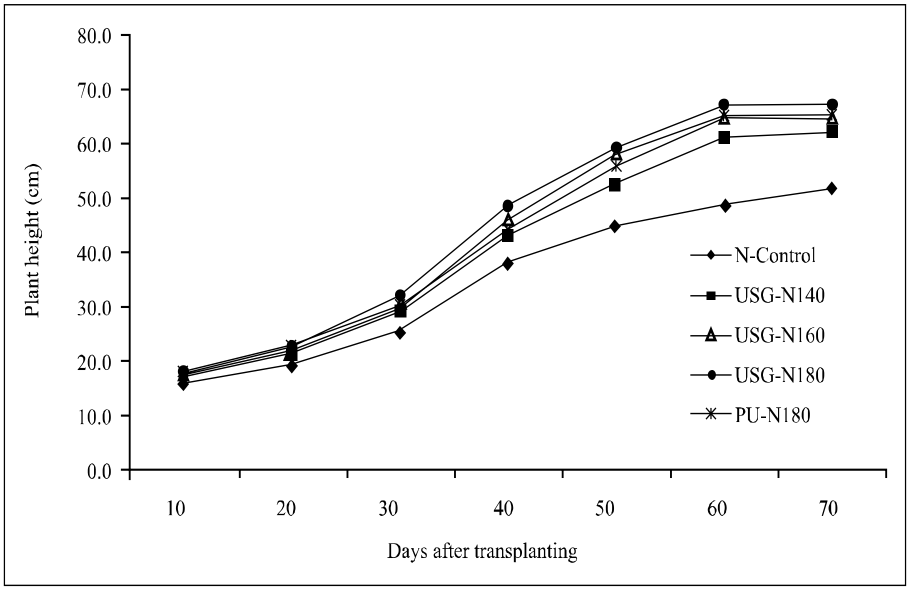

Fig. 1. Growth pattern of broccoli as affected by different levels of USG and PU in relation to plant height.

Number of leaves plant^{-1}

At initial stage up to 20 days after transplanting (DAT), no significant influence was observed in different forms and levels of urea N but in the later stages from 30 DAT, it was significantly affected by different levels of N treatment (Fig.2). Growth pattern in relation to number of leaves plant^{-1} at different DAT was affected by different forms and levels of urea N which was shown in Fig.3 and observed that the number of leaves plant^{-1} rapidly increased in intermediate stage and the maximum number of leaves plant^{-1} was recorded within 60 DAT but a little or no change was observed in the later stages upto harvesting. At harvest(70 DAT), the number of leaves was significantly affected by fertilizer treatments and the maximum number (14.30 plant^{-1}) was recorded from the treatment USG-N_{180}followed by USG-N_{160} kg N ha^{-1}having the number 14.10 (Fig.2). The minimum number of leaves (11.63) was obtained from the control. These results are in accordance with the findings of Ouda and Mahadeen (2008) in broccoli. Thakur *et al.* (1991) reported that increasing rate of N application delayed head maturity and increased the number of leaves plant^{-1}, leaf area, gross plant weight, stalk length, dry matter content and head yield of cauliflower.

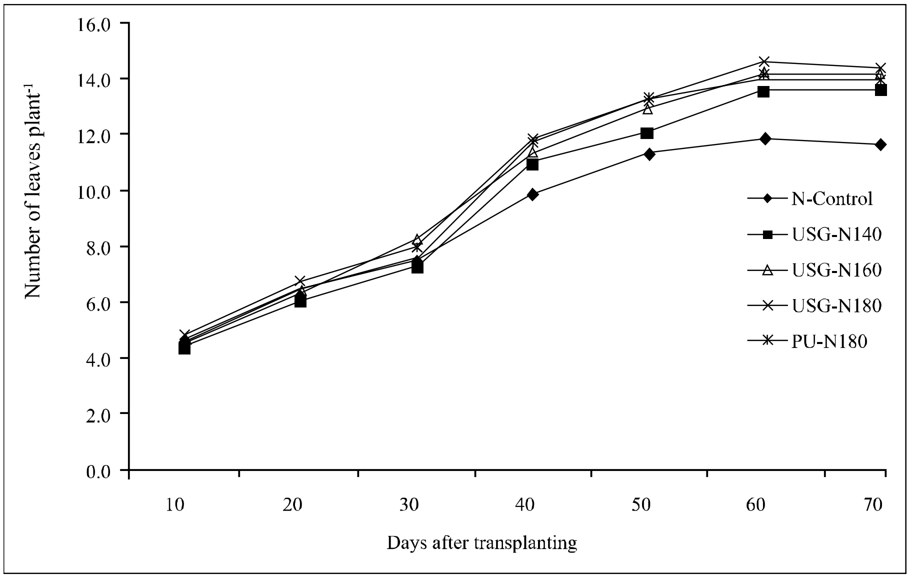

Fig. 2. Growth pattern of broccoli as affected by different levels of USG and PU in relation to number of leaves plant^{-1}.

Days to head initiation

No significant difference was observed among the treatment levels both for 1st and 50% head initiation although the higher days were required in higher rate of N application and also from control (Table 2). The maximum days to first head initiation (47.67 days) was recorded from control followed by USG-N_{180} (46.67 days). Similarly, the maximum days to 50% head initiation (50.00 days) was required in control plot followed by USG-N_{180} (49.00 days). This might be due to higher vegetative growth induced by the higher uptake rate of N by the crop with a sufficient and continuous supply of N by the USG that hindering the head initiation. The higher time required for head initiation from control plot due to lack of optimum development and carbohydrate assimilation which is essential for head initiation. The USG treated plots took more time to 50% head initiation as because of continuous and higher supply of N, which induces higher vegetative growth and consequently delayed head initiation. This finding supported the findings of Default (1988) as reported that increasing N rates decreased the days to heading and harvest in greenhouse broccoli. Thakur *et al.* (1991) found that the increasing rate of N delayed head maturity of cauliflower. Similar findings were reported by Balyan *et al.* (1988) in cauliflower.

Table 2. Effect of different levels of USG and PU on head initiation of broccoli

Treatment	1st HI (DAT)	50% HI (DAT)
Control	47.67	50.00
USG-N_{140}	46.33	47.33
USG-N_{160}	46.33	48.67
USG-N_{180}	46.67	49.00
PU-N_{180}	46.33	48.67
CV (%)	1.92	5.33
SE (±0.05)	0.5164ns	1.487ns

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

HI: Head initiation; DAT: Days after transplanting.

Fresh root weight

Fresh root weight was also significantly influenced by the different levels of urea and the highest fresh root weight (43.83 g plant^{-1}) was found from USG-N_{160} followed by USG-N_{180} which was statistically identical with PU-N_{180} and USG-N_{140} (Table 3). This might be due to higher root expansion with lower availability of N in comparison to USG-N_{180}. The minimum root weight (34.41 g plant^{-1}) was recorded from N-control.

Fresh shoot weight

Fresh shoot weight was also significantly influenced by the different levels of urea and the highest fresh shoot weight (1495.0 g plant^{-1}) was found from USG-N_{180} followed by USG-N_{160} which was statistically identical with PU-N_{180} and USG-N_{140} (Table 3). This higher shoot weight might be due to higher carbohydrate accumulation with higher availability and uptake of N. The minimum shoot weight (543.6 g plant^{-1}) was recorded from N-control plot. Zebarth *et al*. (1995) found that total aboveground dry matter increased linear to curvilinearly with increasing rate of N application in broccoli planting. This result is in accordance with the findings of Thakur *et al.* (1991) in cauliflower.

Root dry weight

Dry root weight was also significantly influenced by the different levels of urea and the highest root dry weight (10.92 g plant^{-1}) was recorded from USG-N_{160} followed by USG-N_{180} which was statistically identical with PU-N_{180} and USG-N_{140} (Table 3). This might be due to higher root expansion with lower availability of nitrogen in comparison to USG-N_{180}. The minimum root weight (8.57 g plant^{-1}) was found from N-control.

Shoot dry weight

Shoot dry weight was also affected significantly by the different levels of nitrogen fertilizer. It was observed that shoot dry weight increased with increasing level of N and the highest shoot dry weight (192.9 g plant^{-1}) was recorded from USG-N_{160} followed by USG-N_{180} which was statistically identical with PU-N_{180} and USG-N_{140} (Table 3). This might be due to higher water content in fresh shoot obtained from USG-N_{180}. The minimum shoot dry weight was found in N-control.

Table 3. Effect of different levels of USG and PU on fresh and dry weight of different growth parameters of broccoli

Treatment	Fresh root weight (g plant^{-1})	Fresh shoot weight (g plant^{-1})	Root dry weight (g plant^{-1})	Shoot dry weight (g plant^{-1})
Control	34.41 b	543.6 b	8.57 b	86.84 b
USG-N_{140}	41.51 a	1363.0 a	10.33 a	175.8 a
USG-N_{160}	43.83 a	1404.0 a	10.92 a	192.9 a
USG-N_{180}	43.67 a	1495.0 a	10.87 a	181.1 a
PU-N_{180}	42.87 a	1392.0 a	10.68 a	179.5 a
CV (%)	7.33	5.57	7.34	5.51
SE (±0.05)	1.746	39.85	0.4351	5.194

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

Head length

Head length was significantly influenced by the different levels of N fertilizer. It was decreased with increasing level of N up to USG-N_{180}(Table 4). The highest head length (14.07 cm) was recorded from USG-N_{140} followed by USG-N_{160} which was statistically identical with PU-N_{180} and USG-N_{180}. The head length recorded in PU-N_{180} was higher than that of USG-N_{180} which might be due to lower flow of translocation to cell development in comparison to cell elongation. The lowest head length was observed in N-control. This result was also in harmony with that of the findings of Chao-Jiong *et al.* (2010) in broccoli.

Head diameter

Head diameter was significantly affected by the different levels of N and the maximum head diameter (19.47 cm) was recorded from USG_{160} treatment which was statistically similar to USG-N_{180} (18.67 cm) but significantly higher than all other treatments (Table 4). This might be due to continuous and balanced supply of assimilates from leaf to floret. The lowest diameter (9.83 cm) was recorded from control. This finding is in agreement with the findings of Yoldas *et al.* (2008) who reported that increased N rates significantly increased yield, average weight of main and lateral heads, and the diameter in broccoli compared to control. This result is also very close to the findings of Thompson and Kelly (1985), who reported that the diameter of cabbage head significantly increased with the optimum dose of N.

Head weight

Individual head weight was significantly influenced by the application of different N levels. It was increased with increasing level of N fertilizer but the highest head weight (364.3 g plant^{-1}) was obtained from USG-N_{160} followed by USG-N_{180} which was statistically identical with PU_{180} (Table 4). This might be due to maximum translocation of carbohydrate from leaf to head which increased size, shape and head compactness with an optimum vegetative growth. The minimum head weight (131.8 g plant^{-1}) was obtained from control. The low crop yield from the control treatment is due to the insufficient supply of N in plants, leading to limit the carbon assimilation, resulting in reduction of plant productivity. This result was supported by the findings of Greenwood *et al.* (1980) who found the highest yield from recommended doses of 175-252 kg N ha^{-1}. Similar results were obtained by Chao-Jiong (2010) in broccoli. Rickard (2008) reported that N had a curvilinear effect on marketable yield and an increase was seen up to application of 165 kg N ha^{-1} where the response is in plateau which also supported these findings.

Compactness coefficient

The higher the head compactness the better the head quality of broccoli. Head compactness were significantly increased with increasing levels of N and the highest compactness coefficient (18.91) was found from PU-N_{180} followed by USG-N_{160} (18.71) which were statistically similar to all the treatments except control that attained the lowest compactness coefficient (13.41)(Table 4). It was due to higher supply of translocates but lower cell elongation which might have caused maximum accumulation of assimilates as well as higher head compactness. This finding is in agreement with the result of Renata *et al*. (2005) in broccoli.

Table 4. Effect of different levels of USG and PU on different parameters of broccoli head

Treatment	Head length (cm)	Head diameter (cm)	Head weight (g plant^{-1})	Compactness coefficient (CC)
Control	10.40 b	9.83 d	131.8 c	13.41 b
USG-N_{140}	14.07 a	17.43 bc	316.3 b	18.15 a
USG-N_{160}	14.00 a	19.47 a	364.3 a	18.71 a
USG-N_{180}	13.07 a	18.67 ab	349.0 ab	18.69 a
PU-N_{180}	13.47 a	17.20 c	325.3 ab	18.91 a
CV (%)	8.58	4.04	6.88	7.53
SE (±0.05)	0.6439	0.3851	11.82	0.7622

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

Head dry weight

The different levels of N application significantly influenced head dry weight. It was increased with increasing level of N fertilizer and the highest head dry weight (60.12 g plant^{-1}) was obtained from the treatment USG-N_{160} followed by USG-N_{180} which were statistically identical to PU-N_{180} (Table 5). This might be due to maximum translocation of carbohydrate from leaf to head which increased size, shape and head compactness producing maximum dry matter. The minimum head dry weight (21.74 g plant^{-1}) was obtained from control. Evaraarts *et al.* (1999) found that band placement of N positively influenced N uptake and this method of N application resulted in a higher head dry matter production.

Harvest index

Harvest index was calculated from head yield (g plant^{-1}) and fresh shoot yield (g plant^{-1}) and is presented in Table 5. The maximum harvest index (25.95 %) recorded from treatment USG-N_{160} followed by N-control. The PU-N_{180} produced lower harvest index (23.37%) than USG-N_{160}.

Head yield

The different N levels significantly influenced head yield of broccoli. It was increased with increasing level of N upto a certain level. The highest head yield (13.49 ton ha^{-1}) was obtained from USG-N_{160}closely followed by USG-N_{180}having no significant difference between these two treatments (Table 5). This might be due to maximum translocation of carbohydrate from leaf to head which increased size and head compactness optimizing vegetative growth. The minimum head yield (4.88 ton ha^{-1}) was noted from the control. The treatment USG-N_{160} produced 276.43% higher yield over control with the harvest index of 25.95% whereas PU-N_{180} produced 246.93% higher yield over control with a harvest index of 23.37% (Table 5). It was observed that 29.5% higher yield was found from USG-N_{160} as compared to PU-N_{180}. USG-N_{180} also produced more yield than that of PU-N_{180}which indicated the superiority of USG over PU. This result is in agreement with the findings of Greenwood *et al.* (1980) concerning the optimization of N dose to receive the maximum broccoli yield with the recommended doses from 175-252 kg N ha^{-1}. Goodlass *et al.* (1997) found that the most effective N rate in broccoli fertilization was 300 kg N ha^{-1}. Zebarth *et al.* (1995) found that crop-marketable yield increased with increasing N rate in a curvilinear pattern. Chao-Jiong (2010) concluded that moderate N fertilization rate (200-300 kg N ha^{-1}) could significantly increase the head size and maintain the storage life. The low crops, harvested from the control treatments are due to the insufficient supply of plants in N, leading at first to limitation of carbon assimilation, resulting in reduction of plant productivity (Lawlor, 2002).

Table 5. Effect of different levels of USG and PU on yield and yield contributing characters of broccoli

Treatment	Head dry weight (g plant^{-1})	Harvest index (%)	Head yield (ton ha^{-1})	Yield increased over control (%)
Control	21.74 c	24.25	4.88 d	-
USG-N_{140}	52.20 b	23.21	11.72 c	240.16
USG-N_{160}	60.12 a	25.95	13.49 a	276.43
USG-N_{180}	57.59 ab	23.34	12.93 b	264.50
PU-N_{180}	53.68 ab	23.37	12.05 c	246.93
CV (%)	6.88	-	6.88	-
SE (±0.05)	1.948	-	0.1693	-

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

Table 6. Effect of different levels of USG and PU on lateral head performance of broccoli

Treatment	Number of lateral head plant^{-1}	Lateral head weight (g plant^{-1})	Lateral head yield (ton ha^{-1})
Control	2.913 c	50.60 d	1.874 d
USG-N_{140}	4.677 b	84.28 c	3.121 c
USG-N_{160}	5.103 ab	120.1 b	4.449 b
USG-N_{180}	5.380 a	163.5 a	6.054 a
PU-N_{180}	5.040 ab	135.8 b	5.030 b
CV (%)	5.44	10.82	10.82
SE (±0.05)	0.1449	6.924	0.2563

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

Number of lateral head

Lateral head of broccoli was produced after harvesting of main head and it was influenced by the rate of N application. Different forms and levels of urea N on the performance of lateral head of broccoli was presented in Table 6. The highest number of lateral head (5.38) was recorded from USG-N_{180} followed by USG-N_{160} (5.103) which was statistically identical with PU-N_{180} (5.04). It was clearly observed that the higher number of lateral head was formed with the application of N as USG form as compared to that of PU. The lowest number (2.913) was recorded from control.

Lateral head weight per plant

Lateral head weight (g plant^{-1}) was significantly influenced by the different form and levels of N fertilizer (Table 6)and it was increased with the increasing levels of N. The maximum lateral head weight (163.5 g plant^{-1}) was recorded from USG-N_{180} followed by PU-N_{180} (135.8 g plant^{-1}) but significantly higher than all other treatment. The higher lateral head weight was observed in case of USG than that of PU. But the lowest lateral head yield (50.60 g plant^{-1}) was obtained from control.

Lateral head yield

Lateral head yield (ton ha^{-1}) was significantly affected by the different forms and levels of N (Table 6) and more or less it was increased with the increasing levels of N application. The highest lateral head yield (6.054 ton ha^{-1}) was achieved from the treatment USG-N_{180} that was significantly higher than all other treatment. The second highest lateral head yield (5.030 ton ha^{-1}) was recorded from PU-N_{180} that was statistically identical with USG-N_{160} (4.449 ton ha^{-1}). From the data recorded, it was clearly observed that the higher lateral head yield was obtained with higher levels of N as USG than that of PU. The lowest lateral head yield (1.874 t ha^{-1}) was obtained from the control.It indicated that nitrogen supply from USG had to be continued even after harvesting of main head which induced lateral head formation but it was not so in case of PU. After conducting experiment on broccoli Yoldas *et al.* (2008) found that N rates significantly increased yield, average weight of main and lateral heads, and the head diameter in broccoli compared to control with the highest total yield (34631 kg ha^{-1}) obtained from 300 kg N ha^{-1}. Similar result was reported by Hussain (2004) in broccoli cultivar Premium Crop.

Table 7. Partial budget analysis of broccoli as influenced by different levels of USG and PU

Treatment combination	Yield (t ha^{-1})	Gross return (Tk.ha^{-1})	TVC (Tk.ha^{-1})	Gross margin (Tk.ha^{-1})	Added return (Tk.ha^{-1})	Added VC (Tk.ha^{-1})	MBCR Over control
Control	4.880	146400	105480.0	40920.0	-	-	-
USG-N_{140}	11.720	351600	115449.7	236150.3	205200	9969.7	20.58
USG-N_{160}	13.490	404700	116994.8	287705.2	258300	11514.8	22.43
USG-N_{180}	12.930	387900	117846.9	270053.1	241500	12366.9	19.53
PU-N_{180}	12.050	361500	120351.6	241148.4	215100	14871.6	14.46

Material cost: PU= Tk.12 kg^{-1}; USG= Tk.12.50 kg^{-1}; Labor= Tk.180 diam^{-1}; **Placement cost (labor ha^{-1}):** For prilled urea: 56.58 labor (2 times) for 180 kg PU ha^{-1}; For USG: 34.29 labor for 140 kg, 39.86 labor for 160 kg, 41.58 labor for 180 kg USG ha^{-1}. **Output cost:** Broccoli price = Tk. 30 kg^{-1}.

Economic analyses and evaluation

From the partial budget analysis it was found that the maximum gross return (Tk. 404700 ha^{-1}) was noted from the treatment USG-N_{160} followed by USG-N_{180} (TK. 387900 ha^{-1}) and USG-N_{140}gave the third highest gross return (TK. 361500 ha^{-1}) with the gross margin of Tk. 287705.2, 270053.1 and 241148.4, respectively (Table 7). From this information the highest calculated MBCR (22.43) was obtained from USG-N_{160} followed by USG-N_{140} (20.58) and it was followed by USG-N_{180} (19.53) which was higher as compared to that of PU-N_{180} (14.46) over control.

Table 8. Partial budget analysis of broccoli as influenced by different levels of USG and PU

Treatment combination	Gross return (Tk. ha^{-1})	TVC (Tk. ha^{-1})	BCR	Gross margin (Tk. ha^{-1})	MGM (Tk. ha^{-1})	MVC (Tk. ha^{-1})	MRR (%)
Control	146400	105480.0	1.39	40920.0	-	-	-
USG-N_{140}	351600	115449.7	3.05	236150.3	195230.3	9969.7	1958.24
USG-N_{160}	404700	116994.8	3.46	287705.2	51554.9	1545.1	3336.67
USG-N_{180}	387900	117846.9	3.29	270053.1	-17652.1	852.1	D
PU-N_{180}	361500	120351.6	3.00	241148.4	-28904.7	2504.7	D

Material cost: PU= Tk.12 kg^{-1}; USG= Tk.12.50 kg^{-1}; Labor= Tk.180 diam^{-1}; **Placement cost (labor ha^{-1}):** For prilled urea: 56.58 labor (2 times) for 180 kg PU ha^{-1}; For USG: 34.29 labor for 140 kg, 39.86 labor for 160 kg, 41.58 labor for 180 kg USG ha^{-1}. **Output cost:** Broccoli price = Tk. 30 kg^{-1}.

From Table 8, it was found that maximum BCR (3.46) and highest MRR (3336.67%) was obtained from USG_{160} followed by USG_{140} which indicated that USG_{160} is the most economically viable N dose in terms of yield and economics for broccoli production. Similar findings was reported by Talukder *et al.*(2004) in tomato; Rahman *et al*. (2004) in potato; Nazrul *et al.* (2007) and Sarker*et al.* (2012) in cabbagethose indicate the superiority of USG over existing PU practice.

Conclusion

Based on the above discussions it may be concluded that USG @ 160kg N ha^{-1}is the superior form and rate of N application getting a good desirable and economic yield of broccoli.Higher number of lateral head (5.38) and lateral head yield (6.054ton ha^{-1}) was produced by USGin comparison to PU. Head compactness was significantly increased with increasing levels of N but it isstatistically identical forboth USG and PU. From economic viewpoint USG @ 160 kg N ha^{-1} (USG-N_{160}) showed the maximum economic profitability in terms of both MBCR (22.43) and MRR (3336.67 %). Therefore, USG @ 160 kg N ha^{-1} (USG-N_{160})with other recommended fertilizer could be suggested as an USG based fertilizer recommendation for broccoli production in terms of yield and economic profitabilityat Salna series soil of BSMRAU in Madhupur Tract.

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EVALUATION OF PLANTAIN GENOTYPES FOR YIELD AND OTHER CHARACTERS

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Abstract

An experiment was carried out at the Regional Agricultural Research Station, BARI, Ishurdi, Pabna during 2013-15, with eleven genotypes of plantain to evaluate their performances for yield attributes, yield and quality characters. The genotypes included in this investigation were MP001, MP002, MP003, MP006, MP007, MP015, MP018, MP024, MP025, ISD002 and BARI Kola-2 as check. The experiment was laid out in randomized complete block design with three replications. The genotype MP002 produced the maximum number of fingers/bunch (105.67) closely followed by BARI Kola-2 (103.00) and MP015 (101.00). Both the genotypes MP024 and MP025 showed the highest fruit length (21.70 cm), but ISD002 gave the maximum fruit girth (16.78 cm), which was statistically similar with that of MP003 (16.30 cm) and MP024 (16.33 cm). The highest yield and the maximum number of hands were produced by the genotype MP024 (47.81 t/ha and (8.33/bunch) followed by MP015 (36.70 t/ha and 6.33/bunch). Fingers of the genotypes required boiling time in the range of 20.00 min (MP001) to 15.00 min (BARI Kola-2). Flesh of all genotypes possesses pleasant aroma except MP002, MP003 and ISD002. Among the eleven genotypes MP001, MP006, MP007, MP008, MP015 and MP024 were found better when cooked as smashed. The genotype ISD002 took the maximum time (467.33 days) to reach the edible maturity stage of fruits whereas MP024 required the minimum (339.00 days). The genotypes MP015 and MP024 performed better than BARI Kola-2 in respect of bunch weight, fruit size, productivity index, yield, sucker production and qualitative characters.

Keywords: Plantain genotypes, *Musa paradisiaca,* yield attributes and cooking quality.

Introduction

Plantain (*Musa paradisiaca* L) locally known as 'kacha kola' is one of the most popular vegetables in Bangladesh. Local popular cultivars of plantain are cultivated mainly in homesteads of different regions of Bangladesh. It plays a vital role in mitigating vegetable demand during the summer and rainy season, when there is acute shortage of nutritious vegetables. It has also a great demand in the urban areas during the lean period of vegetables from May to October. In Bangladesh, plantain is used as 'bharta' (smashed) and curry, and all classes of

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people like it. Plantain is high-calorie fruits which contain 556 KJ of energy per 100g edible portion (Robinson, 1994). Plantain is very rich in nutrients including carbohydrates, phosphorus, calcium, iron, vitamin B complex and vitamin C (Chattopadhyay *et al*., 2001). This group of banana is used as staple food in Uganda, Tanzania, Ivorycoast and South Cameron. It is very cheap and energetic food also. Total production of plantain in Bangladesh during 2014-15 was 147136 MT from an area of 10331 hectares with an average yield of 10.24 t/ha (Anon., 2015). Morphological studies and yield potential of some local plantain germplasm were studied by different investigators (Biswas *et al.,* 1992; Saha *et al.,* 1988 ; Golder *et al.,* 1992) whose findings indicated that both yield contributing characters and yield of the plantain genotypes differ significantly when grown under different agro ecological conditions. BARI released one plantain variety named BARI Kola-2. The variety is very shy in sucker production, which is hindering the extension of the variety. Therefore, the present study was conducted to evaluate the performance of eleven plantain genotypes with a view to develop high yielding and good quality plantain varieties.

