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INFLUENCE OF PLANT GROWTH REGULATORS ON VEGETATIVE GROWTH, SEX EXPRESSION AND YIELD OF SUMMER BOTTLE GOURD

M. MONIRUZZAMAN¹, R. KHATOON², M. MONIRUZZAMAN³
AND A. K. M. QAMRUZZAMAN⁴

Abstract

Field experiments on bottle gourd variety 'BARI Lau -4' were conducted at the Plant Physiology field of Horticulture Research Center, Bangladesh Agricultural Research Institute, Gazipur during two consecutive summer seasons of 2015 and 2016 to investigate the effect of plant growth regulators on growth, sex expression, yield and yield components of the crop. The experiment consisted of different concentrations of Gibberellic acid (GA₃), Naphthalene acetic acid (NAA), Maleic hydrazide (MH) and single concentration of cycocel (CCC) viz., GA₃ @ 10 ppm, GA₃ @ 30 ppm, NAA @ 100 ppm, NAA @ 150 ppm, MH @ 50 ppm, MH @ 150 ppm and CCC @ 500 ppm along with distilled water considered as control. All growth regulators were sprayed to the seedlings at two-leaf stage and 4 days after the first spray. Growth regulator treatments had significant effect on primary branches/plant, node number of 1st male and female flower appearance, number of days to 1st male and female flower appearance, number of male and female flowers, sex ratio (male:female flower) number of fruits/plant, individual fruit weight and fruit yield. Spraying of MH @ 150 ppm gave the highest primary branches/plant (17.0 and 18.0 in first and 2nd year, respectively) and induced maximum female flowers (37.3 and 40.0 in first and 2nd year, respectively) at lower nodes followed by CCC @ 500 ppm (36.3) in the first year and MH @ 50 ppm (40.0) in the 2nd year. Application of MH @ 150 ppm caused early appearance of female flowers on the nearest node (from bottom). Application of MH @ 150 ppm gave the lower number of male flowers (81.7 and 96.0 in first and 2nd year, respectively) and the highest number of female flowers/plant, thereby producing lower male:female sex ratio (2.2 and 2.5 in first and 2nd year, respectively) and the maximum number of fruits/plant (12.0 and 14.0 in first and 2nd year, respectively). The maximum fruit weight/plant was obtained from the application of MH @ 150 ppm (29.3 and 35.8 in first and 2nd year, respectively) followed by CCC @ 500 ppm (26.0 in the 1st year and 29.0 in 2nd year). The highest fruit yield per hectare was recorded significantly with the application of MH @ 150 ppm (97.6 t/ha and 89.6 t/ha in first and 2nd year, respectively) closely followed by CCC @ 500 ppm (88.5 t/ha in 2015) and GA₃ @ 30 ppm (75.3 t/ha in 2016), as compared to

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other treatments. The highest mean yield over the years was also recorded at MH @ 150 ppm (93.6 t/ha) followed by CCC @ 150 ppm (80.6 t/ha) and GA₃ 30 (74.1). Application of MH @ 150 ppm gave the maximum gross return and net return with the highest BCR of 5.24 followed by CCC 500 ppm (4.15) and GA₃ 30 ppm (3.86).

Keywords: Growth regulators, sex expression, fruit yield, summer bottle gourd.

Introduction

Bottle gourd [*Lagenaria siceraria* (Molina) Standley] locally known as 'Lau' or 'Kadu', is one of the important and popular vegetables of the family *Cucurbitaceae*, extensively grown throughout Bangladesh. Fruits at tender stage are used as a cooked vegetable and for preparation of sweets (e.g. *kheer*, *petha*, *burfi* and *halwa*), pickles and rayta. Hard shells of mature fruits are used as water jugs, domestic utensils, floats for fishing nets and making musical instruments, etc. As a vegetable it is easily digestible. It has cooling effect and has diuretic and having cardio-tonic properties. Fruit pulp is used as an antidote against certain poisons and is good for controlling constipation, night blindness and cough. It is especially recommended in the diet of patients suffering from high blood pressure. The composition of immature fruits of bottle gourd per 100 g of fresh edible portion consists of water 93.9 g, energy 88 kJ (21 kcal), protein 0.5 g, fat 0.1 g, carbohydrate 5.2 g, fiber 0.6 g, Ca 44 mg, P 34 mg, Fe 2.4 mg, β -carotene 25 μ g, thiamin 0.03 mg, niacin 1.2 mg, ascorbic acid 10 mg (Leghari *et al.*, 2014).

The growth and yield of cultivated crop plants is mainly influenced by genetic and crop management factors; first factor involves in various breeding techniques while second factor involves cultural operation, plant protection and other agronomic practices, both these factors have been fully exploited by researchers. In recent years, scientists have given attention to the idea of regulating plant growth as third most important factor in improving growth and yield. It helps in efficient utilization of metabolites in certain physiological processes going in plant system (Krisnamurthy, 2011).

Bangladesh Agricultural Research Institute (BARI) has developed five bottle gourd varieties for cultivation in both winter and summer seasons. The variety 'BARI Lau-4' is recommended for cultivation in both winter and summer season. In summer season, the yield of bottle gourd is low. Besides many other reasons for low yield of bottle gourd, there is one acute problem of fewer female flowers and high sex ratio (male:female) during summer. In cucurbitaceous plants, sex expression is determined by gene as well as the environment. Huyskens *et al.* (1992) reported that significantly more male flowers were produced during summer, under long days and high temperature, than in winter, under short days and low temperature condition. Plant growth regulators (PGRs) such as Gibberellic acid (GA₃), Naphthalene acetic acid (NAA), Maleic hydrazide (MH), Cycocel (CCC), etc. are found beneficial for induction of female flowers and reduction of male flowers in summer bottle gourd and sex expression can also be

controlled by using different growth regulators (Kooner *et al.*, 2000; Rahman and Karim, 1997; Hidayatullah *et al.*, 2012; Gaurav *et al.*, 2008 and Kumar *et al.*, 2000). Very little information is available on the effect of growth regulators on sex expression and yield of bottle gourd in Bangladesh. Therefore, this investigation was carried out to assess the effect of PGRs (GA₃, NAA, MH and CCC) on vegetative growth and to narrow the sex ratio by increasing female flowers side by side, decreasing male flowers per plant for yield improvement of bottle gourd in summer.

Materials and Methods

The experiment was conducted at the Plant Physiology field of HRC, BARI, Gazipur during two consecutive summer seasons of 2015 and 2016. The variety 'BARI Lau-4' was used in this experiment. The experiment consisted of eight treatments *viz.*, T₀ = control (distilled water), T₁ = GA₃ @ 10 ppm, T₂ = GA₃ @ 30 ppm, T₃ = NAA @ 100 ppm, T₄ = NAA @ 150 ppm, T₅ = MH @ 50 ppm, T₆ = MH @ 150 ppm and T₇ = CCC @ 500 ppm. The sources of GA₃ and CCC were Isha, Chemical Pvt. Ltd. (India), and those of MH and NAA were BDH Chemicals Ltd. (England) and SD Fine Chemicals Ltd. (Mumbai, India), respectively. All chemicals were Laboratory Grade.

250 mg of gibberellic acid was accurately weighed out using sensitive electronic balance and dissolved in a few ml of alcohol (95%). The solution thus prepared was transferred to 250 ml volumetric flask containing distilled water. The volume of the solution was made upto 250 ml to get the 1000 ppm stock solution. NAA stock solution (1000 ppm) was prepared by dissolving 500 mg NAA powder in 500 ml of distilled water. 500 mg NAA powder was accurately weighed out and dissolved by keeping it in a 500 ml volumetric flask and by adding 1 N NaOH solution drop by drop till the powder was completely dissolved. The volume was adjusted to 500 ml with distilled water in a volumetric flask. Thus the stock solution was prepared. 500 mg MH was accurately weighed out using sensitive electronic balance and dissolved in a few ml of 1 N NaOH. 100 ml of distilled water was added in a 500 ml volumetric flask. The solution was then adjusted to 500 ml by adding distilled water. This gives 1000 ppm stock solution. 2 ml (50% ai) of CCC was taken by 10 ml pipette and dissolved in distilled water by adding-shaking method. The volume was adjusted to 1000 ml with distilled water in a volumetric flask to obtain a stock solution of 1000 ppm. Finally, the required lower concentrations of GA₃ (10 and 30 ppm), NAA (100 and 150 ppm), MH (50 and 150 ppm) and CCC (500 ppm) were prepared from their stock solutions by using the formula: $V_1 \times S_1 = V_2 \times S_2$; where. S₁: concentration of stock solution (1000 ppm) of the desired chemical (GA₃, NAA, MH or CCC), V₁ = volume of stock solution of desired chemical (what we have to calculate), S₂: concentration of desired chemical and V₂: amount of solution required for spray treatment-wise. Then calculated amount (V₁) of desired chemical was taken from stock solution and poured into a pot of known volume and then required amount

of water was added into this pot. Hand sprayer was used for spray of the chemicals.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. For raising seedlings sandy loam soil and well decomposed cowdung were thoroughly mixed in 1:1 ratio and then plastic pots were filled with this mixture. Seeds were placed in plastic pots on 01 March, 2015 and 11 February, 2016. Seeds were soaked in distilled water for 24 hours to facilitate germination. After final land preparation, pits were prepared by spade and size of each pit was 30 cm x 30 cm x 30 cm. One pit was made in the middle of each plot and one seedling was planted in that pit. Plot size was 2.0 m x 1.5 m and 2.0 m x 2.0 m in 2015 and 2016, respectively. Manure and fertilizers were applied as cow dung, N, P, K, S, B and Zn @ 10000, 80, 45, 88, 25, 1.8 and 4.5 kg/ha, respectively (Quamruzzaman *et al.*, 2015). Half of cow dung; full doses of S, Zn and B, and P and K @ 30 kg/ha each were applied during final land preparation. The rest half of cow dung and P and K @ 15 kg/ha was applied as basal in pit. Rest of N and K was applied in 4 equal installments at 20 days interval starting from 20 days after transplanting. Seventeen day- old seedlings were transplanted on 19 March 2015 and 01 March 2016. First spraying of plant growth regulators (PGRs) were done at the 2 true leaf stage on March 23, 2015 and 03 March, 2016. Second spraying of PGRs was done after 4 days of first spray. Control plants were sprayed with distilled water. Trellises made of bamboos and iron nets were used for the support of each plant individually. Plants were allowed to be grown individually and not be allowed to intermingle with other plants grown beside. Weeding and irrigation were done as required. When 1st flower was seen, it was tagged and each male and female flower was tagged separately throughout the growing period, and the number of male and female flowers was counted.

Data were recorded on main vine length, number of primary branches/plant, number of leaves/plant, CCI (Chlorophyll Content Index), Fv/Fm (efficiency of photosystem II), days to first male and female flowers, node order of first and female flowers (from the bottom), number of male and female flowers/plant, number of fruits/plant, individual fruit weight, fruit length, fruit circumference and yield/plot. Then plot yield was converted to per hectare yield. Data on CCI (Chlorophyll Content Index) was taken by Chlorophyll Content Meter (Model: CCM-200, Opti-sciences, USA). The leaf discs were previously adapted to the dark for 20 minutes. The fluorescence data (Fv/Fm) were collected at 70 days after sowing within 10.00 am to 12.00 pm. In the first year (2015), the fruit harvest started from 21 May and ended in 18 June; while, in the 2nd year (2016), fruit harvest started from 09 May and ended in 29 June. Each fruit was harvested after twelve days of anthesis. Thus every fruit was harvested by sharp knife 12 days after anthesis. A total of 7 and 8 harvests were required in 2015 and 2016, respectively. Recorded data were statistically analyzed by MSTAT-C and mean separation was done by Tukey's W test at 5% level of probability.

Results and Discussion

Vegetative growth of bottle gourd plants

Plant growth regulators had significant effect on number of primary branches/plant in both the years. The number of leaves/plant was significantly influenced by growth regulators in 2015 but insignificant effect on length of main vine in both years (Table 1). The maximum number of primary branches/plant was recorded in the plants treated with MH @ 150 ppm (17.0 and 18.0 in 2015 and 2016, respectively; mean 17.5) closely followed by CCC @ 500 ppm (15.0 in both 2015 and 2016; mean 15.0) and MH @ 50 ppm (13.0 in 2015 and 15.0 in 2016, mean 14.00) and GA₃ @ 30 ppm (12.0 in 2015 and 16.0 in 2016, mean 14.0) and its minimum number from control in both years (6.0 in 2015 and 8.0 in 2016; mean 7.0). Ansari and Choudhury (2014) obtained significantly higher number of branches in bottle gourd by the application of GA₃ (50-100 ppm) and MH @ 50 ppm. Sadiq *et al.* (1990) reported to have the highest number of branches per plant in cucumber while spraying with CCC @ 500 ppm at 4 leaf stage. In the first year, spraying of MH @ 150 ppm gave the maximum number of leaves/plant (343.0) which was identical with MH @ 50 ppm (337.0) and CCC @ 500 ppm (341.0). Number of leaves/plant did not vary significantly with PGR treatments in the 2nd year, but numerically the PGR treated plants produced more leaves than control. The highest mean number of leaves/plant (325.0) was recorded at both MH @ 150 ppm and CCC @ 500 ppm. The control treatment gave the minimum number of leaves/plant in both the years.

Table 1. Effect of plant growth regulators on vegetative growth of summer bottle gourd

Treatment	Main vine length (m)			Primary branches/plant (no.)			Leaves/plant (no.)		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
T ₀	12.2	12.0	12.1	6.0 e	8.0c	7.0	277 d	298	288.
T ₁	12.2	12.1	12.1	11.0 cd	10.0c	10.5	304cd	310	307
T ₂	12.1	13.2	12.6	12.0 bcd	16.0a	14.0	309 bcd	318	314
T ₃	12.3	12.4	12.4	9.0 de	11.0bc	10.0	285d	300	294
T ₄	11.9	13.2	12.6	9.0 de	10.0c	9.5	298 d	308	303
T ₅	12.4	12.6	12.5	13.0 abc	15.0ab	14.0	337 abc	309	323
T ₆	13.0	11.8	12.4	17.0 a	18.0a	17.5	343 a	307	325
T ₇	13.00	11.8	12.4	15.0 ab	15.0ab	15.0	341 ab	309	325
CV(%)	3.94	10.37	-	10.97	10.73	-	3.62	5.31	-

Means showing dissimilar letters in a column are significantly different at 5% level by Tukey's W test.

T₀ = Control (distilled water), T₁ = GA₃ @ 10 ppm, T₂ = GA₃ @ 30 ppm, T₃ = NAA @ 100 ppm, T₄ = NAA @ 150 ppm, T₅ = MH @ 50 ppm, T₆ = MH @ 150 ppm, T₇ = CCC @ 500 ppm.

Effect of PGRs on CCI and Fv/Fm values

In both the years all growth regulator treated plants produced identical chlorophyll content index (CCI) and Fv/Fm with control (Table 2). All the treatments gave Fv/Fm values close to 0.80 indicating photosystem II of the plants were not affected by the application of PGRs. The Fv/Fm values close to 0.800 revealed that all the plants under treatment were in healthier condition.

Table 2. Effect of plant growth regulators on chlorophyll content and quantum yield (Fv/fm values) of summer bottle at 70 days after sowing

Treatment	CCI value			Fv/Fm value		
	2015	2016	Mean	2015	2016	Mean
T ₀	20.2	21.3	20.7	0.80	0.81	0.81
T ₁	20.3	21.5	20.9	0.80	0.81	0.81
T ₂	21.4	22.3	21.9	0.80	0.82	0.81
T ₃	20.5	20.2	20.4	0.81	0.81	0.81
T ₄	20.6	21.2	20.9	0.81	0.81	0.81
T ₅	20.7	20.1	20.4	0.80	0.80	0.80
T ₆	20.7	20.8	20.8	0.80	0.82	0.80
T ₇	20.4	21.3	20.9	0.80	0.80	0.80
CV (%)	5.20	4.88	5.13	3.08	4.60	3.52

T₀ = Control (distilled water), T₁ = GA₃ @ 10 ppm, T₂ = GA₃ @ 30 ppm, T₃ = NAA @ 100 ppm, T₄ = NAA @ 150 ppm, T₅ = MH @ 50 ppm, T₆ = MH @ 150 ppm, T₇ = CCC @ 500 ppm.

Node number and number of days to first male and female flowers

Number of node and days required for the appearance of the first male flower were significantly lowered by all PGRs treatments except control (Table 3). The first male flower appeared at the lowest node (18.0 in 2015 and 16.3 in 2016; mean 17.15) on the plants treated with MH @ 150 ppm. The node numbers required for the first male flower were identical in NAA @ 100 ppm, NAA @ 150 ppm, MH @ 50 ppm, MH @ 150 ppm and CCC @ 500 ppm in the 1st year whereas, in 2nd year, node numbers were identical in all treatments except control. The plants treated with MH @ 150 ppm produced the first male flower in the least number of days in both years (59.0 in 2015, 63.0 in 2016 with a mean value 61.0. MH @ 150 ppm was statistically similar to GA₃ @ 30 ppm, and CCC @ 500 ppm with regard to number of days to first male flower appearance in 2nd year. All the PGR treatments significantly lowered the number of nodes and days required for the appearance of the first female flower than control in 2015 but, in 2016, application of MH both at 50 and 150 ppm significantly reduced node number at which female flower appeared and all the PGR treatments significantly lowered number of days required for the appearance of first female flower as compared to control (Table 3). The first

female flower appeared at the lowest node (21.0 in 2015 and 20.0 in 2016; mean 20.5) in the plants treated with MH @ 150 ppm, closely followed by CCC @ 500 ppm, MH @ 50 ppm and NAA @ 150 ppm during 2015, but in 2016, there was no significant differences among PGR treatments in respect of node number of female flower except control. Heslop–Harrison (1957) reported that the sexual differentiation is controlled by endogenous level of auxin content, which favours the formation of female flowers. Browning *et al.* (1992) explained that paclobutrazol induced a large, but transient increase in IAA (natural auxin) concentration within two days after treatment of the plants. These seem to be a reasonable explanation for the early appearance of female flowers at lower node. Similar findings have been reported with CCC by Sharma *et al.* (1988) and with MH by Singh and Choudhury (1988), Patel (1992) and Pandya and Dixit (1997) in bottle gourd. The plants treated with MH @ 150 ppm were able to produce the first female flower in least number of days in both the years (70.0 in 2015, 74.3 in 2016 and mean value 72.15. MH at 50 & 150 ppm and GA₃ @ 30 ppm gave identical number of days to 1st female flower in 2015 whereas, in 2016, MH @ 150 ppm was statistically similar to GA₃ @ 30 ppm with regard to number of days to first female flower appearance.

Male and female flowers

Spraying of CCC @ 500 ppm gave the highest number of male flowers (143.3 in 2015) followed by control treatment (123.0 in 2015) but in 2016, this treatment produced lower male flower than control (Table 3). The lowest male flowers/plant (81.7 in 2015, 96.0 in 2016 and mean 88.8) was recorded at MH @ 150 ppm, which was identical with NAA @ 100 and MH @ 50 ppm in 2015; but in 2016, it was identical with NAA @ 100 and 150 @ ppm. In 2015, all treatments significantly produced the maximum female flowers/plant while in 2016, except NAA @ 150 ppm all other treatments significantly increased number of female flowers/plant as compared to control. In the first year, the maximum number of female flowers/plant was found in MH @ 150 ppm (37.3 in 2015, 40 in 2016; mean 38.7) closely followed by CCC @ 500 ppm (36.3 in 2015, 38.0 in 2016; mean 38.0) and GA₃ @ 30 ppm (34.0 in 2016).

The CCC has been reported to cause reduction in respiration rate and accumulation of photosynthates, an effect similar to low temperature and short days (Choudhury, 1996) which might promote female flower production in cucurbits. Desai *et al.* (2011) obtained male flowers ranging from 86.27 -151 (CCC @ 250 ppm); 111.43 by control treatment and female flowers with a range of 29.7 (control) to 51.1 (PBZ @ 25 ppm); 40.5 by CCC. The present experimental result corroborates the findings of Hidayatullah *et al.* (2012). Pandey and Singh (1976) reported that spraying of NAA @ 100 and 150 @ ppm and GA₃ @ 10 ppm increased the female flowers and decreased the male flowers per plant in sponge gourd compared to control. The present experimental results were also in agreement with the results of Pandey and Singh (1976) and Arora *et al.* (1982).

Table 3. Effect of plant growth regulators on sex expression of summer bottle gourd

Treatment	Node at which the 1 st male flower appeared			Number of days to 1 st male flower			Node at which the 1 st female flower appeared			Number of days to 1 st female flower		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
T ₀	25.3a	21.3a	23.3	67.0a	69.7a	68.3	28.3a	27.0a	27.7	78.3a	81.7a	80.0
T ₁	23.0b	19.3ab	21.2	62.3b	65.7bc	64.0	26.3b	24.3ab	25.3	75.7b	78.7b	77.2
T ₂	22.3c	17.0bc	19.7	60.3cd	63.3cd	61.8	23.0de	21.0ab	22.0	71.00cd	74.7d	72.8
T ₃	21.3cd	18.0bc	19.7	61.0bc	66.7b	63.8	25.3bc	23.0ab	23.2	76.0b	79.00b	77.5
T ₄	21.0cd	18.0bc	19.5	61.3bc	67.3ab	64.3	24.3cd	23.0ab	23.7	76.3b	79.3b	77.8
T ₅	20.3d	17.0bc	18.7	60.3cd	65.7bc	63.0	22.3ef	20.3b	21.3	72.0cd	76.7c	74.3
T ₆	18.0e	16.3c	17.2	59.0e	63.0d	61.0	21.0f	20.0b	20.5	70.0d	74.3d	72.2
T ₇	21.0cd	17.0bc	19.0	60.0cd	65.0bcd	62.5	22.0ef	21.3ab	21.7	72.7c	76.7c	74.7
CV (%)	4.87	5.35	-	4.30	2.26	-	4.02	3.96	-	4.12	3.76	-

Table 3. cont'd.

Treatment	Male flower (no.)			Female flower (no.)			Sex ratio (male : female)		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
T ₀	123.0 b	131.3a	127.2	15.7 c	18.3d	17.0	7.9 a	7.2a	7.5
T ₁	103.7 c	115.3bc	109.5	24.0 b	27.3bc	25.7	4.3 bc	4.3b	4.3
T ₂	103.2 c	118.3b	107.8	23.0 b	34.0ab	28.5	4.5 bc	3.5bc	4.0
T ₃	82.0 de	98.3de	90.2	25.3 b	28.3bc	26.8	3.2 c	3.4bc	3.4
T ₄	94.7 d	104.0e	99.3	23.3 b	25.0cd	24.2	4.1bc	4.2b	4.1
T ₅	93.0 cde	107.3cd	100.2	24.3 b	29.0bc	26.7	3.8 bc	3.8b	3.8
T ₆	81.7e	96.0e	88.8	37.3 a	40.0a	38.7	2.2 c	2.5d	2.3
T ₇	143.3 a	120.3b	131.8	36.3 a	38.0a	37.2	3.9 bc	3.2cd	3.6
CV (%)	4.18	4.87	-	5.74	8.26	-	9.14	11.14	-

Means showing dissimilar letters in a column are significantly different at 5% level by Tukey's W test.

