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EVALUATION OF PUMPKIN (*Cucurbita moschata* Duch. Ex Poir.) FOR YIELD AND OTHER CHARACTERS*

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Abstract

Nineteen inbreds of pumpkin (*Cucurbita moschata* Duch. Ex Poir.) were evaluated at the experimental farm of Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur during the *rabi* season of 2011-12 to select the promising inbreds for higher fruit yield along with other important characters. Thirteen quantitative and three qualitative characters along with fruit fly infestation and virus incidence were studied. The inbreds differed significantly in most of the quantitative characters. All the qualitative characters (fruit shape, fruit skin colour and flesh colour) showed distinct variation among the inbreds. All the inbreds except PK05, PK16, PK17 and PK18 were attacked with Water Melon Virus 2 (WMV2). Fruits of all the lines were more or less infested by fruit fly. The study revealed that the inbreds differing significantly in most of the parameters offer a good scope of selection of better inbreds for desired traits. The flesh thickness, average fruit weight, fruits per plant ranged from 2.61 to 5.39 cm, 1.41 to 5.78 kg and 2.96 to 7.58 respectively. On the basis of yield and other yield attributes nine inbreds viz., PK01, PK02, PK03, PK06, PK07, PK08, PK09, PK10 and PK16 were found promising. These inbreds will be helpful in breeding program to evolve high yielding varieties of pumpkin with better quality.

Keywords: Pumpkin, *Cucurbita moschata*, inbreds, selection, fruit yield.

Introduction

Pumpkin (*Cucurbita moschata* Duch. Ex Poir.) is one of the major cucurbitaceous fruit vegetables grown all over Bangladesh. The crop is variously known as ‘Misti kumra’ or ‘Misti lau’ or ‘Misti kadu’ in different parts of Bangladesh and is consumed by most of the people of the country. Its fruits are extensively used as vegetables both in immature and mature stage. The yellow and orange flesh fruits are very rich in carotene which is the precursor of Vitamin A with Vitamins B and C, and it is particularly important for the supply of antioxidants and especially carotenoids in foods (Gupta and Rai, 1990). It is very popular among the farmers

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* a part of PhD dissertation of the first author.

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owing to its good taste, high nutritive value, good storability and long time of availability and better transport potentialities (Hazra *et al*., 2007; Rashid, 1999). For these reasons its demand is increasing day by day in the country. Pumpkin grows both in *rabi* and *kharif* seasons in Bangladesh. About 14% (8% in *rabi* and 6% in *kharif* seasons) of the total vegetable production comes from pumpkin (BBS, 2013). It ranks 3rd in respect of both area and production next to brinjal and radish. In Bangladesh, it occupies an area 27,500 ha with an annual production of 2,18,000 tons accounting to an average yield of 7.93 t/ha (BBS, 2013) that is miserably low compared to that of other countries like India, China, Iran, Egypt, Australia, etc. It is assumed that more than 20 t/ha yield of pumpkin is satisfactory (Rashid, 1999). There are many factors responsible for this low yield of pumpkin. Among them, lack of high yielding varieties of pumpkin appears to be the most vital factor. Though a fairly common crop, to-date there are a few recommended varieties in Bangladesh. It is required sufficient number of high yielding varieties (HYVs) to meet the ever increasing demand of the farmers and the nutritional requirement of people. This can be achieved through massive breeding programs. The success of any crop improvement depends on the amount of genetic variability present in the population. Pumpkin genotypes grown in different parts of Bangladesh have enormous variability among them. There are number of local cultivars/land races with wide range of variability in size, shape and colour of fruits available in Bangladesh (Rashid, 1993; Kamaluddin, 1996). Many scientists reported significant variations present in pumpkin genotypes (Ahmed *et al.,* 2011; Akter *et al*., 2013; Aruah *et al*., 2012). In order to develop HYVs of Pumpkin the Olericulture Division, HRC, BARI collected a good number of pumpkin germplasm and developed 19 inbreds. Genotypes available in the population do not have uniformity, and thus 19 inbreds have also variability among them. Since there exists a considerable variability in this crop, it is possible to develop HYVs through breeding approaches like selection or hybridization. The present investigation was therefore, conducted to select the promising pumpkin inbred (s) in respect of yield and other important characters with a view to developing high yielding variety (ies) through hybridization.

Materials and Method

The experiment was carried out at the experimental farm of Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) Gazipur, Bangladesh during October 2011 to May 2012. Nineteen pumpkin inbreds (PK01, PK02, PK03, PK04, PK05, PK06, PK07, PK08, PK09, PK10, PK11, PK12, PK13, PK14, PK15, PK16, PK17, PK18 and PK19) were used in this study. The inbreds were collected from the Olericulture Division, HRC, BARI. The experiment was laid out in a Randomized Complete Block Design with three replications. The land was first opened by mould board plough. Three times harrowing were applied to pulverize the soil followed by laddering to have a good tilth. All types of weeds and debris of the previous crop (spinach) were removed. The unit plot size was 2 m × 10 m and the plots were raised by 10 cm from the ground level. Five pits of 50 cm × 50 cm × 30 cm size were prepared in each plot at a spacing of 2 m plant to plant by keeping 60 cm width drain between the plots. About 25 cm deep drain was dug around the plot. Seeds were sown in 9 cm diameter polyethylene bags. The growth medium was prepared by mixing compost and soil in 50: 50 proportion. Intensive care was taken for healthy seedling production. Twenty five days old seedlings were transplanted in well prepared experimental plot. The seedlings were watered immediately after transplanting. Fertilizers were applied @ 5000-78-35-75-18-4.3-2 kg/ha of cowdung-N-P-K-S-Zn-B. The sources of N, P, K, S, Zn and B were urea, TSP, MoP, gypsum, zinc sulphate and boric acid (medicated) respectively (Anon, 2012). The entire amount of cowdung, P, S, Zn, B and 1/3rd K were applied during pit preparation as basal dose before 10 days of transplanting. The rest amount of K was applied in two equal installments at 20 and 35 days after transplanting (DAT). N was applied in four equal installments at 7, 20, 35 and 50 DAT.

Necessary intercultural operations such as irrigation, weeding, mulching pits etc were done during the crop period for proper growth and development of the plants. Control measure was taken against red pumpkin betel by spraying Ripcord @ 1ml/liter of water over seeding once per week for 2 times. At fruiting stage, sex pheromone traps and meshed sweet gourd traps were set up in a density of $5m^2$/trap to control the infestation of fruit fly. The fruits were harvested when the fruit stalk dried and shrivelled. Data were collected from five mature fruits from all the plants of inbreds. Data on different characters were recorded based on the descriptors for pumpkin developed by the International Board of Plant Genetic Resources (IBPGR). The recorded data for different characters were analyzed using software Statistic 10 and means were separated by DMRT at 1 % level of probability.

Results and Discussion

Results pertaining to different characters under study are furnished below:

Days to first male flower

Significant variation was observed among the inbreds for days to first male flower of pumpkin (Table 1). Days to first male flower ranged from 64.50 to 80.63 days. The maximum days to first male flower was recorded in PK01 (80.63) closely followed by PK11 (78.08), PK19 (77.00), PK16 (77.00) and PK17 (77.00) and the lowest days to first male flower were found in PK08 (64.50). Rasul and Raihan (2014) also reported to have significant variation for days to first male flower in different pumpkin genotypes which ranged from 72 to 86.

Days to first female flower

Days to first female flower ranged from 77.25 to 88.50 days (Table 1). The maximum days to first female flower was observed in PK01 (88.50) which was statistically similar to PK04 (87.42), PK05 (87.28), PK19 (86.50), PK03 (85.75), PK16 (85.25), PK01 (84.25) and PK14 (83.75). The minimum days to first female flower was observed in PK12 (77.25) which was identical with PK13 (79.25), PK09 (79.50), PK10 (79.50), PK08 (80.00), PK07 (81.75) and PK06 (82.00). Akter *et al*. (2011) reported significant variation for days to first female flower in nine pumpkin genotypes which ranged from 86 to 92.

Node number of first male flower

Significant variation was noticed in node number of first male flower and it ranged from 5.08 to 8.63 (Table 1). The highest node number of first male flower was recorded in PK10 (8.63) which was statistically similar with all other inbreds except PK02, PK04, PK08, PK13 and PK17. The lowest node number of first male flower was recorded in PK04 (5.08). Mohanty and Mishra (2002) evaluated eight diverse genotypes of pumpkin and found that node number of first male flower showed significant difference, which ranged from 5 to 9 and Akter *et al.* (2011) reported node number of first male flower varied from 6 to 11.

Table 1. Performance of 19 pumpkin inbreds for different reproductive characters

Inbreds	Days to 1st male flower	Days to 1st female flower	Node number of 1st male flower	Node number of 1st female flower
PK 01	80.63 a	88.50 a	7.00 ab	20.25 a-c
PK 02	73.25 c-g	83.00 b-e	5.50 b	17.25 c
PK 03	76.38 b-d	85.75 a-c	6.13 ab	19.13 a-c
PK 04	70.13 fg	87.42 ab	5.08 b	19.29 a-c
PK 05	76.50 b-d	87.28 ab	6.40 ab	22.13 a
PK 06	71.13 e-g	82.00 c-f	6.38 ab	20.38 a-c
PK 07	70.13 fg	81.75 c-f	7.88 ab	21.50 ab
PK 08	64.50 h	80.00 d-f	5.13 b	19.75 a-c
PK 09	70.00 fg	79.50 d-f	7.38 ab	20.13 a-c
PK 10	69.50 g	79.50 d-f	8.63 a	18.88 a-c
PK 11	78.08 ab	83.69 b-e	7.21 ab	18.73 a-c
PK 12	69.25 g	77.25 f	6.63 ab	18.00 bc
PK 13	72.55 d-g	79.25 ef	5.63 b	19.93 a-c
PK 14	74.88 b-e	83.75 a-e	7.13 ab	18.88 a-c
PK 15	75.13 b-e	83.63 b-e	7.00 ab	19.13 a-c
PK 16	77.00 a-c	85.25 a-c	7.75 ab	18.13 bc
PK 17	77.00 a-c	84.25 a-d	5.63 b	17.75 c
PK 18	75.88 b-d	83.48 b-e	7.50 ab	18.75 a-c
PK 19	77.00 a-c	86.50 a-c	5.88 ab	20.50 a-c
Range	64.50 - 80.63	77.25 – 88.50	5.08 – 8.63	17.25 – 22.13
CV (%)	4.01	3.89	11.54	8.93

Means with uncommon letter(s) differ significantly by DMRT at 1% level

Node number of first female flower

Statistically significant variation was observed in pumpkin inbreds in respect of node number of first female flower which ranged from 17.25 to 22.13 (Table 1). The maximum node number of first female flower was found in PK05 (22.13) which was statistically similar with the other inbreds except PK02, PK12, PK 16 and PK17 while the lowest node number of first female flower was recorded in PK02 (17.25). Mohanty and Mishra (2002) evaluated eight diverse genotypes of pumpkin and reported that node number of first female flower showed significant variation ranging from 15 to 26.

Fruit length (cm)

Fruit length differed significantly and ranged from 9.73 to 38.65 cm (Table 2). The highest fruit length was found in PK02 (38.65 cm) while the lowest fruit length was found in PK17 (9.73 cm) which was statistically similar with PK08 (13.54 cm) and PK09 (12.13 cm). Rouf *et al*. (2011) observed significant variation for fruit length in pumpkin which ranged from 10.50 to 24.60 cm.

Fruit diameter (cm)

Marked variation was observed among the inbreds with regard to fruit diameter (Table 2). It ranged from 14.04 to 25.44 cm. The maximum fruit diameter was observed in PK03 (25.44 cm) which was closely followed by PK13 (24.37 cm), PK11 (24.12 cm) and PK07 (24.01 cm) and the minimum fruit diameter was observed in PK02 (14.04 cm) which was identical with PK17 (15.99 cm) and PK01 (16.25 cm). This variation might be due to the inherent genotypic variability of different inbreds used in this study. Rouf *et al*. (2011) observed significant variation for fruit diameter in pumpkin ranging from 8.50 to 28.30 cm.

Cavity length (cm)

Significant variation was observed among the inbreds of pumpkin regarding cavity length (Table 2). The highest cavity length was recorded in PK02 (30.33 cm) and the lowest cavity length in PK17 (4.75 cm) which was statistically similar to PK08 (7.25 cm), PK19 (7.42 cm), PK04 (7.53 cm), PK15 (7.63 cm), PK11 (8.08 cm), PK12 (8.35 cm), PK01 (8.69 cm) and PK03 (8.71 cm).

Cavity width (cm)

Significant variation among the inbreds was observed for this trait (Table 2). The maximum cavity width was obtained from PK11 (15.27 cm) and PK12 (15.28 cm) closely followed by the other inbreds except PK01, PK05, PK09, PK14 and PK16. The lowest cavity width was obtained from PK01 (9.84 cm).

Table 2. Performance of 19 pumpkin inbreds for different fruit characters

Inbreds	Fruit length (cm)	Fruit diameter (cm)	Cavity length (cm)	Cavity width (cm)	TSS (%)
PK01	16.19 f-h	16.25 g-i	8.69 d-i	9.84 cd	9.29 b-d
PK02	38.65 a	14.04 i	30.33 a	14.00 ab	8.13 d-f
PK03	20.24 b-e	25.44 a	8.71 d-i	14.00 ab	8.42 d-f
PK04	15.51 f-h	20.35 de	7.53 f-i	12.26 a-c	8.21 d-f
PK05	15.89 f-h	18.94 d-f	9.73 d-h	11.47 bc	7.88 ef
PK06	21.21 bc	20.14 de	12.71 b-d	12.35 a-c	7.38 f
PK07	20.42 b-d	24.01 ab	12.06 b-e	13.66 ab	8.31 d-f
PK08	13.54 g-i	20.08 de	7.25 g-i	12.50 a-c	9.96 a-c
PK09	12.13 h-i	17.60 f-h	6.14 hi	11.52 bc	8.48 d-f
PK10	19.44 c-f	20.37 de	11.49 c-g	11.86 a-c	9.13 c-e
PK11	14.89 gh	24.12 ab	8.08 e-i	15.27 a	8.19 d-f
PK12	15.81 f-h	23.00 bc	8.35 d-i	15.28 a	10.60 ab
PK13	16.93 d-g	24.37 ab	9.49 d-h	14.07 ab	9.17 c-e
PK14	20.38 b-d	19.50 d-f	11.75 c-f	11.34 bc	10.75 a
PK15	14.26 gh	18.42 e-g	7.63 f-i	12.65 a-c	8.50 d-f
PK16	24.28 b	18.34 e-h	16.19 b	10.61 c	8.06 d-f
PK17	9.73 i	15.99 hi	4.75 i	11.76 a-c	8.65 c-f
PK18	24.19 b	18.00 e-h	14.54 bc	11.76 a-c	8.32 d-f
PK19	15.00 gh	21.33 cd	7.42 f-i	14.09 ab	10.00 a-c
Range	9.73 - 38.65	14.04 - 25.44	4.75 - 30.33	9.84 -15.28	7.38 -10.75
CV (%)	10.78	5.75	16.53	11.02	7.56

Means with uncommon letter(s) differ significantly by DMRT at 1% level.

TSS (%)

Significant differences were observed in TSS (%) of pumpkin inbreds (Table 2). The TSS ranged from 7.38 to 10.75%. The maximum TSS were found in PK14 (10.75%) which was statistically similar to PK12 (10.60%), PK19 (10.00%) and PK08 (9.96%). The lowest TSS was found in PK06 (7.38%) which was identical with PK05 (7.88%), PK16 (8.06%), PK02 (8.13%), PK11 (8.19%), PK04 (8.21%), PK07 (8.31%), PK18 (8.32%), PK03 (8.42%), PK17 (8.65%), PK09 (8.48%) and PK15 (8.50%). Islam *et al*. (2010) reported that TSS ranged from 6 to 12% in pumpkin genotypes. Rouf *et al*. (2011) also found TSS in pumpkin varied from 6.10 to 9.10% which supports the present findings.

Flesh thickness (cm)

The flesh thickness of pumpkin differed significantly among the inbreds (Table 3). The highest flesh thickness was recorded in PK03 (5.39 cm) and the lowest flesh thickness was in PK09 (2.61 cm) which was statistically similar to PK18 (2.95 cm), PK08 (2.96 cm), PK17 (3.06 cm), PK16 (3.11 cm), PK01 (3.13 cm), PK15 (3.19 cm) and PK19 (3.21 cm). In the present study, flesh thickness ranged from 2.61 to 5.39 cm, which is in agreement with the findings of Pandey *et al*. (2003).

Average fruit weight (kg)

Significant difference was observed in pumpkin inbreds in respect of average fruit weight ranged from 1.41 to 5.78 kg (Table 3). The maximum average fruit weight was recorded in PK03 (5.78 kg) closely followed by PK07 (4.86 kg) and the minimum average fruit weight in PK17 (1.41 kg) which was statistically similar to PK09 (1.88 kg), PK01 (2.27 kg) and PK15 (2.33 kg). Fruit weight differed from one another might be due to inherent character of the inbreds. Ahmed *et al*. (2011) reported significant variation present in average fruit weight and it ranged from 1.51 to 4.20 kg. Pandey *et al*. (2003) obtained that the average fruit weight of pumpkin in the range of 1.33 to 9.10 kg.

Number of fruits per plant

The inbreds varied significantly for this parameter (Table 3). Number of fruits per plant ranged from 2.96 to 7.58. The highest number of fruits per plant was observed in PK09 (7.58) while the lowest number of fruits per plant was found in PK14 (2.96) closely followed by the other inbreds except PK01 (5.38), PK02 (5.13), PK09 (7.58) and PK16 (5.13). Ahmed *et al*. (2011) reported significant differences in fruit per plant in different pumpkin genotypes and the highest number of fruits per plant (15.74) was observed in one genotype. Akter *et al*. (2013) found fruits per plant ranging from 1.52 to 4.60.

Fruit yield per plant (kg)

The pumpkin inbreds exhibited a significant variation with regard to fruit yield per plant (Table 3). The fruit yield per plant ranged from 4.84 to 22.45 kg. The maximum yield per plant was recorded in PK07 (22.45 kg) closely followed by PK03 (19.75 kg), PK02 (19.17 kg), PK16 (18.77 kg), PK13 (18.53 kg), PK06 (17.35 kg) and PK04 (15.79 kg) and the lowest yield per plant was obtained from PK17 (4.84 kg) which was identical with PK15 (7.62 kg), PK14 (10.23 kg) and PK08 (10.65 kg). Ahmed *et al*. (2011) obtained significant variation in yield per plant in different pumpkin genotypes in the range of 5.94 to 36.12 kg.

Table 3. Performance of 19 pumpkin inbreds for fruit yield and other characters

Inbreds	Flesh thickness (cm)	Average fruit weight (kg)	Number of fruits per plant	Fruit yield per plant (kg)
PK 01	3.13 e-g	2.27 g-i	5.38 b	12.07 c-f
PK 02	3.49 c-f	3.73 cd	5.13 bc	19.17 ab
PK 03	5.39 a	5.78 a	3.42 d	19.75 ab
PK 04	3.78 b-d	3.29 d-g	4.75 b-d	15.79 a-e
PK 05	3.47 c-f	2.64 f-g	4.68 b-d	12.35 c-f
PK 06	3.62 b-e	3.68 c-e	4.79 b-d	17.35 a-d
PK 07	3.92 bc	4.86 ab	4.63 b-d	22.45 a
PK 08	2.96 fg	2.68 e-h	3.83 b-d	10.65 d-g
PK 09	2.61 g	1.88 hi	7.58 a	14.27 b-f
PK 10	3.93 bc	3.61 d-f	4.25 b-d	15.39 b-e
PK 11	3.58 b-e	3.65 c-f	3.71 cd	13.54 b-f
PK 12	3.77 b-d	3.73 cd	3.79 b-d	14.40 b-f
PK 13	4.20 b	4.65 bc	4.04 b-d	18.53 a-c
PK 14	3.82 bc	3.15 d-g	2.96 d	10.23 e-g
PK 15	3.19 d-g	2.33 g-i	3.25 d	7.62 fg
PK 16	3.11 e-g	3.67 c-f	5.13 bc	18.77 a-c
PK 17	3.06 e-g	1.41 i	3.50 d	4.84 g
PK 18	2.95 fg	3.07 d-g	4.38 b-d	13.39 b-f
PK 19	3.21 d-g	3.50 d-f	4.25 b-d	15.08 b-e
Range	2.61 - 5.39	1.41 - 5.78	2.96 - 7.58	4.84 - 22.45
CV (%)	8.13	14.60	16.46	12.36

Means with uncommon letter(s) differ significantly by DMRT at 1% level.

Qualitative characters

Remarkable variation in different qualitative characters of 19 pumpkin inbreds was observed (Table 4). Seven different fruit shapes were recorded of which flat shape (6 inbreds) was dominant over others. Flesh color was categorized as yellow, light yellow, orange and deep orange. Ten inbreds were orange in color and the rest of them were yellow, light yellow and deep orange. Wide range of variability was observed in fruit skin color at mature stage. Fruit skin colour was found as brown, deep brown, brown with green patches, deep brown with green patches and spotted. Spotted and brown with green patches are dominant over other colored types.

Table 4. Performance of 19 pumpkin inbreds for qualitative characters

Inbred lines	Fruit shape	Fruit skin color	Flesh color
PK 01	G	B	O
PK 02	E	DB + G patches	LY
PK 03	R	Spotted	Y
PK 04	HF	DB	O
PK 05	F	Spotted	O
PK 06	D	DB	LY
PK 07	HF	DB	O
PK 08	F	Spotted	O
PK 09	F	Spotted	O
PK 10	G	DB	Y
PK 11	F	Spotted	DO
PK 12	F	Spotted	DO
PK 13	HF	B + G patches	DO
PK 14	HF	Spotted	O
PK 15	HF	B + G patches	O
PK 16	Oval	DB + G patches	O
PK 17	F	B + G patches	Y
PK 18	Oval	Spotted	Y
PK 19	HF	DB + G patches	O

G = Globular, E = Elliptical, F = Flat, HF = High Flat, D = Dumble, R = Round, B = Brown, DB = Deep brown, B + G patches = Brown with green patches, DB + G patches = Deep brown with green patches, O = Orange, DO = Deep orange, Y = Yellow, LY = Light yellow

Disease and insect reaction

Fruit fly infestation

All the inbreds were found to be infested by cucurbit fruit fly (*Bactrocera cucurbitae*). As control measure was taken earlier, the infestation rate was found very low. Fruit fly infestation varied significantly for different inbred and ranged from 0.12 to 0.77% (Table 5). The highest fruit fly infestation was recorded in PK05 (0.77 %), while the lowest fruit fly infestation was recorded in PK04 (0.12 %) which was statistically similar to PK11 (0.16 %), PK18 (0.17 %) and PK16 (0.19 %).

Virus incidence (%)

All the tested inbreds were found to be infested by Water Melon Virus 2 (WMV2). Among the inbreds significant differences was found in respect of virus incidence ranging from 0.0 to 100% (Table 5). The highest virus incidence was recorded in PK06 (75 %) while virus incidence was not found in four inbreds viz., PK05, PK16, PK17 and PK18. This result could be more conclusive if it was conducted under epiphytic condition with optimum inoculum pressure. However, this preliminary information could be helpful to the breeder during parent selection for hybridization program.

Table 5. Fruit fly infestation and virus incidence in 19 pumpkin inbreds

Inbreds	[1]Fruit fly infestation (%)	[2]Virus incidence (%)
PK 01	0.34 de (3.34)	14.5 f (3.87)
PK 02	0.29 d-g (3.09)	34.0 d (5.87)
PK 03	0.53 b (4.17)	8.8 g (3.05)
PK 04	0.12 j (1.98)	36.5 d (6.08)
PK 05	0.77 a (5.03)	0.0 h (0.71)
PK 06	0.25 f-h (2.86)	75.0 a (8.69)
PK 07	0.33 d-f (3.29)	12.5 fg (3.60)
PK 08	0.23 g-i (2.75)	50.0 c (7.11)
PK 09	0.45 c (3.84)	17.8 f (4.28)
PK 10	0.34 de (3.34)	8.3 g (2.97)
PK 11	0.16 ij (2.29)	34.0 d (5.87)
PK 12	0.36 d ((3.44)	25.5 e (5.05)
PK 13	0.51 bc (4.09)	58.5 b (7.65)
PK 14	0.29 d-g (3.09)	24.5 e (5.00)
PK 15	0.34 de (3.34)	25.3 e (5.08)
PK 16	0.19 h-j (2.50)	0.0 h (0.71)
PK 17	0.27 e-h (2.98)	0.0 h (0.71)
PK 18	0.17 ij (2.36)	0.0 h (0.71)
PK 19	0.24 g-i (2.81)	16.8 f (4.16)
Range	0.12 – 0.77	0.0 – 75
CV (%)	12.0	11.2

[1]Figures within the parenthesis are arcsin-transformed values

[2]Figures within the parenthesis are square root ($\sqrt{x} + 0.5$) transformed values

Conclusion

Based on the above discussion, it can be concluded that nine inbreds viz., PK01, PK02, PK03, PK06, PK07, PK08, PK09, PK10 and PK16 might be suitable for the development of high yielding pumpkin varieies with better quality through hybridization.

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EFFECT OF LEAF TRICHOMES AND METEOROLOGICAL PARAMETERS ON POPULATION DYNAMICS OF APHID AND JASSID IN COTTON

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Abstract

This study was conducted with CB1, CB3, CB5, CB8 and C12 cotton varieties to determine the role of leaf trichomes and meteorological factors on the abundances of aphid and jassid. The mean population of the pests on the tested varieties differed significantly and showed negative correlation with trichomes. The pests were most abundant on CB12, and each variety revealed significantly higher population of jassid than that of aphid. Both the pests built up their population in the juvenile stage of the plants (73 days after sowing) and continued until harvesting. Aphid population was the highest on CB12 in the first week of November, whereas maximum abundance of jassid was on CB12 in the third week of December. Weather parameters were found insignificant on aphid abundance, but jassid population on the varieties was correlated with maximum and minimum temperatures, relative humidity and rainfall. Multiple regression equation based on weather parameters exerted 8.8 - 43.2% and 54.4 - 77.7% role on population build up of aphid and jassid, respectively. Maximum temperature had the most important effect which contributed 61.2% population fluctuation of jassid on CB12.

Keywords: Abiotic factors, *Gossypiun hirsutum*, sucking insects.

Introduction

Twelve species of insects are reported causing damage to cotton, *Gossypium hirsutum* in Bangladesh. Of them aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae) and jassid, *Amrasca devastans* Distant (Hemiptera: Cicadellidae) are the most destructive, and cause damage throughout the season (Amin *et al.,* 2008; Amin *et al.,* 2009; Tithi *et al*., 2010; Azad *et al.,* 2011). Management of these sucking insects in Bangladesh is mostly relied on synthetic insecticides, which pollute the environment and threats to the abundance and diversity of predator and pollinator species (Azad *et al.,* 2010; Hossain *et al.,* 2013).

The aphid and jassid are sucking insects which ingest cell sap from leaves and developing bolls of cotton and transmit viral diseases. During feeding aphids

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secrete honeydew, which enhances sooty mold development, while jassids inject toxic substance, thus the pest retards photosynthesis, transportation of nutrients and water, and growth of the plants (Bi *et al*., 2001). The infested plants produce significantly lower amount of yield with degraded quality of fiber that creates problem in lint processing (Sharma and Singh, 2011). Bangladesh is a highly vulnerable country to climate change. The increasing temperature and CO_2 gases cause irremediable rainfall and drought that enhances pest problems and reduces the effectiveness of current pest management strategies (Amin *et al.,* 2013). Population fluctuations of herbivore insects throughout the cropping season depend on the amount and daily distribution of rainfall, relative humidity, temperature and sunshine (Jindal and Brar, 2005).

Different host plant species and varieties protect themselves from insect attack either with their chemical substances or morphological structures, which interrupt the life cycle, reproduction and population dynamics of the pests. Cotton varieties with higher densities of leaf trichomes exhibit resistance to insects (Bhat *et al.,* 1984). Cultivation of resistant variety ensures the plant to keep free from insect infestation and exerts higher yield without pest management expenditure (Nault *et al*., 2004). Information on cotton insect pests associated with the commercial varieties are inadequate in Bangladesh and the relevance of the results in relation to weather conditions is unknown, however, knowledge on varietal susceptibility or resistance, and population dynamics of the pest regarding weather parameters are fundamental components in forecasting model of an integrated pest management program. Considering the damage severity of aphid and jassid on cotton in Bangladesh, this study was designed to know the impact of weather parameters and leaf trichomes on the population dynamics of these two sucking insects on five commercially cultivated varieties.

Materials and Method

The study was conducted during July 2013 to January 2014 in the research field of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh. The eexperimental location (25°25′ North latitude and 89°5′ East longitude) is surrounded by Sal, *Shorea robusta* Gaertn forest and characterized by a well-defined dry season (February to May), wet season (June to September) and short winter (December and January).

The commercial cotton varieties CB1, CB3, CB5, CB8 and CB12 released by the Cotton Development Board of Bangladesh were cultivated for this study. The experimental design was randomized complete block with three replications. The plot size was 4.0m × 4.0m and the spacing between block to block and plot to plot was 1.0m and 1.0m, respectively. Seeds were sown on 2nd July 2013 in rows apart from 50 cm plant to plant and 1.0 m from row to row. All agronomic practices except pest control were adopted time to time to successfully raise the crops.

To observe the population abundance of aphid and jassid on the tested varieties, field inspection was done weekly from emergence of seedlings to first harvest of the seed cotton. For the counts of aphid and jassid population, three plants were randomly selected from each plot and tagged. The leaves of the plants were observed in such a way that one leaf of the upper part of the first plant, one leaf of the middle part of the second plant and one leaf of the bottom part of the third plant of each variety were taken into account. Both aphid and jassid built up their population in the second week of September (73 day after sowing, DAS) *i. e.,* at the blooming stage of the plants and data collection was started from 75 DAS. The population of aphid and jassid were counted with the help of a magnifying glass (FD75, Ballon Brand, China). Meteorological data related to temperature, relative humidity and rainfall were recorded from the adjoining meteorological observatory section of BSMRAU.

An analysis of variance (ANOVA) with Duncan's Multiple Range Test (DMRT) was applied to compare the population abundance of aphid and jassid on the cotton varieties. Comparison between aphid and jassid population on each variety was made with Student's T test. The Pearson's correlation was used to examine the relationship between trichome number and the pest population. The effects of weather parameters on the population abundance of aphid and jassid on the cotton varieties were determined by working out simple correlation. The combined effect of the maximum and minimum temperature, relative humidity and rainfall on the population abundance of the insects were measured by using a Multiple Linear Regression Equation. All the analyses were performed using IBM SPSS statistics 21.

Results and Discussion

A. Results

Mean abundance of aphid and jassid on the cotton varieties (Fig. 1) ranged from 4.3 ± 0.4 to 6.4 ± 0.7 and 7.3 ± 0.6 to 13.1 ± 1.1 leaf^{-1}, respectively and the results differed significantly (aphid: $F_{4, 250} = 2.9$, $p < 0.05$; jassid: $F_{4, 250} = 9.9$, $p < 0.001$). Among the tested varieties, CB12 revealed significantly higher number of aphid and jassid population compared to other varieties. T statistics demonstrated significantly higher abundance of jassid than aphid on each variety ($t_{50} = 4.7$, $p < 0.001$; $t_{50} = 5.7$, $p < 0.001$; $t_{50} = 4.8$, $p < 0.001$; $t_{50} = 3.2$, $p < 0.01$; $t_{50} = 4.9$, $p < 0.001$ for CB1, CB3, CB5, CB8 and CB12, respectively).

Number of trichomes on the midrib of the varieties showed significant negative correlation ($y = -0.050x + 7.607$, $r = 0.904$, $F_{1, 3} = 13.0$, $p < 0.05$) with aphid, and non-significant negative correlation ($y = -0.107x + 14.57$, $r = 0.684$, $F_{1, 3} = 2.6$, $p = 0.20$) with jassid population (Fig. 2).

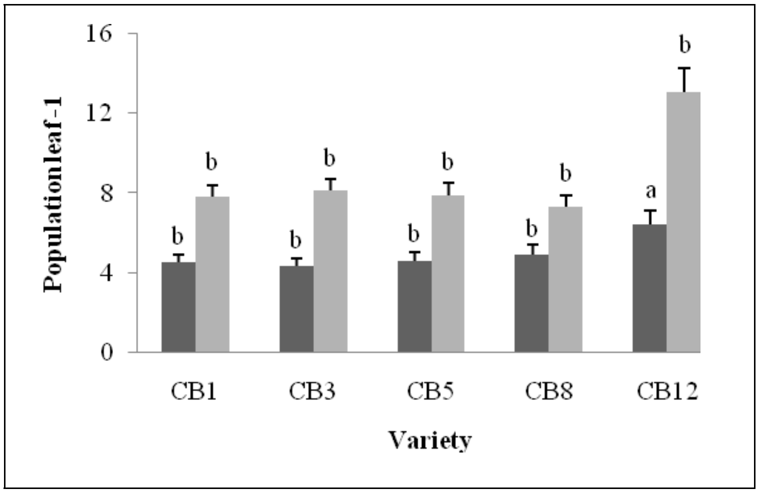

Fig. 1. Abundance (mean ± SE) of aphid (■) and jassid (□) population on five cotton varieties. Bars with same letter are not significantly different (DMRT, $p \leq 0.05$).

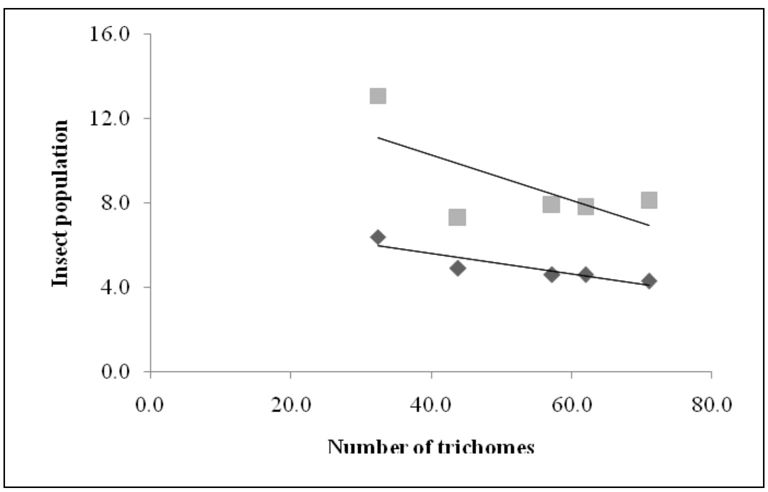

Fig. 2. Relationship between insect population (aphid ■ and jassid □) and number of trichomes on ventral midrib of the five cotton varieties.

Figure 3 showed the population abundance of aphid throughout the season on the tested varieties. An increased trend of population was observed in the first week of November on all the varieties and then declined. At that time, aphid population reached to the peak (17.0 leaf^{-1}) on CB12 followed by CB3, CB8, CB5 and CB1. Again aphid population increased rapidly in early December and reached the highest (15.0 leaf^{-1}) on CB12 followed by CB1, CB3, CB8 and CB5. After that, aphid population declined rapidly and again increased in early January and showed higher density (12.3 leaf^{-1}) on CB12 followed by CB8, CB1, CB5 and CB3.

Jassid population abundance throughout the season on the tested varieties showed fluctuations (Fig. 4). It increased in the second week of November and then declined. At that time, jassid showed the highest density (22.7 leaf^{-1}) on CB12 followed by CB8, CB5, CB1 and CB3. Jassid population increased rapidly and reached to the peak (26.3 leaf^{-1}) after second week of December on CB12. After this peak, its population declined rapidly and again increased in early January and showed higher density (19.7 leaf^{-1}) on CB12.

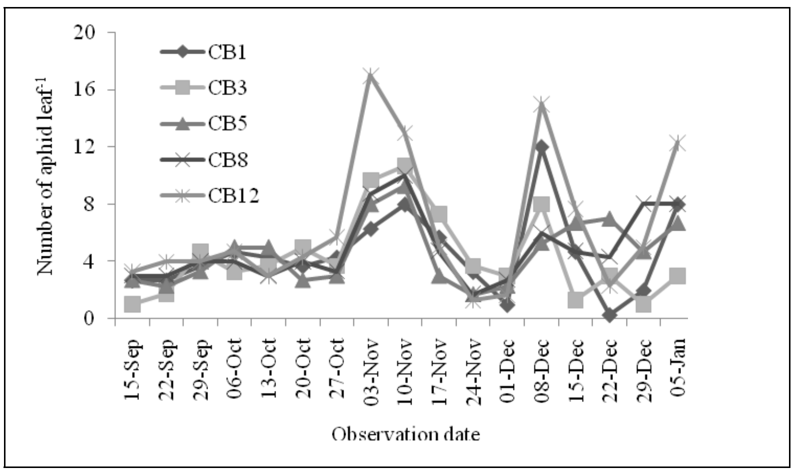

Fig. 3. Population build up of aphid on five cotton varieties.

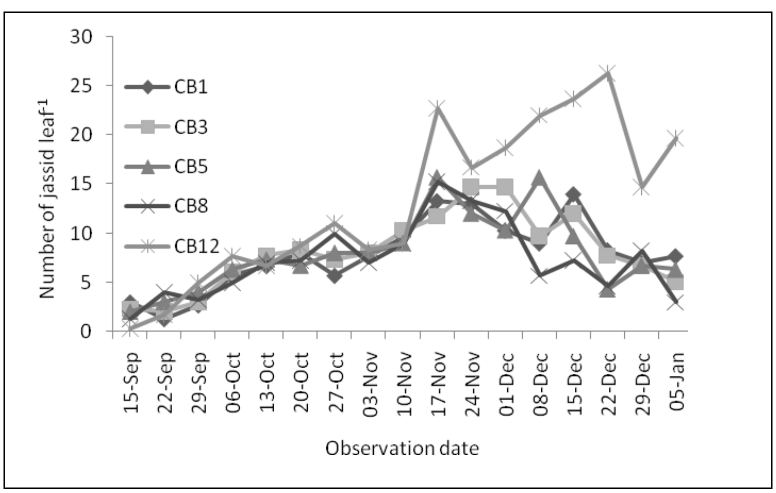

Fig. 4. Population build up of jassid on five cotton varieties.

The weather parameters indicated that in the middle of September when aphid and jassid population were first recorded, the maximum and minimum temperatures were 32.3 ^{o}C and 26.0 ^{o}C, respectively. At that time relative humidity was 85%, and there was no rainfall (Table 1). At the end of October when aphid population started rising, the maximum and minimum temperatures decreased (25.0 ^{o}C and 21.5 ^{o}C, respectively), the relative humidity slightly declined (77%), and there was little rainfall (1.1 mm). The peak of aphid population was recorded in the first week of November and at that time maximum and minimum temperatures, relative humidity were 30.0 ^{o}C, 21.0 ^{o}C and 84% respectively, and there was no rainfall.

Table 1. Data regarding meteorological observations on various weather parameters

Observation date	Temperature ^{o}C		%Relative humidity	Rainfall (mm)
	Maximum	Minimum		
15.09.13	32.3	26.0	85	0.0
22.09.13	33.5	27.5	76	0.0
29.09.13	32.0	26.0	85	1.6
06.10.13	30.0	25.0	92	12.9
13.10.13	34.0	29.0	77	0.0
20.10.13	32.0	26.0	92	0.0
27.10.13	25.0	21.5	77	1.1
03.11.13	30.0	21.0	84	0.0
10.11.13	30.8	16.0	84	0.0
17.11.13	29.0	14.0	73	0.0
24.11.13	28.2	13.5	68	0.0
01.12.13	29.0	15.0	75	0.0
08.12.13	24.0	14.0	75	0.0
15.12.13	24.0	11.5	73	0.0
22.12.13	25.0	13.0	90	0.0
29.12.13	25.0	11.0	89	0.0
05.01.14	22.0	11.0	90	0.0

Table 2. Correlation coefficient (r) values between aphid population on five cotton varieties and weather parameters

Variety	Temperature ^{o}C		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
CB1	- 0.266 NS	- 0.181 NS	- 0.105 NS	0.002 NS
CB3	0.118 NS	- 0.056 NS	- 0.051 NS	- 0.092 NS
CB5	- 0.308 NS	- 0.328 NS	0.344 NS	0.008 NS
CB8	- 0.313 NS	- 0.399 NS	0.401 NS	- 0.122 NS
CB12	- 0.319 NS	- 0.252 NS	0.109 NS	- 0.111 NS

NS, Non-significant ($p \leq 0.05$).

Table 3. Multiple linear regression models along with coefficients of determination (R^2) regarding the impact of weather parameters on the population of aphid throughout the season on five cotton varieties

Variety	Regression equation	R^2	100 R^2	Role of individual factor (%)	F statistic	
CB1	$Y = 10.371 - 0.204X_1$	0.071	7.1	7.1	$F_{1,15} = 1.15$	p = 0.30
	$Y = 11.541 - 0.279X_1 + 0.052X_2$	0.076	7.6	0.5	$F_{2,14} = 0.57$	P = 0.58
	$Y = 16.278 - 0.322X_1 + 0.082X_2 - 0.050X_3$	0.092	9.2	1.6	$F_{3,13} = 0.44$	P = 0.73
	$Y = 16.552 - 0.311X_1 + 0.072X_2 - 0.055X_3 + 0.047X_4$	0.094	9.4	0.2	$F_{4,12} = 0.31$	P = 0.87
CB3	$Y = 1.686 + 0.093X_1$	0.014	1.4	1.4	$F_{1,15} = 0.21$	p = 0.65
	$Y = -3.099 + 0.401X_1 - 0.213X_2$	0.087	8.7	7.3	$F_{2,14} = 0.67$	P = 0.53
	$Y = -4.181 + 0.411X_1 - 0.220X_2 + 0.011X_3$	0.088	8.8	0.1	$F_{3,13} = 0.42$	p = 0.74
	$Y = -4.314 + 0.406X_1 - 0.215X_2 + 0.014X_3 - 0.023X_4$	0.088	8.8	0.0	$F_{4,12} = 0.29$	p = 0.88
CB5	$Y = 9.954 - 0.186X_1$	0.095	9.5	9.5	$F_{1,15} = 1.57$	p = 0.23
	$Y = 8.151 - 0.070X_1 - 0.080X_2$	0.112	11.2	11.2	$F_{2,14} = 0.89$	p = 0.44
	$Y = -3.648 + 0.037X_1 - 0.156X_2 + 0.125X_3$	0.275	27.5	16.3	$F_{3,13} = 1.65$	p = 0.23
	$Y = -3.760 + 0.032X_1 - 0.152X_2 + 0.127X_3 - 0.019X_4$	0.276	27.6	0.1	$F_{4,12} = 1.14$	p = 0.38
CB8	$Y = 10.625 - 0.201X_1$	0.098	9.8	9.8	$F_{1,15} = 1.63$	p = 0.22
	$Y = 7.012 + 0.032X_1 - 0.161X_2$	0.160	16.0	6.2	$F_{2,14} = 1.34$	P = 0.30
	$Y = -8.443 + 0.172X_1 - 0.260X_2 + 0.163X_3$	0.409	40.9	24.9	$F_{3,13} = 3.00$	p = 0.07
	$Y = -9.201 + 0.142X_1 - 0.231X_2 + 0.178X_3 - 0.129X_4$	0.432	43.2	2.3	$F_{4,12} = 2.28$	p = 0.12
CB12	$Y = 18.226 - 0.413X_1$	0.102	10.2	10.2	$F_{1,15} = 1.70$	p = 0.21
	$Y = 18.768 - 0.448X_1 + 0.024X_2$	0.102	10.2	0.0	$F_{2,14} = 0.95$	P = 0.47
	$Y = 11.830 - 0.385X_1 - 0.020X_2 + 0.073X_3$	0.114	11.4	1.2	$F_{3,13} = 0.56$	p = 0.65
	$Y = 10.543 - 0.436X_1 + 0.029X_2 + 0.098X_3 - 0.219X_4$	0.130	13.0	1.6	$F_{4,12} = 0.45$	p = 0.77

Y, aphid population leaf^{-1}; X_1, maximum temperature (°C); X_2, minimum temperature (°C); X_3, relative humidity (%); X_4, rainfall (mm).

Jassid population started increasing after second week of November when daily maximum and minimum temperatures, and relative humidity were 29.0 ^{o}C, 14.0 ^{o}C and 73%, and there was no rainfall (Table 1). Jassid population appeared to the peak in the third week of December when the maximum and minimum temperatures, and relative humidity were 25.0^{o}C, 13.0^{o}C and 90%, respectively and there was no rainfall.

The correlation coefficient values between aphid population and weather parameters exerted that population on CB3 had non-significant positive relationship with maximum temperature, whereas other varieties revealed non-significant negative relationship (Table 2). Multiple linear regressions demonstrated that maximum temperature individually contributed 1.4 - 10.2% aphid population fluctuation among the tested varieties and the effects were non-significant (Table 3). Minimum temperature exerted non-significant negative correlation with aphid population on each variety (Table 2) and its individual contribution on population fluctuation among the varieties ranged from 0.0 - 11.2% (Table 3), and the effects were non-significant.

The relative humidity revealed non-significant negative correlation with aphid population on CB1 and CB3, and non-significant positive correlation on CB5, CB8 and CB12 (Table 2). The relative humidity individually contributed 0.1 - 24.9% population fluctuation among the varieties and its effect was non-significant (Table 3). Rainfall showed non-significant positive correlation with aphid population on CB3 and CB5, and other varieties revealed non-significant negative correlation (Table 2). Multiple regression analysis indicated that rainfall individually exerted 0.0 - 2.3% contribution towards the population fluctuation of aphid on the varieties and its effect was insignificant (Table 3).

The multiple linear regression analysis showed that all the weather parameters together contributed 43.2% population fluctuation of aphid on CB8 followed by 27.6%, 13.0%, 9.4% and 8.8% on CB5, CB12, CB1and CB3, respectively, but none of the equation was found to be significant (Table 3).

Table 4. Correlation coefficient (r) values between jassid population on five cotton varieties and weather parameters

Variety	Temperature ^{o}C		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
CB1	- 0.437	- 0.716**	- 0.442	- 0.210
CB3	- 0.271	- 0.573*	- 0.552*	- 0.185
CB5	- 0.344	- 0.528*	-0.601*	- 0.141
CB8	- 0.083	- 0.391	- 0.579*	- 0.173
CB12	- 0.782 **	- 0.863**	- 0.234	- 0.211

* Significant ($p \leq 0.05$), ** Highly significant ($p \leq 0.01$).

Table 5. Multiple linear regression models along with coefficients of determination (R^2) regarding the impact of weather parameters on the population of jassid throughout the season on five cotton varieties

Variety	Regression equation	R^2	100 R^2	Role of individual factor (%)	F statistic	
CB1	$Y = 19.915 - 0.423X_1$	0.191	19.1	19.1	$F_{1\ 15} = 3.55$	$p = 0.08$
	$Y = 6.239 + 0.458\ X_1 - 0.609X_2$	0.585	58.5	39.4	$F_{2\ 14} = 9.86$	$P < 0.01$
	$Y = 18.657 +0.345X_1 - 0.530X_2 -0.131X_3$	0.656	65.6	7.1	$F_{3,13} = 8.25$	$P < 0.01$
	$Y = 19.708 +0.387X_1 - 0.569X_2 -0.152X_3 + 0.179X_4$	0.675	67.5	1.9	$F_{4\ 12} = 6.23$	$P < 0.01$
CB3	$Y = 16.035 - 0.279X_1$	0.074	7.4	7.4	$F_{1,15} = 1.19$	$p = 0.29$
	$Y = 1.733 +0.642\ X_1 - 0.637\ X_2$	0.454	45.4	38.0	$F_{2,14} = 5.83$	$P < 0.05$
	$Y = 20.856 + 0.469X_1 - 0.514X_2 - 0.202X_3$	0.603	60.3	22.3	$F_{3,13} = 6.58$	$p < 0.01$
	$Y = 22.293 + 0.526X_1 - 0.569X_2 - 0.230X_3 + 0.245X_4$	0.635	63.5	3.2	$F_{4,12} = 5.22$	$p < 0.05$
CB5	$Y = 18.190 - 0.359X_1$	0.118	11.8	11.8	$F_{1,15} = 2.01$	$p = 0.18$
	$Y = 8.029 + 0.296\ X_1 - 0.452X_2$	0.304	30.4	18.6	$F_{2,14} = 3.06$	$p = 0.08$
	$Y = 32.883 + 0.070X_1 - 0.293X_2 - 0.263X_3$	0.547	54.7	24.3	$F_{3,13} = 5.24$	$p < 0.05$
	$Y = 34.497 + 0.135X_1 - 0.355X_2 - 0.294X_3 + 0.275X_4$	0.587	58.7	4.0	$F_{4,12} = 4.26$	$p < 0.05$
CB8	$Y = 9.696 - 0.084X_1$	0.007	0.7	0.7	$F_{1,15} = 0.10$	$p = 0.75$
	$Y = -3.398 + 0.759\ X_1 - 0.583X_2$	0.332	33.2	32.5	$F_{2,14} = 3.48$	$P = 0.06$
	$Y = 17.730 + 0.567X_1 - 0.448X_2 - 0.223X_3$	0.516	51.6	18.4	$F_{3,13} = 4.63$	$p < 0.05$
	$Y = 19.048 + 0.620X_1 - 0.498X_2 - 0.249X_3 + 0.224X_4$	0.544	54.4	2.8	$F_{4\ 12} = 3.57$	$p < 0.05$
CB12	$Y = 61.330 - 1.687X_1$	0.612	61.2	61.2	$F_{1,15} = 23.68$	$p < 0.01$
	$Y = 42.598 - 0.481\ X_1 - 0.834X_2$	0.761	76.1	14.9	$F_{2,14} = 22.23$	$p < 0.01$
	$Y = 55.037 - 0.593X_1 - 0.755X_2 - 0.132X_3$	0.775	77.5	1.4	$F_{3\ 13} = 14.91$	$p < 0.01$
	$Y = 55.741 - 0.565X_1 - 0.781X_2 - 0.145X_3 + 0.120X_4$	0.777	77.7	0.2	$F_{4,12} = 10.43$	$p < 0.01$

Y, aphid population leaf^{-1}; X_1, maximum temperature (ºC); X_2, minimum temperature (ºC); X_3, relative humidity (%); X_4, rainfall (mm).

Jassid population on each variety showed negative correlation with weather parameters (Table 4). Maximum temperature individually exerted 0.7 - 61.2% population fluctuation among the tested varieties and its effect was highly significant only on the CB12 (Table 5). Minimum temperature individually exerted 14.9 - 39.4% population fluctuation and its effect was highly significant on all varieties except CB8. The combination effect of maximum and minimum temperature was found to be significant on CB1, CB3 and CB12.

The individual effect of the relative humidity revealed 1.4 - 24.3% fluctuation of jassid population and its effect was significant on CB3, CB5 and CB8 (Table 4). The combination effect of maximum and minimum temperature and relative humidity was significant on all varieties. Contribution of rainfall regarding population fluctuation of jassid among the tested varieties varied from 0.2 - 4.0% and its effect on each variety was insignificant (Table 5).

The multiple linear regression analysis showed that all the weather parameters together contributed 77.7, 67.5, 63.5, 58.7 and 54.4% population fluctuation of jassid on CB12, CB1, CB3, CB5 and CB8 variety, respectively, and the equations were significant (Table 5).

B. Discussion

Aphid and jassid population on the tested varieties differed significantly, and both the species showed significantly higher abundance on CB12. The differences in abundance of the pests on the tested varieties may be due to the leaf trichomes. Other characteristics, such as leaf thickness and toughness, the pH of the cell sap, content of moisture, sugar, protein, minerals or tanin in the leaf may affect the population abundance. The present study showed close conformity with Amjad *et al.* (2009) who tested five cotton cultivars against whitefly, thrips, jassid and aphid, and found significant variations in population abundance of the pests on different varieties. The present findings also showed congruity with Khan (2011) who studied jassid, thrips and white fly population on nine cotton varieties and found significant variations in their abundance.

This study showed that the leaf trichomes of the varieties had significant negative correlation with aphid and non-significant negative correlation with jassid and the varieties exerted significantly higher abundance of jassid compared to aphid. The trichomes created obstacles in foraging, feeding, ingestion, digestion, mating and oviposition, thus prevented their abundance.

The emergence of aphid and jassid population was associated with juvenile stage of the plants. Variations in weather conditions and time of the season also have affected population dynamics of the pests. Amjad *et. al.* (2009) observed the population abundance of sucking insects on five cotton cultivars and found significant variations in population abundance with time of the season. The population of aphid and jassid built up on the cotton varieties in the middle of September and continued throughout the season. Shivanna *et al.* (2011) found the abundance of aphid on cotton throughout the season except July, August and September when the rainfall was very high. In this study, both aphid and jassid population were found the highest on CB12 in the first week of November and in the third week of December, respectively. The meteorological conditions of those periods may be attributed to the enhanced rate of development and reproduction of the pests on cotton crops.

The individual and combine effect of the weather parameters showed non-significant effect on the population dynamics of aphid, however the combined effect of the parameters resulted 8.8 to 43.2% fluctuation. A study by Mahmood *et al.* (1990) in Pakistan showed that the weather parameters together were responsible for 73.0% population fluctuation of aphid on okra plants. A study by Sharma *et al.* (2013) dipicted that aphid population on tomato was positively but non-significantly correlated with the maximum temperature, negative non-significant with relative humidity and rainfall.