Materials and Methods

The experiment was conducted at the Regional Agricultural Research Station, BARI, Ishurdi, Pabna during 2013-15. The plantain genotypes included in this investigation were MP001, MP002, MP003, ISD002, MP006, MP007, MP015, MP018, MP024, MP025 and BARI Kola- 2 (check). The genotypes MP001, MP002, MP006 and MP025 were collected from Gazipur, ISD002 from Ishurdi, MP024 from Jessore, MP003 and MP015 from Rajshahi, MP007 and MP018 from Chittagong and BARI Kola-2 (FHIA 03) from Belgium through the International Network for the Improvement of Banana and Plantain (INIBAP). The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 5.7 m × 1.9 m. Sword suckers (weight 2.5 kg ± 50 g, age 70 ± 15 days) were planted in the field on 20 October 2013 maintaining a plant spacing of 1.9 m × 1.9 m. The land was fertilized with cowdung @ 30 t/ha, and urea, TSP, MoP and gypsum @ 1550, 1250, 1550 and 620 kg per hectare, respectively as per recommendation of BARI (Anon., 2005). Half of cowdung, TSP and Gypsum were applied in the field during final land preparation and the remaining half were applied in the pit 10 days before planting. Urea and MoP were applied as side dressing in five equal installments at one month interval starting from one month after planting. Weeding, mulching, desuckering, propping and irrigation were done as and when necessary. The fungicide ‘Knowin’ was sprayed five times at 15 days interval @ 1.5% to control sigatoka disease. Harvesting was started from 21 September 2014 and continued up to 30 January 2015. Data were recorded on growth (pseudostem height at shooting, base girth at shooting, top girth at shooting, number of green and yellow leaves/plant at shooting, number of suckers/plant at shooting) yield attributes [pseudostem weight at harvest, number of hands and fingers/bunch, bunch weight (yield/plant), fruit size (length and width), fruit girth, cooking quality (time of boiling, flesh texture after boiling, aroma and taste as smashed) and qualitative characters (shape, peel colour, pulp colour and blossom end of the fruit). Yield/plant (bunch weight in kg) was converted to per hectare yield in tons. The procedure of Islam *et al.* (2002) was followed during data collection on shape, peel colour, pulp colour and blossom end of the fruit, flesh texture after boiling and aroma. Cooking quality and qualitative characters were tested by a panel consisting of seven persons of different levels. After boiling and peeling the fruits were smashed with salt, green chilli, onions and mustard oil, and then the smashed bananas (bharta) were tasted by the members of that panel. The recorded data were analyzed with the help of MSTAT C software and means were compared by DMRT at 5% level of probability.

Results and Discussion

Morphological characters

Pseudostem height at shooting (m): Pseudostem height of eleven plantain genotypes ranged from 2.56 m to 3.11 m (Table 1). The highest pseudo stem height at shooting (3.11 m) was found in MP003 closely followed by MP024 (3.09 m), MP025 (3.08 m), MP015 (3.06 m), MP006 (2.96 m), MP007 (2.88 m) and MP018 (2.81 m). The ISD002 had the shortest pseudostem height (2.56 m). The results are in agreement with the findings of Rahman *et al.* (2005) who obtained pseudostem height in the range of 2.61 m to 3.10 m in plantain lines.

Base girth and top girth at shooting (cm): Base girth and top girth were found the highest (83.30 cm and 69.00 cm, respectively) in BARI Kola-2 which was followed by MP025 (71.00 cm and 51.00 cm) and MP006 (67.67 cm and 45.00 cm), respectively. The lowest base girth and top girth (53.33 cm and 36.67 cm) were obtained from ISD002. Similar results were also observed by Hoque *et. al.* (2003) who obtained base girth ranging from 69.67 cm to 82.33 cm in some plantain genotypes; they observed 82.33 cm base girth for BARI Kola-2 (FHIA 03).

Number of green leaves/plant at shooting: Significant differences were found among the genotypes in respect of number of leaves/plant at shooting (Table 1). The highest number of green leaves was found in MP003 (11.33) closely followed by MP018 (11.00), BARI Kola-2 (11.00) MP007 (10.67), MP006 (9.67) and MP015 (9.67). The lowest number of leaves /plant was recorded in MP002 (2.00). Similar results were also reported by Saifullah *et al.* (2000) who obtained green leaves/plant at shooting in the range of 10.11 to 11.17 when evaluated nine plantain genotypes.

Number of yellow leaves/plant at shooting: The genotypes differed significantly in respect of number of yellow leaves/plant at shooting (Table 1). The maximum number of yellow leaves was obtained from MP018 (3.33) which was closely followed by MP003 (3.30), MP007 (3.00), MP015 (2.67) and MP006 (2.33) while the lowest number was obtained from MP024 (1.65).

Table 1. Morphological characters of eleven plantain genotypes

Genotype	Pseudostem height at shooting (m)	Base girth at shooting (cm)	Top girth at shooting (cm)	Green leaves/plant at shooting (no.)	Yellow leaves/plant at shooting (no.)	Suckers/plant at harvest (no.)	Days to fruit maturity
MP001	2.67c	59.67ef	42.0cde	7.66bc	1.67c	14.30b-e	351.67c
MP002	2.82abc	65.67cd	43.33cd	2.00d	2.00bc	18.67a	350.33cd
MP003	3.11a	62.33de	42.00cde	11.33a	3.30a	11.30e	372.33b
ISD002	2.56c	53.33g	36.67f	7.67bc	2.00bc	12.67de	467.33a
MP006	2.96ab	67.67bc	45.00c	9.67ab	2.33abc	16.33abc	338.00d
MP007	2.88abc	56.00fg	42.00cde	10.67a	3.00ab	13.33cde	352.67c
MP015	3.06a	59.33ef	43.66cd	9.67ab	2.67abc	15.00bcd	374.00b
MP018	2.81abc	62.33de	42.67cde	11.00a	3.33a	15.33bcd	354.33c
MP024	3.09a	59.33ef	38.33ef	7.00c	1.65c	17.33ab	339.00d
MP025	3.08a	71.00b	51.00b	8.00bc	2.00bc	14.00cde	342.66cd
BARI Kola-2	2.58c	83.30a	69.00a	11.00a	2.00bc	11.33e	377.00b
CV (%)	6.98	4.92	5.85	13.98	12.64	13.15	9.14

Means within a column followed by common letter(s) are not significantly different from each other by DMRT at 5% level of probability.

Table 2. Yield and yield attributes of eleven plantain genotypes

Genotypes	Pseudostem weight at harvest (kg)	Hands/bunch (no.)	Fingers/bunch (no)	Bunch weight (kg)	Fruit length (cm)	Fruit girth (cm)	Yield (t/ha)	Productivity index*
MP001	12.51cd	6.00bc	67.33de	11.35e	19.20ab	13.85cd	31.43e	3.33cd
MP002	11.55cdef	6.67b	105.67a	9.75h	13.20d	13.50d	27.00h	2.78e
MP003	10.91f	6.33bc	85.00c	9.17i	16.10bc	16.30ab	25.40i	2.46f
ISD002	10.57f	5.00d	57.67f	9.18i	19.18ab	16.78a	24.42i	1.96g
MP-006	11.00ef	6.33bc	82.00c	10.31g	20.16a	14.50bc	28.55g	3.05de
MP007	12.40cde	5.67cd	72.00d	12.03d	19.10ab	14.00c	33.32d	3.41c
MP015	13.50c	6.33bc	101.00a	13.25b	14.80cd	15.50b	36.70b	3.54b
MP018	10.90f	6.00bc	63.67e	7.53j	19.30ab	14.30bc	20.85j	2.13g
MP024	10.25f	8.33a	93.00b	17.26a	21.70a	16.33ab	47.81a	5.09a
MP025	19.91a	6.00bc	68.65d	10.83f	21.70a	14.20bc	29.99f	3.16cd
BARI Kola -2	17.33b	6.33bc	103.00a	12.55c	15.70c	13.85cd	34.76c	3.25cd
CV (%)	6.82	7.08	9.55	7.60	5.69	4.97	8.63	9.05

Means within a column followed by common letter(s) are not significantly different from each other by DMRT at 5% level of probability.
*Productivity index = 100 x bunch weight/days to maturity (cycling time) (Ayala-Silva *et al*., 2009)

Number of suckers at harvest: Number of suckers/plant at harvest was found the highest in MP002 (18.67) closely followed by MP024 (17.33) and MP006 (16.33) (Table 1). The lowest number of suckers was obtained from the genotype MP003 (11.30).

Days to fruit maturity: The genotypes differed significantly in respect of days to maturity i.e. planting to edible maturity of fruits (Table 1). The genotype ISD002 took the maximum time (467.33 days) to reach the harvesting stage, preceded by BARI Kola-2 (377.00 days), MP015 (374.00 days) and MP003 (372.33) and the genotype MP006 required minimum time for harvesting (338.00 days). Similar observations were also reported by Saifullah *et al*. (2000) who mentioned the range of 316.33 to 379.33 days for fruit maturity of nine plantain genotypes.

Yield and yield contributing characters

Pseudostem weight at harvest: Pseudostem weight in different genotypes ranged from 10.25 kg to 19.91 kg (Table 2). The maximum pseudostem weight was obtained from MP025 (19.91 kg) followed by BARI Kola-2 (17.33 kg) and MP015 (13.50 kg). The minimum weight was recorded in MP024 (10.25 kg).

Number of hands/bunch: The genotype MP024 produced the highest number of hands/bunch (8.33) which was statistically different from the others (Table 2). The genotypes MP002, MP003, MP006, MP015 and BARI Kola-2 also gave better number of hands/bunch because these genotypes produced number of hands/bunch more than 6.00. On the other hand, ISD002 produced the lowest number of hands (5.0). The results are in partial agreement with the findings of Hoque *et al*. (2003) who reported the range of 5.83 to 8.33 for hands/bunch.

Number of fingers/bunch: The maximum number of fingers per bunch was recorded in MP002 (105.67) which was closely followed by BARI Kola-2 (103.00) and MP015 (101.00) (Table 2). The lowest was recorded in ISD002 (57.67).

Bunch weight (yield/plant): The genotype MP024 produced the heaviest bunch (17.26 kg) followed by MP015 (13.25 kg) (Table 2). The genotype MP018 produced the lowest bunch weight (7.53 kg). The result was almost similar to Hoque *et al.* (2003) who reported bunch weight in the range of 9.45 kg to 18.23 kg.

Fruit size: Fruit size ranged from 13.20 cm to 21.70cm in length and 13.50 cm to 16.78 cm in girth (Table 2). The genotypes MP024 and MP025 produced the highest fruit length (21.70 cm) which was similar with MP006 (20.16 cm), MP018 (19.30 cm), MP001 (19.20 cm), MP007 (19.10 cm) and ISD002 (19.18 cm). The lowest fruit length was produced by the genotype MP002 (13.20 cm). The highest girth (16.78 cm) was obtained from ISD002 closely followed by MP024 (16.33 cm) and the lowest from MP002 (13.50 cm). The findings are in conformity with those of Saifullah *et al*. (2000) who reported the range of fruit (finger) length from 9.88 to 20.89 cm and Islam *et al*. (2002) mentioned fruit girth ranged from 11.83 to 16.87 cm.

Yield: The highest yield was obtained from MP024 (47.81 t/ha) followed by MP015 (36.70 t/ha) and BARI Kola-2 (34.76 t/ha). The maximum yield in MP024 was due to the highest number of hands/bunch and the highest bunch weight. The lowest yield was recorded in MP018 (20.85 t/ha). The findings are similar to Islam *et al.* (2002) who reported that the per hectare yield of 10 local plantain varieties ranged from 29.43 to 52.94 tons. These results are also supported by Biswas *et al.* (1992) and Golder *et al.* (1992). Sarker *et al.* (2002) obtained yield in the range of 18.20 to 30.60 tons per hectare; Biswas *et al*. (1992) 29.45 to 48.12 tons per hectare and Golder *et al*. (1992) 28.20 to 41.5 tons per hectare in different plantain lines.

Productivity index: The plantain genotypes showed variation regarding to productivity index which ranged from 1.96 to 5.09 (Table 2). The genotype MP024 gave the maximum productivity index (5.09) followed by MP015 (3.54), MP007 (3.41), MP001 (3.33) and BARI Kola-2 (3.25). Ayala-Silva *et al.* (2009) obtained productivity index for 5 cooking bananas in the range of 0.86 to 1.43 and opined that the variety with the higher productivity index was better in terms of production.

Qualitative Characters

Shape of fruit: The genotypes MP001, MP002, MP006, MP015, MP024 and BARI Kola-2 produced fruits which are straight in shape, while MP003 and MP018 produced fruits which are swollen in middle (Table 3). The genotypes ISD002 and MP007 had the curve shaped fruits and the genotype MP025 produced constricted shaped fruits.

Peel and pulp colour at edible stage: The peel colour of fruit was green in MP001, ISD002, MP006 and MP024, whereas MP003, MP018, MP025 and BARI Kola-2 were deep green, MP002 and MP015 were green with white coated and MP007 was light green (Table 3) . Pulp colour of the fruits was cream, whitish and light yellow to cream. The colour of pulp was cream in MP001, ISD002, MP006, MP007 and MP025. The pulp colour of MP002, MP003, MP018, MP024 and BARI Kola-2 were whitish while the genotype MP015 was light yellow to cream. The results are in line with the finding of Biswas *et al.* (1992) who also found the variation in the pulp colour in plantain cultivars.

Blossom end of the fruit: The blossom end of fingers was slightly blunt in MP001, while those of MP002, MP024 and BARI Kola-2 were pointed blossom end (Table 3). On the other hand, MP003, MP006, MP007 and MP018 were semi pointed. The fingers of ISD002 were slightly curved. The genotype MP025 produced fingers with blunt blossom end and MP015 had slightly constricted blossom end. The result is in agreement with of the findings of Biswas *et al.* (1992) who obtained 7 types of blossom end of fruit.

Table 3. Qualitative characters of fruits of eleven plantain genotypes

Genotype	Shape	Peel colour	Pulp colour	Blossom end
MP001	Straight	Green	Cream	Slightly blunt
MP002	Straight	Green coated with white	Whitish	Pointed
MP003	Swollen in middle	Deep green	Whitish	Semi pointed
ISD002	Curve	Green	Cream	Slightly curve
MP006	Straight	Green	Cream	Semi pointed
MP007	Curve	Light green	Cream	Semi pointed
MP015	Straight	Green coated with white	Light yellow to cream	Slightly Constricted
MP018	Swollen in middle	Deep green	Whitish	Semi pointed
MP024	Straight	Green	Whitish	Pointed
MP025	Constricted	Deep Green	Cream	Blunt
BARI Kola-2	Straight	Deep green	Whitish	Pointed

Table 4. Cooking quality of fruits of eleven plantain genotypes

Genotypes	Time of boiling (min)	Flesh texture after boiling	Aroma	Taste as smashed
MP001	20.00a	Semi soggy	Pleasant	Good
MP002	17.0bc	Firm	Unpleasant	Not good
MP003	17.0bc	Firm	Unpleasant	Not good
ISD002	16.30bc	Firm	Unpleasant	Not good
MP006	18.0ab	Firm	Pleasant	Good
MP007	16.0bc	Semi soggy	Pleasant	Good
MP015	18.50ab	Firm	Pleasant	Very good
MP018	15.50d	Firm	Pleasant	Good
MP024	19.30a	Firm	Pleasant	Very Good
MP025	16.51c	Semi soggy	Pleasant	Good
BARI Kola- 2	15.0d	Firm	Pleasant	Very Good

Cooking quality

Boiling time: The genotype MP001 took the maximum time to boil the fingers (20.00 min) which was similar with MP024 (19.30 min), MP015 (18.00 min) and MP006 (18.00 min) (Table 4). BARI Kola-2 required the minimum time to boil the fingers (15.00 min). The results are in consonance with the findings of Hoque *et al.* (2003) who reported the time required to boil the fingers ranging from 15.33 min (BARI Kola-2) to 19.33 min.

Flesh texture after boiling: After boiling, the flesh texture of MP001, MP007 and MP025 were found semi soggy, whereas the flesh of rest of the genotypes were firm in texture (Table 4).

Aroma: The flesh of boiled fingers of all genotypes had pleasant aroma except MP002, MP003 and ISD002 which had unpleasant aroma (Table 4).

Taste as smashed: Among the genotypes, MP015, MP024 and BARI Kola-2 had very good taste both as smashed. The genotypes MP001, MP006, MP007, MP018 and MP025 had good taste whereas MP002, MP003, ISD002 were not good either as smashed (Table 4).

Conclusion

Based on the above results it can be concluded that the genotypes MP015 and MP024 performed better in respect of yield and qualitative characters. These genotypes might be subjected to further evaluation to release as variety (ies).

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RELATIVE ABUNDANCE OF INSECT PESTS AND THEIR PREDATORS ON BORO RICE

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Abstract

The study was conducted to know the relative abundance of insect pests and their predators on 5 boro rice varieties namely Arize tez, Teea, Sakti, Sathi and BRRI Dhan 28. In Arize Tez variety, short horned grasshopper revealed the highest percent relative abundance (87.25%) at tillering stage and green rice leafhopper was only at panical initiation stage. Among insect predators, wasp showed the highest percent relative abundance (33.33%) both at tillering and panical initiation stages. In Teea variety, the highest percent relative abundance of short horned grasshopper was recorded at tillering (80.21%) and panicle initiation (86.03%) stages while spider and lady bird beetle had 21.05% at tillering stage, wasp (21.05% and 40.00%), damselfly (21.05% and 40.00%) at tillering and panical initiation stages, respectively. In Sakti variety, short horned grasshopper had the highest percent relative abundance (72.54% and 69.05%) at tillering and panicle initiation stages while dragonfly had 30.77% at tillering, wasp had 30.77% and 66.66% at tillering and panicle initiation stages. In Shathi variety, the highest percent relative abundance of short horned grasshopper was recorded at tillering (59.46%) and panicle initiation (52.27%) stages while wasp (41.67%) at panical initiation stage. In variety BRRI dhan 28, the highest percent relative abundance of insect pests was recorded in short horned grasshopper (76.73% and 86.05%) both at tillering and panicle initiation stages while in insect predators, wasp had 40% at tillering and 50% at panicle initiation stages but dragonfly had 50% only at panicle initiation stage.

Keywords: Insect pests, natural enemies, relative abundance, rice varieties.

Introduction

The production of boro rice is seriously hampered by the attack of insect pests. About 266 species of insect have been recorded as rice pests, of these 42 species are economically important in Bangladesh (Islam *et al.*, 2003). Nine insect pests and 9 natural enemies in boro rice from seedling to reproductive stages have been recorded and the relative abundance of insect pests and natural enemies varied with different growth stages of rice plant. The highest percent relative abundance of green leafhopper (41.79%) and wasp (42.53%) are estimated at seedling stage, grasshopper (35.36%) and dipteran fly (35.59%) at early tillering stage while the highest percent relative abundance of rice bug (66.92%) and ground beetle (45.88%) are measured at maximum tillering stage having similar trend at

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reproductive stage (Bakar *et al.*, 2014). Seven different insect pests namely yellow stem borer, rice bug, green leafhopper, short horned grasshopper, long horned grasshopper, leaf floder and brown planthopper while 7 insect predators viz., damselfly, ground beetle, long jawed spider, lynx spider, mirid bug, ichneumonid and lady bird beetle have been occurred in coastal rice habitat. The percent relative abundance of green leafhopper and spider are the highest at maximum tillering stage (Khan, 2013). The highest abundance of insect pests has varied with rice growth stages and observed as yellow rice stem borer at maximum tillering stage, green leafhopper at seedling stage, short horned grasshopper at early tillering stage, stink bug at maximum tillering and reproductive stages, rice bug at reproductive stage and rice hispa at early tillering stage. In case of natural enemies, the highest abundance of lady bird beetle, spider and dipteran fly has occurred at early tillering stage, ground beetle and damselfly at maximum tillering stage, and wasp at seedling stage (Bakar and Khan, 2015). Mukherjee *et al.* (2015) found the highest number of insect pests at panicle initiation stage (1808 insect pests/160 sweeps) and lowest at early tillering stage (131 insect pests/160 sweeps) while the highest number of natural enemies (1026/160 sweeps) has counted at seedling stage and the lowest at early tillering stage (386/160 sweeps). In Southern coastal region, only one published report is available on insect pests of boro rice. Therefore, the study was undertaken to study on the relative abundance of insect pests and their predators on different boro rice varieties.

Materials and Methods

The study was conducted in the research farm of Patuakhali Science and Technology University, Dumki, Patuakhali during boro season (November 2011 to May 2012) to know the relative abundance of insect pests and their predators on five boro rice varieties viz., Arize tez, Teea, Sakti, Sathi and BRRI Dhan 28. Seeds of different rice varieties were collected from Bangladesh Rice Research Institute. Seeds were sprouted by the farm labours by sowing on 28 November 2011 in well-prepared nursery beds. The study was conducted in randomized complete block design with 3 replications. Unit plot size was 5 m × 4 m. Fertilization was done according to BRRI recommended dose in experimental fields. Urea, TSP, MP, gypsum were applied at the rate of 270, 150, 120, 110 kg/ha respectively. One third of the urea and full dose of other fertilizers were applied as basal dose at the time of final land preparation. The rest amount of urea was top dressed in two equal installments at maximum tillering and before panicle initiation stage. The seedlings were transplanted on 02 January 2012 into the prepared land using 2 seedlings per hill. Intercultural operations viz. gap filling, weeding etc. were done properly. Irrigation and drainage have done as per required at the experimental fields.

The insect pests of rice and their natural enemies were collected by a fine nylon cloth sweep net (30 cm diameter). Data were collected on 15 February and 03

March, 2012 at tillering stage while at panicle initiation stage it was done on 30 March, 2012. Sweeping was done on the standing crop from the plant canopy level including the interspaces between plants as well as close to basal region of the plants as far as possible. In each field, 20 complete sweeps were made to collect the insect pests and their predators. Sampling was done at tillering and panicle initiation stages. Sampling was done in between 7:00-10:00 AM. The pests and predators insects from each field were collected separately in labeled container. The collected samples were properly preserved, identified, sorted and counted in the laboratory of the Department of Entomology, Patuakhali Science and Technology University. The samples were sorted and identified under stereoscopic microscope and magnifying glass, and percent relative abundance was calculated. Data were analyzed by using WASP (Web based Agricultural Statistical Package) for t test and means were separated by critical difference (CD) value.

Results and Discussion

Relative abundance of insect pests

Relative abundance of insect pests in rice ecosystem is presented in Table 1. In Arize Tez variety, the highest percent relative abundance of short horned grasshopper (87.25%) was recorded at tillering stage while the lowest was in long horned grasshopper (3.75%). In case of panicle initiation stage, the highest percent relative abundance was in Short horned grasshopper (47.88%) while the lowest in Green leaf hopper (1.96%).

In Teea variety, the highest percent relative abundance of Short horned grasshopper was recorded at both tillering (80.21%) and panicle initiation stages (86.03%) while the lowest percent was in Stink bug (1.87%) at tillering and Green leafhopper (1.07%) at panicle initiation stage.

In Sakti variety, the highest percent relative abundance of Short horned grasshopper (72.54%) and lowest in Green leaf hopper (2.33%) was recorded at tillering stage. However, at panicle initiation stage, the similar trend was observed in Short horned grasshopper (69.05%) while the lowest was in Stink bug (1.00%).

In shathi variety, the highest percent relative abundance of Short horned grasshopper (59.46%) was recorded at tillering stage and lowest was in Stink bug (5.41%). But in case of panicle initiation stage, the highest was in Short horned grasshopper (52.27%) and lowest was in Stink bug (6.82%).

In BRRI dhan28, the highest percent relative abundance of Short horned grasshopper (76.73%) was recorded at tillering stage and the lowest was in Rice bug (2.33%). But in case of panicle initiation stage, the similar trend was in Short horned grasshopper (86.05%) and lowest was in Long horned grasshopper (1.16%).

Table 1. Relative abundance of insect pests on different boro rice varieties at their tillering and panicle initiation stages during 2011-12 at Patuakhali

Rice variety	Insect Pests	Mean abundance (%) at		T ststistic	df	P
		Tillering stage	Panicle initiation stage			
Ariz tez	Yellow rice stem borer	5.45ijk	0.00j	30.12	7	0.01
	Short horned grasshopper	87.25a	49.40c	47.88	7	0.01
	Long horned grasshopper	3.75jkl	5.88gh	-24.46	7	0.01
	Rice bug	0.00m	37.30e	0.42	7	NS
	Stink bug	3.78jkl	5.87gh	-29.82	7	0.01
	Green leafhopper	0.00m	1.96ij	0.51	7	NS
Teea	Yellow rice stem borer	6.58hi	0.00j	47.55	7	0.01
	Short horned grasshopper	80.21b	86.03a	-608.75	7	0.01
	Long horned grasshopper	5.67ij	5.36gh	0.62	7	NS
	Rice bug	0.00m	6.46gh	0.43	7	NS
	Stink bug	1.87lm	1.07j	76.12	7	0.01
	Green leafhopper	5.66ij	1.07j	252.30	7	0.01
Sakti	Yellow rice stem borer	4.64ijk	0.00j	443.05	7	0.01
	Short horned grasshopper	72.54d	69.05b	5.498	7	0.01
	Long horned grasshopper	16.28f	11.90f	6.68	7	0.01
	Rice bug	0.00m	11.90f	0.52	7	NS
	Stink bug	4.65ijk	1.00j	5.17	7	0.01
	Green leafhopper	2.33l	4.78hi	-2.92	7	0.05
Shathi	Yellow rice stem borer	8.11h	0.00j	15.03	7	0.01
	Short horned grasshopper	59.46e	52.27c	10.90	7	0.01
	Long horned grasshopper	0.00m	0.00j	0.46	7	NS
	Rice bug	13.51g	40.91d	-29.66	7	0.01
	Stink bug	5.41ijk	6.82gh	-2.15	7	NS
	Green leafhopper	13.51g	0.00j	25.21	7	0.01
BRRI dhan 28	Yellow rice stem borer	4.65ijk	0.00j	8.68	7	0.01
	Short horned grasshopper	76.73c	86.05a	-6.38	7	0.01
	Long horned grasshopper	12.78g	1.16j	13.85	7	0.01
	Rice bug	2.33l	8.14g	-6.82	7	0.01
	Stink bug	0.00m	4.65hi	0.32	7	NS
	Green leafhopper	3.49kl	0.00j	6.51	7	0.01
CV (%)		5.68	8.87			
CD (0.01)		2.068	3.234			

Means within a column followed by same letter(s) are not significantly different by critical difference (P≤0.01)

Table 2. Relative abundance of insect predators on different boro rice varieties at their tillering and panicle initiation stages during 2011-12 at Patuakhali

Rice variety	Insect predators	Mean abundance (%) at		T ststistic	df	P
		Tillering stage	Panicle initiation stage			
Ariz tez	Spider	16.67g	0.00k	19.93	7	0.01
	Dragon fly	11.11h	22.22f	-12.11	7	0.01
	Damsel fly	11.12h	11.11i	-0.01	7	NS
	Lady bird beetle	16.67g	11.11i	4.90	7	0.01
	Wasp	33.33b	33.33d	0.00	7	NS
	Dipteran fly	11.11h	22.22f	-12.11	7	0.01
Teea	Spider	21.05f	0.00k	24.83	7	0.01
	Dragon fly	0.00j	13.33h	0.41	7	NS
	Damsel fly	21.05f	40.00c	-12.94	7	0.01
	Lady bird beetle	21.05f	6.67j	9.80	7	0.01
	Wasp	21.05f	40.00c	-12.94	7	0.01
	Dipteran fly	15.80g	0.00k	17.60	7	0.01
Sakti	Spider	23.08ef	0.00k	18.30	7	0.01
	Dragon fly	30.77c	16.67g	7.97	7	0.01
	Damsel fly	7.68i	0.00k	9.12	7	0.01
	Lady bird beetle	0.00j	16.67g	0.51	7	NS
	Wasp	30.77c	66.66a	-19.52	7	0.01
	Dipteran fly	7.69i	0.00k	9.09	7	0.05
Shathi	Spider	0.00j	0.00k	0.00	7	NS
	Dragon fly	25.00de	16.67g	4.23	7	0.01
	Damsel fly	25.00de	8.33j	11.73	7	0.01
	Lady bird beetle	12.50h	8.33j	3.29	7	0.05
	Wasp	12.50h	41.67c	-16.13	7	0.01
	Dipteran fly	25.00de	25.00e	0.00	7	NS
BRRI dhan 28	Spider	26.67d	0.00k	31.81	7	0.01
	Dragon fly	13.33h	50.00b	-40.15	7	0.01
	Damsel fly	6.67i	0.00k	7.90	7	0.01
	Lady bird beetle	0.00j	0.00k	0.00	7	NS
	Wasp	40.00a	50.00b	-6.83	7	0.01
	Dipteran fly	13.33h	0.00k	11.28	7	0.01
CV (%)		6.67	5.07			
CD (0.01)		2.418	1.837			

Means within a column followed by same letter(s) are not significantly different by critical difference ($P \leq 0.05$ and $P \leq 0.01$).