T₀ = Control (distilled water), T₁ = GA₃ @ 10 ppm, T₂ = GA₃ @ 30 ppm, T₃ = NAA @ 100 ppm, T₄ = NAA @ 150 ppm, T₅ = MH @ 50 ppm, T₆ = MH @ 150 ppm, T₇ = CCC @ 500 ppm.

Table 4. Effect of plant growth regulators on yield components and fruit yield of summer bottle gourd

Treatment	Fruits/plant (no.)			Fruit length (cm)			Fruit circumference (cm)		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
T ₀	4.7 c	6.7f	5.7	46.7	47.3	47.0	37.9	37.6	37.8
T ₁	7.7 b	9.7cde	8.7	47.5	47.7	47.6	38.3	39.9	39.1
T ₂	8.7 b	12.0ab	10.4	49.6	49.5	49.5	39.8	40.2	40.0
T ₃	6.7 bc	7.7ef	7.2	48.9	49.2	49.1	39.1	39.9	39.5
T ₄	7.0 b	9.0de	8.0	47.7	47.7	47.7	41.3	40.2	40.8
T ₅	8.0 b	10.7bcd	9.3	46.8	47.9	47.4	38.1	40.3	39.2
T ₆	12.0 a	14.0a	13.0	47.2	48.1	47.7	38.7	39.6	39.2
T ₇	11.3 a	11.7bc	11.5	47.2	48.2	47.7	35.8	38.6	27.2
CV (%)	9.76	7.87	-	5.61	6.56	-	10.59	8.13	-

Table 4. cont'd.

Treatment	Individual fruit weight (kg)			Fruit weight/plant (kg)			Fruit yield (t/ha)			Mean yield increase over control (%)
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	
T ₀	2.4	2.5	2.5	11.5e	16.1e	13.8	38.5 e	40.4e	39.4	-
T ₁	2.4	2.5	2.4	18.3cd	20.8d	19.6	61.1 cd	52.0d	56.5	30.2
T ₂	2.7	2.6	2.6	21.8bc	30.1b	26.0	72.8 bc	75.3b	74.1	46.7
T ₃	2.4	2.6	2.5	16.2de	20.1d	18.2	53.5 de	50.4de	52.0	24.1
T ₄	2.8	2.6	2.7	18.6cd	22.8cd	20.7	62.0 cd	56.9d	59.4	33.7
T ₅	2.7	2.6	2.6	21.1c	26.5bc	23.8	70.4 c	66.2c	68.3	42.3
T ₆	2.6	2.7	2.6	29.3a	35.8a	32.6	97.6 a	89.6a	93.6	54.2
T ₇	2.5	2.6	2.6	26.6ab	29.1b	27.8	88.5 ab	72.7b	80.6	51.1
CV (%)	6.18	10.34	-	8.33	6.13	-	8.27	6.10	8.59	-

Means showing dissimilar letters in a column are significantly different at 5% level by Tukey's W test.

T₀ = Control (distilled water), T₁ = GA₃ @ 10 ppm, T₂ = GA₃ @ 30 ppm, T₃ = NAA @ 100 ppm, T₄ = NAA @ 150 ppm, T₅ = MH @ 50 ppm, T₆ = MH @ 150 ppm, T₇ = CCC @ 500 ppm.

Sex ratio of male and female flower

All the treatments resulted in narrowing down of male-female sex ratio over control in both years (Table 3). The lowest sex ratio (male:female) was recorded at MH @ 150 ppm in both the years (2.2 in 2015 and 2.5 in 2016; mean 2.30). In 2015, all the treatments except control produced identical values of sex ratio, but in 2016, MH @ 150 and CCC @ 500 were identical with regard to sex ratio. Again, in 2016, there was no significant difference among GA₃ @ 10 (T₁), GA₃ @ 30 (T₂), NAA @ 100 (T₃), NAA @ 150 (T₄) and MH @ 150 (T₅) ppm in respect of sex ratio. Although CCC @ 500 ppm produced the maximum male flowers compared to control in 2015, it gave lower sex ratio (3.9) than control (7.9) because of producing higher female flowers.

The marked suppression of male flowers and induction of female flowers by all concentrations of GA₃, NAA, MH and CCC @ 500 ppm was noticed. Induction of female flowers by all concentrations of PGRs was the evidence of lowered sex ratio. The sex ratio recorded in this investigation was comparable to the results reported by Hidayatullah *et al.* (2012) with GA₃, Sharma *et al.* (1988) as well as Pandya and Dixit (1997) with CCC and Ingle *et al.* (2000) as well as Arora *et al.* (1982) with MH in bottle gourd.

Yield attributes and yield of bottle gourd

Growth regulator treatments had significant effect on yield components and yield of bottle gourd except fruit length, fruit circumference and individual fruit weight in both the years (Table 4). The maximum number of fruits/plant was found in MH @ 150 ppm in both the years (12.0 in 2015 and 14.0 in 2016; mean 13.0). In the first year, MH @ 150 ppm gave identical fruit number with CCC @ 500 ppm (11.3), but in the 2nd year, number of fruits produced by the plants treated with MH 150 ppm was statistically similar to those of GA₃ @ 30 ppm (12.0). The lowest number of fruits was obtained from control in both the years (4.7 in 2015 and 6.7 in 2016; mean 5.7). The maximum fruit weight/plant was recorded at MH @ 150 ppm in both the years (29.3 kg and 35.8 kg in 2015 and 2016, respectively). In 2015, MH @ 150 ppm was identical with CCC @ 500 ppm in producing fruit weight/plant. In the 2nd year, the second highest fruit weight/plant was obtained from the application of GA₃ @ 30 ppm (30.1 kg) which was statistically similar to CCC @ 500 ppm (29.1 kg). The mean values over two years indicated the highest fruit weight/plant (32.6 kg) was recorded from MH @ 150 ppm followed by CCC @ 500 ppm (27.8 kg) and GA₃ @ 30 ppm (26.0 kg). The lowest fruit weight/plant was found from the control (11.5 kg in 2015 and 16.1 kg in 2016; mean 13.8 kg) in both the years.

Fruit yield per hectare followed the same trend of fruit weight/plant. MH 150 ppm gave the highest fruit yield (97.6 t/ha in 2015, 89.6 t/ha in 2016 and mean 93.6 t/ha). In 2015, CCC @ 500 produced the identical yield (88.5 t/ha) of MH @ 150 ppm. In 2016, application of GA₃ @ 30 ppm gave the 2nd highest yield

(74.1 t/ha) which was statistically similar to CCC @ 500 ppm (72.7 t/ha). It was observed from the mean values that the maximum fruit yield (93.6 t/ha) was recorded from MH @ 150 ppm followed by CCC @ 500 ppm (80.6 t/ha) and GA₃ @ 30 ppm (74.1 t/ha). The control treatment gave the lowest yield (38.5 t/ha and 40.4 t/ha in 2015 and 2016, respectively; mean 39.4) (Table 4). MH (50-150 ppm) produced yields in the range of 70.4 -97.6 t/ha in 2015 and 66.2-89.6 t/ha in 2016. Higher concentration of MH (150 ppm) produced higher yield than MH @ 50 ppm in both the years. On the other hand, GA₃ (10-30 ppm) gave the yields ranged from 61.1 -72.8 t/ha in 15 and 52.0-75.3 t/ha in 2016 and GA₃ @ 30 ppm produced the highest yield in both the years. NAA (100-150 ppm) produced fruit yield ranged from 53.5-62.0 t/ha in the first year and from 50.4-56.9 t/ha in the 2nd year and NAA @ 150 ppm gave the highest fruit yield in both the years. In mean values over two years, plants of bottle gourd treated with 150 ppm MH, 500 ppm CCC and 30 ppm GA₃ gave 54.16%, 51.06% and 46.74 % higher yield, respectively than control. An increase in yield could be attributed to earliness and increased number of female flowers as well as narrowed male:female sex ratio. Arora *et al.* (1982) reported that MH @ 50 ppm was most effective in producing the maximum fruit weight/plant and ultimately the yield. Foliar spray of MH (50-150 ppm) increased the yield in most of the cucurbits (Sonkar, 2003; Jatoi *et al.*, 2010). Plants sprayed with MH @ 50 ppm at 2-leaf stage produced the best yield (Baruah and Das, 1997). Saimbhi and Thakur (2006) reported that single spray of CCC @ 500 ppm increased number of fruits per plant and yield in squash melon (*Citrullus vulgaris*). Sadiq *et al.* (1990) obtained maximum number of fruits/plant and yield/vine from application of CCC 5@ 00 in cucumber. Hidayatullah *et al.* (2012) obtained maximum fruit weight/plant and yield in bottle gourd from the spraying of plants with GA₃ 30 ppm. Desai *et al.* (2011) obtained the maximum yield of bottle gourd from spraying with paclobutrazol @ 25 ppm followed by CCC @ 200 ppm, CCC @ 500 ppm and MH @ 200 ppm.

Partial Economic Analysis

The present study (Table 5) revealed that the maximum gross return (Tk. 11,70,000.00) was found from the plants sprayed with MH @ 150 ppm followed by CCC @ 500 ppm (Tk. 10,07,380.00) and GA₃ @ 30 ppm (Tk. 9,25,750.00) and the minimum gross return was recorded from control (Tk. 4,93,000.00). Net return showed marked difference among the treatments and followed the same trend of gross return. Net return was the highest (Tk. 9,82,600.00) in MH @ 150 ppm followed by CCC @ 500 ppm (Tk. 8,15,580.00) and GA₃ @ 30 ppm (Tk. 7,35,200.00) while the lowest (Tk. 3,06,200.00) in control. The maximum benefit cost ratio (BCR) was obtained from MH @150 ppm (5.24) followed by CCC @ 500 ppm (4.25) and GA₃ @ 30 ppm (3.86); while the minimum from control (1.64). The cost and return analysis revealed that spraying of MH @ 150 ppm was superior to CCC @ 500 and GA₃ @ 30 ppm in terms of net income and BCR.

Table 5. Partial cost benefit analysis of summer bottle gourd production by using plant growth regulators

Treatment	Mean fruit yield (t/ha)	Gross return ('000 Tk./ha)	Cost of treatment ('000 Tk./ha)	Cost of cultivation ('000 Tk./ha)	Net return ('000 Tk./ha)	Benefit-cost ratio (BCR)
T ₀	39.44	493.00	0.00	186.80	306.20	1.64
T ₁	56.54	706.75	1.25	188.05	518.70	2.76
T ₂	74.06	925.75	3.75	190.55	735.20	3.86
T ₃	51.98	649.75	0.55	187.35	462.40	2.47
T ₄	59.44	743.00	0.83	187.63	555.38	2.96
T ₅	68.31	853.87	0.20	187.00	666.87	3.57
T ₆	93.60	1170.00	0.60	187.40	982.60	5.24
T ₇	80.59	1007.38	5.00	191.80	815.58	4.25

T₀ = Control (distilled water), T₁ = GA₃ @ 10 ppm, T₂ = GA₃ @ 30 ppm, T₃ = NAA @ 100 ppm, T₄ = NAA @ 150 ppm, T₅ = MH @ 50 ppm, T₆ = MH @ 150 ppm, T₇ = CCC @ 500 ppm.

Basic cost of cultivation: 186800 Tk./ha.

Cost of PGRs:

1. Gibberellic acid (GA₃): Tk. 500.00/g
2. Naphthalene Acetic Acid (NAA): Tk. 2200.00/100 g
3. Maleic hydrazide : Tk. 1500.00/100g
4. Cycocel (CCC) : Tk. 2000.00/100ml (50% ai)

<u>Treatment</u>	<u>Dose/ha</u>
GA ₃ @ 10 ppm (T ₁)	2.5 g
GA ₃ @ 30 ppm (T ₂)	7.5 g
NAA @ 100 ppm (T ₃)	25.0 g
NAA @ 150 ppm (T ₄)	37.5 g
MH @ 50 ppm (T ₅)	13.33 g
MH @ 150 ppm (T ₆)	40.0 g
CCC @ 500 ppm (T ₇)	500 ml

Market selling price of bottle gourd fruits: Tk. 12.50/kg (Tk 12500.00/ton)

Conclusion

The experimental result revealed that PGR played a significant role in regulating number of branches/plant, male and female flowering, narrowing sex ratio and ultimately increasing number of fruits and yield. Treatments of MH @ 150 ppm, CCC @ 500 ppm and GA₃ @ 30 ppm were superior to the rest of the treatments for the earliness of female flower appearance, narrowing down sex-ratio and

finally increasing yield. These three treatments also registered higher gross return, net return and BCR. Therefore, it can be concluded that spraying MH @150 ppm or CCC @ 500 ppm or GA₃ @ 30 ppm to the seedlings of bottle gourd at two-leaf stage and 2nd spraying after four days of 1st spray should be done in summer to get higher yield with higher return.

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REQUIREMENT OF DIFFERENT NUTRIENTS FOR YIELD MAXIMIZATION OF BT BRINJAL

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Abstract

The experiment was conducted at Agronomy field of Bangladesh Agricultural Research Institute, Gazipur during 2016-2017 and 2017-2018 to determine the nutrient requirement for yield maximization of Bt brinjal (var. BARI Bt Begun-2). The treatments were T₁= STB (soil test base) recommendation (120-36-90-15-2-1 kg/ha N-P-K-S-Zn-B+ 3 t/ha poultry manure), T₂ = T₁ + 25% of N-P-K-S-Zn-B (150-45-112-18-2.5-1.25 kg/ha N-P-K-S-Zn-B +3 t/ha poultry manure), T₃= T₁ + 50% of N-P-K-S-Zn-B (180-54-135-22-3-1.50 kg/ha N-P-K-S-Zn-B +3 t/ha poultry manure), T₄= T₁ + 25% of N-P-K-S-Zn-B + 3 t/ha poultry manure (150-45-112-18-2.5-1.25 kg/ha N-P-K-S-Zn-B+6 t/ha poultry manure), T₅= T₁ + 3 t/ha poultry manure (120-36-90-15-2-1 kg/ha N-P-K-S-Zn-B + 6 t/ha poultry manure). Nutrient uptake, yield components and yield of Bt brinjal varied significantly due to variation of nutrients in the tested years. The highest plant height (98-116 cm), canopy coverage (1.21-1.26 m²/plant), number of fruits/plant (57.69-59.23) and individual fruit weight (83-86 g) were obtained from 180-54-135-22-3-1.50 kg/ha N-P-K-S-Zn-B +3 t/ha poultry manure (T₃) treatment where days to flowering showed the lowest values (109-110 days). The highest pooled yield (58.46 t/ha) of Bt brinjal was observed from the treatment 180-54-135-22-3-1.50 kg/ha N-P-K-S-Zn-B +3 t/ha poultry manure (T₃) and the lowest (23.39 t/ha) from 120-36-90-15-2-1 kg/ha N-P-K-S-Zn-B+ 3 t/ha poultry manure) (T₁). The highest nutrient uptake (214-43-208-60-0.38-0.213-49 kg/ha N-P-K-S-B-Ca) was also observed from the same treatment (T₃). Fruit yield showed a strong ($r=0.97$) linear relationship with applied nutrients. Effect of nutrient application on fruit yield of Bt brinjal was estimated about 86%. The highest gross return (Tk. 587900/ha), gross margin (Tk. 417660/ha) and benefit cost ratio (3.45) were obtained by applying 180-54-135-22-3-1.50 kg/ha N-P-K-S-Zn-B+3 t/ha poultry manure. Results revealed that application of 180-54-135-22-3-1.50 kg/ha N-P-K-S-Zn-B along with 3 t/ha poultry manure would be economically optimum for achieving higher yield of Bt brinjal grown under Grey Terrace soil (Aeric Albaquept) of Gazipur.

Keyword: Nutrient requirement, nutrient uptake, yield and Bt brinjal

Introduction

Brinjal (*Solanum melongena*) is the third most important vegetable in terms of both yield and production area in Bangladesh. Recently Bangladesh Agricultural

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Research Institute has developed four Bt brinjal varieties. It has high potentiality to boost up the yield and brinjal production of the country. Bt brinjal needs additional fertilizer than the recommended dose for proper growth and yield (Mian, 2017). Optimum nutrient dose exerts proper growth and development of crop plant contributing to better yield components and yield (Morgan and Connolly, 2013). Nutrient involves in many important metabolic *processes* in the plant system and influences the growth and development of crop plant. Recommended fertilizer dose for non Bt brinjal is generally used in Bt brinjal because of no fertilizer recommendation for Bt brinjal yet in Bangladesh (FRG, 2018). Bt brinjal produced lower yield when recommended fertilizer dose for non Bt brinjal is used in Bt brinjal (BARI, 2017). Previous field experience and observation indicated that Bt brinjal has profused bearing than non Bt brinjal. Hence, higher fertilizer dose may require for full exploitation of yield potentiality of Bt brinjal. Most of the flowering buds of Bt Brinjal are active for fruiting. Bt gene is resistance to brinjal shoot and fruit borer of Bt brinjal. Probably Bt gene is also tolerance to fungal disease development on flowering buds of Bt brinjal. Consequently, more active flowering buds produce more fruits/plant and higher yield of Bt brinjal. Higher fruit yield of Bt brinjal may require high nutrient dose as compared to recommended nutrient dose for non Bt Brinjal because of high nutrient uptake by Bt Brinjal from the soil. There is a positive relationship between yield and nutrient uptake of a crop (Masni and Wasli, 2019). On the other hand, one of the major causes of low yield of brinjal might be due to low organic matter content as well as low nutrient status of soils those has been declined over time (Mian, 2008). Application of higher dose of nutrients than at present nutrient recommendation for non Bt brinjal may improve the yield of Bt brinjal. Moreover, optimum application of nutrient provides better agronomic and economic benefits to brinjal growers. Very little information is available regarding fertilizer management in Bt brinjal. As such, there is a need to recommend the fertilizer requirement for Bt brinjal. Therefore, the experiment was undertaken to find out economic fertilizer dose for achieving high yield of Bt brinjal.

Materials and Methods

The experiment was conducted at Agronomy field of Bangladesh Agricultural Research Institute, Gazipur during 2016-2017 and 2017-2018. The soil of the experimental field is clay loam under Chhiata series. Soil samples were collected from a depth of 0-20 cm prior to application of fertilizer in both the years. Results of soil analysis are presented in Table 1. Organic matter content and total N were very low. Exchangeable K and available P, S, Zn and B were found to be below the critical level. Five treatments consist of $T_1=120-36-90-15-2-1$ kg/ha of N-P-K-S-Zn-B+ 3 t/ha poultry manure based on STB (FRG, 2012), $T_2 = T_1 + 25\%$ of N-P-K-S-Zn-B (150-45-112-18-2.5-1.25 kg/ha of N-P-K-S-Zn-B +3 t/ha poultry manure), $T_3= T_1 + 50\%$ of N-P-K-S-Zn-B (180-54-135-22-3-1.50 kg/ha of N-P-K-S-Zn-B +3 t/ha poultry manure), $T_4= T_1 + 25\%$ of N-P-K-S-Zn-B + 3 t/ha poultry manure (150-45-112-18-2.5-1.25 kg/ha of N-P-K-S-Zn-B+6 t/ha

poultry manure), T₅= T₁+ 3 t/ha poultry manure (120-36-90-15-2-1 kg/ha of N-P-K-S-Zn-B + 6 t/ha poultry manure). The experiment was conducted in a randomized complete block (RCB) design with three replications. Unit plot size was 6.4 m ×5.4 m. All of poultry manure, phosphorus, sulphur, zinc and boron fertilizers were applied at the time of final land preparation. Nitrogen and potassium fertilizers were applied in four equal splits at 20, 40, 60 and 80 DAT (days after transplanting) around the plant roots and mixed thoroughly with the soil. The brinjal var. BARI Bt Begun-2 was used as test crop. Thirty days old seedling was transplanted on 11 November 2016 and 16 November 2017 at a spacing of 90 cm ×80 cm. Intercultural operations such as weeding, mulching, irrigation etc. were done as per requirement. The crop was harvested from 8-12 February to 1-5 April in 2017 and 2018. Frequent rainfall (66-107 mm in February to April) at later stage affected the crop (Fig.2) and drastically reduced fruit yield. Nutrient concentration in fruit and plant tissues of Bt brinjal was analyzed following the standard laboratory procedures. Nutrient uptake was computed on the basis of dry matter accumulation of Bt Brinjal and nutrient concentration in the tissues (both fruit and plant). Correlation of yield with nutrient uptake and nutrient uptake with applied nutrients were done. Functional relationship between total applied nutrient and fruit yield of Bt brinjal were established. Nutrient from poultry manure were calculated and considered in total applied nutrient (FRG, 2012). Data on yield and other associated characters were recorded. Canopy coverage was measured by meter-stick method (Armbust, 2009). Vertical projection area of the outer most perimeter of the natural spread of foliage of plants was measured. Soil surface coverage (D=diameter of coverage of the plant) was measured at four positions of spreading margin of the plant canopy (perimeter) perpendicular to the soil surface. Randomly selected 5 plant's canopy coverage (D=diameter) was measured from each plot. Then mean value was calculated using the following formula. This measurement ($A= \pi r^2$ where, $D=2r$) was done at first harvesting time of fruits. Data on yield and other associated characters were recorded. Collected data was subjected to analysis of variance. Least significant difference (LSD) value was used for mean separation and treatments means were compared by LSD (0.05) (Gomez and Gomez, 1984). Cost benefit analysis was also evaluated.

Table 1. Chemical properties of the experimental soil (average of two years)

Properties	pH	OM(%)	Total N (%)	Exchangeable K (meq/100g soil)	P (ppm)	S (ppm)	Zn (ppm)	B (ppm)
Nutrient Status	6.25	1.73	0.079	0.16	8.09	9.88	0.47	0.18
Critical limit	-	C:N=10:1	0.12	0.12	10	10	0.60	0.20
Interpretation	Acidic	VL	VL	L	L	L	L	L

VL=Very low, L=Low

Table 2. Total nutrient uptake (kg/ha) by Bt Brinjal fruit and plant as influenced by nutrient level (Average of 2016-2017 and 2017-2018)

Treatment	N	P	K	S	Zn	B	Ca
T ₁	85	17	65	25	0.114	0.072	19
T ₂	134	28	132	32	0.231	0.132	32
T ₃	214	43	208	60	0.380	0.213	49
T ₄	162	35	156	41	0.288	0.158	34
T ₅	127	30	77	38	0.213	0.116	29
SE(±)	6.91	3.09	7.66	3.63	0.010	0.007	3

Table 3. Yield attributes and yield of Bt brinjal as influenced by nutrient level in 201-2017 and 2017-2018

Treatment	Plant height (cm)		Canopy coverage (m ² /plant)		Days to flowering (day)		Fruits/plant (no.)		Individual fruit weight (g)		Fruits yield (t/ha)	
	2016-2017	2017-2018	2016-2017	2017-2018	2016-2017	2017-2018	2016-2017	2017-2018	2016-2017	2017-2018	2016-2017	2017-2018
T ₁	52	66	0.89	1.01	114	112	24.45	22.32	72	61	24.45	22.32
T ₂	76	93	1.05	1.06	113	111	46.77	42.03	78	76	46.77	42.03
T ₃	98	116	1.26	1.21	110	109	59.23	57.69	83	86	59.23	57.69
T ₄	84	103	1.17	1.09	113	111	48.28	46.81	79	79	48.28	46.81
T ₅	65	81	0.89	1.03	113	110	34.35	33.37	75	70	34.35	33.37
LSD _(0.05)	4.22	8.93	0.32	0.18	NS	NS	4.01	3.68	2.3	2.1	4.01	3.68
CV (%)	4.92	5.27	7.85	4.58	5.37	4.33	5.07	5.67	3.11	3.02	5.07	5.67

T₁= 120-36-90-15-2-1 kg/ha N-P-K-S-Zn-B + 3 t/ha poultry manure
 T₂= 150-45-112-18-2.5-1.25 kg/ha N-P-K-S-Zn-B + 3 t/ha poultry manure
 T₃= 180-54-135-22-3-1.50 kg/ha N-P-K-S-Zn-B + 3 t/ha poultry manure
 T₄= 150-45-112-18-2.5-1.25 kg/ha N-P-K-S-Zn-B+6 t/ha poultry manure
 T₅= 120-36-90-15-2-1 kg/ha N-P-K-S-Zn-B + 6 t/ha poultry manure

Results and Discussion

Nutrient uptake:

Uptake of N, P, K, S, Zn, B and Ca by whole plant (stem+leaves+fruit) of Bt brinjal differed among the treatments (Table 2). N uptake by both shoot and fruit varied from 85 to 214 kg/ha. The highest N uptake by whole plant occurred in the 180-54-135-22-3-1.5 kg/ha N-P-K-S-Zn-B + 3 t/ha poultry manure (T₃) treatment. Higher nutrient application into soil enhanced crop growth as well as total dry matter resulting the highest nutrient uptake from soil. Similar results were also reported by Ghosh *et al.* (2014). The uptake of N was the lowest in the treatment 120-36-90-15-2-1 kg/ha N-P-K-S-Zn-B+ 3 t/ha poultry manure (T₁) possibly due to lower availability of N coupled with lower dry matter. P, K, S, Zn, B and Ca uptake by whole plant of Bt brinjal also followed a similar pattern to that obtained for N uptake (Table 2).