The maximum and minimum temperatures, relative humidity and rainfall showed significant negative correlation on the population of jassid on the varieties. The weather parameters together also contributed significant effect on the population which varied from 54.4 to 77.7%. Sharma and Singh (2012) noted 50.0 to 96.0% population fluctuation of jassid on five varieties of potato in Uttar Pradesh, India. Our findings are in line with Patel *et al.* (1997), who reported a negative correlation between the population of jassid and temperature. The present findings are partially in accordance with those of Arif *et al.* (2006), who reported a negative and non-significant correlation between the relative humidity and jassid-population on okra. Prasad and Logiswaran (1997) found a negative association between the jassid population and rainfall.

Understanding the demographic parameters of a pest regarding meteorological parameters, it is essential to develop an integrated pest management strategy for crop varieties, because these parameters provide population growth rate of an insect pest in the current and next generations (Frel *et. al.,* 2003). The present experiment demonstrated significant differences in the abundance of two sucking insects among the five cotton varieties tested. The lower population abundance of aphid and jassid on CB1 and CB3 was due to higher number of trichomes.

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DEVELOPMENT OF COST EFFECTIVE SMALL NO-TILL SEEDER FOR TWO WHEEL TRACTOR IN BANGLADESH

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Abstract

Two wheel tractor (Power tiller) is the common means of soil tillage and other farm operations in Bangladesh due to easy access in fragmented land size with affordable price. A low cost and small robust 2WT driven (12 hp) No-till seeder has been developed with press wheel attachment and inclined plate seed meter assembly in Farm Machinery & Postharvest Process Engineering Division, BARI, Bangladesh for seeding different kinds of seeds. This is a pull type implement hitched at drawbar point of 2WT replacing the regular rotary part. The developed No-till seeder was used in the farmer's field of Rajshahi areas for wheat, maize, pulses, and rice establishment during the year 2011-2014. The planter can pull 4 tynes in soft and medium hard soil but 3 tynes for hard soil. The planter was capable to apply seed and fertilizer in the furrows. The width and depth of the furrow opening were 30 mm and 60 mm, respectively. The planting depth, row spacing and seed rate can be adjusted according to standard practices. The No-till seeder works effectively through high density crop residue (1.5-2.4 t/ha) without any problem as there are sufficient residue clearances between toolbar and ground surface. Depending on the level of weed situation, round up herbicide was applied 2 days before of planting. There were significant yield difference in wheat, pulses but rice yield was lower than conventional transplanting method. No-till planted crops show less lodging tendency compare to conventional planted crops. There were significant cost differences between no-till and conventional method. The planting costs of wheat and maize in No-till system were 60% and 86% less than conventional planting method. It also reduces the average turn around time 7-9 days between the two crops. The effective area coverage by the seeder was 0.13ha/hr. The No-till seeder is a low cost (US$ 350-400; without power unit), light in weight and local manufacturer can fabricate complete unit within a short period of time. The No-till seeder can be used in other countries where 2WT is the common farming equipment.

Keywords: Two wheel tractor, No-till seeder, residue clearance, turn around time, inclined plate seed meter, tyne opener.

Introduction

Conservation agriculture (CA) based two wheel tractor (2WT) operated seeding implements are becoming popular among the farmers in Bangladesh. Zero tillage

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can overcome late planting which is a major problem in most wheat producing areas and it reduces the yield and efficiency of applied inputs to the crop. A linear decline in yield of 1-1.5% per day is observed when wheat is planted after the end of November irrespective of the maturity duration of the varieties. In this case increased nitrogen applications can not compensate for the decline in yield from late planting (Saunders,1988). The area under zero tillage in Indian sub-continent has been increased tremendously since last decades or so, which was estimated to be more than 5.61 lakh ha in 2002-03 with about 1.07 lakh farmers. Zero till minimizes the need for the number of tillage operations, reduces planting time and saves fuel and labour costs in both timely planting and late planting situations. It is reported that yield grains due to zero till planting are more in areas where late planting is a common feature as compared to timely sown areas (Gupta *et al*, 2003). In no-till farming the soil is left intact and crop residue is left on the field. Tilling a field reduces the amount of water, via evaporation around 1/3 to 3/4 inches (0.85 to 1.9 cm) per pass. By no-tilling, this water stays in the soil, available to the plants (Wikipedia, 2010). According to the latest estimates, the number of 2WT are 700,000 operating in the country (Mondal, 2013).

In Bangladesh, No-till seeder of 2WT was first developed in WRC, BARI with FAO-CIMMYT supported programme (2003-04). This seeder had no press wheel and limitation to bold size seeds sowing. The No-till seeder was improved with ACIAR support with the introduction of lighter weight toolbar frame, press wheel attachment, seed and fertilizer box fixing over the handle bar of a tractor for free flow of seeds to ground (Hossain *et al.*, 2009). This seeder performed better through crop residue but operators were still not satisfied due to the height of seed box which blocked the forward view of the field being seeded. Therefore, a user-friendly, small 2WT No-till seeder was developed capable of handling most seeds and managing crop residue properly.

Objectives: The specific objectives of this study are

i) To develop a cost effective No-till seeder for better establishment of crops

ii) To demonstrate the No-till seeder in the farmer's field ; and

iii) To compare the cost of planting of the seeder over conventional method

Materials and method

Two wheel tractor (2WT) operated No-till seeder is a pull type seeder and it has been developed in Farm Machinery & Postharvest Process Engineering Division, BARI, Bangladesh. The major components of the seeder are hitch plate, toolbar frame, seed and fertilizer box, with improved “T” furrow opener, press wheel and chain-sprocket power transmission. The toolbar frame facilitates fittings different types of seed metering devices (Inclined plate seed meter, flute type and cup feed type seed meter as required), furrow openers, seed box. The No-till seeder has been improved with locally available materials such as M.S. angle, stainless steel bar, M.S sheet, ball bearing etc (Fig.1). All accessories were set up under the handle bar of the 2WT , which was not the case in earlier versions. Field performances and adaptive trials of the seeder were conducted in the farmers’ field, by attaching a 12 hp Chinese Dongfeng 2WT. In North West drought prone area during 2011-14; wheat, mungbean, chickpea, maize and rice were successfully established using this seeder. The specification of the No-till seeder is shown in Table 1.

Fig. 1. 2WT operated no till seeder

Table 1. Specification of 2WT operated No-till seeder and accessories

S.N.	Items of No-till seeder	Specification	Remarks
1	Power	12 hp, 2WT; one operator	Dongfeng type, China
2	Hitch plate	120 x 150 mm; Steel plate	Clump and lock pin used
3	Toolbar frame	800 x 1120 mm; 3 bar; 50mm Sq stainless steel	Middle bar position adjustable
4	Seed & fertilizer box	800 x 330 mm; 22 gauge steel plate	
5	Seed metering mechanism	170 mm, Inclined plate, variable cell size	Plate adjustable 30º-60º position
6	Furrow opener	510 x70 x10 mm“T” type; Steel	Using used car leaf spring
7	Press wheel	250-50 mm; rubber coated	Seeding row adjustable
8	Power transmission	Chain No. 428 with different size sprocket	Power from wheel axel
9	Depth control bar	460 x 10 mm steel bar	
10	Over all dimension	2460 x1120 x1200 mm Weight:115 kg (without engine)	Turning 1.5 m space

Wheat, maize, chickpea planted after rice harvest in the month of November and mungbean planted after wheat harvest in early April. The seeder used effectively in the rice and wheat residue condition (1.5 - 2.4 t/ha) without any problem as there are sufficient clearance between toolbar and ground surface. The variety of wheat, maize and mungbean used for calibration and experimentation were Prodip, NK 40, BARI Mung-6, respectively. Di- Ammonium Phosphate (DAP) fertilizer 130 kg/ha was applied along with the planting operation of wheat and maize in the farmer's field. Operation view of press wheel attached No-till drill was shown in Fig.2. The planting depth and seed covering mechanism were adjusted during the field operation. Before planting operation started Roundup herbicide was applied @100 ml in 10 lit water for 5 decimal land irrespective of existing weeds. Field performances data of the seeder were recorded as per Regional Network of Agricultural Machinery (RNAM) Test Code. Fuel consumption, operation time, etc. were also collected to compare the cost saving over conventional method.

Data collection

The following data were collected - i) Depth of seed placement, cm ; ii) Travel speed, km/hr; iii) Effective field capacity, ha/hr ; iv) Field efficiency, % ; v) Fuel consumption, l/hr ; vi) No. of plants/m^2 and viii) Crop yield, kg/m^2. Cost was calculated according to the farm machinery utilization method (Anon., 1991; Hunt, 1995).

Results and Discussions

Field performance of the No-till seeder for wheat, maize, mungbean, chickpea establishment in several farmers field indicated that crops can be established immediate after rice harvest using residual soil moisture. There was enough ground clearance (45 cm) between soil surface and toolbar. Furrow openers lay out was jig-jag way, which facilitated passing crop residue without blocking. Row positions can be adjusted sliding the clump of tynes on the toolbar frame. Soil moisture monitoring during wheat planting period showed that No-till plot had higher moisture content for a longer period than conventional tilled plot (Fig.3). Effective field capacity of the seeder for wheat, maize and mungbean planting recorded 0.12 ha/hr,0.14 ha/hr, and 0.14 ha/hr, respectively. It was reported that the seeder with 4 tynes is more appropriate for soft to medium hard soil and 3 tynes for hard soils. The effective field capacity for maize planting found to be higher than wheat planting that was due to faster speed of operation (Table 2). Average fuel consumption of No-till seeder was 1.2 lit/hr. The seeder was intensively used in the farmers' field for planting various crops.

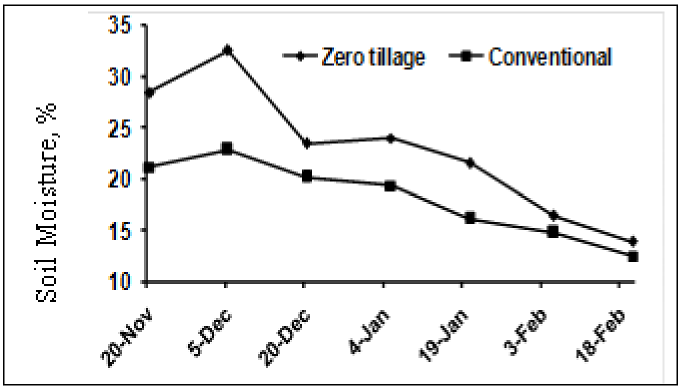

Fig. 3. Soil moisture change over the season.

Table 2. Field performance of 2WT operated no-till seeder

Sl No	Parameters	Wheat	Maize	Mungbean	Chickpea
1	Fuel consumption, lit./hr	1.20	1.20	1.20	1.20
2	Speed of operation, km/hr	2.50	2.70	2.70	2.50
3	Soil moisture content, %	28	28	22	22
4	Effective field capacity, ha/hr	0.12	0. 14	0.14	0.12
5	Field efficiency, %	78	82	82	80

Fig. 4. No till planted wheat field

Crop establishment by No-till seeder was shown in Table 3. Applied seed rate for wheat, maize, mungbean and chickpea were 120 kg/ha, 20 kg/ha and 23 kg/ha, 35 kg/ha, respectively. Average planting accuracy of those seeds were 94% on the basis of desired seed spacing. The average width of soil opening slits by tyne was 2-3 cm and depth of planting 4-5 cm, which was enough for most of the crops. It was found that slower speed was comparatively better for seed placement into the opening slit for all crops. No-till wheat plant establishment plot was shown in Fig.4. The adjustment of row spacing between two successive pass was maintained by an experienced and skilled operator. The width of slit during maize sowing was bigger due to the slightly dipper position of the "T" opener. Maize planting was more accurate with inclined plate seed meter.

Table 3. Crops establishment by No-till seeder

Sl No	Parameter	Wheat	Maize	Mungbean	Chickpea
1	Variety	Prodip	NK 40	BARI Mug-6	BARI Sola 9
2	Seed rate (kg/ha)	120	20	23	35
3	Row to rows spacing (cm)	20	60	30	40
4	Average seed to seed distance (cm)	1	20	5	8-10
5	Number of rows per pass	4	2	3	3
6	Depth of planting (cm)	4	5	4	5
7	Plant population (m^2)	198	9	34	32
8	Width of soil opening slits (cm)	2-3	2.5-3.0	2-3	3
9	Planting uniformity (%)	85	95	88	94

It was observed from Table 4 that there were variations of plant population using press wheel and without press wheel in No-till seeder. Press wheel covered the seeding lines, which ensured seed-soil contact properly. Initial wheat plant population per meter square of with press wheel and without pressed wheel were 235, 205, respectively. Without press wheel seeded plot; direct sunlight exposed on seeds & open furrow, moisture loss, bird damage the seeds which resulted average 15-20% less population in wheat seeding. Similarly, in maize, mungbean and chickpea plots. Press wheel also facilitates seeder transportation from place to place.

Table 4. Effect of plant stand on press wheel (+) and without press wheel (-) by No-till seeder

Sl No.	Name of crop	Seed germination (%)	Seeding depth, mm		Plant population/m^2		
			(+) Press wheel	(-) Press wheel	(+) Press wheel	(-) Press wheel	% increase
1	Wheat	97	40	36-40	235	205	15
2	Maize	94	50	45-47	12	10	20
3	Mungbean	88	40	40	33	28	17
4	Chickpea	96	50	48	40	32	25

The yield of wheat, mungbean, rice, maize and chickpea in No-till and conventional method were presented in (Table 5). The wheat-mungbean-rice crop rotation continues last 4 years on station Rajshahi where the soil type is dominantly silty clay loam. Rice was seeded directly in unploughed/unpuddled soil. It was observed that there were significant yield variations between No-till and conventional method (Table 5). Wheat, mungbean, chickpea yields were comparatively higher than conventional method all the years. But rice and maize yield were slightly lower in No-till plots. Weed management in No-till rice cultivation is still challenging for convince traditional rice farmers. Weed management, herbicide availability, application techniques along with appropriate crop cultivar need to be more correct for disseminating the technology. Farmers reported that rice after mungbean plots required 30% less nitrogen fertilizer. There was a great potential to fit legume crop between rice-wheat by no till planting system in rice-wheat cropping system reducing 7-9 days turn around time. It was also critically observed that No-till wheat, maize were less lodge compare to conventional planted wheat, maize even medium strong wind passes. It was due strong crop root anchor in soil compare to much loose soil in conventional tilled soil.

Table 5. Comparison of yield (t/ha) and planting cost between No-till and conventional planting method

Year	Wheat		Mungbean		Rice		Maize		Chickpea	
	No till	Conv.	No till	Conv.	No till	Conv.	No till	Conv.	No till	Conv.
2011	3.6	3.3	0.9	0.8	3.4	3.5	8.3	8.7	-	-
2012	3.7	3.3	1.0	0.8	3.5	3.7	8.2	8.4	1.8	1.2
2013	3.7	3.4	1.1	0.9	3.63	3.6	8.6	8.7	2.1	1.2
2014	3.9	3.5	1.2	0.9	3.72	4.0	8.8	8.9	1.7	1.1
CV (%)	3.5	3.9	2.3	2.3	5.75	5.5	10.6	7.8	6.7	5.3
LSD (0.05)	0.12	0.11	0.11	0.12	0.119	0.11	0.26	0.23	0.23	0.19
Cost of planting (Tk./ha)	2173	5437	2175	5437	2175	8675	1975	14500	2175	5437

Planting cost and break-even point used for No-till seeder was calculated on the basis of purchase price, fixed cost, variable cost, seeder life, depreciation cost, salvage value, bank interest rate, custom hire price and annual use of the seeder. Seeder price was Tk. 30,000.0 (US$ 400) where planting cost of wheat, mungbean, rice and chickpea were Tk.2175.0/ha and maize only Tk. 1975.00/ha (Table 5). The planting costs of wheat and maize in No-till system were 60% and 86% less than that of conventional planting method. The planting cost variation was due to different effective field capacity of the seeder for different crops as row spacing of crops are different.

Conclusions

- The small 2WT (9 kW) No-till seeder can pull 4 tynes in soft to medium hard soil but 3 tynes in hard soil.
- Interchangeable inclined plate seed metering device can handle efficiently most of the seeds sizes like wheat, maize, chickpea, rice and other pulses seeds.
- Yield of wheat, mungbean, rice, maize and chickpea was not reduced in No-till as compared to conventional method.

- No-till seeder cost to be reduced for growing different crops substantially with reduction around time, so it can be made in local manufacturer.
- No-till seeder is low cost (US$ 350-400; without power unit), lighter in weight and local manufacturer can fabricate complete set within a short period of time.

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EFFECT OF INSECTICIDES ON POPULATION REDUCTION OF SUCKING INSECTS AND LADY BIRD BEETLE IN EGGPLANT FIELD

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Abstract

This study evaluated the field efficacy of three newly introduced synthetic insecticides namely, Python 20SL (Nitenpyrum), Plenum 50WG (Pymetrozin), Polo 500SL (Diafentiuron) along with commonly used chemical Admire 200SL(Imidacloprid) against sucking insects of eggplant such as aphid, jassid, white fly and thrips. The effect of the insecticides on the population reduction of the novel predator lady bird beetle was also studied. Among the chemicals, Polo 500SC was found to be the most effective followed by Plenum 50WG against the sucking insects by reducing significant percentages of their population at 3 and 7 days after spray. Polo 500SC and Plenum 50WG were found to be the least deleterious against lady bird beetle since it caused lowest population reduction. Considering the higher percentages of population reduction of the pests and significantly lower affect on the predator, Polo 500SC and Plenum 50WG may be considered as a tool of IPM for management of sucking insects in the eggplant field.

Keywords: Hemipteroid insects, insecticides, predator, *Solanum melongina*.

Introduction

The eggplants *Solanum melongina* L. are grown throughout the year in Bangladesh. But its production is seriously impeded due to increasing threats from different sucking insect pests such as aphid *Aphis gossypii* Glover, jassid *Empoasca devastans* Distant, white fly *Bamisia tabaci* Gennadius and thrips *Frankliniella occidentalis* Pergande (Dutta *et al.*, 2012). The nymphs and adults of these hemipteroid insects ingest cell sap from the leaves of the plants with their piercing sucking mouthparts. The infested plants lead to crinkling and yellowing of the leaves, and reduce growth and vigour. While sucking the plant sap, jassids inject toxic saliva into the plant tissues which results to yellowing. When several insects attack the same plant, yellow spots appear on the leaves, become bronzing, wither and show “hopper burn” symptom. The leaves and fruits of the thrips infested plants appear cosmetic silvery color and become unhealthy (Srinivasan, 2009). The lady bird beetles are well known beneficial

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arthropods found in many habitats (Ali and Rizvi, 2009). The adults and larvae of lady bird beetles attack aphids, whiteflies, psyllids, scales and many other soft bodied insects and found to be an effective predatory fauna in eggplant ecosystem (Ali *et al.,* 2009).

The eggplant growers of Bangladesh mostly rely on broad spectrum insecticides to suppress sucking insects. The injudicious application of synthetic insecticides creates threats to eggplant ecosystem causing death of the pollinators and natural enemies of the pests. Pesticide residues in eggplant fruits are of great concern from the point of view of domestic consumption and export as well (Rashid *et al.,* 2003). The risk of using chemical insecticides in the management strategies can be reduced by incorporating safer molecules of chemicals. It is therefore, very essential to select insecticides that are very selective in action as well as safer to different beneficial fauna (Soni *et al.*, 2004).

Admire 200 SL is the most widely used insecticide for management of sucking pests of eggplant in Bangladesh. The farmers in Bangladesh often do not get desired result by spraying Admire and other conventional insecticides. More effective and safer insecticides must be introduced into IPM programs to provide alternatives to Admire and other conventional insecticides. Therefore, some new insecticides such as Python 10SL, Plenum 50WG and Polo 500SL have been registered.

The new insecticides that have achieved registration within the current regulatory environment of Bangladesh have reduced-risk and less toxicity to the pollinators, predators and parasitoids. These insecticides could be a potential tool in IPM programs. Therefore, this study was designed with the new insecticides Python 10SL, Plenum 50WG and Polo 500SL in comparison with Admire 200SL to find out the most effective chemical for managing sucking insects in the eggplant field, as well as safer to the lady bird beetles.

Materials and Methods

Study site and climatic conditions

The study was conducted in the field laboratory of the Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh (25°25′N, 89°5′E) during September 2014 to March 2015. The mean annual maximum and minimum temperatures, relative humidity, and rainfall in this area were 36.0°C and 12.7°C, 65.8%, and 237.6 cm, respectively.

Cultivation of the egg plant

The eggplant seedlings (variety BARI Begun-8) were collected from the Horticulture Research Center of BARI and transplanted in the field with an area of 5.5 m × 4.0 m. The experimental design was randomized complete block. The spaces between blocks and between plots were 0.5 m and 1.0 m, respectively. Seedlings were planted on 5th September 2014 in rows. Each plot contained 1 row with 5 plants separated by 60 cm. A total of 75 plants were grown in 15 rows. The manures and fertilizers were applied according to the recommended doses of the BARI. Mulching, weeding and irrigation were done whenever necessary, and the shoot and fruit borer *Leucinodes orbonalis* Guenee (Pyralidae: Lepidoptera) was controlled mechanically.

Monitoring of the pests and application of the treatments

After transplanting, the plants were monitored weekly to observe the abundance and infestations of the sucking insects (aphid, jassid, white fly and thrips). The newly introduced insecticides Python 20 SL (Nitenpyrum), Plenum 50WG (Pymetrozin), Polo 500 SC (Diafenthiuron) and Admire 200 SL (Imidacloprid) were applied with concentrations of 1mL/L, 0.5g /L, 1mL/L and 0.5mL/L water after the infestation had occurred. An untreated control observation was made with spraying water. Each of the treatment was applied in three plots and each plot indicated a replication. All the treatments were sprayed four times at fortnightly interval with a hand sprayer.

Collection of pest and predator population data

Insect population abundance on the eggplants was recorded one day before spraying and, 3 and 7 days after spraying. The numbers of sucking insects (aphid, jassid, white fly and thrips) and lady bird beetles were recorded from the middle plant of each row during early morning. Five leaves were observed from different heights of each plant to record the population (both nymphs and adults) of the sucking pests, while total number of lady bird beetles present on the plant was also recorded. It is noted that two species of lady bird beetles (*Menochilus sexmaculatus* Fab. and *Micraspis discolor* Fab.) were abundant but data were taken together. The observed population reductions of the pests and predator were corrected according to Abbott (1925).

$$Pt = \frac{Po - Pc}{100 - Pc} \times 100$$

Where, Pt = Corrected population, Po = Observed population, Pc = Control population.

Statistical analysis

Data were analyzed by analysis of variance using SPSS (IBM SPSS statistics 21, Georgia, USA) software and means were separated by Duncan’s Multiple Range Test (DMRT).

Results and Discussion

The tested insecticides showed significant difference ($F_{3,\ 8}$ = 4.3, $p < 0.05$) in reducing aphid population after 3 days of spray (Table 1). The population reduction varied from 83.1 ± 4.0 to 92.0 ± 3.1% and the highest and lowest results were obtained in Polo 500SL and Admire 200SL, respectively. Plenum 50WG revealed statistically similar result to Polo 500SL. After 7 days of spray, aphid population reduction ranged from 91.9 ± 2.7 to 93.4 ± 2.2%, and there was no significant difference ($F_{3,8}$ = 0.23, $p = 0.87$) (Table 1). T statistics showed that the aphid population reduction between 3 and 7 days after spray in each treatment was statistically insignificant.

Table 1. Effect of different insecticidal treatments on the population reduction of aphid in eggplant field

Insecticides	%Reduction		T statistic		
	3 day after treatment	7 day after treatment	d.f.	t	p
Python 20SL	89.3 ± 2.5 ab	92.6 ± 2.1 a	2	3.7	0.07
Plenum 50WG	91.2 ± 3.5 a	93.2 ± 2.3 a	2	0.8	0.51
Polo 500SC	92.0 ± 3.1 a	93.4 ± 2.2 a	2	1.7	0.23
Admire 200SL	83.1 ± 4.0 b	91.9 ± 2.7 a	2	4.1	0.06

Data express as mean ± SD. Means within a column followed by same letter(s) are not significantly different by DMRT ($p \leq 0.05$).

Table 2. Effect of different insecticidal treatments on the population reduction of jassid in eggplant field

Insecticides	%Reduction		T statistic		
	3 day after treatment	7 day after treatment	d.f.	t	p
Python 20SL	68.7 ± 1.1 a	72.1 ± 5.2 ab	2	0.9	0.46
Plenum 50WG	67.9 ± 2.8 a	70.4± 3.1 b	2	1.8	0.20
Polo 500SL	71.6 ± 3.1 a	77.8 ± 2.8 a	2	2.4	0.14
Admire 200SL	52.9 ± 2.5 b	59.3 ± 3.0 c	2	3.67	0.07

Data express as mean ± SD. Means within a column followed by same letter(s) are not significantly different by DMRT ($p \leq 0.05$).

There was found significant difference ($F_{3,\ 8}$ = 33.5, $p < 0.001$) in reducing jassid population after 3 days of spray (Table 2). The population reduction varied from 52.9 ± 2.5 to 71.6 ± 3.1% and the lowest result was obtained by Admire 200SL. The other three treatments revealed statistically similar result. After 7 days of spray, jassid population reduction ranged from 59.3 ± 3.0 to 77.8 ± 2.8 %, and there was found significant difference ($F_{3,8}$ = 13.1, $p < 0.001$) (Table 2). T statistics showed that the jassid population reduction between 3 and 7 days after spray in each treatment was statistically insignificant.

In table 3 significant difference ($F_{3, 8} = 258.2$, $p < 0.001$) was found in reducing whitefly population after 3 days of spray. The population reduction varied from 36.7 ± 2.1 to 83.5 ± 1.7%, and the highest and lowest results were found in Polo 500SL and Admire 200SL, respectively. After 7 days of spray, whitefly population reduction ranged from 41.4 ± 3.0 to 85.7 ± 1.6%, and there was found significant difference ($F_{3,8} = 250.6$, $p < 0.001$) (Table 3). T statistics showed that the whitefly population reduction between 3 and 7 days after spray in each treatment was statistically insignificant.

Table 3. Effect of different insecticidal treatments on the population reduction of white fly in eggplant field

Insecticides	%Reduction		T statistic		
	3 day after treatment	7 day after treatment	d.f.	t	p
Python 20SL	56.9 ± 2.81 c	58.7 ± 1.4 c	2	1.3	0.31
Plenum 50WG	77.5 ± 2.3 b	78.3 ± 2.3 b	2	2.7	0.12
Polo 500SL	83.5 ± 1.7 a	85.7 ± 1.6 a	2	2.9	0.10
Admire 200SL	36.7 ± 2.1 d	41.4 ± 3.0 d	2	1.7	0.23

Data express as mean ± SD. Means within a column followed by same letter(s) are not significantly different by DMRT ($p \leq 0.05$).

Table 4. Effect of different insecticidal treatments on the population reduction of thrips in eggplant field

Insecticides	%Reduction		T statistic		
	3 day after treatment	7 day after treatment	d.f.	t	p
Python 20SL	58.4 ± 3.7 b	62.2 ± 2.0 b	2	2.6	0.13
Plenum 50WG	72.4 ± 4.5 a	74.6 ± 1.5 a	2	0.6	0.59
Polo 500SL	74.0 ± 1.1a	76.3 ± 2.0 a	2	1.8	0.21
Admire 200SL	48.7 ± 0.7 c	55.7 ± 4.8 c	2	2.3	0.15

Data express as mean ± SD. Means within a column followed by same letter(s) are not significantly different by DMRT ($p \leq 0.05$).

Table 4 indicated that the population reduction of thrips after 3 and 7 days of spray varied from 48.7 ± 0.7 to 74.0 ± 1.1% and 55.7 ± 4.8 to 76.3 ± 2.0%, respectively, and the results differed significantly (3 days after spray: $F_{3,8} = 48.6$, $p < 0.001$; 7 days after spray: $F_{3,8} = 35.8$, $p < 0.001$). Among the treatments Polo 500SL and Plenum 50WG revealed statistically similar and higher percentages of population reduction both in 3 and 7 days after spray, while the Admire 200SL revealed the lowest percentages of reduction.

Diafenthiuron acts specifically on sucking pests namely aphid, whitefly and mites (Kadir and Knowles, 1991; Ishaaya *et al*. 1993). The findings of this study indicated that Diafenthiuron (Polo 500SL) followed by Pymetrozine (Plenum

50WG) provided higher effectiveness in controlling sucking insect pests as compared to others. However, Nitenpyram (Python 10SL) showed comparatively higher effectiveness to Imidacloprid (Admire 200SL) in reducing population of aphid, jassid, whitefly and thrips. Nitenpyrum showed statistically identical effectiveness to Diafenthiuron in reducing jassid population at 3 days after spray.

Imidacloprid controlled sucking insects attacking cotton (El-Naggar, 2006; El-Seady, 2009; Hossain *et al.,* 2012). In our study, Imidacloprid resulted poor performances in reducing aphid, jasssid, whitefly and thrips. It may be the cause that inadvertent use of Imidacloprid in Bangladesh might have developed certain level of resistance against sucking insect pests.

It is found from table 5 that the population reduction of lady bird beetle after 3 days of spray ranged from 34.4 ± 2.6 to 58.7 ± 2.8%, and after 7 days of spray from 39.1 ± 1.9 to 63.1 ± 3.2%. The percentages of population reduction both in 3 and 7 days after spray differed significantly ($F_{3,8}$ = 49.3, $p < 0.001$ and $F_{3,8}$ = 41.3, $p < 0.001$, respectively). The treatments Polo 500SL and Plenum 50WG revealed statistically identical as well as lower percentages of population reduction.

Table 5. Effect of different insecticidal treatments on the population reduction of lady bird beetle in eggplant field

Insecticides	%Reduction		T statistic		
	3 day after treatment	7 day after treatment	d.f.	t	p
Python 10SL	55.4 ± 2.8 a	63.1 ± 3.2 a	2	2.5	0.13
Plenum 50WG	36.1 ± 4.0 b	41.1 ± 2.9 b	2	2.2	0.16
Polo 500SL	34.4 ± 2.6 b	39.1 ± 1.9 b	2	3.5	0.07
Admire 200SL	58.7 ± 2.8 a	62.2 ± 5.2 a	2	1.6	0.26

Data express as mean ± SD. Means within a column followed by same letter(s) are not significantly different by DMRT ($p \leq 0.05$).

Considering safety to predators, our results clearly indicated that the two Neonicotinoid insectcicides (Admire 200 SL and Nitenpyrum 10 SL) were relatively toxic and Polo 500 SL and plenum 5 WG were relatively less toxic to lady bird beetles. A laboratory study by Bozsik (2006) indicated harmful effect of Imidacloprid on the lady bird beetle *Coccinella septempunctata* L. compared to other insecticides. Hossain *et al.* (2013) observed significantly lower abundance of lady bird beetle in the Imidacloprid treated cotton field compared to the field treated with Monocrotophos 40WSC. Ishaaya *et al.* (2007) observed that Plenum has no detrimental effect on natural enemies and on the environment, and as such is considered a potential component of IPM programs. Carbal *et al.* (2008) in a laboratory study observed that Pymetrozine had no adverse effects on immature or adult stages of *Coccinella undecimpunctata* L.

and hence are suitable for IPM of sucking pests. However, Ahmed *et al.* (2014) observed that Neonictinoids can be a suitable tool for inclusion in integrated pest management of sucking insect pests in major cotton growing areas because these have proved comparatively less toxic to predators as compared to non-selective insecticides.

From the standpoint of safety to lady bird beetles, Polo 500 SL followed by Plenum 50 WG appeared much safer than Python 20 SL and Admire 200 SL. Adoption of Polo 500 SL and Plenum 50 WG in eggplant IPM programs in Bangladesh will benefit producers and consumers by reducing total insecticide applications and subsequent costs for sucking pest control, as well as limiting further resistance development in pest populations. However, the efficacy of Polo 500 SL and Plenum 50 WG should be evaluated across the different locations and varied ecology in Bangladesh.

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RESPONSE OF CAPSICUM TO BORON AND ZINC APPLICATION IN TERRACE SOILS OF GAZIPUR, BANGLADESH

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Abstract

A field experiment was conducted at vegetables research field of Horticulture Research Centre, Gazipur in terrace soils under Madhupur Tract (AEZ 28) during *rabi* seasons of 2009-10, 2010-11and 2011-12 to determine the optimum dose of boron and zinc for yield maximization of capsicum. There were sixteen treatment combinations comprising four levels each of B (0, 1, 2 and 3 kg ha^{-1}) and Zn (0, 2, 3 and 4 kg ha^{-1}) along with blanket dose of $N_{150}P_{65}K_{120}S_{20}$ kg ha^{-1} including cow dung 10 t ha^{-1} were used. The experiment was laid out in RCBD factorial with three replications. Results revealed that maximum mean number of fruits per plant (11.1), the highest fruit length (9.29 cm) and diameter (7.34 cm), maximum individual weight of fruits (122 g) were recorded from the combination treatment of $B_{2.0}Zn_{3.0}$ and the highest mean yield (31.8 t ha^{-1}) was also recorded from the same treatment. The 84.8% yield increase over control (B_0Zn_0) due to combined application of $B_{2.0}Zn_{3.0}$ kg ha^{-1}. The combined application of zinc and boron were observed superior to their single application. Therefore, the combination of $B_{2.0}Zn_{3.0}$ treatment may be considered as suitable dose for capsicum cultivation in terrace soils of Bangladesh.

Keywords: Capsicum, boron and zinc, terrace soils, yield.

Introduction

Sweet capsicum (*Capsicum annum cv. California wonder*) is one of the most important high valued vegetable crop grown extensively throughout the world especially in the temperate countries (Manchanda and Singh, 1987). Capsicum belonging to the family Solanaceae is very sensitive to soil nutrients and environmental factors (Bhatt *et al.,* 1999). The optimum temperature for capsicum ranged from 16^0 to 26^0 C (Bakker, 1989). Capsicum may be eaten as cooked or raw as well as sliced in salads. The leaves are also consumed as salads, soups or eaten with rice. It is a good source of medicinal preparation for black vomit, tonic for gout and paralysis (Knott and Deanon, 1967). It contains 1.29 mg protein, 11 mg Ca, 870 I. U. vitamin A, 175 mg ascorbic acid, 0.06 mg thiamine, 0.03 mg riboflavin and 0.55 mg niacin per 100 g edible fruit. The sweet pepper is the second most important after tomato in the world (AVRDC, 1989).

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But it is a minor vegetable in Bangladesh and production statistics are not available (Hasanuzzaman, 1999). Small scale cultivation is found in peri-urban areas (Savar, Kashimpur, Bogra, Chittagong) for the supply to some city markets in Bangladesh. It has good demand to some big hotels in the city to feed the foreigners residing in Bangladesh. The crop has achieved high export potentiality. Considering its high nutritive value, export potentiality and low production some attempts has been taken to successful cultivation in Bangladesh. But some constraints which include nutrients deficiency, flower dropping, and poor fruit set, susceptibility to viral diseases etc. are affects the good yield of capsicum. For sustainable crop yields balanced fertilizations with all the nutrients (major and trace) that are deficient in soils need to be taken into account. Zinc and B deficiency is widespread in the country; much observed in wetland rice soils and light textured soils (Jahiruddin *et al.*, 1992; Islam *et al.*, 1997). Zinc is involved in auxin formation; activation of dehydrogenase enzymes; stabilization of ribosomal fractions (Obata *et al*., 1999). Boron is essential for reproductive growth, especially flowering and fruit, and seed set is more sensitive to B deficiency than vegetative growth (Dear and Lipsett, 1987). Boron influence the absorption of N, P, K and its deficiency changes the equilibrium of optimum of those three macronutrients (Raj, 1985). Farmers do not have any recommended doses of fertilizers (micronutrients) for boosting fruit yield of capsicum. As a result farmers are not getting desired and expected yield of fruits. Hence, the experiment was undertaken to find out the optimum dose of boron and zinc for maximizing the yield of capsicum in Terrace soils of Bangladesh.

Materials and Method

The field experiment was carried out at the vegetable research field of Horticulture Research Centre, BARI, Gazipur during Rabi season of 2009-10, 2010-11 and 2011-12 to find out the optimum dose of boron and zinc for yield maximization of capsicum. Experimental site-Gazipur (24° 0′ 13″ N latitude and 90° 25′ 0″ E longitude) lies at an elevation of 8.4 m above the sea level. The terrace soil of Gazipur belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agro ecological zone Madhupur Tract and texture is clay loam. There were 16 treatment combinations comprising four levels each of B (0, 1, 2 and 3 kg ha^{-1}) and Zn (0, 2, 3 and 4 kg ha^{-1}) along with a blanket dose of $N_{150}P_{65}K_{120}S_{20}$ kg ha^{-1} and 10 t ha^{-1} cow dung was used. The treatments were arranged viz. T_1= B_0Zn_0; T_2= B_0Zn_2; T_3= B_0Zn_3; T_4= B_0Zn_4; T_5= B_1Zn_0; T_6= B_1Zn_2; T_7= B_1Zn_3; T_8= B_1Zn_4; T_9= B_2Zn_0; T_{10}= B_2Zn_2; T_{11}= B_2Zn_3; T_{12}= B_2Zn_4; T_{13}= B_3Zn_0; T_{14}= B_3Zn_2; T_{15}= B_3Zn_3; and T_{16}= B_3Zn_4. Before setting the experiments, initial soil samples were collected from the experimental field from 0-15 cm depth and the collected samples were analyzed for chemical properties using standard procedures in the laboratory (Table 1). The land was prepared thoroughly by a tractor driven siezel and rotavator. The experiment was laid out in RCBD factorial with three replications. The unit plot size was 2 m × 1 m along with spacing of 50 cm x 40 cm. Nitrogen, P, K and S were supplied as urea, TSP, MoP and gypsum fertilizer, respectively. All P, K, S fertilizer including cow dung were applied and mixed up well at the time of final land preparation. Boron and zinc were applied as boric acid and zinc sulphate in the respective treatments plot during final bed preparation. The 25 days old capsicum (var. *California wonder*) seedlings were transplanted at three consecutive years on 18 December 2009, 19 December 2010 and 18 December 2011. Urea was applied in three equal splits at 30, 45 and 60 days after transplanting. Poly tunnels were used for minimizing the night temperature. Intercultural practices like weeding, irrigation, spraying pesticides etc. were done in time. Data on plant height, number of fruits per plant, length, diameter and individual fruit weight were recorded from five randomly selected plants. All the necessary data on different parameters were computed for statistical analysis and adjusted with DMRT at 5% level of significance.

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

Location	pH	OM	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Mn	Zn
			meq/100g				μg/g						
Joydebpur	6.5	0.91	1.5	0.7	0.18	0.048	10	12	0.1	1.0	140	4.2	1.0
Critical level	-	-	2.0	0.8	0.20	0.12	14	14	0.2	1.0	10	5.0	2.0

Results and Discussion

Effect of Boron

Different levels of boron played a significant role on yield and yield contributing characters of capsicum (Tables 2 & 3). Results revealed that all yield contributing characters were showed increasing trend due to application of 2 kg B ha^{-1} over the other treatments. But over dose of 3 kg B ha^{-1} or lower dose which depressed the all yield attributes. The mean (mean of three years) number of fruits per plant ranged from 5.94 to 9.80. The maximum number of fruits per plant was recorded from the treatment B level 2.0 kg ha^{-1} which was statistically significant with others treatment during 2010, 2011 and 2012. The average fruit length and diameter were varied from 5.90 to 8.17 cm and 4.89 to 6.59 cm, respectively. The highest fruit length and diameter were recorded from the treatment 2 kg B ha^{-1} which was significantly different with the other treatment but statistically identical to the treatment B_1 and B_3 in all the years. The mean individual fruit weight ranged from 79.5 to 110 g, the highest being noted at B application of 2 kg ha^{-1}. Application of B above or less than 2 kg ha^{-1} led to reduce yield of capsicum. All yield attributes were shown lowest due to control (B_0) treatment (Tables 2 & 3). Chilli and tomato yield was increased with boron application (Govindan, 1952). Schon (1990) observed that application of 1.12 kg B ha^{-1} significantly increased the yield and yield component of plant.

Table 2. Main effect of boron on yield contributing characters of capsicum

Treatment	Fruits $plant^{-1}$				Fruit length (cm)				Fruit diameter (cm)			
	2010	2011	2012	mean	2010	2011	2012	mean	2010	2011	2012	mean
B_0	3.57e	6.77c	7.47c	5.94	5.23b	6.23b	6.23b	5.90	4.60b	5.05b	5.03b	4.89
B_1	5.75b	9.78b	10.48b	8.67	6.33a	8.29a	8.27a	7.63	5.74a	6.55a	6.26a	6.18
B_2	7.33a	10.7a	11.36a	**9.80**	6.74a	8.92a	8.84a	**8.17**	6.23a	6.92a	6.61a	**6.59**
B_3	5.75b	9.53b	10.23b	8.50	6.5la	8.05a	8.05a	8.05	5.85a	6.27a	5.96a	6.03
CV (%)	6.91	11.2	10.55	-	5.76	9.75	9.85	-	4.56	8.45	8.65	-

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

Table 3. Main effect of boron on yield and yield contributing characters of capsicum

Treatment	Weight $fruit^{-1}$ (g)				Yield (t ha^{-1})			
	2010	2011	2012	mean	2010	2011	2012	mean
B_0	74.13b	82.5b	81.8b	79.5	8.18b	25.3c	25.6c	19.7
$B_{1.0}$	79.55b	113a	111.9a	101	10.9a	35.3b	35.3b	27.2
$B_{2.0}$	87.08a	122a	120.2a	**110**	11.5a	38.0a	37.8a	**29.1**
$B_{3.0}$	78.57b	111a	109.5a	99.7	10.6a	34.9b	34.9b	26.8
CV (%)	7.13	10.5	10.25	-	7.39	12.7	11.85	-

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

Effect of Zinc

During single application of different level of Zn were contributed significant role for showed positive performance on yield and yield component of capsicum during 2010, 2011 and 2012 (Tables 4 & 5). The average numbers of fruits per plant were varied from 6.56 to 9.57 due to different levels of Zn application where the maximum number of fruits per plant (9.57) were found in 3 kg Zn ha^{-1} and the lowest (6.56) was recorded from Zn_0. The mean of fruit length and fruit diameter ranged from 6.22 to 8.32 cm and 4.96 to 6.61 cm. The highest average length (8.32 cm) and diameter (6.61 cm), respectively were obtained from 3 kg Zn ha^{-1} followed by 4 kg Zn ha^{-1} and 2 kg Zn ha^{-1} and the lowest was recorded from $Zn_{0.}$ The mean fruit weight varied from 84.7 to 109 g. The highest fruit weight (109 g) was produced by 3 kg Zn ha^{-1} followed by 4 kg and 2 kg Zn ha^{-1}. Hossain *et al.* (2010) reported that different level of Zn application with blanket dose of 20-20-20-5-1 kg NPKSB ha^{-1} significantly influenced the yield contributing characters of lentil.

The lowest results of all yield contributing characters were observed in Zn_0 plot. The highest average yield (29.2 t ha^{-1}) was found by the application 3 kg Zn ha^{-1} followed by 4 kg and 2 kg Zn application ha^{-1}. Abdo (2001) reported that the increase in yield contributing characters and yield of plant with foliar spray of Zn. The lowest yield (21.4 t ha^{-1}) was recorded from Zn control treatment (Tables 4 & 5). Results indicated that over dose or lower dose of Zn (Above or lower 3 kg Zn ha^{-1}) application might be suppressed the potential yield of capsicum.

Table 4. Main effect of zinc on yield contributing characters of capsicum

Treatment	Fruits $plant^{-1}$				Fruit length (cm)				Fruit diameter (cm)			
	2010	2011	2012	mean	2010	2011	2012	mean	2010	2011	2012	mean
Zn_0	4.38e	7.30c	7.99c	6.56	5.33e	6.68b	6.64b	6.22	4.68b	5.24b	4.95b	4.96
$Zn_{2.0}$	5.45b	9.03b	9.73b	8.07	6.11b	7.76ab	7.75ab	7.21	5.61a	6.17a	5.89a	5.89
$Zn_{3.0}$	6.55a	10.73a	11.44a	9.57	6.97a	9.03a	8.96a	8.32	6.18a	6.97a	6.67a	6.61
$Zn_{4.0}$	6.02ab	9.68b	10.38b	8.69	6.40ab	8.03ab	8.03ab	7.49	5.95a	6.39a	6.37a	6.24
CV (%)	6.91	11.22	10.55	-	5.76	9.75	9.85	-	4.56	8.45	8.65	-

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

Table 5. Main effect of zinc on yield and yield contributing characters of capsicum

Treatment	Weight $fruit^{-1}$ (g)				Yield (t ha^{-1})			
	2010	2011	2012	mean	2010	2011	2012	mean
Zn_0	75.85b	89.46b	88.75b	84.7	8.69b	27.68c	27.93c	21.4
$Zn_{2.0}$	79.26ab	106.0ab	104.3ab	96.5	10.39ab	35.28b	33.24b	26.3
$Zn_{3.0}$	85.10a	122.5a	120.7a	109	11.57a	38.13a	37.83a	29.2
$Zn_{4.0}$	79. 1ab	110.4a	109.7a	99.7	10.56b	34.45b	34.56b	26.5
CV (%)	7.13	10.55	10.25	-	7.39	12.70	11.85	-

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

Combined effect of B and Zn

Yield contributing characters and yield of capsicum were affected significantly due to combined application of Zn and B fertilizer during 2010, 2011 and 2012 (Tables 6 & 7). The highest number of fruits per plant, length and diameter of fruit were recorded from the combined treatment B_2Zn_3 which were significantly different with the other treatment, but some treatments (T_7, T_{10}, T_{12} and T_{15}) were showed identical and the lowest were recorded from treatment B_0Zn_0. Average number of fruits per plant, length and diameter of fruit were varied from 4.96 to 11.1, 5.06 to 9.29 cm and 4.10 to 7.34 cm, respectively (Table 6). Hatwar *et al.* (2003) reported that application of micronutrients viz., zinc, iron and boron in combination, which resulted in improvement of growth, yield parameters of chilli. From the three years study it seems that the interaction effect showed narrower when either lowest or highest dose of zinc and boron was applied. Similar results were observed by Shil *et al.* (2013).

Table 6. Interaction effect of boron and zinc on yield contributing characters of capsicum

Treatment	Fruits plant^{-1}				Fruit length (cm)				Fruit diameter (cm)			
	2010	2011	2012	mean	2010	2011	2012	mean	2010	2011	2012	mean
$T_1 = B_0Zn_0$	2.47f	5.85j	6.55j	4.96	3.98f	5.64e	5.55e	5.06	3.35f	4.60g	4.35g	4.10
$T_2=B_0Zn_{2.0}$	2.70f	6.35ij	7.05ij	5.37	5.03ef	5.94de	5.95de	5.64	4.2gef	4.90g	4.65g	4.58
$T_3=B_0Zn_{3.0}$	4.80cde	7.93g-I	8.63g-i	7.12	6.06b-e	7.10a-e	7.12a-e	6.76	5.51b-e	5.60d-g	5.32d-g	5.48
$T_4=B_0Zn_{4.0}$	4.30def	6.95h-j	7.65h-j	6.30	5.85cde	6.24c-e	6.28c-e	6.12	5.25cde	5.08fg	5.80fg	5.38
$T_5=B_1Zn_0$	3.20ef	7.25h-j	7.95h-j	6.13	5.65de	6.66b-e	6.62b-e	6.31	4.98de	5.16fg	4.85fg	5.00
$T_6=B_1Zn_{2.0}$	5.80b-d	9.65d-f	10.4d-f	8.62	6.25a-e	8.14a-e	8.17a-e	7.52	5.83a-d	6.60a-f	6.35a-f	6.26
$T_7=B_1Zn_{3.0}$	7.40ab	11.9ab	12.6ab	10.6	7.05abc	9.76ab	9.75ab	8.85	6.16a-d	7.58ab	7.25ab	7.00
$T_8=B_1Zn_{4.0}$	6.60abc	10.3b-e	10.9b-e	9.27	6.35a-d	8.58a-e	8.55a-e	7.83	5.98a-d	6.84a-e	6.58a-e	6.47
$T_9=B_2Zn_0$	6.35abc	7.6g-I	8.3g-i	7.42	5.95cde	6.88b-e	6.85b-e	6.56	5.25cde	5.36e-g	5.05e-g	5.22
$T_{10}=B_2Zn_{2.0}$	7.50ab	11.2a-d	11.9a-d	10.2	6.63a-d	9.16a-d	9.12a-d	8.30	6.35abc	7.10a-d	6.80a-d	6.75
$T_{11}=B_2Zn_{3.0}$	7.80a	12.3a	13.1a	**11.1**	7.51a	10.32a	10.04a	**9.29**	6.78a	7.78a	7.45a	**7.34**
$T_{12}=B_2Zn_{4.0}$	7.68a	11.6a-c	12.3a-c	10.5	6.85a-d	9.32a-c	9.35a-c	8.51	6.52ab	7.42a-c	7.15a-c	7.03
$T_{13}=B_3Zn_0$	5.50cd	8.45f-h	9.95f-h	7.97	5.73de	7.52a-e	7.55a-e	6.93	5.15cde	5.84c-g	5.55c-g	5.51
$T_{14}=B_3Zn_{2.0}$	5.80bcd	8.98e-g	9.68e-g	8.15	6.52a-d	7.78a-e	7.75a-e	7.35	5.95a-d	6.08b-g	5.75b-g	5.93
$T_{15}=B_3Zn_{3.0}$	6.20abc	10.7a-d	11.4a-d	9.43	7.26ab	8.92a-d	8.95a-d	8.38	6.25abc	6.92a-e	6.65a-e	6.61
$T_{16}=B_3Zn_{4.0}$	5.50cd	9.95c-f	10.7c-f	8.72	6.53a-d	7.98a-e	7.95a-e	7.49	6.06a-d	6.22a-g	5.95a-g	6.08
CV (%)	6.91	11.22	10.55	-	5.76	9.75	9.85	-	4.56	8.45	8.65	-

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

Table 7. Interaction effect of boron and zinc on yield and yield contributing characters of capsicum

Treatment	Weight fruit^{-1} (g)			mean	Yield (t ha^{-1})			mean	% Yield increased over control
	2010	2011	2012		2010	2011	2012		
T_1= B_0Zn_0	69.67e	70.40f	71.45f	70.5	6.70d	22.48i	22.45i	17.2	-
T_2=$B_0Zn_{2.0}$	72.33de	77.60ef	75.65ef	75.2	8.05cd	23.77hi	23.75hi	18.5	7.56
T_3=$B_0Zn_{3.0}$	82.33a-d	99.01b-f	97.85b-f	93.1	9.70a-d	30.45e-h	30.55e-h	23.6	37.2
T_4=$B_0Zn_{4.0}$	72.17de	82.40d-f	82.35d-f	78.9	8.25bcd	25.45hi	25.50hi	19.7	14.5
T_5=B_1Zn_0	74.83cde	86.73c-f	85.75c-f	82.4	9.10a-d	27.04g-i	27.05g-i	21.1	22.7
T_6=$B_1Zn_{2.0}$	77.33b-e	115.70a-d	113.85a-d	102	11.25abc	35.65a-f	35.50a-f	27.5	59.9
T_7=$B_1Zn_{3.0}$	84.55abc	134.00ab	132.75ab	117	l2.10a	41.15ab	41.15ab	31.5	83.1
T_8=$B_1Zn_{4.0}$	81.50a-e	116.10a-d	115.25a-d	104	11.30abc	37.35a-e	37.55a-e	28.7	66.8
T_9=B_2Zn_0	81.l7a-e	97.53b-f	95.55b-f	96.5	9.25a-d	29.45f-h	29.35f-h	22.7	31.9
T_{10}=$B_2Zn_{2.0}$	88.55ab	123.20a-c	121.25a-c	111	11.75abc	39.75a-d	39.85a-d	30.5	77.3
T_{11}=$B_2Zn_{3.0}$	92.33a	138.60a	135.65a	**122**	12.88a	41.35a	41.25a	**31.8**	**84.8**
T_{12}=$B_2Zn_{4.0}$	86.25abc	129.50ab	128.50ab	115	11.95ab	40.55a-c	40.85a-c	31.1	80.8
T_{13}=B_3Zn_0	77.73b-e	103.20a-f	102.25a-f	94.4	9.72a-d	32.75d-g	32.85d-g	25.1	45.9
T_{14}=$B_3Zn_{2.0}$	78.83b-e	107.50a-f	106.25a-f	97.5	10.50a-d	33.95c-g	33.85c-g	26.1	51.7
T_{15}=$B_3Zn_{3.0}$	81.17a-e	118.50a-d	116.65a-d	105	11.58abc	38.55a-d	38.35a-d	29.5	71.5
T_{16}=$B_3Zn_{4.0}$	76.55b-e	113.70a-e	112.65a-e	101	10.75abc	34.45b-f	34.35b-f	26.5	54.1
CV (%)	7.13	10.55	10.25	-	7.39	12.70	11.85	-	-

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

The highest fruit weight (g) was found in the treatment T_{11} ($B_2.Zn_3$) which was significantly higher with others treatment but statistically identical to T_7, T_{10}, T_{12} and T_{15} treatments. The average fruit weight ranged from 70.5 to 122 g. The mean yield of capsicum was varied from 17.2 to 31.8 t ha^{-1} due to different treatment combinations. The highest yield was recorded from the treatment combination T_{11} ($B_2.Zn_3$) which showed significantly different among the treatments but statistically identical with T_6, T_7, T_8, T_{10}, T_{12} and T_{15} treatments combination during 2010, 2011 and 2012. The lowest yield was obtained from control (B_0Zn_0) treatment. The fruit yield increased over control ranged from 7.56 to 84.8% where the highest increase (84.8%) was recorded from the treatment combination T_{11} ($B_2.Zn_3$) followed by T_7 and T_{12} treatment. However, combined application of both boron and zinc was found to be more effective than their single application. Hatwar *et al*. (2003) reported application of micronutrients viz., zinc, iron and boron in combination, which resulted in improvement of yield parameters and yield of chilli. Quddus *et al.* (2014) observed that combined application of Zn and B significantly affected the yield and yield contributing characters of lentil. Sakal *et al.* (1986) also reported the similar trend.