Relative abundance of insect predators

Relative abundance of insect predators in rice ecosystem is presented in Table 2. In Ariz tez variety, the highest percent relative abundance of wasp (33.33%) was recorded at tillering stage while the lowest in dipteran fly (11.11%). But in case of panicle initiation stage, the highest was of wasp (33.33%) and the lowest was in lady bird beetle (11.11%) which was statistically identical to damselfly (11.11).

In teea variety, the highest percent relative abundance of spider (21.05%) was recorded at tillering stage which was statistically identical to damselfly, lady bird beetle and wasp while the lowest percent was in dipteran fly (15.80%) was recorded. At panicle initiation stage, wasp (40.00%) had the highest and lady bird beetle possessed the lowest percent (6.67%) relative abundance (Table 2).

In sakti variety, the highest percent relative abundance was found in dragonfly (30.77%) which was statistically identical to wasp (30.77%) at tillering stage while the lowest was in damselfly (7.68%) followed by dipteran fly (7.69%). At panicle initiation stage, the highest percent relative abundance was in wasp (66.66%) while the lowest was in lady bird beetle (16.67%) which was statistically identical to dragonfly (16.67%).

In shathi variety, the relative abundance of insect predators was the highest in dragon fly (25.00%) which was statistically identical to damselfly (25.00%) and dipteran fly (25.00%) while the lowest was in lady bird beetle (12.50%) at tillering stage. But in case of panicle initiation stage, the highest was in wasp (41.67%) and the lowest was in lady bird beetle (8.33%).

In BRRI dhan 28, significantly the highest percent relative abundance was recorded in wasp (40.00%) while the lowest was in damsel fly (6.67%) at llering stage. But in case of panicle initiation stage the highest percent relative abundance was in dragon fly (50.00%) which was statistically identical to wasp (50.00%).

The findings of the present study are in agreement with the findings of Rahman *et al*. (2004) who reported that the abundance of insect pests and natural enemies was influenced by different growth stages of rice plant. The highest abundance was observed at reproductive stage and the lowest was at mid tillering stage. Khan and Alam (2007) also found that the highest number of insect pests and natural enemies was found at reproductive stage and the lowest was at mid tillering stage. Bakar and Khan (2016) reported that diversity indices of insect pests and their natural enemies were found to be affected by the combined effect of rice growth stages and management practices in boro rice. Mukherjee and Khan (2014) found that the highest percent relative abundance (44.14%) was in the population of rice bug and in ground beetle of insect predators while lowest percent (0.31%) was in rice stem borer and in dragonfly (0.51%) of insect predators. Lanjar *et al*. (2002) found that four species infesting rice crop which were *Hieroglyphus banian* (rice grasshopper), *Oxya nitidula* (small green grasshopper), *Chrotogonus trachypterus* (surface grasshopper), and *Aiolopus tamulus* [*A. thalassinus*] (small grasshopper). *C. trachypterus* was recorded in maximum number (12.8 nymphs and 39.2 adults/observation) during July-October under a mean temperature of 37.95^{0}C. Tsueda *et al.* (2002) studied on the occurrence of rice bugs (a total of 22 species) in rice fields. They also observed that *Stenotus rubrovittatus* was the important species and the peak occurrence of it coincided with the date of heading of early-ripening rice. Afsana and Islam (2001) studied abundance of lady bird beetles and found five species of lady bird beetles viz. *M. discolor, M. crocea, Coccinella transversahs, C. septempunctata* and *Brumoides suturalis* in irrigated rice fields at Gazipur in Bangladesh. Among them *M. discolor* was the most dominant species comprising about 92.9% of the total ladybird beetle populations.

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RESPONSE OF STRAWBERRY TO NPKS ON YIELD IN TERRACE SOIL

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Abstract

Strawberry (*Fragaria X annanassa* Duch.) is highly exhaustive and responsive to chemical fertilizers. An experiment on strawberry was conducted in fruits research field of Horticulture Research Centre, BARI, Gazipur over three consecutive years, 2009-2010, 2010-2011 and 2011-2012 to find out the suitable combination of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) for yield maximization of strawberry. Fourteen treatment combinations were tested in this trial comprising four levels each of N (0, 90, 115 and 140 kg ha^{-1}), P (0, 20, 40 and 60 kg ha^{-1}), K (0, 85, 110 and 135 kg ha^{-1}) and S (0, 15, 25 and 35 kg ha^{-1}) with blanket dose of 4 kg Zn ha^{-1}, 2 kg B ha^{-1} and 10 t cowdung ha^{-1}. The experiment was set up in randomized completely block design with three replications. Results showed that treatment combination $N_{115}P_{40}K_{110}S_{25}$ (underscript represent kg ha^{-1}) produced higher strawberry fruit yield (9.59 t ha^{-1}) followed by $N_{90}P_{40}K_{110}S_{25}$ kg ha^{-1} and $N_{140}P_{40}K_{110}S_{25}$ kg ha^{-1} treatment combinations. The lowest fruit yield (6.05 t ha^{-1}) was found in control ($N_0P_0K_0S_0$) treatment. Therefore, the combination of $N_{115}P_{40}K_{110}S_{25}$ kg ha^{-1} may be considered as suitable dose for strawberry cultivation in terrace soils of Bangladesh.

Keywords: Fertilizer (N, P, K and S), strawberry yield, terrace soil.

Introduction

Strawberry (*Fragaria X annanassa* Duch.) belongs to rose family. It is a good source of vitamin C, folate and potassium, and is relatively low in calories. Excellent ice cream and jam or jellies are made with strawberry due to its attractiveness, tasty, pleasant aroma and flavor (Rayees *et al*., 2015). Strawberry has attained a premier position in the fresh fruit market and processing industries of the world (Sharma and Sharma, 2003). Although it is widely grown in temperate zones, its cultivation is also possible in the sub-tropical zones as day neutral cultivars (Asrey and Singh, 2004). Strawberry offers quicker returns than any other fruit crop.

Most of the soils and climatic conditions of Bangladesh are suitable for strawberry production. Cultivation of this fruit has started in Bangladesh.

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However, the average yield is lower compared to the other sub-tropical countries, imbalance fertilization and poor agronomic practices being one of the best reasons. On the other hand, excess use of chemical fertilizers, pesticides and herbicides renders adverse effects on soil health and environment quality (Macit *et al.,* 2007). For sustainable crop yields, balanced fertilizations with all the nutrients (major and trace) that are deficient in soils need to be taken into account. Role of nitrogen involves in vigorous vegetative growth with dark green color. It is a constituent of protein and nucleic acids and an integral part of chlorophyll. Plant cells need to have adequate phosphorus before they divide. Phosphorus increases root growth, yield, enhances plant maturity and promotes resistance to root rot disease and winter kill (Norfleet, 1998). Potassium is associated with activation of enzymes related to starch synthesis, regulation of stomata openings, imparts disease, cold and drought resistance to plants. Sulphur is a constituent of some amino acids, biotin and coenzyme. It is involved in chlorophyll synthesis (FRG, 2012).

Farmers of Bangladesh usually use fertilizers based on their own estimate without thinking of balance fertilization which causes deterioration of soil fertility. As intensive crop cultivation is becoming more and more necessary to meet the demand of the over population, the soil nutrient balance is becoming increasingly negative and thus requiring appropriate supplement through balanced nutrient management. We do not have yet any recommended dose of fertilizers for boosting fruit yield of strawberry in the BARC published Fertilizer Recommendation Guide. Hence, the experiment was undertaken to determine the dose of N, P, K and S for yield maximization of strawberry in terrace soils of Bangladesh.

Materials and Methods

The experiment was done at the fruits research field of Horticulture Research Centre, BARI, Gazipur during *rabi* season of 2009-10, 2010-11 and 2011-12 to find out the suitable combination of N, P, K and S for yield maximization of strawberry. The experimental site (24° 0′ 13″ N latitude and 90° 25′ 0″ E longitude) lies at an elevation of 8.4 m above the sea level. The Gazipur soil belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agroecological zone Madhupur Tract, the soil texture being clay loam. There were 14 treatment combinations comprising four levels each of N (0, 90, 115 and 140 kg ha^{-1}), P (0, 20, 40 and 60 kg ha^{-1}), K (0, 85, 110 and 135 kg ha^{-1}) and S (0, 15, 25 and 35 kg ha^{-1}). A blanket dose of fertilizer viz. $Zn_{4.0}B_{2.0}$ kg ha^{-1} and 10 t ha^{-1}cowdung were used in the trial. The arrangement of treatment combinations is shown in Table 1. Soil samples (0-15 cm) before initiation of the experiment was analyzed for soil pH (Jackson, 1973), organic matter (Nelson and Sommers,1982), total N (Bremner and Mulvaney, 1982), exchangeable K (Jackson, 1973), exchangeable Ca & Mg (Gupta, 2004), available P (Olsen & Sommers, 1982), available S (Fox *et al*., 1964), available Zn (Lindsay and

Norvell, 1978), available B (Page *et al*., 1982). The results of the soil properties are shown in Table 2.

The land was prepared thoroughly by a tractor driven siezel and rotavator. The experiment was laid out in randomized completely block design with three replications. The unit plot size was 2.5 m × 1 m along with crop spacing of 50 cm x 50 cm. Nitrogen, P, K, S, Zn and B were supplied as urea, TSP, MoP, gypsum, zinc sulphate and boric acid fertilizer, respectively. Zinc sulphate, boric acid and cowdung were applied to all plots at the time of final land preparation. Triple super phosphate, gypsum and 50% MoP were added in the respective plots during final bed preparation. Fourty five days old strawberry (var. BARI Strawberry-1) seedlings were transplanted on 20 December 2009, 19 December 2010 and 21 December 2011. Urea and 50% MoP were supplied in three equal splits after 15, 30 and 45 days of transplanting, respectively. Intercultural operations were done as and when required. Data on the number of fruits per plant, length, diameter, fruit weight per plant and individual fruit weight were recorded from eight randomly selected plants. All data on different parameters were computed for statistical analysis and the mean comparisons were adjusted by DMRT at 5% level of significance.

Table 1. Fertilizer rate wise treatment arrangement

Treatment	Subscripts represent kg ha^{-1}	Treatment	Subscripts represent kg ha^{-1}
T_1	$N_0P_{40}K_{110}S_{25}$	T_8	$N_{115}P_{40}K_0S_{25}$
T_2	$N_{90}P_{40}K_{110}S_{25}$	T_9	$N_{115}P_{40}K_{85}S_{25}$
T_3	$N_{115}P_{40}K_{110}S_{25}$	T_{10}	$N_{115}P_{40}K_{135}S_{25}$
T_4	$N_{140}P_{40}K_{110}S_{25}$	T_{11}	$N_{115}P_{40}K_{110}S_0$
T_5	$N_{115}P_0K_{110}S_{25}$;	T_{12}	$N_{115}P_{40}K_{110}S_{15}$
T_6	$N_{115}P_{20}K_{110}S_{25}$	T_{13}	$N_{115}P_{40}K_{110}S_{35}$
T_7	$N_{115}P_{60}K_{110}S_{25}$	T_{14}	$N_0P_0K_0S_0$

Table 2. Soil properties of the experimental field

Location	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Zn
			meq/100g				μg/g			
Joydebpur	6.3	0.95	1.12	0.60	0.17	0.068	9	15	0.1	1.3
Critical level (FRG, 2012)	-	-	2.0	0.5	0.12	0.12	10	10	0.2	0.6

Results and Discussion

Yield contributing characters

Combination of N, P, K and S showed significant influence on yield contributing characters of strawberry in all three years (Tables 3 & 4). The number of fruits per plant and fruit length (mean of three years) ranged from 9.95-15.6 and 3.96-3.11 cm, respectively. The maximum number of fruits per plant was recorded from the combination of $N_{115}P_{40}K_{110}S_{25}$ (T_3) which was significantly different from the other treatment combinations, but statistically identical with T_2 and T_4 treatments in every year. Result of fruit length showed a similar trend. Similar results were reported by Klaas (2000) and Funt and Blerman (2000). The minimum number of fruit per plant and the lowest fruit length were recorded from the T_{14} treatment ($N_0P_0K_0S_0$) (Table 3).

Different combination of N, P, K and S contributed significant role on fruit diameter and fruit weight per plant of strawberry in three following years. Mean fruit diameter varied from 2.17-3.31 cm. The highest fruit diameter (3.31) was recorded from T_3 treatment ($N_{115}P_{40}K_{110}S_{25}$) followed by T_4 and T_2, while the minimum was recorded from the T_{14} ($N_0P_0K_0S_0$). Mean fruit weight per plant varied from 145.9-237.6 g where the highest fruit weight per plant was found in T_3 treatment ($N_{115}P_{40}K_{110}S_{25}$) followed by T_4 and T_2. The lowest fruit diameter was observed in $N_0P_0K_0S_0$ treatment (Table 4). These findings are in agreement with Arancon *et al*. (2004), Singh and Dwivedi (2011).

Table 3. Effects of different combinations of N, P, K and S on fruits plant^{-1} and fruit length of strawberry

Treatments (kg ha^{-1})	Fruits plant^{-1}				Fruit length (cm)			
	2010	2011	2012	mean	2010	2011	2012	mean
$T_1 = N_0P_{40}K_{110}S_{25}$	17.5def	8.33gh	8.15gh	11.3	3.26e	3.09cd	3.24cd	3.20
$T_2 = N_{90}P_{40}K_{110}S_{25}$	19.2a-e	11.75ab	11.55ab	14.2	3.64abc	3.82abc	3.97a-c	3.81
$T_3 = N_{115}P_{40}K_{110}S_{25}$	21.8a	12.55a	12.35a	**15.6**	3.72a	4.01a	4.16a	**3.96**
$T_4 = N_{140}P_{40}K_{110}S_{25}$	20.4abc	12.05ab	11.85ab	14.8	3.69a	3.92ab	4.08ab	3.90
$T_5 = N_{115}P_0K_{110}S_{25}$	17.6def	8.68fgh	8.45f-h	11.6	3.47d	3.12cd	3.26cd	3.28
$T_6 = N_{115}P_{20}K_{110}S_{25}$	18.1b-e	10.15cde	9.95c-e	12.7	3.70a	3.35a-d	3.48a-d	3.51
$T_7 = N_{115}P_{60}K_{110}S_{25}$	19.1a-e	10.85bcd	10.65b-d	13.5	3.56bcd	3.52a-d	3.65a-d	3.58
$T_8 = N_{115}P_{40}K_0S_{25}$	19.9a-d	9.19efg	9.05e-g	12.7	3.44d	3.19bcd	3.35b-d	3.33
$T_9 = N_{115}P_{40}K_{85}S_{25}$	20.7ab	9.82def	9.65d-f	13.4	3.55cd	3.29a-d	3.45a-d	3.43
$T_{10} = N_{115}P_{40}K_{135}S_{25}$	17.8c-f	11.45abc	11.25a-c	13.5	3.46d	3.76a-d	3.90a-d	3.71
$T_{11} = N_{115}P_{40}K_{110}S_0$	16.5ef	9.53d-g	9.35d-g	11.8	3.65abc	3.25a-d	3.41a-d	3.44
$T_{12} = N_{115}P_{40}K_{110}S_{15}$	19.8a-d	11.25abc	11.05a-c	14.0	3.71a	3.65a-d	3.78a-d	3.71
$T_{13} = N_{115}P_{40}K_{110}S_{35}$	19.4a-e	10.35cde	10.35c-e	13.4	3.68ab	3.43a-d	3.56a-d	3.56
$T_{14} = N_0P_0K_0S_0$	15.3f	7.38h	7.15h	9.95	3.16e	3.02d	3.15d	3.11
CV (%)	7.52	5.91	6.42	-	5.11	9.88	8.85	-

Values within a same column with a common letter do not differ significantly (p=0.05) by DMRT.

Table 4. Effects of different combinations of N, P, K and S on fruits diameter and fruit wt. plant^{-1} of strawberry

Treatments (kg ha^{-1})	Fruit diameter (cm)				Fruit wt. plant^{-1} (g)			
	2010	2011	2012	mean	2010	2011	2012	mean
T_1= $N_0P_{40}K_{110}S_{25}$	2.90b-e	2.32gh	2.35gh	2.52	237.3a-e	132.6gh	142.6gh	170.8
T_2= $N_{90}P_{40}K_{110}S_{25}$	2.98bc	3.21ab	3.25ab	3.15	282.7abc	190.6abc	199.6a-c	224.3
T_3= $N_{115}P_{40}K_{110}S_{25}$	3.17a	3.35a	3.41a	**3.31**	292.7a	205.1a	215.1a	**237.6**
T_4= $N_{140}P_{40}K_{110}S_{25}$	2.93b-e	3.25ab	3.29ab	3.16	284.0ab	199.9ab	205.9ab	229.9
T_5= $N_{115}P_0K_{110}S_{25}$	2.87de	2.44fgh	2.48f-h	2.60	216.7de	138.4fgh	145.4f-h	166.8
T_6= $N_{115}P_{20}K_{110}S_{25}$	2.96bcd	2.85b-f	2.88b-f	2.90	254.7a-d	158.3c-g	165.4c-g	192.8
T_7= $N_{115}P_{60}K_{110}S_{25}$	2.97bcd	3.02a-d	3.08a-d	3.02	262.7a-d	172.9a-f	180.9a-f	205.5
T_8= $N_{115}P_{40}K_0S_{25}$	2.88cde	2.52e-h	2.55e-h	2.65	231.3b-e	143.4fgh	152.4f-h	175.7
T_9= $N_{115}P_{40}K_{85}S_{25}$	2.90b-e	2.72c-g	2.75c-g	2.79	236.7 a-e	151.3d-h	160.4d-h	182.8
T_{10}= $N_{115}P_{40}K_{135}S_{25}$	2.99b	3.15abc	3.18a-c	3.11	277.3abc	185.8a-d	195.8a-d	219.6
T_{11}= $N_{115}P_{40}K_{110}S_0$	2.84e	2.65d-g	2.68d-g	2.72	227.3cde	147.6e-h	155.6e-h	176.8
T_{12}= $N_{115}P_{40}K_{110}S_{15}$	2.93b-e	3.09a-d	3.12a-d	3.05	276.7abc	178.7a-e	158.7a-e	204.7
T_{13}= $N_{115}P_{40}K_{110}S_{35}$	2.95bcd	2.92a-e	2.95a-e	2.94	260.0 a-d	168.3b-g	175.3b-g	201.2
T_{14}= $N_0P_0K_0S_0$	2.21f	2.15h	2.16h	2.17	194.0e	118.3h	125.3h	145.9
CV (%)	5.90	6.87	7.25	6.67	7.65	9.40	8.45	8.5

Values within a same column with a common letter do not differ significantly (p=0.05) by DMRT.

Fruit yield

Table 5 shows that combined application of NPKS fertilizers had a significant effect on individual fruit weight and fruit yield of strawberry. The highest fruit weight (mean 16.68 g) and fruit yield (mean 9.59 t ha^{-1}) were obtained with the application of $N_{115}P_{40}K_{110}S_{25}$ treatment (T_3) and the lowest values were noted with $N_0P_0K_0S_0$ treatment (T_{14}). The highest yield was statistically similar with the yield recorded by treatments T_2 ($N_{90}P_{40}K_{110}S_{25}$) and T_4 ($N_{140}P_{40}K_{110}S_{25}$). The maximum fruit yields produced by these treatments can be attributed to cumulative effect of the number of fruits per plant and individual fruit weight. Comparable results were reported by other workers (Koszanski *et al.,* 2002, Mahaveer *et al.,* 2004).

Table 5. Effects of different combinations of N, P, K and S on fruit weight and fruit yield of strawberry

Treatments (kg ha^{-1})	Individual fruit wt. (g)				Fruit yield (t ha^{-1})			
	2010	2011	2012	mean	2010	2011	2012	mean
$T_1 = N_0P_{40}K_{110}S_{25}$	15.85ab	10.85gh	12.80gh	13.17	9.49def	5.98ef	5.95ef	7.14
$T_2 = N_{90}P_{40}K_{110}S_{25}$	16.25a	14.85abc	16.80a-c	15.97	11.31abc	8.15ab	8.10ab	9.19
$T_3 = N_{115}P_{40}K_{110}S_{25}$	16.29a	15.90a	17.85a	**16.68**	11.71a	8.55a	8.50a	**9.59**
$T_4 = N_{140}P_{40}K_{110}S_{25}$	15.81ab	15.45ab	17.40ab	16.22	11.36ab	8.35ab	8.32ab	9.34
$T_5 = N_{115}P_0K_{110}S_{25}$	14.12cde	11.25fgh	13.20f-h	12.86	8.67fg	6.18def	6.15d-f	7.00
$T_6 = N_{115}P_{20}K_{110}S_{25}$	15.52ab	13.25b-f	15.20b-f	14.66	10.19cde	7.12a-e	7.15a-e	8.15
$T_7 = N_{115}P_{60}K_{110}S_{25}$	15.70ab	13.95a-e	15.90a-e	15.18	10.51bcd	7.45a-e	7.48a-e	8.48
$T_8 = N_{115}P_{40}K_0S_{25}$	13.94de	11.78efg	13.75e-g	13.16	7.92g	6.35def	6.38d-f	6.88
$T_9 = N_{115}P_{40}K_{85}S_{25}$	15.83ab	12.88c-g	14.85c-g	14.52	9.46def	6.88b-e	6.90b-e	7.75
$T_{10} = N_{115}P_{40}K_{135}S_{25}$	14.95bcd	14.45a-d	16.40a-d	15.27	11.09abc	7.95abc	7.95a-c	9.00
$T_{11} = N_{115}P_{40}K_{110}S_0$	15.17abc	12.45d-g	14.35d-g	13.99	9.09ef	6.59c-f	6.62c-f	7.43
$T_{12} = N_{115}P_{40}K_{110}S_{15}$	15.47ab	14.15a-d	16.10a-d	15.24	11.07abc	7.65a-d	7.68a-d	8.80
$T_{13} = N_{115}P_{40}K_{110}S_{35}$	15.96ab	13.65a-e	15.55a-e	15.05	10.40bcd	7.22a-e	7.25a-e	8.29
$T_{14} = N_0P_0K_0S_0$	13.48e	9.15h	11.10h	11.24	7.76g	5.18f	5.20f	6.05
CV (%)	7.63	7.69	7.9	7.74	8.99	9.38	9.95	9.44

Values within a same column with a common letter do not differ significantly (p=0.05) by DMRT.

Single effect of N, P, K and S on strawberry yield

Single effects of N application positively increased strawberry yield during 2010, 2011 and 2012 (Table 6). The average fruit yield varied from 7.11-9.59 t ha^{-1}, where the highest yield (9.59 t ha^{-1}) was found in 115 kg N ha^{-1} and the lowest yield (7.11 t ha^{-1}) in N_0. The highest yield was 37% increase over N control. Similar results were reported by Abu-Zahra and Tahboub (2008). Results indicated that the dose above or below 115 kg N ha^{-1} rate suppressed the potential yield of strawberry. Positive effect of P was also noticed on yield increase of strawberry (Table 6). The average fruit yield varied from 7.00-9.59 t ha^{-1} where the highest yield (9.59 t ha^{-1}) was found in 40 kg P ha^{-1} and the lowest (7.00 t ha^{-1}) in P_0. Strawberry yield increased with the increasing level of phosphorus as reported by Yusuf *et al.* (2003) and Mohamed *et al.* (2011). Different levels of K application also demonstrated positive influence on strawberry yield (Table 6). The average fruit yield ranged from 6.88-9.59 t ha^{-1}, the highest yield (38% yield increase over K control) was noted in 110 kg K ha^{-1} and the lowest (6.88 t ha^{-1}) yield was in K_0. The average fruit yield due to S effect was from 7.43-9.59 t ha^{-1}(Table 6). The highest yield which was 29% yield increase over S control was observed in 25 kg S ha^{-1} and the lowest (7.43 t ha^{-1}) yield was recorded from S_0. The findings were corroborated by Klaas (2000) and Yadav *et al*. (2010).

Table 6. Single effect of N, P, K and S on the yield of strawberry

Nutrient levels (kg/ha)	Fruit yield (t ha^{-1})				% yield increase over control			
	2010	**2011**	**2012**	**mean**	**2009-10**	**2010-11**	**2011-12**	**mean**
				N level				
0	9.49	5.90	5.95	7.11	-	-	-	-
90	11.31	8.15	8.10	9.19	19	38	36	31
115	11.71	8.55	8.50	**9.59**	23	45	43	**37**
140	11.36	8.35	8.32	9.34	20	42	40	34
				P level				
0	8.67	6.18	6.15	7.00	-	-	-	-
20	10.19	7.12	7.15	8.15	17	15	16	16
40	11.71	8.55	8.50	**9.59**	35	38	38	**37**
60	10.51	7.45	7.48	8.48	21	21	22	21
				K level				
0	7.92	6.35	6.38	6.88	-	-	-	-
85	9.47	6.88	6.90	7.75	19	8	8	12
110	11.71	8.55	8.50	**9.59**	47	35	33	**38**
135	11.09	7.95	7.92	8.99	40	25	24	30
				S level				
0	9.09	6.59	6.62	7.43	-	-	-	-
15	11.07	7.65	7.68	8.80	21	16	16	18
25	11.71	8.55	8.50	**9.59**	28	30	28	**29**
35	10.40	7.22	7.25	8.29	14	10	10	11

Conclusion

The combination of $N_{115}P_{40}K_{110}S_{25}$ with blanket dose of $Zn_{4.0}B_{2.0}$ kg ha^{-1} and 10 t ha^{-1} cowdung gave higher yield of strawberry. Thus, combined application of N, P, K and S at 115, 40, 110 and 25 kg ha^{-1} can be recommended for yield maximization of strawberry in terrace soil of Madhupur Tract (AEZ 28).