Plant height and yield attributes:

Plant height and canopy coverage/plant showed significant variation among the nutrient level in both the years (Table 3). Plant height was found maximum in T₃ treatment followed by T₄ treatment and the lowest from T₁. Similar trend was also observed in the case of canopy coverage/plant. Higher nutrient level increased plant height and canopy coverage indicated better crop growth. Similar results were reported by Khanum *et al.* (2017) in Bt Brinjal. Days to flowering did not differ significantly among the treatments in both the years. Days to flowering ranged from 109-114 days being the lowest value from T₃ treatment (Table 3). The results indicated that higher nutrient level enhanced early flowering (Ahmad *et al.*, 2011; Sajid and Amin, 2014). The highest number of fruits/plant was found in T₃ treatment and it was significantly different from all other treatments. The lowest number of fruits/plant was obtained from T₁ treatment. The result indicated that higher nutrient level enhanced crop growth resulting higher fruits/plant. Similar results were reported by Sharma and Guru (2016) in brinjal. Individual fruit weight varied considerably and increased significantly in different treatments as compared to T₁. The highest fruit weight was recorded in T₃ treatment and it was significantly superior to all other treatments in both the years. Treatment T₁ produced the lowest individual fruit weight.

Fruit yield:

Application of different nutrients (higher nutrients) increased fruit yield from 24.45 to 59.23 t/ha in 2016-2017 and 22.32 to 57.69 t/ha in 2017-2018 (Table 3). The highest fruit yields (59.23 t/ha in 2016-2017 and 57.69 t/ha in 2017-2018) were obtained from T₃ treatment and it was significantly different from all other treatments. The result indicates that Bt brinjal produced higher fruit yield at higher nutrient level as it was required for exploitation of its high yield

potentiality. The results are in agreement with the findings of Anonymous (2017) and Mian (2017). The yield advantage was achieved through greater nutrient uptake by Bt brinjal resulting increased fruits/plant and individual fruit weight which eventually increased fruit yield of Bt brinjal. Recommended nutrient level for brinjal produced lower yield of Bt brinjal in both the years. Fruit yield was significantly correlated with applied nutrients ($r=0.97$). Correlation of yield with nutrient uptake and nutrient uptake with applied nutrients were positive and significant (Table 4). Functional relationship between applied nutrient and fruit yield of Bt brinjal suggests that variation in yield can be attributed to the differences in applied nutrients. The result shows that higher nutrients gave higher fruit yield of Bt brinjal (Fig.1). Cost and return analysis of different treatments are presented in Table 5. Gross return (Tk. 587900/ha), gross margin (Tk. 417660/ha) and BCR (3.45) were found the highest in T₃ treatment followed by T₄ treatment and T₂ treatment. The results indicated that higher nutrient dose gave higher economic advantage.

Table 4. Correlation of yield with nutrient uptake and nutrient uptake with applied nutrients (average of 2016-2017 and 2017-2018)

Nutrient	Correlation of yield with nutrient uptake (r)	Correlation of nutrient uptake with applied nutrient (r)
N	0.98**	0.86**
P	0.95**	0.73**
K	0.98**	0.79**
S	0.89**	0.85**
Zn	0.99**	0.91**
B	0.99**	0.93**
Ca	0.97**	0.86**

** Significant at 1% level of probability

Table 5. Cost and return analysis of Bt brinjal as influenced by nutrient level (average of 2016-2017 and 2017-2018)

Treatment	Gross return (Tk./ha)	Cost of cultivation (Tk./ha)	Gross margin (Tk./ha)	BCR
T ₁	223200	121600	101600	1.84
T ₂	420300	145920	274380	2.88
T ₃	587900	170240	417660	3.45
T ₄	468100	152000	316100	3.08
T ₅	333700	127680	206020	2.61

Price (Tk./kg)

Urea:16.00, TSP:22.00, MOP:15.00, Gypsum:10.00, Zinc sulphate :170.00, Boric acid:200.00

Bt brinjal fruit: 9.50-10.00, Labour wage: Tk.400.00/day

T₁= 120-36-90-15-2-1 kg/ha N-P-K-S-Zn-B+ 3 t/ha poultry manure

T₂= 150-45-112-18-2.5-1.25 kg/ha N-P-K-S-Zn-B +3 t/ha poultry manure

T₃= 180-54-135-22-3-1.50 kg/ha N-P-K-S-Zn-B +3 t/ha poultry manure

T₄= 150-45-112-18-2.5-1.25 kg/ha N-P-K-S-Zn-B+6 t/ha poultry manure

T₅= 120-36-90-15-2-1 kg/ha N-P-K-S-Zn-B + 6 t/ha poultry manure

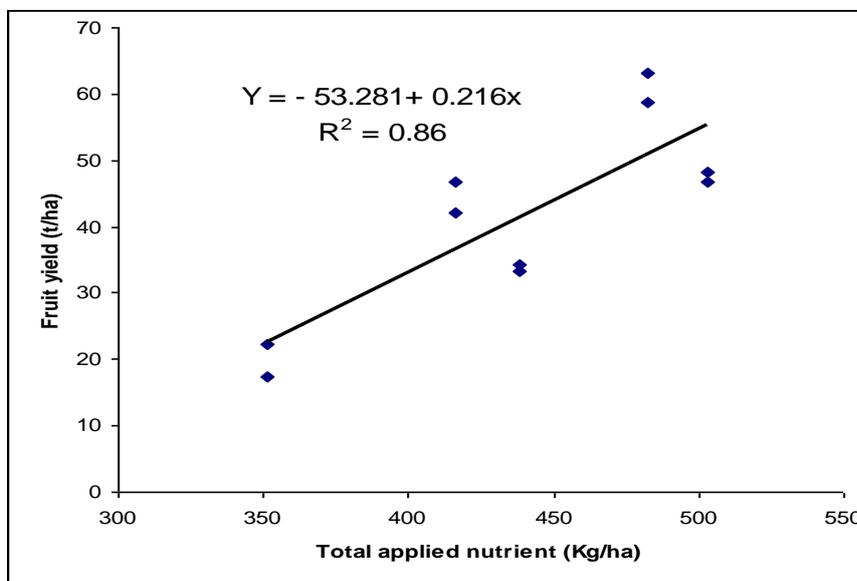


Fig. 1. Functional relationship between applied nutrient and fruit yield of Bt Brinjal (average of 2016- 2017 and 2017-2018).

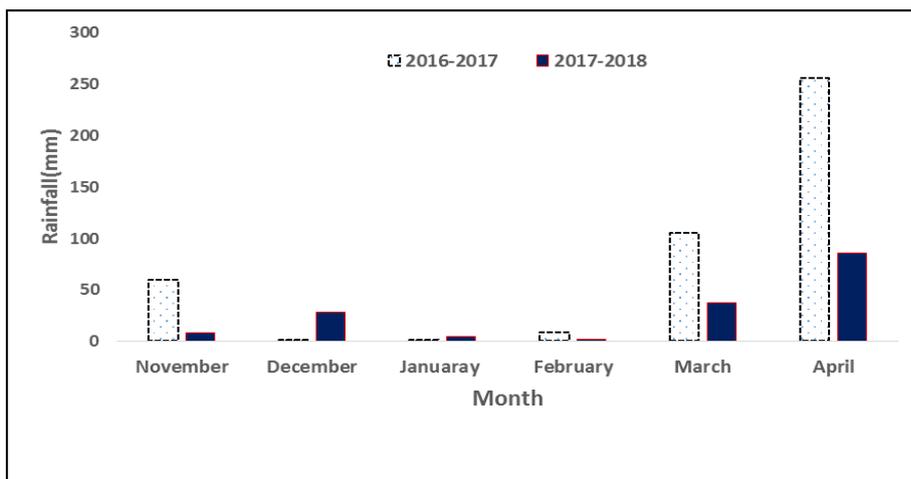


Fig.2. Rainfall distribution during growing period of Bt brinjal (2016-2017 and 2017-2018)

Conclusion

The results of two years’ study revealed that application of 180-54-135-22-3-1.50 kg/ha N-P-K-S-Zn-B along with 3 t/ha poultry manure was the suitable combination of nutrients for raising maximum fruit yield and also economically profitable for brinjal production in Chhiata series of the Grey Terrace soil of Gazipur.

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EFFECTS OF POTASSIUM APPLICATION ON YIELD ATTRIBUTES, YIELD AND GRAIN QUALITY OF LENTIL IN TERRACE SOIL OF JOYDEBPUR

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Abstract

An experiment was conducted in the research field of Pulses Research Sub-Station, BARI, Gazipur during two consecutive years of 2015-16 and 2016-17 to determine the suitable dose of potassium for achieving higher yield attributes, nodulation, nutrient concentration and yield maximization of lentil. There were 5 treatments viz. T₁ = Control, T₂ = 30 kg K ha⁻¹, T₃ = 40 kg K ha⁻¹, T₄ = 50 kg K ha⁻¹ and T₅ = 60 kg K ha⁻¹ along with the blanket dose of fertilizers of N, P, S, Zn and B @ 15, 20, 10, 2 and 1.5 kg ha⁻¹, respectively for all treatments. The experiment was laid out in randomized complete block design (RCBD) with three replications. Results revealed that the highest seed yield (1092 kg ha⁻¹) of lentil (mean of two years) was found in T₄ followed by T₅ treatment and the lowest (736 kg ha⁻¹) was noted in K control (T₁) treatment. The highest % yield increase over control (48.3%) was recorded from T₄ treatment. The maximum nodulation was found in T₅ followed by T₄ treatment. The highest protein (26.9%), N, P, K, S, Zn and B concentrations of lentil seed were recorded in T₄ treatment. Therefore, the results suggest that the application of 50 kg K ha⁻¹ along with N₁₅P₂₀S₁₀Zn₂B_{1.5} kg ha⁻¹ are optimum for achieving higher yield potential of lentil in terrace soils of Bangladesh.

Keywords: Potassium, lentil yield, nodulation, nutrient content, terrace soil

Introduction

Improved variety and intensive cropping followed by imbalanced use of fertilizers make the soils deficient in nutrients and thus the crops grown on such soils show mineral deficiencies. Deficiency of several major and minor nutrients such as K, S, Ca, Zn, Fe and B are increasing with time (Kurahde *et al.*, 2015; Rao and Vittal, 2007). Lentil (*Lens culinaris* Medic) is an edible and popular pulse crop that belongs to the family *Fabaceae*. Lentil seed contains 25% protein, 1.1% fat, 59% carbohydrate, and is also rich in important vitamins, minerals, and soluble and insoluble dietary fiber (Islam *et al.*, 2018). It helps to improve the soil fertility through biological nitrogen fixation (Quddus *et al.*, 2014). The average yield of lentil in Bangladesh is low (752 kg ha⁻¹) due to non-judicious use of manures and fertilizers (Zahan *et al.*, 2009).

Potassium (K), as a plant nutrient, is becoming increasingly important in Bangladesh and shows a good response to pulse crop. Potassium improves

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plant water relationship and improves shoot growth of pulse crop (Kabir *et al.*, 2004). It maintains turgor pressure of cell which is necessary for cell expansion. It helps in osmo-regulation of plant cell, assists in opening and closing of stomata (Yang *et al.*, 2004). Potassium nutrition is associated with the nodulation and grain quality and protein content (Srinivasarao *et al.*, 2003). It also helps improve disease resistance, drought stress, tolerance to water stress, winter hardiness, tolerance to plant pests and uptake efficiency of other nutrients (Gupta *et al.*, 2013). Considering its nutritional value; it is necessary to uplift the production level and nutritional quality of lentil. Therefore, the present study was undertaken to find out the suitable dose of K for yield maximization of lentil.

Materials and Methods

Field experiment was conducted in Rabi season of 2015-16 and 2016-17 in the research field of Pulses Research Sub-Station, Bangladesh Agricultural Research Institute (BARI), Gazipur (24° 0' 13" N latitude and 90° 25' 0" E longitude). Gazipur is medium high land with fine-textured (clay loam) terrace soils. It belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agroecological zone - Madhupur Tract (AEZ-28). The Gazipur area received average rainfall from 1.40 to 118 mm during October to March. The mean minimum and maximum air temperatures during October to March of the experiment were 12.2 & 33.1°C during 2015-16 and 13.6 & 33.1°C, respectively during 2016-17. The average minimum and maximum humidity (%) were 51 and 88 during October to March (Table 1). Before starting the experiment, initial soil (0-15 cm) sample was analyzed as outlined by Page *et al.* (1982) and standard method. The chemical properties are shown in Table 2.

Table 1. Weather data during the experimental period at Gazipur

Months	Avg. Temperature (°C)				Avg. Humidity (%)				Rainfall (mm)	
	2015-16		2016-17		2015-16		2016-17		2015-16	2016-17
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	-	-
October	24.0	33.1	24.8	33.1	76	83	67	79	14	13.7
November	18.2	30.7	19.4	30.1	84	88	61	72	0	1.40
December	16.5	26.2	15.5	28.2	74	82	53	80	0	0
January	12.2	25.2	13.6	27.0	67	80	51	81	0	0
February	17.0	29.6	16.3	30.4	57	74	46	73	0	0
March	19.9	33.1	19.4	30.9	53	73	56	75	118	8.02

Source: Weather centre, BARI, Gazipur, Bangladesh

Table 2. Fertility status of initial soil sample of the experimental field at Gazipur

Location	pH	OM (%)	Total N (%)	Ca	K	P	S	Zn	B
				meq. 100 g ⁻¹		mg kg ⁻¹			
Gazipur (result)	6.2	1.30	0.061	6.55	0.11	13	13.5	0.65	0.16
Critical level	-	-	0.12	2.0	0.12	7	10	0.60	0.20
Interpretation*	acidic	low	very low	high	low	medium	medium	low	low

*FRG, (2012)

The land was firstly opened by a tractor operated chisel plough and then prepared thoroughly by ploughing with a power tiller followed by laddering and leveling. There were 5 treatments consisting of different levels of potassium (0, 30, 40, 50 & 60 kg K ha⁻¹) including control such as T₁ = Control, T₂ = 30 kg K ha⁻¹, T₃ = 40 kg K ha⁻¹, T₄ = 50 kg K ha⁻¹, T₅ = 60 kg K ha⁻¹ along with the blanket dose of other nutrients N, P, S, Zn and B @ 15, 20, 10, 2 and 1.5 kg ha⁻¹, respectively. The experiment was laid out in randomized complete block design (RCBD) with three replications. The unit plot size was 12 m² (4 m x 3 m). Nutrients N, P, K, S, Zn and B were applied as urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively during final plot preparation. Seeds of lentil (cv. BARI Masur-7) were treated using the fungicide Provex 200 (at 2.5 g kg⁻¹ seeds) before sowing for controlling of root rot disease. Treated seeds (@ 30 kg ha⁻¹) were sown on 09 November, 2015 and 16 November, 2016. Seeds were sown continuously in rows (10 rows/plot) maintaining row to row spacing of 30 cm. Hand weeding as well as thinning of seedlings were done at 25 days after sowing (DAS) maintaining the distance of plant to plant 05 cm by making a total of 800 plants per plot (12 m²). Again, hand weeding was done at 50 DAS. Three sprays were done with fungicide of Rovral starting from 55 DAS to control *Stemphylium* disease and two times insecticide (Karate @ 2 ml L⁻¹ of water) sprayed at 10 days interval starting from 60 DAS to overcome insect infestation. The crop was harvested at maturity. Data on seed yield (kg ha⁻¹) at around 10% moisture basis were recorded from the whole plot technique. For stover yield (kg ha⁻¹), mature plants were collected from two 1m² quadrates in each plot at harvest time. The yield contributing characters namely: plant height and number of pods plant⁻¹ were recorded from ten plants selected randomly from each unit plot. Pods were detached from every plant and the number of pods per plant was counted and averaged. Thousand seed weight (g) was determined by the counting of 500 seeds randomly from each plot and weighing through electronic balance and converting it into 1000-seed weight. For nodule counting per plant, 5 plants from each plot were selected randomly at seedling, vegetative, flowering and podding

stages. Plants were smoothly uprooted and the soil from roots was removed carefully using tap water. Separated nodules were sliced into two pieces to observe the inside color for nodules activity. The light-pink or red coloured nodules were considered as active.

Stover and seed samples were digested with di-acid mixture ($\text{HNO}_3\text{-HClO}_4$) (5:1) as described by Piper (1966) for determination of P (spectrophotometer method), K (atomic absorption spectrophotometer method), S (turbidity method using BaCl_2 by spectrophotometer), Zn (atomic absorption spectrophotometer method, VARIAN SpectrAA 55B, Australia) and B (spectrophotometer following azomethine-H method) concentration. The N concentration was determined by Micro-Kjeldahl method. Protein content was calculated multiplying the N value by 6.25 (Hiller *et al.*, 1948).

Data on yield attributes, number of nodules per plant, protein content and N, P, K, S, Zn, B content were computed on average of two study years. Data of all parameters were statistically analysed by ANOVA procedure. Then, multiple comparisons were done by LSD at 5% level (Statistix 10., 1985).

Results and Discussion

Effects of K application on yield attributes of lentil

The yield attributes of lentil such as plant height, pods per plant and seed weight responded significantly to application of different rates of potassium (Table 3). In the present experiment, plant height varied from 27.2 to 30.7 cm. The tallest plant (30.7 cm) was recorded from the treatment T_5 which was statistically identical with T_4 and T_3 treatments. The dwarf plant (27.2 cm) was noted for K control (T_1) treatment. The result is in agreement with the findings of Sahay *et al.* (2013) who observed the maximum plant height of lentil (43.5 cm) due to application of 90 kg $\text{K}_2\text{O ha}^{-1}$. Optimum dose of K can increase flowering, pod formation, grain set and early physiological maturity (Hasanuzzaman *et al.*, 2018). Different levels of K showed significant effect on the number of pods per plant (Table 3). The maximum number of pods per plant (48.4) was found in the treatment T_4 followed by T_5 treatment and the minimum number of pods per plant (30.0) was observed in K control (T_1) treatment (Table 3). Ali *et al.* (2007) reported on chickpea that application of 150 kg $\text{K}_2\text{O ha}^{-1}$ produced significantly maximum number of pods plant^{-1} (61.9). The K application contributed significantly to the seed weight of lentil. The 1000- seed weight varied from 17.2 to 19.9 g, the highest seed weight being recorded for treatment T_5 which was significantly higher than the other treatments. The lowest 1000- seed weight was recorded in K control treatment (Table 3). Higher K levels resulted in higher seed weight probably due to role of potash in translocation of photosynthates and its

ability to develop bold seeds (Ali *et al.*, 2007). Islam and Muttaleb (2016) reported that the higher amount of K helps transfer food material to develop grains.

Table 3. Effects of different levels of K on yield attributes of lentil (pooled data of two years)

Treatment	Plant height (cm)	No. of pods plant ⁻¹	1000- seed wt. (g)
T ₁ (Control)	27.2	30.0	17.2
T ₂ (30 kg K ha ⁻¹)	29.0	38.4	18.6
T ₃ (40 kg K ha ⁻¹)	29.5	39.7	19.0
T ₄ (50 kg K ha ⁻¹)	29.6	48.4	19.2
T ₅ (60 kg K ha ⁻¹)	30.7	44.7	19.9
CV (%)	2.84	3.14	1.71
LSD (0.05)	1.56	2.38	0.60

Effects of K application on yield of lentil

The seed yield of lentil responded significantly to the application of potassium (Table 4). Potassium involves increasing the utilization of carbohydrates, enhances the dry matter accumulation and ultimately increases the yields of crop (Cheema *et al.*, 2012). The highest seed yield of 1015 kg ha⁻¹ in the 1st year was recorded from T₄ which was significantly higher than other treatments except T₅ treatment (994 kg ha⁻¹). The lowest seed yield value (722 kg ha⁻¹) being noted in the K control (T₁) treatment. Similarly in the 2nd year, the significantly highest seed yield (1168 kg ha⁻¹) was recorded in T₄ treatment. The lowest seed yield was observed in K control treatment (Table 4). Potassium might have regulated the biosynthesis, conversion, and allocation of metabolites that ultimately increased the yield. Many research works support the idea that K is directly or indirectly responsible for higher yield of crops (Hasanuzzaman *et al.*, 2018). Sahay *et al.* (2013) reported that grain yield of lentil increased with increase in K level up to 90 kg K₂O ha⁻¹. Regarding stover yield of lentil, the trend was similar to that of seed yield. The mean stover yield (average of two years) of lentil varied from 1669 to 2542 kg ha⁻¹. The percent seed yield increase over control varied from 20.8 to 48.3%. The highest seed yield increase noted from T₄ treatment was followed by T₅ treatment and the lowest from T₂ treatment (Table 4). Jahan *et al.* (2009) reported that 34.2% grain yield increase of lentil over control was obtained by the application of 42 kg K₂O ha⁻¹.