Regression analysis showed positive and quadratic response for mean yield and applied B (Fig. 1). The optimum dose of B was calculated from the quadratic response function and was 2.97 kg ha^{-1} (Table 8). For optimum dose, the maximum yield (29.31 t ha^{-1}) could be expected in Gazipur area (Table 8). However, the optimum economic dose of B was 2.15 kg ha^{-1}. Beyond the optimum dose, 1 kg ha^{-1} excess B was applied, then a risk of 7.65 t ha^{-1} reduced yield was noted (Table 8).

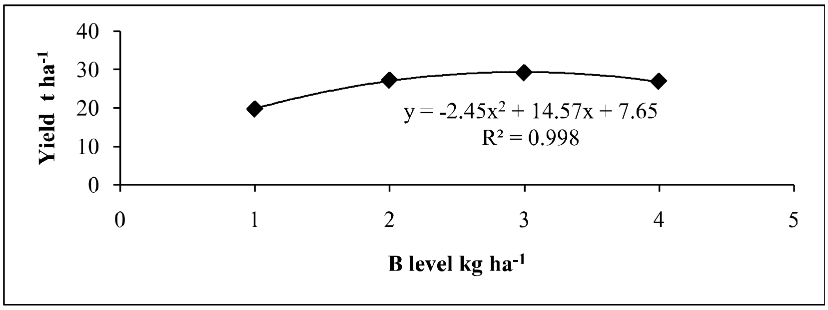

Fig. 1. Response of capsicum to boron fertilization.

A positive and quadratic relationship was also observed between yield and level of Zn (Fig. 2). The optimum dose of Zn from the quadratic production function was 2.98 kg ha^{-1} (Table 8). Using the optimum dose, the maximum yield (28.66 t ha^{-1}) could be expected for Gazipur area (Table 8). However, the optimum economic dose of Zn was 2.48 kg ha^{-1}. Above this optimum dose, 1 kg ha^{-1} excess Zn if applied then there was a risk of 11.8 t ha^{-1} reduced yield (Table 8).

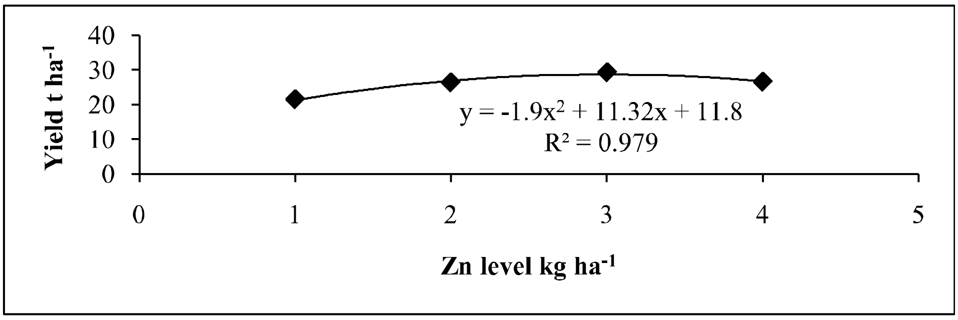

Fig. 2. Response of capsicum to zinc fertilization.

Table 8. Response function of capsicum to B and Zn for yield at Gazipur

Regression equation	Co-efficient of determination (R^2)	Optimum dose (kg ha^{-1})	Economic dose (kg ha^{-1})	Maximum yield (t ha^{-1}) for optimum dose	Beyond optimum dose the reduction of yield (t ha^{-1}) for 1 kg B or Zn
B					
$y = 7.65 + 14.57x - 2.45x^2$	0.998	2.97	2.15	29.31	7.65
Zn					
$y = 11.8 + 11.32x - 1.9x^2$	0.979	2.98	2.48	28.66	11.8

Capsicum= 200 Tk. kg^{-1}; Zn = 377 Tk. kg^{-1}; B = 800 Tk. kg^{-1}.

Conclusion

From the trial, it could be concluded that combined application of boron and zinc at 2 kg and 3 kg ha^{-1}, respectively with blanket dose of $N_{150}P_{65}K_{120}S_{20}$ kg ha^{-1} and cow dung 10 t ha^{-1} gives higher yield of capsicum in terrace soil under Madhupur Tract (AEZ 28). The quadratic response function, the optimum-economic dose of boron and zinc were calculated to be 2.15 and 2.48 kg ha^{-1}, respectively. So, the farmers of Gazipur can use $B_{2.15}Zn_{2.48}$ kg ha^{-1} for capsicum cultivation.

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DYNAMICS OF PHYTOHORMONES AND THEIR RELATIONSHIP WITH CHALKINESS OF EARLY *INDICA* RICE UNDER DIFFERENT POST-ANTHESIS TEMPERATURE REGIMES

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Abstract

A pot experiment on an early *indica rice* cv. 'Shenyou9576' was conducted in the net house of Hunan Agricultural University, Changsha, Hunan, PR China during the early growing season of 2013 to investigate the influence of varying temperatures on chalkiness rate, head rice rate, and phytohormones, namely indole-3-acetic acid (IAA), gibberellins (GA_1 and GA_4), zeatin (Z), zeatin riboside (ZR) and abscisic acid (ABA) both in flag leaves and grain endosperm during grain filling period. The treatments comprised three temperature regimes which are designated as the high (35/28ºC- day/night), low (25/20ºC- day/night) and natural condition as the control (35/25ºC- day/night). The results showed that the maximum chalkiness rate was 61.11% under high temperature and the minimum (22.59%) under low temperature. The lowest head rice rate was 42.76% under high temperature followed by 49.91% in the control, while the highest (62.33%) under low temperature. The contents of GA_1, GA_4, Z and ZR were decreased gradually from 7 to 35 days after anthesis (DAA) irrespective of treatments. IAA content began to decrease from 14 DAA and continued up to 35 DAA and ABA was reduced from 28 to 35 DAA under low temperature in comparison to control and high temperature. ABA content was increased from 7 to 21 DAA and then declined at high temperature. The results showed that contents of $GA_{1,}$ GA_4, Z, ZR were high at low temperature compared to high temperature and control. IAA content was also high during grain development period at low temperature except 7 DAA. Higher phytohormone contents were observed in endosperm than in flag leaves. Phytohormone content ratio (endosperm: flag leaves) was found highest in IAA and the lowest in $GA_{1.}$ A significant positive correlation was found between ABA and chalkiness rate during early to mid grain filling period, while significant negative correlations were noticed between chalkiness rate and other phytohormones during grain filling period. Correlation results revealed that increased level of ABA during early to mid grain filing period caused by high temperature was more responsible for development of chalkiness.

Keywords: Rice (*Oryza sativa* L.*)*, high temperature, phytohormones, head rice rate, chalkiness rate.

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Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops in the world as it serves as the staple food of more than a half of the world's population. Grain quality is one of the most important factors in rice production and in economic returns for the farmers. The most important rice quality components include milling, appearance, cooking, eating and nutrient qualities (Han *et al.*, 2004; Koutroubas *et al*., 2004). Appearance quality of rice grain depends on endosperm color and grain dimension, while endosperm color is mainly determined by the degree of chalkiness i.e. the white opaque part in rice endosperm. The appearance quality of rice kernel with more chalkiness influences on the milling percentage, cooking, nutritional and eating quality. Rice grains with more chalkiness are likely to break during milling, which affects the commercial value of milled rice and the market acceptability (Borrell *et al*., 1997). Chalkiness forms longitudinal and transverse cracks, and causes broken or loosen rice grain when cooked, resulting in poor eating quality. Previous studies showed that the environmental (specially daily average-temperature during grain filling) and genetic factors are associated with chalkiness formation (Dong *et al*., 2006; Koutroubas *et al*., 2004; Zhang *et al*., 2008). It is also reported that high temperature stress affects the occurrence of chalky kernels (Patindol and Wang, 2003).

During the grain filling period, rice grains act as strong carbohydrate sinks (Cao *et al*., 1992). It is assumed that hormones in a sink organ are prominent factors in determining sink strength and it has been proposed that grain development may be mediated through endogenous phytohormones (Naik and Mohapatra, 1999; Yang *et al*., 2000, 2001). It is generally believed that plant hormones including indole-3-acetic acid (IAA), abscisic acid (ABA), zeatin riboside (ZR), and gibberellin (GA) are closely associated with grain development (Wobus and Weber, 1999). The intrinsic factors are responsible for variations in grain development as well as chalkiness. The limited work on the characteristics of endogenous phytohormones changes and their relationships with rice grain chalkiness under post-anthesis temperature conditions was done. Therefore, the present study was conducted to investigate the influence of different temperatures on chalkiness, head rice rate, and changes of IAA, gibberellins (GA_1 and GA_4), cytokinins (Z and ZR) and ABA contents throughout the grain filling period and to reveal the relationship between chalkiness and the phytohormone content.

Materials and Method

Experiment description

The experiment was carried out in the net house of Hunan Agricultural University, Changsha, Hunan, PR China, in the early rice growing season from

April to August of 2013. The tested rice variety was a heat tolerant early *indica* rice ‘Shenyou 9576’. Germinated seeds of rice were pre-grown with complete Kimura B nutrient solution (Yoshida *et al*., 1976) in a green house until 15 days. Seedlings were then transferred to earthen pots of 30 cm in diameter and 32 cm in depth filled with 7.0 kg of sieved, dry paddy soil (the contents of soil organic matter, alkaline hydrolytic nitrogen, effective phosphorus, available potassium were 1.8%, 66.2 mg kg^{-1}, 8.5 mg kg^{-1}, and 8.0 mg kg^{-1}, respectively, and soil pH was 5.4) amended with 1.0 g $CO(NH_2)_2$, 0.4 g P_2O_5, and 0.6 g K_2O per kg soil to grow. Two seedlings were transplanted in each earthen pot. Proper management practices were provided as per requirement for proper growth. The treatment consisted of three temperature regimes which are designated as high temperature (35/28°C, 12h light/12h dark, 75-80% relative humidity), low temperature (25/20°C, 12h light/12h dark, 75-80% relative humidity) and natural condition (35/25°C- day/night) as control. The treatments were imposed after anthesis by transferring pots into different growth chambers, but for the control treatment pots were kept in the net house under natural condition. The experiment was performed according to a complete randomized design (CRD) with three replications.

Sampling method

Panicles and flag leaves from each treatment were collected at 7-day interval after anthesis i.e. 7, 14, 21, 28, 35 days after anthesis (DAA). Samples were collected on 9.00 to 11.00 am and immediately wrapped in aluminum foil and frozen in liquid nitrogen, then placed into a sealed plastic bag and stored at -60°C until use for different analysis. Rice grains were harvested at 35 DAA and then were sun dried to achieve 14% moisture content. Rough rice (paddy rice) was dehusked by a SBS-80 dehuller, then was polished by a rice polisher for 2 minutes. Milled rice samples were kept in sealed bags under refrigeration (4°C) for later analysis.

Chalkiness and head rice rate measurement

Chalkiness was measured with a system composed of a scanner and a special software Chalkiness 2.0 developed by Hunan Agricultural University (Chen *et al*., 2011). Head rice refers to the whole grains of milled rice and was computed by using the following equation (Gummert, 2010).

$$\text{Head rice (\%)} = \frac{\text{Wt of whole grains}}{\text{Wt of paddy samples}} \times 100$$

Extraction, purification and determination of indole-3-acetic acid (IAA), gibberellins (GA_1 and GA_4), zeatin (Z), zeatin riboside (ZR) and abscisic acid (ABA)

Fresh plant materials (panicles or flag leaves) of 500 to 700 mg were frozen in liquid nitrogen and ground in a mortar with a pestle. After adding 800 μL of 80% methanol, samples were mixed thoroughly and kept overnight at 4°C. Then the mixtures were centrifuged at 4,800 g and 4°C for 10 min. The supernatant was transferred to a new tube and the residues were re-extracted with 800 μL of 80% methanol for 4 hours at 4°C for two times. The supernatants were combined and dried in a Jouan RCT-60 vacuum concentration system, then dissolved in 200 μL of 0.1 $molL^{-1}$ buffer (pH 7.8). The aqueous phase was purified through a Waters Sep-pak C_{18} cartridge (Waters, USA) and followed by a wash with 800 μL of ddH_2O, and then the eluted was vacuum freeze dried. The dried extract was dissolved in 40 μL of 50% methanol and used for an assay by a SHIMADJU LCMS-8030 mass spectrometer. A BEH C_{18} column (100 mm × 2.1 mm, 1.7 μm) was used and mass-to-charge ratio were 174/130.05, 220/136.1, 352.2/220.1, 347/259.2, 331/243.25, 263/153.2 for IAA, Z, ZR, GA_1, GA_4 and ABA, respectively.

Statistical analysis

All experimental data were analyzed following analysis of variance. Mean separation of the treatments was done by using Least Significant Difference (LSD) at 5% level. All statistical analysis was performed by using a statistical software, DPS version 12.01 and Microsoft Excel 2003 (Microsoft, USA) was used to generate graphs.

Under the natural condition (control) of the experiment site, daily maximum, minimum and average temperature (ºC) from flowering to harvest are shown in Fig. 1. The average daily temperature lies within 25ºC to 35ºC during this period.

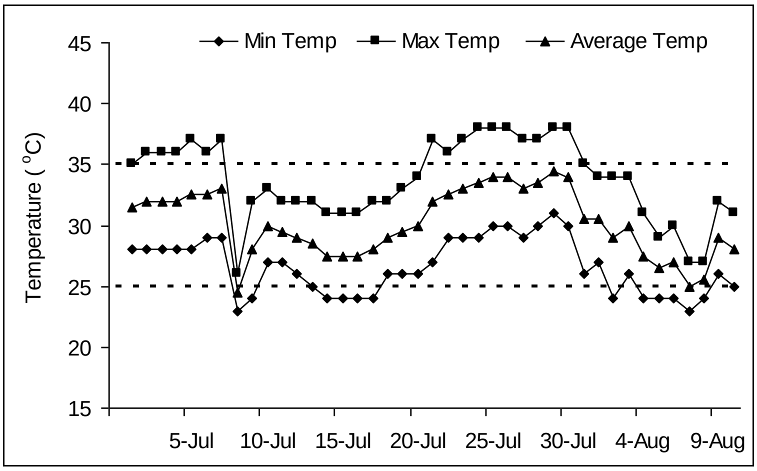

Fig. 1. Daily maximum, minimum and average air temperature (ºC) during anthesis to maturity at Changsha, Hunan, China.

Results and Discussion

A. Results

Changes of chalkiness rate and head rice rate under different temperature regimes:

Chalkiness (%) in different temperature treatments were significantly affected by different temperature regimes (Fig. 2a). The highest chalkiness rate (61.11%) was observed under high temperature and the lowest chalkiness (22.59%) under low temperature, where in control, chalkiness rate was in between high and low temperature, which was 47.81%. Therefore, chalkiness (%) was increased by high temperature stress at the grain filling stage. The highest head rice was 62.33% under low temperature followed by 49.91% under the control and the lowest (42.76%) under high temperature (Fig. 2b). Therefore, the results indicate that high temperature stress has a negative effect on head rice (%), while low temperature has a positive effect.

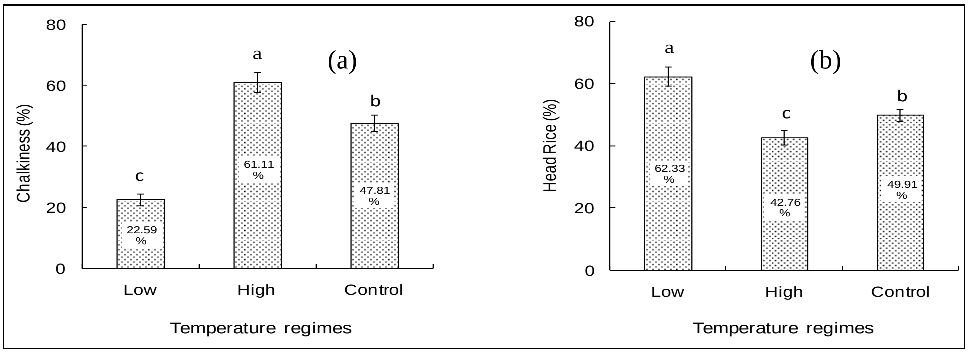

Fig. 2. (a) Chalkiness (%) and (b) head rice (%) influenced by temperature regimes after anthesis. Vertical bars represent ±SE of the mean (n=3). Bars with different letters are significantly different at 5% level by LSD.

Changes of IAA content in rice flag leaf and endosperm:

The variation of IAA content both in flag leaf and endosperm of rice was significant among the treatments in all of the studied DAAs (Fig. 3a, b). The highest IAA content (43.39 ngg^{-1} FW) was observed under high temperature at the early grain filling stage in flag leaf, and then a decreasing trend was observed up to 35 DAA. At the middle grain filling stage (14 DAA) IAA content in flag leaf was the highest under low temperature followed by the control and high temperature treatment. In rice endosperm, at the early grain filling period the highest IAA content (663.58 ngg^{-1} FW) was observed under high temperature treatment followed by the control (630.24 ngg^{-1} FW) and low temperature treatment (576.49 ngg^{-1} FW), while mid to the late grain filling period, the highest IAA content was recorded under low temperature. Therefore, low temperature is favorable for higher IAA content at the middle and the later grain filling period. Furthermore, irrespective of temperature treatments, a decreasing trend of IAA was observed from 14 to 35 DAA.

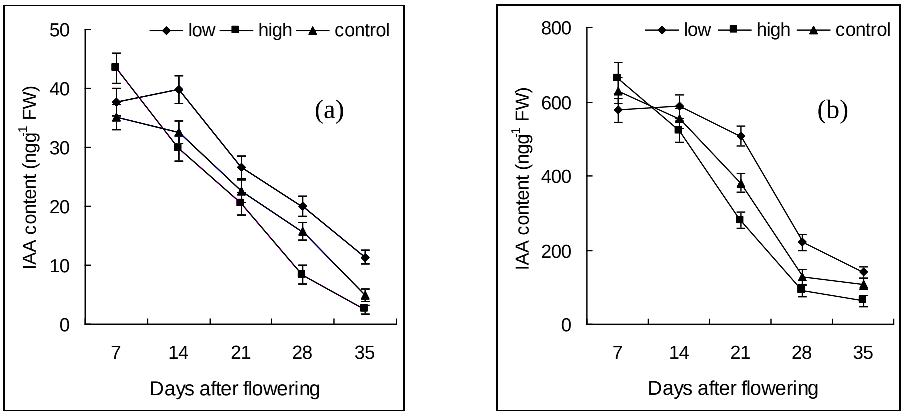

Fig. 3. Changes of IAA content in (a) rice flag leaves and (b) rice endosperm after anthesis under different temperature regimes. Vertical bars represent ±SE of the mean (n=3).

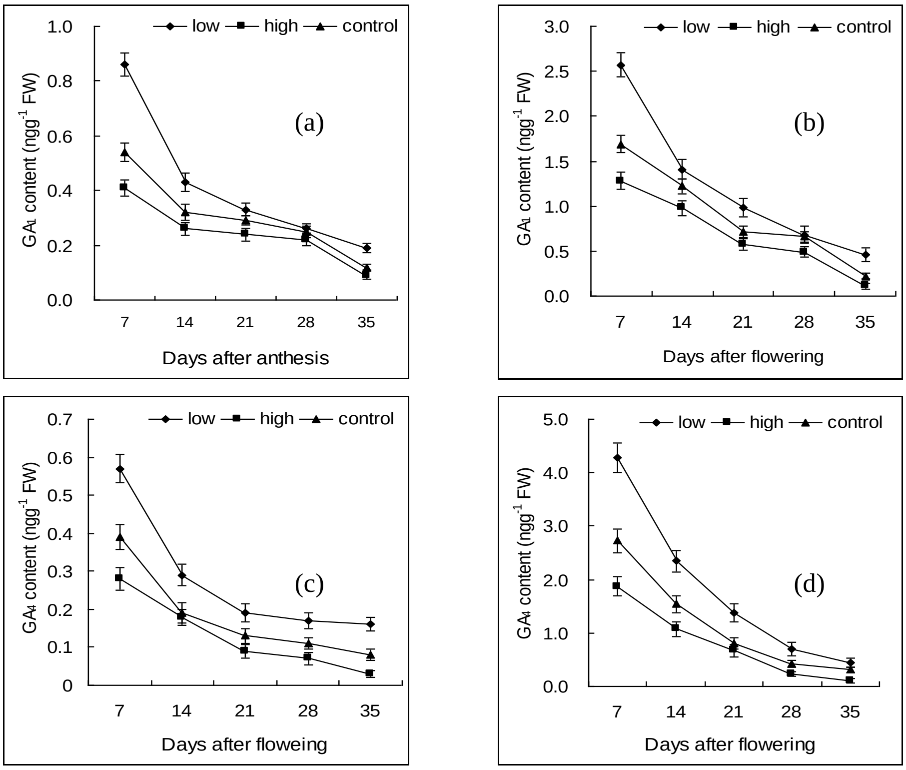

Fig. 4. Changes of GA_1 content in (a) rice flag leaves, (b) rice endosperm and GA_4 content in (c) rice flag leaves, (d) rice endosperm after anthesis under different temperature regimes. Bars represent ± SE of the mean (n=3).

Changes of gibberelins (GA_1 and GA_4) contents in rice flag leaf and endosperm:

The effect of temperature on GA_1 and GA_4 content in rice flag leaf and endosperm displayed a marked variation at all the studied DAAs (Figs. 4a, b, c, d). Irrespective of the temperature treatments higher GA_1 and GA_4 content were observed at the early grain filling period, where the lowest under high temperature and the highest GA_1 and GA_4 content under low temperature throughout the grain filling period both in rice flag leaf and grain. GA_1 content in rice endosperm under low temperature was 1.52 fold and 2 fold higher, while GA_4 content under low temperature increased 1.56 fold and 2.28 fold than the control and high temperature, respectively.

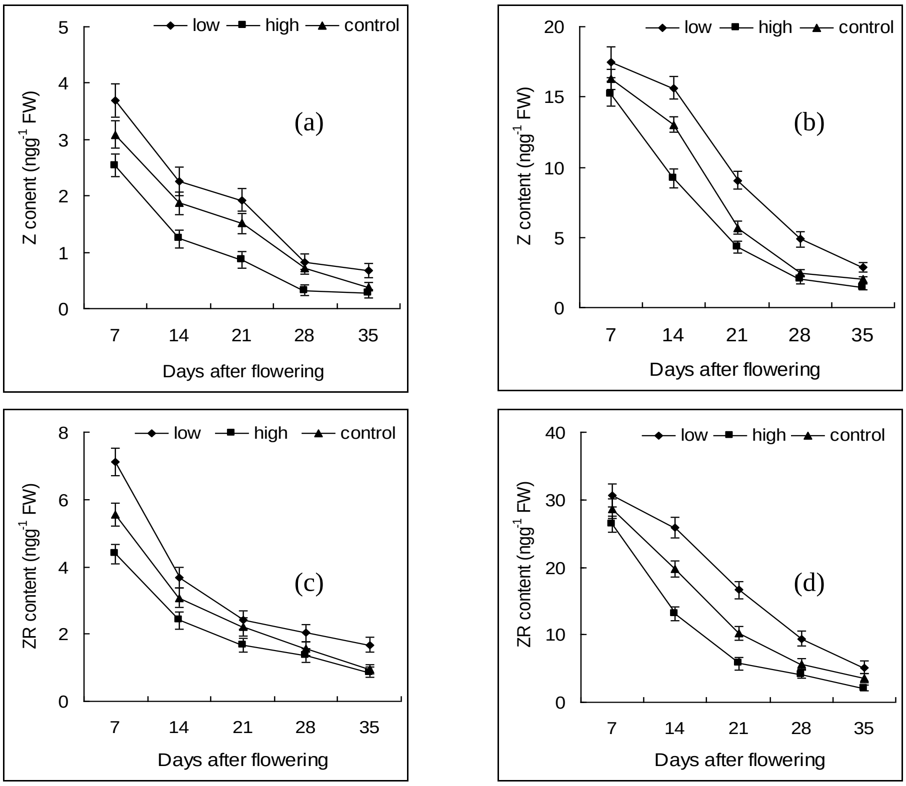

Fig. 5. Changes of Z content in (a) rice flag leaves, (b) rice endosperm and ZR content in (c) rice flag leaves, (d) rice endosperm after anthesis under different temperature regimes. Bars represent ± SE of the mean (n=3).

Changes of cytokinins (Z and ZR) contents in rice flag leaf and endosperm:

The magnitude of the differences among the three temperature regimes on Z and ZR accumulation in rice flag leaf and endosperm were important ones (Figs. 5a, b, c, d). High temperature displayed the lowest Z and ZR contents, while low temperature showed the highest Z and ZR contents both in rice flag leaf and kernel throughout the grain filling period. On an average higher Z and ZR contents were found at the early grain filling period than at the middle or later grain filling period. At 7 DAA, Z content in rice endosperm under low temperature was 7.44% and 14.71% higher than the control and high temperature, respectively. However, Z content in rice endosperm was about 6 times higher than flag leaf. Relative to the control, exposure to high temperature ZR accumulation in kernel was reduced by 8-44% and increased by 7-65% in the different DAAs. The results showed that there was more depletion of Z and ZR contents under high temperature and the control than low temperature both in rice flag leaf and endosperm.

Changes of abscisic acid (ABA) level in rice flag leaf and endosperm:

Significant effect was found among the temperature treatments on ABA content both in rice flag leaf and endosperm (Figs. 6a, b). Under high temperature ABA content in flag leaf increased gradually from 7 DAA, and had a peak (26.45 ngg^{-1} FW) at 21 DAA, while under low temperature reached a peak value of 26.77 ngg^{-1} FW at 28 DAA. High temperature treatment showed a significantly higher ABA level in rice endosperm compared to control and peaked at 21 DAA (Fig. 6b). Low temperature treatment showed significantly lower ABA level up to 21 DAA, but on wards to 28 and 35 DAA in rice endosperm showed higher ABA level.

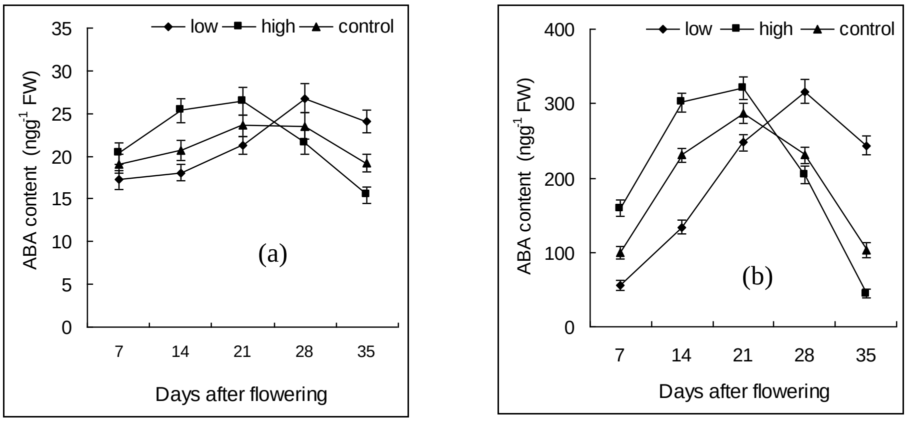

Fig. 6. Changes of ABA content in (a) rice flag leaves (b) and rice endosperm after anthesis under different temperature regimes. Bars represent ± SE of the mean (n=3).

Comparison of phytohormones content between developing endosperm and flag leaves of rice:

The influence of phytohormones on the metabolism of carbohydrates in rice endosperm as well as in photosynthetic tissue, both in the developing endosperm and flag leaf of rice and the phytohormones content ratio between developing endosperm and flag leaves of rice are presented in Table 1. Several-folds (1.22 to 19.12 fold) higher phytohormones were observed in endosperm than in flag leaves. The highest ratio (8.56 to 19.12) was noted in IAA than others hormones irrespective of treatments followed by ABA, while the ratio was lower for GA_1 (1.22 to 3.77). However, the ratio between rice endosperm and flag leaves for GA_4 was markedly higher than GA_1. The ratio was almost similar both for Z and ZR and higher ratio were found under low temperature than the other two treatments both in Z and ZR throughout the endosperm developing period except 7 DAA, which indicated that both Z and ZR play similar role on starch biosynthesis and the low temperature has positive effect on the reduction of chalkiness.

Table 1. Ratio of phytohormones content between rice grain and flag leaf

Name of phytohormones	Treatment	Phytohormones ratio between grain and flag leaf (Mean of 3 replications)				
		7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
	low	15.32	14.72	19.12	13.56	12.38
IAA	High	15.29	17.42	13.70	10.69	8.56
	Control	17.91	17.07	16.82	11.17	9.41
	low	2.99	4.28	2.97	2.62	2.42
GA_1	High	3.12	3.77	2.42	2.03	1.22
	Control	3.13	3.81	2.45	2.34	1.83
	low	6.49	8.32	7.26	4.12	2.75
GA_4	High	6.68	5.94	4 .54	3.29	3.67
	Control	7.00	8.11	6.23	3.82	3.88
	low	4.73	6.95	5.70	5.89	4.31
Z	High	6.00	6.44	4.02	4.28	3.41
	Control	5.26	6.87	3.76	3.44	3.15
	low	4.31	7.03	6.87	4.60	3.08
ZR	High	6.02	5.42	3.41	3.07	2.42
	Control	5.17	6.42	4.60	3.64	3.78
	low	3.24	7.42	11.63	11.81	10.10
ABA	High	7.85	11.90	12.11	9.45	2.87
	Control	5.21	11.13	12.14	9.81	5.40

IAA= Indole-3-acetic acid, GA_1= Gibberellin A_1, GA_4= Gibberellin A_4, Z = Zeatin, ZR = Zeatin riboside and ABA = Abscisic acid, DAA = Days after anthesis

Correlation between phyhormones and chalkiness

The correlations among IAA, ABA, GAs (GA_1 and GA_4), Z & ZR and chalkiness were analyzed and the results are presented in Table 2. It was found that IAA content in rice endosperm was not significantly correlated with chalkiness at 7 and 14 DAA, while significant negative correlation was observed at 21, 28 and 35 DAA. A significant negative correlation was observed between chalkiness and both GA_1 and GA_4 throughout the grain filling period except GA_1 at 28 DAA. All correlation coefficients between the Z and ZR level and chalkiness were negative. At 7 DAA the relationship between the Z and ZR level and chalkiness was weaker and insignificant, but in the later DAAs significantly negative correlations except for ZR at 35 DAA. The ABA levels in rice grains were significantly and positively correlated with chalkiness at 7, 14 and 21 DAA, but significantly and negatively correlated with chalkiness at later grain filling period (28 and 35 DAA).

B. Discussion

Grain filling is the most important developmental process that influences chalkiness, other quality indexes and grain yield of rice. The result showed that chalkiness was reduced by 52.75% under low temperature and increased by 27.82% under high temperature over the control. On the other hand, head rice was increased by 24.88% under low temperature and decreased by 14.33% under high temperature over the control. Furthermore, low temperature at grain developing stage is important for more economic returns for farmers due to reducing grain breakage or increasing head rice production (Koutroubas *et al*., 2004).

Table 2. Coefficient of correlation between chalkiness(%) and phytohormones level in the different DAAs

Name of phytohormones	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
IAA	0.5302^{NS}	-0.3938^{NS}	-0.8814**	-0.7839*	-0.6751*
GA_1	-0.8753**	-0.7928*	-0.6744*	-0.3435^{NS}	-0.7909*
GA_4	-0.8661**	-0.8092**	-0.7183*	-0.7188*	-0.6738*
Z	-0.4102^{NS}	-0.8105**	-0.8492**	-0.7990*	-0.7254*
ZR	-0.4474^{NS}	-0.8368**	-0.8550**	-0.7515*	-0.6347^{NS}
ABA	0.9017**	0.9449**	0.8072**	-0.8386**	-0.9629**

Note: **, * and NS indicate significant differences at 1%, 5% probability level, and non-significant, respectively

IAA= Indole-3-acetic acid, GA_1= Gibberellin A_1, GA_4= Gibberellin A_4, Z = Zeatin, ZR = Zeatin riboside and ABA = Abscisic acid, DAA = Days after anthesis

IAA is the most abundant endogenous hormones in plants, which regulates shoot growth, root branching, flowering and fruit ripening (Srivastava, 2002). It was found that low temperature treatment has an obvious impact to maintain higher IAA both in rice flag leaf and endosperm from the middle to the late grain filling stage. Early senescence of flag leaf under high temperature treatment might be due to the lower IAA content in flag leaf. IAA content in rice endosperm was found 19.12 times higher than in flag leaf. The positive effect of IAA on the photo-assimilate translocation within developing wheat grains have been reported by Darussalam Cole and Patrick (1998).

GAs control a wide range of processes during plant development, including seed germination, organ elongation and flower development (Yamaguchi, 2008). The result showed that lowering temperature increases GA_1 and GA_4 content both in rice flag leaf and endosperm throughout the grain filling period. It is well known that GAs levels are prevalent in developing grains, hence may be related to dry matter accumulation in grains. The relationship between chalkiness and GAs (GA_1 and GA_4) was stronger and more negative at a significant level at 7 and 14 DAA than at 21, 28 and 35 DAA, which indicates that GAs (GA_1 and GA_4) play an important role in the early to the middle grain filling stage than in the later stage for reduction of chalkiness.

Cytokinins are involved in the regulation of nutrient mobilization, senescence and flowering (Silverman *et al.*, 1998). The contents of Z and ZR both in rice flag leaf and endosperm were significantly decreased irrespective of the treatments, but the lower temperature maintained a lead over high temperature and control treatments from 7 DAA to 35 DAA. Higher contents of Z and ZR in the flag leaf under low temperature causes delayed senescence of flag leaf. The results also showed that irrespective of the treatments, the highest levels of Z and ZR were found at the early stage of grain development. The results also showed that high temperature stress reduced kernel Z and ZR contents as compared to control. Significant and negative correlation was observed between Z & ZR, and chalkiness at the middle and late grain filling stage, which indicates that Z and ZR has a positive role in reduction of chalkiness at the middle and late grain filling stage. Considering the physiological function of cytokinines, the reduced cytokinin level resulted in depressed sink activity with higher chalkiness under high temperature stress.

ABA can promote dry matter accumulation in the sink organ which correlated with the growth rate of fruits or seeds (Wang *et al*., 1998; Yang *et al*., 2001). The result showed that relative to the control, high temperature stress increased ABA content both in rice flag leaf and endosperm from 7 DAA to 21 DAA but decreased ABA content at the later grain filling stage (28 and 35 DAA). A reverse trend was observed for low temperature treatment. Therefore, higher ABA content at the early grain filling stage enhances the senescence of flag leaves under high temperature stress. Rice grains mature earlier under high temperature than low temperature because ABA level plays an important role in positively regulating assimilate accumulation and accelerating maturation in developing grain (Yang *et al*., 1999; Duan *et al*., 1999). The relationship between ABA and chalkiness was significantly positive up to 21 DAA, but negative at 28 and 35 DAA. Therefore, rapid accumulation of ABA from the early to the mid-late grain filling stage in rice endosperm, mediated by high temperature stress, enhanced chalkiness, but slower accumulation by low temperature from the early to the mid-late grain filling stage promoted lower chalkiness.

Among those phytohormones, IAA and ABA contents were much higher than GA_1, GA_4, Z and ZR in rice endosperm than in flag leaves which might reveal that IAA and ABA play important role for efficient production of starch as well as chalkiness in rice endosperm.

Conclusion

High temperature stress accelerates senescence of flag leaves, shortens grain filling period and accelerates poor grain filling or formation. In addition, high temperature also increases grain chalkiness and reduces head rice rate. The reduction of rice endosperm chalkiness was closely associated with the increased levels of IAA, GA_1, GA_4, Z, ZR throughout the grain filling period and the increased level of ABA at 28 & 35 DAA under low temperature. The changes of endogenous phytohormone levels under different temperature regimes affected chalkiness through influencing the starch synthesis enzymes activity and other process. Rice grain chalkiness could be reduced by the regulation of phytohormone levels as well as by their balance in rice plants or grain either by using chemical, synthetic phytohormone or genetic improvement.

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CROP COEFFICIENT OF A POPULAR POTATO VARIETY IN BANGLADESH

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Abstract

Crop evapotranspiration (ET_c) and crop coefficient (K_c) values of potato (variety: BARI Alu -7, Diamant) at different growth stages were determined through lysimeter method at Irrigation and Water Management Division of Bangladesh Agricultural Research Institute (BARI), Gazipur during 2008 - 2009. The study was conducted by applying irrigation at 25 and 40 days after planting (DAP) allowing drainage (AD) (T_1), at 25, 40, and 55 DAP AD (T_2), at 25, 40, and 60 DAP AD (T_3), and at 25, 40, 55, and 60 DAP AD (T_4) within and adjacent of four lysimeter tanks. Irrigation at 25, 40, and 55 DAP produced the highest tuber yield and was considered to be suitable for estimating seasonal ET_c, and K_c values. The seasonal highest ET_c was found to be 162 mm. The K_c values of 0.25, 0.62, 0.70 and 0.18 were determined at initial, development, mid-season and late season stages of potato. These values differed slightly from the FAO recommended values. As the lysimeter provides control environment, the K_c values determined by this method are most dependable and recommended for estimating ET_c of potato in semi-arid climatic conditions of Bangladesh.

Introduction

Potato is an important tuber crop in Bangladesh after rice in terms of area and production (BBS, 2014). Its production is increasing day by day due to cultivation of high yielding variety, improved management practices and favourable climatic condition. Potato is an important winter crop, and irrigation is necessary for its normal growth and yield. But, irrigation water becomes costly and scarce resource due to unavailability of rainfall during winter. Utilizing this scare resource for agricultural crop production, proper irrigation scheduling of specific crop is needed. In this regard, crop coefficient values of specific crop are a probable solution. The reliable method for determining the crop coefficient values is using lysimeter. Lysimeter is a device which separates hydro logically from surrounding soil using a container of known volume of soil planted with vegetation (Michael, 2014) and can get accurate crop evapotranspiration (ET_c) data for the specific time.

Crop coefficient (K_c) represents crop actual water need in regional scale which is the ratio of actual crop evapotranspiration (ET_c) and potential evapotranspiration (ET_o) (Allen *et al*., 1998). This value is necessary for the estimation of exact irrigation requirement of various crops for that specific area. However, there are some reported K_c values determined by FAO for different crops and are

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recommended for places where local data are not available. This FAO recommended values differ from location to location as well as from season to season. So, Tyagi *et al.* (2000) recommended utmost importance for the locally calibrated K_c values for a given climatic condition. Many researchers determined K_c values of potato using different lysimeter under various climatic conditions across the world (Carvalho *et al.*, 2013; Kashyap and Panda, 2001; Allen *et al,*. 1998; Ferdous *et al.*, 1985; Hane and Pumphre, 1984; Doorenbos and Kassam, 1979; Doorenbos and Pruitt, 1977). Karim and Akhand (1982) presented the result of evapotranspiration of potato in 18 locations of Bangladesh. They determined the average K_c values of potato for the month of November to March after determining ET_c from FAO recommended value. Besides, they used indigenous potato cultivar to calculate ET_c value owing to nonexistence of hybrid or modern potato variety before 1990 in Bangladesh. But, in this experiment, the variety we used is short durated and high yield potential, and can easily fit in four crop-based cropping patterns in Bangladesh. Besides, the physiological characteristics of a crop differ with various soil and climatic conditions which is related to change in the ET process. In consideration of this, it is necessary to determine crop coefficient values locally to get the exact regional scale data. Besides, the information on crop water requirement is also necessary for policy planning on water management (Mainuddin et al., 2015) as well as fitting crop in a cropping pattern for a specific location. Therefore, this study was conducted to determine crop coefficient values of a popular potato variety (BARI Alu-7, Diamant) at different growth stages by micro lysimeter in the experimental field of IWM division, BARI, Gazipur, Bangladesh.

Materials and Method

The experiment was conducted at the research farm of Irrigation and Water Management Division, Bangladesh Agricultural Research Institute, Gazipur, (latitude, longitude, and elevation from MSL were $24^0 00'$N, $90^0 25'$E and 8.40 m) during 2008 – 2009 using micro lysimeter. The weather data during the crop period was collected from the Agro-meteorological station which was very close to the experimental field. The weather variations during the crop period are presented in Figs.1–4. The soil was silty clay loam with field capacity and bulk density of 28% and 1.5 g/cc, respectively.

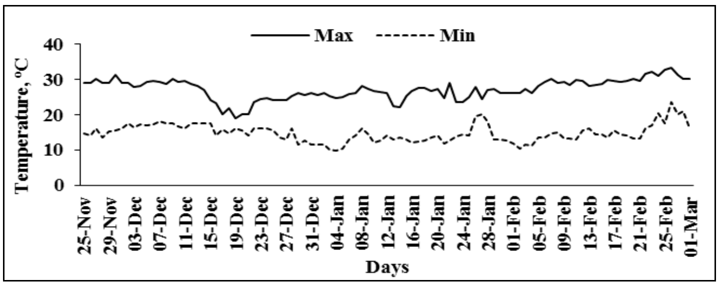

Fig. 1. Daily maximum and minimum air temperatures during 2008-2009 crop cycle.

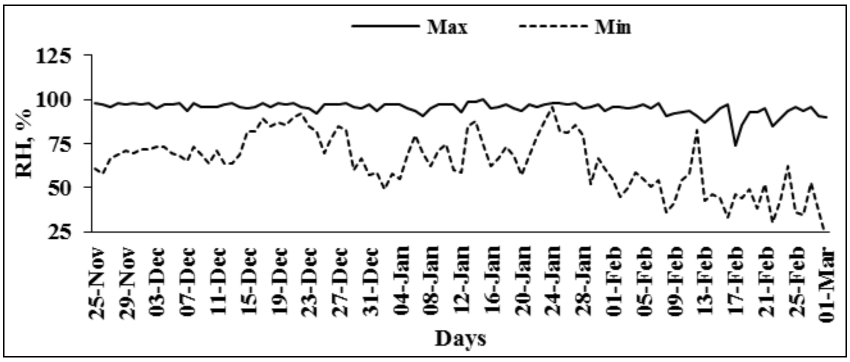

Fig. 2. Daily maximum and minimum relative humidity during 2008-2009 crop cycle.

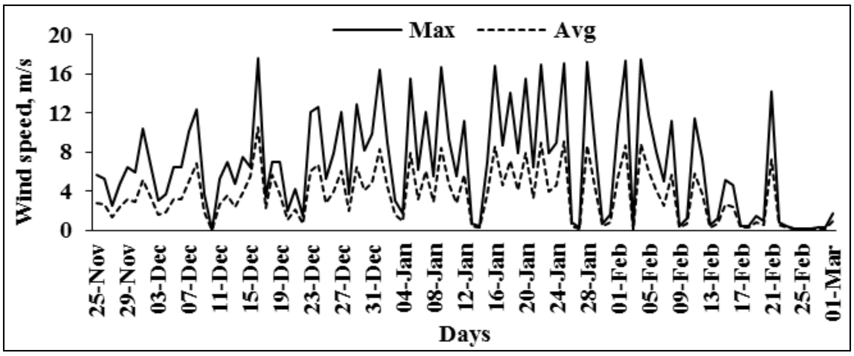

Fig. 3. Daily maximum and average wind speed during 2008-2009 crop cycle.

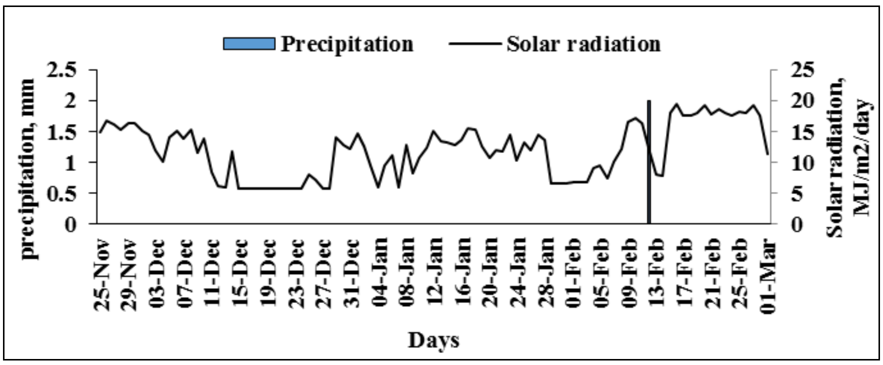

Fig. 4. Daily precipitation and solar radiation during 2008-2009 crop cycle.

Potato seeds (variety: BARI Alu -7, Diamant) were planted on 25 November, 2008 in four lysimeter tanks maintaining row to row and plant to plant spacing of 60 cm × 25 cm. Recommended fertilizer was applied at the rate of N_{121}, P_{27}, K_{125}, S_{12}, Mg_7, Zn_2, and B_1 kg/ha and cowdung 5 t/ha. During final land preparation, half of N and total amount of other fertilizers were applied and rest of N was top dressed after 30 DAP. Intercultural operation (ear thing up after 30 DAP, and weeding) and pesticides were applied according to necessity. A pre-irrigation of 25 mm was applied in the field for proper seed germination and plant establishment. Also, to maintain a similar atmosphere, the same crop was grown in the entire field around the lysimeter tanks (Fig. 5). The crop was harvested at 01 March, 2009. The selected treatments were as follows:

T_1= Irrigations at 25 and 40 days after planting (DAP) allowing drainage (AD)

T_2= Irrigation at 25, 40 and 55 DAP AD

T_3= Irrigation at 25, 40 and 60 DAP AD

T_4= Irrigation at 25, 40, 55 and 60 DAP AD

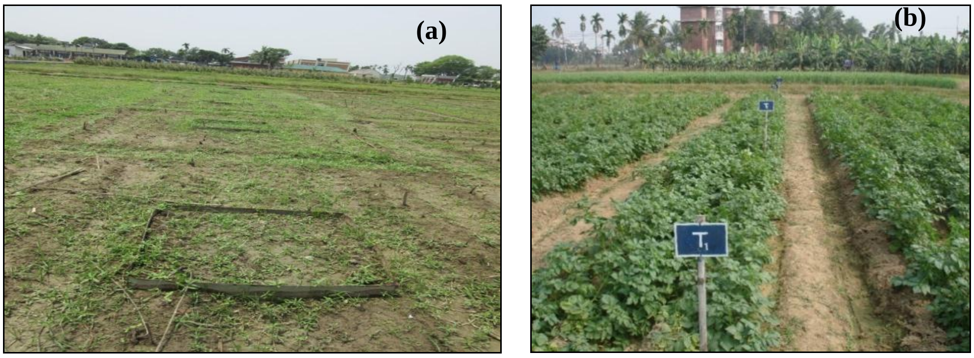

Fig. 5. Overview of experimental field (a) Lysimeter tank and (b) potato crop at vegetative stage.

The micro lysimeter contains 4 tanks, each having an area of 1.0 m^2 which was designed and installed by Khan *et al.* (1993) at IWMD, BARI, Gazipur. As this was a controlled structure from surrounding soil so no further replication of the treatments was done (Islam and Hossain, 2010) for calculating ET_c. CROPWAT software was used to calculate potential evapotranspiration (ET_o) by inserting climatic data of maximum and minimum temperatures, air humidity, sunshine hours and wind speed together with the location information.

The crop was irrigated in according to the design of the treatments. Measured quantity of water was applied to the tanks to ensure drainage. Soil moisture was measured in gravimetric method during plantation, prior to irrigation and at maturity to determine the irrigation quantity and depleted soil moisture. During the crop season, negligible amount of rainfall was occurred (Fig.4). Crop evapotranspiration (ET_c) was calculated by using water balance equation (Eq. 2) (Itier *et al.*, 1997). Therefore, the stored soil moisture during the period under consideration and drainage amount were subtracted from the applied water and rainfall to obtain ET_c i.e.,

$$ET_c = W_a - (D_w \pm \Delta S_s) \text{ -------------- } (1)$$

Where, ET_c = Crop evapotranspiration in mm for time t

W_a = Applied water + rainfall (mm) for time t

D_w = Drainage water (mm) for time t

ΔS_s = Stored soil moisture (mm) for time t

Then from the potential evapotranspiration (ET_o) estimated for the specified period, the value of K_c for the period was determined using the following equation.

$$ET_c = K_c * ET_o \text{ --------------------------- } (2)$$

At 65 days after sowing, the data on plant height were recorded from 8 plants in each lysimeter. The yield and yield contributing data (no of tuber/plant, tuber length, tuber diameter, and tuber weight/plant) were collected during and after harvest.

Results and Discussion

Yield and yield parameters

The yield and yield parameters of potato are presented in Table 1. All the parameters were found highest in treatment T_2 except number of tuber per plant. Among other treatments, it was also noticed that larger size of tuber was obtained in treatment T_2. This treatment (irrigation at 25, 40 and 55 DAP) also gave the highest tuber yield (35.70 t/ha). The reason was that the treatment T_2 got the most favorable soil moisture conditions to produce healthy plants as seen from the data of yield parameters. Treatment T_3 received three irrigations at 25, 40 and 60 DAP which produced the second highest yield (33.90 t/ha). In case of treatment T_3 and T_4, the yield was almost similar, though three and four number of irrigation were applied. The lowest yield (28.70 t/ha) was obtained in treatment T_1 which received only two irrigations at 25 and 40 DAP. Doorenbos and Pruitt (1977) recommended that the best growing plants producing the highest yields are suitable for calculating the crop coefficient values for different growth stages. Hence, the treatment T_2 was selected for determining the crop coefficient values of potato in this study.

Table 1. Effect of irrigation on yield and yield parameters of potato

Treatments	Plant height (cm)	No of tuber/plant	Tuber length (mm)	Tuber dia. (mm)	Tuber weight/plant (g)	Tuber yield (t/ha)
T_1	55.54	6.5	66.00	38.8	286.98	28.70
T_2	73.80	6.9	72.64	45.17	441.95	35.70
T_3	61.00	7.2	71.80	45.80	428.98	33.90
T_4	56.60	7.7	65.60	46.50	358.05	33.50

Determination of crop ET

Table 2 represents the total crop ET (ET_c) during the growing season. It was found that the seasonal ETc of potato was 162 mm. Badr *et al.,* (2012) reported the total ET_c of potato was 362 mm at the full irrigation supply in Nubaria region, west of Nile Delta, Egypt. They did experiment on late maturity potato variety 'Cara' (*Solanum tubero-sum* L.) during late summer from September to December, 2010. Besides, they calculated ET_c from FAO recommended value (Allen *et al.,* 1998). This crop received a total rainfall of 16.5 mm during crop period, while our crop received only a negligible amount of rainfall (Fig. 4). In our experiment, we applied only three irrigations through furrow method, while they applied irrigation through drip irrigation method up to developmental stage and after that every 2 days up to physiological maturity. Doorenbos and Pruitt (1977) reported the seasonal ET value of potato ranges from 350 to 625 mm depending on season. Hane and Pumphre (1984) found the seasonal ET ranges from 300 to 650 mm in north central Oregon. Our estimated value was found much lower than the value found by other scientists. This may be the reason of variety, location, and weather condition. Karim and Akhand (1982) determined evapotranspiration of potato in 18 districts of Bangladesh which ranges from 264.6- 408.2 mm. Much deviation was found with the values found by Karim and Akhand (1982) within the same country. They calculated crop evapotranspiration from FAO recommended K_c values as there was no regional value.

The negative value in soil moisture storage indicates the depleted soil moisture used by the crop. On the other hand, the positive values indicate the water stored in the soil in excess of ET.

Table 2. Determination of ET_c during the crop season by lysimeter study

Duration in days	Applied water (mm)	Effective rainfall (mm)	Percolation (mm)	Soil moisture storage (mm)	Crop ET (mm)
0-25	4	0	0	-13	17
25-40	36	0	12	-18	42
40-55	27	0	5	-33	55
55-95	54	0	8	-2	48
Total	-	-	-	-	162

Determination of crop coefficient

The duration of crop growth stage depends on the length of growing season of a particular crop and climate (Doorenbos and Pruitt, 1977; Smith *et al.,*1992). Here, the total crop growth period was 97 days and the highest ET_c and ET_o was recorded at the mid-season stages (Table 3).