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STABILITY OF HYBRID RICE GENOTYPES FOR GRAIN YIELD AND MATURITY

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Abstract

An experiment was conducted using nine hybrid rice genotypes along with two inbred standard check varieties in five different locations of Bangladesh to assess their stability in terms of grain yield and maturity in diverse environments. For this, adaptability, stability, genotype × environment (G×E) interaction effect for grain yield and maturity of 11 rice varieties in five agro ecological zones in Bangladesh were assessed during T. Aman season of 2015. The analysis of variance for growth duration and grain yield (t/ha) for genotypes, environment and genotype-environment interaction were highly significant at 1% level of probability indicating the variable response of genotypes and environments. The hybrid genotypes IR79156A/BRRI20R, BRRI hybrid dhan3, BRRI33R/BRRI26R, BRRI hybrid dhan4, standard check variety BRRI dhan49 and BR11 had high yield performance and widely adapted to all environments and these were non sensitive to environmental interactive forces, while the hybrids BRRI7A/BRRI31R, IR79156A/BasmatiR and SL-8 were sensitive to environmental interaction. Environment such as Gazipur (E1) and Faridpur (E3) having positive IPCA1 score and positive interaction with the hybrids BRRI7A/BRRI13R, SL-8H and IR79156A/BasmatiR were considered as the favourable environments for these hybrids.

Keywords: AEZ, adaptability, AMMI analysis.

Introduction

Hybrid rice is one of the proven technologies in the world for addressing food security and self-sufficiency in rice. Stability in yield is one of the vital desirable properties of a genotype to be released as a variety for cultivation. Presently, rice has special position as a source of food supply over 75% of Asian population and more than three billion of world population which represents 50 to 80% of their daily calorie intake (Amirjani, 2011). This population will increase to over 4.6 billion by 2050 (Honarnejad *et al.*, 2000) which demands more than 50% of rice needs to be produced what is produced at present to cope with the growing population (Srividya *et al.*, 2010).

Among the many available genetic approaches being exploited to break the yield barrier in rice, hybrid rice technology is considered as one of the promising,

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practical, sustainable and eco-friendly options to break the yield ceiling in rice (Sheeba *et al.*, 2009). The general rice breeding scheme includes evaluating a number of genotypes at various stages and testing selected ones at several locations. Information on genotype × environment interaction leads to successful evaluation of stable genotype, which could be used for general cultivation. Yield is a complex quantitative character and is greatly influenced by environmental fluctuations; hence, the selection for superior genotypes based on yield per se at a single location in a year may not be very effective (Shrestha *et al.*, 2012). In the process of evaluation of genotypes under different environmental situation stability performance for yield has been an effective part of any breeding program. Considerable number of methods have been developed to analyze genotype × environment interaction and phenotypic adaptability. In them the additive main effect and multiplicative interaction analysis (AMMI) has been broadly applied in the statistical analysis of all-environment genotype trials (Gauch and Zobel, 1997). AMMI biplot analysis is argued to be an useful tool to diagnosticate GEI patterns graphically. In AMMI, the additive portion is separated from interaction by analysis of variance (ANOVA). The biplot show PCA scores decorated against each other gives apparent inspection and explanation of genotype × environment interaction components. The present investigation of hybrid rice was started to analyze G × E interaction using AMMI model and to assess stability and adaptability of genotypes in various environments.

Materials and Methods

The experiments were conducted under hybrid rice division of Bangladesh Rice Research Institute (BRRI) at five different agro-ecological zones (Gazipur =E1, Rangpur =E2, Faridpur = E3, Rajshahi =E4 and Sonagazi =E5) during T Aman season of 2015. The entry comprises four promising, 5 released rice hybrid varieties and two standard inbred checks BRRI dhan49 and BR11 (Table 1). The experiments were carried out in a randomized complete block design with three replications. The size of each experimental plot was 5 × 6 m. Standard agronomic practices were followed and plant protection measures were taken as required. Two border rows were used to minimize the border effects. Growth duration were recorded and the grain yield (t/ha) data was estimated and adjusted at 14% moisture.

Table 1. List of materials with sources

SL No.	Designation	Sources	SL No.	Designation	Sources
1	BRRI33A/BRRI26R	BRRI	7	Heera F_1	Supreme Seed Company
2	BRRI7A/BRRI31R	BRRI	8	Teea F_1	Lal Teer Seed (BD) Ltd.
3	IR79156A/BRRI20R	BRRI	9	BRRI hybrid dhan4	BRRI
4	BRRI hybrid dhan3	BRRI	10	BRRI dhan49	BRRI
5	IR79156A/BasmatiR	BRRI	11	BR11	BRRI
6	SL-8H	BADC			

Statistical analysis

AMMI model was used to quantify the effect of different factors (genotype, location) of the experiment. The AMMI statistical model is most appropriately termed as a hybrid model. It makes use of standard ANOVA procedures to separate the additive variance from multiplicative variance (genotype by environment interaction). Then it uses a multiplicative procedure- PCA- to extract the pattern from the G x E portion of the ANOVA (Zobel *et al*., 1988). Thy hybrid model is:

$$Y_{ge} = \mu + \alpha_g + \beta_e + \sum_{n=1}^{N} \lambda n \gamma_{gn} \delta_{en} + \rho_{ge}$$

Where:

Y_{ge} = yield of the genotype (g) in the environment (e)

μ = grand mean

α_g = genotype mean deviation

β_e = environment mean deviation

N = No. of IPCAs (Interaction Principal Component Axis) retained in he model.

λn = singular value for IPCA axis **n**

γ_{gn} = genotype eigenvector values for IPCA axis **n**

δ_{en} = environment eigenvector values for IPCA axis **n**

ρ_{ge} = the residuals

The model further provides graphical representation of the numerical results (Biplot analysis) with a straight-foreword interpretation of the underlying causes of G x E (Gauch, 1988), (Kempton, 1984), (Bradu and Gabriel, 1978).

Results and discussion

Significant Mean Sum of Squares (MSS) of genotypes, environment and G×E interaction for growth duration and yield were estimated (Table 2). The highly significant effects of environment indicated the differences in environmental factors of the locations. Significant MS for genotypes indicated differential genotypic composition of the genotypes. The variation in soil composition and other factors across the different environments were considered as the major underlying causal factors for the G×E interaction. The analysis of variance of AMMI showed that the mean sum of squares (MSS) due to treatments, genotypes, environments and genotype × environment interactions were significant, indicating broad range of diversity existed among genotypes (Anandan *et al.,* 2009, Vijayakumar *et al.,* 2001). Environment relative magnitude was much higher than the genotype effect, suggesting that genotype performance was influenced more by the environmental factors. Analysis of variance based on AMMI model for grain yield is presented in Table 2. The effects of genotype × environment interaction could be divided into four components, i.e.; IPCA1, IPCA2, IPCA3 and IPCA4 where IPCA1 and IPCA2 were significantly different but IPCA3 and IPCA4 were not significantly different.

Table 2. Analysis of variance of the G×E interaction of hybrid rice for growth duration and grain yield

Source of variation	df	Mean sum of squares	
		Growth duration	Yield (t/ha)
Genotypes (G)	10	1133.73**	14.18**
Environment (E)	4	74.13**	2.09**
Replication	2	44.58**	1.66**
Interaction G x E (GEI)	40	10.30**	0.51**
AMMI Component 1	13	7.66**	0.34**
AMMI Component 2	11	1.82	0.15*
AMMI Component 3	9	1.74	0.05
AMMI Component 4	7	0.31	0.03
G×E (Linear)	10	8.46**	0.31**
Pool deviation	30	1.76	0.12
Pooled error	88	5.45	0.21

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

Stability of the tested hybrids based on growth duration are presented in Table 3.The hybrids IR79156A/BasmatiR, SL-8H, Heera and BRRI hybrid dhan4 exhibiting negative phenotypic index (Pi), insignificant regression coefficient (bi) and deviation from regression (S^2di) values can be considered as stable across all environments with shorter growth duration. Kulsum *et al.* (2015) showed the genotype HS273, Heera 2, Doel, BRRI dhan29 and BRRI hybrid dhan1 are stable over all environments with short growth duration. Short growth duration is required for development of early maturing variety. BRRI hybrid dhan3 had negative phenotypic index (Pi), significant regression coefficient (bi) and insignificant deviation from regression (S^2di) values which indicated that this hybrid would be highly responsive to the favorable environments of E4 and E5.

Table 3. Stability analysis for growth duration of promising hybrid rice genotypes in five environments

En. no	Genotypes	Environments						Phenotypic Index (Pi)	bi	S^2di
		E1	E2	E3	E4	E5	Overall Mean			
1	BRRI33A/BRRI26R	115.7	116.0	114.3	111.3	115.0	114.5	2	1.14	0.75
2	BRRI7A/BRRI31R	115.3	119.0	117.3	116.3	115.7	116.7	4.2	0.14	2.86
3	IR79156A/BRRI20R	112.7	109.7	114.7	106.7	110.7	110.9	-1.6	1.70	3.63
4	BRRI hybrid dhan3	105.7	106.7	106.0	104.7	105.3	105.7	-6.8	0.38*	0.30
5	IR79156A/BasmatiR	108.3	105.7	107.7	102.3	106.3	106.1	-6.4	1.48	0.72
6	SL-8H	107.0	105.7	104.7	103.3	104.7	105.1	-7.4	0.76	0.76
7	Heera	111.7	107.7	110.7	104.3	109.7	108.8	-3.7	1.74	2.13
8	Teea	107.0	106.3	106.7	107.3	105.7	106.6	-5.9	-0.16*	0.47
9	BRRI hybrid dhan4	109.7	109.7	109.0	105.0	107.7	108.2	-4.3	1.28	0.26
10	BRRI dhan49	132.7	132.7	134.3	123.0	130.7	130.7	18.2	2.91*	1.37
11	BR11	127.0	127.0	123.0	127.3	127.7	126.3	13.8	-0.36	4.35*
	Mean	114.2	114.3	113.6	108.5	112.2	112.5			
	E index (Ij)	1.7	1.8	1.1	-4.0	-0.3				
	CV (%)	2.13	1.13	1.92	2.20	1.98				
	LSD (0.05)	4.12	2.18	3.72	4.13	3.79				

* indicates slopes significantly different from the slope for the overall regression which is 1.00.

E1= Gazipur, E2= Rangpur, E3= Faridpur, E4= Rajshahi and E5= Sonagazi.

Standard check variety BRRI dhan49 had positive phenotypic index (Pi), significant regression coefficient (bi) and non significant S^2di value indicating higher growth duration and highly responsive to the favorable environments of E1, E2 and E3. Standard check variety BR11 had positive phenotypic index (Pi), insignificant regression coefficient (bi) and S^2di value indicating late maturing in E4 and E5. The promising hybrid BRRI33A/BRRI26R had higher mean value than the grand mean, positive Pi value, insignificant regression coefficient (bi) and deviation from regression (S^2di) values indicating stable hybrid over all environments for longer days to maturity (Table 3). Aditya *et al.,* (2010) observed the genotype BRRI dhan29-SC3-28-L3 had short growth duration and stable over locations.

Among the hybrids IR79156A/BRRI20R had the highest mean grain yield, positive phenotypic index (Pi), insignificant regression coefficient (bi) and deviation from regression (S^2di) values indicating stable hybrid over all environments E1, E2, E3, E4 and E5. It is the best hybrid for grain yield. Kulsum et al. (2015) also observed thats the genotype ACI93024 was more adapted to a wide range of environments.

Table 4. Stability analysis for grain yield (t/ha) of promising hybrid rice genotypes in five environments

En. no	Genotypes	Environments						Phenotypic Index (Pi)	bi	S^2di
		E1	E2	E3	E4	E5	Overall Mean			
1	BRRI33A/ BRRI26R	6.47	6.47	6.53	6.28	5.77	6.30	0.54	0.31	0.12
2	BRRI7A/ BRRI31R	6.65	5.56	6.37	5.32	5.71	5.92	0.16	1.89	0.12
3	IR79156A/ BRRI20R	7.57	7.51	7.70	7.59	6.98	7.47	1.71	0.35	0.10
4	BRRI hybrid dhan3	6.98	6.73	6.81	6.76	6.75	6.80	1.04	0.38*	0.00
5	IR79156A/ BasmatiR	6.60	4.40	6.36	5.52	5.99	5.77	0.01	3.06	0.22
6	SL-8H	6.76	4.68	6.45	5.75	6.19	5.96	0.2	2.87	0.18
7	Heera	5.43	4.36	4.06	5.04	4.78	4.73	-1.03	1.13	0.28
8	Teea	5.16	4.61	4.14	4.88	4.56	4.67	-1.09	0.60	0.16
9	BRRI hybrid dhan4	6.32	6.22	6.38	6.11	6.02	6.21	0.45	0.31	0.02
10	BRRI dhan49	5.26	5.22	5.37	5.31	5.31	5.30	-0.46	0.07*	0.00
11	BRRI dhan11	4.23	4.22	4.22	4.17	4.20	4.21	-1.55	0.03*	0.00
	Mean	6.13	5.45	5.86	5.70	5.66	5.76			
	E index (Ij)	0.37	-0.31	0.1	-0.06	-0.1				
	CV (%)	3.81	5.76	12.74	8.35	4.45				
	LSD (0.05)	0.4	0.53	1.27	0.81	0.43				

* indicates slopes significantly different from the slope for the overall regression which is 1.00.

E1= Gazipur, E2= Rangpur, E3= Faridpur, E4= Rajshahi and E5= Sonagazi.

The hybrid BRRI33A/BRRI26R, BRRI hybrid dhan4, SL-8H, BRRI7A/BRRI31R and IR79156A/BasmatiR showed positive and considerable phenotypic index (Pi), insignificant regression coefficient (bi) and deviation from regression (S^2di) which indicated that these hybrids were stable over all environments (Table 4). BRRI hybrid dhan3 showed positive phenotypic index (Pi), significant regression coefficient (bi) and insignificant deviation from regression (S^2di) which was stable in E1 and E3. Kulsum *et al.* (2013) observed that the promising hybrid II32A/BR12R was suitable for Gazipur location and another promising hybrid BR10A/BR13R was favorable for Comilla location. The grain yield was sensitive and highly influenced by environment resulting in higher G × E interaction under stress environments in rainfed ecosystem (Ouk *et al.,* 2007).

Biplot analysis is possibly the most powerful interpretive tool for AMMI models. Biplots are graphs where aspects of both genotypes and environments are plotted on the same axes so that interrelationships can be visualized. There are two basic AMMI biplots, the AMMI 1 biplot where the main effects (genotype mean and environment mean) and IPCA1 scores for both genotypes and environments are plotted against each other and the AMMI 2 biplot where scores for IPCA1 and IPCA2 are plotted.

In AMMI 1 biplot, the usual interpretation of a biplot is that the displacements along the abscissa indicate differences in main (additive) effects, whereas displacements along the ordinate indicate differences in interaction effects. AMMI 2 biplot presents the spatial pattern of the first two PCA axes of the interaction effect corresponding to the genotypes and helps in visual interpretation of the GEI patterns and identify genotypes or locations that exhibit low, medium or high levels of interaction effects (Sharma *et al.* 1998). Points of either genotypes or environments which are near each other have similar interaction patterns while points distant from each other are different.

The AMMI 1 biplot gave a model fit 96.0%. This result is agreed with the findings of Naveed *et al.*, (2007); Gauch and Zobel (1996). Among the hybrids IR79156A/BRRI20R, BRRI hybrid dhan3, BRRI hybrid dhan4 and BRRI33A/BRRI26R exhibited high main effect with negative IPCA1 score (Fig. 1). Hence, they were identified as specifically adapted to favourable environments.

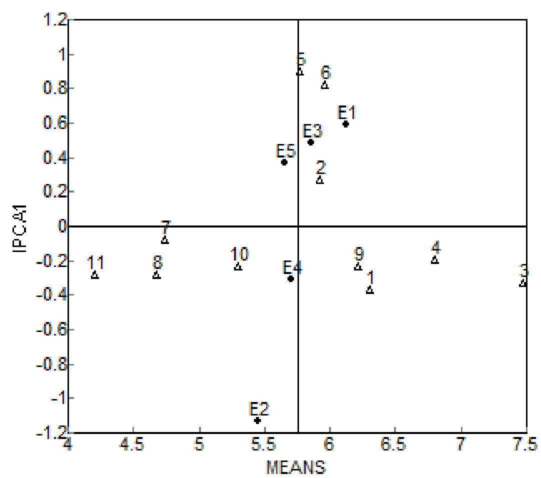

Fig. 1. Biplot of the first AMMI interaction (IPCA 1) score (Y-axis) plotted against mean yield (X-axis) for promising hybrid rice genotypes.

The environments E4 had negative IPCA1 score and it is considered as favourable environment for these hybrids. On the other hand BRRI7A/BRRI31R, SL-8H and IR79156A/BasmatiR had positive IPCA score with high main effect. The environments E1 and E3 had positive IPCA1 score, it had positive interaction with these hybrids and these two were considered as the favorable environments for these hybrids. However, these hybrids had negative interaction with other environment (E4 and E2) as it possessed negative IPCA1 score. Genotypes near the origin are non sensitive to environmental interactive forces and those distant from the origins are sensitive and have large interaction (Muthuramu *et al.,* 2011). Since IPCA2 scores also play a significant role in exploiting the GEI, the IPCA1 scores were plotted against the IPCA2 scores to further explore adaptation (Fig 2). According to figure 2 the hybrids BRRI33A/BRRI26R, IR79156A/BRRI20R, BRRI hybrid dhan3, BRRI hybrid dhan4, standard check variety BRRI dhan49 and BR11 were close to the centre of the origin and showed to be more stable when plotting the IPCA1 and IPCA2 score.

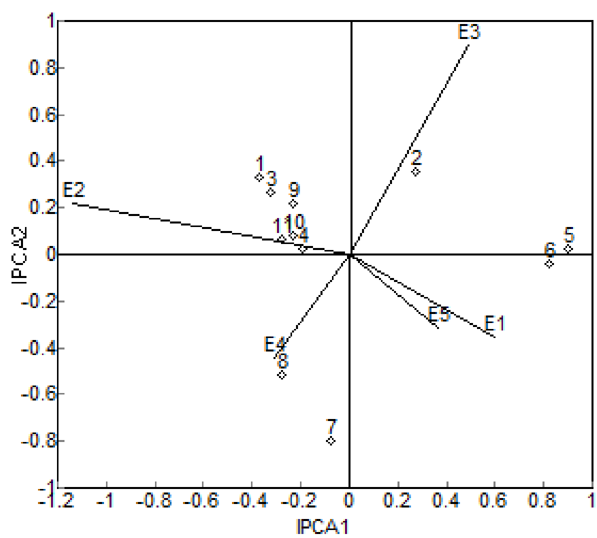

Fig. 2. Biplot of the first AMMI interaction (IPCA 2) score (Y-axis) plotted against AMMI interaction (IPCA 1) score (X-axis) for promising hybrid rice genotypes.

Conclusion

The hybrids BRRI7A/BRRI31R, IR79156A/BasmatiR, SL-8H, Heera and Teea were far from the centre of origin and showed instability due to their dispersed position. Environmental factors and genotype by environment interaction had the highest influence on the yield of those rice hybrids. The AMMI statistical model showed that the largest proportion of the total variation in grain yield was attributed to environments in this study. The hybrid BRRI33A/BRRI26R and IR79156A/BRRI20R had the highest yield and were hardly affected by the GEI effects as a result, they will perform well across a wide range of environments. The yield of BRRI7A/BRRI31R was also stable against environmental changes but its potential was lower than BRRI33A/BRRI26R and IR79156A/BRRI20R.

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THE POLICY ANALYSIS MATRIX OF PULSE CROPS PRODUCTION IN BANGLADESH

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Abstract

This study examined the relative efficiency of producing of selected pulse crops in Bangladesh and their comparative advantage in international trade. To know the comparative advantage in production of selected pulse crops. The study have calculated net financial and economic profitability, nominal protection coefficient of output (NPCO), nominal protection coefficient of input (NPCI), effective protection co-efficient (EPC), private cost ratio (PCR), policy analysis matrix (PAM) and domestic resource cost (DRC). Data used in this study were collected through Household surveys from 300 sample farms located in 12 villages under 6 districts in Bangladesh for the period 2015 to 2016. The selected pulse crops i.e lentil, chickpea and mungbean cultivation at farm level is very much remunerative to its growers. The domestic-border price ratio of selected pulse crops indicates that domestic pulse production was taxed and consumers were subsidized. The border price of selected pulse crops at producer level was mostly higher than the domestic producer price indicating that there is a wide scope to cultivate pulse crops for import substitution in Bangladesh. Policy Analysis Matrix for selected pulse crops under import parity prices showed that revenue transfer (Tk -14,755/mt) was negative indicated that government policies affect negatively to the pulse producer. The input transfer (Tk -1108/mt) was also negative indicating that the government has implemented input subsidy policy to the crop sector to offset higher cost of production. The domestic factor transfer was positive (Tk 15,171/mt) indicating that opportunity costs of non-tradable inputs were lower than their market prices. Finally the net profit/net policy transfer (Tk -28,503/mt) was negative which means that, the producers earn less profit and cannot minimize loss under existing condition and vice-versa. This means that under free trade, producers could make more profit in contrast to the existing policy environment. The NPCO values less than one imply that policies do not provide nominal protection for the pulse producers. The findings based on the indicators of NPCO, NPCI, EPC and PCR conclude that the existing government policy environment tends to protect the interest of the pulse producers in agricultural sector at production level. DRC results indicated that Bangladesh had comparative advantage of producing pulse crops and production of pulse crops would be highly efficient for import substitution.

Keywords: Nominal protection coefficient (NPC), Effective protection coefficient (EPC), Policy analysis matrix (PAM), Domestic resource cost (DRC), Profitability, Pulse crops, Bangladesh.

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1. Introduction

Bangladesh is one of the major potential pulse growing countries of the world, but it has not yet been able to attain self-sufficiency in pulse production. Besides, the high population growth in Bangladesh causes pulse deficiency in this country. Bangladesh had to import pulse every year to meet this deficit. Continued imports of pulse should neither be encouraged nor accepted as the right way for meeting the pulse deficit, since Bangladesh has the capacity to increase pulse production to a substantial extent. Internal production not only saves foreign exchange but also keeps the production machinery viable and strong to face the vagaries of nature, helps in employment generation and makes the country self-reliant. The government policy in this respect is the most important catalyst. Bangladesh is a densely populated country where per capita cultivable land availability is not more than 0.066 ha. It has been projected that per capita land availability may come down to 0.061 ha by the year 2010 and 0.053 ha by 2020. Farmer is not likely to come forward with a risky crop because harvest risky. The country is facing acute shortage of pulses due to accelerated increase of requirements with its rapid growth of population. Side by side the fallow period between two major crops to be utilized for production of pulse crops. Pulses area decreased from 7.35 lakh hectares in 1988-89 to 3.57 lakh hectares in 2014-15 (BBS, 2015). Production also decreased from 5.12 lakh tonnes to 3.79lakh tonnes during the same period (Table.1.1). The average yield of pulse was 1.25 mt/ha. The area and production were decreased due to increase of the area for *boro* rice and other high value crops. Food and Agricultural Organization (FAO) recommended consumption of pulse amounting 45gm/head/day for fulfilling protein requirements for an adult. Presently per capita availability of pulses in Bangladesh is about 17gm, which is far below the actual requirement. Under this situation, more thrust should be given in developing technologies relating to pulses crops so that the farmer feels secured about the crops.

Import substitute of pulse crops would determine the position of the Bangladeshi cultivators in respect of production of this commodity by using scarce resources. Again, the trading opportunities of the country’s products depend on the comparative advantage, without subsidies or with limited subsidies that are permitted for all trading partners by the rules governing the new trading environment. All these information would be of much help to the planners and policy-makers in formulating appropriate policies for optimum and efficient resource allocation within agriculture and between agriculture and non-agricultural sectors, consistent with a balanced and integrated development of Bangladesh economy. In order to formulate an appropriate policy for import substituting, so the present study was undertaken to highlight the economic performance as well as comparative advantage of pulse crops cultivation in Bangladesh.

Table 1.1. Area, production and yield of pulses in Bangladesh

Year	Area (ha)	Production (mt)	Yield (t/ha)
1988-89	735448	495548	1.48
1989-90	738053	512210	1.44
1990-91	728395	523060	1.39
1991-92	721893	519155	1.39
1992-93	713231	516905	1.38
1993-94	709391	530455	1.34
1994-95	710504	533640	1.33
1995-96	696905	523930	1.33
1996-97	687607	523490	1.31
1997-98	682817	517515	1.32
1998-99	546883	417375	1.31
1999-00	497692	383030	1.30
2000-01	474595	365410	1.30
2001-02	451996	342490	1.32
2002-03	448415	349140	1.28
2003-04	420933	332890	1.26
2004-05	383306	316080	1.21
2005-06	337368	279420	1.21
2006-07	311352	257505	1.21
2007-08	225712	203535	1.11
2008-09	226484	196071	1.16
2009-10	242261	220486	1.10
2010-11	253898	232127	1.09
2011-12	269636	238000	1.13
2012-13	283806	265000	1.07
2013-14	333198	352000	0.95
2014-15	357490	379000	0.94

Source: BBS (1992), BBS (1997), BBS (2004), BBS (2008), BBS (2012), BBS (2015).

Objectives of the study

i. To estimate the financial and economic profitability of pulse cultivation,
ii To assess the import substitution status of major pulse crops,
iii To drive the policy implications from the above.

2. Materials and Methods

2.1 Selection of Samples

The pulses growing farmers were considered as the population for this study. Keeping in view the objectives and time constraint of the study, altogether 300 sample taking 50 from each crop and each location. The study areas were purposively selected based on intensive pulse growing pockets in Bangladesh. The distribution of crops and their respective locations and sample size are shown in Table 2.1.

Table 2.1. Crops and locations wise sample size of selected pulse crops

Name of the crops	Study locations	Sample size
Lentil	Natore and Jessore	100
Chickpea	Rajshahi and Natore	100
Mungbean	Rajshahi and Jessore	100
Total		**300**

The study also required official exchange rate (Tk/USD), public transport freight rate (Tk/ ton/Km), 0cean freight rate, commodity prices at international market, commodity prices at domestic market, fertilizer prices at international market etc. which have been collected from different published and unpublished sources.

2.2 Analytical Technique

Both financial and economic profitability of the selected pulse crops have been estimated to fulfill the study objectives.

2.2.1 Measurement of financial profitability

In this study for financial profitability estimation, costs and returns analyses were done on both variable and total cost basis. The following equation (Π) was developed to assess the financial profitability of cultivating pulse crops in Bangladesh.

$$\Pi_i = \sum_{i=1}^{n} P_iQ_i - TC = \sum_{i=1}^{n} P_iQ_i - (VC + FC)$$

Where,

Π_i = Profit or value addition from i^{th} pulse crop production

Q_i = Quantity of the i^{th} product (kg/ha)

P_i = Average price of i^{th} product (Tk/kg)

TC = Total cost (Tk/ha)

VC = Variable cost (Tk/ha)

FC = Fixed cost (Tk/ha)

i = 1, 2, 3, ………., n

Per hectare profitability of growing pulse crops from the view points of individual farmers was measured in terms of gross return, gross margin and net return.

Gross return: Gross return was calculated by simply multiplying the total volume of output with it's per unit price in the harvesting period.

Gross margin: Gross margin is the difference between total return and variable costs. The argument for using the gross margin analysis is that the farmers of Bangladesh are more interested to know their return over variable costs.

Net return: The analysis considered fixed cost which included land rent and family supplied labour. Net margin was calculated by deducting total costs (Variable and Fixed) from gross return.