Table 4. Effects of different levels of K on seed and stover yield of lentil

Treatment	Seed yield (kg ha ⁻¹)			% yield increase over control	Stover yield (kg ha ⁻¹)		
	1 st Yr.	2 nd Yr.	mean		1 st Yr.	2 nd Yr.	Mean
T ₁ (Control)	722	750	736	-	1793	1544	1669
T ₂ (30 kg K ha ⁻¹)	879	899	889	20.8	2233	1809	2021
T ₃ (40 kg K ha ⁻¹)	949	932	941	27.9	2538	1871	2205
T ₄ (50 kg K ha ⁻¹)	1015	1168	1092	48.3	2816	2267	2542
T ₅ (60 kg K ha ⁻¹)	994	1022	1008	36.9	2628	2073	2351
CV (%)	2.03	4.74	-	-	2.25	2.81	-
LSD (0.05)	34.9	85.0	-	-	102	101	-

Effects of K application on nodulation and protein content of lentil

Adequate K supply enhances the biological nitrogen (N) fixation (Srinivasarao *et al.*, 2003). Table 5 shows that the number of nodules per plant increased from 32 days after sowing (DAS) to 62 DAS, and then it decreased. Nodulation was influenced significantly due to application of potassium. At 32 days after sowing, the number of nodules per plant varied from 6.30 to 9.33, at 47 DAS it ranged from 15.4 to 26.7, at 62 DAS it was from 15.7 to 27.3 and at 77 DAS, this range varied from 11.1 to 16.9 (Table 5). The maximum number of nodules per plant was recorded from the treatment T₅ in all the dates of nodule collection followed by T₄ treatment except the collection date 47 (DAS) it was highest in T₄ treatment followed by T₅ treatment. The lowest number of nodules was found in the K control treatment (Table 5). The experimental results show that the maximum nodule formation occurred during early to mid flowering. After flowering, nodule efficiency was reduced. The result of this study indicates that the different rates of K application contributed for higher seed protein content in lentil (Table 5). The maximum seed protein (26.9%) of lentil was found in T₄ treatment followed by T₅, T₃ and T₂ treatments. The lowest amount (24.3%) was found in K control (T₁) treatment (Table 5). Similar result was observed by Sahay *et al.* (2013) who noted that the highest protein content (22.01%) in lentil grain was obtained by fertilization of 90 kg K₂O ha⁻¹.

Table 5. Effects of different levels of K application on number of nodules per plant and on protein concentration of lentil seed (pooled data of two years)

Treatment	No. of nodules 32 DAS	No. of nodules 47 DAS	No. of nodules 62 DAS	No. of nodules 77 DAS	Protein (%)
T ₁ (Control)	6.30	15.4	15.7	11.1	24.3
T ₂ (30 kg K ha ⁻¹)	7.98	23.3	23.7	15.4	26.2
T ₃ (40 kg K ha ⁻¹)	8.43	24.1	24.4	15.5	26.6
T ₄ (50 kg K ha ⁻¹)	8.83	26.7	25.8	15.3	26.9
T ₅ (60 kg K ha ⁻¹)	9.33	25.6	27.3	16.9	26.8
CV (%)	1.62	2.90	3.35	5.28	3.09
LSD (0.05)	0.25	1.26	1.47	1.48	1.53

Effects of K application on nutrient concentration of lentil seed

Potassium plays a significant regulatory role in numerous plants' physiological processes- seed germination and emergence, protein synthesis, nutrient content and nutrient balance (Marschner, 2012). The N, P, K, S, Zn, and B concentration of lentil (seed) was markedly influenced by the K application (Tables 6). The highest N concentration in lentil seed (4.31%) was found in the T₄ treatment, which was statistically identical to T₅, T₃ and T₂ treatments. The lowest seed N concentration (3.88%) was noted from the K control (T₁) treatment. In case of P concentration, the highest P content in seed (0.45%) was recorded in T₅ treatment followed by T₄ treatment. The lowest P concentration (0.31%) in seed was found in K control treatment (Table 6). The highest K concentration in lentil seed (0.66%) was recorded from the T₄ treatment, which was statistically similar to T₅, T₃ and T₂ treatments. The lowest seed K concentration (0.57%) was found in control (T₁) treatment (Table 6). Regarding S concentration, the highest S concentration in lentil seed (0.37%) was recorded in T₅ treatment followed by T₄ treatment. The lowest S concentration in seed was found in control (T₁) treatment (Table 6). The highest Zn concentration in lentil seed (75.7 ppm) was noted from the T₄ treatment. The lowest seed Zn concentration was noted in the control (T₁) treatment. The highest B concentration (46.4 ppm) in lentil seed was observed in the T₄ treatment, which was statistically similar to T₅ treatment. The lowest seed B concentration was estimated from K control (T₁) treatment (Table 6). Similar results were reported earlier that the K application influenced the uptake of N, P, K, S, Zn, and B (Kurahde *et al.*, 2015; Chaudhari *et al.*, 2018).

Table 6. Effects of different levels of K on nutrient concentration of lentil seed (Pooled data of two years)

Treatment	N (%)	P (%)	K (%)	S (%)	Zn (ppm)	B (ppm)
T ₁ (Control)	3.88	0.31	0.57	0.28	74.1	40.2
T ₂ (30 kg K ha ⁻¹)	4.20	0.38	0.62	0.31	74.5	42.0
T ₃ (40 kg K ha ⁻¹)	4.26	0.40	0.63	0.33	74.8	44.3
T ₄ (50 kg K ha ⁻¹)	4.31	0.44	0.66	0.36	75.7	46.4
T ₅ (60 kg K ha ⁻¹)	4.28	0.45	0.64	0.37	74.9	46.2
CV (%)	3.04	4.72	4.18	3.03	1.34	2.08
LSD (0.05)	0.24	0.04	0.05	0.02	ns	1.72

Conclusion

Application 50 kg K ha⁻¹ gave the highest seed yield of lentil. The K application contributed to pod setting, which finally increased the seed yield. The same K rate also showed the highest nutrient and protein content in lentil. Application of 50 kg K ha⁻¹ along with N₁₅P₂₀S₁₀Zn₂B_{1.5} kg ha⁻¹ can be recommended for lentil cultivation in terrace soils of Bangladesh.

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PHYSICAL AND ENGINEERING PROPERTIES OF BARI RELEASED THREE GROUNDNUT VARIETIES

M. A. HOQUE¹

Abstract

The knowledge of the physical characteristics of particles is essential for the designer of agricultural machines. The study was aimed to determine physical and engineering properties of three selected varieties of groundnuts cultivated in Bangladesh such as Dhaka-1, BARI Badam-8 and BARI Badam-9 at safe storage moisture content of 7.5%. One hundred groundnut pods and kernels were randomly selected and the length, width and thickness were measured using a vernier caliper. The geometric mean diameter, sphericity, aspect ratio was calculated using standard formula and measured values. Bulk density, true density, mass and porosity were found through direct weighing and water displacement. Angle of repose of pods and kernels was also measured on wood, glass and mild steel sheet surfaces. BARI Badam-9 had the highest pod geometric mean diameter and BARI Badam-8 had the highest kernel geometric mean diameter. Sphericity of groundnut pod was the highest for Dhaka-1. Surface area of pod and aspect ratio of both pod and kernel were the highest in BARI Badam-9. Porosity of the pod was the least for BARI Badam-8. Angle of repose of kernel varied on wood and glass. But it was similar for kernel on MS sheet for the varieties. This result will be useful to design and develop groundnut processing equipment for different varietal variability.

Keywords: Groundnut, Engineering properties, geometric dimensions, BARI

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the important oilseed crops in the world. It is rich in protein and has a high energy value. Groundnut is grown on 26.4 million ha worldwide with a total production of 37.1 million metric tons (Mt) and an average productivity of 1.4 Mt/ha (GOI, 2008). Groundnut is one of the oilseed crop in Bangladesh on the basis of both in area and production (Biswas *et al.*, 2000). Production area and amount of groundnut in Bangladesh is 36842 ha and 66000 metric tons, respectively (BBS, 2017). All parts of groundnut are consumed such as kernels and oil for human and hay for livestock feeds. It is also processed into cake or further processed into confectionary products or snack food. Groundnut oils used in make-up, medicines, textile materials, cosmetics, nitroglycerin, plastics, dyes and paints as well as many other uses (Firouzi *et al.*, 2009). Groundnut production and marketing play a

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significant role in the agricultural economies as the most important sources of employment and income (Ntare *et al.*, 2008).

The knowledge of the engineering and other physical properties of groundnut is very fundamental because they expedite the design and development of equipment for harvesting, handling, separation, oil extraction and other forms of processing agricultural materials (Singh and Goswami, 1996; Chukwu and Sunmonu, 2010). Some studies had been done on properties of groundnut kernels (Olajide and Igbeka, 2003; Aydin, 2007; Davies, 2009, Firouzi *et al.*, 2009, Atasie *et al.*, 2009, Jean-Baptiste, *et al.*, 2012, Fashina *et al.*, 2014). Hossain and Haque (1999) evaluated geometric properties of four Bangladeshi groundnut varieties namely Basanti, Maischar, Jhinga and Tridana. But, there is no study on such properties for BARI developed latest groundnut varieties.

In developing country like Bangladesh, the equipment used in the processing of groundnut has been generally designed without taken into consideration of the physical properties of the seeds. Most of the agricultural processing equipment designed for planting, harvesting, threshing, handling, processing and storage of agricultural materials are largely seen to be of low efficiency in terms of the quality of their output and the economy of using which is largely due to non-availability of data and other engineering properties such as size, mass, density and sphericity of the materials to design such machines. Akanni *et al.*, (2005) reported that inadequate engineering data of groundnuts have greatly influenced the development of processing machinery. The study of these parameters has become necessary to develop an effective groundnut processing equipment resulting in a low breakage of pods and kernels. Therefore, this study was investigated to obtain some engineering properties of pods and kernels of the three selected groundnut varieties.

Materials and Methods

The experiment was conducted at Farm Machinery and Postharvest Process Engineering (FMPE) Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh during 2015-16. Three varieties of groundnut commonly cultivated in Bangladesh were identified, selected and collected from Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur. These were Dhaka-1, BARI Badam-8 and BARI Badam-9 (Table-1). These varieties were selected on the basis that BARI Badam-8 and BARI Badam-9 are trying to replace local and old varieties for better yield and reduce insect and pest susceptibility (BARI, 2017). Samples were collected at maturity from the field and harvesting was done manually. The pods were cleaned to remove all foreign materials (Table-1).

Table 1. Pictorial views of Pod and Kernel of different groundnut varieties

	Dhaka-1	BARI Badam-8	BARI Badam-9
Pod			
Kernel			

All samples were dried with mechanical dryer and maintained same storage moisture content of 7.5% (db) for the experiment. The moisture content was determined by drying the samples in an oven at 60°C for 12 h to a constant weight and their respective moisture contents were determined using Equation (1) as suggested by Baumler *et al.* (2006).

$$MC(\%) = \frac{W_{wd} - W_d}{W_d} \times 100 \quad (1)$$

Where,

MC= Moisture content (db), %

W_{wd} = Initial weight of sample, g

W_d =Final weight of sample, g

In order to determine dimensions, one hundred groundnut pods were randomly selected. For each pod, the three principal dimensions, namely length, width and thickness of pods and kernels were measured using a vernier caliper having the least count of 0.01 mm. The grain mass was determined using an electronic balance having an accuracy of 0.01 g. The physical properties of the three groundnut varieties were determined by following some equations.

According to Baryeh (2001) and Fashina *et al.* (2014), the geometric mean diameter, the sphericity and the surface area of groundnut pods and kernels were calculated using the following relationships (Equations (2) to (5)).

$$D_{gmp} = (LWT)^{1/3} \quad (2)$$

$$D_{gmk} = (lwt)^{1/3} \quad (3)$$

$$\varphi_p = \frac{D_{gmp}}{L} \quad (4)$$

$$\varphi_k = \frac{D_{gmk}}{l} \quad (5)$$

Where,

L= pod length, mm

W= pod width, mm

T= pod thickness, mm

l= kernel length, mm

w= kernel width, mm

t= kernel thickness, mm

D_{gmp} = geometric mean diameter of pod, mm

D_{gmk} = geometric mean diameter of kernel, mm

φ_p = pod sphericity, %

φ_k = kernel sphericity, %

The surface areas S (cm^2) of groundnut pods and kernels were calculated using Equations (6) and (7) stated below (Moshenin, 1986 and Jean-Baptiste *et al.*, 2012):

$$S_{ap} = \pi \times D_{gmp}^2 \quad (6)$$

$$S_{ak} = \pi \times D_{gmk}^2 \quad (7)$$

Where:

S_{ap} = surface area of the pod, mm^2

S_{ak} = surface area of the kernel, mm^2

The aspect ratio (R) is the ratio of the width of the pod or the kernel to its respective length which was calculated by applying the following relationships according to Maduako and Faborode (1990):

$$R_{ap} = \frac{W}{L} \times 100 \quad (8)$$

$$R_{ak} = \frac{w}{l} \times 100 \quad (9)$$

Where:

R_{ap} = Aspect ratio of the pod

R_{ak} = Aspect ratio of the kernel

The bulk density (ρ_b), which is defined as the ratio of the mass sample of the grains to its total volume, was determined according to Singh and Goswami (1996):

$$\rho_b = \frac{M}{V} \quad (10)$$

where ρ_b = Bulk density, kg/m³

M = Mass of seeds or kernels, kg

V = Volume occupied, m³

The volumes of randomly selected 100 groundnut pods from each of the three selected varieties were determined by displacement method (Olajide and Ade-Omowaye, 1999). Water was poured in a 1000 cm³ capacity measuring cylinder. The initial level was recorded. Three groundnut pods were immersed in the water at a time while noting the new level to which the water rose. Since groundnut pods float in water, a small metal bob was used as a sinker. Its rise in water level was also noted such that it was deducted from the final water level when tied with the groundnut pods. The volume of the groundnut pod was computed by subtracting the volume of the bob from the difference. The experiment was replicated ten times for each variety. The weights of 100 randomly selected groundnut pods and kernels from the three selected varieties were determined by digital electronic weighing balance (2 kg capacity with 0.01 accuracy) as suggested by Milani *et al.* (2007); Mohsenin (1986). The true density was determined using the unit values of unit volume and unit mass of individual pod and kernel and calculated using the following relationship:

$$\rho_t = \frac{M}{V_d} \quad (11)$$

where ρ_t = True density, kg/m³

M = Mass of seeds or kernels, kg

V_d = Volume of water displaced, m³

The porosity value (ε) which is defined as the fraction of space in the bulk grain, not occupied by the grain, was calculated from the following relationship (Mohsenin, 1986):

$$\varepsilon(\%) = \left(1 - \frac{\rho_b}{\rho_t}\right) * 100 \quad (12)$$

Thousand grain weight (g) was determined by weighing 100 seeds and kernels in an electronic balance to an accuracy of 0.01 g and then multiplying by 10 to get

the mass of 1,000 grains. The angle of repose (θ) of pods or kernels was measured by the emptying method in bottomless cylinder (diameter, 5 cm; height, 8.5 cm). The cylinder filled with groundnut seeds or kernels was placed on a wooden table, glass sheet and Mild Steel (MS) sheet separately and raised slowly until it forms a heap. The diameter (D) and height (H) of the heap were recorded (Malik and Saini, 2016). Using the following equation, θ was determined.

$$\theta = \tan^{-1} \frac{2H}{D} \quad (13)$$

Results and discussion

Moisture content (MC) of collected samples was maintained at 7.5% (db) over the experimentation by mechanical drying. Physical properties of groundnut pod and kernel are genetically controlled but the application of these values in practical field is affected by the environmental factors in particular moisture content (Baumler *et al.*, 2006; Yalcin, 2007; Firouzi *et al.*, 2009). Thus, the engineering properties of three selected groundnut varieties of Bangladesh were measured at 7.5% MC for both pods and kernels. Frequency distribution of length of pod and kernel of selected three varieties is shown in Fig. 1. Length of pod and kernel of BARI Badam-9 was the highest where pod ranged from 22 to 34 mm and kernel ranged from 8 to 16 mm (Fig. 1). Width of kernel ranged from 4 to 10 mm irrespective of variety and pod width ranged least (10 to 14 mm) as shown in Fig. 2. Thickness of kernel also ranged from 4 to 10 mm irrespective of variety (Fig. 3). Pod width of BARI Badam-8 and BARI Badam-9 ranged from 10 to 14 mm whereas that of Dhaka-1 ranged within 8 to 16 mm range (Fig. 2).

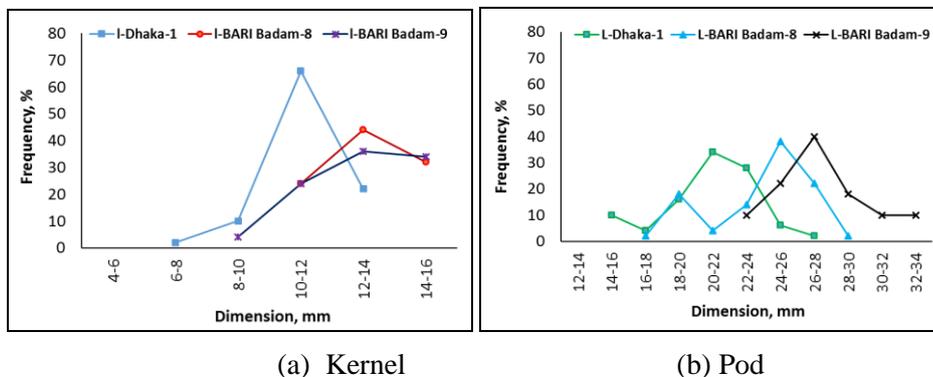


Fig. 1. Frequency distribution of length of pod and kernel of selected three varieties.

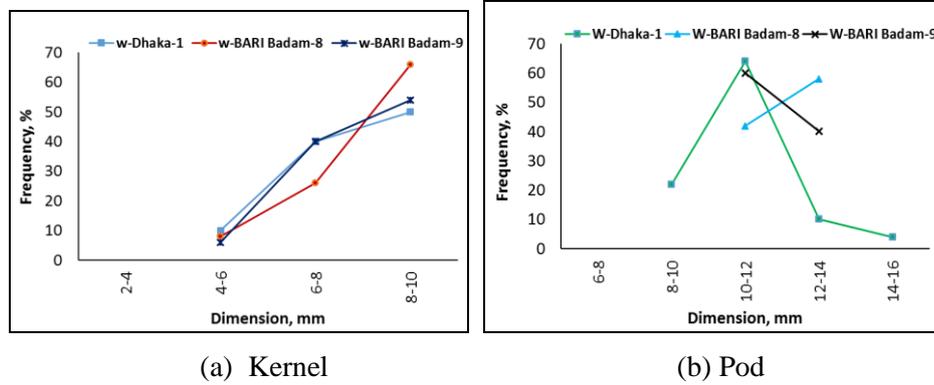


Fig. 2. Frequency distribution of width of pod and kernel of selected three varieties.

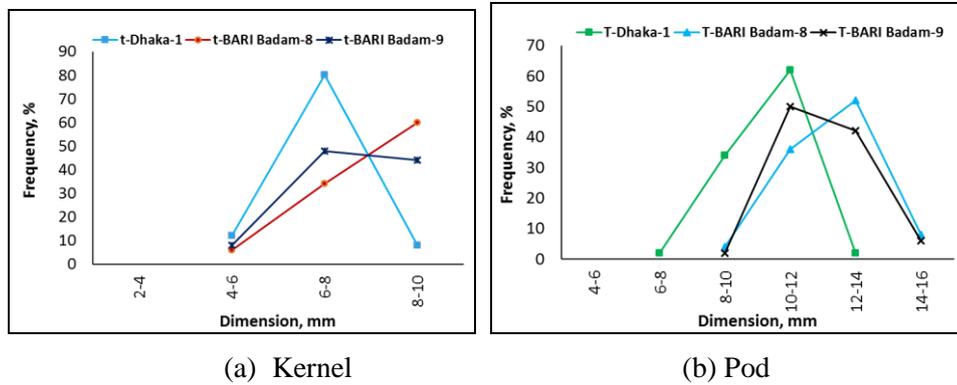


Fig. 3. Frequency distribution of thickness of pod and kernel of selected three varieties.

Physical dimensions (length, width and thickness) are important parameters which are useful in determining aperture size in grain handling machinery. The average values for the length, width, thickness, geometric mean diameter, sphericity, surface area, aspect ratio, bulk density, true density, porosity, thousand grain weight and angle of repose of the three selected groundnut varieties were measured at moisture content of 7.5% (db). The determined engineering properties of the groundnut pods are presented in Table 2 while their corresponding values for the kernels were exposed in Table 3. The highest mean length, width and thickness were recorded for BARI Badam-9. It was exposed from the geometric dimensions of these varieties that BARI Badam-9 had the highest pod geometric mean diameter (12.08 mm) and BARI Badam-8 had the highest kernel geometric mean diameter (9.74 mm) (Table 2). The lowest pod and kernel geometric mean diameter were for Dhaka-1. The average dimension of the pods in length, width and thickness of Dhaka-1 were 20.99, 11.20, and 10.46 mm, respectively. Thus, it has been recognized that substantial differences among the three selected groundnut varieties cultivated in Bangladesh were

found in terms of their geometric dimensions. This is in agreement with the variability for the engineering properties among varieties reported by Fashina *et al.* (2014); Jean-Baptiste *et al.* (2012); Firouzi *et al.* (2009); Olajide and Igbeka (2003).

The ability of the grain to roll or slide depends on its aspect ratio and sphericity. Sphericity of both the groundnut pods and the kernels are dynamic parameter of processing. Sphericity affects how easily grains can be processed by the food industry (Kabas *et al.*, 2001). It also indicates the relative nearness of the product shape to spherical shape. Sphericity of groundnut pod was the highest for Dhaka-1 (65%) though that of kernel was statistically similar for Dhaka-1 and BARI Badam-8. The average kernel sphericity was lower than that reported by Olajide and Igbeka (2003) corresponding to the value of 76% but higher than the values of 51.6% to 57.1% obtained by Aydin (2007).

Geometric surface is dependent on length, breadth and thickness which is importantly useful in determination of heat and mass transfer (Adebowale *et al.*, 2011). Surface area of pod was found the highest in BARI Badam-9 (778 mm²) but for kernel, it was the highest in BARI Badam-8 (301 mm²).

The aspect ratio of a product is an indicator which expresses its tendency towards an oblong shape. The study found the aspect ratio of the groundnut pods for Dhaka-1, BARI Badam-8 and BARI Badam-9 varieties to be 54.06, 50.58 and 44.23, respectively. The corresponding aspect ratio values for the kernels were found to be 71.63, 65.08 and 59.70. Significantly lowest aspect ratio of pod and kernel was found in BARI Badam-9.

Bulk density of BARI Badam-8 was the highest for both pod (342.51 kg/m³) and kernel (658.56 kg/m³). The value of kernel agrees with Davies (2009) who found the average density of 753 kg/m³. Porosity of the pod was the least for BARI Badam-8 (64.06%) but that of kernel was similar for all varieties.

Seed weight is an important attribute that determines the consumer preference in groundnut cultivars. Kernel weight had positive and significant correlations with geometric surface, degree of sphericity and porosity of the seeds (Jean-Baptiste *et al.*, 2012).

Research findings indicate positive correlation between weight and oil content of groundnut kernels (Dwivedi *et al.*, 1990). Thousand grain weight of BARI Badam-8 was the highest (886.67 g) among the selected varieties but for kernel, it was statistically similar between BARI Badam-9 (497.33 g) and BARI Badam-8 (373.33 g). Relatively lighter pod and kernel were obtained from Dhaka-1 variety.