Table 3. Estimation of crop co-efficient of potato

Crop growth	Duration (days)	Crop ET (ET_c) (mm)	Reference ET (ET_o) (mm)	Crop coefficient (K_c)
Initial	15	11.12	44.86	0.25
Development	20	35.32	56.55	0.62
Mid-season	35	90.10	113.15	0.79
Late season	27	26.32	145.8	0.18
Total	97	-	-	-

Evapotranspiration and crop coefficients are varied according to the crop growth stages (Fig. 6 - 8). At the initial stage, ET_c was about 0.63 mm/day and fluctuated, reached at peak during the period of 64, was 1.87 mm/day and after that it sharply fall by 1.63 mm/day at 72 days after sowing. On the other hand, ET_o values fluctuated within the range of 1.10 - 3.48 mm/day while at the primary stage its value was about 2.34 mm/day, then gradually fall during the mid-season and again rose up to 3.48 mm/day prior to harvest (Fig. 6). In Fig. 7, cumulative crop evapotranspiration values are increasing during the crop season. At the initial stage (25 days after sowing) it was 17 mm after that it sharply increased and rose to 162 mm. Therefore, crop coefficient values were found 0.25, 0.62, 0.79 and 0.18 at initial, development, mid-season, and late season stages (Table 3) though three stages value was given in Fig. 8 and was done by following averaging method (Biswas *et al*., 2014).

Carvalho *et al.* (2013) found the K_c values of 0.35, 0.45, 1.29 and 0.63 for initial, development, mid-season and late season, respectively in Rio de Janeiro (RJ), Brazil. Kashyap and Panda (2001) found the K_c values of potato at initial, crop development, reproductive and maturity were 0.42, 0.85, 1.27 and 0.57, respectively at the experimental farm of the Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India. Ferdous *et al.*, (1985) found the K_c values of 0.30 at emergence, 1.23 during full coverage, and 0.48 at maturity stage in Amman, Jordan. Hane and Pumphre (1984) found that K_c values increased from 0.3 at emergence to over 0.8 during maximum leaf area and declines with crop maturity in north central Oregon. Doorenbos and Pruitt (1977) reported the K_c values of potato for mid-season and at harvest was 1.05 to 1.1 and 0.7 depending on minimum relative humidity of >70% and 1.15 to 1.2 and 0.75 depending on minimum relative humidity of <20%. Doorenbos and

Kassam (1979) reported K_c values of 0.4- 0.5, 0.7- 0.8, 1.05-1.2 and 0.85-0.95 for initial, crop development, mid-season, and late season stages, respectively.

These crop coefficient values slightly differed from those recommended by FAO (Doorenbos and Pruitt, 1977). The lower value of K_c value compared to other findings was due to lower length of season, lower temperature, higher humidity, lower solar radiation, etc. But FAO values are the standard values and need calibration for a specific region or location as per guidelines suggested in FAO Irrigation and Drainage paper (Allen *et al.,* 1998). The crop coefficient during the crop season was 0.50, 0.65, 1.15 and 0.75 at initial, developmental, middle and tuber maturity stages, respectively (Allen *et al.,* 1998). The values determined by lysimeter study are more dependable than the values obtained by calibration from the FAO recommended values.

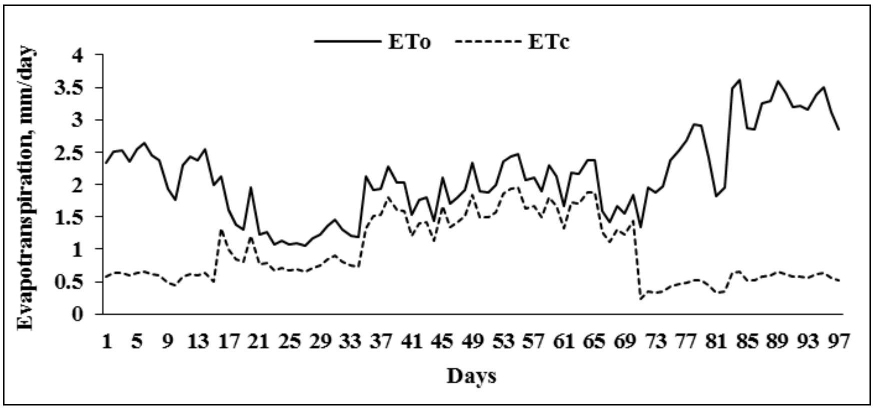

Fig. 6. Crop evapotranspiration (ET_c) and potential evapotranspiration (ET_o) of potato during the crop growth period.

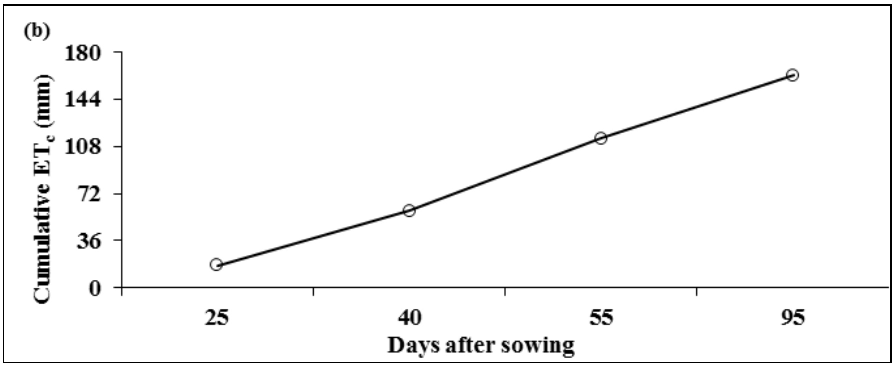

Fig. 7. Cumulative crop evapotranspiration (ET_c) of potato during the crop growth period.

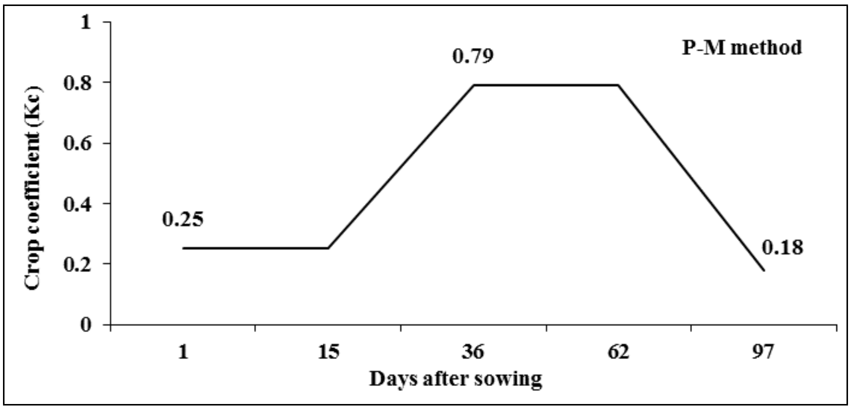

Fig. 8. Crop coefficient values of potato during the crop growth period.

Conclusion

The crop coefficient values of potato were 0.25, 0.62, 0.79 and 0.18 at initial, development, mid-season and late season stages from the Lysimeter study. Lysimeter provides a control environment and the values determined by this method are most dependable and can be used for estimating crop water requirement for potato in Bangladesh. The seasonal evapotranspiration of potato was 162 mm.

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EFFECT OF NITROGEN ON GROWTH AND YIELD ON MUNGBEAN IN LOW NUTRIENT SOIL

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Abstract

A pot experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during *kharif II* season of 2011 to investigate the growth, dry matter production and yield of mungbean genotypes under nutrient stress soil. Ten mungbean genotypes viz., IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Bina moog- 5 and six nitrogen fertilizer levels viz., 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results revealed that increasing nitrogen level in nutrient stress soil increased growth and dry matter production up to 60 kg N ha^{-1} irrespective of genotype and thereafter decreased. Among the mungbean genotype IPSA 12 showed maximum leaf area, dry matter production and seed yield (14.22 g $plant^{-1}$) in nutrient stress soil. The lowest seed yield (7.33 g plant $^{-1}$) was recorded in ACC12890053 under control condition.

Keywords: Mungbean genotype, Nutrient stress, Dry matter, Seed yield.

Introduction

Mungbean is one of the most important pulse crop in the south Asia. It is primary source of high quality, easily digestible protein and provides vitamin A, vitamin C, zinc and foliate to the predominantly vegetarian population of south Asia (Chanda, 2007).

However, yield of mungbean in south Asia is very low due to different causes like, nutrient stress, salinity, rainfall and lack of suitable variety. Among them mungbean cultivation under nutrient stress soil and also low utilization of N fertilizer, where as optimum N fertilizer enhance grain growth and development.

It is now well established that despite nitrogen fixation, N alimentation in legumes is limiting factor in terms of either quantitative (seed) or qualitative (N) yields. In fact, young plants find their initial nitrogen requirements through soil mineral nitrogen. After nodules have been established, N fixation succeeds to assimilation, reaches peak at pod developing stage and declines thereafter. Later, most of the seed filling is achieved by the redistribution of N from vegetative plant organs to the developing seeds. The beneficial effect of applied nitrogen is to retained more leaf area causing accelerated photosynthetic rate which led to

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more dry matter production and consequently higher yield per plant (Dahatonde and Nalamwar, 1996; Sushant *et al.*, 1999). Such improvement in yield components and yield of mungbean by applied nitrogen was also reported by many researchers. Patra and Bhattacharyya (1997) observed that the highest seed yield and yield components were obtained by applied urea at the rate of 25 kg N ha^{-1}. Ashraf, (2001); Mahboob and Asghar (2002) also found that number of pods per plant, seeds per pod, 1000-seed weight were significantly affected by the application of nitrogen from 20 to 50 kg ha^{-1}. The present study was therefore, aimed to evaluate the effect of nitrogen levels on growth, dry matter production and yield of mungbean genotypes under nutrient stress condition.

Materials and Methods

The pot experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during *kharif II* (August to November) season of 2011 of AEZ 28. The experimental site was located at $24^{0}09'$ N latitude and $90^{0}26'$ E longitude and 8.4 m above the sea level which is characterized by subtropical climate. The physical and chemical properties of soil are presented in table 1. The soil was sandy loam having 6.9 pH, 0.538 % organic matter, 0.05%N, 0.16 mg kg^{-1} P, 0.85 meq % K, and 0.70 mg kg^{-1} and the Rhizobium count was 4.55×10^{8} g soil. Each pot containing 12 kg soil was fertilized with 32 kg K ha^{-1} in the form of muriate of potash and mixed thoroughly with soil

The experiment was established in pot containing 12 kg soil collected from codda bazaar which belongs in codda series. Experimental soil was fertilized 25 kg P and 32 kg K ha^{-1} in the form of triple super phosphate and muriate of potash, respectively and incorporated thoroughly into soil. The experiment was laid out in completely randomized design (CRD) with 4 replications. There were 10 genotypes like IPSA 12, GK 27, IPSA 3, IPSA 5, ACC12890055, GK 63, ACC12890053, BUmug 4, BARI Mung 6 and Bina moog 5 and six level of nitrogen 0, 20, 40, 60, 80 and 100 kg N ha^{-1} as treatment variable and applied at 15 days after sowing.

Seeds were sown on 31 August, 2011. For uniform germination, a light irrigation was given immediately after sowing of seeds., the plants were thinned at first trifoliate stage and 4 plants was remained maintained for recorded growth parameter and one plants remained finally for seed yield in pot. All agronomic management and plant protection measures were kept uniform during the whole growing period of mungbean. Data on growth parameters, dry matter partitioning and yield were recorded. Leaf area were measured using automatic leaf area meter at 50% flowering stage.

Table 1. Physical and chemical properties of the experimental soil before sowing

Soil properties	Present value	Critical limit
Sand (%)	62.23	-
Silt (%)	21.77	-
Clay (%)	16.00	-
Soil pH	6.90	-
Textural class	Sandy loam	-
Rhizobium/g soil	4.55×10^{8}	-
Total N (%)	0.05	0.10
Available P (ppm)	0.16	8.0 0
Exchangeable K (meq/100g soil)	0.85	0.08
Available S (ppm)	7.00	8.00
Available B (ppm)	0.15	0.16
Available Zn (ppm)	0.25	0.50
Exchangeable Ca (meq/100g soil)	14.83	2.00
Exchangeable Mg (meq/100g soil)	1.76	0.50
CEC meg/100g soil	6.904	3-7.5
Organic matter (%)	0.536	-

For dry matter partitioning shoots and roots were oven dried at 70^{0} C to constant weight. Data on different parameters were subjected to statistical analysis and means compared by DMRT at 5% level of probability.

Results and Discussion

Leaf area

Leaf area of mungbean was increased with the increasing of N fertilizer up to 60 kg ha^{-1} in most of the genotypes and thereafter decreased with further increase of applied nitrogen (Fig. 1). As N is constituent of enzyme and nucleic acids, it is essential for the development of new cells particularly under N deficient soil. Thus one of the obvious manifestations of N limitation is in the inhibition of leaf area development under low N environment (Sinclair and Vandez. 2002). Other authors (Gimenez *et al.,* 1994; Vos and Putten, 1998) also observed that substantial decrease in leaf area of different field crops under N deficiency condition. This is consistent with present study that the inability to generate new cells for expanding leaf area under N deficient soil. Genotypic variation in leaf area development at various N levels is conspicuous and it was the highest in genotype, IPSA 12. This genotype maintained the highest leaf area both under deficient (416 cm^2) and sufficient (605 cm^2) N condition.

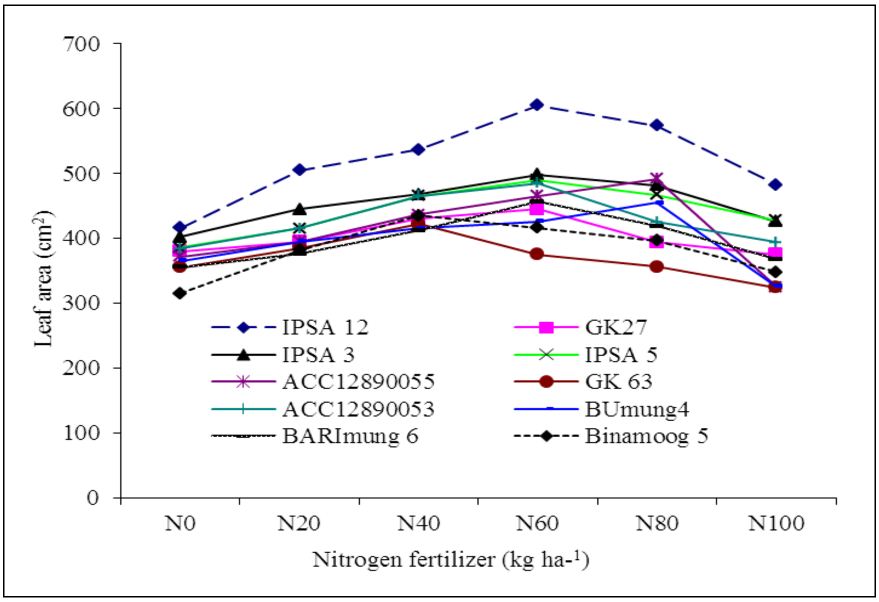

Fig. 1. Leaf area development (trifoliate stage) of mungbean genotypes under different levels of nitrogen fertilizer.

Dry matter accumulation

Accumulation of dry matter was increased with the increasing N levels but it peaked (at 40 or 60 kg N ha^{-1}) of different mungbean genotypes (Fig. 2). The lowest dry matter was accumulated in plants of control treatment and lower level of N fertilizer (Fig. 2). Accumulation of lower dry matter at N deficient conditions might be due to internal nutrient stress of plant which caused reduction in cell division, cell elongation, carbohydrate synthesis and hence the growth was reduced (Karmar, 1988). These results agreed with Akhtaruzzaman (1998) in mungbean and Matsunaga *et al*. (2008) in cowpea that crops grown under lower N levels accumulated less dry matter and inhibited the crop growth. Genotypic variation in dry matter accumulation revealed that the genotype IPSA 12 grown at 60 kg N ha^{-1} accumulated the highest dry matter (30.25 g $plant^{-1}$) and it was the lowest (16.26 g $plant^{-1}$) in genotype Bina Moog-5.

Considering dry matter accumulation in root, the highest (1.12 g $plant^{-1}$) the genotype IPSA 12 grown under 60 kg N ha^{-1}. Conversely, the genotype IPSA 5 accumulated more dry matter in leaves (7.93 g $plant^{-1}$) and in stem (5.86 g $plant^{-1}$) which are supposed to be less efficient in yield formation of mungbean.

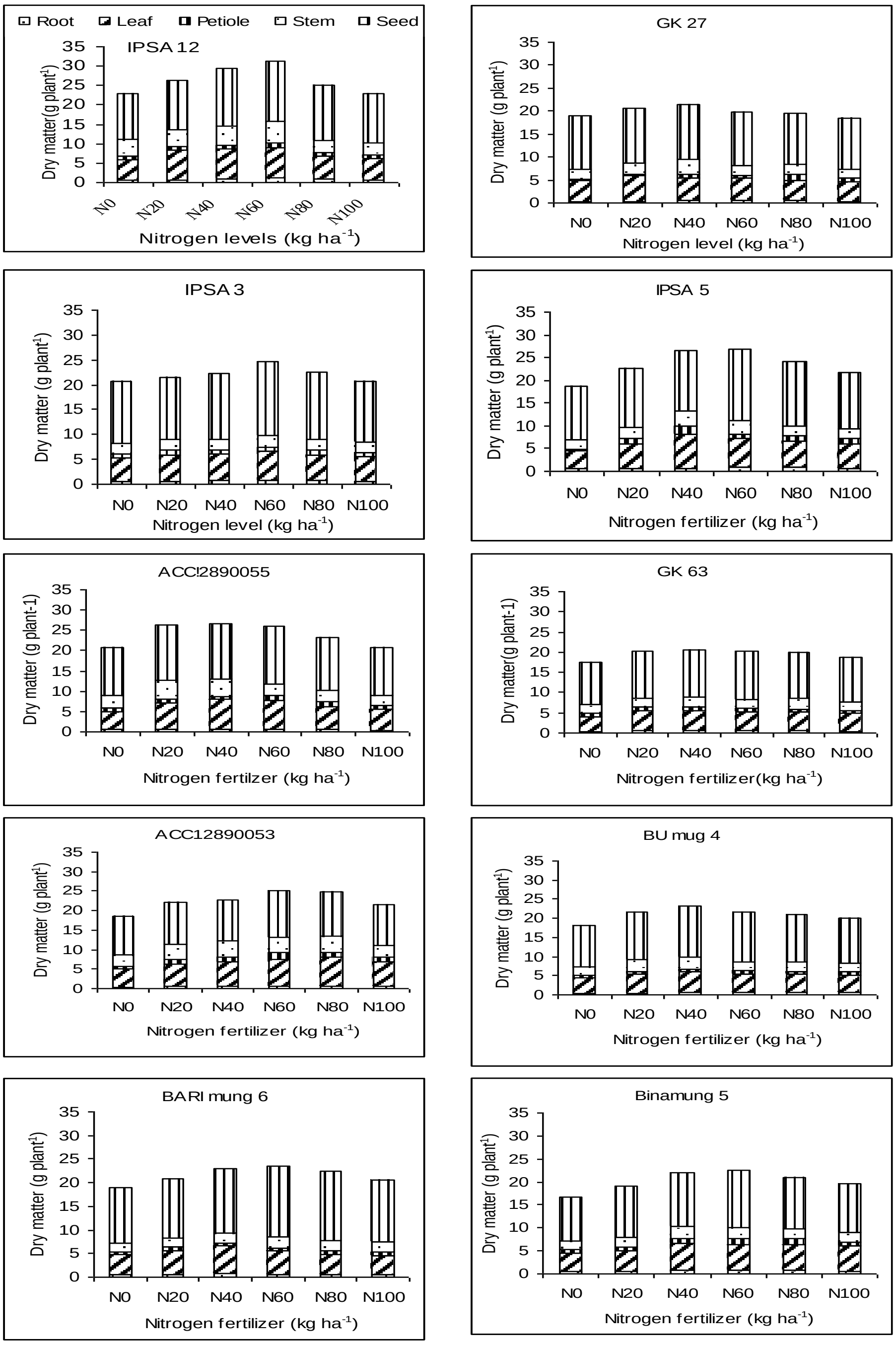

Fig. 2. Pattern of dry matter partitions (trifoliate stage) in mungbean genotypes under different nitrogen levels.

Crop growth

Nitrogen fertilizer influenced profoundly on crop growth rate of mungbean. Increase of nitrogen fertilizer increased crop growth rate for all the genotypes up to 60 kg ha^{-1} and further increase nitrogen fertilizer decreased the growth rate of mungbean (Fig. 3). It might be due to immobilization of nitrogen fertilizer which did not involve in physiological activities in plant. Crop growth rates further decreased after pod development stage and it is likely that photosynthetic capacity of the plant might have decreased at this stage because of reduction of leaf area. However, the genotype IPSA 12 produced the maximum leaf area which exhibited the highest crop growth rate (0.62 g plant^{-1} day^{-1}).

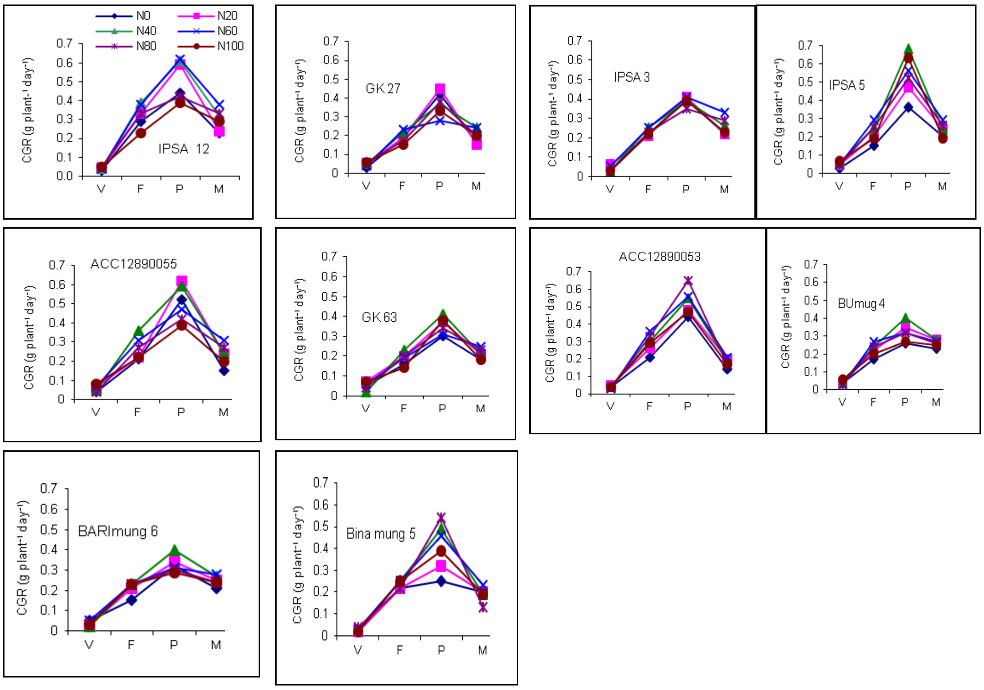

Fig. 3. Crop growth rate of mungbean genotypes as affected by different nitrogen levels (V= Vegetative, F= Flowering, P= pod developing ,M= Maturity).

Pods per plant

Number of pods per plant of mungbean genotypes significantly influenced by different N levels. Increasing nitrogen level led to increase pod plant^{-1} up to 60 kg N ha^{-1} and thereafter decreased (Table 2). These results are in conformity with the findings of (Patra and Parner, 1991) who reported that pod per plant of mungbean increased with application of nitrogen fertilizer and excess application reduced pod number of mungbean.

There were genotypic variations in pod development in variable to N level where the genotype IPSA 12 produced the highest pods / plant at 60 kg N ha^{-1} (30.16). The lowest number of pods (16.16) per plant was recorded in genotype GK 63 with highest N dose but it was identical with of Bina moog 5 (16.83) with o kg N ha^{-1}. These results are supported by Ashraf (2001) that number of pods per plant was significantly affected by the application of N fertilizer. These means that mungbean genotypes require additional N for better pod development although it is capable to fix atmospheric N through rhizobium species living in root nodules (Anjum *et al*., 2006).

Table 2. Number of pods per plant of mungbean genotype as affected by nitrogen levels

Genotype	Nitrogen level					
	N_0	N_{20}	N_{40}	N_{60}	N_{80}	N_{100}
IPSA 12	22.00cA	24.83bcA	27.50bA	30.16aA	26.16bA	22.66cA
GK 27	20.00bA	22.50abAB	23.60aB	23.50aC	22.33abB	19.66bB
IPSA 3	19.66cAB	22.16bAB	23.16bB	25.16aB	22.50bB	20.33bcB
IPSA 5	21.83bcA	25.33aA	26.33aA	27.50aB	26.00aA	23.16bA
ACC12890055	20.16cA	23.00abAB	23.16abB	25.00aB	21.66bB	20.83bcB
GK 63	18.83cB	21.33bB	21.63bC	23.33aC	22.33abB	16.16cC
ACC12890053	20.33cA	22.00bcAB	22.66bC	25.83aB	22.00bB	22.16bA
BU mug 4	19.00cAB	22.00bAB	25.16aAB	24.16aC	21.83bBC	21.00bcAB
BARI Mung 6	18.93cB	20.50bB	22.50abC	23.33aC	22.33aB	20.83bBC
Bina moog 5	16.83dC	19.83cC	23.33aB	24.83aC	21.50bB	17.66dC

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

Seed yield

Seed yield per plant was significantly affected by genotypes and N fertilizer applications. Seed yield of mungbean varied from 7.33 g to 14.22 g plant^{-1} (Table 3) and it was the maximum in IPSA 12 (14.22 g plant^{-1}) grown with 60 kg N ha $^{-1}$ and the lowest in ACC12890053 (7.33 g plant^{-1}) followed by Bina moog 5 under control condition. The genotype IPSA 12 also well responded (11.32 g plant^{-1}) under control condition. There was general trend of increase in seed yield with the increase of N fertilizer but it was at par with 60 kg N ha^{-1} and thereafter decreased the seed yield of mungbean. Among the tested mungbean genotype IPSA 12 produced highest seed yield in control condition. So, genotype IPSA 12 might be considered as suitable genotype in nutrient stress soil. These findings agreed with Biswas and Hamid (1989) and Mitra and Ghildiyal (1988) that seed yield of mungbean is limited by nitrogen supply. Application of N fertilizer enhanced leaf area, dry matter production and yield component which consequently improved yield of mungbean genotypes.

Table 3. Seed yield (g plant^{-1}) of mungbean genotype as affected by nitrogen fertilizer

Genotypes	Nitrogen level (kg ha^{-1})					
	N_0	N_{20}	N_{40}	N_{60}	N_{80}	N_{100}
IPSA 12	11.32Ac	11.87Ac	12.87Ab	14.22Aa	12.41Ab	10.80Ac
GK-27	10.97Ab	12.34Aa	12.80Aa	12.61Ba	11.94Ab	10.43Ab
IPSA 3	10.78Abc	11.83Ab	12.82Aa	13.32ABa	11.65Ab	10.35Ac
IPSA 5	9.60Bc	11.72Ab	12.45Aa	13.64Aa	12.36Aa	10.10Abc
ACC12890055	9.33Bc	11.90Aab	11.81Bab	12.29Ba	10.93Bb	9.87ABb
GK-63	10.06Bb	12.00Aa	12.20Ba	13.09Ba	11.99Aa	9.23ABb
ACC12890053	7.33Dcd	8.49Db	9.12Cab	9.60Ca	9.31BCab	7.95Cc
BU mug 4	8.93Bbc	10.35Bab	11.14Ba	10.85Ba	10.40Bab	9.59ABbc
BARI Mung 6	8.55Bbc	10.78Bb	11.82Bab	12.84Aa	12.40Aa	11.24Aab
Bina moog 5	7.48Dc	8.61Cb	9.31BCab	10.23Ca	9.71Cab	8.37Cbc

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

Conclusion

The results revealed that nitrogen is necessary to ensure better growth and productivity of different mungbean genotypes under nutrient stress soil. But the genotype IPSA 12 performed better in nutrient stress soil where 60 kg N ha^{-1} is optimum for better crop growth and development

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DETERMINATION OF THE FREQUENCY AND DENSITY OF WEED SPECIES IN APPLE ORCHARDS IN KAHRAMANMARAS REGION OF TURKEY

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Abstract

A study was carried out in Kahramanmaras region of Turkey during 2012-13 having ten subregions namely, Afsin, Andırın, Caglayancerit, Ekinozu, Elbistan, Göksun, Center, Nurhak, Pazarcık and Türkoglu to determine the range, density and frequency of weeds in apple orchards. In the orchards 133 weed species from 31 families were determined. The average density of weeds was 112.49 plants m^{-2}. The maximum density of weed species was found in Göksun (127.30 plants m^{-2}) followed by Elbistan (126.13 plants m^{-2}), Ekinozu (125.95 plants m^{-2}), Afsin (120.39 plants m^{-2}), Center (117.94 plants m^{-2}) and Caglayancerit (114.90 plants m^{-2}), and the minimurn density was determined in Pazarcık (69.51 plants m^{-2}). From the identified 133 weed species one species belonged to Pterydophyta, 2l species to Monocotyledoneae and 111 species to Dicotyledoneae. The average densities of the weed species over l0 subregions for *Agropyron repens* (L.) P. Beauv., *Chenopodium album* L., *Bromus arvensis* L. and *Amaranthus retroflexus* L. were found to be 13.76, 12.17, 12.10 and 10.76 plants m^{-2}, respectively. With regard to frequency of occurrence, *C. album* L. was detected more than 56% in six subregions excluding Andırın, Pazarcık, Türkoglu and Center; *A. retroflexus* L. more than 54% in 7 subregions excluding Center, Pazarcık and Türkoglu and *A. repens* (L.) P. Beauv. more than 50% in 10 subregions. Frequency of occurance of *Cynodon dactylon* (L.) Pers. was observed 50.1, 50.9, 76.9% in Afsin, Caglayancerit and Andırın, respectively and it was below 50% in other 7 subregions. In terms of coverage, *Alopecurus myosuroides* Huds., *A. retroflexus*, *A. repens*, *B. arvensis*, *C. album*, *Convolvulus arvensis* L., *C. dactylon* and *Lactuca serriola* L. were determined to be within the range of 20.2 to 48.2% in the study areas while the other species were below 20%.

Keywords: Apple orchards, weed, density, frequency and general coverage.

Introduction

Turkey has huge fruit production potential due to its suitable ecological conditions and it ranks third after China and the USA with its 69,492,000 tons annual apple production (Anon., 2012). In apple farming of Turkey, Isparta ranks first with its 634,795 tons and then Karaman and Nigde with their production 388,400 and 317,271 tons, respectively. Kahramanmaras ranks 10th in total land area of 56,060 ha and 12th in total production of 97,673 tons (Anon., 2013).

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Many factors affect the productivity and quality of apple production one of the most important is weed. Generally apple orchards are fertilized heavily to get higher fruit yield and the weeds grown in the orchards rob up the fertilizer at a faster rate than the apple plants resulting in lower yields (Verma and Chauhan, 2013). The weeds also harbor insects, diseases and rodents and thus they lower the quality and quantity of apples and may increase the cost of production by causing difficulties during fruit harvest. It is reported that both narrow leaved and broad leaved weeds grow in the apple orchards of Turkey and other apple growing countries of the world and caused problems of orchard management (Zeki *et al*., 1994; Tepe, l997; Yazlik and Tepe, 2001; Karaca and Guncan, 2003; Akbolat *et al*.,2007; Ustuner and Akyol, 2007; Junk *et al*.1997; Dastgheib and Frampton, 2000; Harington *et al*. 2000).

Since apple trees are poor competitors, their effective control becomes necessary. For this the weeds growing in any particular region must be properly identified. It is essential to know densities and frequencies of weed species grown in that region for their successful control. Besides, different weed species respond to different control methods. The challenge without identifying weed species will be unsuccessful and these will cause wastage of time, money and environmental pollution of herbicides. The most effective chemical control with weeds is the period when the weeds are 3-5 leaves. So determination of frequency occurrence, density, coverage of weeds and recognizing the life stages of those identified weeds will help selecting suitable control method. The survey study was therefore, conducted to identify weed species, and to determine their density, frequency of occurrence and coverage in Kahramanmaras region of Turkey.

Materials and Method

In the study, surveys made applied in the apple orchards in Kahramanmaras region (Center, Afsin, Andırın, Caglayancerit, Ekinozu, Elbistan, Göksun, Nurhak, Pazarcık and Türkoglu) in 2012-2013. Considering the distribution and density of the apple orchards in the region, 10 subregion were selected and the samples were obtained from these subregion. In the survey, it was considered at least 3 km among the gardens and the samples were obtained from the 15 m inside of the edge of the garden. Within the 1000 square meters, 4 frames (1 square fareme) were used and weeds were obtained and counted (Odum, 1971). The number of the weed in the 1 square meter were calculated by dividing of the total number of the each species in 1 square meter to the survey area.

Weed density was calculated via Density = B/n formula (Guncan, 2001).
Here B = Total weeds number in the sample, n = Number of sample

In the evaluation, broad leaved weeds were considered as a whole plant while narrow leaved weed were considered as their stems and they were recorded on the survey cards. Species, numbers and coverages of weeds were recorded and frequency of occurrence, number of plant and general coverages of obtained data were calculated by using the following formulas:

Frequency of occurrence (F.O.): The per cent of the occurance of the weeds (%) in an area.

Frequency of occurrence (%) = n/mx100
n: the number of the orchards containing species
M: total number of the orchards measured

Species Coverage (T.K.A.): It is expressed as average value that any species of weed covered surface.

G.K.A (%) = T.K.A./m
G.K.A.: General coverage, m: Total number of surveys

As suggested by Ustuner and Guncan (2002), density scale was used as follows:

A. High dense (average more than 10 in per square meter)
B. Dense (average between 1-10 in per square)
C. Low dense (average between 0.1-1 in per square meter)
D. Rarely observed (average between 0.01-0.1 in per square meter)

The surveyed areas were divided in 10 subregions (Table 1).

Table 1. Surveyed regions, the area of apple plantation and the number of frame in the study (Anon., 2013)

Subregions	Apple plantation area (da)	The number of the frame
Afsin	4889	195
Andırın	182	60
Caglayancerit	3878	155
Ekinözü	5395	215
Elbistan	6149	245
Göksun	29881	500
Center	3667	146
Nurhak	1271	53
Pazarcık	83	33
Türkoglu	211	64
Total	55606	1666

Because fruit trees are perennial, both summer and winter weeds grow in the apple orchards. Therefore, a total of 1666 samples were obtained in two different seasons. The first survey was made on April and May 2012-2013 while the second survey was made on August and September.

Results and discussion

In the surveys of Kahramanmaras region's apple orchards a total of 133 species of weeds belonging to 31 families including 1 pterydophyta, 21 monocotyledoneae and 111 dicotyledoneae and 112.49 (plants/m^2) were detected (Table 2).

Table 2. Number of families and weed species found in Kahramanmaras region

Phylum/Subclass	Number of families	Number of weed species
Pterydophyta	1	1
Monocotyledoneae	3	21
Dicotyledoneae	27	111

The average density of weeds in unit area was 13.76 plants m^2 for *A. repens*, 12.17 for *C. album*, 12.10 for *B. arvensis*, 10.76 for *A. retroflexus* and it was high in density. 9.25 for *C. dactylon*, 9.06 for *A. myosuroides*, 6.80 for *C. arvensis*, 4.54 for *D. glomerata*, 4.41 for *B. tectorum*, 3.94 for *L. serriola*, 2.50 for *S. viridis*, 2.28 for *D. sangunialis*, 2.11 for *L. temulentum*, 1.99 for *S. halepense*, 1.33 for *C. draba* ssp *draba*, 1.25 for *A. cylindrica*, 1.07 for *C. arvense*, 1.04 for *C. galaticus* and 1.03 for *M. chamomilla* was densely detected.

Table 3. Weed density, frequency of occurrence and general coverage of weeds in Kahramanmaras region

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Agropyron repens (L.) P.Beauv.	13.76	>50	20.2-48.2
Chenopodium album L.	12.17	>56	20.2-48.2
Bromus arvensis L.	12.10	>50	20.2-48.2
Amaranthus retroflexus L.	10.76	>54	20.2-48.2
Cynodon dactylon (L.) Pers.	9.25	>50	20.2-48.2
Alopecurus myosuroides Huds.	9.06	>50	20.2-48.2
Convolvulus arvensis L.	6.80	<50	20.2-48.2
Dactylis glomerata L.	4.54	<50	<20
Bromus tectorum L.	4.41	<50	<20
Lactuca serriola L.	3.94	<50	20.2-48.2
Setaria viridis (L.) P.Beauv.	2.50	<50	<20
Digitaria sanguinalis (L) Scop.	2.28	<50	<20
Lolium temulentum L.	2.11	<50	<20
Sorghum halepense (L.) Pers.	1.99	<50	<20
Cardaria draba ssp *draba* (L.) Desv.	1.33	<50	<20
Aegilops cylindrica Host.	1.25	<50	<20
Cirsium arvense (L.) Scop.	1.07	<50	<20
Convolvulus galaticus Rost. ExChoisy.	1.04	<50	<20
Matricaria chamomilla L.	1.03	<50	<20

Frequency of occurrence of weeds in the region indicated that *C. album* was more than 56% in 6 subregions except for Andırın, Pazarcık, Türkoglu and Center. *A. repens* was more than 50% in 10 subregions. *A. retroflexus* was more than 54% in 7 subregions except from Center, Türkoglu and Pazarcık. *C. dactylon* was less than 50.1% in Afsin, 50.9% in Caglayancerit, 76.9% in Andırın and 50% in other 7 subregions while *B. arvensis* was less than 50% in Center subregion, more than 52% in the other 9 subregions. *A. myosuroides* was detected more than 50% in Andırın, Center, Caglayancerit and Göksun and less than 50% in the other subregions. *C. arvensis* was only detected 55.6% in Center and less than 50% in the other subregions (Table 3). The coverages for *A. myosuroides, A. retroflexus, A. repens, B. arvensis, C. album, C. arvensis, C. dactylon* and *L. serriola* varied from 20.2 to 48.2%, while it was less than 20% for other species.

Afsin subregion

In this subregion, *C. album, A. repens, A. retroflexus, C .dactylon, B. arvensis, A. myosuroides* and *D. sanguinalis* were determined high densely. *C. arvensis, C. arvense, L. serriola, C. galaticus, M. chamomilla, A. cylindrica, B. tectorum, E. crus-galli, L. temulentum* and *P. rhoeas* were determined densely (Table 4).

Table 4. Weed density, frequency of occurrence and general coverage of weeds in Afsin subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Chenopodium album L.	16.2	60.8	48.2
Agropyron repens (L.) P.Beauv.	15.8	50.4	27.9
Amaranthus retroflexus L.	13.7	57.6	32.6
Cynodon dactylon (L.) Pers.	12.6	50.1	20.3
Bromus arvensis L.	11.4	52.5	28.1
Alopecurus myosuroides Huds.	10.9	48.6	19.5
Digitaria sanguinalis (L) Scop.	10.5	39.2	11.8
Convolvulus arvensis L.	7.4	42.3	14.7
Cirsium arvense (L.) Scop.	2.6	0.9	9.1
Lactuca serriola L.	2.3	0.8	6.5
Convolvulus galaticus Rost.Ex Choisy	2.2	0.13	1.9
Matricaria chamomilla L.	2.1	0.45	1.1
Aegilops cylindrica Host	2.1	0.11	1.8
Bromus tectorum L.	1.7	0.15	2.0
Echinochloa crus-galli (L.) P.Beauv.	1.4	0.02	2.3
Lolium temulentum L.	1.2	0.23	1.4
Papaver rhoeas L.	1.2	0.6	2.2
Others	5.04	-	-
Total	120.34	-	-

The maximum frequency of occurence for weed species was 60.8% for *C. album*, 52.5% for *B. arvensis*, 42.3% for *C. arvensis*, 57.6% for *A. retroflexus*, 50.4% for *A. repens* and 50.1 %.for *C. dactylon.* General coverage of weeds were 48.2% for *C. album*, 32.6% for *A. retroflexus*, 28.1% for *B. arvensis*, 27.9% for *A. repens* and 20.3% for *C. dactylon.*

Andırın subregion

In Andırın's apple orchards, *A. repens*, *C. dactylon*, *D. glomerata*, *B. arvensis* and *A. myosuroides* were determined high densely. *C. arvensis, A. cylindrica, E. crus-galli*, *B. tectorum* and *S. viridis* were determined densely (Table 5).

The maximum frequency of occurence of weed species were 81.4 % for *A. repens*, 76.9% *C. dactylon*, 69.3% for *D. glomerata*, 63.2% for *B. arvensis* and 40.1% *A. myosuroides*. General coverage of weeds were 42.3% for *A. repens*, 35.6% for *C. dactylon*, 28.4% for *D. glomerata* and 24.8% *B. arvensis*.

Table 5. Weed density, frequency of occurrence and general coverage of weeds in Andırın subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Agropyron repens (L.) P.Beauv.	19.8	81.4	42.3
Cynodon dactylon (L.) Pers.	15.46	76.9	35.6
Dactylis glomerata L.	13.3	69.3	28.4
Bromus arvensis L.	12.5	63.2	24.8
Alopecurus myosuroides Huds.	10.4	40.1	19.2
Convolvulus arvensis L.	2.63	29.5	6.9
Aegilops cylindrica Host.	1.7	10.4	3.6
Echinochloa crus-galli (L.) P.Beauv.	1.68	7.3	1.2
Bromus tectorum L.	1.4	5.6	1.1
Setaria viridis (L.) Pal. Beauv.	1.29	3.3	0.6
Others	5.76	-	-
Total	85.92	-	-

Caglayancerit subregion

The weed species, *B. tectorum, B. arvensis, C. album, A. myosuroides, A. repens, A retroflexus* and *C. dactylon* were determined high densely. *C. arvensis, D. glomerata, Cuscuta campestris, L. temulentum* and *S. viridis* were determined densely (Table 6).

The maximum frequency of occurence of weed species were 76.7% for *B. tectorum*, 73.3% for *B. arvensis*, 70.1% for *C. album*, 54.2% for *A. retroflexus*, 52.7% for *A. myosuroides*, 50.9% for *C. dactylon* and 50.3% for *A. repens*. General coverage of weeds were 47.3% for *B. tectorum*, 41.2% for *C. album*, 40.8% for *B. arvensis*, 35.2% for *A. retroflexus*, 28.9% for *C. dactylon* and 26.3% for *A. repens*.

Table 6. Weed density, frequency of occurrence and general coverage of weeds in Caglayancerit subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Bromus tectorum L.	18.8	76.7	47.3
Bromus arvensis L.	14.61	73.3	40.8
Chenopodium album L.	12.90	70.1	41.2
Alopecurus myosuroides Huds	11.23	52.7	22.5
Agropyron repens (L.) P.Beauv.	10.46	50.3	26.3
Amaranthus retroflexus L.	10.23	54.2	35.2
Cynodon dactylon (L.) Pers	10.12	50.9	28.9
Convolvulus arvensis L.	6.28	41.8	25.6
Dactylis glomerata L.	2.47	11.9	3.8
*Cuscuta campestris*Yuncker	2.4	9.45	0.24
Lolium temulentum L.	1.41	5.6	2.3
Setaria viridis (L.) Pal. Beauv.	1.35	3.8	1.2
Others	12.64	-	-
Total	114.90	-	-

Ekinözü subregion

In this subregion's apple orchards, *C. album*, *A. retroflexus*, *B. arvensis*, *A.repens*, *C. dactylon* and *A. myosuroides* were determined high densely. *C. arvensis*, *S. viridis*, *L. serriola*, *C. draba* ssp *draba*, *C. galaticus*, *A. cylindrica*, *E. crus-galli*, *B. tectorum*, *C. arvense* and *Amaranthus blitoides* were determined densely (Table 7).

Table 7. Weed density, frequency of occurrence and general coverage of weeds in Ekinozu subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Chenopodium album L.	21.8	65.4	46.8
Amaranthus retroflexus L.	18.7	60.7	41.3
Bromus arvensis L.	15.4	58.2	30.4
Agropyron repens (L.) P.Beauv.	13.8	50.1	22.6
Cynodon dactylon (L.) Pers	12.9	46.7	23.5
Alopecurus myosuroides Huds	10.1	43.5	28.4
Convolvulus arvensis L:	8.3	42.9	29.2
Setaria viridis (L.) Pal. Beauv.	5.3	16.3	12.4
Lactuca serriola L.	4.9	15.2	10.3
Cardaria draba ssp *draba* (L.) Desv.	1.9	10.4	4.8
Convolvulus galaticus Rost.Ex Choisy.	1.6	0.24	3.9
Aegilops cylindrica Host.	1.5	0.15	3.0
Echinochloa crus-galli (L.) P.Beauv.	1.4	0.23	2.2
Bromus tectorum L.	1.3	0.16	0.8
Cirsium arvense (L.) Scop.	1.1	0.4	2.0
Amaranthus blitoides S.Wats.	1.0	0.11	1.2
Others	4.95	-	-
Total	125.95	-	-

The maximum frequency of occurence of weed species were 65.4% for *C. album*, 60.7% for *A. retroflexus*, 58.2% for *B. arvensis*, 50.1% for *A. repens* and 46.7% for *C. dactylon*. General coverage of weeds were 46.8% for *C. album*, 41.3% for *A. retroflexus*, 30.4% for *B. arvensis*, 29.2% for *C. arvensis* and 28.4 % for *A. myosuroides*.

Elbistan subregion

In Elbistan, *C. album, B. arvensis, A. retroflexus, A. repens, L. serriola, C. dactylon* and *A. myosuroides* were determined high densely whereas *C. arvensis, L. temulentum, C. draba* ssp *draba, A. cylindrica, C. arvense* and *P. lanceolata* were determined densely (Table 8).

The maxiumum frequency of occurence of weed species were 73.6% for *C. album*, 65.8 % for *B. arvensis,* 62.4% for *A. retroflexus,* 51.7% for *A. repens* and 44.2% for *L. serriola*. General coverage of weeds were 39.6% for *C. album,* 30.2% for *B. arvensis,* 29.8% for *A. retroflexus*, 26.1% for *C. arvensis* and 25.4% for *A. repens*.

Table 8. Weed density, frequency of occurrence and general coverage of weeds in Elbistan subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Chenopodium album L.	19.40	73.6	39.6
Bromus arvensis L.	14.62	65.8	30.2
Amaranthus retroflexus L.	14.43	62.4	29.8
Agropyron repens (L.) P.Beauv.	13.25	51.7	25.4
Lactuca serriola L.	10.62	44.2	21.3
Cynodon dactylon (L.) Pers	10.30	38.5	20.2
Alopecurus myosuroides Huds	10.11	36.3	19.6
Convolvulus arvensis L.	9.8	35.2	26.1
Convolvulus galaticus Rost.Ex Choisy	3.4	0.2	2.4
Lolium temulentum L.	3.3	18.9	8.2
Cardaria draba ssp *draba* (L.) Desv.	3.2	15.3	7.9
Aegilops cylindrica Host.	2.8	4.3	4.5
Cirsium arvense (L.) Scop.	2.1	10.5	6.3
Plantago lanceolata L.	1.3	0.96	2.1
Others	7.50	-	-
Total	126.13	-	-

Göksun subregion

The weed species, *A. repens, A. retroflexus, C. album, B. arvensis, A. myosuroides, L. serriola, C. dactylon, L. temulentum, D. glomerata* were detected high densely whereas *C. arvensis, D. carota, A. cylindrica, C. draba* ssp *draba, S. viridis, D. sanguinalis, B. tectorum, P. lanceolata, C. arvense, C. galaticus* and *P. media* were determined densely (Table 9).

The most frequency of occurence of weed species were *C. album* 71.4%, *A. retroflexus* %70.9, *B. arvensis* L. 69.3 %, *A. repens* 68.6% and *A. myosuroides* %54.8. General coverage of weeds were *A. repens* 43.2%, *A. retroflexus* 38.1%, *C. album* 33.4%, *B. arvensis* L. 32.5%, *C. arvensis* L. 30.0% and *A. myosuroides* 21.6% rate.

Table 9. Weed density, frequency of occurrence and general coverage of weeds in Göksun subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Agropyron repens (L.) P.Beauv.	21.5	68.6	43.2
Amaranthus retroflexus L.	18.9	70.9	38.1
Chenopodium album L.	17.8	71.4	33.4
Bromus arvensis L.	16.9	69.3	32.5
Alopecurus myosuroides Huds.	11.2	54.8	21.6
Lactuca serriola L.	11.0	49.9	20.8
Cynodon dactylon (L.) Pers.	10.8	38.5	19.9
Lolium temulentum L.	10.7	32.1	18.4
Dactylis glomerata L.	10.4	28.7	17.3
Convolvulus arvensis L.	8.6	47.2	30.0
Daucus carota L.	4.6	13.10	8.2
Aegilops cylindrica Host.	4.1	10.8	7.3
Cardaria draba ssp *draba* (L.) Desv.	3.92	9.2	6.5
Setaria viridis (L.) P.Beauv.	3.8	7.5	6.2
Digitaria sanguinalis (L.) Scop.	3.1	8.6	6.1
Bromus tectorum L.	2.6	3.4	5.9
Plantago lanceolata L.	2.30	3.3	4.1
Sorghum halepense (L.) Pers.	2.30	1.4	0.3
Cirsium arvense(L.) Scop.	1.9	2.8	3.4
Convolvulus galaticus Rost.Ex Choisy	1.7	2.6	3.8
Plantago media L.	1.1	2.4	2.0
Others	8.08	-	-
Total	177.30	-	-

Center subregion

In Center subregion's apple orchards, *A. repens* (L.) P.Beauv., *A. myosuroides* and *C. arvensis* were determined high densely whereas *B. tectorum* L., *C. album, A. retroflexus, C. dactylon, D. sanguinalis, D. glomerata, S. halepense, C. campestris, A. sterilis, P. trivialis, C. solstitialis* subsp. *solstitialis, S. viridis, C. draba* ssp *draba, A. repens* (L.) DC., *B. arvensis, M. chamomilla, C. rotundus* and *P. australis* species were determined densely (Table 10).

The maximum frequency of occurence of weed species were 58.1 % for *A. repens* (L.) P.Beauv, %57.2 for *A. myosuroides*, 55.6% for *C. arvensis* (L.) Pers., 53.7 % for *B. tectorum* L. and 42.5% for *C. album*. But general coverage of weeds were 30.3% for *C. album*, 30.2% for *C. arvensis* (L.) Pers., 28.3% for *A. retroflexus*, 24.7% for *B. tectorum* and *A. myosuroides* 22.6% rate.

Table 10. Weed density, frequency of occurrence and general coverage of weeds in Center subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Agropyron repens (L.) P.Beauv.	11.4	58.1	20.4
Alopecurus myosuroides Huds.	10.9	57.2	22.6
Convolvulus arvensis L.	10.8	55.6	30.2
Bromus tectorum L.	9.74	53.7	24.7
Chenopodium album L.	8.2	42.5	30.3
Amaranthus retroflexus L.	7.6	25.3	28.3
Cynodon dactylon (L.) Pers.	7.3	28.9	16.4
Digitaria sanguinalis (L) Scop.	5.6	8.4	2.1
Dactylis glomerata L.	5.4	28.7	12.8
Sorghum halepense (L.) Pers.	4.9	34.3	8.9
Avena sterilis L.	2.1	12.4	3.5
Poa trivialis L.	2.0	6.2	0.89
*Cuscuta campestris*Yuncker	1.82	9.3	0.3
Centaurea solstitialis subsp. s*olstitialis*	1.72	1.3	0.92
Setaria viridis (L.) P. Beauv.	1.68	1.4	1.03
Cardaria draba ssp *draba* (L.) Desv.	1.59	18.4	2.8
Acroptilon repens (L.) DC.	1.53	2.1	0.5
Bromus arvensis L.	1.4	22.8	2.1
Matricaria chamomilla L.	1.25	20.1	1.6
Cyperus rotundus L.	1.2	17.9	1.6
Phragmites australis (cav.) Trin. Ex steudel	1.06	3.2	2.8
Others	18.75	-	-
Total	117.94	-	-

Nurhak subregion

In this area, *B. arvensis*, *A. repens* (L.) P.Beauv., *D. glomerata*, *A. retroflexus*, *C. album* and *A. myosuroides* were determined high densely. *L. serriola, S. viridis, C. dactylon, C. arvensis, C. solstitialis* subsp. *solstitialis*, *E. crus-galli*, *L. temulentum* and *M. longifolia* were determined densely (Table 11).

The maximum frequency of occurence of weed species were 60.6% for *B. arvensis*, 59.4% for *A. retroflexus,* 56.2% for *C. album*, 54.3% for *A. repens* and 52.1% for *D. glomerata*. General coverage of weeds were 32.6% for *B. arvensis*, 34.8% for *A. retroflexus*, 29.3% for *C. album*, 26.5% for *D. glomerata* and 23.4% for *A.repens*.

Table 11. Weed density, frequency of occurrence and general coverage of weeds in Nurhak subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Bromus arvensis L.	12.8	60.6	32.6
Agropyron repens (L.) P.Beauv.	11.2	54.3	23.4
Dactylis glomerata L.	11.0	52.1	26.5
Amaranthus retroflexus L.	10.7	59.4	34.8
Chenopodium album L.	10.5	56.2	29.3
Alopecurus myosuroides Huds.	10.3	43.8	20.5
Lactuca serriola L.	5.2	27.3	12.7
Setaria viridis (L.) P.Beauv.	5.0	10.2	9.6
Cynodon dactylon (L.) Pers.	4.7	13.5	8.3
Convolvulus arvensis L.	3.8	20.7	7.2
Centaurea solstitialis subsp. *solstitialis*	2.64	2.5	1.1
Echinochloa crus-galli (L.) P.Beauv**.**	1.5	2.1	1.6
Lolium temulentum L.	1.28	4.6	4.5
Mentha longifolia (L.) Hudson.	1.12	1.3	2.1
Others	6.01	-	-
Total	97.75	-	-

Pazarcık subregion

The weed species, *B. arvensis, A. repens* (L.) P.Beauv. were determined high densely. *B. tectorum, C. dactylon, C. album, A. retroflexus, C. arvensis, A. myosuroides, S. halepense, D. glomerata, C. solstitialis* subsp. *solstitialis, D. sanguinalis, S. viridis, L. temulentum, L. amplexicaule* and *A. columnaris* species were determined densely (Table 12).