2.2.2 Policy Analysis Matrix (PAM) framework

Policy Analysis Matrix (PAM) framework was used to measure competitiveness, economic efficiency and effects of policy interventions of the pulse crops. This framework was developed first by Monke and Pearson (1989), and augmented by recent developments in price distortion analysis by Masters and Winter-Nelson (1995). PAM is a tool that allows to examine the impact of policy by constructing two enterprise budgets, one valued at market prices and the other valued at social prices. The PAM, once assembled, provides a convenient method of calculating the measure of policy effects and measures of competitiveness and economic efficiency/ comparative advantage. This framework is particularly useful in identifying the appropriate direction of change in policy (Gonzales *et al*., 1993). In the present study, particular attention is given to competitiveness and economic efficiency in domestic resources by using a PAM framework. The assessment of competitiveness and economic efficiency of pulse crops production at the farmgate level in different locations of Bangladesh were undertaken and the necessary indicators were derived to explain the private profitability, social profitability and divergence.

Table 2.2. Framework of Policy Analysis Matrix (PAM)

Items	Revenue	Costs		Profit
		Tradable inputs	Domestic factors	
Private prices	A	B	C	D
Social prices	E	F	G	H
Divergences	I	J	K	L

Source: Monke and Pearson (1989).

Private profit (D) = A-(B+C), Social profit (H) = E-(F+G), Output transfer (I) = A-E,

Input transfer (J) = B-F, Factor transfer (K) = C-G, Net transfer (L) = D-H or I-J-K

Valued at Private prices A= $Pid * Qi$, B= $Pjd * Qj$, C= $Pnd * Qn$ D

Valued at Social prices E= *Pib* * *Qi*, F= *Pjb* * *Qj*, G= *Pns* * *Qn* H

Where: *Pid = domestic price of output i*

Pjd = domestic price of tradable input j

Pib = international price of output i

Pjb = international price of tradable input j

Pnd = market price of non-tradable input n

Pns = shadow price of non-tradable input n

Qi = quantity of output

Qj = quantity of tradable input.

Qn = quantity of non-tradable input.

The indicators in the first row of Table 2.1 provide a measure of private profitability (D), or competitiveness, and are defined as the difference between observed revenue (*A*) and costs (*B*+*C*). Private profitability demonstrates the competitiveness of the agricultural system, given current technologies, prices for inputs and outputs, and policy interventions and market failures. The second row of the matrix calculates the measure of social profitability (H) defined as the difference between social revenue (E) and costs (F+G). Social profitability measures economic efficiency/ comparative advantage of the agricultural system.

2.2.3 Ratio indicators

The PAM framework can also be used to calculate important indicators for policy analysis. The computations of the following measures are established based on Appleyard (1987).

a) Nominal Protection Coefficient on Output (NPCO)

This ratio shows that the extent to which domestic prices of output differ from international reference prices. If NPCO is greater than one, the domestic farm gate price is greater than the international price of output and thus the system receives protection. On the contrary, if NPCO is less than one, the system is disprotected by policy. NPCO is expressed as:

NPCO = (A)/(E) =(Pid * Qi)/(Pib * Qi) ---(1)

b) Nominal Protection Coefficient on Input (NPCI)

This ratio shows how much domestic prices for tradable inputs differ from their social prices. If NPCI exceeds one, the domestic input cost is greater than the comparable world prices and thus the system is taxed by policy. If NPCI is less than one, the system is subsidized by policy. Using the PAM framework, NPCI is derived as:

NPCI = (B)/(F) =(Pjd * Qj)/(Pjb * Qj) ---(2)

c) Effective Protection Coefficient (EPC)

EPC is the ratio of value added in private prices (A-B) to value added in social prices (E-F). An EPC value of greater than one suggests that government policy protects the producers, while values less than one indicate that producers are disprotected through policy interventions. EPC is expressed as:

EPC = (A-B)/(E-F) ={(Pid * Qi)-(Pjd * Qj)}/{(Pib * Qi)-(Pjb * Qj)} --------(3)

d) Domestic Resource Cost (DRC)

The DRC is the ratio of the cost in domestic resources and non-traded inputs (valued at their shadow prices) of producing the commodity domestically to the net foreign exchange earned or saved by producing the good domestically.

Formally DRC is defined as:

$$DRC = \frac{\text{Cost of domestic resource and non-traded inputs for producing per unit of output}}{\text{Value of tradable output - Value of tradable inputs}}$$

$$\text{Or, } DRC = \frac{\sum f_{ij} p_j d}{U_i - \sum a_{ik} p_k^b} \qquad \text{------------------(4)}$$

Where,

f_{ij} = Domestic resource and non-traded inputs j used for producing per unit commodity i

P^d_j = Price of non-traded intermediate inputs and domestic resource

U_i = Border price of output i

a_{ik} = Amount of traded intermediate inputs for unit production of i

P^b_k = Border price of traded intermediate input

If DRC < 1, the economy saves foreign exchange by producing the good domestically either for export or for imports substitution. This is because the opportunity cost of domestic resources and non-traded factors used in producing the good is less than the foreign exchange earned or saved. In contrast, if DRC > 1, domestic costs are in excess of foreign exchange costs or savings, indicating that the good should not be produced domestically and should be imported instead.

e) Private Cost Ratio (PCR)

PCR is the ratio of factor costs (C) to value added in private prices (A-B). This ratio measures the competitiveness of a commodity system at the farm level. The system is competitive if the PCR is less than one. Using the PAM framework the PCR can be expressed as:

PCR = (C)/(A-B) =(Pnd * Qn)/{(Pid * Qi)-(Pjd * Qj)} ------------------------(5)

2.2.4 Import Parity Analysis

The estimates of world price at import parity level are based on the assumption that imports compete with domestic production at the producer level. The border prices of selected commodities have been adjusted for marketing cost (which includes handling, transportation, storage cost) and price spent between the wholesale market to the farmers level. Border prices of commodities are used as reference or shadow prices in measuring the effects of government intervention polices. Without government intervention, the domestic producer prices are expected to be closely related to the border prices.

Import parity: Import parity price at farm level is estimated using the following formulae

$$P_j = P_j^b + C_{jm} - C_{jd} \qquad \text{---------------------------------- (6)}$$

Where,

P_j= Producer price of j^{th} importable commodity,

P_j^b= World price at port of entry (c.i.f),

C_{jm}= Marketing margin from the port of entry to the wholesale market and

C_{jd}= Components of the marketing spread between the wholesale market and farm gate.

2.2.5 Shadow Pricing of Inputs for PAM Analysis

- Land – Rental value of per unit of land is applied for calculating the shadow price of land
- Labor – Market wage rate is considered for shadow pricing because no substantial market imperfection exists in agricultural labor market
- Working capital – Interest rate for working capital
- Fertilizers– International prices are used to calculate the import parity prices
- Seed – Actual market price

3. Results and Discussion

3.1 Pattern of Input Use for Selected Pulses Cultivation

Farmers employed different level of inputs for pulse cultivation. An attempt was made to estimate the level of inputs used and benefits obtained by the farmers of selected pulses. On an average, farmers applied Urea at the rate of 33 kg/ha, TSP 66 kg/ha, and MoP 39 kg/ha for lentil cultivation, whereas it was 40 kg/ha, 63 kg/ha and 54 kg/ha for mungbean cultivation respectively. For chickpea cultivation, farmers were applied only Urea (32 kg/ha), DAP (72 kg/ha) and

Boron (7 kg/ha) in the study areas. It was observed that among the selected pulses, farmers used Urea and MoP common in the study areas (Table 3.1). They employed on an average 113 man-days per hectare of total human labour (both family & hired) for lentil cultivation, which was 96 man-days for chickpea cultivation and 150 man-days for mungbean cultivation. Respondent applied pesticides once a season and no weeding and irrigation were applied for selected pulses cultivation.

Table 3.1. Per hectare use of input in producing selected pulses

Items	Selected pulses		
	Lentil	*Chickpea*	*Mungbean*
Hired labour (man-days)	77	57	85
Family labour(man-days)	36	39	65
Total human labour (man-days)	113	96	150
Mechanical power (Tk/ha)	4869	4491	4603
Fertilizers (kg):			
Urea	33	32	40
TSP	66	-	63
MoP	39	-	54
DAP	-	72	-
Boron	-	7	-
Seed (Kg)	56	60	23
Insecticide (Tk)	676	1404	1415

3.2 Yield performance

The average yield of lentil, chickpea and mungbean were 2.0 tons, 1.6 tons and 1.7 tons fresh yield per hectare respectively in the study areas (Table 3.2). In all study districts farmers produced the highest yield in Jessore district (2.1 tons/ha) in respect of lentil compared to mungbean (1.8 tons/ha) in same district. In the case of chickpea production the higher yield was recorded in Rajshahi district (1.6 tons/ha) compared to Natore district (1.5 tons/ha).

Table 3.2. Yield of lentil, chickpea and mungbean under studied districts

(ton/ha)

Pulse crops	District			
	Rajshahi	Natore	Jessore	All
Lentil	-	1.9	2.1	2.0
Chickpea	1.6	1.5	-	1.6
Mungbean	1.5	-	1.8	1.7

3. 3 Cost of Cultivation for Selected Pulses

The estimated total variable cost were Tk 39,493 , Tk 34,215 and Tk 39,938 per hectare for lentil, chickpea and mungbean cultivation respectively. These costs shared 56%, 52% and 49% of the total cost of production respectively. Among the cost items, human labour was the major cost item which shared 32%, 26% and 31% of the total cost respectively in the study areas (Table 3.3). Mechanical power cost accounted for about 6% -7% of the total cost for selected pulse cultivation. Pesticides cost were more for chickpea and mungbean cultivation compared to lentil cultivation but in the case of irrigation, farmers did not apply irrigation for lentil and chickpea cultivation in the study areas. Rental value of land and family supplied labour were considered as fixed cost of production for selected pulses. The cost of these items were Tk 31,233 for lentil cultivation, Tk 32,177 for chickpea cultivation and Tk 41,330 for mungbean cultivation per hectare which accounted for about 44%, 48% and 51% respectively of the total cost of production (Table 3.3). Total cost of production included variable costs (summation of all cash and non-cash expenses) and fixed costs incurred for selected pulses cultivation. On an average total cost of production were Tk 70,726 for lentil cultivation, Tk 66,392 for chickpea cultivation and Tk 81,268 for mungbean cultivation per hectare. It was observed that the total cost of production of mungbean was highest (Tk 81,268 per hectare) compared to other two pulses due to use of high amount of inputs, especially human labour and chemical fertilizers.

3.4 Profitability of pulses Crop

The average marketable yield (which was brought to the market) of lentil was slightly higher (2.10 t/ha) compared to mungbean (1.65 t/ha) and chickpea (1.57 t/ha). On an average gross return were Tk 145,961/ha for lentil, Tk 108,468 for chickpea and Tk 115,704 for mungbean . Highest gross return was obtained by lentil (Tk 145,961/ha) compared to other two pulses. Gross margin was obtained by deducting total variable cost from gross revenue. Gross margin was Tk 106,468 per hectare for lentil which was highest in chickpea (Tk 74,252 per hectare) and mungbean (Tk 75,766 per hectare). Net return followed the similar trend like gross return. The net return was Tk 75,235 per hectare for lentil which was highest in chickpea (Tk 42,119 per hectare) and mungbean (Tk 34,434per hectare). The benefit cost ratio (BCR) was also highest for lentil (2.07) compared to other two pulses. On the basis of total cost, the cost of production per kilogram were Tk 34.96 for lentil Tk 42.43 for chickpea and Tk 49.51 for mungbean. On the other hand, variable cost basis calculation showed that the per kilogram production costs were Tk 19.64 for lentil, Tk 22.0 for chickpea and Tk 24.35 for mungbean (Table 3.4).

Table 3.3. Per hectare costs in producing selected pulses

Items	Cost of cultivation (Tk/ha)		
	Lentil	*Chickpea*	*Mungbean*
Variable cost:			
Hired human labour	22950 (32.45)	17100(25.77)	25350(31.19)
Mechanical power	4869(6.88)	4491(6.77)	4603(5.66)
Chemical Fertilizers:			
Urea	520(0.74)	512(0.77)	632(0.78)
TSP	2112(2.99)	-	2000(2.46)
MoP	624(0.88)	-	855(1.05)
DAP	-	2145(3.23)	-
Boron	-	780(1.17)	-
Seed	6719(9.50)	6890(10.38)	2990(3.68)
Irrigation	-	-	1161(1.43)
Insecticide/Pesticides	676(0.96)	1409(2.12)	1309(1.61)
Interest on operating capital	1025(1.45)	888(1.34)	1038(1.28)
Total variable costs:	39,493(55.84)	34,215 (51.57)	39,938(49.14)
Fixed cost:			
Family Labour	10650(15.06)	11550(17.41)	19500(23.99)
Rental value of land	20583(29.10)	20627(31.02)	21830(26.86)
Total fixed cost:	31,233(44.16)	32,177(48.43)	41,330(50.86)
Total cost	70,726(100.00)	66,392(100.00)	81,268(100.00)

Figures in the parenthesis indicate percent of total cost

Table 3.4. Per hectare return in producing lentil in the study areas

Items	**Return (Tk/ha)**		
	Lentil	***Chickpea***	***Mungbean***
Yield (ton/ha)	2.03	1.57	1.65
Gross return	145,961	108,468	115,704
Gross margin	106,468	74,252	75,766
Net return	75,235	42,119	34,434
Benefit cost ratio (BCR)	2.07	1.64	1.42
Production cost (Tk/kg):			
Full cost basis	34.96	42.43	49.51
Cash cost basis	19.64	22.0	24.35

3.5 Economic Profitability of Pulses Crop

3.5.1 Results of the Policy Analysis Matrix for selected pulses crop

The results of PAM as well as the coefficients of different indicators derived from PAM are discussed sequentially with necessary interpretations.

Policy Analysis Matrix constructed for selected pulse crops under import parity price is presented in Table 3.5. Table showed that different policy transfer or divergences such as output, tradable input, domestic factor and net policy transfer. Under import parity prices of selected pulse crops, it is evident that revenue transfer (difference between private revenue and social revenue) was negative. This negative value indicated that government policies affect negatively to the pulse producers. The input transfer (differences between private and social price of tradable inputs) was also negative indicating that the domestic pulse producers bought the imported inputs at prices which was less than the world price. It means that pulse producers received input subsidies for selected pulse production. The domestic factor transfer (difference between private and social price) was positive illustrating that the opportunity costs of non-tradable inputs were lower than their market prices. Finally the net profit/net policy transfer (difference between private and social profit) was negative which means that under the existing policy circumstances, the producers earn less profit and enjoy limited scope for minimizing the net policy transfer.

Table 3.5. Policy Analysis Matrix for selected pulse crops

Items	Revenue	Costs (Tk/m.ton)		Profit
		Tradable inputs	Domestic factors	
Private prices	70,664	1886	40,221	28,567
Social prices	85,104	2994	25,040	57,070
Divergences	-14,755	-1108	15,171	-28,503

Source: Authors own calculation

3.6 Ratio indicators under import parity

Important indicators for calculating the level of protection and different ratios such as NPCO, NPCI, EPC, PCR and DRC which were used to measure the effects of policy interventions on the producer incentives and comparative advantage.

3.6.1 Domestic and border price of selected pulse crops

The border parity price of selected pulse crops at producer level measured at official exchange rate was mostly higher than the domestic producer price. So, the trends in domestic and border price of selected pulse crops indicated that there is a wide scope to cultivate pulse crops for import substitution in Bangladesh (Table 3.6).

3.6.2 Nominal Protection Co-efficient on Output (NPCO)

The study revealed that NPCO values of all selected pulses under import parity were found to be less than one (<1), close to one (Table 3.7). The values close to one imply that producers were nearly protected through the existing policy environment. The NPCO values less than one imply that policies do not provide nominal protection for the producers. The NPCO value of mungbean was 0.91, it meaning that under the market price regime, mungbean producers are getting 9 percent less than the world price.

Table 3.6. Domestic and border price of selected pulse crops at official exchange rate

Crops	Domestic price[a] Tk/ton	Border price[b] Tk/ton
Lentil	72,740	98,359
Chickpea	68,999	79,858
Mungbean	70,251	77,567

Source: Own estimation

Note: a. Harvest time domestic price, b. Economic import parity border price

3.6.3 Nominal Protection Co-efficient on Input (NPCI)

For all selected pulse crops, the NPCI values were found to be less than one (<1) under import parity indicating that the government policies were reducing input costs and reducing their average market prices below the world prices (Table 3.7). NPCI values of less than one clearly indicate that the government provides efforts to support these sectors.

3.6.4 Effective Protection Co-efficient (EPC))

The study also estimated EPC which is better indicator of effective incentive than the NPC, as it finds the impact of protection on inputs and outputs and depicts the degree of protection according to the value addition process in the production activity. The EPC values under import parity were found to be less than one (EPC<1) for all selected pulse crops (Table 3.7). But the values of EPC were very close to one indicating that producers were not significantly discouraged by the existing policy regimes.

3.6.5 Private Cost Ratio (PCR)

The PCR values found to be less than one (PCR<1) for all pulse crops under import parity indicating that the commodity system was competitive at the producer level (Table 3.7).

3.6.6 Comparative Advantage Analysis

Comparative advantage in the production of a given crop for a particular country is measured by comparing its border price with the social or economic opportunity costs of producing, processing, transporting, handling and marketing an incremental unit of commodity. The results of DRC are presented in Table 3.7. DRC indicates whether the domestic economy has a comparative advantage in pulse crops production relative to other countries. The estimates of DRCs for selected pulse crops were observed to be less than unity implying that Bangladesh had comparative advantage in pulse crops production for import substitution.

Table 3.7. Results of the nominal protection coefficient on output (NPCO), Nominal protection coefficient of input (NPCI), effective protection coefficient (EPC), private cost ratio (PCR) and Domestic cost ratio (DRC)

Crops	NPCO	NPCI	EPC	PCR	DRC
Lentil	0.740	0.667	0.741	0.469	0.348
Chickpea	0.864	0.685	0.872	0.599	0.522
Mungbean	0.911	0.548	0.927	0.690	0.640

The above findings based on the indicators of NPCO, NPCI, EPC and PCR conclude that the existing government policy environment tends to protect the interest of the pulse producers in agricultural sector at production level.

4. Conclusions and Recommendations

Pulse cultivation is highly remunerative to the respondent farmers in the study areas. The highest cost was estimated for mungbean (Tk 81,268/ha) followed by lentil (Tk 70,726/ha) and chickpea (Tk 66,392/ha). However, the highest net return was estimated for lentil (Tk 75,235/ha) followed by chickpea (Tk 42,119/ha). The highest benefit cost ratio (BCR) was also for lentil followed by chickpea. PAM results under import parity prices of pulse crops showed that revenue transfer was negative indicating the government policies affect negatively to the pulse producer. The input transfer was also negative indicating that pulse producer received input subsidies for pulse production. The domestic factor transfer was positive illustrating that opportunity costs of non-tradable inputs were lower than their market prices. Finally the net profit/net policy was negative which means that under the existing policy circumstances, the producers earn less profit and enjoy limited scope for minimizing the net policy transfer. DRC results indicated that Bangladesh has comparative advantage of producing pulse crops as the estimates of domestic resource cost (DRC) were less than one implied that the production of pulse crops would be highly efficient for import substitution. From the findings of comparative advantage analyses, it is revealed that Bangladesh has comparative advantage of pulse crops production and can produce pulse crops for import substitution. Therefore, research and extension services should be strengthened to introduce modern technologies for higher crop productivity and quality assurance for maintaining competitiveness in the world market should also be considered.

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COMBINING ABILITY AND HETEROSIS STUDY IN MAIZE (*Zea mays* L.) HYBRIDS AT DIFFERENT ENVIRONMENTS IN BANGLADESH

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Abstract

The aim of this study was to isolate superior inbred lines and better combining parents for suitable hybrids and to determine percent of heterosis using standard commercial checks in a 7 × 7 diallel analysis excluding reciprocals over five environments. The mean sum of square obtained from combined analysis of variance showed the presence of genetic variability among the crosses, environment and crosses × environment interaction for all of the characters under study. The variances for general combining ability (GCA) and specific combining ability (SCA) of variance were found significant for all the characters. However, relative magnitude of variances indicated that additive gene effects were more prominent for all the characters studied. GCA and SCA effects both showed significant interaction with environment for all the traits. This clearly suggested the need of selecting different parental lines for hybrids for different ecological situations. Parents $P_{3,}$ P_5 and P_6 were the best general combiner for high yield; parents P_6 for earliness; and $P_{1,}$ P_2 and P_3 for dwarf plant type. The range of heterosis expressed by different crosses was from -13.04 to 5.25 % percent for grain yield. The better performing six crosses ($P_1 \times P_2$, $P_1 \times P_{5,}$ $P_3 \times P_{4,}$ $P_3 \times P_6$, $P_3 \times P_7$ and $P_4 \times P_5$) can be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigour. These crosses also need to be evaluated further in multilocations.

Keywords: Combining ability, across locations, maize hybrids.

Introduction

Maize is one of the oldest and most important crop in the world. It is the highest yielding grain crop having multiple uses. Now maize has become an important cereal crop in Bangladesh. In Bangladesh it is the third most important crop after rice and wheat and it accounts for 4.8% of the total cropped land area and 3.5% of the value of agricultural output (Ahmad *et al.,* 2011). In 2015-16, maize was cultivated in 3.5 lakh hectare of land in Bangladesh and production was 25 lakh mtons (Bidan, 2016).

Hybrid maize has much higher yield potentiality than those of synthetics and composites. The hybrid seeds currently being used are imported and involved

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huge amount of foreign currency. In the recent past, exploitation of hybrid vigour and selection of parents based on combining ability has been used as an important breeding approach in crop improvement. Developing of high yielding F_1 hybrids along with other favorable traits are receiving considerable attention. For developing good hybrids, information about combining ability of the parents and the resulting crosses is essential. The present study involving a 7 × 7 diallel analysis over five environments aimed to determine the better general combining parents and for isolating good cross combinations in maize for evolving suitable hybrid(s) locally.

Materials and Methods

Seven inbred lines of maize viz. P_1 (CML429), P_2 (CLG1837), P_3 (CML285), P_4 (CML451), P_5 (CML431), P_6 (CML223) and P_7 (CML551) collected from CIMMYT- Mexico, were crossed in all possible combinations (excluding reciprocals) during *rabi* season of 2014-2015 at Gazipur. During *rabi* 2015-2016, the 21 F_1's and along with three commercial hybrids viz. BHM9, 981 and NK40 were grown following Alpha lattice design with three replications in five different environments viz. Gazipur, Burirhat, Hathazari, Rahmatpur and Jessore. In Gazipur sowing was done on 22 November, 21 November in Burirht, where as it was 30 November in Hathazari, 22 November in Rahmatpur and 1 December in Jessore. Each plot comprised of two rows 4 m long. Spacing was maintained 0.6 m between rows and 0.25 m spacing between plants. One healthy seedling per hill was kept after proper thinning. Fertilizers were applied @ 250, 55, 110, 40, 5 and 1.5 kg/ha of N, P, K, S, Zn, B, respectively. Standard agronomic practices were followed and plant protection measures were taken when required. Data on days to 50% pollen shedding and silking were recorded on whole plot basis. Ten randomly selected plants were used for recording observations on plant height and ear height. All the plants in two rows were considered for plot yield which was later converted to t/ha. The combining ability analysis was carried out following Model I (fixed effects) and Method IV (one set of F_1's but neither parents nor reciprocal F_1's is included) described by Griffing (1956) in multi environment using PB Tools.

Results and Discussion

The mean sum of square obtained from combined analysis of variance showed the presence of genetic variability among the crosses and environment for all the characters under studied (Table 1).This indicated influence of differential environmental factors at different locations on the expression of different characters on maize. Crosses × Environment interaction was also highly significant for all the characters. From the results, it could be concluded that maize genotypes responded significantly for yield and other characters to the environment.

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

Both GCA and SCA effects showed significant interaction with environment for all the traits. This suggested the need of selecting different parental lines for hybrids for different ecological situations. Previous investigations have shown that both GCA and SCA can interact with environments (Rojas and Sprague, 1952; Matzinger *et al*. 1959; Paroda and Hayes, 1971; Pixley and Bjarnason, 1993; Nass *et. al.* 2000).

Table1. Analysis of variance for combining ability for yield and yield contributing characters in maize over five environments during rabi 2015-16

Source of variation	df	Yield (t/ha)	Days to pollen shedding	Days to silking	Plant ht.(cm)	Ear ht.(cm)	1000-kernel wt.
Environment (E)	4	125.17**	1044.5**	1301.90**	5041.59**	5637.78**	31949.93**
Crosses	20	4.94**	5.46**	5.38**	2719.37**	1201.84**	3048.82**
Crosses × E	80	3.10**	3.24**	4.27**	735.36**	363.65**	952.83**
GCA	6	10.51**	11.87**	6.52**	8054.12**	3636.81**	2987.07**
SCA	14	2.55**	2.71**	4.89**	433.04**	158.29**	3075.29**
GCA × E	12	3.20**	2.56**	6.34**	1506.28**	805.51**	1186.15**
SCA × E	28	3.06**	3.54**	3.39**	404.97**	174.28**	852.84**
Residuals	20	0.44	1.87	2.25	169.67	96.40	1106.53

**P=0.01.

General combining ability (gca) effects

The GCA effect is shown in Table 2. None of the parents were found to be a good general combiner for all the characters studied. A wide range of variability of GCA effects was observed among the parents. In the present study, for days to pollen shedding, silking, plant and ear height the inbred lines with significant and negative GCA effects were considered as good general combiners. On the other hand, for yield and other yield components i.e. 1000-kernel wt., those with significant and positive GCA effects was considered as good general combiners.

For grain yield (t/ha), parents $P_{3,}$ P_5 and P_6 showed significant and positive GCA effect. In addition to grain yield, parents P_5 were also good general combiner for 1000-kernel weight Sharma *et al.* (1982) reported that parents with good general combiners for grain yield generally shows good performance for various yield components. Similar views have been given by Malik *et al*. (2004), Ahmed *et al*. (2008) and Abdel-Moneam *et al*. (2009). So, these three parents ($P_{3,}$ P_5 and P_7) could be used extensively in hybrid breeding program with a view to increasing the yield level.

Parent P_6 showed significant and negative GCA for days to pollen shedding. None of the parent showed significant and negative GCA for silking though some parents showed negative values. So, use of this parent might be useful in developing early hybrid variety(s).

Parents P_1 and P_2 exhibited significant and negative GCA effect for plant height and P_1, P_2 and P_3 for ear height. Uddin *et al.* (2006) and Ahmed *et al.* (2008) also found inbred line(s) as good general combiner for short plant type in their study.

For 1000-kernel weight, P_5 was found significant and positive GCA effect. This parent is expected to contribute towards increasing the kernel size. Highly significant and positive gca effects for 1000-kernel weight was observed by Uddin *et al.* (2006), Alam *et al.* (2008) and Abdel-Moneam *et al*. (2009).