Table 2. Some physical and engineering properties of the pods of the selected groundnut varieties at 7.5 % MC (db)

	Dhaka-1	BARI Badam-8	BARI Badam-9	CV	HSD
Length, mm	20.99±2.72 ^c	23.98± 3.20 ^b	27.09±2.35 ^a	10.43	1.19
Width, mm	11.20±1.24 ^b	11.88± 1.09 ^a	11.90±0.72 ^a	8.23	0.46
Thickness, mm	10.46±0.99 ^b	12.44± 1.20 ^a	12.08±1.05 ^a	8.06	0.45
Geometric mean diameter, mm	13.46±1.19 ^c	15.20± 1.25 ^b	15.71±0.87 ^a	6.24	0.44
Sphericity, %	64.72±6.05 ^a	64.08± 6.17 ^b	58.24±3.97 ^b	8.63	0.03
Surface area, mm ²	574.18±100.28 ^c	731.17±116.26 ^b	777.84±85.95 ^a	12.29	40.61
Aspect ratio	54.06±8.28 ^a	50.58±9.37 ^a	44.23±4.51 ^b	14.91	3.52
Bulk density, kg/m ³	303.87±5.52 ^b	342.51±11.05 ^a	311.60±3.03 ^b	2.01	11.58
True density, kg/m ³	908.14±30.35 ^b	968.43±12.94 ^a	970.69±13.11 ^a	1.95	53.81
Porosity, %	66.51±1.51 ^a	64.06±0.77 ^b	67.93±0.40 ^a	1.12	2.15
1000 grain wt, g	593.33 ±23.09 ^c	813.33±11.55 ^b	886.67±30.55 ^a	2.05	45.52
Angle of repose (degree) on					
Wood	29.28±0.43	26.24 ±0.70	28.66±2.81	6.60	ns
Glass	28.51±0.47	24.94±2.18	26.22±1.76	7.47	ns
MS Sheet	28.76 ±2.00	25.03±2.63	26.97 ±1.78	5.70	ns

Foot notes: Value is for Mean± sd; Similar letter in same rows did not significantly varied

The angle of repose of a granular material is the steepest angle of descent or dip of the slope relative to the horizontal plane when material on the slope face is on the edge of sliding. Angle of repose of groundnut pod on wood, glass and MS sheet did not vary for the selected varieties. Again, angle of repose of kernel was statistically similar for BARI Badam-8 and BARI Badam-9 but significantly higher than that found for Dhaka-1 on wood and glass. But angle of repose did not vary for kernel on MS sheet for the varieties. This might be due to the relative smoothness of the surface of the kernels. Results found from this experiment were similar to that of Davies (2009) who noted the angle of repose as 28° for pod at moisture content of 7.6% (db).

The angle of repose was higher for pod than kernel on all surfaces as evaluated. This is because groundnut pods are more cohesive than kernels. Eventually more cohesive surface of the tested grain will have higher angle of repose which were also reported on sunflower (Santalla and Mascheroni, 2003) and Canavalia (Niveditha *et al.*, 2013).

Table 3. Some physical and engineering properties of the kernels of the selected groundnut varieties at 7.5 % MC (db)

	Dhaka-1	BARI Badam-8	BARI Badam-9	CV	HSD
Length, mm	11.24 ± 1.13 ^b	13.27±1.55 ^a	13.16±1.63 ^a	11.64	0.70
Width, mm	8.02 ± 1.09 ^b	8.59±1.02 ^a	7.84±1.61 ^{ab}	15.39	0.60
Thickness, mm	7.12±0.83 ^b	8.18±0.99 ^a	7.75±1.23 ^a	12.73	0.47
Geometric mean diameter, mm	8.61±0.89 ^c	9.74±0.93 ^a	9.24±1.29 ^b	10.84	0.47
Sphericity, %	76.83±5.55 ^a	73.81±6.24 ^a	70.41±8.27 ^b	9.35	0.03
Surface area, mm ²	235.57±47.16 ^c	300.94±54.80 ^a	273.14±67.84 ^b	20.31	26.09
Aspect ratio	71.63±8.71 ^a	65.08±7.43 ^b	59.70±12.16 ^c	15.17	4.73
Bulk density,kg/m ³	630.94±6.05 ^c	658.56±7.20 ^a	647.51±4.62 ^b	0.89	10.37
True density,kg/m ³	930.31±41.55	983.33±28.87	994.67±23.44	4.00	ns
Porosity, %	31.99±3.63	32.55±1.54	34.99±1.56	8.78	ns
1000 grain wt, g	241.33±8.08 ^c	373.33±11.55 ^a	497.33±11.72 ^a	3.21	34.69
Angle of repose (degree) on					
Wood	17.76±0.66 ^b	20.05±0.80 ^a	20.67±0.21 ^a	3.00	1.70
Glass	16.77±2.18 ^b	19.55±1.41 ^a	19.27±1.39 ^{ab}	4.73	2.55
MS Sheet	17.67±1.57	19.87±2.38	19.65±1.85	10.71	ns

Foot notes: Value is for Mean± sd; Similar letter in same rows did not significantly varied

Conclusions

BARI Badam-9 had the highest pod geometric mean diameter and BARI Badam-8 had the highest kernel geometric mean diameter at moisture content of 7.5% (d.b). The lowest pod and kernel geometric mean diameters were for Dhaka-1. Sphericity of groundnut pod was the highest for Dhaka-1. Surface area of pod was the highest in BARI Badam-9. Aspect ratio of pod and kernel was the lowest in BARI Badam-9. Porosity of the pod was the least for BARI Badam-8. Angle of repose of kernel was statistically similar for BARI Badam-8 and BARI Badam-9 on wood and glass. But angle of repose did not vary for kernel on MS sheet for the varieties. The results thus help the designers to design an efficient groundnut processing machines for groundnut varieties in Bangladesh.

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INCIDENCE OF MAJOR INSECT PESTS ON SWEET GOURD GERMPLASM

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Abstract

Abundance of the major insect pests viz., red pumpkin beetle, epilachna beetle and fruit fly on twelve sweet gourd germplasms namely BD 264, BD 265, BD 266, BD 268, BD 269, BD 274, BD 275, BD 277, BARI Mistikumra 1, BARI Mistikumra 2, Gazipur Local Line and China line was studied in the experimental field of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during July 2018 to June 2019. The mean number of red pumpkin was the highest (2.3 adults/ 3 leaves) during 4th week of December and the lowest (0.7 adults/ 3 leaves) during 4th week of March. The mean number of grub (6.5 grubs/3 leaves) and adult (2.3 adults/ 3 leaves) of epilachna beetle were the highest during 2nd week of March and 4th week of February, respectively. The mean number of fruit fly was found the lowest (1.0 adults plant⁻¹) during 5th week of January and the highest (2.5 adults plant⁻¹) during 4th week of February. BARI Mistikumra 1, BARI Mistikumra 2 and China Line provided the lowest yield ranged from 4.8 ± 5.3 to 7.4 ± 0.5 t ha⁻¹ and the remaining germplasms showed statistically similar yield.

Keywords: *Cucurbita moschata*, germplasms, red pumpkin beetle, epilachna beetle, fruit fly.

Introduction

Sweet gourd, *Cucurbita moschata* Duch, a nutritive vegetable belongs to the family Cucurbitaceae grows in Bangladesh and around the world. Cucurbitaceae is one of the largest families having 118 genera and 825 species (Rai and Kumar, 2008). In Bangladesh, a total of 28.5 thousand hectares of land were occupied for sweet gourd cultivation with an annual production of 294.5 thousand tons in the year of 2016-17, and the average yield of sweet gourd was 9.22 t ha⁻¹ and 11.0 t ha⁻¹ in summer and winter, respectively (BBS, 2017).

The red pumpkin beetle, epilachna beetle, cucurbit fruit fly, thrips, cutworm, aphid and whitefly are the major constraints of cucurbit production due to their constant attacks which lead to severe yield loss. Among the harmful insects, red pumpkin beetle *Aulacophora foveicollis* Lucas (Coleoptera: Chrysomelidae), epilachna beetle *Epilachna dodecatigma* Wied., *E. vigintioctopunctata* Fab. (Coleoptera: Coccinellidae) and cucurbit fruit fly *Bactrocera cucurbitae*

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Coquillett, *B. dorsalis* Hendel (Diptera: Tephritidae) showed higher abundance and caused serious damage on sweet gourd (Ali *et al.*, 2015; Nancy *et al.*, 2018).

Red pumpkin beetle attacks young plants, leaves and flowers and feed on both surface of leaves and produce a characteristic, circular ring like injury and cause 30 to 100% yield loss (Aslam *et al.*, 2017). Both adult and grub of epilachna beetle infest throughout the growth stages of crop and the grubs scrap the epidermis while the adults make semicircular cuts in rows on the epidermis of leaves thus cause up to 80% infestation of the host plant (Ghule *et al.*, 2014). Female fruit fly deposits eggs below the skin of the fruit and the maggots developed inside the fruit feed on the inner pulp and they cause up to 71.5% fruit infestation on sweet gourd in Bangladesh (Amin *et al.*, 2011a).

Seasonal variations of the weather factors play a vital role in multiplication, growth, development and distribution of insects, and influence on their population dynamics (Namni *et al.*, 2017). Fruit flies showed fluctuations in their abundance on sweet gourd and caused higher infestation in summer than winter (Amin *et al.*, 2019). Plant species and their varieties, cultivars and germplasms varied in their morphological traits and biochemical contents and affect the growth, development, reproduction and abundance herbivore insects (Amin *et al.*, 2011b; Amin *et al.*, 2015a; Amin *et al.*, 2017).

Information on population fluctuations and infestation of the major insect pests is important in forecasting and warning system and to find out resistant germplasm through screening is very useful in pest management program. With this point in view, the study was conducted to know the abundance of red pumpkin beetle, epilachna beetle and fruit fly on twelve germplasms of sweet gourd.

Materials and Methods

Study site and condition

The study was conducted during July 2018 to June 2019 in the field and laboratory of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh. The site is located at 25°25' North latitude and 89°5' East longitude having annual mean maximum and minimum temperatures, relative humidity and rainfall 36.0 and 12.7 °C, 65.8% and 237.6 cm, respectively (Amin *et al.*, 2015b).

Experimental materials and raising of seedling

Twelve sweet gourd germplasm, namely BARI Mistikumra-1, BARI Mistikumra-2, BD 264, BD 265, BD 266, BD 268, BD 269, BD 274, BD 275, BD 277, Gazipur Local Line and China Line were used in this study. The seeds were collected from Bangladesh Agricultural Research Institute, local market of Gazipur and Department of Entomology, BSMRAU, and the seeds were sown in polybags on 14 November to raise seedling.

Experimental design and cultivation of the germplasms

The germplasms were cultivated in 4.0 m × 3.0 m plots following randomized complete block design with three replications. The spacing between block to block and plot to plot was 1.0 m and 1.0 m, respectively. Three weeks aged seedlings were transplanted to the field on December 4, 2018. All the intercultural operations except insect pest management were done whenever necessary and fertilizers were applied according to Fertilizer Recommendation Guide (FRG, 2018).

Observation of plant growth and morphological traits

Weekly observations were done to collect data on initiation of branch, flower and fruit, fruit elongation, maturity of fruit for market and seed production.

Observation of insect abundance

Systemic sampling at weekly interval was employed to collect data on the abundance of red pumpkin beetle, epilachna beetle and fruit fly. Five plants for each germplasm were selected and the abundance (number/ 3 leaves) of adult red pumpkin beetle, and grub and adult epilachna beetle on top, middle and bottom leaves of a plant was noted. The number of adult fly sitting on the fruits of a plant was considered to know its abundance and the observations were replicated for five times.

Quantifying yield

The mature fruits of each plot were harvested and weighed using a digital balance (CANRY, China) and the data were converted to ton ha⁻¹.

Data analysis

One way analysis of variance (ANOVA) followed by Tukey's HSD posthoc test was employed for analyzing the data. All the analyses were performed using IBM SPSS 21.0.

Results and Discussion

The abundance of adult red pumpkin beetle on sweet gourd germplasms showed fluctuations throughout the study period (Figure 1). The incidence of red pumpkin beetle was found from 2nd week of December to 4th week of March. Red pumpkin beetle population showed a sudden decrease in 3rd week of December having the mean abundance 1.0 adult/3 leaves. This might happen due to sudden winter rainfall during that period. Khan *et al.* (2015) found that rainfall had negative impact on red pumpkin beetle population. Red pumpkin beetle population sharply increased and reached to the peak with mean abundance 2.3 adults/3 leaves during 4th week of December. This finding was different from that

of Khan *et al.* (2015) who found the peak abundance of red pumpkin beetle during February to April. The variation might happen due to the variation of crop growing period. They conducted the experiment during summer whereas the present study was conducted during winter. With the advent of plant growth, the population of beetle declined. As the beetles prefer young plants, their population was the maximum during early growing season. Shrikrushna (2012) reported that the adult and grub of the insect caused the most serious damage to seedlings due to their attractive greenness and palatability. During the next few months, red pumpkin beetle showed a little change in its population. The beetle population increased slightly with mean abundance 1.4 adults/3 leaves during 2nd week of March and finally decreased at the very end of growing season during 4th week of March (0.7 adult/3 leaves).

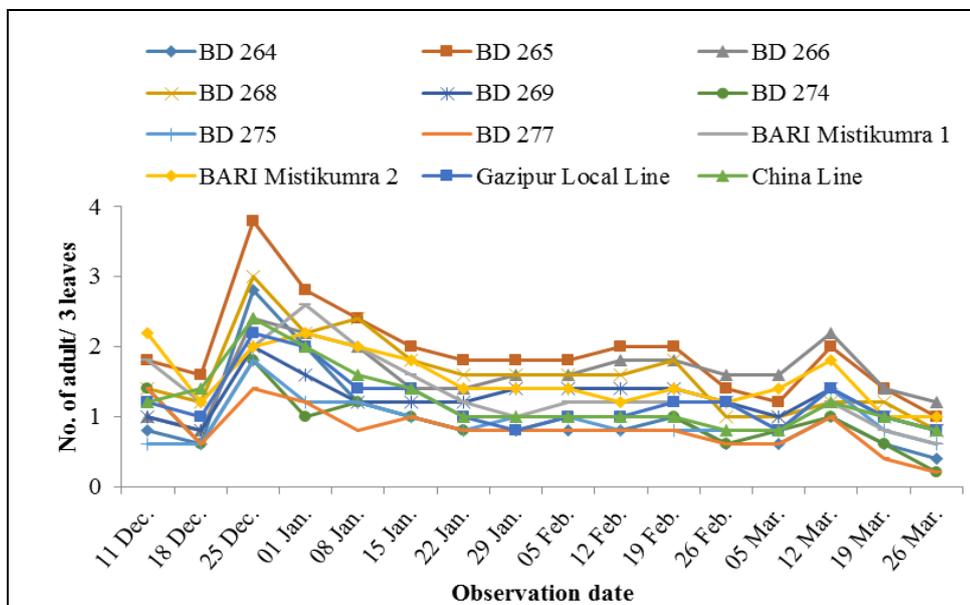


Fig. 1. Abundance of red pumpkin beetle on twelve sweet gourd germplasm during December 2018 to March 2019.

In the present study, the grub of epilachna beetle was first observed during 2nd week of January and was persistent until harvesting of the crop (Figure 2). The presence of grub was more or less constant throughout the growing period and the lowest abundance of grub was recorded in 2nd week of January with mean abundance 2.5 grubs/3 leaves. The population of grub reached its peak (6.5 grubs/3 leaves) in 2nd week of March. Ghule *et al.* (2014) found that the population of epilachna beetle remained active during March to May. Uikey *et al.* (2016) observed that the population of epilachna beetle on bottle gourd remained active during the warmer part of the crop growing season and found a maximum of 8.4 grubs plant⁻¹ during the 4th week of March.

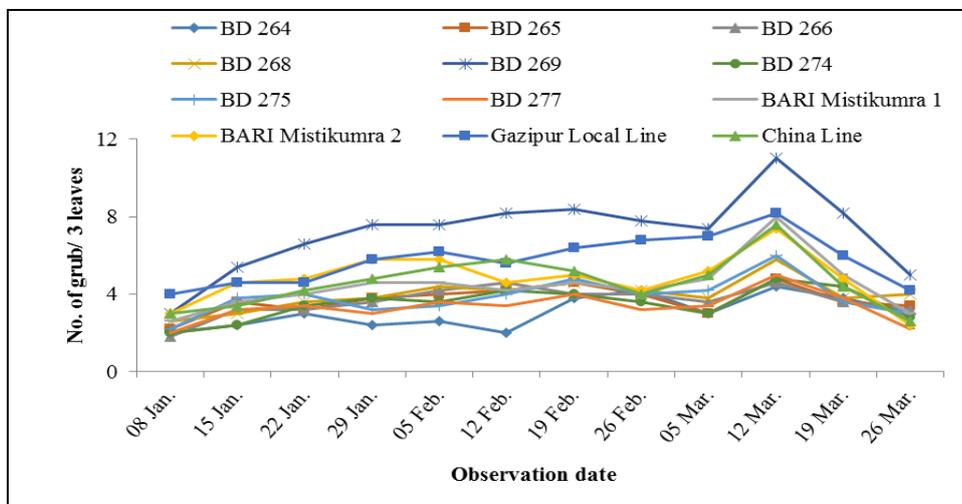


Fig. 2. Abundance of grubs of epilachna beetle on twelve sweet gourd germplasm during December 2018 to March 2019.

The adult epilachna beetle was first observed in 2nd week of January and was continuously present till 4th week of March (Figure 3). The mean abundance of the adult was the lowest (1.4 adults/ 3 leaves) during 1st week of February. Then the number of adult epilachna beetle showed an increasing trend and reached the peak during 4th week of February with the mean abundance 2.3 adults/3 leaves. After that, the abundance was gradually decreasing till 4th week of March, the period of final harvesting. Bhowmik and Saha (2017) reported epilachna beetle as a serious pest of bottle gourd found its infestation from early September.

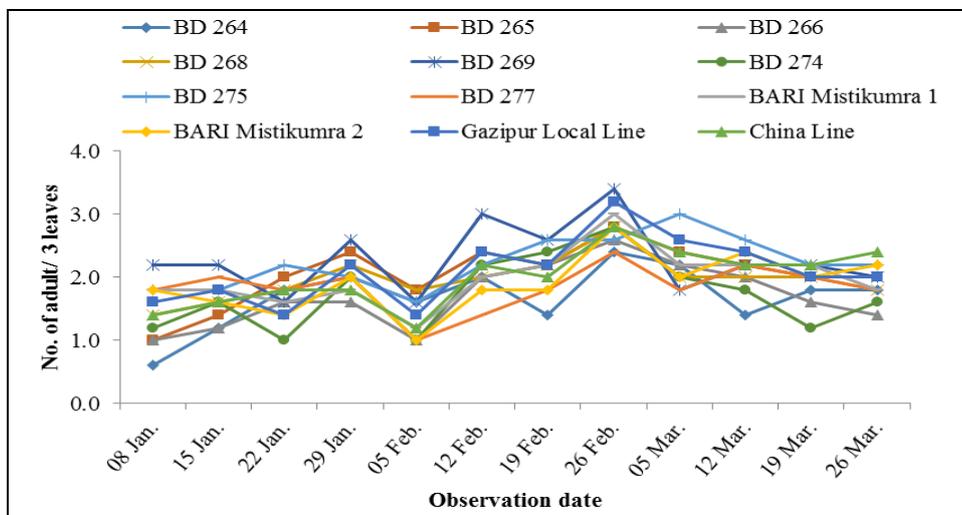


Fig. 3. Abundance of adult epilachna beetle on twelve sweet gourd germplasm during December 2018 to March 2019.

The population of adult fruit fly started to appear in 5th week of January which coincided with the period of fruit initiation and remained in the field till harvesting (Figure 4). The lowest mean number of fruit fly (1.0 plant⁻¹) was found during 5th week of January. The peak abundance of adult fruit fly was recorded during 4th week of February with mean abundance 2.5 plant⁻¹. Then the population declined and a little number of fruit flies was recorded at the end of growing season. The present finding showed agreement with Amin *et al.* (2019) who reported that the *B. cucurbitae* increased in their abundance from the second week of January, increasing before reaching peak abundance in the fourth week of February.

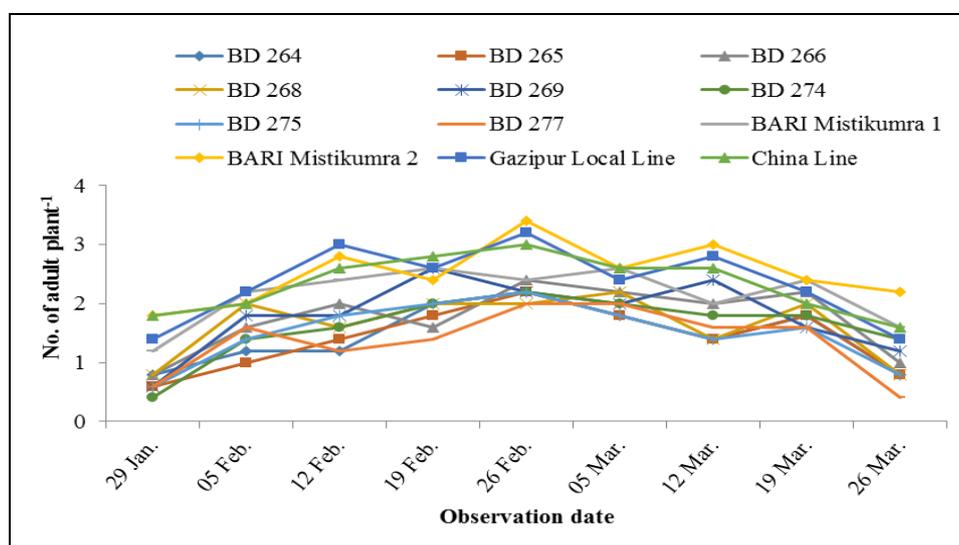


Fig. 4. Abundance of adult fruit fly on twelve sweet gourd germplasm during December 2018 to March 2019.