Table 12. Weed density, frequency of occurrence and general coverage of weeds in Pazarcık subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Bromus arvensis L.	10.5	54.9	30.3
Agropyron repens (L.) P.Beauv.	10.1	53.6	25.1
Bromus tectorum L.	7.2	38.3	19.8
Cynodon dactylon (L.) Pers.	5.3	32.8	17.2
Chenopodium album L.	4.9	30.4	16.4
Amaranthus retroflexus L.	4.3	25.7	19.3
Convolvulus arvensis L.	3.2	20.3	16.0
Alopecurus myosuroides Huds.	2.4	8.2	5.6
Sorghum halepense (L.) Pers.	2.1	9.2	4.7
Dactylis glomerata L.	1.6	9.6	3.2
Centaurea solstitialis subsp. *solstitialis*	1.4	4.1	2.4
Digitaria sanguinalis (L.) Scop.	1.3	3.9	2.9
Setaria viridis(L.) P.Beauv.	1.2	6.5	1.8
Lolium temulentum L.	1.19	2.1	1.6
Lamium amplexicaule L.	1.11	3.2	1.9
Aegilops columnaris Zhuk.	1.1	1.3	0.3
Others	10.61	-	-
Total	69.51	-	-

The most frequency of occurence of weed species was 54.9% for *B. arvensis*, 53.6% for *A. repens*, 38.3% for *B. tectorum*, 32.8% for *C. dactylon* and 30.4% for *C. album*. General coverage of weeds were 30.3% for *B. arvensis*, 25.1% for *A. repens*, 19.8% for *B. tectorum*, 19.3% for *A. retroflexus* and 17.2% for *C. dactylon*.

Türkoglu subregion

In this region, *B. arvensis, S. halepense* ve *A. repens* (L.) P.Beauv. were determined high densely. *C. album, A. retroflexus, C. arvensis, S. viridis, L. serriola, A. myosuroides, C. dactylon, M. chamomilla, D. sanguinalis, S. arvensis, C. rotundus, S. asper* and *D. glomerata* were determined densely (Table 13).

The frequency of occurence of weed species were %54.2 for *B. arvensis*, 52.4% for *S. halepense*, 51.8% for *A. repens*, 43,9% for *C. album* and 37.3% for *A. retroflexus*. General coverage of weeds were 30.9% for *B. arvensis*, 29.4% for *S. halepense*, 28.2% for *A. retroflexus,* 25.1% for *C. album* and 24.6% for *A. repens*.

Table 13. Weed density, frequency of occurrence and general coverage of weeds in Türkoglu subregion

Weed species	Density (plants/m^2)	Frequency(%)	Coverage(%)
Bromus arvensis L.	10.9	54.2	30.9
Sorghum halepense (L.) Pers.	10.6	52.4	29.4
Agropyron repens (L.) P.Beauv.	10.3	51.8	24.6
Chenopodium album L.	9.2	43.9	25.1
Amaranthus retroflexus L.	8.1	37.3	28.2
Convolvulus arvensis L.	7.2	22.6	19.5
Setaria viridis (L.) P.Beauv.	3.4	14.1	12.2
Lactuca serriola L.	3.2	13.6	10.4
Alopecurus myosuroides Huds.	3.1	12.1	10.6
Cynodon dactylon (L.) Pers.	3.0	11.5	8.9
Matricaria chamomilla L.	2.5	10.2	6.4
Digitaria sanguinalis (L) Scop.	2.3	7.8	6.5
Sinapis arvensis (L.)	2.1	9.1	5.3
Cyperus rotundus L.	1.9	8.7	5.7
Sonchus asper (L.) Hill.	1.4	7.4	5.2
Dactylis glomerata L.	1.2	5.9	3.6
Others	8.74	-	-
Total	89.14	-	-

Species and densities of the weeds found in the apple orchards of Kahramanmaras showed differences according to the subregions. Some species were distributed in all regions while some species were distributed regionally. *A.*

repens (L.) P. Beauv. was determined at high density in the all subregions. *C. album* was observed as high dense in the subregions of Afsin, Caglayancerit, Ekinozu, Elbistan, Göksun and Nurhak while it was detected dense in the subregions of Center, Pazarcık and Türkoglu and it was found low dense in the Andırın. *B. arvensis* was high dense found in the subregions of Afsin, Caglayancerit, Ekinozu, Elbistan, Göksun, Nurhak, Pazarcık and Türkoglu while it was found dense in Andırın and Center subregion. Similarly, *A.retroflexus* was observed with high dense in the subregions of Afsin, Caglayancerit, Ekinozu, Elbistan, Göksun, Center, Nurhak and Türkoglu while it was observed dense in the Pazarcık and low dense in the Andırın. *C. dactylon* was detected as high dense in the subregions of Afsin, Andırın, Caglayancerit, Ekinozu, Elbistan and Göksun while it was determined as dense in the subregions of Center, Nurhak, Pazarcık and Türkoglu. *A. myosuroides* was detected as high dense in the subregions of Afsin, Caglayancerit, Ekinozu, Elbistan, Göksun, Center and Nurhak while it was found dense in the subregions of Andırın, Pazarcık and Türkoglu.

C. arvensis was found high dense in Center and Türkoglu, dense in Afsin, Andırın, Caglayancerit, Ekinozu, Elbistan, Göksun, Nurhak and Pazarcık. *D. glomerata* was found high dense in Andırın and Göksun, dense in Caglayancerit, Center, Pazarcık and Türkoglu, and it doesn't exist in Afsin, Ekinozu and Elbistan. *B. tectorum* was found high dense in Caglayancerit and Center, dense in Afsin, Andırın, Ekinözü, Göksun and Pazarcık, and low dense in Elbistan, Nurhak, and Türkoglu. *L. serriola* was found high dense in Elbistan and Göksun, dense in Afsin, Ekinozu, Nurhak, Türkoglu and low dense in Andırın, Caglayancerit, Center and Pazarcık. *S. viridis* was found dense in Andırın, Caglayancerit, Ekinözü, Göksun, Center, Nurhak, Pazarcık and low dense in Afsin and Elbistan. *D. sanguinalis* was found high dense in Afsin, dense in Göksun, Center, Pazarcık and Türkoglu and it doesn't exist in Andırın, Caglayancerit, Ekinözü, Elbistan and Nurhak. *L. temulentum* was high dense in Göksun, dense in Afsin, Caglayancerit, Elbistan, Nurhak and Pazarcık and low dense in Andırın, Ekinozu, Center and Türkoglu. *S. halepense* was high dense in Türkoglu, dense in Göksun, Center and Pazarcık, and it doesn't exist in Afsin, Andırın, Caglayancerit, Ekinozu, Elbistan and Nurhak. *C. draba* sp *draba* was found dense in Ekinozu, Elbistan, Göksun and Center, low dense in Afsin, Caglayancerit, Nurhak, Pazarcık and Türkoglu and rarely observed in Andırın. *A. cylindrica* was found dense in Afsin, Andırın, Ekinozu, Elbistan and Göksun, low dense in Caglayancerit, and it doesn't exist in Center, Nurhak, Pazarcık and Türkoglu. *C. arvense* was dense in Afsin, Ekinozu, Elbistan and Göksun, low dense in Caglayancerit, Center, Nurhak, Pazarcık and Türkoglu and low dense in Andırın. *C. galaticus* was found dense in Afsin, Ekinozu, Elbistan and Göksun, low dense in Andırın, Caglayancerit and Center and it doesn't exist in Nurhak and Pazarcık. *M. chamomilla* was found dense in Afsin, Center and Türkoglu, low dense in Caglayancerit, Ekinozu, Elbistan, Göksun, Nurhak, Pazarcık and Andırın.

Kahramanmaras region is located in Mediterranean region and Continental climate zones. Therefore, while Center, Pazarcık and Türkoglu subregions are located in the Mediterranean climate, Andırın and Caglayancerit are located in the transition climate. However, Göksun, Afsin, Elbistan, Nurhak and Ekinozu have a continental climate. The region have different soil structure types. The pH of the soil in the region varied from 7.06 to 8.33 and generally it was 7.60. Calcareous contents of the region were generally less than 5% (Yılmaz *et al*., 2000).

The weed density in the Göksun subregion was found much more than that of the other subregion because it had 6 times larger apple orchards area than other subregions. Because Pazarcık subregion was the smallest apple orchads area, its weed density was found low. Determined density, frequency of occurance and coverage of the some species of weeds varied according to subregions. In this study, densities of the perennial plants with rhizome and stolon were especially found high.

Densities of *Cyperus* spp. and *P. oleracea* in the Mediterranean region were reperted as the most common weeds especially in the summer season (Kadıoglu and Ulu, 1993). Frequency of occurrence of *Stelleria media, M. chamomille, Oxalis* spp., *Poa annua* and *L. serriola* were more than 50% on March and April in the same study. In Aydın region, 47 weed species belonging to 20 families were reported by Ögüt and Boz (2007) and frequency of occurrence were 79.80% for *S. media*, 63.60% for *M. chamomilla*, 55.50% for *Oxalis corniculata*, 52.80% for *Poa annua* and 50.0% for *L. serriola* in the dormand season. On the summer season, frequency of occurrence of *P. oleracea*, *C. rotundus* and *Amaranthus* spp. were 87.80, 85.80 and 63.30%, respectively. Frequency of occurrence of *T. terrstris, C. dactylon, C. arvensis, D. sanguinalis, L. serriola, C. album, E. crus-galli* and *S. halepense* varied from 20 to 45% while the other weeds were in between 2 and 10% frequency of occurrence. The coverage of the weeds were 56.25% for *P. oleracea,* 52.70% for *C. rotundus,*16.62% for *C. dactylon*, 16.54 % for *Trifolium* spp., 13.39% for *D. sanguinalis,* and 12.74% for *Amaranthus* spp. (Ögüt and Boz, 2007). A total of 47 weed species belonging to 19 families were identified on the apple orchards in Nigde region (Ustuner and Ustuner, 2011). In the survey studies in Isparta's apple orchards, densities of *A. retroflexus, P. oleracea* (8.92 plants m^{-2}) and *Setaria verticillata* were detected as 10.56%, 8.92% and 4.79%, respectively. The coverage areas were 5.14% for *A. retroflexus*, 3.69% for *Tribulus terrestris* and 3.00% for *P. oleracea*. The most common weed species in the apple orchards were 83.33% for *C. album, C. arvensis* and *P. oleracea,* 77.78% for *A. retroflexus* and 77.22% for *L. serriola* (Kitis, 2011).

Densities and frequency of occurrence of weeds in Turkey were reported by Kadıoğlu and Ulu (1993), Zeki *et al.*, (1994), Tepe (1997), Yazlık and Tepe (2001), Karaca and Guncan (2003), Ustuner and Akyol (2007), Ögüt and Boz (2007) and Kitis (2011). The results of this studies were similar with our results. Majority of the weeds were *A. repens* (L.) P.Beauv., *A. myosuroides*, *Amaranthus* spp., *B. tectorum, C. album, C. dactylon, S. viridis, D. glomerata, C. arvensis, M. chamomilla, L. serriola, S. halepense* and *D. sanguinalis.* However, the species of *Trifolium* spp., *Lolium perenne, Lotus corniculatus* L., *Taraxacum* spp., *P. annua, P. lanceolata, Stelleria media, Oxalis corniculata, P. oleracea, C. bursa-pastoris, C. rotundus, E. crus-galli* and *T. terrestris* showed differencies according to the region. The reason of these differences is different climate due to conditions, irrigation systems, soil type and altitudes of the regions.

The results of the present study were also consistent with the results of the studies carried out different region in the world (Dastgheib and Frampton, 2000; Harrington *et al.*, 2002; Hamma and Ibrahim, 2013; Verma and Chauhan, 2013). *A. retroflexus*, *A. repens C. album* and *C. arvensis* in the present study were similar with the species in the previous studies.

Some of the factors such as the altitude, soil structure, climate, irrigation system and plant communities of the region played a vital role in these similarities.

Consequently, densities, frequency of occurrence and coverage of the weeds may be different according to the subregion. These numerical values may also vary in the same region. The factors such as altitude, climate, soil structure, irrigation systems, tree corolla width (shadowing) and plantation area's size of the region may play a role in emerging of this variation.

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MORPHOLOGICAL CHARACTERIZATION OF GEOGRAPHICAL INDICATION LITCHI CROPS AND RELEASED VARIETIES GROWN IN BANGLADESH

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Abstract

Four Geographical Indication litchi genotypes (GIs) viz., Kadmi Lichu, Mongalbari Lichu, Deshi/Ati/Rajshahi Local (BARI Lichu-1) and Bedana Lichu, and three released varieties viz., BARI Lichu-2, 3 and 4) were characterized morphologically during July 2012 to June 2013 with a view to identifying the degree of morphological and genetic variation of litchi within cultivars, and to establish a permanent database for documentation of litchi. Morphological characterization data were recorded from standing trees of the most concentrated areas of cultivation for GIs and the respective stations from where the variety was released viz., Kadmi from Sonargaon, Narayanganj; Mongalbari from Pakundia, Kishoreganj; Rajshahi Local from Mohanpur village of Shyampur union under Rajshahi district; Bedana from Masimpur, Dinajpur; BARI Lichu-2 and BARI Lichu-3 from RARS, Akbarpur and BARI Lichu-4 from BSPC, Debiganj. Historical background of geographical indication crops of litchi as described by aged people of their most concentrated areas of cultivation indicated that the cultivars were originated naturally in those areas. The cultivars were very location specific. They do not perform well in respect of yield and quality outside their areas of origin indicating their very narrow adaptability range. It was another indication regarding location of origin of the GI crops. On the other hand, the exotic cultivars grown in the country such as BARI Lichu-2, BARI Lichu-3 etc. possess country wide adaptability. Wide variations were observed among the GI crops and released varieties included in this study for plant, leaf, inflorescence, flower and fruit characters. Variation was also recorded in respect of incidence of biotic and abiotic stresses like insect pests, mites, diseases, sunburn, fruit cracking and fruit drop. Each GI/released variety possesses some unique characters, which distinguish it from all other genotypes.

Keywords: Litchi, characterization, geographical indication, released varieties.

Introduction

The litchi (*Litchi chinensis*) is one of the major fruit crops in Bangladesh. It is a member of the family Sapindaceae. Litchi fruit is famous for its excellent quality, characteristic pleasant flavour and for attractive red colour. Olfert Dapper (1670) wrote that the tree in fruit seems to be decorated with 'purple hearts' which melt like sugar in the mouth and that rightly the litchi should be called 'the queen of

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fruits'. In Bangladesh, it is liked very much as a table fruit and the fruits are in great demand during the season which, however, is rather too short, lasting about one month during May to June. It is also used as an excellent canned fruit. It is admitted that the litchi is a native of the South China (very close to Bangladesh). From China litchi reached Eastern India first via Burma by the end of 17th century and thereafter by the end of 18th century, it was introduced to Bengal (Goto, 1960; Knight, 1980 and Liang, 1981). From Bengal it spread to other parts of India (Pandey and Sharma, 1989). Hence, it can be said that Bangladesh (the then Bengal) is the secondary centre of diversity for this species.

It is grown all over the country sporadically especially in homesteads. In some areas like Dinajpur, Rajshahi, Pabna, Kustia and Chittagong Hill Tracts litchi is grown commercially in small to medium orchards. In some pocket areas of Narayanganj (Sonargaon) and Kishoreganj (Pakundia), it is cultivated in mini orchard form and in homesteads. Area under litchi cultivation in Bangladesh in orchard form is about 1725 hectare and total production in inside and outside orchard is 64995 metric tons (BBS, 2011). Several local and exotic cultivars are grown in the country. The cultivars are mostly location specific. Bangladesh Agricultural Research Institute (BARI) has developed five improved varieties through selection. Some cultivars have been originated in some localities and are being cultivated in those areas from more than several hundred years, which can be termed as geographical indication crops (GIs) for those locality. It is essential to characterize the GIs and released varieties of litchi both in morphological and molecular level for establishment of Intellectual Property Rights (IPR). A project was undertaken by Bangladesh Agricultural Research Council (BARC) to characterize GIs and released varieties of some crops grown in the country with the financial support of Sponsored Public Goods Research - National Agricultural Technology Project (SPGR-NATP) Phase-1. BARI has been assigned with 10 of its mandated crops and litchi is one of them. Four GIs and three released varieties of litchi have been included in this programme for characterization at their morphological level. The present study was, therefore, undertaken to identify the degree of morphological and genetic variation of litchi within cultivars, and to establish a permanent database for documentation of litchi, which will ultimately facilitate establishment of IPR for GI crops of litchi.

Materials and Method

Selection of trees for GI and released varieties

Seven genotypes of litchi (four GI crops and three released varieties) were characterized morphologically under SPGR-NATP financed project entitled "Characterization of important plant genetic resources" during July 2012 to June 2013. Four GI crops viz., Kadmi Lichu, Mongalbari Lichu, Deshi/Ati/Rajshahi Local (BARI Lichu-1) and Bedana Lichu and three released varieties viz., BARI

Lichu-2, 3 and 4 was included in this programme. Morphological characterization data were recorded from standing trees. The centre of diversity or most concentrated area of cultivation of the respective GI was identified through discussion with experienced fruit scientists and Department of Agriculture Extension (DAE) Officials at district and upazila level. A team of scientists, involved in this programme, visited Sonargaon upazila of Narayanganj for Kadmi Lichu, Pakundia upazila of Kishoreganj for Mongalbari Lichu, Mohanpur village of Shyampur union under Rajshahi district for Deshi/Ati/Rajshahi Local (BARI Lichu-1), Masimpur village under Dinajpur Sadar upazila for Bedana Lichu, and located the targeted trees of selected GIs. Then three plants were selected in each location for each GI crop for data collection. Each plant was labeled with laminated paper sheet as plant number 1, 2 and 3 for each GI. For released varieties, the team visited Regional Agricultural Research Station, Akbarpur, Moulvibazar for BARI Lichu-2 and BARI Lichu-3; Breeder Seed Production Centre, Debiganj, Panchagarh for BARI Lichu-4 from where the varieties were developed. Discussing with the station heads and working scientific personnel, the original mother tree(s) (OMT) was identified and selected for data collection. In cases where there was only one OMT, daughter mother trees (DMT) were also selected for data collection. Each OMT and DMT was labeled as plant number 1, 2 and 3.

Recording historical background

Scientists discussed with aged people of the growing areas to find out the historical background of the respective GIs of litchi. The team also located some very old trees (>100 years) as indicated by the nearby people and symptoms on the tree like canopy coverage, trunk circumference, extra-rough trunk surface and galls on trunk etc.

Management practices

Farmers normally sell their crop as total plantation either in orchard or in homesteads just after harvest of the previous year's fruit. Then entire liability of the plantation goes to the traders. Management practices like pruning, weeding, irrigation, and fertilizer and pesticide application etc. were done by the traders. Chemical fertilizers like urea, TSP, MoP, gypsum etc. were applied at different rates. None of the traders used recommended doses of fertilizers. Pesticides as prescribed by the dealers or experienced traders were used indiscriminately even one or two days before harvesting especially for controlling fruit borer. All traders used to prune the mite infested top shoot during fruit harvesting. In the research stations application of fertilizers and other cultural practices like ploughing, weeding, irrigation, pruning etc. were done as per recommendation of BARI.

Observation, data collection and record keeping

The selected trees were visited frequently at different stages of growth, flowering and fruiting. Passport information and morphological data in respect of plant, leaf, flower/inflorescence, fruit and stone characters were recorded following IPGRI Descriptors for Litchi (IPGRI, 2002) at appropriate time. A data collection book was prepared following IPGRI Descriptors prior to initiation of the programme. The photographs of the specific trait considered to be helpful for identification of the variety/cultivar were taken from each genotype at appropriate time of traits to compare the distinctness among them. Data related to distinctness in morphological traits were photographed on each of the seven litchi genotypes.

Results and Discussion

Historical background

1. Kadmi Lichu: This cultivar of litchi is commercially cultivated in Sonargaon municipality area, and Mograpara and Bodyerbazar unions of Sonargaon upazila under Narayanganj district. It is also sporadically planted in homesteads of other areas of the upazila. A gentle man namely Amendra Sen planted the first plant of the cultivar in Panamgabtali village under Bodyerbazar union more than 120 years ago. Mr. Saroz Roy established an orchard more than 90 years ago in the same village taking air layerage from this plant. Later on this orchard got reputation in the name of his (Saroz Roy's) son as 'Sadhu's orchard'. The variety spread in other areas of the upazila from this orchard as 'Kadmi Lichu'. At present Hazi Abdul Latif Gazi, a resident of nearby village Haria Chaudhurypara is the owner of this orchard. His father bought this orchard in 1959. Hazi Md. Fazar Ali (more than 90 years old villager) described the history of Kadmi Lichu, which was supported by Hazi Abdul Latif Gazi (65 years).

2. Mongalbari Lichu: Cultivation of this variety was initiated from Mongalbaria village of Pakundia upazila under Kishoreganj district. Commercial cultivation of this variety is still concentrated in this village only. In recent days, some farmers of nearby villages started establishing orchard with this variety seeing its commercial potentiality. The variety was named as per name of the village, where it is commercially grown. There is a close relationship between initiation of cultivation of Mongalbari Lichu and establishment of Mongalbaria Kamil Madrasa. Moulvi Azim Khandaker established the Madrasa in 1802 a.c. and in the same year he planted the first plant of the variety in the Madrasa premises. Later on it has disseminated throughout the village at homestead level. Commercial cultivation was started about 40 years ago. Very large and aged plants were found during visiting the Mongalbaria village. Maulana Md. Toibuzzaman, Principal, Mongalbaria Kamil Madrasa described the history of Mongalbari Lichu. He also mentioned that they are maintaining history of both Madrasa and Mongalbari Lichu.

3. Rajshahi Local (Deshi) Lichu/BARI Lichu-1: Rajshahi Local (Deshi) lichu is commercially cultivated in Rajshahi region (Rajshahi, Natore, Chapainawabganj and Pabna districts). Initiation of cultivation of the variety in this region could not be known. Some old plants (more than 100 years) were located in Mohanpur village of Shyampur union under Rajshahi district. Some old men of this area stated that they have been seeing the cultivation of the variety since childhood. Their father or grandfather planted those plants. Most of those plants died due to over age. Md. Shetar Uddin Mondal (about 90 years old) of Mohanpur village described the history of Rajshahi Local (Deshi/Ati) Lichu, which was supported by Md. Aizuddin (about 70 years old). It can be guessed from the statement of the old people that cultivation of Rajshahi Local (Deshi) Lichu has been initiated in this region more than 150 years ago. This cultivar has been released as BARI Lichu-1 in 1996.

4. Bedana Lichu: The general people of the locality confidently stated that cultivation of Bedana Lichu was initiated in Masimpur village under Dinajpur Sadar upazila. A 65 years old villager Md. Azhar Ali claimed that the first plant of the variety was planted by his father in the vicinity of his house more than 100 years ago. About 80 years old villager Md. Asim Uddin told that he has been observing this litchi since his childhood. Some aged plants were found in the village, which were seemed to be over 100 years old. The villagers stated that earlier the variety was called as Kancha Mitha Lichu as it was less sour at green stage. According to their statement, the variety was not much popular before 1980s because of poor bearing. Virtually the variety needs intensive care and nourishment. When litchi attained commercial importance, traders started applying fertilizer and irrigation to litchi orchards. Then it flourished as a quality variety having high yield and its demand increased rapidly, and the price went sky-high within very short time during early 1980s (from Tk.150 to 2000 per 1000 fruits). Based on its colour, seed size and high price someone compared it with pomegranate (which is termed as 'Bedana' in Bangla), and spontaneously the variety was named as 'Bedana Lichu.'

5. BARI Lichu-2: The variety has been selected from exotic germplasm and released in 1996 for cultivation in Bangladesh after a long time evaluation at the Regional Agricultural Research Station, Akbarpur, Moulvibazar. It is a late variety and is suitable for cultivation in eastern and north eastern region of the country.

6. BARI Lichu-3: The variety has been selected from exotic germplasm and released in 1996 for cultivation in Bangladesh after a long time evaluation at the Regional Agricultural Research Station, Akbarpur, Moulvibazar. It is a mid season variety and is suitable for cultivation all over the country.

7. BARI Lichu-4: The variety has been selected from several locally collected germplasm planted at the Breeder Seed Production Centre (BSPC), Debiganj, Panchagarh and released in 2008 as BARI Lichu-4 for cultivation in the north-western region of Bangladesh after a long time evaluation. Mr. Md. Abdul Quadir, the then Assistant Agronomist of the centre collected several local germplasm of litchi and planted in the farm during 1960s. Parentage and origin of the variety is unknown. It is assumed that this variety was evolved from chance seedling more than 100 years ago. Md. Asimuddin (100 years old), resident of nearby village Khaturia under Domar upazila of Nilfamari district (former master roll labour of the centre) described the history of BARI Lichu-4. It is a mid season variety and is adapted only in the north-western region of the country. Source of collection, name of collector and actual date of planting of original mother tree (OMT) could not be traced out.

Passport data, plant, leaf, inflorescence/flower, fruit and seed characteristics and incidence of pest and diseases recorded for the geographical indications and released varieties of litchi are presented in tables 1 to 7.

Plant characters

Results presented in Table 2 revealed that litchi genotypes included in this study varied widely in respect of plant characters like tree vigour, trunk surface, crown shape, growth habit, branching density, branching pattern and young shoot pubescence. Tree vigour was high for GI crops and low or medium in exotic genotypes (BARI Lichu-2, 3). Rajshahi Local/BARI Lichu-1 had the maximum tree height (12.12 m) and trunk circumference (278 cm) while BARI Lichu-4 had the minimum tree height (5.50m) and BARI Lichu-3 had the minimum trunk circumference (82 cm). Crown diameter and tree volume were also maximum (16.56 m and 979.25 m^3) in Rajshahi Local/BARI Lichu-1 and minimum (7.30 m and 99.70 m^3) in BARI Lichu-3. Variations in quantitative plant characters (tree height, trunk circumference, crown diameter and tree volume) might be due to both genetic behaviour of the genotypes and tree age. Trunk surface was rough in all the genotypes except BARI Lichu-2, which possesses smooth trunk surface. Rajshahi Local/BARI Lichu-1 had distinct crown shape (irregular) as against semi-circular crown shape in other genotypes. Tree growth habit was semi-erect in five genotypes while that in Mongalbari and Bedana was erect. Branching was dense in four genotypes and medium dense in the remaining three genotypes. Branching pattern was irregular in all the genotypes. This might be due to vegetative propagation of the trees through air layering. Only BARI Lichu-2 had glabrous young shoot. That of other genotypes was pubescent. Khurshid *et al.* (2004) recorded wide variation among litchi cultivars for canopy spread and tree shape, Miao *et al.* (1998) and Rai *et al*. (2001) recorded wide variation for tree height. The results are in accordance with the findings of present investigation.

Table 1. Passport data of geographical indications and released varieties of litchi grown in Bangladesh

Character / Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Collecting Institute	BARI	BARI	BARI	BARI	BARI	BARI	BARI
Country of origin	Bangladesh	Bangladesh	Bangladesh	Bangladesh	-	-	Bangladesh
Name of farmer	Hazi A. Latif Gazi	Mukhlesur Rahman	Md. Alaluddin	Mohammed Azhar Ali	CSO, RARS, Akbarpur, Moulvibazar	CSO, RARS, Akbarpur, Moulvibazar	CSO, BSPC, Debiganj, Panchagarh
Location of collecting site	Vill: Panamgabtali UP: Bodyerbazar, Uz:Sonargaon Dist: N'ganj	Vill: Mongalbaria UP: Pakundia, Uz: Pakundia, Dist: K'ganj	Vill: Mohanpur, UP: Harian, Uz: Motihar, Dist: Rajshahi	Vill: Masimpur, UP: Auliapur, Upazila: Sadar Dist: Dinajpur	RARS, Akbarpur, Moulvibazar	RARS, Akbarpur, Moulvibazar	BSPC, Debiganj, Panchagarh
Latitude of the site	$23^{0}39.660'$N	$24^{0}19.428'$N	$24^{0}21.096'$N	$25^{0}34.46'$N	$24^{0}25.892'$N	$24^{0}25.892'$N	$26^{0}15.270'$N
Longitude of the site	$90^{0}37.077'$E	$90^{0}41.244'$E	$88^{0}48.675'$E	$88^{0}37.55'$E	$91^{0}45.692'$E	$91^{0}45.692'$E	$88^{0}51.311'$E
Commercial value	High	High	High	High	High	Very high	Very High
Cultivation practices	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard
Area coverage	30 ha	40 ha	328 ha	-	-	-	-

Table 2. Plant characters of geographical indications and released varieties of litchi grown in Bangladesh

Character / Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Tree age	90 yrs	42 years	> 80 years	>100 years	> 50 years	> 50 years	50 years
Tree vigour	High	High	High	High	Medium	Low	High
Tree height	7.20 m	11.41 m.	12.12 m	10.26 m	6.67 m	6.35 m	5.50 m
Trunk circumference	189 cm	197 cm	278 cm	156 cm	110 cm	82 cm	170 cm
Trunk surface	Rough	Rough	Rough	Rough	Smooth	Rough	Rough
Crown diameter	9.13 m	12.03 m	16.56 m	9.83 m	8.24 m	7.30 m	11.0 m
Tree volume	176.84 m^3	486.50 m^3	979.25 m^3	292.09 m^3	133.43 m^3	99.70 m^3	195.91 m^3
Crown shape	Semi-circular	Semi-circular	Irregular	Semi-circular	Semi-circular	Semi-circular	Semi-circular
Tree growth habit	Semi-erect	Erect	Semi -erect	Erect	Semi-erect	Semi-erect	Semi-erect
Branching density	Medium	Dense	Dense	Medium	Medium	Dense	Dense
Branching pattern	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular
Young shoot pubescence	Pubescent	Pubescent	Pubescent	Pubescent	Glabrous	Pubescent	Pubescent

Table 3. Leaf characters of geographical indications and released varieties of litchi grown in Bangladesh

Cultivar / Character	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Young leaf colour	Pinkish green	Yellowish green	Yellowish green	Purple	Purple	Purple	Pinkish green
Mature leaf colour	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green
No. of leaflet per leaf	6.00	7.00	6.50	7.00	6.33	4.33	6.00
Arrangement of leaflets	Opposite	Alternate	Both alternate and opposite	Both alternate and opposite	Both alternate and opposite	Opposite	Both alternate and opposite
Rachis length	8.48 cm	10.23 cm	13.93 cm	7.8 cm	7.17 cm	6.47 cm	6.90 cm
Petiole length	0.65 cm	0.73 cm	0.70 cm	0.43 cm	0.93 cm	0.67 cm	0.63 cm
Leaf blade length	13.90 cm	10.39 cm	15.13 cm	12.73 cm	11.03 cm	14.57 cm	9.73 cm
Leaf blade width	4.45 cm	3.83 cm	4.33	2.64	5.33 cm	4.73 cm	2.63
Leaflet blade shape	Elliptic	Elliptic	Elliptic	Elliptic	Elliptic	Elliptic	Oblong
Leaflet apex shape	Acuminate	Acuminate	Acuminate	Acute	Acuminate	Acute	Acute
Leaflet base shape	Cuneate	Attenuate	Cuneate	Attenuate	Cuneate	Cuneate	Attenuate
Leaflet upper surface pubescence	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Leaflet lower surface pubescence	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Leaflet midrib appearance	Prominent	Prominent	Prominent	Slightly prominent	Slightly prominent	Prominent	Prominent
Leaflet venation appearance	Slightly prominent	Slightly prominent	Slightly prominent	Not prominent	Slightly prominent	Slightly prominent	Not prominent
Leaflet curvature	Curve down slightly at top	Curve upward from midrib	Curve upward from midrib	Curve down slightly at top	Curve upward from midrib	Curve upward from midrib	Curve down slightly at top
Date of initiation of new flushes	Oct.-Nov.	Oct.-Nov.	Sep.- Oct.	Oct.-Nov.	Sep.-Oct.	Sep.-Oct., Dec.-Jan.	Oct.-Nov.
Protuberance on petiole	Present	Present	Present	Absent	Absent	Absent	Present

Leaf characters

Wide variation was observed among the genotypes in respect of all the leaf characters recorded except mature leaf colour, leaflet upper surface pubescence and leaflet lower surface pubescence (Table 3). Young leaf colour was yellowish green in Mongalbari and Rajshahi Local, and purple in other genotypes except Kadmi and BARI Lichu-4 having pinkish green leaf. Singh *et al*. (1999) noted that litchi cultivars can be distinguished on the basis of young leaf colour. Number of leaflets per leaf ranged from 4.33 in BARI Lichu-3 to 7.00 in Mongalbari and Bedana. Leaflets were arranged in opposite, alternate or both opposite and alternate modes. Rachis length was maximum (13.93 cm) in Rajshahi Local and minimum (6.47 cm) in BARI Lichu-3. BARI Lichu-2 had maximum (0.93 cm) and Bedana had minimum (0.43 cm) petiole length. Leaf blade length varied from 9.73 cm in BARI Lichu-4 to 15.13 cm in Rajshahi Local while leaf blade width varied from 2.63 cm in BARI Lichu-4 to 5.33 cm in BARI Lichu-2. BARI Lichu-4 showed distinctness in leaflet blade shape (oblong). Leaf blade shape was elliptic in other genotypes. Leaflet apex shape was acute or acuminate while Leaflet base shape was Cuneate or Attenuate. Protuberance on petiole was present in four genotypes (Kadmi, Mongalbari, Rajshahi Local and BARI Lichu-4) and absent in the remaining three genotypes. Wide variation among litchi cultivars for leaf length, leaf shape, young leaf colour and number of leaflets per leaf was also reported by Khurshid *et al.* (2004).

Inflorescence and flower characters

As per opinion of farmers and scientific staff engaged in farm management, first flowering occurred 3-4 years after planting in most of the genotypes (Table 4). Only BARI Lichu-2 flowered earlier (1-2 years). Panicle emerged during mid to late January in four genotypes but in Bedana, BARI Lichu-2 and BARI Lichu-4 it emerged in early February. Panicle emergence continued up to mid or late February, and in some cases (BARI Lichu-2, 3, 4) up to early March. According to Khurshid *et al.* (2004) environment profoundly influenced cultivar characteristics. So, variation in the time of panicle emergence might be due to varietal character or variation in weather condition among the locations. Mainly three types of flowers were observed in all the genotypes viz. male, functional male and functional female (Pandey and Sharma, 1989). Male or staminate flowers can easily be distinguished by the absence of pistil. The filaments in this type of flower varied in length. The functional female flowers strongly resembled the hermaphrodite flowers with 5-8 contabescent stamens and one bicarpeliate pistil. In functional male flower both pistil and stamens were present but the pistil was non-functional as the lobes of the stigma did not open to permit the entrance of the pollen. These three types of flowers were observed in all the seven genotypes studied.

Table 4. Inflorescence and flower characters of geographical indications and released varieties of litchi grown in Bangladesh

Character / Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Flowering precocity	3-4 yrs	3-4 yrs	3-4 yrs	3-4 yrs	1-2	3-4 yrs	3-4 yrs
Panicle duration	Late Jan. to late Feb.	3rd week of Jan. to 3rd week of Feb	Mid Jan. to mid Feb.	Early Feb. to late Feb.	2nd week of Feb. to 2nd week of Mar.	Late Jan. to 1st week of Mar.	Early Feb. to early Mar
Flowering duration (male)	Mid Feb. to late Feb.	3rd week of Feb. to early Mar.	Early Feb. to mid Feb.	Late Feb. to Early Mar.	1st week of Mar. to 3rd week of Mar.	Late Feb. to early Mar.	Late Feb. to mid Mar.
Flowering duration (functional male)	Late Feb. to Late Mar.	Late Feb. to mid Mar.	Mid Feb. to mid Mar.	Early Mar. to Late Mar.	3rd week of Mar. to 1st week of Apr.	1st week of Mar. to Late Mar.	Mid Mar. to early Apr
Flowering duration (functional female)	Early Mar. to Late Mar.	Early Mar. to Mid Mar.	Late Feb. to mid Mar.	Mid Mar. to Late Mar.	3rd week of Mar. to 2nd week of Apr.	1st week of Mar. to late Mar.	Mid Mar. to early Apr
Position of inflorescence	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary
Panicle stalk colour	Green	Light green	Light green	Light green	Green	Green	Green
Flower disk colour	Light yellow	Light cream	Yellow	Light cream	Light yellow	Light cream	Yellow
Flower size	Medium	Medium	Medium	Small	Small	Small	Medium
Inflorescence length	29.00 cm	37.00 cm	32.00 cm	29.00 cm	20.00 cm	21.00 cm	30.50 cm
Width of inflorescence	27.00 cm	24.00 cm	19.00 cm	15.00 cm	15.00 cm	14.00 cm	17.00 cm
Abundance of flower	Profuse	Profuse	Profuse	Moderate	Profuse	Moderate	Moderate

Male flowers opened and dried prior to opening of functional male and female flowers in all the genotypes. Synchronization was observed in anthesis of functional male and functional female flowers resulting successful pollination for fruit setting. Inflorescences were basically terminal in all the genotypes but simultaneously axillary inflorescences were also found. Inflorescence stalk colour was green or light green. Flower disk colour was light yellow in Kadmi and BARI Lichu-2, light cream in Mongalbari, Bedana and BARI Lichu-3. While that of Rajshahi Local and BARI Lichu-4 was yellow. Length of inflorescence ranged from 20.00 cm in BARI Lichu-2 to 37.00 cm in Mongalbari. Widest inflorescence (27.00 cm) was observed in Kadmi and the narrowest (14.00 cm) in BARI Lichu-3. Profuse flowers were borne by the local cultivars except Bedana while abundance of flowers was moderate in the released varieties except BARI Lichu-2 (profuse).

According to Menzel (1984), and Menzel and Simpson (1992), the flowers are in order of appearance, functionally male, functionally female and functionally male. Menzel (1983) reported that panicles were normally produced terminally in clusters, but in some trees a high percentage of axillary panicles may also be produced. Robbertse *et al.* (1995) observed that the apical bud of a modular branch produced one inflorescence. One or more of the lateral buds directly below the apical bud were also produced resulting in more than one inflorescence at the tip of a module. All the above results are in conformity with the results of present study.

Fruit characters

Geographical Indications and released varieties included in this study showed wide variation for almost all the characters recorded in respect of fruits (Table 5). All the genotypes took 4-5 years for fruiting from planting except BARI Lichu-3 which took little longer time (5-6 years). Fruit setting was completed within March in all the genotypes. Kadmi took minimum time (60-65 days) from fruit set to maturity closely preceded by Mongalbari (60-70 days). Maximum time (75 days) was taken by Bedana and BARI Lichu-2. Harvesting duration was also very short for all the genotypes. Narrower variation in fruit set duration and time taken for maturity from fruit set with shorter harvesting duration resulted very short harvesting season for this fruit. As per opinion of the farmers and researchers all the genotypes are regular in bearing. Local cultivars (GIs) except Bedana are heavy bearer while released varieties are medium in bearing intensity. Rajshahi Local had maximum fruits per cluster (17.6) and BARI Lichu-3 had the minimum (3.5).

Fruit shape was oval in Kadmi; oblong in Mongalbari and Rajshahi Local; cordate in Bedana and BARI Lichu-3 and round in BARI Lichu-2 and BARI Lichu-4. Kadmi and BARI Lichu-3 had even fruit shoulder while the shoulder of the remaining genotypes was protruding. Shape of fruit tip was obtuse only in BARI Lichu-3, which distinguished it from other genotypes having round fruit tip. Fruit segment was smooth in Kadmi and BARI Lichu-4. That of other genotypes was swelling type. Length of fruit ranged from 3.10 cm in BARI Lichu-3 to 3.67 cm in Mongalbari. BARI Lichu-4 produced the widest fruit (3.77 cm) and Rajshahi Local produced the narrowest (3.10 cm). Mongalbari, Bedana and BARI Lichu-4 were not prone to fruit cracking while in other genotypes fruit cracking was observed at various level. Colour of mature fruit was partially reddish yellow in Kadmi, BARI Lichu-2 and BARI Lichu-3; uniformly rosy red in Mongalbari; partially pinkish red in Rajshahi Local, and uniformly dark red in Bedana and BARI Lichu-4. The genotypes differed from each other in respect of shape and density of tubercles. Fruit suture was prominent in Kadmi, BARI Lichu-2 and BARI Lichu-4 while other genotypes had weak suture. BARI Lichu-4 had the maximum fruit (26.6 g) and aril (20.6 g) weight, and edible portion (77.44%). Fruit weight (18.0 g), aril weight (12.30 g) and edible portion (68.33%) was minimum in BARI Lichu-2. Total soluble solids content in fruit juice varied from 19.78% in Kadmi to 22.00% in BARI Lichu-4. Aril flavour was strong in Rajshahi Local and BARI Lichu-4, and intermediate in the other genotypes. Aril quality was very sweet for BARI Lichu-4, sour sweet for Kadmi and sweet for the remaining genotypes. Juicy aril was found in Kadmi, Rajshahi Local and BARI Lichu-2 while the aril of other genotypes was very juicy. Overall taste (eating quality) of Bedana and BARI Lichu-4 was excellent, and that of other genotypes was good to very good.

Pandey and Sharma (1989) reported that litchi fruits are produced in loose clusters of 2 to 20 or even more. The results are in consonance with the findings of the present study. Siddiqui (2002) categorized Rajshahi Local/BARI Lichu-1 as early, BARI Lichu-2 as late and BARI Lichu-3 as mid season variety. He also reported 19.5 g, 15.2 g and 18.4 g fruit weight, and 18.4 to 20.5%, 16.1 to 20.5% and 18.9 % total soluble solids content for BARI Lichu-1, BARI Lichu-2 and BARI Lichu-3, respectively which are in line with the results of present study.

Seed characters

Variation was also noticed for shape, size and colour of seed (Table 6). Mongalbari produced the longest (2.49 cm) and widest (1.57 cm) seed while BARI Lichu-3 had the shortest (1.82 cm) and BARI lichu-2 had the narrowest (1.30 cm) seed. Individual seed weight was minimum (2.30 g) in BARI Lichu-3 closely preceded by BARI Lichu-2 (2.70 g) and BARI Lichu-4 (2.78 g). Maximum seed weight (4.00 g) was recorded in Mongalbari. Oval shaped seed was found only in BARI Lichu-3 while seed shape of other genotypes was oblong. Seed coat colour was dark brown in Kadmi and Mongalbari, dull brown in BARI Lichu-4 and brown in the remaining genotypes.

Table 5. Fruit characters of geographical indications and released varieties of litchi grown in Bangladesh

Character / Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
No. of yrs to 1st fruiting from planting	4-5	4-5	4-5	4-5	4-5	5-6	4-5
Fruit set duration	2nd week of Mar. to 3rd week of Mar.	Early Mar. to 3rd week of Mar.	Early Mar. to 3rd week of Mar.	Mid Mar. to end of Mar.	Second week of Mar. to 3rd week of Mar.	Second week of Mar. to 3rd week of Mar.	Last week of Mar. to 1st week of Apr.
No. of days from fruit set to maturity	60-65 days	60-70 days	65-75 days	75 days	75 days	70 days	65 to 75 days
Fruit maturity group	Early	Early	Early	Medium	Late	Medium	Medium
Fruit availability period	1st week of May to 3rd week of May	1st week of May to 3rd week of May	3rd week of May to end of May	Last week of May to 1st week of Jun.	1st week of June to 3rd week of Jun.	4th week of May to end of May	1st week of Jun. to 2nd week of Jun.
Harvesting duration	2-3 weeks	2-3 weeks	2 weeks	2 weeks	1-2 weeks	1-2 weeks	2 weeks
Fruit ripening	Synchronous	Synchronous	Synchronous	Synchronous	Synchronous	Synchronous	Synchronous
Fruit bearing habit	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Fruit bearing intensity	Heavy	Heavy	Heavy	Medium	Medium	Medium	Medium
Fruit clustering habit	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters
No. of fruits per cluster	10.5	12.3	17.6	9.0	4.5	3.5	6.0
Fruit shape	Oval	Oblong	Oblong	Cordate	Round	Cordate	Round
Fruit shoulder	Even	Protruding	Protruding	Protruding	Protruding	Even	Protruding
Shape of fruit tip	Round	Round	Round	Round	Round	Obtuse	Round
Fruit segment	Smooth	Swelling type	Swelling type	Swelling type	Swelling type	Swelling type	Smooth
Fruit length	3.63 cm	3.67 cm	3.52 cm	3.53 cm	3.41 cm	3.10 cm	3.56 cm
Fruit diameter	3.39 cm	3.15 cm	3.10 cm	3.48 cm	3.11 cm	3.24 cm	3.77 cm
Fruit cracking	Prone	Not prone	Prone	Not prone	Prone	Prone	Not prone

Character / Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Fruit skin thickness	Medium	Thin	Medium	Medium	Thick	Medium	Medium
Mature fruit colour	Reddish yellow	Rosy red	Pinkish red	Dark red	Reddish yellow	Reddish yellow	Dark red
Distribution of colour on fruit	Partial	Uniform	Partial	Uniform	Partial	Partial	Uniform
Shape of tubercles	Sharp pointed	Slightly pointed	Sharp pointed	Smooth	Obtuse	Smooth	Smooth
Tubercle density	Dense	Medium	Medium	Sparse	Medium	Sparse	Sparse
Presence of suture	Prominent	Weak	Weak	Weak	Prominent	Weak	Prominent
Fruit attractiveness	Good	Good	Good	Excellent	Good	Good	Excellent
Fruit weight	23.0 g	22.0 g	20.0 g	24.6 g	18.0 g	22.0 g	26.6 g
Aril weight	16.0 g	15.4 g	14.0 g	18.6 g	12.3 g	16.8 g	20.6 g
Skin weight	3.60 g	2.6 g	2.60 g	3.20 g	3.00 g	2.90 g	3.22 g
Seed weight	3.40 g	4.0 g	3.40 g	2.80 g	2.70 g	2.30 g	2.78 g
Skin content	15.65 %	11.82 %	13.00 %	13.01 %	16.67 %	13.18 %	12.11 %
Seed content	14.78 %	18.18 %	17.00 %	11.38 %	15.00 %	10.45 %	10.45 %
Edible portion	69.57 %	70.00 %	70.00 %	75.61 %	68.33 %	76.36%	77.44 %
Aril thickness	Medium	Medium	Medium	Thick	Medium	Thick	Very thick
Aril texture	Fibrous	Soft	Crisp	Soft	Soft	Soft	Soft
Aril TSS	19.78 %	20.85 %	20.88 %	21.00 %	20.69 %	21.78 %	22.00 %
Aril flavour	Intermediate	Intermediate	Strong	Intermediate	Intermediate	Intermediate	Strong
Aril quality	Sour sweet	Sweet	Sweet	Sweet	Sweet	Sweet	Very sweet
Aril juiciness	Juicy	Very juicy	Juicy	Very juicy	Juicy	Very juicy	Very juicy
Aril colour	Dull white	Waxy white	Waxy white	Waxy white	Waxy white	Dull white	Dull white
Eating quality	Good	Good	Good	Excellent	Very good	Very good	Excellent

Table 6. Seed characters of geographical indications and released varieties of litchi grown in Bangladesh

Cultivar / Character	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Seed length	2.19 cm	2.49 cm	2.40 cm	2.09 cm	2.13 cm	1.82 cm	2.08 cm
Seed width	1.53 cm	1.57 cm	1.49 cm	1.43 cm	1.30 cm	1.47 cm	1.36 cm
Seed weight	3.40 g	4.00 g	3.40 g	2.80 g	2.70 g	2.30 g	2.78 g
Seed shape	Oblong	Oblong	Oblong	Oblong	Oblong	Oval	Oblong
Seed coat colour	Dark brown	Dark brown	Brown	Brown	Brown	Brown	Dull brown

Table 7. Incidence of biotic and abiotic stresses in GIs and released varieties of litchi grown in Bangladesh

Cultivar / Character	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Biotic and Abiotic Stress Susceptibility							
Insect Pests/Mites							
Fruit borer	Low	Low	Low	Low	Low	Low	Low
Bark eating caterpillar	Very low	Nil	Low	Low	Low	Low	Low
Trunk borer	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Litchi mite	Very low	Very low	Very low	Low	Low	Medium	Medium
Fungal Disease							
Leaf spot	Low	Very low	Very low	Nil	Medium	Medium	Nil
Flower blight	Nil	Nil	Nil	Nil	High	Low	Nil
Fruit rot	Very low	Nil	Very low	Nil	Low	High	Nil
Abiotic stress							
Sunburn	Low	Very low	Very low	Very low	Low	Very low	Very low
Fruit cracking	Low	Very low	Very low	Very low	Low	Low	Very low
Fruit drop due to wind	Low	Low	Low	Low	Low	Very low	Very low

Incidence of biotic and abiotic stresses

Incidence of biotic and abiotic stresses was recorded at varying level among the genotypes (Table 7). All the GIs and BARI Lichu-4 showed highly resistant to resistant reaction against all the stresses recorded under natural epiphytotic condition. But medium to high incidence of leaf spot, flower blight and fruit rot was recorded in BARI Lichu-2 and BARI Lichu-3.

Conclusion

Historical background of geographical indications of litchi as described by aged people of their most concentrated areas of cultivation indicated that the cultivars have been originated naturally in those areas. The cultivars possess high commercial value and are being cultivated widely around their areas of origin. Every GI possesses some special characters, which it might gain from its habitat. Each genotype had some unique characters, which distinguished it from all other genotypes. Considering all characteristics, BARI Lichu-4 can be ranked as the best among the genotypes studied. Some of the GIs viz. Bedana and Rajshahi Local are located along the periphery of the country. Both Bangladesh and India can claim them as their own property. It is essential to give proper attention to establish legal rights on these invaluable wealth of the country. For identification of the degree of morphological and genetic variation of litchi within cultivars and establishment of Intellectual Property Rights (IPR), characterization at molecular level is essential. Immediate action should be undertaken to perform molecular characterization of the geographical indications and released varieties of litchi with ultimate goal to provide necessary information for establishment of IPR on the same.

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NUTRIENT BALANCE UNDER WHEAT-MUNGBEAN-T. AMAN CROPPING PATTERN IN CALCAREOUS SOILS OF BANGLADESH

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Abstract

Field experiments on Wheat-Mungbean-T. *aman* cropping pattern were conducted at Regional Pulses Research Station (RPRS), Madaripur in calcareous soils under Low Ganges River Floodplain (AEZ-12) during 2009 to 2010 to prepare nutrient balance sheet for the cropping pattern and fertilizer recommendation for study area. The treatments were T_1= Control; T_2 = Farmer's practice; T_3 = AEZ based recommended fertilizer dose and T_4 = Soil test based fertilizer dose. The experiment was laid out in RCBD with three replications. Results revealed that the average yields of wheat, mungbean and T. aman ranged from 1517 to 3124 kg ha^{-1}, 1320 to 1863 kg ha^{-1} and 2974 to 4859 kg ha^{-1}, respectively. Grain yield of all crops increased significantly higher in soil test based (STB) fertilizer treatment (T_4) over the other treatments. Among the major nutrients, the magnitude of negative balance was greater with N and K followed by Mg and Ca. The negative balance of N (-56.0 to -183 kg ha^{-1}), K (-71.0 to -167 kg ha^{-1}), Ca (-7.50 to -27.1 kg ha^{-1}), and Mg (-16.7 to -35.7 kg ha^{-1}) was observed in all the managements might be due to added lower amount of nutrients in soil and higher removal by the crops from the soil. Positive balance of P indicated that the added amount of P is larger than the removal; P fertilization was enough to make apparent balances positive. Across various treatments, there was some amount of positive apparent S balance except absolute control plots and farmer's practice. On the other hand, Zn and B balance in the system was neutral to slightly positive. Results revealed that, N, K, Ca, and Mg balance after two years of cropping was negative regardless of soil type and management strategies adopted. There was an improvement in organic matter in all treatments where biomasses of mungbean were incorporated. Organic matter, N, P, S, Zn and B status in soil was improved due to soil test based fertilization over the initial status. Considering the gross margin and soil fertility the soil test based (STB) fertilizer management practice is economically profitable and sustainable.

Keywords: Cropping pattern, management, nutrient balance, calcareous soils.

Introduction

Cropping pattern means yearly sequence of crop production followed in an area. The pattern in an area depends largely on agro-climatic, technical and

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institutional factors. Among food grain crops, rice occupies the first position both in terms of areas and production, next to wheat (Ghosh, 2011). These cereal based patterns cause considerable depletion of soil fertility and threat to long-term crop productivity. Besides that, farmers of Bangladesh use imbalanced of fertilizers for crop production leading to degraded in soil health and fertility (Ali *et al.,* 2010). High yielding varieties of crops uptake higher amount of nutrient from soils resulting dwindling soil organic matter and deterioration of native soil fertility, poses a serious threat to long-term sustainability of crop production. Moreover, continuous cropping without adequate replacement of removed nutrients in harvested materials, nutrient loss through erosion, leaching and gaseous emission deplete soil fertility and causes soil organic matter level to decline (Yu *et al*., 2014). The bulk of the literature indicates that, apart from residue management, cropping system productivity may become sustainable through integrated use of organic and inorganic nutrients.