Table 2. Estimates of general combining ability effects (GCA) of the parents for yield and yield contributing characters in maize over three environments during rabi 2015-16

parents	Yield (t/ha)	Days to pollen shedding	Days to silking	Plant ht.(cm)	Ear ht.(cm)	1000-kernel wt.
P1	-0.03	0.16	-0.10	-17.89**	-9.67**	-8.51
P2	-0.57**	-0.08	-0.38	-7.24**	-4.22**	3.61
P3	0.22**	0.01	-0.02	-2.77	-5.76**	5.19
P4	-0.25**	0.40*	0.50**	-0.17	0.08	0.13
P5	0.42**	0.04	0.21	9.41**	5.44**	10.27*
P6	0.41**	-0.42**	-0.23	8.63**	4.19**	-1.92
P7	-0.19*	-0.11	0.02	10.03**	9.94**	-12.28**
SE (gi)	0.07	0.14	0.16	1.39	1.04	3.87
LSD(5%)	0.17	0.34	0.39	3.39	2.54	9.94
LSD(1%)	0.21	0.43	0.49	4.27	3.19	11.88

*P=0.05, **P=0.01.

P1= CML429, P2= CLG1837, P3= CML285, P4= CML451, P5= CML431, P6= CML223 and P7= CML551.

Specific combining ability effects (SCA)

For grain yield, five crosses ($P_1 \times P_2$, $P_1 \times P_5$, $P_3 \times P_4$, $P_3 \times P_6$, $P_3 \times P_7$ and $P_4 \times P_5$) exhibited significant and positive SCA effects for grain yield. These crosses involved low x low, low x high, high x high and high x low general combining parents and produced moderate grain yield. Ivy and Hawlader (2000) also reported that good general combining parents do not always show high SCA effects in their hybrid combinations. On the contrary, Paul and Duara (1991) reported that the parents with high GCA always produce hybrids with high estimates of sca. Thus the SCA effects of the crosses were not reflected through the GCA effects of the parents.

Table 3. Specific combining ability effects (SCA) of the crosses for yield and yield contributing characters in maize over three environments during rabi 2015-16

Crosses	Yield (t/ha)	Days to pollen shedding	Days to silking	Plant ht.(cm)	Ear ht.(cm)	1000-kernel wt.
P1 × P2	0.71**	0.35	0.52	4.65	4.22	1.40
P1 × P3	-0.41**	0.24	0.23	-1.66	-1.39	-24.61**
P1 × P4	-0.52**	0.12	0.29	-0.71	0.66	5.97
P1 × P5	0.45**	0.35	0.19	2.52	-3.79	12.71
P1 × P6	-0.16	-0.58*	-0.75*	-2.16	0.75	19.53*
P1 × P7	-0.06	-0.48	-0.48	-2.62	-0.45	-15.03
P2 × P3	-0.44**	0.23	0.37	-11.87**	-4.08	22.48**
P2 × P4	0.01	0.51	0.51	-0.23	0.89	-16.29
P2 × P5	-0.31*	-0.72*	-0.72*	2.4	2.65	0.52
P2 × P6	0.03	-0.12	-0.27	-1.64	-5.31*	-13.26
P2 × P7	-0.01	-0.23	-0.40	6.68*	1.61	5.14
P3 × P4	0.46**	-0.99**	-1.11**	4.14	1.13	-10.10
P3 × P5	-0.35*	-0.09	0.17	-2.7	0.65	-13.12
P3 × P6	0.33*	0.16	0.29	7.28*	-0.78	1.31
P3 × P7	0.40**	0.25	0.03	4.87	4.48*	24.07**
P4 × P5	0.42**	-0.22	-0.42	3.59	-0.63	8.74
P4 × P6	-0.12	0.24	0.36	-0.87	2.22	6.91
P4 × P7	-0.24	0.33	0.36	-5.91*	-4.2	4.76
P5 × P6	-0.09	0.33	0.32	-2.66	2.79	-2.21
P5 × P7	-0.11	0.16	0.45	-3.09	-1.66	-6.64
P6 × P7	0.02	-0.11	0.04	0.07	0.31	-12.28
SE (ij)	0.14	0.28	0.31	2.74	2.06	7.84
LSD(5%)	0.29	0.58	0.64	5.70	4.28	16.31
LSD(1%)	0.40	0.80	0.88	7.78	5.85	22.27

*P=0.05, **P=0.01

P1= CML429, P2= CLG1837, P3= CML285, P4= CML451, P5= CML431, P6= CML223 and P7= CML551

Significant and negative SCA effects for days to pollen shedding and silking are desirable for selection of early maturing hybrids. Three crosses ($P_1 \times P_6$, $P_2 \times P_5$ and $P_3 \times P_4$) exhibited significant and negative sca effects for days to pollen shedding and silking. These crosses mostly involved average × high, average x average, average x high and average x low general combining parents. These findings are consistent with the results of Ahmed *et al.* (2008).

Two crosses ($P_2 \times P_3$ and $P_4 \times P_7$) exhibited significant and negative SCA effects for plant height and one cross ($P_2 \times P_6$) for ear height which are desirable for exploiting non additive gene. This cross involved high x average, average x high and high x low general combining parents (Table 2 and 3).

For 1000-kernel weight, three crosses ($P_1 \times P_6$, $P_2 \times P_3$ and $P_3 \times P_7$) showed significant and positive SCA effects involved low × low, average × average and average × low combining parents and also possessed high mean value.

Heterosis

The standard/economic heterosis expressed by the F_1 hybrids over the commercial check variety BHM9 for yield and yield related traits are shown in Table 4. All the traits showed significant heterosis in different crosses.

For grain yield(t/ha) four crosses showed significant and positive heterosis over the standard check variety BHM-9 which was found in the range of -13.04 to 5.25 %. Amiruzzaman (2010) and Kadir (2010) in their study found -17.60 to 9.71 % and -15.21 to 27.97 % standard heterosis for kernel yield, respectively.

Significant and negative heterosis was exhibited by all of the crosses both days to pollen shedding and days to silking indicating earliness. Negative heterosis is desirable for plant height which helps to develop short stature plant leading to lodging resistant. Heterosis for different crosses ranged from -18.47 to -1.20 percent and -23.20 to 1.10 percent, respectively, for plant and ear height. Significant and negative heterosis for both these traits was reported by Uddin *et al*. (2006), Alam *et al*. (2008) and Amiruzzaman (2010).

Two crosses showed significant and positive heterosis for 1000-kernel weight. Heterosis for different crosses ranged from -8.61 to 9.59 percent.

Results of overall means across five locations from combined analysis are presented in Table 5. Considering overall mean grain yield across locations, three crosses $P_1 \times P_5$ (10.22 t/ha), $P_3 \times P_6$ (10.36 t/ha) and $P_5 \times P_6$ (10.13) out yielded the better check hybrid BHM9 (9.84 t/ha). Days to tasseling and silking, ranged from 85 to 88 days and 87 to 90 days respectively (Table 5). Plant height was found the highest (238 cm) in check variety BHM9 and the lowest (194 cm) in $P_2 \times P_3$. Ear height was found the highest (124 cm) in $P_6 \times P_7$ and the lowest (93) in $P_2 \times P_3$. 1000-kernel weight ranged from 319 to 383 g.

Table 4. Heterosis of the crosses over BHM9 for different characters in maize over five environments during rabi 2015-16

Crosses	Yield (t/ha)	Days to pollen shedding	Days to silking	Plant ht.(cm)	Ear ht.(cm)	1000-kernel wt.
P1 × P2	-3.63**	-1.42**	-2.23**	-17.69**	-17.25**	-0.36
P1 × P3	-6.98**	-1.42**	-2.16**	-18.28**	-23.20**	-7.35**
P1 × P4	-13.04**	-1.12	-1.49**	-8.58**	-16.64**	-0.05
P1 × P5	3.88**	-1.27**	-1.94**	-3.68	-15.89**	4.78*
P1 × P6	-2.53**	-2.86**	-3.48**	-2.61	-13.14**	3.24
P1 × P7	-7.76**	-2.41**	-2.89**	-1.20	-9.38**	-8.61**
P2 × P3	-12.68**	-1.73**	-2.30**	-18.47**	-20.91**	9.59**
P2 × P4	-13.04**	-0.97**	-1.57**	-12.30**	-11.92**	-2.95
P2 × P5	-9.33**	-2.79**	-3.26**	-7.45*	-6.01**	4.76
P2 × P6	-5.91**	-2.64**	-3.26**	-5.89*	-13.65**	-2.68
P2 × P7	-12.54**	-2.41**	-3.12**	-2.20	-3.13	0.63
P3 × P4	-0.28**	-2.56**	-2.97**	-16.98**	-12.99**	-0.73
P3 × P5	-1.61	-1.73**	-1.86**	-7.16*	-8.95**	1.31
P3 × P6	5.25**	-2.18**	-2.23**	-3.56	-11.18**	1.95
P3 × P7	-0.29**	-1.73**	-2.23**	-7.42*	-2.03	6.49*
P4 × P5	1.37**	-1.65**	-1.94**	-11.58**	-5.16**	6.12
P4 × P6	-4.39**	-1.65**	-1.57**	-9.19**	-3.82	2.10
P4 × P7	-11.78**	-1.19**	-1.27**	-3.98	-4.46*	-0.47
P5 × P6	2.89**	-1.95**	-1.94**	-13.88**	1.10	2.39
P5 × P7	-3.57**	-1.80**	-1.49**	-5.09	2.17	-0.84
P6 × P7	-2.27**	-2.56**	-2.45**	-13.49**	2.78	-5.94
Minimum	-13.04	-2.86	-3.48	-18.47	-23.2	-8.61
Maximum	5.25	-1.12	-1.27	-1.20	1.10	9.59
LSD(5%)	0.29	0.25	0.30	5.73	3.66	9.59
LSD(1%)	0.40	0.34	0.40	7.77	4.97	8.64

*P=0.05, **P=0.01.

P1= CML429, P2= CLG1837, P3= CML285, P4= CML451, P5= CML431, P6= CML223 and P7= CML551.

Table 5. Mean performance of the crosses for yield and yield contributing characters in maize over five environments during rabi 2015-16

Crosses	Yield (t/ha)	Days to pollen shedding	Days to silking	Plant ht.(cm)	Ear ht.(cm)	1000-kernel wt. (g)
P1 × P2	9.48	87	88	196	100	348
P1 × P3	9.15	87	88	194	93	324
P1 × P4	8.56	87	89	217	100	349
P1 × P5	10.22	87	89	229	101	366
P1 × P6	9.59	85	87	232	105	361
P1 × P7	9.08	86	88	235	109	319
P2 × P3	8.59	86	88	194	95	383
P2 × P4	8.56	87	89	209	106	339
P2 × P5	8.92	85	87	220	113	366
P2 × P6	9.26	86	87	224	104	340
P2 × P7	8.61	86	88	233	117	352
P3 × P4	9.81	86	88	198	105	347
P3 × P5	9.68	86	89	221	110	354
P3 × P6	10.36	86	88	229	107	356
P3 × P7	9.81	86	88	220	118	372
P4 × P5	9.98	86	89	210	114	371
P4 × P6	9.41	86	89	216	116	357
P4 × P7	8.68	87	89	228	115	348
P5 × P6	10.13	86	89	205	122	358
P5 × P7	9.49	86	89	226	123	347
P6 × P7	9.62	86	88	206	124	329
BHM9	9.84	88	90	238	120	350
981	11.47	86	89	228	109	351
NK40	9.81	86	89	211	107	340
F-test	**	**	**	**	**	**
Minimum	8.56	85	87	194	93	319
Maximum	11.47	88	90	238	124	383

*P=0.05, **P=0.01.

P1= CML429, P2= CLG1837, P3= CML285, P4= CML451, P5= CML431, P6= CML223 and P7= CML551.

Conclusion

Both GCA and SCA effects showed significant interaction with environment for all of the traits. This suggested the need of selecting different parental lines for hybrids for different ecological situations. Parents with good positive GCA for yield (P_5 and P_6) and 1000- kernel wt. (P_5); and negative GCA for days to pollen shedding and silking (P_6 and P_7), plant height and ear height (P_1, P_2 and P_3) might be extensively used in hybridization program as a donor. The better performing six crosses ($P_1 \times P_2$, $P_1 \times P_5$, $P_3 \times P_4$, $P_3 \times P_6$, $P_3 \times P_7$ and $P_4 \times P_5$) could be utilized for developing high yielding hybrid varieties as well as for exploiting hybrid vigour. These crosses also need to be evaluated further in wider agro-climatic conditions. Additionally, it could be concluded that all these selected crosses could be treated as well buffered hybrids.

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PROFITABILITY OF LENTIL CULTIVATION IN SOME SELECTED SITES OF BANGLADESH

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Abstract

The study estimated the profitability, farm specific technical efficiency of lentil growers and measured the impacts of different factors associated with technical efficiency of lentil farmers. The study employed farm level cross sectional data from three lentil growing districts namely Jessore, Meherpur and Natore of Bangladesh. The study revealed that HYV lentil is profitable than local variety. Cost of human labour, organic fertilizer, TSP, MoP and irrigation cost were found to contribute significantly in the efficiency of lentil farmers. The average technical efficiency of lentil growers in Bangladesh is 64 percent. This indicates a good potential for increasing lentil output by 36 percent with the existing technology and level of inputs. Farmers' educations and training have positive significant effect on yield and efficiency of lentil production. Farmers faced some problems like disease infestation, lack of storage facilities, lack of knowledge, untimely rainfall, high price of input and unavailability of HYV seed. Therefore, researchers should develop integrated pest, disease and insect management schedule which are environment friendly and ecologically sound. Good quality seeds of lentil should be made available locally to the farmers at a reasonable price.

Keywords: Profitability, lentil, technical efficiency.

Introduction

Pulse crops are important for the people of Bangladesh. It plays a vital role in the Bangladesh diet as a cheap source of protein. Eight kinds of pulses, such as lentil, mungbean, blackgram, grasspea, chickpea, cowpea, filed pea and pigeon pea are grown in Bangladesh (Bakr *et al.,* 1997). Among the pulses, lentil *(lens culinaris)* commonly known as "masur" is a popular pulse crop in Bangladesh. It contains more protein than any other agricultural produce, and is nearer to animal flesh in food value for which it is often called poor man's meat. Lentil is a winter pulse of temperate and subtropical region. Its contribution to pulse production of the world is 2.4% (Knight, 1987). Being legume, lentil is restorative in nature and its seed contains average 25.7% protein, which is almost three times higher than that of cereals (Erskine and Witcombe, 1984) and 59% carbohydrate (Bakhsh *et al.,* 1991). The per capita pulses consumption required for balance diet as given by FAO is 15 gm. Lentil ranks first among the pulses in terms of area (40%) and

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consumer preferences (Mia, 1991). The area under lentil cultivation in Bangladesh is declining but recently it was slightly upward and the average yield is only 960 kg/ha (BBS, 2012).

Table 1. Area, production, yield and harvest price of lentil in Bangladesh from 1981-82 to 2010-11

Year	Area (ha)	Production (MT)	Yield (T/ha)
1981-82	74706	47755	0.639
1982-83	73312	43750	0.597
1983-84	72907	47883	0.657
1984-85	70789	48442	0.684
1985-86	67470	47096	0.698
1986-87	212838	148988	0.700
1987-88	216404	158919	0.734
1988-89	215393	158040	0.734
1989-90	209178	155120	0.742
1990-91	210172	157280	0.748
1991-92	209004	152820	0.731
1992-93	207532	163425	0.787
1993-94	207642	167615	0.807
1994-95	207356	167945	0.810
1995-96	205868	169945	0.826
1996-97	206439	170505	0.826
1997-98	205858	162775	0.791
1998-99	205577	165315	0.804
1999-00	166781	127750	0.077
2000-01	164567	125905	0.765
2001-02	157229	115205	0.733
2002-03	154123	115590	0.750
2003-04	154810	122225	0.790
2004-05	153899	121065	0.787
2005-06	134694	115370	0.857
2006-07	137613	116810	0.849
2007-08	72613	71535	0.985
2008-09	70983	60537	0.853
2009-10	77321	71100	0.920
2010-11	83005	80442	0.960

Source: BBS, Different Issues.

Sikder and Elias (1985) reported that the average yield of lentil in Bangladesh was very poor, but varied widely between farms and between locations. In a study of Tomer *et al*. (1987) showed that the average yield of lentil increased with and increase in farm size. Bangladesh Agricultural research Institute (BARI) with other institutes has developed a number of high yielding lentil varieties and disseminated to farmers fields through different agencies. So it is essential to know the economic profitability of lentil production at farm level. But there is very few study conducted. Therefore, the present study was undertaken with the following objectives:

1. to know the input use pattern in lentil cultivation;
2. to estimate the profitability of the lentil cultivation and
3. to estimate the tecnical efficiency of lentil growers.

Materials and Methods

a) *Sampling technique:* Jessore, Meherpur and Natore districts were selected purposively as the study areas because these districts are leading lentil producing areas of Bangladesh. From each district, three upazilas namely Lalpur, Natore Sadar, and Baraigram from Natore and Bagarpara, Chougacha and Jhekorgacha from Jessore and Meherpur Sadar, Mujibnagor and Gangni from Meherpur were purposively selected on the basis of intensive lentil cultivation respectively. From each upazila one village under one block was selected with the help of knowledgeable persons and Department of Agricultural Extension (DAE) personnel. A complete list of all lentil growers from the selected villages was prepared with the help of extension personnel. From the list, 180 farmers from each district were selected randomly taking 60 farmers from each upazila.

b) *Method of data collection:* Data were randomly collected from improved and local variety growers. A total of 540 farmers were selected for the study using simple random sampling technique. Secondary data were collected from relevant upazilas, and statistical bulletin. Data were collected by the eexperienced field investigators with direct supervision of the researchers using a pre-tested interview schedule.

Analytical Technique

Empirical Cobb-Douglas frontier production function model

The Cobb-Douglas production function is used for functional analysis of the data. It is the most widely used form for fitting agricultural production data, because of its mathematical properties, ease of interpretation and computational simplicity. It is a homogeneous function that provides a scale factor enabling one to measure the return to scale and to interpret the elasticity coefficient with relative ease. It is also relatively easy to estimate because in logarithmic form it is linear and parsimonious (Beattic and Taylor, 1985). Thus Cobb-Douglas specification provides an adequate representation of the agricultural production technology.

The empirical Cobb-Douglas stochastic frontier production function with double log form can be expressed as:

$$LnY_i = \beta_0 + \beta_1 LnX_{1i} + \beta_2 LnX_{2i} + \beta_3 LnX_{3i} + \beta_4 LnX_{4i} + \beta_5 LnX_{5i} + \beta_6 LnX_{6i} + \beta_7 LnX_{7i} + \beta_8 LnX_{8i} + \beta_9 LnX_{9i} + \beta_{10} LnX_{10i} + \beta_{11} LnX_{11i} + \beta_{12} LnX_{12i} + v_i - u_i \quad \text{.......} (1)$$

Where,

Ln = Natural logarithm,

Y_i = Yield of lentil of the i-th farm (kg/ha)

X_{1i} = Land preparation cost of the i-th farm (Tk/ha)

X_{2i} =Human labour used by the i-th farm (man-days/ha)

X_{3i} = Seed used by the i-th farm (kg/ha)

X_{4i} = Organic fertilizer use by the i-th farm (kg/ha)

X_{5i} =Urea used by the i-th farm (kg/ha)

X_{6i} =TSP used by the i-th farm (kg/ha)

X_{7i} =MoP used by the i-th farm (kg/ha)

X_{8i} = Pesticide/Insecticides cost of the i-th farm (Tk/ha)

X_{9i} = Irrigation cost of the i-th farm (Tk./ha)

X_{10i} = Dummy for land type of the i-th farm (1= MHL, 0= otherwise)

X_{11i} = Dummy for sowing of the i-th farm date [1= optimum (30-35 kg/ha), 0= otherwise]

X_{12i} = Dummy for variety of the i-th farm (1= HYV 0= otherwise)

β's and η's are unknown parameters to be estimated

v_i - u_i = error term the i-th farm (Tk/ha

V_i are assumed to be independently and identically distributed (iid) random errors, having N $(0, \sigma_v^2)$ distribution.

Technical inefficiency effect model

The u›s in equation (1) are non-negative random variables, called technical inefficiency effects, assumed to be independently distributed such that the technical inefficiency effects for the i^{th} farmer, u_i, are obtained by truncation of normal distribution with mean zero and variance σ_u^2, such that

$$u_i = \delta_0 + \delta_1 z_{1i} + \delta_2 z_{2i} + \delta_3 z_{3i} + \delta_4 z_{4i} + \delta_5 z_{5i} + W_i \quad \text{.......} (2)$$

Where,

Z_{1i} = Farm size of the i-th farm (ha)

Z_{2i} = Age of the i-th farm operator (year)

z_{3i} = Education of the i-th farm operator (year of schooling)

z_{4i} = Family Size of the i-th farm operator

z_{5i} = Dummy for occupation of the i-th farm operator (1= Farming, 0 = Otherwise)

z_{6i} = Dummy for Training of the i-th farm operator (1= Trained, 0 = Otherwise)

z_{7i} = Dummy for extension contact of the i-th farm operator (1= contacted, 0= Otherwise)

z_{8i} = Dummy for seed source of the i-th farm operator (1= own, 0= Otherwise)

δ's are unknown parameters to be estimated

W_i are unobservable random variable or classical disturbance term, which are assumed to be independently distributed, obtained by truncation of the normal distribution with mean zero and unknown variance σ^2, such that u_i is non-negative.

The β, η and δ coefficients are unknown parameters to be estimated, together with the variance parameters which are expressed in term of

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \qquad \text{...} (3)$$

and $$\gamma = \sigma_u^2 / \sigma^2 \qquad \text{...} (4)$$

γ is the ratio of variance of farm specific technical efficiency to the total variance of output and has a value between zero and one.

The estimates for all parameters of the stochastic frontier (1) and inefficiency model (2) were estimated in a single stage by using the Maximum Likelihood (ML) method. The econometric computer software package FRONTIER 4.1 (Coelli and Battese, 1996) was applied to estimate the parameters of stochastic frontier models using the ML method.

Profitability analysis of lentil

An attempt was made to estimate the detailed cost and return, relative profitability, resource use efficiency. The financial profitability of improved lentil production over their traditional varieties was calculated using simple accounting procedures. Hence, data relating to input use for the production of lentil and their market prices were collected. Besides, data on outputs and their prices were also gathered for the study. Finally, the cost and return of improved pulse variety were compared with the respective cost and return of local pulse variety.

For calculating per hectare cost of lentil cultivation, all variable costs like human labour, land preparation, seed, manure, fertilizers, insecticides, irrigation and interest on operating capital were considered. The fixed cost of lentil cultivation included cost of land use and family labour. The land use cost was calculated on the basis of lease value of land. Finally cost was determined by adding fixed cost and variable cost.

Result and discussion

Input use pattern

On an average, 89 man-days of human labour per hectare were used for HYV lentil cultivation but it was only 62 man days for local variety. In the case of HYV, the highest number of human labour was used in Jessore (94 man-days/ha) and lowest in Natore (85 man-days/ha). Both type of farmers used 35 kg of seeds per hectare which was similar to the recommended rate of 30-35 kg/ha (BARI, 2011). Highest seed rate was used in Meherpur (37 kg/ha) and lowest in Natore (33 Kg/ha) for HYV cultivation while for local variety highest amount of seed was used in Jessore (35 kg/ha) and lowest in Meherpur (32kg/ha). HYV lentil farmer used 2984 kg cowdung per hectare as manure while it was 3566 kg/ha for local variety. It was mentioned that, farmers at Natore did not use cowdung in local variety cultivation. The farmers applied urea, TSP and MoP at the rate of 38, 81 and 47 kg/ha respectively in HYV cultivation while for local variety it was 35, 80 and 33 kg/ha of urea, TSP and MoP, respectively. Comparatively Jessore farmers used less amount of fertilizer in local variety, it may be due to more use of cow dung (Table 1).

Table 1. Level of input used in HYV and local variety of lentil cultivation in the study areas

Inputs	HYV				Local variety			
	Natore	Jessore	Meherpur	All	Natore	Jessore	Meherpur	All
Human labour (m-d/ha**)**	85	94	88	89	65	61	61	62
Seed (kg/ha)	33	36	37	35	34	35	32	35
Cow dung (kg/ha)	2447	4013	2684	2984	0	4151	1457	3566
Urea (kg/ha)	36	36	42	38	55	32	41	35
TSP(kg/ha)	76	78	90	81	84	79	88	80
MoP (kg/ha)	37	46	57	47	42	30	47	33

Source: Field Survey (2011-12).

Cost of lentil cultivation

The total cost of production of HYV and local variety of lentil were found Tk.43906 and Tk.38092 in which per hectare fixed cost were Tk.14391 and

Tk.12798, respectively. The average cost of production for HYV was higher than local variety, because the farmers used more inputs for HYV lentil cultivation. The cost of production in Jessore was higher than that of Natore and Meherpur due to more use of human labour, manures and land use cost (Table 2).

Table 2. Cost of cultivation of lentil in the study areas *(Taka /ha)*

Input costs	HYV				Local variety			
	Natore	Jessore	Meherpur	All	Natore	Jessore	Meherpur	All
A. Variable cost:								
Land preparation	5783	7186	6062	6287	5868	6435	5165	6168
Hired human labour	11499	12683	11768	11936	7134	8202	7339	8068
Seed	2555	2829	2807	2723	2021	2470	2161	2419
Manures	1147	1881	1330	1424	0	2446	748	2168
Fertilizers:								
Urea	729	717	843	766	693	648	623	648
TSP	2312	2122	2395	2286	2218	2194	1848	2162
MOP	677	772	975	810	619	640	855	659
Total	3718	3611	4213	3862	3530	3482	3326	3469
Insecticides	1474	1160	1185	1281	741	1207	1084	1173
Irrigation	1122	978	1296	1142	741	967	861	946
Int. on opt. capital	819	910	860	860	601	756	621	883
Total variable cost (TVC)	28117	31238	29521	29515	20636	25965	21304	25294
B. Fixed cost (FC)	14052	15400	13910	14391	11629	13006	11506	12798
Land use cost	8388	9153	8114	8512	7788	8590	7554	8453
Family lab our	5664	6247	5796	5879	3841	4416	3952	4345
C. Total cost (TVC+FC)	42168	46638	43431	43906	32265	38971	32810	38092

Source: Field Survey (2011-12).

Profitability

The average yield of HYV lentil was estimated at 1479 kg/ha which was much higher than the national average of 920 kg/ha (BBS, 2012). But the average yield of local variety of lentil was found 819 kg/ha which was lower than the national average. For HYV, the highest yield was found in Natore (1656 kg/ha) and the lowest in Jessore (1347 kg/ha). On the other hand, the highest yield of local variety was found in Natore (903 kg/ha) and the lowest in Meherpur (808 kg/ha). The average gross return, gross margin and net return were Tk.79440, Tk.49925 Tk.35534 per hectare respectively for HYV while it was Tk.46417, Tk.21123 and Tk.8325 per hectare respectively for local variety cultivation. The benefit cost ratio (BCR) for HYV lentil was found 1.81 while in local variety, it was 1.22 on full cost basis. Whereas, BCR on cash cost basis, HYV and local variety was 2.69 and 1.84 respectively (Table 3).