Different germplasms of sweet gourd vary in their durations of growth and development. The study revealed that there was significant variation in the durations of different developmental phenomena such as branch initiation ($F_{11,48} = 5.3$, $p < 0.001$), flower initiation ($F_{11,48} = 10.5$, $p < 0.001$), fruit initiation ($F_{11,48} = 3.2$, $p < 0.01$), fruit elongation ($F_{11,48} = 2.8$, $p < 0.01$), marketable maturity of fruit ($F_{11,48} = 5.3$, $p < 0.001$) and seed production maturity of fruit ($F_{11,48} = 3.4$, $p < 0.01$) among twelve sweet gourd germplasms (Table 1). Results showed that the duration of branch initiation was the highest and statistically similar in BD 264, BD 274 and BARI Mistikumra 1 having mean duration 26.8 ± 1.1 , 26.8 ± 0.8 and 26.6 ± 0.7 days after transplanting (DAT), respectively. BD 266 took the shortest period for initiating branch with mean duration 20.2 ± 0.4 DAT. In case of flower initiation, Gazipur Local Line took the highest time (46.0 ± 0.7 DAT). BD 274 and BD 275 showed statistically similar results and took the lowest

Table 1. Variation in the durations (mean \pm SE days after transplanting) of different developmental phenomena among twelve sweet gourd germplasm during December 2018 to March 2019

Germplasms	Developmental time at different DAT						
	Branch initiation	Flower initiation	Fruit initiation	Fruit elongation	Marketable maturity of fruit	Seed production maturity of fruit	
BD 264	26.8 \pm 1.1 a	42.0 \pm 1.0 bf	56.8 \pm 0.8 ac	61.0 \pm 0.8 ab	98.4 \pm 1.2 ad	106.6 \pm 0.9 ab	
BD 265	25.0 \pm 0.6 ac	43.2 \pm 0.8 ae	56.4 \pm 1.1 ac	60.4 \pm 1.0 ab	95.6 \pm 0.9 cd	104.4 \pm 0.5 b	
BD 266	20.2 \pm 0.4 c	40.4 \pm 0.8 df	55.2 \pm 0.9 ac	60.4 \pm 1.6 ab	93.8 \pm 1.3 d	105.6 \pm 0.5 ab	
BD 268	26.4 \pm 1.0 ab	41.6 \pm 1.0 cf	55.6 \pm 0.7 ac	59.8 \pm 0.7 ab	96.0 \pm 1.2 bd	103.8 \pm 1.2 b	
BD 269	21.4 \pm 1.3 bc	44.0 \pm 0.7 ad	58.8 \pm 1.0 ac	62.8 \pm 0.9 ab	101.4 \pm 0.9 ac	109.0 \pm 1.3 ab	
BD 274	26.8 \pm 0.8 a	39.4 \pm 1.3 f	54.8 \pm 2.2 bc	58.8 \pm 2.3 b	98.6 \pm 1.9 ad	105.0 \pm 2.1 ab	
BD 275	22.8 \pm 0.4 ac	38.8 \pm 0.4 f	53.0 \pm 0.9 c	57.6 \pm 1.0 b	96.4 \pm 1.0 bd	104.6 \pm 1.3 b	
BD 277	25.0 \pm 2.0 ac	40.0 \pm 0.4 ef	57.6 \pm 1.3 ac	62.0 \pm 1.4 ab	101.8 \pm 1.3 ab	109.2 \pm 1.2 ab	
BARI Mistikumra 1	26.6 \pm 0.7 a	43.8 \pm 0.6 ad	57.8 \pm 1.1 ac	62.2 \pm 1.2 ab	99.2 \pm 1.6 ad	106.8 \pm 1.5 ab	
BARI Mistikumra 2	22.4 \pm 0.7 ac	45.0 \pm 0.7 ac	59.4 \pm 1.5 ac	63.4 \pm 1.4 ab	100.4 \pm 0.9 ac	108.8 \pm 0.7 ab	
Gazipur Local Line	25.4 \pm 0.9 ab	46.0 \pm 0.7 a	61.4 \pm 0.8 a	65.6 \pm 0.9 a	103.4 \pm 0.8 a	110.8 \pm 0.9 a	
China Line	21.4 \pm 1.4 bc	45.6 \pm 0.8 ab	60.2 \pm 2.6 ab	63.8 \pm 2.0 ab	100.6 \pm 0.7 ac	109.2 \pm 1.9 ab	

Means within a column followed by same letter(s) are not significantly different by Tukey's HSD posthoc statistic at < 0.05 .

period for flower initiation (39.4 ± 1.3 and 38.8 ± 0.4 DAT, respectively). Gazipur Local Line took the highest duration and BD 275 took the shortest duration for fruit initiation (61.4 ± 0.8 and 53.0 ± 0.9 DAT, respectively). Gazipur Local Line took the maximum period for fruit elongation (65.6 ± 0.9 DAT). BD 274 and BD 275 had identical as well as lower duration for fruit elongation (58.8 ± 2.3 and 57.6 ± 1.0 DAT, respectively). Gazipur Local Line took the maximum period for attaining the fruit of marketable maturity and seed production maturity (103.4 ± 0.8 and 110.8 ± 0.9 DAT, respectively). BD 266 showed the shortest duration for producing marketable matured fruit (93.8 ± 1.3 days). BD 265, BD 268 and BD 275 had the minimum duration for attaining marketable maturity and seed production maturity of fruit (104.4 ± 0.5 , 103.8 ± 1.2 and 104.6 ± 1.3 DAT, respectively). So, the total developmental period of tested germplasms during the study ranged from 103.8 ± 1.2 to 110.8 ± 0.9 DAT. The results were in accordance with the findings of Ahamed *et al.* (2011) who reported that genotypes of sweet gourd took 104 to 123 days for total development.

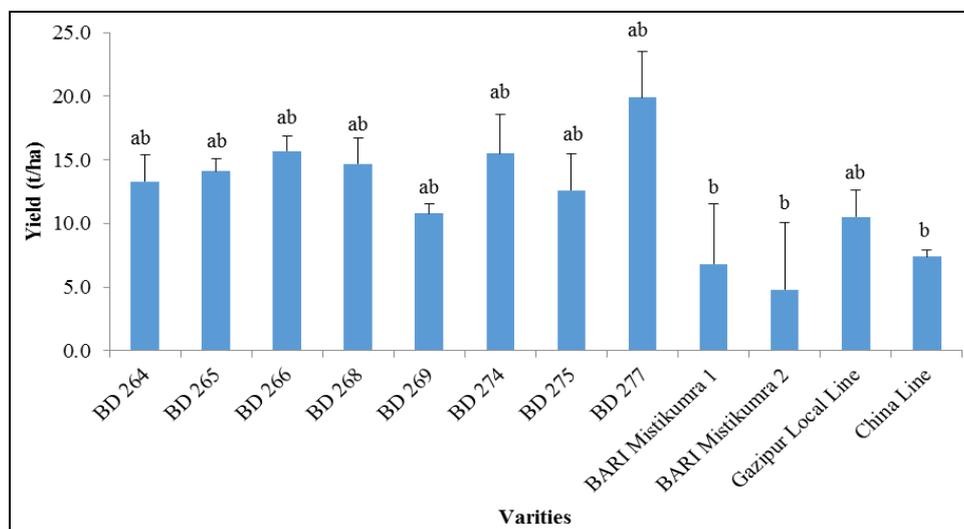


Fig. 5. Comparison of yield (mean \pm SE) among twelve sweet gourd germplasm.

The yield of the tested germplasms is presented in figure 5. The yield of BD 264, BD 265, BD 266, BD 268, BD 269, BD 274, BD 275, BD 277 and Gazipur Local Line was statistically similar and comparatively higher ranged from 10.5 ± 2.1 to 19.9 ± 3.6 t ha⁻¹. BARI Mistikumra 1, BARI Mistikumra 2 and China line had the lowest and statistically similar yield ranged from 4.8 ± 5.3 to 7.4 ± 0.5 t ha⁻¹.

The abundance of red pumpkin beetle, epilachna beetle and fruit fly on sweet gourd germplasms showed fluctuations during the study period. The insect infested plants showed a great variation in case of duration for development, morphological traits and yield. The results of this study provide information for

forecasting regarding the incidence of the major insect pests of sweet gourd and find out variations among the germplasms that could be helpful to develop resistant variety.

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MOISTURE LEVEL AND STORAGE CONTAINER EFFECTS ON SEED QUALITY OF SOYBEAN GENOTYPES UNDER AMBIENT CONDITION

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Abstract

The experiment was conducted at the Seed Laboratory, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jamalpur in 2013 to study the effect of seed moisture content and storage containers on seed quality of soybean genotypes. Three genotypes of soybean (AGS 191, ASET 93 and Shohag), four initial seed moisture content (6, 8, 10 and 12%) and two types of storage containers (polythene bag and glass jar) were included in the experimental treatment. Seeds of soybean genotypes was stored at ambient condition were temperature ranged from 15.97 to 29.37 °C, relative humidity ranged from 75.21 to 86.23% and rainfall ranged from 0.00 to 425mm during the whole storage period. Seed moisture content (%), germination (%) and vigour index were recorded at 50, 100, 150 and 200 days after storage (DAS). Result showed that final seed moisture content increased with the increase of initial seed moisture content. Genotype AGS 191 showed the highest germination (%) and vigour index. Seeds stored in polythene bag or glass jar showed similar performance for germination (%) and vigour index. Highest seed moisture content significantly reduced the germination and vigour index irrespective of containers. The results indicate that soybean seed can be stored safely for at least 200 days maintaining >80% germination and high vigour when stored in polythene bag or glass jar with 6-8% initial moisture content at ambient room temperature and relative humidity.

Keywords: Soybean, seed moisture, storage container, vigour

Introduction

Soybean (*Glycine max* [L.] Merrill) is the world's most important grain legume crop in terms of total production and international trade. Soybean seed contains 36-47% protein and 15-25% oil, 20-26% carbohydrate (Rahman, 2001). It is a high and available source of calcium, phosphorus, iron, thiamine including vitamins A, B, C and D. The common people of Bangladesh can not afford animal protein like egg, milk, meat and fish in their daily diet because of their high cost. The demand of soybean is increasing for making different food

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products for human consumption as well as feed for poultry and fish in Bangladesh. The soil and climatic condition of Bangladesh is congenial for soybean production. The lack of supply of quality seed to the farmers render major problem in the expansion of area under soybean cultivation. It has been reported that soybean seed is short lived and loses its viability in very short period of storage even with good nonporous storage container. Arunnandhy and Senanayaka (1991) reported that the soybean seeds can be kept with high germination and vigour for more than one year when stored in sealed containers. Storage containers or packaging materials are considered as one of the most important factors influencing longevity of seeds in storage. Storage container had significant effect on moisture content of wheat seed at different observation date of storing (Rahman *et al.*, 2010). When seed could be packaged in moisture proof containers, the relative humidity of the air around the seed remains low, then the seed equilibrium moisture remains low and the seed maintains its viability and vigour for a longer time (Poonam *et al.*, 2001; Agha *et al.*, 2004). Storage container influences seed quality and initial adjustment of seed moisture played a vital role in the preservation and longevity of seeds. The physical properties and storage potential of seed were influenced to a very large extent by moisture content and the relative humidity of the atmosphere surrounding the seed (Kong *et al.*, 2008). Reports are also available that polythene bags can be used as moisture proof container (Alam and Rahman, 2005). Soybean seeds stored in moisture proof containers retain high viability than those in moisture permeable containers (Tatipata, 2009). Depending on initial condition, seed deteriorates less rapidly in impermeable than permeable containers. Use of proper storage container to maintain the quality of farmer-saved seed in storage and preserving its viability should be an important consideration to reduce seed loss and increase crop yield. In view of the above facts, the present study was undertaken to develop appropriate storage techniques to maintain desired viability and vigour of soybean seeds.

Materials and Methods

The experiment was conducted at Seed Laboratory of Regional Agricultural Research Station, BARI, Jamalpur during May to December 2013. Daily temperature (maximum, minimum and mean), total monthly rainfall and monthly relative humidity were collected from records of the Regional Agricultural Research Station, Jamalpur. The average monthly maximum and minimum temperature, relative humidity and total rainfall that prevailed during the experimental period have been presented in Table 1. The maximum and minimum temperatures were found in the month of April and January, Heavy rainfall was observed during the month of April to October whereas it was scanty during the month of November to March. There was no rainfall in the month of December. Monthly average relative humidity ranged from 75.21 to 86.23%.

Table 1. Monthly record of air temperature, rainfall and relative humidity the experimentation period at Bangladesh Agricultural Research Station,, Jamalpur from January to December 2013

Month	Air temperature			Relative humidity (%)	Rain fall (mm)
	Maximum	Minimum	Average		
January	21.77	10.17	15.97	83.65	Trace
February	26.67	15.49	21.08	75.21	27.10
March	27.95	18.11	23.03	75.39	114.00
April	31.63	22.25	26.94	80.07	96.20
May	32.03	23.33	27.68	81.13	265.00
June	30.57	25.68	28.13	86.23	425.30
July	31.81	26.89	29.35	85.00	212.90
August	31.36	26.42	28.89	85.00	192.40
September	32.22	25.95	29.09	84.23	330.90
October	31.29	22.89	27.09	84.77	105.80
November	28.79	18.54	23.67	82.53	83.10
December	25.32	14.40	19.86	84.06	00.00

Source: Regional Agricultural Research Station, Jamalpur.

Three soybean genotypes (AGS 191, ASET 93 and Shohag), two storage container (polythene bag and glass jar) and four level of initial seed moisture content (6, 8, 10 and 12%) were used as treatment variables. The experiment was laid out in a Completely Randomized Design with three replications. The crop was grown at Regional Agricultural Research Station Farm, Jamalpur with proper agronomic management. The crop was harvested at full maturity and after proper processing, cleaning and drying the seed was stored in polythene bags until used for experimentation. The seed was dried in the sun on a *tripale* set on the cemented floor to about 6% initial seed moisture content (SMC). Just before final storage the seed was re-hydrated at 70% relative humidity (RH) for required period of time to obtain targeted moisture contents were achieved. Each container was completely filled with seed as per experimental specification and then made air tight. The seed was tested for different quality parameters at 50, 100, 150 and 200 days after storage (DAS). The containers were kept in the laboratory under ambient room condition (23-32°C temperature and 78.64% relative humidity). The quality parameters tested were seed moisture content, germination percentage and vigour index.

Seed moisture content was measured using high constant temperature oven dry method following ISTA rules (2003). About 5-8g of seeds were taken in the

aluminium dish and dried in the oven at 130 °C for 2 hours (until constant weight reached). Germination test was done in sand culture method. Two third of a plastic dish (20 cm diameter and 15 cm deep) was filled with sterilized sand having 60% water holding capacity. Randomly collected 100 seeds from each container were placed into the sand for the germination test. The germination dishes were placed in the germination cabinet and seedling evaluation was done at 8 days after placing the test. The number of normal seedlings per dish was regarded as the germination percentage. Germination index of seed was estimated from the seed set in the germination test by calculating the vigour index formula. The seedling emerged each day having radical length of 2 cm or more was considered as germinated. At the end of the storage period, randomly selected 100 seeds from each seed lot in three replications were sown in the well prepared field. The number of seedlings emerged each day were counted up to 15 days after sowing.

Data analysis was done following the analysis of variance (ANOVA) technique and mean differences were adjusted by Duncan's New Multiple Range Test at 5% level of significance with a computer package programme MSTAT-C.

Results and Discussion

Seed moisture content (SMC)

The effect of storage container, initial seed moisture content and genotypes on seed moisture content and germination performance was evaluated in terms of germination, germination index and field performance. The interaction effect of storage container, initial seed moisture content and genotypes on moisture content of soybean seed was statistically significant at each of the observation dates during the storage period in 2013. The moisture content of ASET 93 stored in glass jar with 6% initial MC were 6.90, 7.23, 8.09 and 8.70%, respectively at 50, 100, 150 and 200 DAS and it was statistically at par to those of AGS 191 or ASET 93 or Shohag in polythene bag or glass jar with 6% initial MC with, respectively (Table 1). The moisture content of Shohag stored in polythene bag at 12% initial MC were 12.40, 12.70, 13.40 and 13.93%, respectively at 50, 100, 150 and 200 DAS and it was statistically at par to those of AGS 191 and ASET 93 stored in glass jar or polythene bag with 12% initial MC (Table 2). When seed could be packaged in moisture proof containers, the relative humidity of the air around the seed remains low, then the seed equilibrium moisture remains low (Poonam *et al.*, 2001; Agha *et al.*, 2004, Kong *et al.*, 2008). Similar genetic variations in moisture content of soybean seed have also been reported by Tatic *et al.*, 2012. These results are in good agreement with those reported by Tatipata (2009).

Table 2. Interaction effect of storage container, genotype and initial seed moisture content on moisture content of soybean seed at different days after storage

Container×genotype × initial SMC	Seed moisture content (%) at different days after storage			
	50	100	150	200
C ₁ V ₁ M ₁	7.14e	7.60e	8.40def	8.95ef
C ₁ V ₁ M ₂	8.36d	8.90c	9.50cb	10.03d
C ₁ V ₁ M ₃	10.47c	11.04b	11.60b	12.13b
C ₁ V ₁ M ₄	12.35a	12.60a	13.25a	13.64a
C ₁ V ₂ M ₁	7.07e	7.55e	8.32ef	8.96ef
C ₁ V ₂ M ₂	8.50d	8.90c	9.21c-f	10.10d
C ₁ V ₂ M ₃	10.28c	10.80b	11.40b	11.93bc
C ₁ V ₂ M ₄	12.40a	12.70a	13.04a	13.32a
C ₁ V ₃ M ₁	7.08e	7.80de	8.50c-f	9.02ef
C ₁ V ₃ M ₂	8.38d	8.96c	9.53c	10.16d
C ₁ V ₃ M ₃	10.39c	10.80b	11.43b	11.85bc
C ₁ V ₃ M ₄	12.40a	12.70a	13.40a	13.93a
C ₂ V ₁ M ₁	7.01e	7.48e	8.21f	8.86ef
C ₂ V ₁ M ₂	8.44d	8.90c	9.33cd	9.87d
C ₂ V ₁ M ₃	11.02b	11.30b	11.65b	11.87bc
C ₂ V ₁ M ₄	12.30a	12.70a	13.20a	13.49a
C ₂ V ₂ M ₁	6.90e	7.29e	8.09f	8.70f
C ₂ V ₂ M ₂	8.43d	8.70c	9.15c-f	9.49de
C ₂ V ₂ M ₃	10.21c	10.60b	11.02b	11.36c
C ₂ V ₂ M ₄	12.31a	12.60a	13.02a	13.30a
C ₂ V ₃ M ₁	7.00e	7.40e	8.10f	8.73f
C ₂ V ₃ M ₂	8.22d	8.60cd	9.10c-f	9.50de
C ₂ V ₃ M ₃	10.20c	10.60b	11.00b	11.40c
C ₂ V ₃ M ₄	12.20a	12.70a	13.19a	13.53a
CV (%)	4.28	6.29	5.34	7.21

CV= Coefficient of variation, C₁= Polythene bag, C₂=, Glass jar, V₁= AGS-191, V₂= ASET-93, V₃= Shohag, SMC= Seed moisture content, M₁= 6% SMC, M₂= 8% SMC, M₃= 10% SMC, M₄= 12% SMC, In a column, figures having similar letter(s) do not differ significantly by DMRT.

Germination percentage

The interaction of effect of storage container, genotypes and initial seed moisture content on germination percentage was statistically significant at each of the observation dates during the storage period in 2013. The germination percentage of AGS 191 stored in glass jar with 6% MC were 96.66, 94.00, 93.33 and 92.00%, respectively at 50, 100, 150 and 200 DAS and it was statistically at par to those of AGS 191 or ASET 93 or Shohag stored in glass jar or polythene bag with at 6% and 8% initial SMC. Those values for Shohag in polythene bag with 12% initial SMC were 74.00, 62.00, 24.00 and 6.33%, respectively (Table 3). These results are conformity of those reported by Balesevic-Tubic *et al.*, 2005. Storage containers or packaging materials are considered as one of the most important factors influencing longevity of seeds in storage. Storage container had significant effect on moisture content of wheat seed at different observation date of storing (Rahman *et al.*, 2010 and Ali *et al.*, 2018).

Field emergence performance

Field emergence performance was evaluated in terms of field emergence and mean germination time in field. Soybean genotype, storage container and initial seed moisture content had significant effect on field emergence of soybean seed at 200 DAS (Table 3). The field emergence percentage of AGS 191 seed stored in polythene bag were 88.66, 88.00, 36.00 and 8.00% at 6, 8, 10 and 12% initial SMC while those stored in glass jar were 90.00, 88.00, 54.00 and 16.00%, respectively (Table 3). The field emergence of ASET 93 seed stored in polythene bag were 86.30, 83.33, 42.66 and 6.00% at 6, 8, 10 and 12% initial SMC while those stored in glass jar were 86.00, 84.00, 40.00 and 18.00%, respectively (Table 3). The field emergence of Shohag seed stored in polythene bag were 80.00, 80.00, 16.33 and 3.33% at 6, 8, 10 and 12% initial SMC while those stored in glass jar were 80.00, 80.00, 36.00 and 12.00%, respectively (Table 3). Though the field emergence (%) among the genotype was statistically identical but AGS 191 showed the best performance followed by ASET 93 and Shohag. Upto 8% SMC, more than 80% field emergence was observed. After that the same was drastically declined irrespective of container. Poonam *et al.* (2001) also reported that seeds of soybean cv. PK-327 at moisture content of 7-8% stored in single and double polyethylene bags could be stored for up to 8 months under ambient conditions.

Table 3. Interaction effect of storage container, genotype and initial seed moisture content on germination and field emergence of soybean seed

Container×genotype× initial SMC	Germination (%) at different days after storage				Field emergence at 200 days after storage
	50	100	150	200	
C ₁ V ₁ M ₁	96.33a	94.00a	92.00a	91.66a	88.66a
C ₁ V ₁ M ₂	96.00a	93.33ab	90.92ab	90.00a	88.00a
C ₁ V ₁ M ₃	89.33c-f	83.33de	62.00e	40.00ef	36.00c
C ₁ V ₁ M ₄	80.00gh	60.00g	30.00hi	8.66i	8.00def
C ₁ V ₂ M ₁	94.00ab	92.33abc	88.66abc	87.33abc	86.3a
C ₁ V ₂ M ₂	94.00abc	92.00a-d	88.00abc	85.33abc	83.33a
C ₁ V ₂ M ₃	84.33efg	72.00fg	64.00e	46.66e	42.66bc
C ₁ V ₂ M ₄	78.00gh	60.00g	33.00ghi	10.00i	6.00ef
C ₁ V ₃ M ₁	92.00a-d	86.00b-e	84.00bc	82.00bc	80.00a
C ₁ V ₃ M ₂	92.00a-d	84.00cde	82.00cd	80.00c	80.00a
C ₁ V ₃ M ₃	89.33c-f	72.00g	43.33fg	21.33h	16.33d
C ₁ V ₃ M ₄	74.00h	62.00g	24.00i	6.33i	3.33f
C ₂ V ₁ M ₁	96.66a	94.00a	93.33a	92.00a	90.00a
C ₂ V ₁ M ₂	96.00ab	93.66ab	92.33a	91.33a	90.00a
C ₂ V ₁ M ₃	90.00c-f	84.00cde	74.00d	62.00d	54.00b
C ₂ V ₁ M ₄	82.00fgh	62.00g	42.00fg	27.00gh	16.00d
C ₂ V ₂ M ₁	94.00abc	92.00abc	90.00ab	88.00ab	86.00a
C ₂ V ₂ M ₂	94.00abc	92.00ab	90.00ab	87.00abc	84.00a
C ₂ V ₂ M ₃	90.00b-e	82.00ef	62.00e	48.00e	40.00c
C ₂ V ₂ M ₄	80.00gh	70.00g	40.00fg	26.00gh	18.00d
C ₂ V ₃ M ₁	92.00a-e	86.00b-e	84.00bc	82.00bc	80.00a
C ₂ V ₃ M ₂	92.00a-d	86.00b-e	84.00bc	82.00bc	80.00a
C ₂ V ₃ M ₃	89.33c-f	67.00g	48.66f	34.00fg	36.00c
C ₂ V ₃ M ₄	85.33d-g	60.00g	34.66gh	21.33h	12.00de
CV (%)	4.95	6.69	7.23	8.20	7.32

CV= Coefficient of variation, C₁= Polythene bag, C₂=, Glass jar, V₁= AGS-191, V₂= ASET-93.

V₃= Shohag, SMC= Seed moisture content, M₁= 6% SMC, M₂= 8% SMC, M₃= 10% SMC, M₄= 12% SMC.