Hence, it is important to develop a cropping system based fertilizer dose for specific agro-ecological zones. Low levels of plant nutrients (macro and micro) in many soils especially calcareous soil accompanied with improper nutrient management are major constraints for food security and malnutrition. Quantification of the loss or gain of nutrients under different cropping patterns has not been done properly. Nutrient balance is an important tool for assessing the fate of native and added nutrients in soils. Plant fertilization and yield increase is the main objectives of nutrient balance calculations (FRG, 2012).

Therefore, the existing situations are appeared to be threatening to the whole agricultural system. In this situation, introducing legume crop and proper fertility management practices in the existing cropping patterns is the only means of rejuvenation of soil as well as increase in total national product. Considering the above circumstances, the study was under taken to prepare nutrient balance sheet for Wheat-Mungbean-T. aman cropping pattern and fertilizer recommendation for the study area.

Materials and method

The field experiments were conducted for consecutive two years from *rabi* 2008-09 to October 2010 at Regional Pulses Research Station (RPRS), BARI, Madaripur (23° 10′ 53″ N latitude and 90° 11′ 28″ E longitude) at an elevation of 7.0 m above the sea level. The land belongs to the agro ecological zone, Low Ganges River Floodplain (AEZ-12) and Gopalpur soil series (Soil taxonomy: Aquic Eutrochrepts). The soil had neutral pH (7.3) and loamy in texture. The other soil properties were 1.32% organic matter, total N was 0.063%, exchangeable K, Ca and Mg were 0.14 meq. 100 g^{-1}, 10.3 meq. 100 g^{-1} and 3.10 meq. 100 g^{-1}, respectively. The available P, S, Zn and B were 13.5 µg g^{-1}, 18 µg g^{-1}, 1.20 µg g^{-1} and 0.14 µg g^{-1}, respectively. Cropping system Wheat-Mungbean-

T. *aman* was considered for the study. The experiments were carried out over the three crop seasons such as Rabi, *Kharif-I* and *Kharif-II*. Wheat, mungbean and T. aman were grown in *rabi*, *Kharif-I* and *Kharif-II* season, respectively. There were four treatments along with control for each crop. The treatments were T_1= Control; T_2 = Farmer's practice; T_3 = AEZ based recommended fertilizer dose and T_4 = Soil test based fertilizer dose. The descriptions of treatments are given in Table 1.

Table 1. Rates of fertilizers (kg ha^{-1}) for wheat, mungbean and T. *aman*

Treatments	Wheat	Mungbean	T. *aman*
T_1	Control	Control	Control
T_2	$N_{85}P_{24}K_{24}$	$N_{23}P_{15}K_8$	$N_{70}P_{10}K_{15}$
T_3	$N_{90}P_{16}K_{25}S_8Zn_1B_{0.5}$	$N_{15}P_{18}K_9S_8$	$N_{66}P_6K_{12}S_7Zn_1$
T_4	$N_{120}P_{22}K_{62}S_{25}Zn_2B_1$	$N_{21}P_{23}K_{30}S_{18}Zn_2B_{1.5}$	$N_{100}P_{14}K_{66}S_6Zn_{1.5}B_1$

T_1= Control, T_2= Farmers' practice, T_3= AEZ based recommended fertilizer dose, T_4= Soil test based fertilizer dose.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 4 m × 3 m for all crops having the spacing of 30 cm × 10 cm for wheat, 40 cm × 10 cm for mungbean and 20 cm × 15 cm for T. *aman* rice. The layout was kept undisturbed for the cropping system over two years. The amount of all fertilizers, except urea in rice crop of each treatment was applied to respective plot at the time of final land preparation. Fertilizers were mixed with soil by spading. Urea was applied in three equal splits for T. *aman* rice (first split was applied immediately after seedling establishment, the second split during maximum tillering stage and before panicle initiation stage last split was applied). The sources of N, P, K, S, Zn and B were urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively. Wheat (var. BARI Gam-24) seeds were sown on 22 November 2008 and 23 November 2009. Mungbean (BARI Mung-6) seeds were sown on 18 March 2009 and on 27 March 2010. T. *aman* rice (var. BRRI dhan33) seedlings (30 days old) were transplanted on 23 July 2009 and on 9 July 2010. The crop wise seed rate was-wheat: 120 kg ha^{-1}, mungbean: 30 kg ha^{-1} and T. *aman* rice: 25 kg ha^{-1}. Intercultural operations like irrigation, weeding and plant protection measures (insecticides and fungicides) were done as and when required. The transplanted rice seedlings were nursed properly in the seedbed. The crops were harvested after maturity. Data on yield and yield contributing characters of all crops from all plots were recorded. The yields data were expressed as kg ha^{-1} which was adjusted to 14% moisture content for T. *aman* rice and 12% moisture for wheat and mungbean. Analysis of variance (ANOVA) for the yield and yield contributing characters and different nutrient content was done following the principle of F-statistics and the mean values were separated by Duncan's Multiple Range Test (DMRT) using MSTAT-C software.

Soil solutions were collected at intervals of 15 days starting from the date after transplantation with the help of 50 ml plastic syringe and analyzed for determined nutrient leaching loss. Soil solution was collected at intervals of 15 days starting from the date after transplantation to harvest of rice crop with the help of 50 ml plastic syringe. The samples were brought to the laboratory immediately after collection, filtered through Whatman No. 42 filter paper and preserved for the determination of N, P, K, S, Ca, Mg, Zn and B. Rain and irrigation water were collected and analyzed for determining the nutrients (N, P, K, S, Ca, Mg, Zn and B) added to the soil. In calculating percolation water (L m^{-2}) the formula $Q = -K_wAT.\Delta\Psi_h/\Delta z$ given by Hanks and Ashcroft (1980) was used. Where, Q = Quantity of water K_w= Hydraulic conductivity, A = Area, T = Time, H = Difference in hydraulic potential and Z = Difference between two points taking 0 to downward as negative.The hydraulic potential was again calculated by adding the component potentials as $\Psi_h= \Psi_m+ \Psi_p+ \Psi_z$ where h, m, p, and z represent hydraulic, metric, pressure and gravitational potentials. Negative Q was considered as downward movement of water.

An apparent nutrient balance was made by considering the nutrient input and output. The inputs were N, P, K, S, Ca, Mg, Zn and B which were supplied from (i) fertilizer (ii) rainfall and (iii) irrigation water. On the other hand, the outputs were calculated from the (i) crop uptake and (ii) leaching loss by percolation in a cycle.

A partial budget (average of two years) was calculated by a standard procedure. Benefit cost ratio (BCR) was used as a tool of partial budget analysis. It is the ratio of gross return and total cost. Gross returns were calculated by multiplying yield with the price of output. Total costs were calculated by variable cost. Variable cost consisting market price of fertilizer, pesticides and labor wages for land preparation, ploughing, weeding, seed sowing and fertilizers application. Land used cost or rental value of land was not considered here. Cost and return were estimated of crops due to different treatment.

Results and Discussion

Crops yields

The grain and straw/stover yields of wheat and mungbean exhibited significant variation due to different nutrient management practices in the consecutive two years (Table 2). Grain yield of wheat and mungbean increased significantly being higher under soil test based (STB) fertilizer treatment (T_4) over the other treatments. This indicated that the treatment T_4 was more balanced than that of T_2 and T_3. Balanced fertilization through soil test based treatment produce higher yields of crops as well as sustains soil fertilty (Hossain *et al.*, 2008). Biswas *et al.* (2009) found that balanced fertilizer management practice ($N_{20}P_{20}K_{20}S_{10}Zn_2$) showed higher seed yield (1214 kg ha^{-1}). The average grain yields of wheat and mungbean ranged from 1517 to 3124 kg ha^{-1} and 1320 to 1863 kg ha^{-1}, respectively. In case of straw/stover yield, the effects of treatments were statistically differed with some exception and significantly highest value found in T_4 treatment. The highest seed and stover yields of mungbean due to soil test based balanced fertilization was also found by other researchers (Kumar and Singh 2009). The lowest grain and straw/stover yields of wheat and mungbean were found in control T_1 treatment in both the years. The percent grain yield of wheat and mungbean increased over control due to different nutrient management practices were 43 to 106% and 15 to 41% for calcareous soils (Madaripur), respectively. Most of the yield contributing characters of wheat and mungbean were highly responded to soil test based fertilization (T_4) followed by AEZ based fertilization (T_3). Aggarwal *et al.* (1997) also found that incorporation of green manure and chemicl fertilizer into soil which enhanced the yield contributing characters of wheat. Ved Ram *et al.* (2008) also observed that the application of N, P, K, S and Zn nutrients favoured the seeds per pod and 1000 seed weight.

The grain and straw yields of T. *aman* (3rd crop) responded significantly to different nutrient management practices in both the years at calcareous soils (Table 2). The grain yield recorded from the treatment soil test based fertilizer dose and BARC recommended fertilizer dose (T_3) was statistically identical during 2009 and higher than farmer's practice (T_2) and control treatment. In case of straw yield, the treatments soil test based fertilizer dose (T_4) and BARC recommended fertilizer dose (T_3) differed significantly in 2010 but in 2009 they were statistically alike although soil test based fertilizer dose dominated over T_3. Rahman *et al.* (2011) observed that the grain and straw yields of T. aman were favoured by balanced nutrient application. Similar results were also observed by Biswas *et al.* (2009). The yield of T. aman was comparatively higher in first year than in second year in all treatments except control. The windy weather along with heavy shower at the flowering and ripening stage hampered pollination as a consequence the yield declined in second year. The lowest grain and straw yields were found in the control treatment. The grain yield (2 years' average) of T. *aman* varied from 2974 to 4859 kg ha^{-1}. The different nutrient management practices produced 32 to 63% yield increased over the control. Islam *et al.* (1996) also reported 42% yield increase of rice over control due to balanced fertilization.

Table 2. Effect of nutrient management practices on grain and straw/stover yields of Wheat-Mungbean-T.*aman* cropping sequence

Treatment	Grain yield (kg ha^{-1})				Straw/stover yield (kg ha^{-1})		
	2009	2010	mean	% of increase over control	2009	2010	mean
				Wheat			
Control (T_1)	1555d	1478d	1517	-	2302d	2189d	2245
F. practice(T_2)	2061c	2168c	2168	43	2499c	2712c	2605
AEZ (T_3)	2804b	2933b	2868	89	3471b	3546b	3508
STB (T_4)	3019a	3229a	3124	106	3599a	3767a	3683
CV (%)	2.52	2.88	-	-	3.16	3.46	-
$LSD_{0.05}$	161.85	172.5	-	-	246.3	259.1	-
				Mungbean			
Control (T_1)	1360d	1280d	1320	-	2613c	2590d	2602
F. practice (T_2)	1566c	1467c	1517	15	2912b	2844c	2878
AEZ (T_3)	1701b	1620b	1661	26	3056b	3004b	2950
STB (T_4)	1926a	1800a	1863	41	3110a	3075a	3093
CV (%)	2.32	3.20	-	-	3.31	4.33	-
$LSD_{0.05}$	162	240	-	-	175	296	-
				T. *aman*			
Control (T_1)	3211c	2736d	2974	-	3376c	2870d	3123
F. practice (T_2)	3973bc	3859c	3916	32	4128bc	3958c	4043
AEZ (T_3)	4518ab	4500b	4509	52	4614ab	4590b	4602
STB (T_4)	4938a	4779a	4859	63	5036a	4909a	4972
CV (%)	5.21	3.80	-	-	4.94	3.74	-
$LSD_{0.05}$	502.5	318.8	-	-	446.7	321.7	-

Values within the same column with a common letter do not differ significantly (p=0.05). F= Farmers.

Nutrient uptake

Nutrient management practices have made significant effect to uptake of N, P, K, S, Ca, Mg, Zn and B by wheat, mungbean and T. aman under Wheat-Mungbean-T. *aman* cropping pattern during 2009 & 2010 (Tables 3 & 4). The soil test based fertilizer treatment (T_4) showed the significantly higher nutrients uptake by wheat in both the years. Similar results were found by Jahan *et al.* (2015a). The second highest uptake was observed in T_3 which was followed by T_2. The nutrient uptake followed the order: N>K>Ca>Mg>P>S>Zn>B. Almost all nutrient found higher uptakes by mungbean in soil test based fertilizer treatment (T_4) followed by T_3 and then T_2 treatments.The soil test based fertilizer treatment (T_4) influenced to uptake highest amount of all nutrients by T. *aman* rice followed by T_3 and than T_2 treatment. The lower nutrient uptake was found in control (T_1) treatment by all crops (Tables 3 & 4). The total uptake of nutrients by crops (wheat+mungbean+T. *aman*) ranged from 183-305 kg N ha^{-1}, 21.1-38.5 kg P ha^{-1}, 148-223 kg K ha^{-1}, 9.45-18.6 kg S ha^{-1}, 37.8-60.5 kg Ca ha^{-1}, 28.4-46.6 kg Mg ha^{-1}, 0.47-0.82 kg Zn ha^{-1} and 0.25-0.43 kg B ha^{-1}. These observations are in agreement with Tarafder *et al.* (2008) in potato-boro-T. *aman* rice cropping pattern. The uptake of all nutrients due to different nutrients management practices followed almost same trend (Fig. 1 & 2).

Table 3. Effect of nutrient management practices on nutrient uptake (kg ha^{-1}) by Wheat-Mungbean-T. aman (grain+straw/stover) cropping pattern

Treatment	N		P		K		S	
	2009	2010	2009	2010	2009	2010	2009	2010
	Wheat							
Control (T_1)	42.2d	39.3d	6.00c	5.63c	35.7d	33.4d	3.17d	2.64b
F. practice (T_2)	54.0c	56.7c	8.16b	8.35b	40.2c	42.6c	4.06c	3.85b
AEZ (T_3)	74.7b	76.7b	11.2a	11.7a	56.2b	57.1b	5.86b	5.42a
STB (T_4)	81.6a	85.8a	12.5a	13.2a	59.8a	61.8a	6.56a	6.24a
CV (%)	2.24	3.57	8.63	10.25	2.72	3.62	6.10	8.18
$LSD_{0.05}$	3.12	4.61	1.63	1.99	2.65	3.52	1.19	1.29
	Mungbean							
Control (T_1)	79.2d	75.3d	8.66d	7.98d	74.7d	70.1d	3.19c	2.71b
F.practice (T_2)	91.1c	86.2c	9.96c	9.10c	84.6c	80.9c	3.60b	3.03b
AEZ (T_3)	98.6b	94.6b	10.9b	10.3b	89.8b	87.1b	4.32b	3.72ab
STB (T_4)	108a	103a	12.3a	11.5a	95.0a	91.9a	5.11a	4.44a
CV (%)	2.45	1.85	4.57	5.16	1.21	1.29	8.01	9.25
$LSD_{0.05}$	3.10	1.53	1.14	1.03	1.95	1.63	1.23	1.00
	T. aman							
Control (T_1)	72.2d	57.8d	7.85d	6.13d	44.8d	37.3d	4.31c	2.82c
F.practice (T_2)	91.8c	87.6c	10.5c	8.95c	55.8c	53.2c	5.69b	4.70b
AEZ (T_3)	106b	104b	12.3b	11.3b	62.5b	62.2b	6.86a	6.36ab
STB (T_4)	118a	113a	14.4a	13.0a	69.3a	67.5a	7.99a	6.79a
CV (%)	1.39	2.25	4.46	4.86	2.05	2.47	5.29	4.46
$LSD_{0.05}$	2.70	3.68	1.01	1.45	2.38	2.49	1.00	0.87

Values within the same column with a common letter do not differ significantly (p=0.05). F= Farmers.

Table 4. Effect of nutrient management practices on nutrient uptake (kg ha^{-1}) by Wheat-Mungbean-T. aman (grain+straw/stover) cropping pattern

Treatment	Ca		Mg		Zn		B	
	2009	2010	2009	2010	2009	2010	2009	2010
	Wheat							
Control T_1)	8.55b	7.55d	6.94c	6.08b	0.17d	0.16d	0.10c	0.09d
F. practice (T_2)	10.2b	10.1c	8.34b	7.97b	0.20c	0.21c	0.11c	0.12c
AEZ (T_3)	14.6a	14.1b	11.8a	11.2b	0.29b	0.31b	0.16b	0.17b
STB (T_4)	15.7a	15.9a	13.1a	13.1a	0.32a	0.35a	0.18a	0.19a
CV (%)	7.11	6.87	6.47	7.97	8.41	8.01	4.64	6.08
$LSD_{0.05}$	1.73	1.64	1.29	1.81	0.02	0.02	0.04	0.019
	Mungbean							
Contro l (T_1)	18.0d	17.2d	14.0d	12.9d	0.09b	0.08b	0.07b	0.06b
F.practice (T_2)	20.2c	19.1c	15.8c	14.6c	0.10ab	0.09ab	0.07ab	0.07ab
AEZ (T_3)	21.9b	20.9b	17.2b	16.1b	0.11ab	0.10ab	0.09ab	0.08ab
STB (T_4)	23.6a	22.4a	18.6a	17.4a	0.12a	0.11a	0.10a	0.09a
CV (%)	4.05	3.81	4.53	3.77	6.23	5.26	7.02	6.76
$LSD_{0.05}$	1.32	1.52	1.36	1.15	0.03	0.02	0.04	0.019
	T. aman							
Control (T_1)	13.6d	10.7c	9.59d	7.31d	0.24d	0.20d	0.10d	0.09d
F.practice (T_2)	17.1c	15.7b	12.2c	9.80c	0.29c	0.28c	0.12c	0.11c
AEZ (T_3)	19.7b	18.7ab	14.2b	12.8b	0.35b	0.34b	0.14b	0.15b
STB (T_4)	22.5a	20.9a	16.5a	14.6a	0.37a	0.36a	0.17a	0.16a
CV (%)	4.60	5.12	4.94	5.51	5.02	4.52	4.69	3.79
$LSD_{0.05}$	1.57	1.87	1.29	1.47	0.019	0.05	0.019	0.02

Values within the same column with a common letter do not differ significantly (p=0.05). F= Farmers.

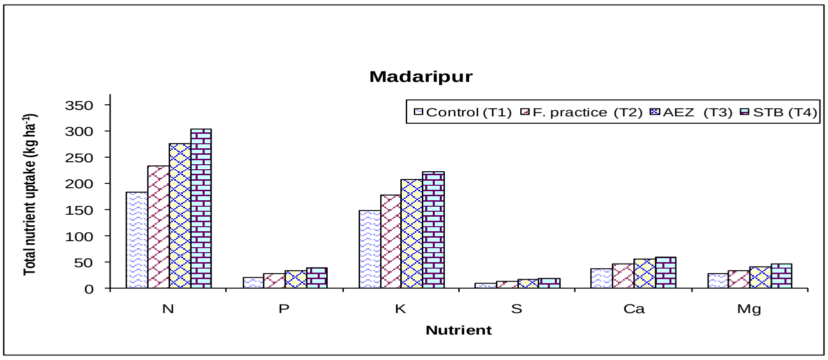

Fig. 1. Effect of fertilizer management practices on total uptake of nutrients by crops (wheat+mungbean+T. aman) under Wheat-Mungbean-T. aman cropping pattern at Madaripur.

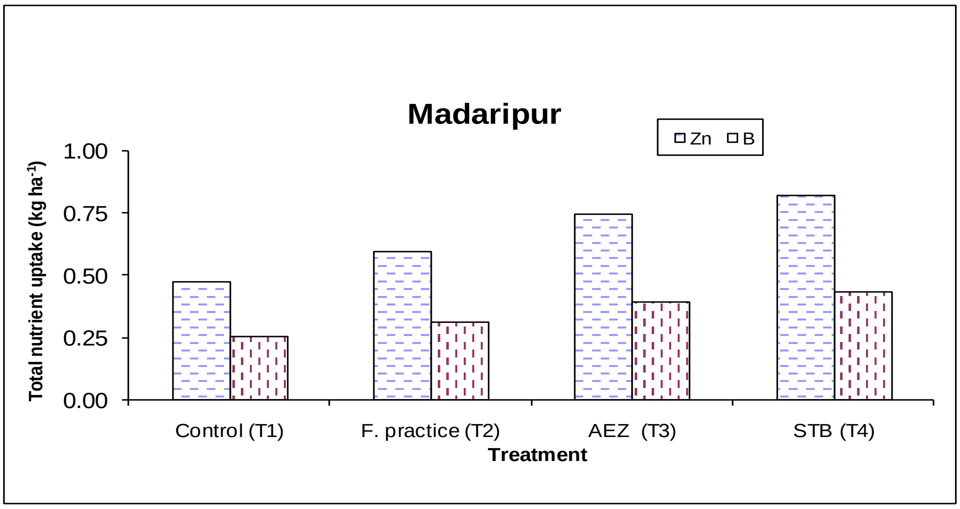

Fig. 2. Effect of fertilizer management practices on total uptake of zinc & boron by crops (wheat+mungbean+T. aman) under Wheat-Mungbean-T. aman cropping pattern.

Leaching of nutrients

Loss through leaching was taken into account only to T. *aman* rice. We assumed that there would be no loss of nutrients through leaching from the soil during wheat and mungbean cultivation. Nutrient loss was calculated from the results of percolation water and nutrient concentration in soil solution. Nitrogen loss was ignored due to very low concentration in soil solution. Different nutrient management practices favoured the loss of P, K, S, Ca, Mg, Zn and B element through leaching. The loss of nutrients (average of two years) through leaching ranged from 0.30 to 0.71 kg P ha^{-1}, 3.29 to 11.9 kg K ha^{-1}, 1.57 to 4.35 kg S ha^{-1}, 15.3 to 20.5 kg Ca ha^{-1}, 9.66 to 10.6 kg Mg ha^{-1}, 0.05 to 0.12 kg Zn ha^{-1} and 0.10 to 0.37 kg B ha^{-1}. Katoh *et al.* (2003) reported that the amounts of nutrients leached by percolation ranged from 25-130 kg ha^{-1} Ca, 8-24 kg ha^{-1} Mg, from -1 to 9 kg ha^{-1} K, respectively were lost each year from the soil layer during rice cultivation. The highest and lowest values of nutrients were always found in T_4 and T_1 treatments, respectively (Table 5).

Table 5. Effect of nutrient management practices on nutrient loss through leaching under Wheat-Mungbean-T. *aman* cropping pattern (average of two years)

Treatment	P	K	S	Ca	Mg	Zn	B
	kg ha^{-1}						
Control (T_1)	0.30	3.29	1.57	15.3	9.66	0.05	0.10
F. practice (T_2)	0.60	8.60	2.49	18.1	10.4	0.06	0.10
AEZ (T_3)	0.66	11.1	3.93	18.9	10.5	0.11	0.35
STB (T_4)	0.71	11.9	4.35	20.5	10.6	0.12	0.37

Total input of nutrients

The nutrient input mainly from fertilizer but in this estimate, the nutrients supply from fertilizer, rainfall and irrigation under Wheat-Mungbean-T. *aman* cropping pattern. BNF was not considerd. Total input of nitrogen was 178-241 kg N ha^{-1} of which the major part was added through fertilizer application, except in control treatment. Phosphorus input ranged from 0.55 to 59.5 kg ha^{-1} yr^{-1} and K from 5.75 to 164 kg ha^{-1} yr^{-1} (Table 6). The S input varied from 3.26 to 52.6 kg ha^{-1} yr^{-1}, Ca and Mg input from 45.7 to 53.9 kg ha^{-1} yr^{-1} and 21.3 to 21.3 kg ha^{-1} yr^{-1}, respectively. Input of Zn ranged from 0.076 to 5.58 kg ha^{-1} yr^{-1}. Zinc and B input was estimated 0.076 to 5.58 kg ha^{-1} yr^{-1} and 0.34 to 3.84 kg ha^{-1} yr^{-1}, respectively (Table 6).

Table 6. Total input of N, P, K, S, Ca, Mg, Zn and B from fertilizer, rainfall and irrigation under Wheat-Mungbean-T. *aman* cropping pattern

Treatment	N	P	K	S	Ca	Mg	Zn	B
	2009-10	2009-10	2009-10	2009-10	2009-10	2009-10	2009-10	2009-10
	kg ha^{-1}							
Control(T_1)	0.00	0.55	5.75	3.26	45.7	21.3	0.076	0.34
F. practice(T_2)	178	49.5	52.8	3.41	51.7	21.3	0.076	0.34
AEZ (T_3)	171	40.5	51.8	26.5	51.3	21.3	2.076	0.84
STB (T_4)	241	59.5	164	52.6	53.9	21.3	5.58	3.84

Total output of nutrients

Output of nitrogen with the harvested product was about double time larger than the sum of inputs. We could not include N from leaching. The output of phosphorus is also moderate (21.4 to 39.2 kg P ha^{-1} yr^{-1}). The removal of potassium is 2 to 4 folds greater than the sum of inputs. The removal of calcium with the yield and leaching is greater than the sum of inputs. For magnesium, the nutrient removal with the yield and leaching is about two times larger than the sum of inputs. The output of nutrients (mean of two years) ranged from 183 to 305 kg N ha^{-1}, 21.4 to 39.2 kg P ha^{-1}, 151 to 235 kg K ha^{-1}, 11.0 to 22.9 kg S ha^{-1}, 53.2 to 81.0 kg Ca ha^{-1}, 38.0 to 57.0 kg Mg ha^{-1}, 0.52 to 0.94 kg Zn ha^{-1} and 0.36 to 0.83 kg B ha^{-1} (Table 7).

Table 7. Effect of nutrient management practices on total output (crop uptake and leaching loss) of nutrients by Wheat-Mungbean-T. *aman* cropping pattern (average of two years)

Treatment	N	P	K	S	Ca	Mg	Zn	B
	kg ha^{-1}							
Control (T_1)	183	21.4	151	11.0	53.2	38.0	0.52	0.36
F. practice (T_2)	234	28.1	188	15.0	64.0	45.0	0.65	0.40
AEZ (T_3)	277	35.0	219	20.2	74.0	52.0	0.85	0.75
STB (T_4)	305	39.2	235	22.9	81.0	57.0	0.94	0.83

Apparent nutrients balance

An apparent nutrient balance was calculated considering the amount of added nutrient through fertilizer, rain, irrigation water minus the amount of nutrient removed by crops and losses occurred through crop harvest and leaching. However, the nutrient balance did not account for the addition of N from rainfall, irrigation water, or gaseous losses of N or BNF. Apparent balance of N, P, K, S, Ca, Mg, Zn and B are shown in Figs. 03 & 04. The balance was mainly affected by different nutrient management practices. The apparent balance of N was negative in all the treatment and the soil depletion ranged from −56.0 to −183 kg N ha^{-1} yr^{-1}. Some researchers supported the results: in rice-maize system in Bangladesh, the apparent nutrient balances have been highly negative for N (–120 to –134 kg ha^{-1} yr^{-1}) (Timsina *et al*., 2010). In case of P balance which was negative in control treatment T_1 and the P balance was positive in all the other treatment where P containing fertilizer was utilized. This evident indicated that P depletion was fewer amounts as compared added fertilizer. Saleque *et al.* (2006) expressed the same agreement.The balance of K was negative in all the treatments where the K mining ranged from −71.0 to −167 kg K ha^{-1} yr^{-1}. The maximum K depletion was observed in control plot and application of K gradually decreased the depletion with increasing rate. Bijay and Yadvinder (2002) observed that the depletion of K decreased with increasing rate of K application in soil. The negative S, Zn and B balance was observed in control and farmers practice treatments ranged from –7.74 to –11.6, -0.44 to -0.57 and –0.02 to –0.06 kg ha^{-1} yr^{-1}, respectively. Remaining treatments showed positive balance ranged from 6.30 to 29.7, 1.23 to 3.66 and 0.10 to 3.01 kg ha^{-1} yr^{-1}, respectively. Among the treatments, the maximum positive balance was observed in STB followed by AEZ treatment. Alam *et al.* (2000) observed that S balance was positive in soil due to integrated application of fertilizer and manure. The apparent balance for Zn and B was negative in the treatment of T_1 and T_2 and positive in T_3 and T_4 treatments due to their application. Similar results were also obtained by Hossain *et al.* (2008). Apparent balance for Ca and Mg was negative in all treatment. Calcium and Mg uptake was comparatively higher than that of supplied which got from soil, irrigation and rain water. The calcareous soil having more $CaCO_3$, but the Ca balance was negative; it might be due to less soluble form in high pH. Jensen and Thomas (2010) reported that soil pH greater than 7.2-7.5, phosphate ions tend to react quickly with Ca and Mg to form less soluble compounds. A long term study by Srinivasarao *et al*. (2014) on groundnut-fingermillet crop rotation, a negative balance to positive balance (–315 to 12.37 kg Ca ha^{-1} yr^{-1}) was found for Ca. On the other hand, Mg balance was found to be negative which ranged from –64 to –207 Kg Mg ha^{-1} yr^{-1}.

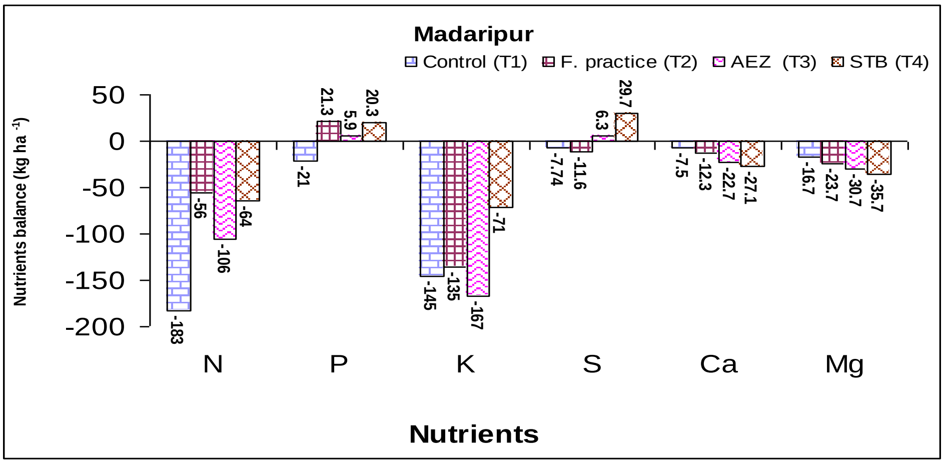

Fig.3. Apparent nutrient balance of N, P, K, S, Ca and Mg under Wheat-Mungbean -T. aman cropping pattern at Madaripur.

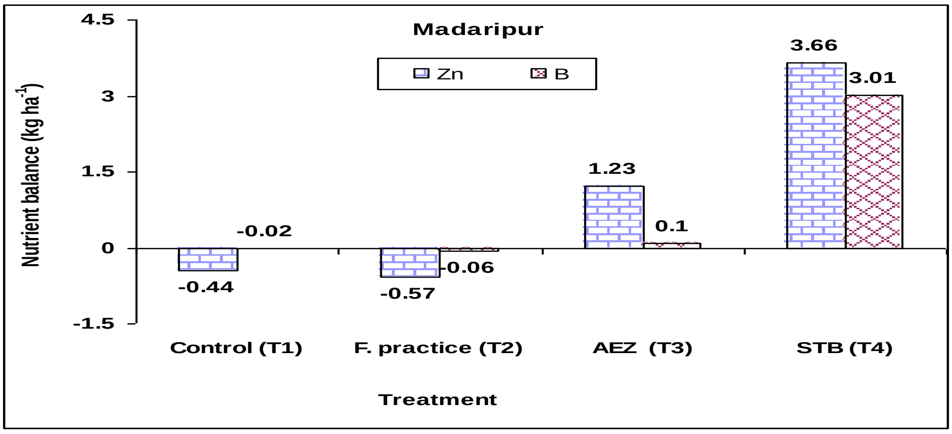

Fig. 4. Apparent nutrient balance of zinc and boron under Wheat-Mungbean -T. aman cropping pattern at Madaripur.

Soil fertility

Initial soil samples were collected from the experimental field and post harvest soil samples were also collected from each treated plot after two cycles of Wheat-Mungbean-T. aman cropping pattern for analyzing different soil properties viz. soil pH, organic matter, total N and available P, K, S, Ca, Mg, Zn and B. The initial and post harvest soil results are presented in Table 8. Initially the soil pH was 7.3, but after completion of two crop cycles and incorporation of mungbean stover and other crop residues in soil, the pH remained unchanged although minor variation existed. A minor change in soil fertility occurred from initial status due to different fertilizer management practices over two years. Soil test based fertilizer application (T_4) tended to maintain the initial fertility or increased slightly (Table 8). Aggarwal *et al.* (1997) observed that the fertility of soil was improved due to incorporation of green manure into soil. The treatment T_4 showed an encouraging effect on organic matter, N, P, S, Ca, Zn and B only. Potasium (K) and Mg slightly decreased in all plots over the initial status. The available Zn and B content of the soil slightly decreased when they were not applied, but remained almost static or increase when applied (Table 8).

Table 8. Initial and post soil fertility status after two cycles of Wheat-Mungbean-T. aman cropping pattern due to different fertilizer management practices

Treatment	pH	OM (%)	Total N (%)	Ca	Mg	K	P	S	Zn	B
				Meq. 100 g^{-1}			µg g^{-1}			
Initial	7.3	1.32	0.063	10.3	3.10	0.14	13.5	18.0	1.20	**0.14**
Control(T_1)	7.3	1.31	0.062	10.0	2.99	0.11	13.8	17.6	1.17	**0.12**
F. practice(T_2)	7.3	1.35	0.064	10.3	3.00	0.12	14.3	18.0	1.17	0.12
AEZ (T_3)	7.2	1.38	0.065	10.3	3.02	0.12	14.3	18.3	1.26	0.14
STB (T_4)	7.2	1.40	0.068	10.4	3.02	0.13	14.5	19.0	1.34	0.16

Economic analysis

Gross returns varied in different treatments Wheat-Mungbean-T. *aman* cropping system which were directly related to the price that received from the product. The gross returns were highest (Tk. 263260 ha^{-1} yr^{-1}) in the treatment T_4 followed by T_3 and T_2 and the lowest was in control treatment (Table 8). Cost of cultivation was involved with wage rate, pesticides, irrigation and fertilizers cost. Data on cost and return analysis showed that the maximum gross margin (Tk. 173663 ha^{-1} yr^{-1}) was calculated from T_4 and minimum from T_1. The gross margin by T_4 was increased two fold over control (T_1) treatment due to get higher crop yield. Similar observation was showed by Malika *et al.* (2015). The highest benefit cost ratio (3.29) was obtained from T_3 followed by T_4 (2.94) and T_2 (2.88). Considering the benefit cost ratio (BCR) T_3 treatment showed ranked first followed by T_4. However, the cost of production of T_3 (Tk. 72881 ha^{-1} yr^{-1}) was lower than T_4 (Tk. 89595 ha^{-1} yr^{-1}).

Table 9. Economic analysis of Wheat-Mungbean-T.*aman* cropping pattern affected by different nutrient managements (after completing two years cycle)

Treatment	Variable cost	Gross return	Gross margin	BCR
	Tk. $ha^{-1}yr.^{-1}$			
Control(T_1)	59875	163699	103824	2.73
F. practice(T_2)	71549	206148	134599	2.88
AEZ (T_3)	72881	240062	167181	3.29
STB (T_4)	89595	263260	173663	2.94

Input prices: Urea=Tk.12 kg^{-1}, T.S.P= Tk.22 kg^{-1}, MoP= Tk.20 kg^{-1}, Gypsum= Tk.6 kg^{-1}, Zinc sulphate= Tk.120 kg^{-1}, Boric acid= Tk.300 kg^{-1}, Rovral fungicide = Tk.250 100^{-g} , Bavistin fungicide= Tk.200 100^{-g}, Provex fungicide= Tk.3200 kg^{-1}, Ripcord insecticide= Tk.105 100^{-g}, Karate insecticide= Tk.450 500^{-ml} , Plowing= Tk.1400 ha^{-1}(one pass), Labour wage= Tk.125 day^{-1}, Wheat seed= Tk.25 kg^{-1}, Mungbean seed= Tk.60 kg^{-1}, T. aman rice seed= Tk.35 kg^{-1}.

Output prices: Wheat= Tk.18.75 kg^{-1}, Mungbean= Tk.55 kg^{-1}, T. aman rice= Tk.19 kg^{-1}, Wheat straw rate = Tk.1 kg^{-1}, Rice straw= Tk.1.25 kg^{-1}.

The BCR and gross margin was the highest in T_3 and T_4, respectively and economically viable. The fertilizer doses under T_3 were very low, hence its nutrients balance was highly negative after control. On the other hand, the fertility of soil remains almost static or increased slightly due to T_4 treatment. Therefore, considering the gross margin and soil fertlity the treatment T_4 is preferable to T_3.

Conclusion

The magnitude of negative balance was greater with N and K followed by Mg and Ca. Nitrogen and K mining occur remarkably from the soil. So, the rates of application of these two nutrients should be increased. Considering the gross margin and soil fertility the soil test based fertilizer management practice (STB) is economically profitable and sustainable. Therefore, Wheat-Mungbean-T. *aman* cropping pattern is good in sustaining soil fertility and found economically sound and viable for Madaripur region in Bangladesh.

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COMPARATIVE PROFITABILITY ANALYSIS OF SHIFTING LAND FROM FIELD CROPS TO MANGO CULTIVATION IN SELECTED AREAS OF BANGLADESH

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Abstract

Mango has emerged as an important area for diversification and as an alternative cropping pattern due to higher returns and productivity. The study was conducted in three mango growing districts, namely Chapai Nawabganj, Natore, and Rajshahi during 2014-2015 to estimate the financial benefit of shifting cereal lands to mango production, factors influencing shifting decision, and explore related problems of mango cultivation in the study areas. A total of 180 farmers taking 60 farmers from each district were selected through using multistage stratified random sampling for the study. About 49% lands were shifted to mango cultivation from cereal crops which was higher in Chapai Nawabganj (55%) followed by Natore (48%) district. The main reason of this shifting was reported to be higher profit compared to other crops. The average total cost of mango cultivation was Tk. 1, 33,889 per hectare. Higher cost was observed in the 16th-20th year of garden (Tk. 1, 52,010) followed by 11th -15th year (Tk. 1, 48,952). The average yield of mango was found to be the highest in 16th – 20th year (26.48 ton/ha) followed by 11-16th year (19.38 ton/ha). Per hectare net return from mango cultivation was Tk. 1, 75,244. Total cost of mango cultivation was 10% higher than Boro-Fallow-T.Aman cultivation. On the other hand, total cost was about 40% lower than Wheat- Jute- T.Aman, Wheat-Aus-T.Aman and Potato-Fallow-T.Aman. The net return from mango cultivation was 75% higher than other cropping patterns. The shifting of cereal lands to mango cultivation was found to be a profitable since the BCR (2.89), net present value (Tk. 33, 71,166) and internal rate of return (39%) were very high. Relative income, farm size and education turned out to be positively significant, whereas age was negatively significant for shifting decision from cereal crops to mango cultivation. Therefore, Farmers should be motivated to cultivate mango in the fallow lands or areas where other crops are not grown well.

Keywords: Financial impact, mango, cereal crops, relative profitability and factors responsible.

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1. Introduction

Farmers' crop diversification decision is considered as one of the important economic decisions which have strong influence on their welfare in terms of income level and returns. While taking decisions farmers make choices in the context of their production possibility frontier, their expectations of relative prices and their sense of risk from both an agronomic and market perspective for various alternatives. The first decision is about the choice of number of crops. While taking decision on number of crops and level of spread in the cropping pattern, farmers also take another critical decision as to which crops to produce and how much land to be allocated to that crop. Hence, the area substitution for crop decision comes from this concept.

The sustained economic growth, rising per capita income and growing urbanization have caused a shift in the consumption patterns in favour of high value crops like fruits and vegetables from staple food crops such as rice and wheat (Joshi, 2005). In recent years, demand for fruits has grown much faster than that of food grains. Fruits play a significant role in nutritional improvement, employment generation, food and financial security of the people of Bangladesh. The consumption pattern of people in Bangladesh shows that there has been a constant increase in demand for fruits as compared to other crops. In 2009-2010, the national production and area of fruits were 1.09 million MT and 2.42 lakh hectares respectively (BBS, 2010). Among the various fruits mango is one of the most important fruit crops in Bangladesh. Mango grows widely throughout the country and is raised mostly as homestead plantations. The soil and climatic conditions of Bangladesh especially northern regions are suitable for mango cultivation. Therefore, a large number of farmers in northern region namely Pabna, Natore, Rajshahi, Chapai Nawabganj, Naogaon and Dinajpur are preferred to cultivate mango in their field. Moreover, a huge portion of lands are now substituting to mango cultivation. In 2013-2014, the area under mango cultivation was about 34632 hectares with a total production of about 992296 metric tons (BBS, 2014). The area and production of mango is increasing day by day owing to its higher returns. The growth rates of area, production and yield of mango are 2.41%, 4.74% and 2.33%, respectively (Table 1). Due to higher returns and productivity, mango has emerged as an important area for diversification and as an alternative cropping pattern. With this backdrop, area shift in favour of fruits has been suggested as a viable option to stabilize and raise farm income, enhance agricultural growth and increase employment opportunities.

The shifting of land allocation decisions are generally analyzed at the macro level on the basis of distributive lag model that capture the role of several economic and non-economic factors in decision making. Nerlove (1958) was the first to initiate a study on this aspect where he endeavored to find the role of farmers' expectation of future prices in shaping their decisions on the extent of land allocation of these crops. He devised a model relating the expected normal price to “past-observed” prices. Later on, many studies used the Nerlovian model, with some modifications also, to investigate the importance of price of crop in shaping farmer’s supply response behaviour (Krishna, 1963; Behrman, 1968; Askari and Cummings, 1976; De, 2005; Mythili, 2006). Deshpande and Chandrashekar (1982) made an attempt to study the role of income in the farmers’ decisions at the district level, but heterogeneity in the cost across farms made it more robust to study such decisions at the micro level, viz. farmers. However, studies relating to micro-level decision for area shifting in favour of high value crops such as fruits are very scanty. Therefore, an attempt was made to focus the profitability, factors responsible and the problem of shifting of lands from cereal crops to mango cultivation in Bangladesh.

Table 1. Area, production and yield of mango in Bangladesh

Year	Area (ha)	Production (M.tons)	Yield (M.tons/ha)
2004-2005	25055	662100	10.70
2005-2006	25972	639820	9.97
2006-2007	29109	766930	10.67
2007-2008	31658	802750	10.27
2008-2009	31059	828161	10.80
2009-2010	32011	842312	10.65
2010-2011	27466	889176	13.11
2011-2012	30680	945059	12.47
2012-2013	30804	956867	12.58
2013-2014	34632	992296	11.60
Growth rate	2.41	4.74	2.33

Source: BBS, 2011and 2014

1.1 Objectives

i. To estimate and compare relative profitability of mango production with its competitive cereal crops;

ii. To estimate the financial profitability of mango production through using investment analysis; and

iii. To identify the factors influencing the shift of land from cereal crops to mango cultivation; and

iv. To derive policy implications from the above.

2. Methodology

2.1 Area Selection

The study was conducted in three major mango growing areas, namely Chapai Nawabganj, Natore and Rajshahi. Nachol upazila from Chapai Nawabganj district, Lalpur upazila from Natore district and Poba upazila from Rajshahi district were selected for administering questionnaire survey.

2.2 Sampling Technique and Sample Size

A multistage stratified random sampling design was followed to collect sample farmers for this study. At first stage, three districts were selected according to the highest concentration of mango production. In the second stage, one upazila from each three districts and two blocks from each upazila were selected according to the above mentioned criteria. Finally, a total of 180 farmers taking 60 farmers from each district were randomly selected for interview. Because of common heterogeneity among agricultural household populations, it is necessary to undertake population stratification (Nyariki, 2009). Data were categorized according to year of mango cultivation. The ages of mango trees were classified as 1^{st} year, 2^{nd} year, 3^{rd} year, 4^{th} year, 5^{th} year, 6-10^{th} year, 11-15^{th} year, 16-20^{th} year and 20-25^{th} year.

2.3 Method of Data Collection and Period of Study

The study was mainly based on primary data collected during the month of January to April 2015. Field investigators under the direct supervision of the researcher collected field level cross-sectional data using pre-tested interview schedule. Necessary information regarding this study was collected based on input costs, price, yields etc.

2.3 Analytical Techniques

a) Tabular Technique

Collected data were edited, summarized, tabulated and analyzed to fulfill the objectives of the study. Descriptive statistics using different statistical tools like averages, percentages and ratios were used in presenting the results of the study. The profitability of mango production was examined on the basis of gross return, gross margin and benefit cost ratio analysis. Besides, the opportunity cost of family supplied labour was taken into consideration in estimating total cost. Land use cost was calculated on the basis of per year lease value of land. Project analysis and sensitivity analysis were done. Benefit Cost Ratio, Net Present Value and Internal Rate of Return were calculated (at 6.5% discount rate) with the following formulas:

Net Present Value (NPV): The NPV of an investment is the discounted value of all cash inflows and cash outflows of the project during its lifetime. It can be computed as

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

Benefit Cost Ratio (BCR): The BCR of an investment is the ratio of the discounted value of all cash inflows to the discounted value of all cash outflows during the life of the project. It can be estimated as follow:

$$BCR = \sum_{t=1}^{n} \frac{\frac{B_t}{(1+r)^t}}{\frac{C_t}{(1+r)^t}}$$

Internal Rate of Return (IRR): IRR is that rate of return at which the NPV is equal to zero. The IRR is computed as:

$$r = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} = 0$$

Where,

B_t = Total benefit (Tk/ha) in time t

C_t = Total cost (Tk/ha) in time t

r = Rate of interest (discount rate)

t = Number of years (t = 1, 2, 3 …25)

Profitability analysis

Profitability of mango and crops was analyzed to compare the return received by the farmers.

Measurement of cost and return from crop cultivation

Equations for cost analysis are as follows

Variable Cost = $VC_{ij} = \sum_{l=1}^{n} (X_{ij} P_{ij})$

$TVC_{ij} = VC_{ij} + 10C_{ij}$

$TC_{ij} = TVC_{ij} + TFC_{ij}$

Where, TC_{ij} = Total cost (Tk/ha)

TVC_{ij} = Total variable cost (Tk/ha)

TFC_{ij} = Total fixed cost (Tk/ha)

VC_{ij} = Variable cost (Tk/ha)

IOC_{ij} = Interest of operating capital (Tk/ha)

X_{ij} = Quantity of inputs (kg)

P_{ij} = Price of inputs (Tk/kg)

j = Number of crops

i = Number of farmers (1.2.3……..n)

Equations for profitability analysis

Gross return + $GR_{ij} = Y_{ij}P_{ij}$

Net return = $GR_{ij} - TC_{ij}$

Gross margin = $GR_{ij} - VC_{ij}$

Where,

GR_{ij} = Gross return (Tk/ha)

P_{ij} = Price (Tk/ha) of *j* the crops received by *i*th farmer

Y_{ij} = Quantity (kg/ha) produced

b) Statistical Technique

Multiple Regression Model

The regression model was used to assess the factors affecting the extent of substitution by the farmers, while considering both the economic and non-economic factors as explanatory factors. The relative price and relative income were used as explanatory variables to test whether farmers cared for only price or also the income (included price and yield) in their crop substitution decisions. The following empirical multiple linear regression function was fitted in the study.

$$Y= a + b_1x_1+b_2x_2+b_3x_3 +b_4x_4 +b_5x_5 +b_6x_6+ b_7x_7+ b_8x_{8+}e$$

Where,

Y= Shift of area from cereal crops to mango cultivation (ha)

x_1= Relative price of the product (Tk/kg)

x_2= Relative income (Tk/year)

x_3= Yield (kg/ha)

x_4= Education level of the farmers (years of schooling)

x_5= Farm size (ha)

x_6= Age of the farmers (years)

x_7= Annual non-farm income (Tk)

x_8= Food crop (wheat/rice) requirements at home (Tk)

a= Intercept

b_1, b_2, b_3------------------b_8= Coefficients of the respective variables to be estimated

e = Random error

3. Results and Discussion

This chapter captures amount of land shifted to mango cultivation, cost and return of mango, relative profitability of mango and cereal crops cultivation, factors affecting changing cropping pattern.

3.1 Area Substitute to Mango Cultivation

3.1.1 Area shifted for mango cultivation: Responded farmers were asked how much land they shifted for mango cultivation from cereal crops. About 48% of their net cultivated land were shifted to mango cultivation which was higher in ChapaiNawabganj district (53%) followed by Natore district (48%) (Table 2). The farmers shifted 34% land of their farm size to mango cultivation. More than 50% of own cultivable land was shifted to mango cultivation. On an average, 49% lands were shifted for mango cultivation in the study areas which was the highest in Chapai Nawabganj district (55%) and the lowest in Rajshahi district (45%).

Table 2. Area shifted for cultivating mango

Particulars	Chapai Nawabganj	Natore	Rajshahi	All areas
Area shifted for mango (ha)	0.52	0.45	0.36	0.43
% of farm size	35	33	32	34
% of own cultivable land	68	49	54	57
% of net cultivated land	53	48	42	48
Average land shift (%)	55	48	45	49

3.1.2 Reasons for shifting land to mango cultivation: Farmers in the study areas were asked to mention the reasons behind mango cultivation in the crops land. Respondent farmers mentioned that higher profit compared to other crops

(73%) was the main reason for cultivating mango (Table 3). About 61% farmers mentioned the lower price of other crops as an important factor of shifting. Easy cultivation process (47%) was opined to be the third reasons. These responses were more or less similar in three districts. As Rajshahi and ChapaiNawabganj were in Barind region, farmers of these two districts reported that lack of irrigation facility for rice was the main reason. Some farmers (17%) preferred mango because they could cultivate more than one crop in mango field (intercropping) which also influenced them to cultivate mango. Suitability of land for mango rather than other crops (35%), not requiring extra care (22%), and the lower yield of other crops (25%) were mentioned as the reasons for cultivating mango.

Table 3. Reasons for shifting to mango cultivation

Reasons	% farmers responded			
	Chapai Nawabganj	Natore	Rajshahi	All areas
Higher profit	69	77	74	73
Lower price of other crops	63	59	61	61
Easy cultivation process	43	51	47	47
Lack of irrigation facility for rice	57	19	51	42
Non-suitable land for other crops	39	33	32	35
Lower yield of other crops	21	12	23	25
Not required extra care	23	14	28	22
Can cultivate two crops at a time (Intercropping)	14	21	16	17

3. 2 Source of Inspiration and Influence to Start Mango Cultivation for the First Time

The sample farmers mentioned various sources that influenced or inspired them to switch over from field crops to mango cultivation for the first time. The highly reported source was neighbouring farmers (37%) (Table 4). About 24% farmers opined that they were influenced by their relatives to cultivate mango. In contrast, some farmers (17%) reported that they were not influenced by anyone. They cultivated by their own experience and interest. Again, 14% farmers were inspired by the businessmen and 8% influenced by extension worker.

Table 4. Source of inspiration and influence to start mango cultivation for the first time

Items	% farmers responded			
	Chapai Nawabganj	Natore	Rajshahi	All areas
Neighbouring farmers	41	33	36	37
Relatives	23	29	21	24
Own experience	18	15	19	17
Businessman	11	14	16	14
Extension worker	7	9	8	8
Total	100	100	100	100

3.3 Farmers' Perception about Cost and Return of Mango Cultivation

The study found out farmers perception about cost of mango cultivation which is presented in Table 5. The highest percentage of farmers (56%) mentioned that cost of mango cultivation was almost similar than competitive crops. On the other hand, 30% farmers expressed their opinion that cost of mango cultivation was lower than other crops. Only 14% farmers said that cost of mango cultivation was higher than other crops. Farmers who said that mango cultivation required higher cost also mentioned that higher profit was the main reason for cultivating mango.

Table 5. Farmers' perception on cost of mango cultivation compare to other crops

Items	% farmers responded			
	Chapai Nawabganj	Natore	Rajshahi	All areas
Almost equal	56	59	53	56
Lower	33	28	30	30
Slightly higher	11	13	17	14
Total	100	100	100	100

As farmers in the study areas were much interested in mango cultivation, it is common perception that it is highly profitable crop. Although profitability of mango cultivation was measured in this study, farmers' perception about comparative profitability was also revealed in Table 6. A large portion of the respondent farmers (49%) told that mango was highly profitable crop compared to other crops. Besides, 41% farmers mentioned that profitability of mango cultivation was slightly higher than other crops. Very small percentage of farmers (10%) pointed out that profitability of mango cultivation was almost equal to other crops.

Table 6. Farmers' perception on profitability of mango cultivation compare to other crops

Items	% farmers responded			
	Chapai Nawabganj	Natore	Rajshahi	All areas
Much higher	46	49	51	49
Slightly higher	44	43	38	41
Almost equal	10	8	11	10
Total	100	100	100	100

3.4 Cost and Return of Mango Cultivation

3. 4. 1 Intercropping with mango

Most farmers (84%) in the study areas practiced intercropping with mango (Table 7). In Natore district more farmers cultivated intercrop than other districts. It was found that a large number of crops were grown as intercrops in the mango field. Among the intercrops, majority of the farmers (21%) preferred intercropping with sweet gourd followed by lentil (19%) in all areas (Table 8). Farmers in the Chapai Nawabganj district also cultivated guava (27%) with mango which was not found in other districts, whereas farmers in Rajshahi cultivated papaya (5%) as intercrop. The study revealed that 16% farmers did not adopt intercrop. The main reasons for not intercropping were the reduction of mango yield and poor yields of intercrops.