Table 3. Per hectare return from HYV and local variety lentil cultivation in the study areas

Inputs	HYV				Local variety			
	Natore	Jessore	Meherpur	All	Natore	Jessore	Meherpur	All
Grain yield (kg/ha)	1656	1347	1409	1479	903	816	808	819
Gross return (GR) (Tk/ha)	87060	73533	76570	79440	50157	46258	46162	46417
Main product	84333	70919	73945	76786	47883	44064	44036	44226
By-product	2727	2614	2625	2654	2274	2194	2126	2191
Total variable cost (TVC)	28117	31238	29521	29515	20636	25965	21304	25294
Total cost	42168	46638	43431	43906	32265	38971	32810	38092
Gross margin (GR-TVC)	58943	42295	47049	49925	29521	20293	24858	21123
Net return (GR-TC)	44891	26895	33139	35534	17892	7287	13352	8325
Benefit cost ratio:								
Cash cost basis	3.10	2.35	2.59	2.69	2.43	1.78	2.17	1.84
Full cost basis	2.06	1.58	1.76	1.81	1.55	1.19	1.41	1.22

Source: Field Survey (2011-12).

Maximum likelihood estimates of farm–specific stochastic frontier production function and inefficiency model for lentil

The empirical results indicate that, the coefficients of human labour, organic fertilizer, TSP, MoP and irrigation cost were positive and significant. The for dummy for land type and sowing date was positive and significant implies that in general, the level of lentil production is higher in medium high land and for optimum sowing. This may be due to better suitability of medium high land and optimum sowing for lentil cultivation. At 1% level of significance, human labour had the largest positive coefficient compared to other inputs. In other words, the elasticity of human labour (0.118) is the biggest among all variables, implying that human labour had positive and greatest impact on lentil production. At 5% level of significance the coefficients of organic fertilizer, TSP, and MoP were positive implies that organic fertilizer, TSP, and MoP had a significant and positive impact on lentil production. The yield of lentil will be increased by 0.001, 0.006 and 0.012 percent if farmers apply one percent additional amount of organic fertilizer, TSP, and MoP, respectively. The coefficient of irrigation was also positive and significant at 10% level of significance (Table 4). It was observed that, except few exception more or less same results was found in HYV and local variety farmers.

Table 4. Maximum likelihood estimates of frontier production function and technical inefficiency model for lentil in the study areas

Independent variable	Para-meter	HYV farms (n=498)	Local variety farms (n=42)	All farm (n=540)
Stochastic frontier:				
Constant	β_0	7.485*** (0.065)	7.194*** (0.312)	6.931** (0.181)
Land preparation (Tk./ha)	β_1	-0.050 (0.010)	-0.148 (0.173)	-0.008 (0.018)
Human labour (m-day/ha)	β_2	0.187 *** (0.023)	0.155** (0.508)	0.118*** (0.028)
Seed (kg/ha)	β_3	-0.021 (0.008	0.149(0.341)	-0.018 (0.020)
Organic fertilizers (kg/ha)	β_4	0.004*** (0.001)	0.008** (0.035)	0.001** (0.001)
Urea (kg/ha)	β_5	-0.009(0.004	-0.021(0.077)	0.005 (0.006)
TSP (kg/ha)	β_6	0.013*** (0.004)	0.041** (0.088)	0.006** (0.006)
MoP (kg/ha)	β_7	0.021*** (0.021)	0.002** (0.071)	0.012** (0.006)
Pesticides (Tk./ha)	β_8	0.005** (0.001)	-0.154 (0.049)	0.005 (0.002)
Irrigation (Tk/ha)	β_9	0.009 (0.001)	0.059** (0.015)	0.004* (0.001)
Dummy for land type (1=MHL, 0= otherwise)	β_{10}	0.023*** (0.007)	0.004*** (0.112)	0.028** (0.019)
Dummy for sowing date (1=optimum, 0= otherwise)	β_{11}	0.019*** (0.004)	0.253** (0.088)	0.013* (0.006)
Dummy for variety (1=HYV, 0= otherwise)	β_{12}	-	-	0.295 (0.051)***
Technical inefficiency model:				
Constant	δ_0	4.086 (0.242)	6.093 (0.641)	7.067 (0.231)
Farm size (ha)	δ_1	0.002 (0.022)	-0.189** (0.054)	0.015 (0.282)
Age (year)	δ_2	-0.001 (0.002)	0.002 (0.006)	-0.003 (0.002)
Education (year of schooling)	δ_3	-0.006** (0.006)	-0.019 (0.038)	-0.004* (0.008)
HH size (no)	δ_4	-0.007(0.015)	0.047(0.043)	-0.001(0.013)
Dummy for occupation (1=Farming, 0=Otherwise)	δ_5	0.001 (0.002)	0.002 (0.004)	0.005 (0.004)

Independent variable	Para-meter	HYV farms (n=498)	Local variety farms (n=42)	All farm (n=540)
Dummy for Training (1=Trained, 0=Otherwise)	δ_6	-0.098* (0.057)	-0.102* (0.046)	-0.071** (0.068)
Dummy for extension contact (1=Contacted, 0=Otherwise)	δ_7	-0.327 (0.158)	-0.132 (0.704)	-0.245 (0.155)
Dummy for seed source (1=Own, 0=Otherwise)	δ_8	-0.017 (0.056)	-0.086 (0.370)	-0.044 (0.074)
Variance parameters:				
Sigma-squared	σ^2	0.193*** (0.021)	0.158** (0.054)	0.184*** (0.025)
Gamma	γ	0.899*** (0.002)	0.919*** (0.001)	0.903** (0.005)
Log likelihood function		152.240	40.175	161.429

Note: ***, ** and * indicate significant at 1, 5 and 10 percent level of probability, respectively.

Effect of inefficiency variable

The estimated coefficients presented in Table 4 showed that education and training of the farmers has a negative and significant effect on the inefficiency effects for lentil production. This

means that the technical inefficiency decreases with the increase of farmers' education and training. So, the production can be attained maximum level by providing investment on farmers' education and training purposes.

The estimated values of variance parameters (σ and γ) were large and significantly different from zero which indicated a good fit and correctness of the specified distributional assumption. The significant value of γ also indicated that there were significant technical inefficiency effects in the production of lentil.

Farm specific technical efficiency

It was observed that the mean value of technical efficiency was 0.64. This implied that, on average, the lentil producers in the study areas were producing lentil for about 64 percent of the potential (stochastic) frontier production levels, given the levels of their inputs and the technology currently being used. This also indicated that there existed an average level of technical inefficiency of 36 percent (Table 5). The technical efficiency was found slightly higher for the HYV adopters (0.65) compared to non-adopters (0.63).

Technical efficiency level of different producer type indicated that majority of the producers (54.4%) had technical efficiency level below 70 percent followed by the level 91-100 percent (18.5%). For the local variety practitioners more number of farmers (71.4%) had technical efficiency level below 70 percent followed by the level 71-80 percent (16.7%). But for HYV practitioners, more number of farmers (53.0%) had technical efficiency level below 70 percent followed by the level 91-100 percent (19.7%) (Table 6**).**

Table 5. Farm specific technical efficiencies of lentil producers in the study areas

Variety	No. of farm	Technical efficiency			
		Mean	Maximum	Minimum	SD ±
HYV	498	0.65	1.00	0.38	0.19
Local	42	0.63	1.00	0.44	0.12
All types	540	0.64	1.00	0.38	0.14

Table 6. Frequency distribution of technical efficiencies of lentil producer

Technical efficiency (%)	No. of farmers	Percent (%)
≤70	294	54.4
71-80	73	13.5
81-90	74	13.7
91-100	100	18.5
All	540	100
Mean	0.64	
Maximum	1.00	
Minimum	0.38	

Yield of lentil under technical efficiency levels

The yield of lentil was examined under farm specific technical efficiency levels and was presented in table 7. As technical efficiency was defined by technically more efficient farms who obtained higher levels of yield. The highest level yield of lentil was obtained by the farmers who had technical efficiency level 91-100 percent (2135 kg/ha) followed by technical efficiency level of 81-90 percent (1633 kg/ha) and 71-80 percent (1246 kg/ha**)** (Table 7**)**. The lowest level of yield (916 kg/ha) was obtained by the farmers who had lowest levels of technical efficiency (≤70%). This further established the fact that technical efficiency and yield had a direct and positive correlation. Similar trend were also observed for HYV and local variety adaptors.

Table 7. Yield of Lentil as affected by technical efficiency level

Producer type	Yield (kg/ha)				
	≤70	*71-80*	*81-90*	*91-100*	*All*
HYV	1022	1283	2018	2167	1474
Local	674	826	864	1086	819
All types	916	1246	1633	2135	1428

Constraints

Although lentil is a profitable crop in the study areas, the sample farmers encountered different constraints. The major constraints faced by the HYV farmers were disease infestation and lack of storage facities (19%), lack of knowledge (18%), untimely rainfall (17%), high price of input (16%), lack of suitable land (15%) and unavailability of HYV seed (13%). The constraints faced by the local farmers were disease infestation (25%), lack of knowledge (22%) and untimely rainfall (18%). Farmers opined that for these constraints they were not getting the normal yield (Table 8).

Table 8. Constraints to lentil cultivation

Constraints	HYV				Local variety			
	Natore	Jessore	Meherpur	All	Natore	Jessore	Meherpur	All
Lack of suitable land	11	14	21	15	12	14	19	15
Disease infestation	20	22	15	19	25	27	22	25
Unavailability of HYV Seed	10	13	16	13	-	-	-	-
Untimely rainfall	18	16	17	17	19	18	16	18
High input price	17	15	16	16	16	13	15	15
Lack of training/ knowledge	16	18	20	18	21	24	22	22
Lack of storage facilities	18	19	21	19	16	15	17	16
Impure fertilizer	11	10	13	11	9	8	10	9

Conclusion and Recommendations

Farm level input use varied significantly from area to area. This might be due to the knowledge gap among the lentil growers. The average technical efficiency of lentil growers is found 64 percent. This indicates a good potential for increasing lentil output by 36 percent with the existing technology and level of inputs used. Farmers' educations and training have positive significant effect on yield and efficiency of lentil production. Improved varieties of lentil cultivation increase yield as well as highly profitable to the farmers. But infestation of insects like aphid, and diseases (stemphyllium blight, foot rot) is a common constraint in lentil cultivation. Short duration and stress tolerant improved lentil varieties are pre-requisites for expanding the cultivation throughout the country. Therefore, continuous effort should be given by the breeders for developing high yielding lentil varieties. And also researchers should develop integrated pest, disease and insect management schedule which are environment friendly and ecologically sound. Farmers training on lentil production should be needed and also extension works should be strengthen on lentil cultivation. Therefore, Government may provide more subsidies on the production and distribution of these important inputs, and make them available at local markets with reasonable price.

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DETECTION OF SOIL FUNGI FROM WHEAT CULTIVATED AREA

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Abstract

Experiments were conducted to find out different soil fungi from wheat cultivated area during 15 April to 10 May, 2013-2014. The obtained soil fungi from wheat cultivated area were *Aspergillus spp., Penicillum spp., Geotrichum spp., Gloesporium spp., Fusarium spp., Mycelia sterilia, Arthrobotrys spp., Cladosporium herbarum* in district Allahabad, Various soil fungi from wheat cultivated area from Mirzapur district were which *Aspergillus spp., Penicillum spp., Rizoctinia spp., Fusarium spp., Mucor spp***.** and In Varanasi district, various soil fungi were obtained also from wheat cultivated area which are *Aspergillus spp., Penicillum spp., Rizoctinia spp., Fusarium spp., Mucor spp***.,** *Alternaria spp., Helminthosporium oryzae,* and *Humicola grisea. Aspergillus spp.* and *Penicillum spp.* was common fungi presented in three different districts Allahabad, Mirzapur and Varanasi, of Uttar Pradesh.

Keyword: Soil fungi, Wheat, Uttar Pradesh.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereals in the world and is part of a staple diet for nearly 35% of the world's population (Behl *et al.*, 2006). It is grown in about 102 countries of the world covering about 220.69 million hectares of land which is 32% of the total cultivated land of the world. The area and production increased to 0.83 million hectare and 1.84 million metric tons, respectively in 2000 (Hasan, 2006).

Soil fungi play an important role as major decomposers in the soil ecosystem. There are about 75,000 species of soil fungi in the world (Finlay *et al.*, 2007). Fungi are one of the dominant groups present in soil which strongly influence ecosystem structure and functioning and thus plays a key role in many ecological services (Orgiazzi *et al.*, 2012). Therefore, there is a growing interest in assessing soil biodiversity and its biological functioning (Barrios, 2007).

The yield was 2.8 t/ha in 2011-12 cropping year (BBS, 2012) which is very low compared to those in the research farm level (3.5 to 5.1 t/ha) (Hasan, 2006). Coupled with many other factors, diseases also play an important role in lowering the yield (Saundersv, 1990, Badaruddin *et al.*, 1994).

The process of decomposition is governed by the succession of fungi at various stage of decomposition (Beare, 1993; Valenzuela *et al.*, 2001; Rai. *et al.*, 2001;

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Santro *et al.*, 2002) nutrient level of soil, crop residue and prevailing environmental conditions (Nikhra, 1981; Coockson *et al.,* 1998; Cruz, *et al.*, 2002; Simoes *et al.,* 2002; Mc Tiernan, *et al.,* 2003).

The current study was aimed detection of soil fungi from wheat field. The study involved isolation, identification and screening of soil fungi of fungal species prevailed Allahabad, Varanasi, and Mirzapur districts of Uttar Pradesh in India.

Materials and Methods

The present studies were carried out at Bhargava Agricultural Botany laboratory, Department of Botany, University of Allahabad, Allahabad**.** Soil samples were collected from wheat cultivated areas of selected sites of Allahabad, Varanasi and Mirzapur district during 15 April to 10 May 2013-2014 for detection of soil fungi.

Study Area:

Three studies area were select, first district Allahabad is situated in Southern Eastern. It lies between the parallels of 24º 47’ north latitude and 81º 19’ east longitudes, Second is Mirzapur District located at 25.15^0 N and 82.58^0 E, and third Varanasi is situated at 25.28^0 N and 82.96^0 E in Uttar Pradesh, India. Soil taken 15 cm depth and put in small sterilized polythene bags for laboratory analysis.

Isolation of Soil fungi:

The samples were processed for isolation using the soil dilution plate (Waksman, 1922). The soil fungi were isolated following the soil dilution plating technique of (Jonhson *et al*., 1960). The moisture content of a certain amount of soil was determined and fresh soil quantities corresponding to 25 gm of oven-dried soil were calculated (Öner, 1973). 1×10^{-4} then dilutions of the samples were prepared (Warcup, 1955). Each soil sample was diluted to 1×10^{-4} concentration suspension. Then, 1 ml of the soil suspension (containing 0.0001 g wet soil) was drawn by pipette into a Petri dish (90 mm). A mixture of 25 ml of warm, molten glucose-ammonium nitrate agar (GAN) added with Rose Bengal and streptomycin was poured over the soil suspension and the Petri dish was rotated gently to let the soil suspension mix well with the medium. Five replications were completed for each soil sample (0.0005 gm wet soil). All the Petri dishes were incubated at room temperature (26-28°C) in darkness for 3-5 days or longer.

Identification of the soil fungi:

Fungal morphology was studied by observing colony features such as (Colour and Texture) and by staining with lacto-phenol, cotton blue and observe under compound microscope for the conidia, conidiophores and their arrangement. The fungi were identified with the help of literature (Nagamani and Manoharachary 2006). The colonies were counted and identified using the soil dilution plate method. The counting and identification procedure was carried out under a stereomicroscope. Then the identified colonies were transferred to Petri dishes containing agar. In the Petri dishes, different types of colonies developed. Identification of the organism was made with the help of the relevant literature (Thom and Raper 1945, Gilman 1957). For the identification of the isolates, Smith (1971) was followed. Identification of the taxa were carried out according to Hasenekoglu (1991), Subramanian (1983), Ellis (1971), Raper and Thom (1949), Raper and Fennell (1965), Zycha (1969), Samson and Pitt (1985, 2000)

Screening of soil fungi

Screening of soil fungi after each stage the ineffective isolates were excluded from further testing. Isolation of microorganisms and primary screening was done according to the method given by Vega *et al.* (2012). Various soil fungi recorded from different three districts *viz.* Allahabad, Mirzapur and Varanasi.

Results and Discussion:

The results obtained of different three district screening of soil fungi wheat cultivated area from the analyses 10 blocks of soil through soil dilution plate methods to determine the screening of soil fungi. Different soil fungi were recorded from wheat cultivated areas *Aspergillus spp., Penicillum spp., Geotrichum spp,. Gloesporium spp., Fusarium spp., Mycelia sterilia, Arthrobotrys spp., Cladosporium herbarum.* In which *Aspergillus spp.* and *Penicillum spp.* common soil fungi recorded of district Allahabad in (Table: 1)

Table 1. Isolation and identification of soil fungi from wheat cultivated area in district Allahabad

S.No.	Blocks	Isolated Fungi
1.	Bahadurpur Holagarh, Pratappur, Phulpur, Saidabad, Handia, Meja, Manda, Koroan Saidabad	***Aspergillus sp.***
		Aspergillus oryzea (Ahlburg Cohn) *Aspergillus flavus (*Link) *Aspergillus variecolor* (Thom and Church) *Aspergillus ochraceus* (Withelm) *Aspergillus niveus* (Blotch)
2.		***Penicillum Sp.***
		Penicillum variabil (Sopp.) *Penicillum citrinum (*Thom) *Penicillum notatum* (Westling) *Penicillum steckii* (Zaleski) *Penicillum Spp.*(Perithecial)

S.No.	Blocks	Isolated Fungi
3.		*Geotrichum spp.*
4.		*Gloesporium spp.*
5.		*Fusarium spp.* (Sterile)
6.		*Mycelia sterilia* (Four)
7.		*Arthrobotrys spp.*
8.		*Cladosporium herbarum* (Persoon)

The five *Aspergillus species* were recorded *viz. Aspergillus oryzea, Aspergillus flavus, Aspergillus variecolor, Aspergillus ochraceus, Aspergillus niveus* where as the five *Penicillum speciese* were recorded *viz. Penicillum variabil, Penicillum citrinum, Penicillum notatum, Penicillum steckii, Penicillum Sp,* in Allahabad district. Saksena, and Sarbhoy *et al.* (1962) also were recorded soil fungi in Allahabad district.

In the experiment detection of soil fungi from wheat cultivated area consists of 10 blocks in district Mirzapur. The soil fungi were recorded from wheat cultivated area are *Aspergillus spp., Penicillum spp., Rizoctinia spp., Fusarium spp., Mucor spp.* *Aspergillus spp. Penicillum spp.* and *Fusarium spp.*, were common soil fungi recorded. (Table 2).

Table 2. Isolation and identification of soil fungi from wheat cultivated area in district Mirzapur.

S. No.	Blocks	Isolated Fungi
1	Chhanvey Haliya Jamalpur Kon Lalganj Madihaon Majhawan Narainpur Rajgarh Skhdi	***Aspergillus sp.***
		Aspergillus niger (Tiegh) *Aspergillus flavus* (Link) *Aspergillus oryzea* (Ahlburg Cohn) *Aspergillus luchuensis* (Inui) *Aspergillus terreus* (Thom) *Aspergillus variecolor* (Thom and Church) *Aspergillus awamori* (Nakazawa) *Aspergillus niveus* (Blotch)
2		***Penicillum Sp.***
		Penicillum funiculosum (Thom) *Penicillum frequentans* (Westling) *Penicillum steckii* (Zaleski) *Penicillum Sp.*(Perithecial) *Penicillum variabil* (Sopp.)
3		***Rizoctinia Sp.***
		Rizoctinia oryzae (Went and Geerl.) *Rizoctinia cohnii (Berl. And de Toni)*

S. No.	Blocks	Isolated Fungi
4		***Fusarium sp.***
		Fusarium sp. (Sterile) *F,usarium avenaceum* (Fr.) *Fusarium oxysporium (Schlect. Ex Fr.)* *Fusarium javanicum* (Koord)
5		***Mucor sp.***
		Mucor fragilis (Bain) *Mucor jansseni* (Lendner)

The eight *Aspergillus speciese* were recorded *viz. Aspergillus niger, Aspergillus flavus, Aspergillus oryzea, Aspergillus luchuensis, Aspergillus terreus, Aspergillus variecolor, Aspergillus awamori, Aspergillus niveus*, where as the five *Penicillum speciese* were rcorded *viz. Penicillum funiculosum, Penicillum frequentans, Penicillum steckii, Penicillum Spp, Penicillum variabil,* the two *Rizoctinia spp* were recorded i.e. *Rizoctinia oryzae, Rizoctinia cohnii,* four *Fusarium spp.* were recorded *of Fusarium spp., Fusarium avenaceum, Fusarium oxysporium, Fusarium javanicum*. The two *mucor speciese* were recorded i.e. *Mucor fragilis,* and *Mucor jansseni* in district Mirzapur. Saksena, and Sarbhoy *et al.* (1966) also finding these fungi in Mirzapur district.

In district Varanasi, detection of soil fungi from wheat cultivated area consists of 8 blocks. The results were obtained of soil fungi from wheat cultivated area are *Aspergillus spp., Penicillum spp., Rizoctinia spp., Fusarium spp., Mucor spp.*, *Alternaria spp., Helminthosporium oryzae,* and *Humicola grisea,* In which *Aspergillus spp., Penicillum spp.* and *Fusarium spp.* were common soil fungi found. in (Table: 3).

Table 3. Isolation and identification of soil fungi from wheat cultivated area in district Varanasi.

S No.	Blocks	Isolated Fungi
1	Arajiline Baragavon Chiraigaon Cholapur Harhua Kashi Vidya Peeth Pindra Sewapuri	***Aspergillus sp.***
		Aspergillus niger (Tieghem) *Aspergillus flavus (*Link) *Aspergillus luchuensis* (Inui) *Aspergillus terreus* (Thom) *Aspergillus variecolor* (Thom and Church) *Aspergillus awamori* (Nakazawa) *Aspergillus niveus* (Blotch) *Aspergillus sydowi* (Bainier & Sastary)

S No.	Blocks	Isolated Fungi
2		***Penicillum Sp.***
		*Penicillum funiculosum (*Thom) *Penicillum frequentans* (Westling) *Penicillum steckii* (Zaleski) *Penicillium rubrum* (Stoll) *Penicillium chrysogenum* (Stoll)
3		***Rizoctinia sp.***
		Rizoctinia oryzae (Went and Geerl.)
4		***Fusarium sp.***
		*Fusarium semitectum (*Berkeley & Revenel) *Fusarium oxysporium (*Schlechtendahl) *Fusarium javanicum* (Koord)
5		***Mucor sp.***
		Mucor racemosus (Fresenius)
6		***Alternaria sp.***
		Alternaria alternata (Fr.) Keissler *Alternaria solani (*Sorauer) *Alternaria claymydospora*
7		*Helminthosporium oryzae* (Sacc.)
8		*Humicola grisea* (Traaen)
9		*Pythium aphanidermatum* (Edson) Fitzpatrick

The eight *Aspergillus spp.* were recorded *viz. Aspergillus niger, Aspergillus flavus, Aspergillus luchuensis, Aspergillus terreus, Aspergillus variecolor, Aspergillus oryzea, Aspergillus luchuensis, Aspergillus terreus, Aspergillus variecolor, Aspergillus awamori, Aspergillus niveus, Aspergillus sydowi spp.*, where as the five *Penicillum spp* were recorded *viz. Penicillum funiculosum, Penicillum frequentans, Penicillum steckii, Penicillium rubrum Penicillium chrysogenum spp.*, one *Rizoctinia sp* was recorded i.e. *Rizoctinia oryzae,* Three *Fusarium sp.* were recorded *viz. Fusarium semitectum, Fusarium oxysporium, Fusarium javanicum,* and one *Mucor speciese* i.e. *Mucor racemosus*, three *Alternaria sp*. were recorded *Alternaria alternata, Alternaria solani,* and *Alternaria claymydospora* were recorded from wheat cultivated area in Varanasi district.

Conclusion:

The two common soil fungi were obtained *Aspergillus spp.* and *Penicillum spp.* in three different districts at Allahabad, Mirzapur and Varanasi, of Uttar Pradesh in India.

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ADOPTION OF LENTIL VARIETIES IN BANGLADESH: AN EXPERT ELICITATION APPROACH

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Abstract

The study was undertaken to find out variety wise adoption rate of lentil in Bangladesh through expert elicitation procedure. Many varieties have been developed by BARI and BINA but in details of varietal information and adoption information database was not developed which is very important and valuable for the scientist and policy planner. From all over the Bangladesh, 12 experts was invited to share their valuable knowledge and experience on lentil cultivation and adoption in the country. The average age of the experts were 51 yrs and average experience on lentil adoption was 21 yrs. The lentil expert informed that 16 major varieties are adopted by the farmers in the recent year (2013-14). Among those varieties, BARI Masur-6 covered highest cultivated area (54,642 ha) which shared 30.04% of total lentil cultivated area. BARI Masur-4, BARI Masur-3 and BARI Masur-5 ranked 2nd, 3rd and 4th position according to the share of cultivated area covered. The seed production information showed that BADC the only lentil seed producer supplied 2151 mt of lentil seed in the year 2009-2013.The adoption of variety BARI Masur-6 increased due to its high yield attribute. The another variety BARI Masur-4 and BARI Masur-3 adoption increased due to its high yield, resistant to rust disease attributes which showed increasing adoption path among the expert. Satisfying higher demand for lentil consumption and ensuring food security through providing alternative to winter crops are the major concerning issue of the policy planner and the scientist. To ensure nutrition security in the country, it is very important to encourage and support the farmers to grow more lentil through providing improved cultivation technology to the farmers.

Keywords: economics, expert elicitation, varietal adoption

1. Introduction

Lentil (*Lens culinaris* M.) is among the important pulse crops contributing to food and nutritional security of people in Asia and Africa. Its seed contain high levels of protein, macronutrients, micronutrients and vitamins that provide nutritional security to poor consumers who cannot afford animal products due to

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high prices. Additionally, lentil straw is valuable feed for animals. Growing lentils in rotations provides sustainable cereal-based cropping systems.

Bangladesh rank in 3rd among the lentil growing countries of Asia Pacific region. Lentil is the second most important pulse crop in area and production, but stands first in the consumer's preference in this country.

It is grown on about 153912 ha, producing 127159 tonnes of grain, with average yield of 850 kg ha^{-1} (Table 1.1) and contributes about 28% to the total pulses production. Lentil is cultivated during winter (rabi of post rainy season; Nov-Mar). Cultivation of lentil is mainly concentrated within the Gangetic floodplains in the northern and southern districts.