In a column, figures having similar letter(s) do not differ significantly.

Table 4. Interaction of storage container, genotype and seed moisture content on germination index of soybean seed at different days after storage

Container×genotype × initial SMC	Germination index at different days after storage			
	50	100	150	200
C ₁ V ₁ M ₁	38.00ab	34.00a	28.00ab	24.33abc
C ₁ V ₁ M ₂	38.00ab	35.00a	27.00ab	23.66abc
C ₁ V ₁ M ₃	34.00a-e	26.00def	18.00de	12.00de
C ₁ V ₁ M ₄	34.00a-e	19.33h	9.0gh	1.00h
C ₁ V ₂ M ₁	38.00ab	32.00abc	27.00ab	24.33abc
C ₁ V ₂ M ₂	37.00abc	30.00a-d	26.00ab	24.33abc
C ₁ V ₂ M ₃	32.00c-f	25.00d-g	18.00de	11.00def
C ₁ V ₂ M ₄	30.00ef	20.00gh	7.00gh	1.37h
C ₁ V ₃ M ₁	31.00def	27.00cde	24.00abc	20.66bc
C ₁ V ₃ M ₂	30.00ef	27.00cde	23.00bcd	20.33c
C ₁ V ₃ M ₃	24.00gh	18.00hi	11.00fg	8.00efg
C ₁ V ₃ M ₄	20.00h	12.00j	5.00h	1.00h
C ₂ V ₁ M ₁	39.00a	35.00a	30.00a	26.33a
C ₂ V ₁ M ₂	39.00a	34.00a	28.00ab	25.55ab
C ₂ V ₁ M ₃	36.00a-d	30.00a-d	24.00abc	14.33d
C ₂ V ₁ M ₄	34.00a-e	22.00e-h	15.00ef	4.40gh
C ₂ V ₂ M ₁	38.00ab	33.00ab	29.00ab	25.66ab
C ₂ V ₂ M ₂	38.00ab	32.00abc	28.00ab	26.00a
C ₂ V ₂ M ₃	33.00b-e	26.00def	20.00cde	15.00d
C ₂ V ₂ M ₄	31.00def	21.00fgh	10.00fgh	5.10gh
C ₂ V ₃ M ₁	32.00c-f	28.00bcd	25.00abc	22.33abc
C ₂ V ₃ M ₂	32.00c-f	27.00cde	24.00abc	21.66abc
C ₂ V ₃ M ₃	28.00fg	22.00e-h	15.00ef	7.00fg
C ₂ V ₃ M ₄	22.00h	14.00ij	8.00gh	3.66gh
CV (%)	8.41	6.48	5.75	7.32

CV= Coefficient of variation, C₁= Polythene bag, C₂=, Glass jar, V₁= AGS-191.

V₂= ASET-93, V₃= Shohag, SMC= Seed moisture content, M₁= 6% SMC, M₂= 8% SMC, M₃= 10% SMC, M₄= 12% SMC In a column, figures having similar letter(s) do not differ significantly.

Germination index

The interaction of storage container, genotypes and initial seed moisture content on germination index was statistically significant at each of the observation dates during the storage period in 2013. The highest germination index for AGS 191 in glass jar with 6% initial MC were 39.00, 35.00, 30.00 and 26.33, respectively at 50, 100, 150 and 200 DAS and it was statistically at par to those of AGS 191 in glass jar with 8% initial MC, ASET 93 in polythene bag with 6% and 8% SMC, Shohag in glass jar with 6 or 8% initial MC. Those values for Shohag in polythene bag with 12% initial MC were 20.00, 12.00, 5.00 and 1.00 and it was statistically identical to Shohag in glass jar with 12% initial MC, respectively (Table 4). These results are conformity of those reported by Balesevic-Tubic *et al.*, 2005. Agha *et al.*, 2004 reported that when seed could be packaged in moisture proof containers, the relative humidity of the air around the seed remains low, then the seed equilibrium moisture remains low and the seed maintains its viability and vigour for a longer time.

Conclusion

The study conclude that seeds of AGS 191, ASET 93 and Shohag could be stored in polythene bag or glass jar at 6 to 8% initial seed moisture content safely for maintaining high seed quality. However, seed with high moisture content should never be stored in air tight container.

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***IN VITRO* PROPAGATION OF POPULAR BANANA CULTIVAR
(*Musa* spp. cv. Patakpura)**

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Abstract

The present experiment was conducted to optimize protocols for *in vitro* propagation of banana (*Musa* sp.) cv. 'Patakpura' (AAB), supplemented with different growth regulators. Shoot tips obtained from sword suckers were cultured aseptically on MS medium supplemented with different concentrations of cytokinins like 6-Benzylaminopurine (BAP) and Kinetin (KN) for multiplication of shoots and auxins such as indole acetic acid (IAA) and naphthalene acetic acid (NAA) for induction of roots. The best result from the initial culture was obtained from MS medium supplemented with 4 mg/l BAP + 0.5 mg/l IAA. The highest shoot fresh weight, shoot length and number of shoots per explant were recorded from MS medium supplemented with 4 mg/l BAP + 0.5 mg/l IAA + 0.25 mg/l NAA. Therefore, the MS medium supplemented with 4 mg/l BAP + 0.5 mg/l IAA + 0.25 mg/l NAA was found to be most effective and productive combination for shoot multiplication and proliferation of the culture *in vitro*. IAA at a concentration of 1 mg/l was found to be most suitable for rooting of the shoots.

Keywords: *Musa*; *in vitro*; micro propagation; MS medium; phytohormones.

Introduction

Cultivated banana is derived from two diploid species of genus *Musa acuminata* X *Musa balbisiana*. Banana and plantain approximately account for 21-22 % of the fresh fruit production of the world and is one of the major economic crops. It is world's second largest fruit crop and fourth most important global food crop which is produced over 100 million metric tons per year (Banana Market Review and Banana Statistics 2012-2013, FAO, 2014). India, the largest banana producer in the world, has been rapidly increasing cultivated area and volumes of production over the past decade. Although India currently produces predominantly for the domestic market, it also supplies bananas to other countries. The 'Patakpura' variety of Odisha belongs to *Musa pradiasiaca* (*Musa pradiasiaca* = hybrid between *Musa acuminata* and *Musa balbisiana*) having the genotype of AAB and is among one of the most popular local banana cultivars of Odisha which have a very high demand in the markets of many states of India.

Researchers have found that fruits of banana contain various antioxidants such as vitamin C, vitamin E and β -carotene (Kanazawa and Sakakibara, 2000). It has

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been reported that the fruit has been used as anti-scorbutic, aphrodisiac and diuretic (Salawu *et al.*, 2010). It also contains dopamine, a powerful antioxidant, and all the B group vitamins present in the plant kingdom [Banana inter professional association (AIB), 2014]. Thus bananas contribute to the proper functioning of energy metabolism and the nervous system and to maintain of good digestive transit in human (Aprifel, 2015).

Banana species are normally propagated through vegetative parts (suckers) because all the cultivated banana varieties are triploid and have sterile seeds (Muhammad *et al.*, 2013). Conventional vegetative means of banana propagation was noted to have several negative impacts which include diseases transmission, low production, very slow rate of multiplication of suckers and poor preservation of original plant genetic material (Hussein, 2012). The cultivation of 'Patakpara' is mostly restricted to the coastal areas of Odisha. Mainly it is affected with diseases like panama wilt and banana streak disease. In conventional method adequate numbers of suckers are not available. Transfer of diseases through suckers is also one of its major drawbacks. The disadvantages arising from conventional propagation can be terminated by propagating banana through *in vitro* propagation (tissue culture) which offers clean planting material by mass propagation (Ali *et al.*, 2011).

Previously many researchers reported rapid regeneration of *Musa* sp. through *in vitro* propagation (Nauyen & Kozai, 2001; Krishnamoorthy *et al.*, 2001; Roels *et al.*, 2005). Cytokinins and auxins play key role in *in vitro* culture as the later are concerned with root formation, the former is mainly required for shoot formation and growth of buds. Cytokinins such as benzyl aminopurine (BAP) and kinetin are known to reduce the apical meristem dominance and induce both auxiliary and adventitious shoot formation from meristematic explants in banana (Khalid, 2011).

The presences of BAP in higher concentrations inhibit elongation of adventitious meristems and development into complete plants (Busing, 1994). Auxins and other growth regulators such as gibberellins play important roles in the growth and differentiation of cultured cells and tissues (Alexandrova, 1996). The present study was undertaken for optimization of protocols for rapid multiplication of 'Patakpara' banana on using Murashige and Skoog medium supplemented with different plant growth regulators.

Materials and Methods

The present study was conducted in Banana Tissue Culture laboratory, Regional Plant Resource Centre, Bhubaneswar, Odisha, India. Sword suckers with an average height of 30-45 cm and with of 3 cm of selected plants from eastern coasts of Odisha was collected and the rhizomes were selected as explant. Suckers for initial tissue culture were collected in the month of July, 2017 and it took 8 months for completion of *in vitro* propagation of Patakpara. Explants were

processed by cutting the corm portion of the suckers into cylindrical shape of 4-5 cm in height and 2 cm in diameter. Then the explants were washed with detergent (Labolene) and treated with Bavistin for 45 mins. Surface sterilization with 0.5% Sodium hypochloride for 30 mins was done followed by washing thrice in sterile distilled water in aseptic condition (under Laminar Air flow). The explants were inoculated aseptically in MS Medium (Murashige and Skoog, 1962).

The growth regulators used for shoot culture studies were Benzyl Amino Purine (BAP), Kinetin (KN), Indole-3-acetic acid (IAA) and Naphtalene acetic acid (NAA). For the initial culture the concentration and combination of plant growth regulators used with MS medium were as follows: 2 mg/l BAP + 0.5 mg/l IAA (P₁), 4 mg/l BAP + 0.5 mg/l IAA (P₂), 8 mg/l BAP + 0.5 mg/l IAA (P₃), 5 mg/l KN + 0.5 mg/l IAA (P₄) and 10 mg/l KN + 0.5 mg/l IAA (P₅). Different concentrations of growth regulators supplemented in MS medium during multiplication culture of *Musa* spp. cv. 'Patakpura' explants were as follows: 2 mg/l BAP + 0.5 mg/l IAA (T₁), 4 mg/l BAP + 0.5 mg/l IAA (T₂), 2 mg/l BAP + 0.5 mg/l IAA + 0.25 mg/l NAA (T₃), 4 mg/l BAP + 0.5 mg/l IAA + 0.25 mg/l NAA (T₄), 2 mg/l KN + 0.5 mg/l IAA + 0.25 mg/l NAA (T₅), 4 mg/l KN + 0.5 mg/l IAA + 0.25 mg/l NAA (T₆), 1 mg/l BAP + 1 mg/l KN + 0.5 mg/l IAA + 0.25 mg/l NAA (T₇) and 2 mg/l BAP + 2 mg/l KN + 0.5 mg/l IAA + 0.25 mg/l NAA (T₈). MS media supplemented with three concentration of IAA such as 0.5 mg/L (R₁), 1.0 mg/L (R₂) and 2.0 mg/L (R₃) were used for root development.

At first the explants were grown on initial culture medium for 15 days. Then the initial culture were transferred to multiplication culture stage. During multiplication stage the explants were cultured up to six sub-cultures and in each sub-culture the explants were grown on MS media for 21 days. After formation of individual shoots the explants were the culture in rooting medium for root development. All of the explants were cultured on MS media solidified with agar (6.5 gm/L). After preparation of MS media the pH was adjusted to 5.75-5.8 by using 1% NaOH or 1% HCl, which is suitable for the growth of cultured plantlets during *in vitro* culture before autoclaving the media for 15-20 mins at 121°C and 15 PSI. The culture bottles containing the explants were kept in culture rack. For each treatment twenty explants were taken into consideration.

The culture room was maintained at 22°C to 25°C, 16 hr photo period of 35-50µEm-2s-1 intensity provided by cool white fluorescent tubes. After the root formation the banana plantlets were transferred to green house for primary hardening. The plantlets were planted in soilrite inside the primary hardening chamber and watered regularly. After primary hardening for 2-3 weeks the plantlets were transferred to polybags in secondary hardening containing soil, sand and FYM in the ratio 1:1:1.

The experiment was repeated thrice for confirmation of findings. The data collected at different stages of the experiment were analysed in MS Excel to find mean and standard error.

Results and Discussion

The explants were inoculated on MS medium with different concentration and combination of plant growth regulators (Auxins and Cytokinins). During the initial stage the rate of contamination remained high (10 %) because the suckers were obtained directly from soil. After 20-30 minutes of inoculation secretion of phenolic compound was observed on the whitish portion of the explant as it turned into light brown in colour. After 1 week of culture all explants in initial mediums became enlarged and changed to greenish in colour.

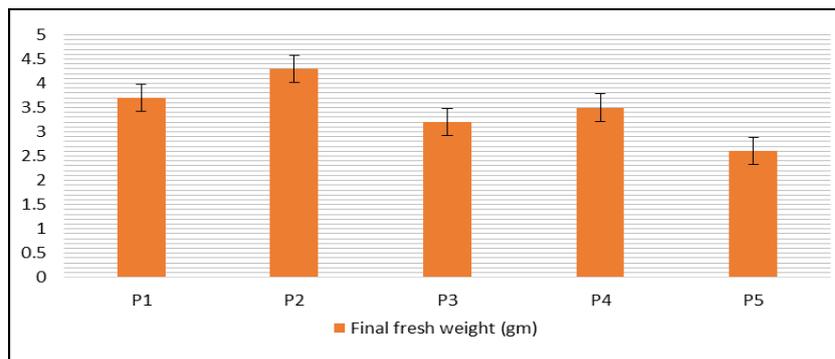


Figure 1: Growth of *Musa* cv. 'Patakura' explants during initial culture after 2 weeks of inoculation.



Fig. 2. a- *Musa* cv. 'Patakura' explant on initial culture medium and b- Growth after 15 days of inoculation, c- 'Patakura' explants cultured on medium containing with 2 mg/l KN + 0.5 mg/l IAA + 0.25 mg/l NAA, d-Explants cultured on medium containing with 4 mg/l BAP + 0.5 mg/l IAA + 0.25 mg/l NAA.

Best response from the initial cultures was obtained on medium supplemented with 4 mg/L BAP where explants showed better growth and proliferations in comparison to other media. Cytokinins like benzylaminopurine (BAP) and kinetin play significant role to reduce the apical meristem dominance and induce both auxiliary and adventitious shoot formation from meristematic explants in banana (Khalid, 2011). Highest final fresh weight (4.3 ± 0.18 gm) was observed from explants in 4 mg/L BAP + 0.5 mg/L IAA medium (P2). Poor response was observed in explants grown on medium with high Kinetin content (10 mg/L), producing least final fresh weight (2.6 ± 0.18 gm) among all the explants cultured on other media. Explants exhibited vigorous proliferation in lower concentration of BAP in comparison to Kinetin. Venkatachalam *et al.*, 2007 and Farahani *et al.*, 2008 reported the importance of BAP than other cytokinins in inducing growth of shoot tip cultures in different cultivars of bananas. Rahman *et al.*, 2006 and Dhed'a *et al.*, 1991 reported that BAP has a remarkable effect in inducing the growth of axillary and adventitious buds and foliar development of shoot tip cultures. During Multiplication stage growth and proliferation of explants were seen after 6-7 days after inoculation in all the 8 different media compositions.

Table 1. Effect of plant growth regulators on shoot proliferation of 'Patakpara'.

Medium Code	Avg. Fresh Weight (gm)	Avg. Shoot Length (cm)	Avg. Number of shoot
T1	5.29	2.9	6.9
T2	6.15	3.75	7.1
T3	6.81	3.17	9.37
T4	8.53	3.61	13.57
T5	4.78	2.89	5.8
T6	5.38	2.35	6.57
T7	5.77	3.1	8.7
T8	5.21	3.31	11.9

The lowest shoot buds number as well as percentage of response (50 %) was marked in culture medium supplied with 2 mg/L KN. Media containing only BAP and IAA were marked by inducing shoot proliferation. Better results were obtained when explants cultured on medium containing BAP along with IAA and NAA. The highest number of shoot (13) was observed in explants cultured on medium supplied with 4 mg/l BAP + 0.5 mg/l IAA + 0.25 mg/l NAA (T4).

Table 2. Effect of plant growth regulators on root induction of ‘Patakpara’.

Parameters	Medium Code		
	R1	R2	R3
Average no. of roots per shoot	4	6	6
Average root length (cm)	4	5	3
Average shoot length (cm)	5	4	4
Average no. of leaves per shoot	3	4	4

Robert *et al.*, (2013) reported that the highest multiple shoot induction was found in MS + 5 mg/l BAP while MS + 1 mg/l NAA + 0.2 mg/l BAP gave the longest regenerated shoots after 45 days of incubation. The developed shoots were cultured in MS medium with different auxin concentrations for root induction and growth. Previously Wong (1986) stated that by increasing the concentration of BAP the production of shoots per explants was also increased. Devendrakumar *et al.*, 2013 studied that use of BAP at 20 μ M/L showed better results in comparison to its low and high concentrations for shoot induction and proliferation.



Fig. 3. a- Root induction of ‘Patakpara’ shoots supplemented with IAA (1 mg/l); b- Tissue cultured ‘Patakpara’ plants in RPRC nursery.

The best response for root induction was observed in MS medium containing 1 mg/l IAA. In an average of 6 ± 0.95 roots per shoot was observed in 1 mg/L IAA medium within 8 days of culture, and the average length of roots was 5 ± 1.61 cm. Auxins such as Indole -3-acetic acid (IAA) and Naphtalene acetic acid (NAA) have been reported to promote plant rooting *in vitro* (Vuylsteke, 1989). Auxins also play vital roles in the growth and differentiation of cultured cells and tissues (Bohidar *et al.*, 2008; Ngomuo *et al.*, 2014).

Conclusion

From the present study it was observed that the response of 'Patakpura' banana explants was better when cultured in medium containing BAP in comparison to Kinetin during initial as well as in the multiplication stages. It was observed that auxins like IAA and NAA also play a vital role in shoot formation during proliferation stages. The uses of auxins are very much essential during *in vitro* culture of banana as they are involved in root formation and proliferation. The optimum concentrations of growth regulators for initial and shoot multiplication during *in vitro* culture of 'Patakpura' banana were 4 mg/l BAP + 0.5 mg/l IAA and 4 mg/l BAP + 0.5 mg/l IAA + 0.25 mg/l NAA respectively.

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DETERMINANTS OF HOUSEHOLD FOOD SECURITY IN RURAL BANGLADESH: AN EMPIRICAL ANALYSIS OF FARM LEVEL DATA

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Abstract

The study endeavors to estimate the food security status and identify the determinants of food security among households in Hakimpur Upazila in Dinajpur district, Bangladesh. It was found that households of Hakimpur upazila in Dinajpur district were food insecure during the period of the survey. Number of dependents, income of household head, age of household head and level of education were found to significantly influence household head food security in the study area positively. It is recommended that social security measures must ensure that the benefits of public efforts to improve food security and nutrition are universal. Human rights based practices are preferable.

Introduction

Now a day's food security issue is getting more attention in the world. The stability means both the availability and accessibility of food in various dimensions of food. Food security comprised of four components such as food availability, accessibility, utilization and stability. Bangladesh is an over populated country having a population density of 1104 per square kilometer. Agriculture is the most important sector for the economy of Bangladesh contributing 14.74% to the GDP. The huge population of the country depends on agriculture sector for their foods and calories.

The population growth rate of Bangladesh is 1.03%. According to this rate, the total population will become 233.2 million within 2050. In Bangladesh, about 0.08 million of arable land are going out of production every year (Mondal, 2010). However, the country faces a tremendous challenge for providing food security to the increasing population. Therefore, it is important to increase food production in order to meet the growing demand for food emanating from population growth. Although there are significant achievements in food grain production but, food insecurity both in national and household level remains a matter of major concern in Bangladesh. Like many other developing countries, food security in Bangladesh is also threatened by the global economic crisis and soaring price of essentials. Food security is viewed as the "number one" priority of the government. Poverty is the major factor effecting food security in

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Bangladesh. According to World food Summit, 1996 food security is defined as “when all people all the times access to sufficient, safe, nutritious food to maintain a healthy and active life.” Commonly, the food security is defined as including both physical and economic access to food that meets people’s dietary needs as well as their food preferences. Food security is built on three pillars namely, Food availability, Food access and Food use. People are considered food secure when they have availability and adequate access at all times to sufficient, safe, nutritious food to maintain a healthy and active life. Food security analysts look at the combination of the following three main elements such as food availability, food accessibility and food utilization.

Rice is the staple food and its production plays an important role in the economy of the country. In Bangladesh, rice alone constitutes 92 percent of the total food grain production annually. It provides about 80 percent of the people’s energy intake (Tetens *et al.* 2003), the majority of their protein intake, and a considerable proportion of several micronutrients in their average daily diet (Hels *et al.* 2003). Food availability of a country may depend on some other factor also. Among them, different socio-economic and demographic variables like population, total food production, imports of the food items, per capita income, adult literacy rate, female attending school, male attending school, infant mortality rate, employed labour force are remarkable. Therefore it is our particular interest to investigate the determinants of food security of Bangladesh using econometric time series approach. In this view points a number of studies which have been conducted to investigate such determinants are reviewed are noted bellow.

Gebre (2012) applied logistic regression model to examined the determinants of food insecurity among urban households in Addis Ababa city and pointed out six important factors out of ten factors. The identified significant factors are household size, age of household head, education of the household head, and access to credit, household asset possession, and access to employment. Sultana and Kiani (2011) studied to examine the determinants of household’s food security in Pakistan using micro data for the year of 2007-08 and found that place of residence has a significant and negative effect on household’s food security status. They also identified that the dependency ratio has a significant impact on food security and has expected sign negative. Educational attainment level of household’s head beyond intermediate level has also significant and positive impact on food security status of household. Whereas social capital and employment do not effect household’s food security significantly. They advised different policies and programs that should be needed to address for the wellbeing of their people. Some other remarkable research have been cited in the literature [Iram and Butt (2004), Hazarika and Khasnabis (2005); Omotesho *et al.*, (2010); Arene and Anyaeji (2010); Sisay and Edriss, (2012); Bogale and

Shimelis (2009) and Mitiku *et. al.*, (2012)] to investigate and identified some important factors through their research in food security area.

Faridi and Wadood (2010) studied to investigate the determinants of household food security situation in Bangladesh applying the logistic regression. They found different household characteristics which are strongly correlated with food security indicator. They also show that food security indicator is also highly sensitive to rice price changes. Most of the studies have been introduced regression technique. As therefore, it is our particular interest to investigate the determinants of food security of Bangladesh using household level data. Most of the studies have been introduced regression techniques having without or partial involvement of econometric tests may questionable on their application. As therefore, it is our particular interest to investigate the determinants of food security of Bangladesh using Logistic Regression Analysis approach which could be able to meet the existing research gap. Therefore the study is very important to have an idea about the factors affecting food security might help in making decision by the policymakers for policy making in future.