Table 7. Percentage of farmers practiced intercropping in the mango field

Items	% farmers responded			
	Chapai Nawabganj	Natore	Rajshahi	All areas
Intercropping with mango	83	88	82	84
Not intercropping	17	12	18	16
Total	100	100	100	100

Table 8. Types of crop cultivated as intercrop

Types of crop	% farmers responded			
	Chapai Nawabganj	Natore	Rajshahi	All areas
Sweet gourd	36	6	24	21
Lentil	11	35	10	19
Turmeric	7	19	16	14
Black gram	13	13	16	14
Brinjal	-	21	10	11
Bitter gourd	7	6	12	8
Guava	27	-	-	8
Papaya	-	-	14	5
Total	100	100	100	100

3.4.2 Cost of mango cultivation (including intercrops)

The cost of production included different variable cost items like land preparation, human labour, sapling, manures, fertilizer, insecticides etc. Both cash expenditure and imputed value of family supplied inputs were included in the analysis. Besides, interest on operating capital was also considered for the estimation of cost of mango cultivation. Table 9 represents the cost of mango cultivation in different years in the study areas. The average total cost of mango cultivation in all years was found Tk. 1,33,889 per hectare of which 57% were variable cost and the rest 43% were fixed cost. Higher cost was observed in the 16^{th} -20^{th} year of garden (Tk. 1, 52,010) followed by 11^{th} -15^{th} year (Tk. 1, 48,952). It might be due to the cost of human labour, cost of intercrop and higher use of insecticides. The land preparation cost and saplings costs were 0.4% and 2% of the total cost. But this two cost items were incurred only in the 1^{st} year. Land use cost occupied the largest share (32%) of the total cost. On an average, labour involvement incurred 31% of the total cost. Fertilizers cost shared only 4% of the total cost and 7% of the total variable cost. On the other hand, the cost of insecticides and irrigation occupied 10% and 6% of the total cost, respectively. Farmers in the study areas spent on an average Tk. 2,599 per hectare for manures. The cost of intercrop occupied 12% of the total cost in the study areas. On an average, farmers spent Tk. 15,840 per hectare for cultivating intercrop. In the first year, responded farmers did not cultivate other crops in the mango field. That's why the cost of intercrop was considered zero in the first year. The cost of supporting stick was Tk. 8,245 per hectare in mango cultivation.

3.4.3 Profitability of mango cultivation

The return from mango cultivation in different years is presented in Table 10. Farmers in the study areas obtained, on an average, 12.07 ton/ha yield. In the 1^{st} year and 2^{nd} year farmers did not find any yield. Farmers started getting yield from 3^{rd} year garden. In the third year, they obtained 0.38 ton/ha yield. The yield had increasing trend from 4^{th} year garden. The highest amount of yield was found in 16^{th} – 20^{th} year (26.48 ton/ha) old mango garden followed by 11-16^{th} year (19.38 ton/ha). After 20 years, yield followed decreasing trend. The farmers in the study areas found on an average 16 ton/ha yield in 21-25^{th} year. Likewise, the highest gross return of mango was found 16^{th}-20^{th} year (Tk. 7, 94,490/ha) and the lowest was found in 3^{rd} year (Tk. 11,430/ha). They received on an average Tk. 3, 09,133 as gross return from mango per hectare. In the second year, the gross return of intercrop was Tk. 31,546 per hectare. Highest gross return from intercrop was found in 3^{rd} year (Tk. 35,980/ha). The average gross return from intercrop was found Tk. 29,267 per hectare. Farmers received the highest amount of gross margin in the 16^{th}-20^{th} year (Tk. 7, 37,852/ha) followed by 11-15^{th} year (Tk. 5, 24,325/ha). Similarly, the higher amount of net return was found in the 16^{th}-20^{th} year (Tk. 6, 75,465/ha) followed by 11^{th}-16^{th} year (4, 63,806/ha). Farmers gained negative gross margin and net return in the 1^{st}, 2^{nd} and 3^{rd} year of mango field. They received on an average Tk. 1, 75,244 per hectare as net return and Tk. 2, 33,039 as gross margin from mango cultivation. Farmers in the study areas spent on an average Tk. 14 for producing 1 kg mango.

Table 9. Cost of mango cultivation with intercrops in the study areas (in Tk. /ha)

Items	1st year	2nd year	3rd year	4th year	5th year	6th-10th year	11th-15th year	16th-20th year	21th-25th year	All years
Observations	n=15	n=15	n=15	n=15	n=15	n=30	n=30	n=30	n=15	n=180
A. Variable Cost	88681	47255	57807	65323	81897	86506	88433	89623	79319	76095 (57)
Hired labour	13916	9876	13452	17678	31456	33678	34187	39054	31345	24960 (19)
Land preparation	4901	0	0	0	0	0	0	0	0	545 (0.41)
Saplings	20081	0	0	0	0	0	0	0	0	2231 (2)
Manures	9691	0	4689	4325	0	2345	2341	0	0	2599 (2)
Fertilizers										
Urea	1831	1649	1275	1326	1513	1292	1003	1139	1224	1361 (1)
TSP	4145	4080	3146	2834	2262	2028	2470	1768	1976	2745 (2)
MoP	1544	1072	1216	944	1152	992	1392	1216	864	1155 (1)
Gypsum	197	150	0	165	115	160	0	110	185	120 (0.09)
Insecticides	13998	6750	7546	8787	17769	14414	19453	14861	15908	13276 (10)
Irrigation	7103	6541	5632	8425	9876	7675	9345	10453	9214	8252 (6)
Stick	8245	0	0	0	0	0	0	0	0	916 (1)
Intercrop	0	15586	19258	18936	15326	21569	16136	18964	16782	15840 (12)
Interest on operating capital	3029	1551	1593	1903	2428	2353	2106	2058	18215	2094 (1)
B. Fixed cost	54282	50514	55641	56079	61630	59110	60519	62387	59994	57795 (43)
Family labour	11628	7860	12987	13425	18976	16456	17865	19733	17340	15141 (11)
Land use cost	42654	42654	42654	42654	42654	42654	42654	42654	42654	42654 (32)
C. Total Cost (A+B)	142963	97769	113448	121402	143527	145616	148952	152010	139313	133889 (100)

Note: Figures in the parentheses indicate percentage of total cost.

Table 10. Profitability of mango cultivation with intercrops in the study areas

Items	1st year	2nd year	3rd year	4th year	5th year	6th-10th year	11th-15th year	16th-20th year	21th-25th year	All years
Sample	n=15	n=15	n=15	n=15	n=15	n=30	n=30	n=30	n=15	n=180
A. Total cost (Tk/ha)	142963	97769	113448	121402	143527	145616	148952	152010	139313	133889
Variable cost	88681	47255	57807	65323	81897	86506	88433	89623	79319	76094
Fixed cost	54282	50514	55641	56079	61630	59110	60519	62387	59994	57795
Cost of intercrops	0	15586	19258	18936	15326	21569	16136	18964	16782	15840 (12)
B. Yield of mango (kg/ha)	0	0	381	1271	6848	13629	19382	26483	15966	9329
C. Price (Tk/kg)	30	30	30	30	30	30	30	30	30	30
D. Gross return of mango (Tk/ha)	0	0	11430	38130	205440	408870	581460	794490	478980	279867
E. Gross return of intercrop (Tk/ha)	0	31546	35980	31546	35674	28970	31298	32985	35400	29267
F. Total gross return (Tk/ha)	0	31546	47410	69676	241114	437840	612758	827475	514380	309133
G. Gross margin (Tk/ha)	-88681	-15709	-10397	4353	159217	351334	524325	737852	435061	233039
H. Net return (Tk/ha)	-142963	-66223	-66038	-51726	97587	292224	463806	675465	375067	175244
I. Benefit Ratio (Undiscounted)	0.00	0.32	0.42	0.57	1.68	3.01	4.11	5.44	3.69	2.31
J. Per unit production cost (Tk/kg)	-	-	298	96	21	11	8	6	9	14

3.4.4 Returns to investment in mango cultivation

The results of project analysis are shown in Table 11 and 12. Normally the best discount rate to use is the “opportunity cost of capital”- i.e., the profitability of the last possible investment in an economy given the total available capital (Islam etl, 2014). To calculate benefit-cost ratio (BCR) and net present worth (NPV) the cost and returns were discounted at 6.5% rate of interest.

Table 11. Financial analysis of mango cultivation

Year	Gross cost (Tk)	Gross benefit (Tk)	Discount factor at 6.5%	PW of cost at 6.5%	PW of benefit at 6.5%
1	142963	0	0.943396226	134870.7547	0
2	97769	31546	0.88999644	87014.06194	28075.8277
3	113448	47410	0.839619283	95253.12842	39806.35021
4	121402	69676	0.792093663	96161.7549	55189.91808
5	143527	241114	0.747258173	107251.7238	180174.4071
6	145616	437830	0.70496054	102653.5341	308652.8734
7	145616	437830	0.665057114	96842.95666	291181.9561
8	145616	437830	0.627412371	91361.27987	274699.9585
9	145616	437830	0.591898464	86189.88667	259150.9043
10	145616	437830	0.558394777	81311.21384	244481.9852
11	148952	612768	0.526787525	78466.05548	270968.9673
12	148952	612768	0.496969364	74024.58064	255631.1012
13	148952	612768	0.468839022	69834.51004	241161.4163
14	148952	612768	0.442300964	65881.61325	227510.7701
15	148952	612768	0.417265061	62152.46533	214632.8019
16	152010	827485	0.393646284	59838.17159	325736.3951
17	152010	827485	0.371364419	56451.10527	307298.4859
18	152010	827485	0.350343791	53255.75969	289904.232
19	152010	827485	0.33051301	50241.28273	273494.5585
20	152010	827485	0.311804727	47397.43653	258013.7344
21	139313	514380	0.294155403	40979.67162	180249.0178
22	139313	514380	0.277505097	38660.06757	170046.2432
23	139313	514380	0.261797261	36471.76185	160420.9842
24	139313	514380	0.246978548	34407.3225	151340.5511
25	139313	514380	0.232998631	32459.73821	142774.1048
Total	3548564	9780161	11.46992122	1779431.837	5150597.544

Firstly, the cost and benefit streams of mango garden were discounted to find out their present worth. Dividing the present worth of the gross benefits by the present worth of the gross cost, the benefit cost ratio was found. In the study areas BCR was found 2.89 at 6.5% discount rate which is greater than unity and acceptable. The most straightforward discounted cash flow measures of the project worth are the net present worth. It is the difference between the present worth of benefits and present worth of costs. The estimated NPV of the project was Tk. 33, 71,166 per hectare which indicates that mango cultivation was profitable in the study areas.

The internal rate of return (IRR) for the investment is that discount rate which nullifies the present worth of cash flows and outflows. It represents the average earning power of the money used in the project over the project life. The IRR was found to be 39%. It is highly acceptable because it is much higher than the opportunity cost of capital.

Table 12. Financial analysis of mango cultivation

Year	Incremental benefit	Discount factor at 35%	PW of benefit at 35%	Discount factor at 40%	PW of benefit at 40%
1	-142963	0.714286	-102116	0.689655	-98595.2
2	-66223	0.548697	-36336.4	0.510204	-33787.2
3	-66038	0.406442	-26840.6	0.364431	-24066.3
4	-51726	0.301068	-15573.1	0.260308	-13464.7
5	97587	0.223014	21763.22	0.185934	18144.78
6	292214	0.165195	48272.35	0.13281	38809.03
7	292214	0.122367	35757.29	0.094865	27720.74
8	292214	0.090642	26486.88	0.06776	19800.53
9	292214	0.067142	19619.91	0.0484	14143.23
10	292214	0.049735	14533.27	0.034572	10102.31
11	365428	0.036841	13462.64	0.024694	9023.882
12	365428	0.027289	9972.329	0.017639	6445.63
13	365428	0.020214	7386.91	0.012599	4604.022
14	365428	0.014974	5471.785	0.008999	3288.587
15	365428	0.011092	4053.174	0.006428	2348.991
16	675475	0.008216	5549.693	0.004591	3101.421
17	675475	0.006086	4110.884	0.00328	2215.301
18	675475	0.004508	3045.099	0.002343	1582.358
19	675475	0.003339	2255.629	0.001673	1130.255
20	675475	0.002474	1670.836	0.001195	807.3253
21	473455	0.001832	867.5002	0.000854	404.1941
22	473455	0.001357	642.5927	0.00061	288.7101
23	473455	0.001005	475.9946	0.000436	206.2215
24	473455	0.000745	352.5886	0.000311	147.3011
25	473455	0.000552	261.1767	0.000222	105.215
Total			45145.31	2.474814	-5493.41

3.4.5 Sensitivity analysis

Sensitivity analysis is a technique to assess the effects of adverse changes in the project. For making a valid generalization about mango cultivation sensitivity analysis was necessary. For doing this, all cost of mango cultivation were considered constant while benefit decreases at the rate of 10% or if benefit of mango remains the same but all cost increase at the rate of 10% and if benefit decrease and cost increase at the rate of 10%. The results of sensitivity analysis considering the above mentioned situation is presented in Table 13. BCR of mango cultivation was found greater than one. NPV was positive at 6.5% discount rate and IRR was also higher than the opportunity cost of capital. This indicates that if the returns decrease at 10% while the cost of mango remains unchanged investment in mango is profitable from the point of view of the owner. On the other hand, if gross cost increase at 10% and returns decrease at 10%, BCR>1, NPV was positive and IRR was higher than the opportunity cost of capital which implies that mango cultivation is profitable.

Table 13. Result of sensitivity analysis of mango cultivation in the study areas

Situation	BCR at 6.5%	NPW at 6.5% (Tk.)	IRR (%)
Current situation	2.89	3371166	39
Increase cost 10% but return constant	2.68	3295411	36
Decrease return 10% but cost constant	2.54	2493533	36
Increase cost and decrease return 10%	2.31	2331941	35

3.5 Profitability of Cereal Crops Cultivation

3.5.1 Cropping pattern before shifting land to mango cultivation

Respondent farmers in the study areas mostly cultivated two crops in a year. Some farmers cultivated three crops per year. Before shifting land to mango cultivation, they cultivated Boro, wheat, T. Aman, jute, sesame, aus, lentil, potato and some short duration vegetables. Variations found among the farmers in case of cropping pattern. A total of 19 types of cropping patterns were found in the study areas which were shifted by the 180 farmers. Major 11 cropping patterns are presented in Table 14.The highest percentage (25%) of farmers mentioned that they followed Wheat- Jute-T.Aman cropping pattern before shifting land. The second highest percentage (18%) of farmers followed Boro-Aus-Fallow cropping pattern which was high in Rajshahi district and low in Natore district. About 14% farmers cultivated Boro-Fallow-T.Aman before cultivation of mango. Farmers in the Natore district mentioned that they cultivated sesame and lentil before cultivating mango which was not found in other districts. A good number of farmers in Rajshahi district cultivated potato and some short duration vegetables. In all areas, 13% farmers cultivated Boro-Jute-Fallow and 12% farmers cultivated Wheat-Aus-T.Aman in their field before cultivating mango.

Table 14. Types of cropping pattern followed by the farmers before cultivating mango

Types of Cropping pattern	% farmers responded			
	Chapai Nawabganj	Natore	Rajshahi	All areas
Wheat-Jute –T.Aman	11	28	31	25
Boro-Aus-Fallow	22	9	23	18
Boro-Fallow-T.Aman	30	9	8	14
Boro-Jute –Fallow	19	9	11	13
Wheat-Aus-T.Aman	14	17	7	12
Wheat-Fallow-T.Aman	5	2	8	5
Boro-Sesame-T.Aman	-	11	0	4
Wheat-Jute-vegetables	-	-	8	3
Lentil-Jute-T.Aman	-	9	-	3
Wheat-Sesame-T.Aman	-	34	-	1
Potato-Fallow-T.Aman	-	-	3	1
Total	100	100	100	100

3.5. 2 Profitability of cereal crops cultivation

Data in Table 15 shows the profitability of cereal crops. Total cost for Wheat-Fallow-T.Aman cultivation was Tk. 1, 19,155 and net return was Tk. 24,983 per hectare. Per hectare total cost for Wheat-Jute-T.Aman cultivation was Tk. 1, 81,007 whereas it was Tk. 1, 64,335 for Wheat-Sesame-T.Aman cultivation. Among the cropping patterns, total cost and total variable cost for Potato-Fallow-T.Aman was higher than other cropping patterns which was Tk. 1, 82,735 and Tk. 1, 34,130 per hectare, respectively. Total cost and total variable cost of Wheat-Aus-T.Aman was higher than Lentil-Jute-T.Aman and Wheat-Jute-Vegetables. Boro- Fallow-T.Aman cultivation required Tk. 1, 13,336 as total cost which was lower than Boro-Aus-Fallow (Tk. 1, 15,593) per hectare. Highest gross return and net return was found for the cropping pattern Potato-Fallow-T.Aman cultivation which were Tk. 2,45,407 and Tk. 62,672 per hectare respectively. In contrast, lowest gross return and net return was found in the cropping pattern Boro-Fallow-T. Aman. On an average net return of different cropping pattern varies from Tk. 13,668 (Boro-Fallow-T.Aman) to Tk. 62,672 (Potato-Fallow-T.Aman). Highest gross margin was found for Potato-Fallow-T.Aman cultivation (Tk. 1, 11,277) followed by Wheat-Sesame-T.Aman (Tk. 93,976) and Wheat-Jute-T.Aman (Tk. 83,245). Return per taka invested on total cost and on variable cost was estimated higher in the case of Potato-Fallow-T.Aman which was 1.34 and 1.83, respectively. BCR on total cost for different cropping pattern varies from 1.12 to 1.34, whereas it was 1.36 to 1.83 on variable cost.

Table 15. Profitability of cereal crops cultivation

Items	Total Cost (Tk/ha)	Total variable Cost (Tk/ha)	Gross Return (Tk/ha)	Net Return (Tk/ha)	Gross Margin (Tk/ha)	Return per Tk. invested as TC	Return per Tk. invested as TVC
Potato-Fallow-T.Aman	182735	134130	245407	62672	111277	1.34	1.83
Wheat-Sesame-T.Aman	164335	115621	209597	45262	93976	1.27	1.81
Wheat-Jute-vegetables	143257	102978	178867	35610	75889	1.24	1.73
Boro-Sesame-T.Aman	158516	117801	192463	33947	74662	1.21	1.63
Wheat-Fallow-T.Aman	119155	86163	144138	24983	57975	1.20	1.67
Wheat-Jute - T.Aman	181007	133453	216698	35691	83245	1.19	1.62
Wheat-Aus-T.Aman	179058	135115	211901	32843	76786	1.18	1.56
Lentil-Jute-T.Aman	176188	128535	202099	25911	73564	1.14	1.57
Boro-Jute -Fallow	117542	93688	134657	17115	40969	1.14	1.43
Boro-Fallow-T.Aman	113336	88343	127004	13668	38661	1.12	1.43
Boro-Aus-Fallow	115593	95350	129860	14267	34510	1.12	1.36

3.6 Relative Profitability of Mango Cultivation

Table 16 and 17 depicted the relative profitability of mango cultivation. Total cost (TC) and total variable cost (TVC) of mango were higher than Wheat-Fallow-T.Aman, Boro-Jute-Fallow, Boro-Fallow-T.Aman and Boro-Aus-Fallow whereas TC and TVC of mango were lower than cost incurred for other seven cropping patterns. Total cost of mango cultivation was 10% higher than Boro-Fallow-T.Aman cultivation whereas it was on an average 40% lower than Potato-Fallow-T.Aman and Wheat-Jute-T.Aman cultivation. Moreover, mango cultivation required Tk. 13,915 more as total cost instead of cultivating Boro-Fallow-T.Aman (Table 26 and Table 27). For maintaining cropping pattern Wheat-Jute-T.Aman farmers required Tk. 63,997 more than mango cultivation per hectares as total variable cost. Total variable cost of mango cultivation was 34% and 32% higher than the cost incurred for Boro-Aus-Fallow and Boro-

Jute-Fallow cropping pattern cultivation whereas it was 84% lower than Wheat-Jute-T.Aman and Potato-Fallow-T.Aman cultivation. The gross return, gross margin and net return from mango cultivation were also higher than any of the eleven cropping patterns. Mango farmers got 59% higher gross return compared to Boro-Fallow-T.Aman cultivation. The gross margin of mango was 85% higher than Boro-Aus-Fallow which amounted Tk. 1, 98,529 per hectare. The average net return was on an average more than 75% higher than the eleven cropping pattern. The net return of mango was 85% higher than Lentil-Jute-T.Aman whereas it was 64% higher than Potato-Fallow-T.Aman. Likewise, the gross margin of mango was 68% higher than Lentil-Jute-T.Aman whereas it was 52% higher than Potato-Fallow-T.Aman. BCR on total cost and variable cost were also higher in mango cultivation then this eleven studied cropping patterns.

Table 16. Relative profitability of mango cultivation with other competing crops

Items	Wheat-Fallow-T.Aman	Boro-Jute-Fallow	Boro-Fallow-T.Aman	Boro-Aus-Fallow
Total cost lower than mango (Tk)	8096	9709	13915	11658
Total cost lower than mango (%)	6	7	10	9
Total variable cost lower than mango (Tk)	16707	24232	18887	5894
Total variable cost lower than mango (%)	22	32	25	34
Gross return lower than mango (Tk)	164995	174476	182129	179273
Gross return lower than mango (%)	53	56	59	58
Gross margin lower than mango (Tk)	175064	169108	194378	198529
Gross margin lower than mango (%)	75	82	83	85
Net return lower than mango (Tk)	150261	158129	161576	160977
Net return lower than mango (%)	86	90	92	92

3.7 Impact of Mango Cultivation on Income and Livelihood Pattern

Mango cultivation has created tremendous impact to many of the respondent farmers in the study areas. Survey results exposed that 83% respondent farmers opined that switching from cereal crops to mango cultivation brought them positive impacts to some extent on household income, food intake, and livelihood improvement (Table 18).

Table 17. Relative profitability of mango cultivation with other competing crops

Items	Wheat-Jute T.Aman	Wheat-Seasame-T.Aman	Wheat-Jute-vegetables	Wheat-Aus-T.Aman	Lentil-Jute-T.Aman	Potato-Fallow-T.Aman	Boro-Sesame-T.Aman
Total cost higher than mango (Tk)	53756	37084	16006	51807	48937	55484	41299
Total cost higher than mango (%)	40	28	12	39	37	41	31
Total variable cost higher than mango (Tk)	63997	46165	33522	65659	59079	64674	59539
Total variable cost higher than mango (%)	84	61	44	86	78	85	78
Gross return lower than mango (Tk)	92435	99536	130266	97232	107034	63726	116670
Gross return lower than mango (%)	30	32	42	31	35	21	38
Gross margin lower than mango (Tk)	149794	139063	157150	156253	15946875	121762	158377
Gross margin lower than mango (%)	64	60	67	67	68	52	68
Net return lower than mango (Tk)	139553	129982	139634	142401	149333	112572	141297
Net return lower than mango (%)	80	74	80	81	85	64	81

Table 18. Impact of mango cultivation to farmers

Impact	% farmers responded			
	Chapai Nawabganj	Natore	Rajshahi	All areas
Positive impact	68	93	87	83
No impact	32	7	13	17
Total	100	100	100	100

3.10 Factors Influence Decision for Shifting Area in Favour of Mango Cultivation

A multiple linear regression analysis was carried out for studying the influence of different factors that affect farmers to substitute their land to mango cultivation. The estimated regression coefficients and related statistics are presented in Table 19. The variations in eight independent variables included in the regression model explained nearly 80% variations in the crop substitution of mango. The F value was significant indicating thereby the good fit of the regression model.

The results revealed that the relative income from the crop was positive and significant in explaining the crop substitution decisions of farmers. The relative price variable came out to be insignificant. This showed that farmers, generally, calculate the aggregate gain from the crop in their decision rather referring to only the price of the crop. The variables age turned out to be negatively significant for shifting decision to mango cultivation. It indicated that older farmers are less likely to be interested for shifting their land as compared to young farmers. Education had positive and significant effect implying that educated farmers were more concerned about profit and income and hence they preferred to have a higher level of substitution in their cropping pattern. Farm size was positively significant which indicated that farmers with large farm size were more interested for altering their land to mango cultivation.

Table 19. Factors influencing decision for area shift in favour of mango cultivation

Regression variable	Regression co-efficient	t-value	Standard error	P- value
Constant	-0.762***	2.978	0.256	0.003
Relative price (Tk/kg)	0.018	1.374	0.013	0.172
Relative income (Tk/farm/year)	0.445***	2.981	0.149	0.002
Yield (kg/ha)	0.020	1.623	0.012	0.107
Age (year)	-0.028**	2.215	0.013	0.031
Education (year of schooling)	0.034**	2.045	0.017	0.043
Farm size (ha)	0.946*	1.935	0.489	0.055
Non-farm income (Tk/farm/year)	0.318	0.648	0.491	0.518
Food crop requirements at home (Tk)	-0.168	0.345	0.486	0.731
R squire	80%			
F-values	1.871***			

Note: '***', '**' and '*' indicates 1%, 5%, and 10% level of significance

4. Conclusions and Recommendations

The study assessed the profitability of mango cultivation in comparison of cereal crops cultivation. Respondent farmers shifted about half of their total land to mango cultivation. Although mango cultivation required slightly higher cost it received the higher net return compared to other crops. This was the main reason behind the shifting of crop land to mango cultivation. The rate of returns (i.e. BCR, NPV and IRR) indicated that mango cultivation was highly profitable for the farmers. Mango cultivation also had positive impact to household income and livelihood pattern. There was concern for household food security could hinder shift in the cropping pattern from food crop to mango. Regarding food security, majority of the farmers mentioned that they were food-self-sufficient along with increased consumption level after cultivating mango. Moreover, as the net income from mango was high so it could cover the expenditure of farm families. Farmers mentioned that as the prices of food crop were not much high so they had never faced any problem in obtaining food crops from the market. Farmers in the study areas reported some sources from which they were motivated to mango cultivation rather than cereal crops. Among them neighbouring farmers were opined to be as an important source of influence. This study also found out the factors that influence farmer's decision to shift from cereal crops to mango cultivation. Income, education and farm size had positive effect whereas age had negative effect to substitute their land from cereal crops to mango cultivation.The following recommendations are put forwarded for mango cultivation.

- Farmers should be motivated to cultivate mango in the fallow lands or areas where other crops are not grown well.
- As mango cultivation was highly profitable in the study areas, there is a tendency in the study areas to reduce crop land. Therefore, scientists should develop new cropping pattern with mango so that farmers can cultivate different food crops with mango.

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EFFECT OF SUBSTRATES TO FORMULATE *Trichoderma harzianum* BASED BIO-FUNGICIDE IN CONTROLLING SEEDLING DISEASE (*Rhizoctonia solani)* of BRINJAL

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Abstract

Efficacy of three different substrates viz., rice bran, wheat bran, grass pea bran and their combinations with mustard oilcake (MOC) were tested to formulate a suitable *Trichoderma harzianum* based bio-fungicide for controlling seedling disease of brinjal caused by *Rhizoctonia solani* in tray soil as well as in seedbed soil under net house condition of Bangladesh Agricultural Research Institute (BARI), Gazipur during 2010 to 2014. The results of three years experiments revealed that *T. harzianum* bio-fungicides formulated in five different combinations of substrates viz., (1) rice bran + wheat bran, (2) rice bran + mustard oilcake (MOC) (3) rice bran + grasspea bran, (4) rice bran + wheat bran + MOC and (5) rice bran + grasspea bran +MOC were equally effective to control the soil borne seedling disease of brinjal caused by *Rhizoctonia solani* in tray soil and seedbed condition. In addition, vegetative growth of brinjal seedlings viz., shoot length, shoot weight, root length and root weight were enhanced significantly by the *T. harzianum* bio-fungicides in *R. solani* inoculated seedbed condition.

Keywords: *Trichoderma harzianum, Rhizoctonia solani*, brinjal seedling.

Introduction

Quality food and nutrition are the serious challenges worldwide where vegetable can play a vital role in everyday diet in general. Among the vegetables, brinjal (*Solanum melongena* L.) is the major crop that achieves tremendous popularity over the last century in Bangladesh. It grows round the year in any space available for crop cultivation in the country and uses as multifarious item of every day dish (Rashid, 1976; Bose and Som, 1986). The productivity of brinjal in Bangladesh is 17.5 t/ha while in Japan 32 t/ha, Italy 28.2 t/ha and Turkey 30.2 t//ha (FAOSTAT, 2012). It is estimated that 10% of crops are lost due to plant diseases worldwide annually which incurs considerable financial losses to the farmers (Strange and Scott, 2005). The pathogen *Rhizoctonia solani* causing germination failure, damping off and seedling rot is the major constraint to brinjal cultivation (Najar *et al.*, 2011; Seema and Devaki, 2010). The management of this soil borne disease is difficult owing to long saprophytic survival ability of pathogen in soil (Dey, 2005). Suppression or elimination of soil borne inoculums is the only effective solution which may be achieved

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through effective fungal antagonists. The beneficial microbe such as *Trichoderma harzianum* has been reported as a potential bio-control agent that effectively controlled the soil borne pathogens including *R. solani* (Elad *et al.*, 1980; Roy *et al*., 1989; Anand and Reddy, 2009). The *Trichoderma* spp. are considered as potential biocontrol and plant growth promoting agents for many crop plants (Verma *et al*., 2007; Bai *et al*., 2008; Savazzini *et al*., 2009). The native bio-control agents usually remain in the agricultural soil in low population density. Augmenting their density to higher stability level in soil through artificial inoculation may successfully control soil borne pathogens in brinjal seed bed. Many bio-product/farm household bio-products which are locally available could easily be used as substrates to promote *Trichoderma* population in the soil. Therefore, the present study was undertaken to find out the effective local substrates to formulate the best medium for mass culturing of *T. harzianum* to be used as effective bio-fungicides against seedling disease (*R. solani*) of brinjal under seed bed condition.

Materials and Method

An experiment was conducted in the plastic tray and three other experiments in seed bed conditions of the net house of Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur during the period from 2010 to 2014 to find out the suitable carrier material for mass culturing of *Trichoderma harzianum* and thereby formulation of effective bio-fungicides against *Rhizoctonia solani* causing seedling disease of brinjal. A pure culture of bio-control agent *T. harzianum* (TM14) was grown on Potato Dextrose Agar (PDA) medium which was subsequently used as an inoculum of bio-fungicide that multiplied on rice bran, wheat bran, grasspea bran and their combination with mustard oilcake (MOC). The treatment combinations of the study were T_1= Rice bran, T_2= Wheat bran, T_3= Grasspea bran, T_4= Rice bran + Wheat bran (1:1), T_5=Rice bran + Grasspea bran (1:1), T_6= Rice bran + MOC (1:1), T_7= Rice bran + Wheat bran + MOC (1:1:1), T_8= Rice bran + Grasspea bran + MOC (1:1:1), T_9= Wheat bran + Grasspea bran + MOC (1:1:1), T_{10}= Rice bran + Wheat bran + Grass pea bran+ MOC (1:1:1:1), T_{11}=Seed treatment with Provax and T_{12}= Control. According to the treatment combinations 600 g of individual or combination of substrate materials were taken separately in 1000 ml Erlenmeyer flasks and sterilized in an autoclave at 121^0C for 15 minutes. After cooled down the substrate was inoculated individually with 5 mm diameter mycelia disc of five-day old culture of *T. harzianum* grown on PDA and finally incubated at 25±2 ^{0}C for 15 days. After incubation the colonized substrates were removed from the flasks and air dried and preserved in refrigerator at 10 ^{0}C. Besides, the pathogenic fungus *R. solani* was multiplied on sterilized barley grains in 1000 ml Erlenmeyer flask at temperature of 25±2 ^{0}C for 15 days.

In plastic tray experiment both pathogenic fungus *R. solani* and *T. harzianum* bio-fungicide were used at the rate of @) 20 g/kg soil where the control treatment received *R. solani* only and the seeds of BARI Bagun-7 were sown in the tray soil @100 seeds per tray. The experiment was laid out in completely randomized design (CRD) with six replications. Intercultural operations were done to grow the crop (Anon., 2007).

In seed bed trials the colonized barley grains were incorporated in the seed bed soils @100 g/m^2 soil. Inoculated seed bed soil was allowed to multiply the pathogen *R. solani* for 10 days with proper soil moisture. The *T. harzianum* bio-fungicides were incorporated to the seed bed and kept for 7 days with proper soil moisture for establishment of *T. harzianum* in the soils. The control bed received only *R. solani*. The seeds of BARI Bagun-7 were sown in the seed bed @ 200 seeds per treatment. The experiment was laid out in completely randomized design (CRD) with four replications. Necessary intercultural operations were done as per recommendation of the crop (Anon., 2007).

Data were collected on percent seed germination, seedling mortality, shoot height, shoot weight, root length and root weight of brinjal seedlings. The percent data were converted into arcsine transformation values before statistical analysis. The data were analyzed statistically and means were separated by Duncun's New Multiple Range Test (DMRT).

Results and Discussion

Screening of substrates based *T. harzianum* bio-fungicides in plastic tray

The seedling emergence of brinjal was significantly higher and ranged from 76% (grasspea bran) to 95% (rice bran + mustard oilcake) due to the carrier based on *T. harzianum* bio-fungicide treatments whereas untreated control tray gave lower seedling emergence (71%) (Table 1). Pre-emergence and post-emergence seedling mortality was also varied among the treatments and the highest seedling mortality of 47% was recorded in control trays. Soil treatment with *T. harzianum* bio-fungicides reduced seedling mortality of 25.53% –76.60% as compared to untreated control (Table 1). The result showed that *T. harzianum* treated tray soil gave higher amount of healthy seedlings (65% - 89%) while untreated control tray soil produced only 53% healthy seedling in *R. solani* inoculated soil. The overall performance of the bio-fungicide *T. harzianum* with respect to seedling emergence, seedling mortality and healthy seedlings of brinjal under *R. solani* inoculated condition was better.

Table 1. Effect of different carrier based *T. harzianum* bio-fungicides on the emergence and mortality of brinjal seedling in *R. solani* inoculated soils in the plastic tray

Name of substrates for *T. harzianum*	Seedling emergence (%)	Pre-emergence mortality (%)	Post-emergence seedling mortality (%)	Total seedling mortality (%)	Seedling mortality reduction (%) over control	Total healthy seedling (%)
Rice bran	82	18	5	23	51.06	77
Wheat bran	81	19	13	32	31.91	68
Grasspea bran	76	24	11	35	25.53	65
Rice bran + Wheat bran	88	12	12	24	48.94	76
Rice bran + Grasspea bran	85	15	7	22	53.19	78
Rice bran + MOC	95	5	6	11	76.6	89
Rice bran + Wheat bran + MOC	86	14	13	27	42.55	73
Rice bran + Grasspea bran +MOC	92	8	8	16	65.96	84
Wheat bran + Grasspea bran + MOC	85	15	8	23	51.06	77
Rice bran + Wheat bran + Grasspea bran+ MOC	91	9	8	17	63.83	83
Seed treatment with Provax	86	14	11	35	25.53	65
Untreated Control	71	29	18	47	-	53

Efficacy of substrates based *T. harzianum* bio-fungicides and provax in seed bed

The emergence of brinjal seedling in *R. solani* inoculated soils was sharply enhanced by the application of different carrier material based *T. harzianum* bio-fungicides and Provax in seedbed (Table 2). The individual as well as combined application of *T. harzianum* bio-fungicides was found superior in seedling emergence as compared to the untreated control during three consecutive years. The seedling emergence of brinjal ranged from 55.67% to 65.67%, 71.67% to 80.67%, and 60% to 72%, respectively in consecutive three years due to the application of different bio-fungicides in seed bed while lower seedling emergence (49.33%, 56.67%, and 50%) was recorded from the control seedbed. The trend of pre-emergence mortality was almost similar among the bio-fungicide treatments over the years that ranged from 39.68-44.33% in 1st year trial, 19.33-28.33% in 2nd year and 28-40% in 3rd year trial (Table 2). The pre-emergence seedling mortality in the control treatments was 50.67, 43.33, and 50% during 1st, 2nd and 3rd year trials, respectively. The effect of Provax was inferior or similar to that of *T. harzianum* bio-fungicide in respect of emergence and mortality of brinjal seedling in seedbed. The results of three years trial indicated that the effects of single as well as mixed carrier based *T. harzianum* bio-fungicides were very much similar in increasing seedling emergence and reducing pre-emergence mortality of brinjal seedling caused by *R. solani* under seedbed conditions.

Table 2. Effect of different carrier material based *T. harzianum* bio-fungicides on the emergence and pre-emergence mortality of brinjal seedling in *R. solani* inoculated seed bed soil

Name of substrates	Seedling emergence of brinjal in consecutive three years (%)			Pre-emergence mortality in consecutive three years (%)		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Rice bran	59.00	77.67	60.00	41.00	22.33	40.00
Wheat bran	59.33	74.33	61.00	40.67	25.67	39.00
Grasspea bran	56.00	71.67	69.00	44.00	28.33	31.00
Rice bran + Wheat bran	60.33	74.33	67.00	39.68	25.67	33.00
Rice bran + Grass pea bran	57.67	75.00	67.00	42.33	25.00	33.00
Rice bran + Mustard oilcake	55.67	80.67	69.00	44.33	19.33	31.00
Rice bran + Wheat bran + MOC	58.00	79.67	68.00	42.00	20.33	32.00
Rice bran + Grasspea bran + MOC	57.67	76.00	70.00	42.33	24.00	30.00
Wheat bran + Grass pea bran + MOC	57.33	74.33	72.00	42.67	25.67	28.00
Wheat bran + Grass pea bran+ Rice bran + MOC	65.67	72.33	66.00	44.33	27.67	34.00
Seed treatment with Provax	63.67	77.67	59.00	46.33	22.33	41.00
Control	49.33	56.67	50.00	50.67	43.33	50.00

The post emergence seedling mortality of brinjal in *R. solani* inoculated soils in seed bed was significantly reduced by the application of different carrier material based *T. harzianum* bio-fungicides and Provax (Table 3). The individual as well as combination of mixed carrier material based *T. harzianum* bio-fungicides were found superior in reduction of post emergence seedling mortality as compared to the untreated control. The highest seedling mortality of 17.33%, 25.33% and 21%, respectively was recorded in untreated control seedbed during the consecutive three years. Seedling mortality of brinjal ranged from 4.67%-7.33% in 1st year, 6.67%-12.67% in 2nd year and 7.67% - 9.33% in 3rd year due to the application of *T. harzianum* bio-fungicides were recorded (Table 3). Provax treated seedbed showed similar seedling mortality as observed in the bio-fungicides treated beds every year. The effect of different carrier material based *T. harzianum* bio-fungicides was much encouraging that reduced post-emergence seedling mortality of brinjal from 57.70% -73.05% in 1st year, 49.98% -73.67% in 2nd year and 55.57% - 63.48% in 3rd year over untreated control in *R. solani* inoculated seedbeds (Table 3).

Table 3. Efficacy of various carrier material based *T. harzianum* bio-fungicides on the post-emergence mortality of brinjal seedling in *R. solani* inoculated soils in seed bed

Name of substrates	Post-emergence seedling mortality in consecutive three years (%)			Seedling mortality reduction over control in consecutive three years (%)		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Rice bran	7.00 bc (15.31)	12.67 b (20.84)	9.33 b (17.05)	59.61	49.98	55.57
Wheat bran	6.33 bc (14.58)	10.00 b (17.71)	9.00 b (17.44)	63.47	60.52	57.14
Grasspea bran	7.33 b (15.72)	11.00 b (19.36)	9.33 b (16.75)	57.70	56.57	55.57
Rice bran + Wheat bran	5.67 bc (13.77)	10.67 b (18.89)	7.67 b (16.05)	67.28	57.88	63.48
Rice bran + Grasspea bran	5.33 bc (13.36)	8.00 b (16.41)	8.33 b (16.75)	69.24	68.42	60.33
Rice bran + Mustard oilcake	6.00 bc (14.19)	8.67 b (17.05)	9.00 b (16.75)	65.38	65.77	57.14
Rice bran + Wheat bran + MOC	5.33 bc (13.38)	6.67 b (14.95)	8.67 b (16.02)	69.24	73.67	58.71
Rice bran +Grasspea bran +MOC	5.33 bc (13.41)	9.00 b (17.21)	8.33 b (17.08)	69.24	64.47	60.33
Wheat bran + Grasspea bran + MOC	7.00 bc (15.33)	9.00 b (17.39)	9.33 b (17.78)	59.61	64.47	55.57
Wheat bran + Grasspea bran+ Rice bran + MOC	4.67 c (12.48)	8.67 b (16.96)	9.00 b (16.77)	73.05	65.77	57.14
Seed treatment with Provax	6.00 bc (14.21)	9.33 b (17.49)	8.33 b (17.75)	65.38	63.17	60.33
Control	17.33 a (24.59)	25.33 a (30.17)	21.00 a (27.48)	-	-	-

Values in a column having same letter did not differ significantly ($p=0.05$) by LSD.

Arcsine transformed values were within the parentheses.

Shoot length and shoot weight of seedlings were increased significantly (p=0.05) by the *T. harzianum* bio-fungicides in the *R. solani* inoculated seed bed soil (Table 4). In 1st year trial, the shoot length of brinjal seedlings ranged from 15.87 cm to 18.80 cm due to *T. harzianum* bio-fungicides and minimum shoot length (13.40 cm) was obtained from the control bed. Similarly, application of individual and mixed carrier material based *T. harzianum* bio-fungicides gave higher shoot length ranged from 7.67 cm – 10.60 cm in 2nd year and 6.77 cm-9.07 cm in 3rd year, while shorter shoots were observed in Provax and untreated control seedbed (Table 4). The shoot weight of individual brinjal seedling was enhanced up to 8.72 g by the *T. harzianum* bio-fungicide where minimum shoot weight of 5.87 g was recorded from the control bed during the 1st year trial. Similarly, maximum shoot weights of 6.80 g, and 7.80 g were recorded from the bio-fungicide treated seedbeds of 2nd and 3rd year trials where control beds gave shoots of 3.28 g and 4.37 g, respectively. Seed treatment with chemical fungicide Provax gave comparatively lower shoot weight of brinjal seedling in all the years.

Table4. Effect of different carrier material based *T. harzianum* bio-fungicides on the shoot growth of brinjal seedling in *R. solani* inoculated seed bed soil

Name of substrates	Shoot length in consecutive three years (cm)			Shoot weight in consecutive three years (gplant^{-1})		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Rice bran	16.43 cd	8.07 bcd	9.07 a	8.34 ab	5.05 c	6.17 b
Wheat bran	16.80 bcd	8.13 bcd	6.77 bc	8.69 ab	4.87 cd	6.60 b
Grasspea bran	17.27 bc	7.67 cd	7.73 ab	8.57 ab	4.87 cd	6.70 b
Rice bran + Wheat bran	15.87 cd	8.40 bc	8.90 a	8.36 ab	6.76 a	7.80 a
Rice bran + Grasspea bran	18.80 a	8.22 bcd	8.60 a	8.72 a	6.80 a	7.80 a
Rice bran + Mustard oilcake	16.67 bcd	8.97 bc	8.57 a	8.53 ab	6.10 ab	7.73 a
Rice bran + Wheat bran + MOC	16.20 cd	9.27 ab	8.97 a	8.31 ab	6.63 a	7.50 a
Rice bran+ Grasspea bran +MOC	17.03 bc	10.47 a	8.73 a	8.35 ab	6.52 a	7.70 a
Wheat bran + Grasspea bran + MOC	16.67 bcd	9.43 ab	7.83 ab	8.45 ab	5.35 bc	7.43 a
Wheat bran + Grasspea bran+ Rice bran + MOC	18.00 ab	10.60 a	8.63 a	8.16 ab	5.10 c	7.77 a
Seed treatment with Provax	15.33 d	6.86 de	5.97 cd	7.51 b	4.19 d	5.43 c
Control	13.40 e	5.80 e	5.00 d	5.87 c	3.28 e	4.37 d

Values in a column having same letter did not differ significantly (p=0.05) by LSD.

The root length was enhanced up to 6.80 cm by wheat bran based bio-fungicide followed by rice bran + grass pea bran (6.73 cm) and the shortest root was found in untreated control in 1st year trials (Table 5). The root length ranged from 6.80 cm – 8.60 cm in 2nd year and 6.60 cm- 7.93 cm in 3rd year trials while the shorter roots were recorded from Provax and untreated control treatments. The *T. harzianum* based bio-fungicides also augmented the root weights of brinjal seedlings as compared to untreated control.

Table 5. Role of various carrier material based *T. harzianum* bio-fungicides on the root growth of brinjal seedling in *R. solani* inoculated seed bed soil

Name of substrates	Root length in consecutive three years (cm)			Root weight in consecutive three years (mgplant^{-1})		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Rice bran	6.57 ab	7.00 abc	6.73 c	400	440 a	430 bc
Wheat bran	6.80 a	7.13 abc	6.87 bc	350	410 ab	450 abc
Grasspea bran	6.57 ab	6.80 abc	6.60 c	390	410 ab	460 abc
Rice bran + Wheat bran	6.40 ab	7.13 abc	7.93 a	380	420 ab	520 ab
Rice bran + Grasspea bran	6.73 a	7.80 ab	7.37 abc	400	430 ab	500 abc
Rice bran + Mustard oilcake	6.30 ab	8.47 a	7.60 ab	390	450 a	520 ab
Rice bran+ Wheat bran + MOC	6.43 ab	8.00 ab	7.70 a	400	440 a	550 a
Rice bran+ Grasspea bran +MOC	6.50 ab	8.60 a	7.73 a	380	440 a	480 abc
Wheat bran + Grasspea bran + MOC	6.30 ab	8.40 a	7.67 a	390	450 a	490 abc
Wheat bran + Grasspea bran+ Rice bran + MOC	6.70 a	8.57 a	7.63 ab	400	430 ab	500 abc
Seed treatment with Provax	5.80 bc	5.73 c	5.53 d	370	370 bc	420 bc
Control	5.13 c	5.53 c	4.87 d	330	320 c	380 c

Values in a column having same letter did not differ significantly (p=0.05) by LSD.

The overall effects of the carrier based *T. harzianum* bio-fungicides on the emergence, mortality, growth and development of brinjal seedlings under *R. solani* inoculated soils as revealed from the results of three years trials indicated that five different combination of carriers materials viz. (1) rice bran + wheat bran, (2) rice bran + grass pea bran (3) rice bran + MOC, (4) rice bran + wheat bran + MOC, and (5) rice bran + grass pea bran +MOC were superior for brinjal seedling disease (*R. solani*) management in seed bed condition.

Results of the present study revealed that *T harzianum* bio-fungicides were effective to control seedling disease of brinjal caused by *R. solani* in the tray and in seedbed condition. Many researchers reported that soil amendment with formulated *Trichoderma* was effective in controlling seedling disease of many crops especially the fungal pathogens such as *R. solani, Fusarium oxysporum* and *S. rolfsii* (Lo *et al.,* 1996; Tran, 1998; Bari *et al.,* 2000; Shamsuzzaman *et al.,* 2003; Benítez *et al*., 2004; Clear and Valic, 2005; Ngo *et al.,* 2006; Shalini *et al.,* 2006; Dubey *et al*., 2007; Rojo *et al*., 2007). The effect of *Trichoderma* spp. as bio-control agents against phytopathogenic fungi *Rhizoctonia* spp. and *Fusarium* spp. was also reported by other investigators (Poddar *et al*., 2004; Rojo *et al.,* 2007). Harman *et al.* (2004) reported that the biocontrol agents *Trichoderma* spp. influenced seed germination, seedling vigor and increased shoot and root growth as well as productivity of brinjal. The growth promotion in plant with special reference to the length and weight of their shoots and roots was enhanced due to *Trichoderma* spp. soil amendment (Samolski *et al*., 2012; Harman *et al*., 2012; Hermosa *et al*., 2012). Similarly, enhanced root length and root weight of many plants were also reported by the application of *Trichoderma* spp. (Chang *et al*., 1986; Kleifeld and Chet, 1992; Azarmi *et al*., 2011). Elad *et al*. (1980) reported that incorporation of *T. harzianum* bio-fungicide in the pathogen-infested soils significantly reduced bean seedling diseases caused by *R. solani* and *Sclerotium rolfsii*. Meah *et al.* (2004) reported the formulated *T. harzianum* grown on peat soil based black bran was found to be effective in controlling some of the nursery diseases like damping off, tip over and seedling blight of eggplant and also promoted seed germination. The present study revealed that rice bran based *Trichoderma* bio-fungicide gave better seed germination, reduced seedling mortality and increased growth of brinjal seedling. Sangeetha *et al.* (1993) found rice bran as the best substrate for the formulation of *Trichoderma* which gave 35% higher seed germination in brinjal and wheat. The disease incidence of brinjal, water melon and cotton was reported to be reduced considerably by the application of *T. harzianum* (Sivan and Chet, 1986). Tehroni and Nazari (2004) observed *T. harzianum* as an effective remedy against damping-off of cucumber. Shoresh *et al*. (2005) stated *Trichoderma* spp. as effective bio-control agents for a number of soil borne plant pathogens and induced a potentate state in the plant enabling it to be more resistant to subsequent pathogen infection.

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POSTHARVEST LOSS ASSESSMENT OF MAJOR FRUITS GROWN IN HILL REGIONS OF BANGLADESH

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Abstract

The study was conducted for assessing postharvest loss of major fruits in different hill regions of Bangladesh. The study areas covered four hill districts, namely Rangamati, Khagrachari, Bandarban and Moulvibazar and six selected fruits, namely mango, jackfruit, litchi, banana, pineapple and orange. These fruits are grown intensively in hill regions compared to other parts of Bangladesh. Data were collected from 2050 fruit growers and 749 traders of eight (8) upazilas considering accessible and less accessible areas. At farmers and traders level, the total postharvest loss of banana, pineapple, orange, mango, litchi and jackfruit were 372, 274, 200, 243, 165 and 380 kg/mt which was accounted about 37%, 27%, 20%, 24%, 17% and 38% of total production respectively. The main postharvest losses at farm level were incurred due to severe attack of insect, bat, squirrel and monkey. For traders, major losses were incurred during transportation. On the basis of retail price, the annual economic loss was estimated as Tk. 2107.5 crore and the maximum loss was incurred for banana (Tk. 705.79 crore) followed by pineapple (Tk. 550.58 crore) and mango (Tk. 508.95 crore) and the lowest for orange (Tk. 1.12 crore). It is interesting to note that, transportation dummy, labour dummy and market demand dummy had negative and significant effect on the postharvest losses. If transportation facilities can be improved and market demand and labour availability can be increased, postharvest loss will be decreased to an acceptable level at the study areas.

Keywords: Hill regions, fruits, postharvest loss, and national loss.

1. Introduction

The hilly areas have the great potentialities for fruit cultivation. Higher yield can be attained by adopting modern technologies as well as to mitigate balanced nutrition of the farmer. Most of the fruits like pineapple, mango, banana, jackfruit, guava, papaya, malta, orange, pomelo, litchi, lemon etc. are grown in different hilly areas of Bangladesh. The characteristics of agricultural commodities like fruits are bulky in production and perishable in nature. The surplus production of different fruits grown in hill regions are not marketed in proper time due to lack of transport and infrastructural facilities. Due to seasonal glut and absence of proper marketing system, bulk amount of harvested produce

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get wasted every year. Postharvest losses occur at different points from fruit harvest to marketing chain. The extent of loss varies with the type of commodity and its level of management. In most of the developing countries, the postharvest loss is very high and it is about 50% of fresh fruits and vegetable production. Even in developed countries like USA, Postharvest loss is up to 20% (Yahia and Oubahou, 2001). The postharvest loss of fruits and vegetables in Bangladesh ranged from 23.6% to 43.5% which accounts for an annual loss Tk. 3442 crore (Hassan, 2010). Similar losses of fruits and vegetables have also been reported from other Asia-Pacific countries, for example, 40% in India, 20-50% in Indonesia, 20-50% in Korea, 27-42% in the Philippines, 16-41% in Srilanka, 17-35% in Thailand and 20-25% in Vietnam (Rolle, 2006). In general, the postharvest losses of fruits and vegetables in the developing countries are substantial (24-40%) as compared to the developed countries (2-20%) (Sirivatanapa, 2006).

The loss of any harvested crops has enormous negative impact on the economy of the country. By developing and adopting the appropriate techniques of postharvest technologies, a large amount of money can be saved annually which can make a significant contribution in case of food security of Bangladesh. Improved postharvest practices will bring financial gain to the farmers as well as satisfaction to the traders and consumers.

So, to compare with the previous studies an attempt had been made to analyse the present status of postharvest loss explaining the causes of postharvest loss both at farmers and traders level and also the factors responsible for this postharvest losses which will help in adopting appropriate interventions in reducing postharvest losses. Based on the postharvest losses, national economic loss as a whole was estimated on the basis of total production of the country for the year 2009-2010. Therefore, this study was undertaken with the following objectives:

i. To know the present status of postharvest losses of major fruits and their causes both at farmers and traders level;

ii. To find out the factors responsible for this postharvest losses;

iii. To estimate national economic loss per year.

2. Methodology

2.1 Study areas: The study areas covered four hill districts, namely Rangamati, Khagrachari, Bandarban and Moulavibazar where fruits are intensively grown compared to other parts of Bangladesh.