Table 1.1. Area, production and yield of lentil in Bangladesh

Year	Area (ha)	Production (mt)	Yield (t/ha)
1990-91	210172	157280	0.748
1991-92	209004	152820	0.731
1992-93	207532	163425	0.787
1993-94	207642	167615	0.807
1994-95	207356	167945	0.810
1995-96	205868	169945	0.826
1996-97	206439	170505	0.826
1997-98	205858	162775	0.791
1998-99	205577	165315	0.804
1999-00	166781	127750	0.766
2000-01	164567	125905	0.765
2001-02	157229	115205	0.733
2002-03	154123	115590	0.750
2003-04	154810	122225	0.790
2004-05	153899	121065	0.787
2005-06	134694	115370	0.857
2006-07	137613	116810	0.849
2007-08	72613	71535	0.985
2008-09	70983	60537	0.853
2009-10	77321	71100	0.920
2010-11	83006	80442	0.969
2011-12	86245	80125	0.929
2012-13	90002	93098	1.034
2013-14	124549	157422	1.263

Source: BBS (1992), BBS (1997), BBS (2004), BBS (2008), BBS (2012), BBS (2014).

Research on lentil was initiated during the early 1950s.Where efforts were confined to the collection and evaluation of local germplasm. A few lines were tested over locations during the early 1960s, but the research virtually stopped, as the germplasm was not properly maintained. To halt steady decline and to attain self-sufficiency in pulses production, an intensive research effort was launched at the Bangladesh Agricultural Research Institute in 1979 under a research grant project of the International Development Research Centre (IDRC), Canada. Eventually the Pulses Improvement Program transformed into a Pulses Research Centre (PRC), in mid-eighties with its 4-5 testing stations at major pulses-growing zones of the country.

With the detailed adoption information, the concern authority and agencies can formulate appropriate policy for the development of lentil crop across the country. Again, potential adoption of the improved varieties would generate employment and additional income for the rural poor and save foreign exchange through producing more of this crop utilizing fallow and under used lands in the country. Therefore, nationally representative and up-to-date data and information on the adoption of lentil cultivation are lacking in Bangladesh. This information could be useful for both government and donor agencies in investing more on lentil improvement programs in Bangladesh.

1.1 Objectives for the study

i) To document and process on varietal release at the national level

ii) To find out variety wise adoption rate of lentil in Bangladesh and

iii) To suggest policy implications from the above.

2. Methodology

2.1 Data and data sources

The main approach is to assemble the relevant data for the most recent years from multiple sources such as national data sources (BBS, DAE), Annual Report of pulse research center of BARI, BARI & BINA annual report, Books of BARI developed crop varieties, consultation with related scientists and expert elicitation (EE) workshop.

2.2 Details of experts

A panel of experts knowledgeable about the adoption of lentil cultivars in the zones (ecosystem, season or administrative zone) was formed. Typically, a panel consisted of 12 experts including scientists (breeders, agronomists, and agricultural economists), extension workers, seed producers & traders, development worker and farmers about lentil production systems in the locality (Table 2.1)**.** Among the experts, 5 members were from NARS and 7 members were from non-NARS at the EE workshop in Bangladesh.

Table 2.1. Distribution of expert according to discipline

Discipline of experts	No. of experts by discipline	No of experts from NARS	No of experts from non-NARS
Scientist	6	5	1
Extension	3	-	3
Development worker	1	-	1
Farmers	1	-	1
Seed production expert	1	-	1
Total	12	5	7

Source: Expert Elicitation workshop-2015.

Lentil is grown in most of the areas of Bangladesh. As per the statistics of DAE, the total area under lentil cultivation is 0.18 million hectare with the production of 2.16 million tons during 2013-14. The adoption study of lentil variety has been taken-up top four zones of Rajshahi, Jessore, Barisal zone of Bangladesh because they were the top producer's zones of lentil occupying an area 92.36% and production of about 94% during 2013-14 (Table 2.2).

Table 2.2. Zone wise gross cropped areas and production of lentil during 2013-14

Crop Zone	Lentil			
	Gross cropped area (ha)	Share (%)	Production (MT)	Yield (t/ha)
Rajshahi Zones	59939	32.95	78928	1.32
Jessore Zones	65442	35.97	86763	1.33
Barisal Zones	42631	23.44	50538	1.19
Others	13893	7.64	15974	1.15
Total	181905	100.00	232203	1.28

Source: DAE, 2014.

3. Results and Discussion

3.1 More details about experts

Age of experts plays an important role to share knowledge regarding the varietal adoption in EE workshop. The average age of the expert was 50.75 yrs and the range of their age was from 28 to 69 yrs (Table 3.1). The average year of experience on lentil was 19.83 yrs and the experience of expert range from 5 to 31 yrs. Expert who were invited in the workshop had 21.25 yrs of average working experience in the affiliated organization. The working experience (yrs) of the experts in the organization ranged from 9 to 31 yrs.

Table 3.1. Qualification of expert's characteristics

Expert characteristics	Mean	Min	Max
Age (years)	50.75	28	69
Years of experience on crop	19.83	5	31
Years of experience in present institute	21.25	9	31

Source: Expert Elicitation workshop-2015.

3.2 Trends in varietal release

BARI began a program in the mid 1990 to develop its own lentil variety in collaboration with international partners, particularly ICARDA, and it released its first lentil (BARI Masur-1 and 2) in 1991 and 1993 respectively. Two further lentil BARI Masur-3&4 (released in 1996) and BARI Masur-5, released in 2006. BARI has released two other lentil variety BARI Masur-6 (released in 2006), BARI Masur-7 (released in 2011) (Table 3.2).

Table 3.2. Number of variety released in different period

Period	Total varieties	No. of modern varieties
1991-1995	2	2
1996-2000	2	2
2001-2005	3	3
2006-10	3	3
2010 till now	6	6
Total	16	16

Source: BARI, 2010-2012.

The variety cultivated in Bangladesh, all of them are officially developed and released varieties. Variety developed are 100% modern variety. The variety that is developed locally are released by government authority. The developed varieties have linkage with NARS and international organization like ICARDA of CGIAR. Among the modern varieties (16) of lentil the top most contributor was NARS (62.5%) followed by CGIAR (37.5%) (Table 3.3).

Table 3.3. Share of contribution and linkage of different organization in varietal Development

Crop	Total number of varieties	Number of varieties linked with CGIAR	Number of varieties linked with NARS	Number of varieties linked with Private Sector companies/ institutions
Lentil	16	6 (37.5%)	10 (62.5%)	0

Source: Expert Elicitation workshop-2015.

Among the modern varieties (16), NARS was the key role player to develop lentil varieties during period 1991-2014 followed by NARS (10) and CGIAR (6) in Bangladesh. Highest number of lentil variety (6) developed and released in the country during the period 2010 and onward. In that period NARS developed 4 varieties and rest of the varieties are developed by the NARS with the linkage of CGIAR (Table 3.4).

Table 3.4. Number of varieties linked with CGIAR, NARS

Period	Total MV's	Number of varieties linked with CGIAR	Number of varieties linked with NARS
1991-1995	2	1	1
1996-2000	2	1	1
2001-2005	3		3
2006-10	3	2	1
2010 till now	6	2	4
Total	16	6	10

Source: BARI, 2010-2012.

Table 3.5. Percentage of adoption areas mentioned by expert

List top Modern Variety (MV) as identified in EE	Total country/ domain cropped/ net sown area (ha)	% Area adopted under the variety (ha) by EE
BARI Masur-1	3094.74	1.70
BARI Masur-2	3409.63	1.87
BARI Masur-3	23834.82	13.10
BARI Masur-4	42592.87	23.41
BARI Masur-5	13454.6	7.40
BARI Masur-6	54642.25	30.04
BARI Masur-7	8711.97	4.79
Binamasur-1	1893.27	1.04
Binamasur-2	1262.6	0.69
Binamasur-3	1322.81	0.73
Binamasur-4	0	0.00
Binamasur-5	3530.97	1.94
Binamasur-6	0	0.00
Binamasur-7	0	0.00
Binamasur-8	0	0.00
Binamasur-9	0	0.00

Source: Expert elicitation workshop, 2015.

3.3 Trends in varietal adoption

An attempt was made to assess the level of adoption in terms of percent of farmers adopted lentil variety at farm level. The level of adoption of lentil variety was mostly depended on the dissemination process used by BARI, BINA in association with the DAE. The finding of the EE workshop revealed that the farmers adopted lentil varieties such as BARI Masur-6, BARI Masur-4 and BARI Masur-3. BARI Masur-6 was highly adopted variety (30.04%) followed by BARI Masur-4 (23.41%), BARI Masur-3 (13.1%), BARI Masur-5 (7.4%), BARI Masur-7 (4.79%), Binamasur-5 (1.94%), BARI Masur-2 (1.87%), and BARI Masur-1 (1.7%) (Table-3.5). Others varieties such as Binamasur-1, Binamasur-2 and Binamasur-3 etc. occupied rest of the total lentil areas in Bangladesh (Table-3.5).

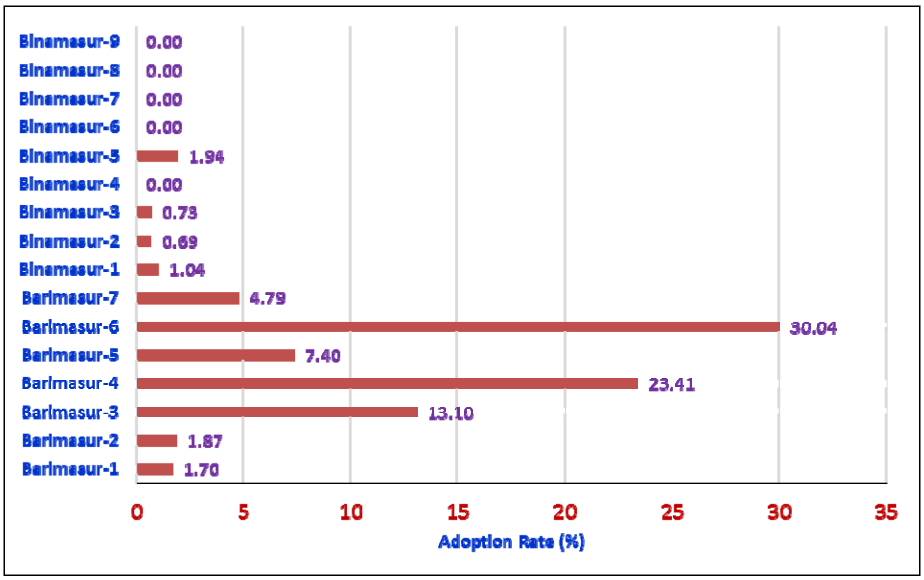

Fig. 1. Varietal Adoption of Lentil in Bangladesh

3.4 Adoption statistics seen in literature

There is no detail lentil varietal adoption study in Bangladesh. Matin *et al*. (2014) conducted a study regarding varietal adoption of lentil in some selected areas and found that BARI Masur-6 is the dominant variety followed by BARI Masur-3, BARI Masur-4, and BARI Masur-5 in the selected areas which covered 36.11%, 29.63%, 20.37% and 5.37% respectively of total lentil areas (Table-3.6). Some results supported and some results did not support with the percentage of adoption level mentioned by the expert. The difference might be due to variation in study location selection, source of information. As because there is no variety wise adoption level information of lentil at national level, so variety wise cultivation area coverage information is hard to collect. In this condition, researcher try to collect varietal adoption information from department of agricultural extension, local businessman of very specific locations.

Table 3.6. Adoption area and their difference with other sources

List top MV variety as identified in EE	% Area adopted under the variety (ha) by EE	% Area adopted under the variety (ha) as seen in literature/ national survey/ other source	% difference between the two
BARI Masur-1	1.70	-	-
BARI Masur-2	1.87	-	-
BARI Masur-3	13.10	29.63	-16.53
BARI Masur-4	23.41	20.37	3.04
BARI Masur-5	7.40	5.37	2.03
BARI Masur-6	30.04	36.11	-6.07
BARI Masur-7	4.79	1.30	3.49
Binamasur-1	1.04	-	-
Binamasur-2	0.69	-	-
Binamasur-3	0.73	-	-
Binamasur-4	0.00	-	-
Binamasur-5	1.94	-	-
Binamasur-6	0.00	-	-
Binamasur-7	0.00	-	-
Binamasur-8	0.00	-	-
Binamasur-9	0.00	-	-

Source: Expert elicitation workshop, 2015 & Matin *et al*. (2014).

3.5 Variety wise quantities of foundation seed

Seed production information is also not widely available from the sources. Seed production information for private seed producer is hard to collect compare to public seed producer organization. Seed production information of breeder seed was available from BADC only. In the year 2009-2013, the foundation seed production of BARI Masur-3 was highest in amount (897 mt) followed by BARI Masur-6 (640mt) and BARI Masur-5 (345 mt) (Table-3.7). The change in seed production over the period (2009-2013) showed that BARI Masur-3 increased sharply but BARI Masur-4 gradually decreased.

Table 3.7. Average seed production by the BADC seed producer over the period 2009-2013

Variety name	Produced foundation seed (2009-2013) Ton
BARI Masur-1	-
BARI Masur-2	-
BARI Masur-3	897
BARI Masur-4	256
BARI Masur-5	345
BARI Masur-6	640
BARI Masur-7	13
Binamasur-1	0
Binamasur-2	31.68
Binamasur-3	9.3
Binamasur-4	4.46
Binamasur-5	9
Binamasur-6	9

Source: BADC, 2015

3.6 Varieties attributes

Experts asked in the EE workshop that the farmers to give preference for cultivation existing varieties due to high yielder, disease resistant. The adoption of variety BARI Masur-6 increased due to its high yield attribute. The another variety BARI Masur-4 and BARI Masur-3 adoption increased due to its high yield, resistant to rust disease attributes.

In case of earlier popular varieties were gone out from the farmer's preferences due to best varieties available to the farmers, tolerance to disease, easy seed production and storage, rust disease resistance and change in consumption preferences.

4. Conclusion and Recommendation

Very valuable information about lentil was collected through the elicitation of 12 experts who had expertise of different discipline of pulse sector through involving in lentil research and extension at different corners of the country. On an average, the expert's age was 51 years, and had 21 years of experience on lentil research and extension.

The adoption rate information provided by experts revealed that 12 different varieties were cultivated on highest percentage of cultivation area. Among those cultivated varieties, finding of the EE workshop revealed that the farmers adopted lentil varieties such as BARI Masur-6, BARI Masur-4 and BARI Masur-3 etc. BARI Masur-6 was highly adopted variety (30.04%) followed by BARI Masur-4 (23.41%), BARI Masur-3 (13.1%), BARI Masur-5 (7.4%), BARI Masur-7 (4.79%), Binamasur-5 (1.94%), BARI Masur-2 (1.87%), and BARI Masur-1 (1.7%). Others varieties such as Binamasur-1, Binamasur-2 and Binamasur-3 etc. occupied rest of the total lentil areas in Bangladesh. A difference was found between the percentage of adoption area mentioned by the experts and percentage found in secondary source. The difference in adoption percentage might be due to different study year and also difference in study area location. Seed production information is not publicly available. In spite of that, the breeder seed information from BADC showed that BARI Masur-3 increased sharply but BARI Masur-4 gradually decreased.

The adoption of variety BARI Masur-6 increased due to its high yielder attribute. The another variety BARI Masur-4 and BARI Masur-3 adoption increased due to its high yield, resistant to rust disease attributes.

Variety developed by NARS with the support of ICARDA has a small share in adoption status. This indicated that there is a very wide scope to give more emphasis on varietal improvement of lentil by NARS. To ensure nutrition security in the country, it is very important to encourage and support the farmers to grow more lentil through providing improved cultivation technology to the farmers.

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MOLECULAR DIVERSITY STUDY IN ADVANCED EARLY MATURING LINES OF RICE USING RAPD TECHNIQUE

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Undoubtedly rice (*Oryza sativa* L.) is the staple food for peoples of many countries. Bangladesh is the fourth largest producer and consumer of rice in the world with annual production about 32 million tones (Anonymous 2014). The global demand of rice will be 880 million tons which is 70% more than present production in 2025 (IRRI 2010). But production is not increasing accordingly and agricultural lands are decreasing gradually due to intensive and unplanned urbanization. Hence, it is of prime importance for developing short duration and high yielding rice varieties for increasing the cropping intensity purposefully. The knowledge of genetic variability in a given crop species for the characters need to be improvement is important for the success of any plant breeding programme (Bisne et al. 2009). PCR based markers may be used to identify and assess the genetic diversity and phylogenetic relationships in plant genetic resources. Among them RAPD technique is comparatively reliable, faster and easier for exploiting genetic polymorphism within and among species and populations (Shivapriya and Hitalmani 2006). Advantages associated with RAPDs have made them a favorite marker technique in mapping, the determination of phylogenetic relationships, genetic diversity, and identification of cultivars and parents in a number of plant species. RAPD techniques have been successfully used in rice (Rajani et al. 2013; Rahman et al. 2007; Shivapriya and Hitalmani 2006). Thus the present investigation was conducted in order to study the performance of yield and yield contributing characters in early maturing rice genotypes and to determine the variations and also the inherent relationship among the individuals using RAPD marker most successfully.

The youngest healthy leaf samples were collected from the 15-days old seedlings of the rice genotypes. Modified CTAB mini-prep method was followed to extract DNA from leaf samples (Rahman et al. 2007). The concentration of DNA in the samples was determined using a UV Spectrophotometer at 260nm. The quality of the DNA was verified by electrophoreses on a 0.8% agarose gel in TBE (Tris-boric acid-EDTA) buffer. RAPD amplification reactions were maintained essentially following William et al. (1990) with some modifications. The screening was done with fifteen arbitrary decamer primers (Bengalore Genei, India) using DNA from two cultivars. Three primers resulting scorable and reproducible bands were selected for subsequent RAPD analysis of rice

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germplasms (Table 1). PCR reactions were performed on each DNA sample in a 10 µl reaction mixture containing 1x PCR buffer (10 mM Tris HCl pH 8.5, 50mM KCl and 15 mM $MgCl_2$), 10 mM each dNTPs, 5 pmols primer, 2 U of Taq DNA polymerase (Bengalore Genei, India), 100 ng of genomic DNA and rest amount of sterile deionized water. DNA amplification was carried out in a DNA thermocycler (Biometra, Germany) as the following thermal profile: initial denaturation for 3 min at 94°C followed by 41 cycles of 1 min denaturation at 94°C, 1 min annealing at 35°C and extension at 72°C for 2 min. A final extension step at 72°C for 7 min was allowed for complete extension of all amplified fragments. The PCR products were kept at 4°C until electrophoresis. Reaction mixtures were mixed with 2.0 µl 6X loading dye. Amplified fragments were separated on a 1.5% agarose (Bengalore Genei, India) gel in 0.5 X TBE buffer along with 20 bp DNA weight marker (Bengalore Genei, India) for 2 hours at 100V. Gel was stained with Ethidium bromide solution (0.1 µg ml^{-1}) for 15 min. Finally fragments were visualized under UV-transilluminator and photographed by Gel Documentation System (Biometra, Germany). The amplified bands were visually scored as present (1) and absent (0) separately for each individual and each primer. The scores obtained were pooled to create a single data matrix, which was used to estimate polymorphic loci, Nei's (1972), genetic diversity, genetic distance and a UPGMA (Unweighted Pair Group Method with Arithmetic Means) dendrogram using a computer program, POPGENE (Version 1.31) (Yeh et al. 1999).

Fifteen primers were initially screened on four genotypes for their ability to produce polymorphic patterns and four primers viz. OPB01, OPB02, OPC01 and OPC05 which gave reproducible and distinct polymorphic amplified products were selected. A total of 36 RAPD bands were scored of which 31 (86.24%) polymorphic amplification products were obtained by using these arbitrary primers. The size of the amplification size ranged from 100-2072 bp (Table 1). The selected four primers produced comparatively the maximum number of high intensity band with minimal smearing, good technical resolution and sufficient variation among different cultivars. The dissimilar numbers of bands were generated by primer OPB01, OPB02, OPC01 and OPC05.

Table 1. RAPD primers with corresponding bands score and their size range together with polymorphic bands observed in four rice genotypes

Primer code	Sequences (5′-3′)	Number of bands scored	Size ranged (bp)	Number of polymorphic bands	Polymorphic loci (%)
OPB01	GTTTCGCTCC	10	100-2072	10	100.00
OPB02	TGCCGAGCTG	9	100-2072	8	88.89
OPC01	TTCGAGCCAG	11	100-2072	8	72.73
OPC05	GATGACCGCC	6	100-2072	5	83.33
Total		36		31	344.95
Average		9.0		7.75	86.24

Besides, the primer OPB01 amplified the maximum number of polymorphic bands (100%) while the primer OPC01 generated the least (72.73%) polymorphic bands which were minimal in number. The banding patterns of four genotypes using primers OPB02 and OPC05 are shown in Figs. 1, and 2, respectively.

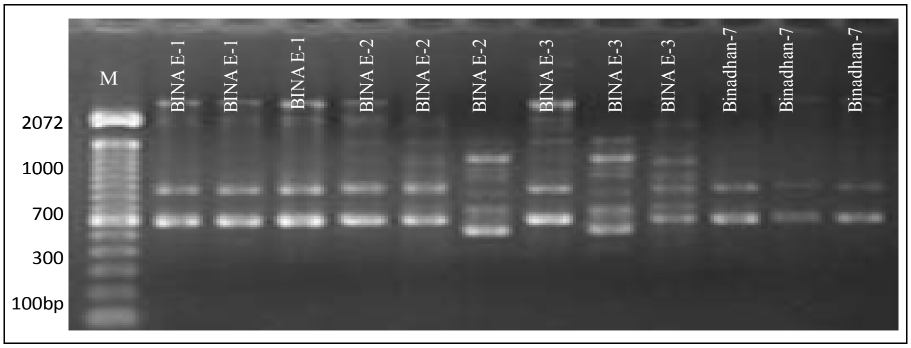

Fig. 2. RAPD profiles of different rice genotypes using primer OPB02. (M): 100 bp ladder

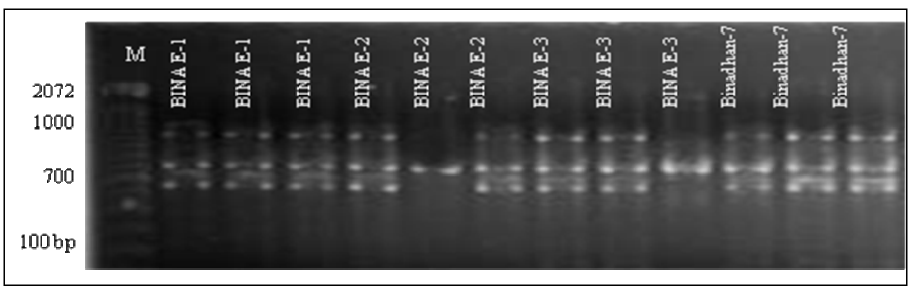

Fig. 4. RAPD profiles of different rice genotypes using primer OPC05. (M): 100 bp DNA ladder

Intra-genotype similarity indices (Si) were higher ranging from 51.07-94.48% with an average of 73.85% (Table 2). The highest and lowest intra-genotype similarity indices (S_i) value was found in Binadhan-7 and BINA E-3, respectively.

Table 2. Summary of the band sharing based on percentage similarity indices between individuals of four rice genotypes

Genotypes	Band sharing values (%)				
	OPB01	OPB02	OPC01	OPC05	Average
BINA E-1	100.00	92.58	83.33	100.00	93.98
BINA E-2	22.22	67.95	77.78	55.55	55.88
BINA E-3	28.79	57.69	51.14	66.67	51.07
Binadhan-7	94.87	100.00	90.47	92.58	94.48
Average	61.47	79.56	75.68	78.7	73.85

The highest proportion of polymorphic loci 75.00% was found in BINA-E-3 which gave 27 polymorphic bands and the lowest proportion of polymorphic loci 11.11% was found in BINA E-1 and Binadhan-7 had four polymorphic bands (Table 3). BINA-E-3 showed the higher level of gene diversity 0.3032 than other genotypes. Gene diversity across all genotypes for all loci was 0.6826. Binadhan-7 showed the lowest 0.0438 gene diversity. Shannon’s Information index (I) of all rice genotypes was 0.9932. BINA E-3 and Binadhan-7 showed the highest and lowest ‘I’ value which were 0.4427 and 0.0643, respectively (Table 10). Since BINA E-3 exhibited higher percentage of polymorphic loci, gene diversity and Shannon’s Information index suggested higher polymorphism.

Table 3. Estimates of genetic variation, Percentage of polymorphic loci. Nei’s gene diversity and Shannon’s Information index (I) obtained from studied four rice genotypes

Genotypes	No. of polymorphic loci	Proportion of polymorphic loci (%)	Gene diversity	Shannon’s nformation index (I)
BINA E-1	4	11.11	0.0542	0.0757
BINA E-2	25	69.44	0.2814	0.4105
BINA E-3	27	75.00	0.3032	0.4427
Binadhan-7	4	11.11	0.0438	0.0643
Total	60		0.6826	0.9932

The values of pair-wise comparisons of Nei's (1972) genetic distance among four rice genotypes were computed from combined data sets for the four primers ranging from 0.0554 to 0.9461 (Table 4). Comparatively higher genetic distance was found between BINA E-2 and BINA E-3. The lowest genetic distance was revealed between BINA E-3 and BINA E-2.

Table 4. Summary of Nei’s (1972) genetic distance (below diagonal) values among studied four rice genotypes

Genotypes	BINA E-1	BINA E-2	BINA E-3	Binadhan-7
BINA E-1	****	0.7172	0.7879	0.8993
BINA E-2	0.3324	****	0.9461	0.6602
BINA E-3	0.2383	0.0554	****	0.7498
Binadhan-7	0.1062	0.4152	0.2880	****

A dendrogram was constructed based on Nei's (1972) genetic distance following the Unweighted Pair Group Method of Arithmetic Means (UPGMA). The four genotypes of rice were grouped into two main clusters (Fig 3). Genotypes BINA E-1 and Binadhan-7 were included in the first cluster while BINA E-2 and BINA E-3 genotypes in the second cluster. Genetic relationship was present between two clusters. Rana et al. (2007) observed similar clustering for the combined data of RAPD and STMS revealed two broad clusters.

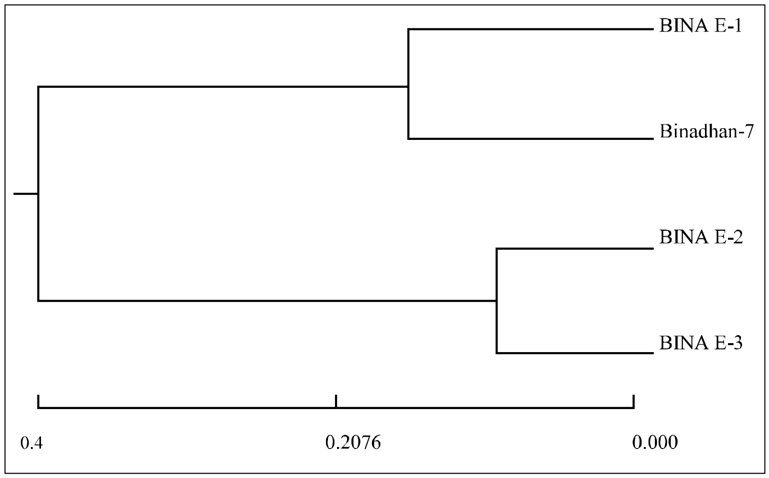

Fig. 3. UPGMA dendrogram based on Nei's (1972) genetic distance summarizing the data on differentiation between 4 rice genotypes, according to RAPD analysis

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