2.2 Sample size: From eight upazilas of four districts a total of 1230 growers were selected as sample farmers (Table 1). Another 820 farmers (Table 1) were selected whose gardens are more than 4 years old and presently they are marketed their fruits in the markets. In the case of different intermediaries, a total of 746 samples were selected from both primary and secondary markets of which 240 were local traders, 144 bepari, 48 urban aratdars, 144 local retailers and 96 were urban retailers.

Table 1. Distribution of fruits growing farmers according to different locations

Name of fruits	Total sample (No)	Farmers who are cultivating different fruits							
		Khagrachari		Rangamati		Bandarban		Moulavibazar	
		Matiranga	Dighinala	Sadar	Naniarchar	Sadar	Ruma	Sreemongal	Juri
Banana	240	30	30	30	30	30	30	30	30
Pineapple	210	30	30	30	30	30	30	30	0
Orange	150	30	0	30	30	0	30	0	30
Mango	180	30	30	30	30	30	30	0	0
Litchi	210	30	30	30	30	30	0	30	30
Jackfruit	240	30	30	30	30	30	30	30	30
Total	**1230**	**180**	**150**	**180**	**180**	**150**	**150**	**120**	**120**
		Farmers who are presently marketed their fruits							
Farmer	820	120	100	120	120	100	100	80	80

2.3 Sampling technique: For selecting the farmers, simple random sampling technique and for intermediaries stratified proportionate random sampling technique for each group of intermediaries were followed. The farmers who possess more than 1 hectares of owned cultivable land and having the fruit garden (not less than 0.50 hectare) and depend on farming were selected as respondent farmers. The intermediaries werefaria, *bepari, paiker, aratdar,* wholesaler and retailer.

2.4 Postharvest loss assesment using multiple linear regression model: The data were collected from households on socioeconomic variables such as age, educational background, family members, occupation, earning person, average annual income. Information on different postharvest activities was collected from the respondents.Averages and percentages were used to compute the postharvest losses. Information about postharvest losses was obtained from the households during following operations: (i) harvesting, (ii) grading/handling (iii) loading/unloading and (iv) transportation. The total postharvest losses were estimated as a sum of all these losses. Functional analysis was carried out to examine the factors affecting postharvest losses at farm level in fruits, as used by Nag *et al.,* (2000) in chickpea. The following multiple linear regression function was specified in the present study:

$$Y_i = a + b_1X_{1i} + b_2X_{2i} + b_3X_{3i} + \ldots\ldots\ldots\ldots + b_{10}X_{10i} + e_i$$

Where,

Y_i = Postharvest losses of i^{th} fruits at farm level in kg per ha.

X_{1i} = Age of the farmers in years.

X_{2i} = Education of the farmers in schooling years.

X_{3i} = Total production of i^{th} fruits in M.tons.

X_{4i} = Weather dummy which takes the value '1' if the weather during harvesting was favourable and value '0', otherwise.

X_{5i} = Transportation dummy which takes the value '1' if transport facility was adequate and value '0' otherwise.

X_{6i} = Labour dummy which takes the value '1' if the labour availability during harvesting was adequate and value '0' otherwise.

X_{7i} = Training dummy which takes the value '1' if the farmer received training about production and value '0' otherwise.

X_{8i} = Distance dummy which takes the value '1' if the distance from farm to market was favourable and value '0' otherwise.

X_{9i} = Market demand dummy which takes the value '1' if the market demand was favourable and value '0' otherwise.

X_{10i}= Market place dummy which takes the value '1' if the market place was favourable and value '0' otherwise

a=intercept.

$b_1, b_2, b_3, \ldots\ldots\ldots\ldots\ldots\ldots.. b_{10}$=Coefficients of the respective variable

i=1,2,3,…6 and 1= banana, 2=pineapple, 3=orange, 4=mango, 5=litchi, 6=jackfruit.

e_i = Random-error.

3. Results and Discussion

3.1 Postharvest loss at farmers' level

Postharvest losses of different fruits at different operational stages at farm level in hilly areas are shown in Table 2. For banana, the average loss per metric ton was 64 kg (6.4%) and highest loss (1.4%) was occurred due to spoilage. Major portion of losses were found due to rough handling at harvesting (1.3%) and insect attack (1.2%). For pineapple, the amount of losses per metric ton was 66 kg (6.6% of total production) and the highest amount of losses was observed at harvesting (1.4%) and spoilage loss (1.4%). A notable portion (0.8%) of pineapple was rotten due to rain. In the case of orange, average losses per metric ton was 94 kg (9.4% of the total production). Farmers noted that highest loss (2.6%) was occurred due to insect attack. Spoilage loss (2.1%) was also prominent in orange.The total amount of losses for mango at farmers level was 98 kg/mt which was 9.8% of total production. Major loss of mango is occurred due to insect attack (3%), traditional harvesting system (1.7%) and spoilage loss (1.5). Postharvest losses for litchi were 84kg/mt (8.4% of total production). Major portion of losses is occurred due to insect attack (2.5%) and rough handling at harvesting stage (1.5%). Besides, remarkable portion of losses is occurred at grading (1%), storage (0.9%) and spoilage loss (1.3%).For jackfruit, per metric ton losses was 56 kg (5.6%)which is comparatively lower than other fruits and the highest amount of losses were observed due to insect attack (1.6%). Losses of jackfruit also occurred due to storage (0.6%), rough handling at harvesting (1%), delay selling (0.6%), grading (0.4%) and spoilage (0.5%).

For all fruits, the major postharvest loss occurred due to the attack of insect and pest at ripening stage (Table 2). Furthermore, a major portion of losses occured during harvesting and also due to spoilage during rainy season. This loss also occured due to lack of assembling point or temporary storage facilities for storage at market place.

Table 2. Postharvest losses of different fruits at farmers' level

Particulars	Fruits					
	Banana	Pineapple	Orange	Mango	Litchi	Jackfruit
Total yield (kg/ha)	33653	21156	23622	22253	9243	32498
Total loss (kg/ha)	2019(6)	1481 (7)	2212 (9)	2151 (10)	774 (8)	1826 (6)
Loss (kg/mt)	64 (6.4)	66 (6.6)	94 (9.4)	98 (9.8)	84 (8.4)	56 (5.6)
Harvesting loss (kg/mt)	13 (1.3)	14 (1.4)	10 (1)	17(1.7)	15(1.5)	10 (1)
Grading loss (kg/mt)	2 (0.2)	6 (0.6)	6 (0.6)	5 (0.5)	10 (1)	4 (0.4)
Storage loss (kg/mt)	4 (0.4)	7 (0.7)	7 (0.7)	6 (0.6)	9 (0.9)	6 (0.6)
Delay selling (kg/mt)	5(0.5)	6(0.6)	6(0.6)	7 (0.7)	5 (0.5)	6 (0.6)
Weight loss (kg/mt)	-	1 (0.1)	2(0.2)	3 (0.3)	-	-
Spoilage loss (kg/mt)	14 (1.4)	14 (1.4)	21 (2.1)	15 (1.5)	13 (1.3)	5 (0.5)
Loss due to insect attack (kg/mt)	12 (1.2)	6 (0.6)	26 (2.6)	30 (3)	25 (2.5)	16 (1.6)
Rotten due to rain (Kg/mt)	4 (0.4)	8 (0.8)	10 (1)	11 (1.1)	2 (0.2)	6 (0.6)
Other losses (Kg/mt)	10 (1)	4 (0.4)	6 (0.6)	4(0.4)	5 (0.5)	3 (0.3)

Note: Figures in the parentheses indicate percentage of total losses

Others indicate fruits damage by monkey, bat and squirrel

3.2 Postharvest losses at traders' level: The most important chain through which major amount of fruits (banana, orange, litchi and jackfruit) was transacted was Local trader-*Bepari*-*Paikar*-Urban retailer/Rural retailer-Consumer. For pineapple and mango the most important chain ofmarketingwas Local trader-*Paikar*-Urban retailer-Rural retailerand *Bepari*-*Paikar*-Urban retailer, respectively. For all fruits except mango, postharvest losses were found more in urban retailer level than other traders. The main reason for losses in urban retailer level was due to the poor storage facilities and delay selling of the product. Sometimes it required more time to dispose of due to large supply of the same product in the market.In case of mango the highest losses occured in case of *Bepari* followed by urban retailer. The major cause of postharvest losses for all traders were found to be due to carrying/transportation followed by delay selling and storage loss.

Postharvest losses of banana at traders' level

As banana is a highly perishable product and it stays comparatively more time to the traders,postharvest losses at intermediaries' level were much higher than farm level. Highest losses of banana were found in case of urban retailers (8.9%) and comparatively lower losses were found in case of rural retailers (3.2%). Total 30.8% losses were found at traders' level (Table 3). Highest 8.8% loss was occurred in case of carrying banana from one area to another. This is because of having poor road and transportation facilities in the hill areas. In Ethiopia Mebratie et.al (2015) estimated postharvest losses as higher at retailers level (56% of total loss) while the wholesale and farm levels' losses were 27% and 17%, respectively.

Table 3. Postharvest losses of banana at different intermediaries level (kg/mt)

Particulars	Local Trader	Bepari	Paiker	Urban Retailer	Rural Retailer	Total loss
Loading/Unloading	5 (0.5)	8 (0.8)	9 (0.9)	6 (0.6)	7 (0.7)	35 (3.5)
Carrying	12 (1.2)	38 (3.8)	21 (2.1)	9(0.9)	8 (0.8)	88 (8.8)
Grading & Packing	8 (0.8)	6 (0.6)	6 (0.6)	-	5 (0.5)	25 (2.5)
Storage loss	20 (2)	5 (0.5)	6 (0.6)	29 (2.9)	6 (0.6)	66 (6.6)
Delay Selling	20 (2)	6 (0.6)	4 (0.4)	30 (3)	3 (0.3)	63 (6.3)
Spoilage loss	7 (0.7)	4 (0.4)	2 (0.2)	15 (1.5)	3 (0.3)	31 (3.1)
Total loss	72 (7.2)	67 (6.7)	48 (4.8)	89 (8.9)	32 (3.2)	308 (30.8)

Note: Figures in the parentheses indicate losses in percentage

Postharvest losses of pineapple at traders' level

Postharvest losses of pineapple at intermediaries' level were much higher than farm level. Total losses at traders' level were found 20.8%. Highest losses of pineapple were found in case of urban retailers (9.6%) and comparatively lower losses were found in case of rural retailers (2.5%). (Table 4). Highest (5%) losses were occurred in case of carrying pineapple from one area to another. This is because of having poor road and transportation facilities in the hill areas. A noticeable portion of pineapple was lost due to delay selling (4.6%).

Table 4. Postharvest losses of pineapple at different intermediaries' level (kg/mt)

Particulars	Local trader	*Paiker*	Urban retailer	Rural retailer	Total
Loading/Unloading	10 (1)	8(0.8)	9(0.9)	6 (0.6)	33 (3.3)
Carrying	18(1.8)	12 (1.2)	14 (1.4)	6(0.6)	50 (5)
Grading & Packing	8(0.8)	5(0.5)	8(0.8)	5 (0.5)	26 (2.6)
Storage loss	10(1)	6 (0.6)	26 (2.6)	2 (0.2)	44 (4.4)
Delay Selling	3(0.3)	7(0.7)	30 (3)	6 (0.6)	46 (4.6)
Spoilage loss	-	-	9(0.9)	-	9 (0.9)
Total loss	49 (4.9)	38 (3.8)	96(9.6)	25(2.5)	208(20.8)

Note: Figures in the parentheses indicate losses in percentage

Postharvest losses of orange at traders' level

Postharvest losses of orange at intermediaries' and farm level were more or lesssimilar. Total losses at traders' level were found 10.7%. Highest losses were found in case of urban retailers (5.4%) and comparatively lower losses were found in case of local traders (0.6%) (Table 5). Highest (2.6%) losses were occurred in case of carrying one area to another. This is because of having poor road and transportation facilities in the hill areas. A noticeable portion of losses were found due to delay selling (2.1%) and spoilage losses (2.1%).

Table 5. Postharvest losses of orange at different intermediaries' level (kg/mt)

Particulars	Local trader	*Bepari*	*Paiker*	Urban retailer	Rural retailer	Total
Loading/Unloading	2 (0.2)	3 (0.3)	2 (0.2)	8 (0.8)	3 (0.3)	18 (1.8)
Carrying	2 (0.2)	7 (0.7)	5 (0.5)	8 (0.8)	5 (0.5)	26 (2.6)
Grading & Packing	1 (0.1)	2 (0.2)	1 (0.1)	3 (0.3)	-	7 (0.7)
Storage loss	1 (0.1)	3 (0.3)	1 (0.1)	12 (1.2)	4 (0.4)	21 (2.1)
Delay Selling	-	4 (0.4)	-	15 (1.5)	4 (0.4)	21 (2.1)
Spoilage loss	-	2 (0.2)	-	10 (1)	1 (0.1)	14 (1.4)
Total loss	6 (0.6)	21(2.1)	9 (0.9)	54(5.4)	17(1.7)	107(10.7)

Note: Figure in the parentheses indicate losses in percentage.

Postharvest losses of mango at traders' level

Postharvest losses of mango at intermediaries' level were found 14.5% which was higher than farm level. Highest losses of mango were found in case of beparilevel (7.2%) which was about half of the total losses at traders' level and comparatively lower losses were found in case of paikers level (1.9%) (Table 6). Highest (5.5%) losses were occurred in case of carrying mango from one area to another. Poor road and transportation facilities in the hilly areas are the major causes of losses at traders level. A noticeable portion of mango was lost due to storing mango at traders' level (2.6%).

Table 6. Postharvest losses of mango at different intermediaries' level (kg/mt)

Particulars	*Bepari*	*Paiker*	Urbanretailer	Total
Loading/Unloading	14 (1.4)	5 (0.5)	3 (0.3)	22 (2.2)
Carrying	40 (4)	8 (0.8)	7 (0.7)	55 (5.5)
Grading & Packing	4 (0.4)	3 (0.3)	-	7 (0.7)
Storage loss	9 (0.9)	3 (0.3)	14 (1.4)	26 (2.6)
Delay Selling	5 (0.5)	-	17 (1.7)	22 (2.2)
Spoilage loss	-	-	13 (1.3)	13 (1.3)
Total loss	72 (7.2)	19 (1.9)	54 (5.4)	145 (14.5)

Note: Figure in the parentheses indicate losses in percentage

Postharvest losses of Litchi at traders' level

Postharvest losses of litchi at intermediaries' level were 8.1% which is similar to farm level (Table 7). The perishability of this fruit is attributed to immense physiological changes after harvest (Momen *et. al*., 1993). Amiruzzaman (1990) reported that postharvest losses of fresh fruits including litchi in Bangladesh is 25-50%, while it is only 5-25% in developed countries (Khader, 1992). Highest losses of litchi were found in case of urban retailer (4.3%) and comparatively lower loss was found in case of bepari (0.9%) (Table 7). Molla *et. al.* (2010) reported that average losses of litchi at growers, beparies, arathdars, retailers, and and consumers level were found as 13%, 4.25%, 7.75%, 4.10%, and 7.50% respectively. Highest (2.6%) losses were occurred in case of carrying litchi from one area to another. This is because of having poor road and transportation facilities in the hill areas. A noticeable portion of litchi was lost in the time of grading and packing (1.9%).

Table 7. Postharvest losses of Litchi at different intermediaries' level (kg/mt)

Particulars	Localtrader	*Bepari*	*Paiker*	Urbanretailer	Ruralretailer	Total
Loading/Unloading	-	2 (0.2)	4 (0.4)	8 (0.8)	4 (0.4)	18 (1.8)
Carrying	1 (0.1)	3 (0.3)	3 (0.3)	12 (1.2)	7 (0.7)	26 (2.6)
Grading & Packing	-	4 (0.4)	2 (0.2)	9 (0.9)	4 (0.4)	19 (1.9)
Storage loss	-	-	2 (0.2)	-	-	2 (0.2)
Delay Selling	-	-	-	8 (0.8)	2 (0.2)	10 (1)
Spoilage loss	-	-	-	6 (0.6)	-	6 (0.6)
Total loss	1 (0.1)	9 (0.9)	11 (1.1)	43 (4.3)	17 (1.7)	81 (8.1)

Note: Figures in the parentheses indicate losses in percentage

Postharvest losses of jackfruit at traders' level

Postharvest losses of jackfruit at intermediaries' level were much higher than farm level. Total losses at traders' level were found 32.4%. Highest losses of jackfruit were found in case of bepari and urban retailers (9.5%) and comparatively lower losses were found in case of rural retailers (2.3%). (Table 8). Highest (15.1%) losses were occurred in case of carrying jackfruit from one area to other. This is because of having poor road and transportation facilities in the hill areas. A noticeable portion of jackfruit was lost in the time of loading/unloading and storing at traders' level (6.2%).

Table 8. Postharvest losses of Jackfruit at different intermediaries' level (kg/mt)

Particulars	Localtrader	*Bepari*	*Paiker*	Urbanretailer	Ruralretailer	Total
Loading/Unloading	12 (1.2)	18 (1.8)	16 (1.6)	13 (1.3)	2 (0.2)	62 (6.2)
Carrying	25 (2.5)	45 (4.5)	32 (3.2)	43 (4.3)	7 (0.7)	151 (15.1)
Grading & Packing	5 (0.5)	10 (1)	9 (0.9)	-	-	23 (2.3)
Storage loss	6 (0.6)	13 (1.3)	6 (0.6)	25 (2.5)	9 (0.9)	62 (6.2)
Delay Selling	-	9 (0.9)	-	10 (1)	5 (0.5)	23 (2.3)
Spoilage loss	-	-	-	4 (0.4)	-	3 (0.3)
Total loss	48 (4.8)	95 (9.5)	63 (6.3)	95 (9.5)	23 (2.3)	324 (32.4)

Note: Figures in the parentheses indicate losses in percentage

3.3 Total Postharvest losses

The postharvest losses of banana, pineapple, orange, mango, litchi and jackfruit at traders level were worked out as 308 kg, 208 kg, 106 kg, 145 kg, 81 kg and 324 kg per ton respectively (Table 9). The total loss that represent about 30.8%, 20.88%, 10.6%, 14.5%, 8.1% and 32.4% of total volume of fruits handled by different intermediaries.Total post- harvest losses of banana, pineapple, orange, mango, litchi and jackfruit were found 37%, 27%, 20%, 24%, 17%, and 38%, respectively.

Table 9. Postharvest losses at farmers and traders level (kg/mt)

Fruits	Farmers loss (kg/mt)	Traders loss (kg/mt)	Total loss (kg/mt)
Banana	64 (6.4)	308 (30.8)	372 (37)
Pineapple	66 (6.6)	208 (20.8)	274 (27)
Orange	94 (9.4)	106 (10.6)	200 (20)
Mango	98 (9.8)	145 (14.5)	243 (24)
Litchi	84 (8.4)	81 (8.1)	165 (17)
Jackfruit	56 (5.6)	324 (32.4)	380 (38)
All Average	77 (7.7)	195 (19.5)	272 (27.2)

Note: Figures in the parentheses indicate losses in percentage

3.4 National economic loss assessment

Both at farmers and traders level, the total postharvest lossesfor banana, pineapple,orange ,mango, litchi, and jackfruit were 372, 274, 200, 243, 165, and 380 kg/mt (Table 10).The total economic loss of major fruits was calculated on the basis of the latest production data obtained from BBS 2010. Based on harvest price,national economic loss was estimated to be Tk. 922.17 crore.The maximum loss was incurred for mango (Tk. 364.12 crore) and the lowest for orange (Tk. 0.37 crore). Similarly, on the basis of retail price, the total economic loss was estimated to be Tk. 2341.66crore and the maximum loss was incurred for banana(Tk. 705.79 crore) followed by pineapple (Tk. 550.58 crore) and mango (Tk. 508.95 crore) and the lowest for orange (Tk. 1.12 crore). In monetary term, the prices prevailing in retail market is always higher than the farm harvest price. So in retail level, the postharvest losses were highest. Actual economic loss was again estimated considering 10% acceptable loss both at farmers and traders level. By considering 10% acceptable loss, the total postharvest losses were estimated Tk. 829.95 crore/year at farm harvest price and Tk. 2107.50 crore/year at retail price.

Table 10. Annual economic loss of fruits occurred at harvest and postharvest stages

Particulars	Banana	Pineapple	Orange	Mango	Litchi	Jackfruit	Total
Production (mt)	818254	234493	2666	1047849	64995	1005164	4173421
Loss at farmers&traders level in study areas (kg/mt)	372	274	200	243	165	380	1634
Total national loss (mt)	304390	64251	533	254627	10724	381962	1016487
Harvest price (Tk./mt)	6017	25809	6920	14300	88542	2978	
Retail price (Tk./mt)	23187	85692	21000	19988	180208	10000	
Total loss based on harvest price (crore Tk.)	183.15	165.83	0.37	364.12	94.95	113.75	922.17
Total loss based on retail price (crore Tk.)	705.79	550.58	1.12	508.95	193.26	381.96	2341.66

3.5 Factors affecting postharvest losses at farm level

For studying the influence of different socio-economic features of farmers on postharvest losses at the farm level, a multiple linear regression analysis was carried out. The estimated regression coefficients are presented in table 11 to table 13. The variations in 10 independent variables included in the regression model explained nearly 59per cent in the total postharvest losses in banana, 68 per cent in pineapple, 59 per cent in orange, 79 per cent in mango, 75 per cent in litchi and 69 per cent in jackfruit. The F-ratio was significant in all cases, indicating thereby the good fit of the regression models.

Table 11. Estimated values of coefficients and related statistics of multiple linear regression model for postharvest losses of banana and pineapple at farmers' level

Explanatory variables	Banana		Pineapple	
	Coefficients	P-value	Coefficients	P-value
Intercept	10.034^{**}	0.052	12.071^{**}	0.053
Age of the farmer(years) X_1	0.039	0.193	6.722	0.539
Education (Schooling years) X_2	0.432	0.372	0.790	0.695
Total production (M.ton) X_3	0.820	0.489	**10.005***	0.065
Weather dummy X_4	1.029	0.702	**-0.192****	0.053
Transportation dummy X_5	**-0.043*****	0.002	**-0.034****	0.040
Labour dummy X_6	0.925	0.429	**-1.294*****	0.000
Training dummy X_7	1.043	0.792	0.009	0.649
Distance dummy X_8	**-1.503****	0.040	**-1.002****	0.024
Market demand dummy X_9	**-0.294***	0.063	**-0.139*****	0.001
Market place dummy X_{10}	0.043	0.673	0.943	0.709
N	90		120	
R^2	0.592		0.682	
F value	17.850^{**}		27.042^{**}	

'***', '**' and '*' denote 1%, 5% and 10% level of significance

It is clear that in case of banana (Table 11) and litchi (Table 13), the variables like transportation dummy, distance dummy and market demand dummy were negatively significant which indicate that with the increase of transportation facilities and market demand, postharvest loss will decrease. Again, if the distance from farm to market is favourable to the farmer, postharvest loss will also decrease.

In case of pineapple (Table11) the variables like weather dummy, transportation dummy, labour dummy, distance dummy and market demand dummy were negatively significant which indicate that with the increase of transportation facilities, labour availabilities and market demand, postharvest loss will decrease. If the weather and distance from farm to market is favourable to the farmer, postharvest loss will decrease. Total production had positive and significant relationship with total postharvest losses which indicates that, with the increase of production of pineapple, postharvest loss will increase.

Table 12. Estimated values of coefficients and related statistics of multiple linear regression model for postharvest losses of orange and mango at farmers level

Explanatory variables	Orange		Mango	
	Coefficients	P-value	Coefficients	P-value
Intercept	-6.750***	0.000	0.642**	0.023
Age of the farmer (years) X_1	1.250	0.430	0.239	0.234
Education (Schooling years) X_2	0.893	0.690	0.094	0.109
Total production (M.ton) X_3	**7.843***	0.070	**8.034****	0.042
Weather dummy X_4	-2.095	1.007	1.027	0.639
Transportation dummy X_5	**-0.043****	0.045	**-0.039*****	0.003
Labour dummy X_6	**-0.375****	0.050	**-0.005***	0.067
Training dummy X_7	0.008	0.200	1.752	0.920
Distance dummy X_8	0.002	0.870	-0.829	0.439
Market demand dummy X_9	**-1.039*****	0.005	**-0.052****	0.042
Market place dummy X_{10}	0.007	1.002	2.701	0.597
N	90		180	
R^2	0.592		0.790	
F value	17.850**		20.430**	

'***', '**' and '*' denote 1%, 5% and 10% level of significance

In case of orange and mango (Table 12) and jackfruit (Table 13), the variables like transportation dummy, labour dummy and market demand dummy were negatively significant which indicate that with the increase of transportation facilities, labour availabilities and market demand, postharvest loss will decrease. Total production had positive and significant relationship with total postharvest losses which indicates that, with the increase of production of fruits like mango, orange and jackfruit, postharvest loss will increase.

It is interesting to note that, transportation dummy and market demand dummy were negatively significant for all fruits in all locations. If these facilities like transportation, market demand and labour availability can be increased, postharvest loss will decrease at the study areas. Scarcity in storage and transportation infrastructure resulted in 25-40 percent postharvest losses that shrinks supply and put pressure on prices.

Table13. Estimated values of coefficients and related statistics of multiple linear regression model for postharvest losses of litchi and jackfruit at farmers' level.

Explanatory variables	Litchi		Jackfruit	
	Coefficients	P-value	Coefficients	P-value
Intercept	15.228***	0.001	3.019**	0.053
Age of the farmer (years) X_1	-0.780	0.901	0.872	0.672
Education (Schooling years) X_2	0.815	0.875	-0.734	0.220
Total production (M. ton) X_3	0.058	0.632	9.073	0.782
Weather dummy X_4	-0.728	0.557	1.792	0.900
Transportation dummy X_5	**-0.543****	0.053	**-0.472*****	0.001
Labour dummy X_6	0.039	0.542	**-0.927***	0.067
Training dummy X_7	0.495	0.352	0.027	0.697
Distance dummy X_8	**-0.870****	0.030	0.407	0.824
Market demand dummy X_9	**-0.156***	0.073	**-0.039****	0.043
Market place dummy X_{10}	0.782	0.791	0.053	0.789
N	210		210	
R^2	0.751		0.692	
F value	22.032***		32.029**	

'***', '**' and '*' denote 1%, 5% and 10% level of significance

4. Summary

At farmers and traders level, the total postharvest loss of banana, pineapple, orange, mango, litchi and jackfruit were 372, 274, 200, 243, 165, and 380 kg/mt which was accounted about 37%, 27%, 20%, 24%, 17% and 38% of total yield respectively. The main Postharvest losses were incurred due to severe attack of insect and severe attack of bat, squirrel and monkey for farmers. For traders, major loss was incurred during transportation. On the basis of retail price, the total economic loss was estimated as Tk. 2341.66 crore and the maximum loss was incurred for banana (Tk. 705.79 crore) followed by pineapple (Tk. 550.58 crore) and mango (Tk. 508.95 crore) and the lowest for orange (Tk. 1.12 crore). It is interesting to note that, transportation dummy and market demand dummy were negatively significant for all fruits in all locations. If these facilities like transportation, market demand and labour availability can be increased, postharvest loss will be decreased to an acceptable level at the study areas. Lack of technical knowledge about Postharvest activities, severe attacks of insect and pest, attacks by bat, squirrel, monkey, storage facilities, transportation facilities, lack of agro processing industries and low prices were identified as the major constraints in the hill areas of Bangladesh.

5. Recommendations

The following policies/suggestions should be implemented which deserves immediate attention for reducing the existing postharvest loss of major fruits in hill regions of Bangladesh:

- An appropriate training programme on different postharvest activities like handling, grading, packaging, carrying etc. should be provided with a view to increasing the efficiency as well as awareness of the farmers and traders.
- Storage facilities should be established in hilly areas to ensure fair price of their product. Private entrepreneur should come forward to establish storage facilities at the important fruit concentrated areas and different wholesale and retail markets. Facilities should be developed for one to two days reservation for unsold fruits at market place.
- Transportation and communication system should be developed through constructing of different feeder road. Low cost quick transportation facilities will ensure to carry fruits from farmyard to local market place or in distant bigger market for the farmers and intermediaries where they are likely to get better price for their products.

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EFFECT OF LIGHT QUALITY AND PLANT GROWTH REGULATOR ON ORGANOGENESIS OF ORKID *Cymbidium dayanum*

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Keywords: Chitosan, hyaluronic acid, polysaccharide, protocorm-like body, tissue culture

Orchids include some of the world's most important floricultural (cut-flower) and ornamental (pot and garden) plants (Teixeira da Silva, 2013). *Cymbidium dayanum* is important evergreen, epiphytic orchid which is valued for their attractive flowers. This species that is quite widespread from Northern India right through to Japan and is one of the most sought after ornamentals in local cut flower market. In recent years, the population of *C. dayanum* has declined rapidly due to unregulated heavy collection, excessive habitat destruction and deforestation. *C. dayanum* had been declared as vulnerable and threatened orchid in Red Data Book (Nayar and Sastry, 1990). There is an increasing risk of this important orchid becoming extinct from its natural habitat if uncontrolled exploitation continues unabated (Nongdam and Chongtham, 2012). Effective conservation strategies should be devised to prevent further loss of the already depleted of this orchid population. The *in vitro* approach through the application of plant tissue culture technology provides an excellent opportunity for effective conservation by mass propagating orchids in short time span. Though there are several reports on tissue culture of different orchids, the micropropagation of *C. dayanum* has been very less documented in the literature.

Light is one of the basic factors needed by plant for its development. Tissue culture and growth rooms have long been using artificial light sources, including fluorescent lamps, high pressure sodium lamps, metal halide lamps, and incandescent lamps, etc. Among these, fluorescent lamps have been the most popular in tissue culture rooms (Economou and Read, 1987). In recent years, light emitting diodes (LEDs) have been proposed as a primary light source for space-based plant research chambers or bioregenerative life-support systems, and a potential alternative light source for *in vitro* plant growth and development (Bula *et al*., 1991; Yeh and Chung, 2009). Ki-Ho Son and Myung-Min (2013) reported that, LEDs have some advantages over traditional lighting sources in plant cultivation due to high light-conversion efficiency with low radiant heat output, have variety of narrow wavebands would be possible to optimize light quality to improve both crop yield and quality.

Plant growth regulator is indispensable material in culture media, and is important to the plant tissue induction, organ differentiation and growth. The use of elicitors in crop protection and pest management is still in the very early stages

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of use as a new control method (Thakur and Singh, 2013). Plants treated with elicitors develop a general resistance. Chitosan and hyaluronic acid is well known elicitors; chitosan, obtained primarily from the exoskeleton of crustaceans, but also found in cuticles of insects as in the cell walls of fungi and some algae, is one of the most common polymers that could be found. Chitosan has had a strongly positive effect on many growth responses in a number of plants, including orchids (Kaewjampa *et al*., 2010; Nahar *et al*., 2011; Teixeira da Silva, 2013) the mechanism of action remains unknown. Hyaluronic acid (HA), composed of glucuronic acid and N-acetyl glucosamine joined alternately by β-1-3 and β-1-4 glycosidic bonds, has biological functions in lower and higher organisms, including in cell adhesion, migration, proliferation and differentiation, regulation of protein secration and gene expression (reviewed by Fraser *et al*., 1997). HA suppresses disease in cucumber, tomato and pepper (Park *et al*., 2008) and has shown to have antioxidant activity. HA have of recent been suggested as important components of *Cymbidium in vitro* culture media (Nahar *et al*., 2011, 2012; Nahar and Shimasaki, 2014; Kaewjampa *et al*., 2012). Therefore, the objective of this study was to investigate the effect of light quality and plant growth regulator on organogenesis of *C. dayanum in vitro*.

Protocorm-like bodies (PLBs) of *Cymbidium dayanum* were collected from local orchid growers. PLBs of *C. dayanum* were proliferated in the modified MS medium (Shimasaki and Uemoto, 1990) by transferring to a new medium every two months. After excision of PLB (appox. 5 mm in diameter) into pieces, they were used for explants. The experiment was conducted at the Lab. of Vegetables and Floriculture Science, Faculty of Agriculture, Kochi University, Japan from May, 2013 to June, 2013 (five weeks). MS medium with 412.5 mg l^{-1} ammonium nitrate, 950 mg l^{-1} potassium nitrate, 20 g l^{-1} sucrose, and 2 g l^{-1} Phytagel (Sigma) was adjusted to pH 5.5- 5.8 before autoclaving. Plant growth regulators (PGRs) like chitosan (Chitosan H- Kimica Co., Japan) and hyaluronic acid (HA9- Shiseido, Japan) were added to culture media at different concentrations (control, 0.1 and 1 mg l^{-1},) before sterilization to ascertain the growth response of the culture. Jars of 250 ml (UM culture bottle, As one, Japan) with plastic caps were used, each bottle receiving 30 ml of medium. The experiment was performed by taking 15 replicates for each treatment. Five explants were placed in each culture vessel and three culture vessels were used for each treatment.

The cultures of *in vitro* plantlets were illuminated using different light conditions of photon flux density (PFD) of 50 µmole m^{-2} s^{-1} . Three sources of light were used: red LED (Jefcom, P18W-E1701-R, peak wavelength: 640 nm), blue LED (Jefcom, P18W-E1701-B, peak wavelength: 450 nm) and green LED (Jefcom, P18W-E1701-G, peak wavelength: 510 nm). The plantlets were exposed to a 16 h photoperiod for 5 weeks. Experimental data were collected after 5 weeks of culture by counting the average number of PLBs, shoots and roots; percentage of PLB, shoot and root and the fresh weight of PLBs were measured. The average and percentage was derived by using the formula given below: Average number of PLB: number of PLB/one PLB explants

$$\text{Percentage of formation} = \frac{\text{Number of culture explants with new PLB/ shoot}}{\text{Total number of culture explant}} \times 100$$

The data were statistically analyzed by calculating standard errors of the means (means ± SE) and significant differences assessed by Tukey HSD test ($P \leq 0.05$).

The growth and development of protocorm-like bodies (PLBs) of *C. dayanum* were affected under different sources of lights. Addition of hyaluronic acid and chitosan with modified MS media, PGRs enhanced the better formation of PLBs, shoot and root within short duration of culture periods. The significance different observed under blue and green LED by hyaluronic acid (HA9) and chitosan (Chitosan H) treatments. The highest formation of PLB (93%) and shoot (53%) were observed that the PLBs cultured at 1 mg/l HA9 with modified MS medium under blue LED (Table 1) while 1 mg/l chitosan promoted 80% PLB formation under red LED and green LED (Table 2 & 3). The average number of PLB (5.6 PLBs/explant) and shoot (1.5 shoots/explant) were significantly increased under blue LED with 1 mg/l HA9 treatment (Table 1). Meanwhile the lowest number of PLB (0.9 PLBs/explants) and shoot (0.3 shoots/explants) were grown under green LED at control (Table 3). The root formation and the fresh weight (FW) of PLBs were recorded. The maximum fresh weight of PLBs (101.1 mg) and the highest root formation (40%) were observed under red LED with 1 mg/l chitosan treatment (Table 2).

Table 1. Effect of different concentrations (control, 0.1 and 1 mg/l) of chitosan (Chi H) and hyaluronic acid (HA) with modified MS medium on protocorm-like bodies (PLBs) of *C. dayanum* under blue LED

Treatment (mg/l)	PLB			Shoot		Root	
	No./explant	Rate (%)	FW (mg)	No./explant	Rate (%)	No./explant	Rate (%)
Control	2.7 ± 1.0b	60	51.4 ± 7.4ab	0.2 ± 0.2b	20	0.2 ± 0.2	20
Chi H 0.1	1.4 ± 1.0ab	33	37.8 ± 11.3b	0.5 ± 0.5b	27	0.2 ± 0.2	20
Chi H 1	2.1 ± 1.0a	53	46.6 ± 6.4ab	0.3 ± 0.3b	20	0.2 ± 0.2	20
HA 0.1	2.0 ± 0.6ab	67	52.1 ± 11.7ab	0.5 ± 0.5b	27	0.3 ± 0.3	27
HA 1	5.6 ± 1.3ab	93	87.5 ± 19.5a	1.5 ± 0.7a	53	0.4 ± 0.3	33

The data were statistically analyzed by calculating standard errors of the means (means ± SE) and different letters show significant differences by Tukey HSD test ($P \leq 0.05$). Fresh weight= FW.

Table 2: Effect of different concentrations (control, 0.1 and 1 mg/l) of chitosan (Chi H) and hyaluronic acid (HA) with modified MS medium on protocorm-like bodies (PLBs) of *C. dayanum* under red LED

Treatment (mg/l)		PLB		Shoot		Root	
	No./explant	Rate (%)	FW(mg)	No./explant	Rate (%)	No./explant	Rate (%)
Control	3.3 ± 1.1	67	79.0 ± 12.9a	0.4 ± 0.2	40	0.2 ± 0.2	20
Chi H 0.1	3.9 ± 2.2	47	67.7 ± 14.2a	0.5 ± 0.5	27	0.3 ± 0.3	20
Chi H 1	5.3 ± 1.7	80	101.1 ± 13.9a	0.6 ± 0.3	47	0.6 ± 0.3	40
HA 0.1	3.0 ± 1.1	67	62.4 ± 12.5a	0.5 ± 0.4	33	0.3 ± 0.3	20
HA 1	3.6 ± 1.2	73	66.6 ± 10.5a	0.5 ± 0.4	33	0.3 ± 0.4	20

The data were statistically analyzed by calculating standard errors of the means (means ± SE) and different letters show significant differences by Tukey HSD test (P≤0.05). Fresh weight= FW.

Table 3. Effect of different concentrations (control, 0.1 and 1 mg/l) of chitosan (Chi H) and hyaluronic acid (HA) with modified MS medium on protocorm-like bodies (PLBs) of *C. dayanum* under green LED

Treatment (mg/l)	PLB			Shoot		Root	
	No./explant	Rate (%)	FW(mg)	No./explant	Rate (%)	No./explant	Rate (%)
Control	0.9 ± 0.6ab	33	38.9 ± 6.5	0.3 ± 0.2	33	0.3 ± 0.2	27
Chi H 0.1	1.9 ± 1.4ab	33	43.1 ± 10.7	0.5 ± 0.5	27	0.2 ± 0.4	13
Chi H 1	5.3 ± 1.7a	80	65.7 ± 8.9	0.7 ± 0.4	40	0	0
HA 0.1	3.7 ± 1.5b	53	53.5 ± 12.0	0.4 ± 0.6	20	0	0
HA 1	2.9 ± 1.4b	53	73.6 ± 15.0	0.7 ± 0.5	40	0.4 ± 0.4	27

The data were statistically analyzed by calculating standard errors of the means (means ± SE) and different letters show significant differences by Tukey HSD test (P≤0.05). Fresh weight= FW.

Light directly influences plant growth and flowering by inducing photosynthesis and feeding plants energy. Plants are dependent on light to generate food, induce the growing cycle and allow for healthy development. LEDs began to be investigated for germinating seeds and rooting cuttings in the Netherlands (Nijssen *et al*., 1990) and for tissue culture systems in Japan (Miyashita *et al*., 1995). Initial studies included only red LEDs because they were the most efficient and emit light that coincides with the maximum absorption of chlorophyll (660 nm). However, it quickly became apparent that some blue light was necessary for normal growth and development of soybean, wheat, lettuce (Dougher and Bugbee, 2001; Yorio *et al*., 2001) spinach, and radish (Yorio *et al*., 2001). This study showed the results that blue LEDs had good effects on new PLBs and shoot formation; the root formation and fresh weight became higher under red LED. Sultana *et al.* (2014) reported that blue and red LED plays an important role in stimulating PLBs and shoot formation of *Dendrobium* *kingianum*; our results agree with these previous findings and additionally show that blue LEDs are more efficient to induce new PLB and shoot of *Cymbidium dayanum* (Fig.1). To increase the efficiency of *in vitro* techniques, plant growth regulators are frequently used for orchids (Shimasaki and Uemoto, 1990; Teixeira da Silva, 2014). *Cymbidium* is rapidly turning into a model orchid, if not a model plant, at least for *in vitro* studies due to the fine scale nature of experiments conducted on this genus (Teixeira da Silva, 2014). LEDs lights are suitable and new technology for the culture of plants in a tightly controlled environment such as space based plant culture systems. Additionally, chitosan and HA added with culture medium helps to induce new PLBs and shoot in *Cymbidium dayanum* within short duration of culture *in vitro*. The present study revealed that these newly developed light sources will be protect *Cymbidium dayanum* from extinction.

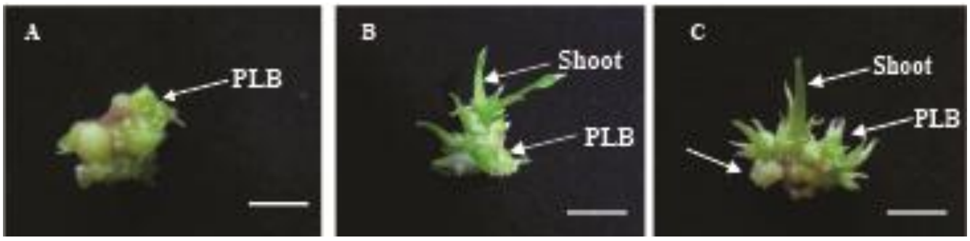

Fig 1. Effect of hyaluronic acid and chitosan on organogenesis of *Cymbidium dayanum* under three LED lights. A: Control (Green LED); B: 1 mg/l HA9 (Blue LED); C: 1 mg/l chitosan (Red LED); Bar = 10 mm.

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Bangladesh J. Agril. Res. 42(1): 191-196, March 2017 **Short Communication**

THE ECONOMIC BENEFIT OF AGARWOOD PRODUCTION THROUGH AERATION METHOD INTO THE *Aquilaria malaccensis* TREE IN BANGLADESH

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Keywords: Agarwood, usage, aeration technique, benefit-cost ratio

Agarwood is a precious incense substance which is extremely rare. This fragrant wood is only formed in *Aquilaria* and *Gyrinops* species under family the Thymelaeaceae (Blanchette, 2006). It is a diseased tissues located in the heartwood which is a resultant substance of plant defense against outside attacks and impacts, such as (i) naturally pathological infection (insects, fungi, bacteria etc), (ii) mechanical injury (impacted by human being or outer factors), (iii) wounding and pathological infection (artificial inducement), and (iv) floristic composition of vegetational cover (companion plants, insects) (Ba, 2010). To preserve these wounds, initially, plant secretes a brown color oleoresin to the injured place. With the passage of time, it becomes dense and dark in color. The more resin deposit, the more quality ensure and the precious wood would be formed. It has been using for 3000 years in the China, Japan, India, and especially in Arabian countries (Le, 2003) and known by many names depending on place and cultures such as Agar (Bangladesh, India), Aguru (Sanskrit), Oud (Arabic), Eagle/Agilawood (Europe) (Akter *et al*., 2013).

Agarwood has been used for medicinal purposes for thousands of years, and still using in Ayurvedic, Tibetan and traditional East Asian medicine (Chakrabarty *et al*., 1994), aromatherapy (LaFrankie, 1994), pharmaceutical tinctures (Van Beek & Phillips, 1999), asthma, rheumatism and other body pain treatment (Hajar, 2013). Many religious groups use it as a meditation incense to calm the mind and spirit. It is also the main ingredient of perfumery as well as cosmetic industry (Chaudhari, 1993). In the Middle East, both agarwood smoke and oil are customarily used as perfume (Chakrabarty *et al*., 1994).

International agarwood market has a terrible experience of price fluctuation. By 1970s, it was sold up to $42.5 and then raised straightly $1250 and $2500 per kg in 2000 and 2005, respectively (Abdin, 2014). First-grade agarwood is one of the most expensive natural raw materials in the world. Singapore trades agarwood $1.2 billion alone each year (Hansen, 2000). The trading value of pure agar oil is $30,000 to 40,000 per kilogram (Abdin, 2014). Based on resin presence, agarwood chips sell from $30 to $10,000 per kilogram (Babatunde, 2015). Akter *et al.,* (2013) reported that in the year of 2013, the global market for agar oil and

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other agarwood related products was estimated in the range of $6 to 8 billion and the major agar oil industrial buyer expects to exceed it up to $36 billion in 2017 (http://www.ouddh. com/?cid =2065877).

Natural agarwood formation is difficult and harvesting wood from those trees causes greatly to the near-extinction of natural stands of trees (Blanchette, 2006). In the context of Bangladesh, agar trees are being cultivated in many places on a large scale but the agarwood farmers are failed to get the proper profit because of their unfamiliarity with the proper and scientific inoculation methods. They are used to practice the nailing method which is time-consuming and yield is very poor. Aeration method might be a suitable solution for this problem as it is easy to inoculate, inoculation materials are locally available, comparatively low cost and as long as the wound remains open to the air, agarwood will increasingly accumulate. Keeping the above facts in view, the objective is to evaluate the economic benefit of agarwood cultivation through aeration technique into agar trees.

The experiment was performed at Birisiri, Durgapur Upazila of Netrakona district, Bangladesh during 10th March 2013 to 30th May 2014. Geographically it is located in 25°10" N latitude and 90°44" E longitude at an elevation of 42 m above the sea level. The site falls under both the Agro-ecological Zone 9 and 22 (UNDP & FAO, 1990). Three Aquilaria malaccensis trees were selected for artificial inducement at Birisiri natural agar garden. The trees were selected on the basis of age and trunk diameter. All trees were 8-9 years old and trunk diameters were between 15-19 cm.

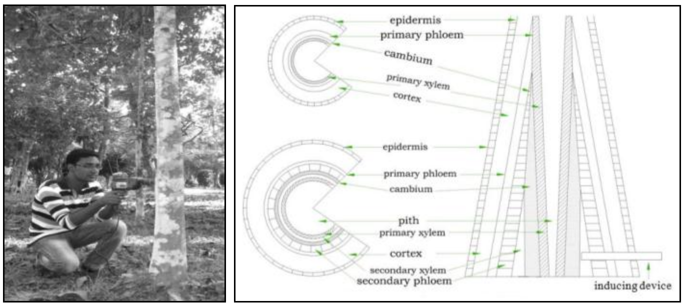

Fig. 1. Photographic and cross-sectional view of wounding.

Selected trees were wounded by making 7/8" drilled hole up to the xylem to a depth of approximately 5.0 cm using electric driller. Wounds were made in a spiral shape separated by 15 cm from each other. Drilling was started from the bottom of the tree trunk and ended at the tree branching point. All wounds were slightly sloped down wherein rainwater could not stand. 15 cm long and 2 cm dia Plastic tubes were inserted into the wounds. The tubes were kept extended 10 cm from the outer surface so that the holes could not be closed for many years and a periodic re-wounding facilitates air availability into the inner wounded xylem. Finally, 5g+5g+15g=20g sodium bisulfite, Difco yeast extract, and iron powder, respectively were inserted each tube at a ratio 1:1:3. All inserted tubes were rotated in a 2-month interval.

After 15 months of artificial inducement three trees were harvested and brought to the workshop of farm Power and Machinery department, BAU for analysis. The resin formatted areas were separated by splitting the trees through the wounded region and weighted.

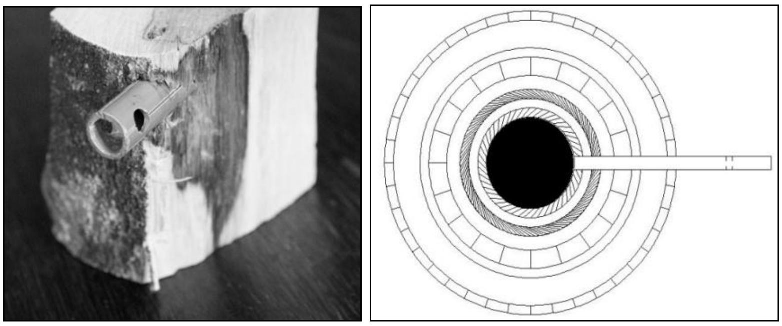

Fig. 2. Photographic and cross-sectional view of harvested tree block.

Table 1. Cost involvement in different growing stages (Based on Ahmed, 2010)

Head of Expenditure	Unit of cost	Cost			
		1st year	**2nd** year	**3rd** year	**4th to 9th** year
Seedling	BDT/seedling	10	-	-	-
Pit making and transplant (labour)	BDT/tree	5	-	-	-
Bamboo stick	BDT/ tree	5	5	-	_
Cow dung	BDT/pit	5	5	5	-
Urea	BDT/pit	-	4.67	7.05	11.40
TSP	BDT/pit	-	12.43	18.74	31.2
MOP	BDT/pit	-	1.76	2.65	4.40
DAP	BDT/pit	-	4.91	7.42	4.0
Irrigation and fertilizer	BDT/tree	5	-	-	-
Inoculation (materials)	BDT/tree	-	-	-	300
Inoculation (labour)					300
After care	BDT/ year	5	5	5	10
Land use up to 15 years	BDT/tree	15	-	-	-
Interest on operating capital (up to 15 years)	BDT/tree	105	-	-	-
Total Expenditure	BDT/tree	155	38.77	45.86	661
Total Expenditure **up** to **9th** year	BDT/tree	**BDT 900.63 ~ US$12**			

BDT=Tk. (Bangladesh); US$=American dollar

Each tree had 45 holes. Each hole was filled up with sodium bisulfate, yeast extract and iron powder @ 5g : 5g : 15g at 1:1:3 ratio. The total inoculation expenditure was $35 per tree (Table 2)

The total expenditure for one agar tree cultivation up to 10 years was US$ 12 (Table 1) and the inoculation expenditure was US$35 (Table 2).

Table 2. Cost involvement in inoculation stage

Expenditure	Unit of cost (Tk./Kg)	Amount per hole	Cost (BDT)
Sodium bisulfate	1200[a]	5g	6
Yeast extract	3000[b]	5g	15
Iron powder	1200[b]	15g	18
Plastic pipe	20[b]	15 cm	20
Total Expenditure	BDT per hole		59
Total cost for **45** holes	BDT per tree		BDT 2655 ~ US$35

[a] Bdbazar24.com, [b] Local market price; US$= Tk. 75.86.

Agarwood formation is a result of resin synthesis in the xylem tissues of *Aquilaria* plant. This resin is a chemical substance which consists of aromatic, sesquiterpenes, fatty acids, chromones, phenolic and specially 3-phenyl-2-butanone and alpha-cubebene (Naef, 2011; Hashim *et al*., 2014). Artificial agarwood or agar oil formation is quite impossible as it is a composition of numerous volatile and semi-volatile compounds. However, the chemical composition of cultivated agarwood is almost similar with naturally inoculated agarwood (Espinoza *et al*., 2014).

Cost involvement in different processing stages i.e. nursing of tree (up to 10 year), carrying, logging, chipping, collection of inoculants and establishment were 500, 50, 50, 100, 100 and 50 BDT per tree, respectively. So the total expenditure of agarwood processing was BDT 850 ~ US$ 11 per tree. Grand total expenditure of agar wood harvesting = Total cultivation expenditure + total inoculation expenditure + total processing expenditure = US$(12+35+11) per tree = US$ 58 per tree (Tk. 4399.88).

Each tree gave yield around 55-75 kg of useful wood which can be graded as fresh, semi-resinous and resinous woods. The value of wood in the international market ranges from a few dollars a kilogram for the lowest quality to over thousands of dollars for the top quality (Table 3).

Table 3. Gross return estimation from a ten years old agar tree

Types of wood	Usage	Unit of price (Tk./Kg)	Amount of wood (Kg/tree)	Gross return (Tk./tree)
Fresh wood	Cooking	9.86[a]	50	379.3
Semi-resinous wood	Incense stick	379.3[b]	17	6448.1
Resinous wood	agarwood	682744	0.5	34137
			Total	40964.4

[a] local market price, [b] alibaba.com, 1 US$ = Tk. 75.86

Net return was calculated as the difference between gross return and gross cost as follows:

Net return = Gross return - Gross cost = Tk. (40964.4 - 4399.88) = Tk. 36564.52.

Benefit-cost ratio (BCR) is the ratio of gross return divided by gross cost. In this experiment, BCR was 40964.4/4399.88 = 9.31 per tree where BCR from cash crop like High Yielding Variety (HYV) Boro, HYV Aman, Wheat, HYV Maize, Jute, Lentil and fruit like banana are 1.14-1.28, 1.10-1.23, 1.12-1.27, 1.21-2.85, 1.17-1.24, 1.18-1.21 and 3.69, respectively (Rahman *et al*., 2013; Kamal *et al*., 2015; Rahman *et al*., 2016). Though agar tree takes 10/11 years for giving yield which is 10/11 folds of any cereal crop, total profit included intercropping in agarwood cultivation will be higher than any other crops.

Let, the total number of trees is 1500. At the 8/9th year, we may harvest about 40% (600 Nos.) of the total with a view to thinning out the tree population for further growth and development of remaining 900 trees along with to generate an interim income. The final harvesting would be done at the 13-15th year. Each year after 10th, yield and income from an inoculated agar tree will increase gradually.

Based on the cost-effective assessment, it could be concluded that agarwood production using aeration method would be more economically profitable for the rural agar tree growers rather than other agricultural crops in Bangladesh. From this experiment, obtained agarwood (resinous) was 0.5 kg from a 10 years old agar tree. The gross expenditure, gross return, and benefit-cost ratio (BCR) were Tk. 4399.88, Tk. 40964.4 and 9.31 per tree, respectively. Depending on BCR analysis, it was clearly seen that agarwood production is highly profitable which could change the economic condition of the agarwood growers. There is a need to boost up its production and to identify the weak points for increasing the returns.

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