The Specific Objectives of the study are:

- (i) To explore the present status of food security in Bangladesh on the basis of availability, accessibility and utilization of food.
- (ii) To identify the factors influencing food security/ insecurity in Bangladesh.
- (iii) To establish an econometric time series model to forecast the future food security status.
- (iv) To formulate policy guidelines/suggestions

Materials and Method

The study was conducted in Hakimpur (Hili) Upazila in Dinajpur district in Bangladesh. Hakimpur (Hili) is located at the North-Western part of the country and considered as the center of northwestern Bangladesh. Hakimpur (Hili) is an emerging urban center and magnification rate of the urban population has been incrementing at an expeditious rate and commercialization active have been on the incrimination placing most of the inhabitants who are mostly farmers, civil servants, handicrafts worker and traders under economic stress.

Selection of the Study area and Sample Size

Purposive Simple random sampling techniques were adopted for selecting reasonable numbers of sample from farmers, traders/merchants, handicrafts worker and civil/public servants. At the first stage of Sampling, one districts was selected from 10 most poor districts (Kurigram, Dinajpur, Magura, Bandarban,

Khagrachari, Shariatpur, Lalmonirhat, Gaibandha, Nilphamari and Thakurgaon) for the study. At the second stage of sampling, one Upazila, Hakimpur was selected purposively for the study. Then sample farmers, traders/merchants, handicrafts worker and Civil/public servants were randomly selected for primary data collection. The population of the study was purposively drawn from respondents who are mainly farmers. Traders/merchants, handicrafts, worker and civil/public servants. A total of 56 respondents were arbitrarily drawn from the Hakimpur (Hili) Upazila in Dinajpur district.

Data/information and Analytical Technique

Both primary and secondary data and information were used for the study. Primary data were collected from field level through questionnaire survey from the aforesaid locations. Secondary data and information relating to different statistics were gathered from various published Sources like BBS, FAOStat, research reports etc.

Data were analyzed applying descriptive statistics and logistic regression analysis. Firstly, a set of brief descriptive coefficients that summarizes a given data set. Which can either be a representation of the entire population or a sample. The measures used to describe the data set are measures of central tendency and measures of variability or dispersion. Measures of central tendency include the Mean, Median and Mode while measures of variability include the Standard Deviation (or variance), the minimum and maximum variables, Kurtosis and Skewness. Food security status was quantified setting a binary value of one or zero. Where one represents food secure and zero represents food insecure. The logistic regression then provides a model of observing the probability of a household becoming food secure or food insecure.

The logistic model is designated explicitly as:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6$$

Where Y=Food security status (1, if household is food secure; 0,if household is food insecure)

X_1 =Sex of household head (Male=1; female=0)

X_2 =Household size (Member of dependents)

X_3 =Manthly Income of household (TK)

X_4 =Age of household head (Year)

X_5 =Level of education of household head (Year of schooling)

X_6 =Per Capita monthly food expenditure

Results and Discussion

Socioeconomic characteristics of the respondents:

Age of the respondents

It was found that the highest percentage (46.42%) of the respondents was in the age group of 46-60 years followed by 31-45 years (44.67%) and age group up to 30 years (5.36%) and age group above 60 years has the lowest percentage (3.58%) (Table 1)

Education level of the respondents

On an average, 10.71% respondents were illiterate and others having variable levels of academic background. Among the educated respondents 21.43% had primary level of education, 33.92% had S S C level of education, 19.65% had H S C level of education, 14.29% had education at above H.S.C.(Table 1)

Table 1. Socioeconomic characteristics of the respondents

Age :	Items	
	No. of the respondents	% of the respondents
Up to 30 years	3	5.36%
31-45 years	25	44.64%
46-60 years	26	46.42%
Above 60 years	2	3.58%
Education :		
Illiterate	6	10.71
Primary	12	21.43
SSC	19	33.92
HSC	11	19.65
Above HSC	8	14.29

Descriptive Statistics

Descriptive Statistics provide a useful summary of security returns when performing empirical and analytical analysis, as they provide a historical account behavior. Although past information is useful in any analysis, one should always consider the expectations of future events. There are 48 male and 8 female among 56 respondents.

Table 2. Descriptive Statistics on the selected variable

Variables	Maximum	Minimum	Average
Number of Dependents	10	1	3.694
Income of Household head (Tk./Month)	75000	3500	24022
Age of Household Head	65	28	46.34
Per Capita monthly food expenditure	9000	1200	3313
Level of Education	15	0	8.304

Source Field Survey 2019

Table 2 shows the descriptive statistics. The variable number of dependents means value is 3.694, and the maximum and the minimum value are 10 and 01 respectively. Consequently, the average income, the maximum income and the minimum income of household head are respectively Tk. 75000, Tk. 3500. Similarly, the respondents average age, maximum age and are respectively 46, 65 and 28. Per Capita monthly food expenditure, the maximum food expenditure and the minimum food expenditure of the household are respectively Tk. 3313, Tk. 9000 and Tk.1200.

Food Security index

This analysis evaluates the food security status of respondents using per capita expenditure on food (Table 3).

Table 3. Food Security line for the respondents

Respondents	MPCFE (Tk.)	Stats	Respondents	MPCFE (Tk.)	Stats
01	2600	High	31	3000	High
02	2500	High	32	3500	High
03	3900	High	33	2500	High
04	4000	High	34	2500	High
05	4000	High	35	2500	High
06	5000	High	36	8000	High
07	3000	High	37	2500	High
08	3000	High	38	2000	Low
09	4500	High	39	2000	Low

Respondents	MPCFE (Tk.)	Stats	Respondents	MPCFE (Tk.)	Stats
10	2500	High	40	1500	Low
11	5000	High	41	2000	Low
12	2400	High	42	3000	High
13	2000	Low	43	2500	High
14	2100	Low	44	1500	Low
15	1595	Low	45	1500	Low
16	3000	High	46	1800	Low
17	2500	High	47	1800	Low
18	1900	Low	48	1950	Low
19	2000	Low	49	3500	High
20	2800	High	50	1950	Low
21	1900	Low	51	2000	Low
22	3600	High	52	2000	Low
23	7500	High	53	9000	High
24	6900	High	54	3500	High
25	7500	High	55	1200	Low
26	2200	Low	56	1950	Low
27	4500	High	Total	185545	
28	7500	High	Mean MPCFE	3313.304	
29	7500	High	2/3MPCFE	2208.869	
30	5000	High	<i>Source: field Survey, 2019</i>		

Note: Mean per Capita Food Expenditure = MPCFE in TK

The analysis ascertained that more than the respondents (37.5%) are food insecure since their monthly per capita food expenditure falls below two-third (2/3) of the mean monthly per capita food expenditure.

Logistic Regression Analysis Result

The logistic regression analysis identified the factors affecting the ability of the households to secure available food supplies .the result of analysis is demonstrated in Table 4.

Table 4. Logistic Regression Result for the Determinants of food Security status

Explanatory variable	Coefficients	Standard	Z-Statistics	Pr(>z)
Sex of household head	0.06138	1.181	0.520	0.60332
Number of dependents or household size	-1.227	0.4598	-2.669**	0.00761
Income of household head	0.000175	0.0000643	2.732**	0.00630
Age	-0.1229	0.05911	-2.078*	0.03768
Level of education	-0.1557	0.1332	-1.168*	0.04261
Per capita monthly food expenditure	-0.0005415	.0003338	1.622	0.10474
Constant	6.825	3.829	1.782	0.07472
chi-square	39.182			
R ²	67.22			

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

Source: field survey, 2019

Four Variables are important in explaining the food security status of the household . They are number of dependents, income of household head, age of household head and level of education. The other variables demonstrate not to be important. Sex of household head has a negative impact on food security status because more dependents want more food with in the household with a fixed income of household head. Income of household has positive effect on food security status suggesting that the more gainfully employed a household head is, the greater his or her chances of being food secure. The level of education has positive effects on food security status point toward that higher of level education has a greater chance to get a better job, which indirectly helps to earn higher income. Higher income also has positive effects on food security status

In brief, it is yielded that number of dependents, income of household head, age of household head and level of education of the households are the determinants of food security status among the responds of Hakimpur Upazila in Dinajpur District. The coefficient of determination, R² is 67.22 percent inferring that the variation in food security status is due to the stated socio-economic characteristics of Hakimpur Upazila in Dinajpur District households. The result further showed that the overall logistic model was significant based on the chi-square. Thus representing that the explanatory variables are relevant in determining the household food security status.

Conclusion

The study has found that households of Hakimpur Upazila in Dinajpur District were food insecure during the period of the survey. Number of dependents, income of household head, age of household head and level of education were found to significantly influence household head food security in the study area positively. However, sex of household head, Per Capita monthly food expenditure was found to influence food security negatively at the household level.

Based on the results, It is recommended that social security measures must ensure that the benefits of public efforts to improve food security and nutrition are universal. Human rights based practices are preferable. Extremely versatile, tolerant and nutrient-sensitive, it is vital to grow agriculture.

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EFFECT OF POTASSIUM ON YIELD, QUALITY AND SHELF LIFE OF TOMATO

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Abstract

The experiment was conducted at the experimental field of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, to study the effect of potassium on yield, quality and shelf life of tomato under ambient condition during 15 October 2015 to 30 June 2016. Six levels of K viz., 0, 35, 70, 105, 140 and 175 kg/ha consisted of the treatments of the experiment. The tomato plant treated with K₁₀₅ produced maximum plant height (128.50 cm), number of fruits plant⁻¹ (26.49), fruit diameter (5.71 cm), fruit length (5.83 cm), weight of fruits plant⁻¹ (1.72 kg), fruit yield ha⁻¹ (71.96 ton), dry matter (7.56 %), firmness (1.22 N), shelf life (15 days), TSS (10.30 %), β carotene (0.090 mg/100 g), ascorbic acid (26.49 mg/100 g) and total sugar (5.05 %). Contents of iron (123.20 ppm), calcium (0.42%) and potassium (0.71%) were recorded maximum in K₁₄₀, K₃₅ and K₁₇₅ respectively. Iron and potassium content increased with the increasing level of potassium but reverse effect was found in case of calcium. The regression equation for applied K were $Y = -3.339x^2 + 636.5x + 42606$. Based on this equation, the optimum dose of K for tomato was 95.31 kg ha⁻¹ in salna series of shallow red brown terrace soil and its corresponding yield is 71.96 t ha⁻¹.

Keywords: Potassium, yield, quality and shelf life, tomato.

Introduction

Tomato (*Solanum lycopersicum*) is one of the most important vegetable crops grown throughout the world under field and green house conditions (Kaloo, 1986). In terms of human health, tomato is a major component in the daily diet in many countries and constitutes an important source of minerals, vitamins, and antioxidants (Grierson and Kader, 1986). The global production area for tomato was estimated at 44,12,757 ha with world production quantity estimated at 15,16,99,405 metric tons and global yield was estimated 34.38 t/ha (FAO, 2010). The area of tomato in Bangladesh is 26,316 ha and production is 2,50,947 metric tons. While the yield is 9.54 t/ha (BBS, 2013) which is relatively very low in Bangladesh as compared to other tomato producing countries (Vanitha *et al.*, 2013).

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Tomato is a highly perishable vegetable with limited shelf life and can be kept very short period in room temperature. The post harvest loss reported upto 32.90% in tomato (Hassan *et al.*, 2010). Moreover, it grows in Bangladesh mainly in winter period which lead to market glut in season. Adequate supply of nutrient can increase the yield, fruit quality, fruit size, keeping quality, colour and taste of tomato (Shukla and Naik, 1993). Concerning plant nutrition, potassium plays an important role in the improvement of post harvest quality traits in tomato (Cakmak, 2005). Adequate K nutrition has also been associated with increased yield, fruit size, increased soluble solids and ascorbic acid concentrations, improved fruit colour, increased shelf life and shipping quality of many horticultural crops (Lester *et al.*, 2007). Potassium act like a spark-plug for activation of more than 60 enzymes which needs improvement of yield and quality of plant (Malvi, 2011). So application of proper doses of potassium is of great importance.

But little specific work has been carried out in Bangladesh condition to investigate the effect of potassium on yield, quality and self life improvement of tomato. Considering the above facts, the present study was undertaken to find out the optimum dose of potassium for yield, quality and shelf life improvement of tomato.

Materials and Methods

The experiment was conducted at the experimental field of Horticulture and at the laboratory of Horticulture and Soil Science Department of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh during October 2015 to June 2016. Six levels of potassium viz. $T_0=K_0(0 \text{ kg MoP ha}^{-1})$, $T_1=K_{35}(70 \text{ kg MoP ha}^{-1})$, $T_2=K_{70}(140 \text{ kg MoP ha}^{-1})$, $T_3=K_{105}(210 \text{ kg MoP ha}^{-1})$, $T_4=K_{140}(280 \text{ kg MoP ha}^{-1})$ and $T_5=K_{175}(350 \text{ kg MoP ha}^{-1})$ consisted of the treatments of the experiment. The treatments were selected on the basis of initial soil test value. The soil contained 1.06 % organic matter, 0.114% total nitrogen, 3.70 $\mu\text{g/g}$ available phosphorus, 0.11 meq/100g exchangeable potassium, 12.00 ppm sulphur, 1.30 $\mu\text{g/g}$ zinc and 0.20 ppm available boron. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The dimension of each plot was 1.8×2 m. The unit plots and blocks were separated by 0.50 m and 1.0, m respectively. The selected land was prepared in October 2015 by tractor drawn plough followed by harrowing and laddering. The plots were prepared, drains were made around each plot and the excavated soil was used for raising the plots about 10 cm high from the soil surface. Other fertilizers were applied @10000-126-64-12-2-1 kg ha^{-1} of Cowdung-N-P-S-Zn-B. Doses of fertilizer were calculated according to Fertilizer Recommendation Guide (FRG, 2012). Full doses of well decomposed cowdung, P, S, Zn, B, 50% potassium were applied as basal dose and were incorporated into the prepared plots a few days before planting.

Remaining 50% potassium and full dose of urea were applied in two splits after 20 and 40 days of transplanting. Seeds of tomato variety BARI Tomato-14 were collected from the Horticulture Research Centre of BARI, Gazipur. Seeds were sown in plastic trays on 26 October, 2015 in 2-3 cm deep furrows at 10 cm apart rows. Seedlings emerged between 3-4 days after sowing. After 5 days of germination, seedlings were transferred into poly bags. Twenty days old seedlings were transplanted in the experimental field on 20 November, 2015 at 60 cm row to row and 40 cm plant to plant distance.

Necessary intercultural operations such as weeding, staking, pruning, irrigation and mulching were done as and when necessary during the crop growing period. Admire 20 SL @ 0.5 ml/l, dithane M-45 @ 2.5 g/l of water was applied to control insect pest and fungus diseases. Tomato was harvested at breaker stage from randomly selected 10 plants of each plot. Data on plant height, number of fruit per plant, fruit diameter and length, weight of fruit per plant were recorded in the field at last harvest and yield per hectare were estimated from plot yield. The following chemical and nutritive components were recorded after harvesting.

Determination of shelf life (days)

Days required from harvest to ripening (marketable condition) under ambient condition.

Weight loss (%)

Loss of weight were estimated by the following formula

$$\text{Percent weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Determination of moisture percent (%)

Moisture percent was calculated according to the following formula:

$$\text{Moisture percent} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Dry matter (%)

Dry matter percent of tomato was calculated according to the following formula:

$$\text{Dry matter percent} = \frac{\text{Dry weight of pulp}}{\text{Fresh weight of pulp}} \times 100$$

Total soluble solids (%)

Total soluble solids were determined by an ATAGO NT hand refractometer and expressed in percentage.

Firmness (N)

Firmness was determined by using Fruit Texture Analyzer (Guss, Model No. GS25, SA) supported by FTA win software. Results were expressed in Newton (N).

Nutrient content analysis

Ascorbic acid was determined as per Pleshkov (1976), β - carotene was calculated according to Nagata *et al.*, (1992), total sugar was estimated according to bertrand method and mineral elements viz. iron, calcium, potassium as described by Piper (1966)

Statistical analysis

The recorded data were statistically analyzed by using MSTAT-C software and mean were compared by DMRT at 5% or 1% level of probability.

Results and Discussion

Plant height

Different doses of potassium had no significant effect on plant height (Table 1). The tallest plant was found in K₁₀₅ (128.50 cm) and it was followed by K₇₀ (128.00 cm) K₃₅ (127.50 cm) and K₁₄₀ (127.30 cm). The shortest plant height was found in K₁₇₅ (125.50 cm). Similar opinion was also express by Bhagat *et al.* (2014) who found the tallest tomato plant in 100 kg K ha⁻¹.

Number of fruits per plant

Different doses of potassium had significant effect on number of fruit per plant (Table 1). The highest number of fruit per plant was observed in K₁₀₅ (26.49) which was statistically alike to K₇₀ (26.01). On the other hand, the plants under control (K₀) gave the lowest number of fruit (17.60) per plant. Similar result was also reported by Bhagat *et al.*, (2014) who found the highest number of tomato per plant with 100 kg K ha⁻¹.

Fruit diameter

Significant variation in fruit diameter (cm) was found due to the effect of potassium (Table 1). The highest fruit diameter (5.71 cm) was found in K₁₀₅ which was statistically similar to K₇₀ (5.63 cm) and it was minimum (4.68 cm) in K₀. The results were in line with the report of Mazed *et al.*, (2015) who found maximum diameter of fruit from 140 kg K ha⁻¹ and minimum from control (K₀).

Fruit length

Highest fruit length was recorded in K₁₀₅ (5.83 cm) and it was statistically similar to K₇₀ (5.71 cm), K₃₅ (5.50) and K₁₄₀ (5.51 cm). On the contrary, the fruit length

was the minimum (5.05 cm) in K₁₇₅. Optimum potassium influenced nutrient absorption capacity of plant that encouraged cell division, hormonal and enzymatic activities resulting higher fruit length.

Fruit yield per plant

Significant variation of yield per plant was found due to the influence of potassium (Table 1). The maximum yield was observed in K₁₀₅ (1.72 kg) which was statistically alike to K₇₀ (1.68 kg) and it was minimum in K₀ (0.99 kg).

Fruit yield per hectare

The highest yield was recorded in treatment K₁₀₅ (71.96) which was statistically similar to K₇₀ (70.34). The lowest yield was recorded in K₀ (41.25) (Table 1). Bhagat *et al.*, (2014) also reported that 100 kg K/ha gave the highest yield in tomato. Usherwood (1985) reported that adequate K fertilizer involved in photophosphorylation, transportation of photoassimilates from source tissues via the phloem to sink tissues, enzymes activation, turgor maintenance and stress tolerance resulting in higher yield.

Table 1. Yield and physical characteristics of tomato in response of potassium

Level of K	Plant height (cm)	No. of fruit/plant	Fruit diameter (cm)	Fruit length (cm)	Fruit yield (kg plant ⁻¹)	Fruit yield (t ha ⁻¹)	Dry matter (%)	Firmness (N)	Weight loss (%)
K ₀	126.17c	17.60e	4.68 c	5.31 b	0.99e	41.25e	5.41c	0.90c	12.24 a
K ₃₅	127.50b	23.63c	5.21b	5.50 ab	1.49c	62.39c	6.13b	1.10ab	10.76b
K ₇₀	128.00ab	26.01ab	5.63 ab	5.71 ab	1.68a	70.34a	7.29a	1.17ab	9.36 bc
K ₁₀₅	128.50a	26.49a	5.71 a	5.83 a	1.72a	71.96a	7.56a	1.22a	8.36 c
K ₁₄₀	127.30b	25.08b	5.42 b	5.51 ab	1.59b	66.33b	7.47a	1.07b	10.05bc
K ₁₇₅	125.50c	21.46d	4.78 c	5.05 c	1.24d	51.91d	6.27b	0.92c	10.76 b
Level of significance	**	**	**	**	**	**	**	**	**
CV (%)	4.49	3.43	3.02	3.75	3.69	3.63	4.84	7.91	3.12

Means bearing same letter (s) do not differ significantly at 1% level of probability by DMRT.

** 1% level of probability.

Dry matter

Dry matter content of tomato varied significantly at different doses of potassium (Table 1). The highest dry matter was recorded in K₁₀₅ (7.56%) which was statistically similar to K₁₄₀ (7.47%) and K₇₀ (7.29%). The lowest dry matter was

found in K₀ (5.41%). This might be due to optimum supply of potassium that increased photosynthesis and translocation of photosynthetic from source to sink.

Firmness

Firmness varied significantly with the different levels of potassium (Table 1). The highest firmness (1.22 N) was found in K₁₀₅ which was statistically similar to K₇₀ (1.17 N) and K₃₅ (1.10 N) While K₀ showed the lowest firmness (0.90 N). Potassium may helped in increase fibre and lignin formation that resulted in more compactness of fruit.

Weight loss

Significant variation of weight loss (%) was found due to different doses of potassium at ambient condition (Table 1). However, maximum weight loss (12.24%) was found in K₀. The minimum weight loss was found in K₁₀₅ (8.36 %) which was statistically identical with K₇₀ (9.36%) and K₁₄₀ (10.05%).

Shelf life

Shelf life of tomato varied significantly with the different rate of potassium (Fig 1.). The highest shelf life (15 days) was found in K₁₀₅. On the contrary, the lowest shelf life was found in K₀ (9 days). With optimum K nutrition, fruit is generally higher in total solids, sugars, acid, carotene and lycopene content and has a better keeping quality (Munson, 1985). Optimum dose of K may promote the development of thicker outer wall by producing lignin in the epidermal cells to prevent disease attack and increase shelf life.

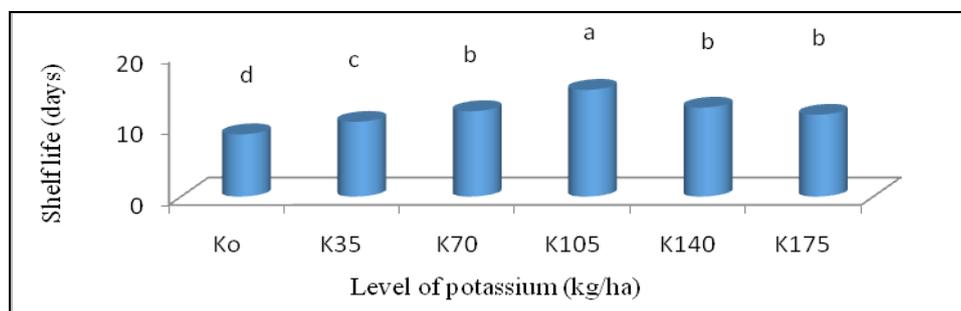


Fig. 1. Influence of potassium on shelf life (days) of tomato.

(Means bearing same letter (s) do not differ significantly at 0.05 level by DMRT).

Total soluble solids

Potassium had significant influence on total soluble solids (Table 2). The highest TSS (10.30%) was found in K₁₀₅ which was statistically similar with K₇₀. whereas the lowest was found in K₀ (9.17%). These results are in line with Cakmak (2005). He reported increasing trend of sugar contents as well as TSS in tomato with K fertilizer application.

Table 2. Nutritive quality of tomato in response of potassium

Level of K	TSS (%)	β carotene (mg/100 g)	Ascorbic acid (mg/100 g)	Total sugar (%)	Iron (ppm)	Calcium (%)	Potassium (%)
K ₀	9.17c	0.050d	14.30e	3.62d	23.75d	0.40ab	0.33c
K ₃₅	9.82b	0.057c	19.76c	4.45c	51.03c	0.42a	0.35c
K ₇₀	10.05ab	0.072b	22.68a	4.94ab	62.28b	0.40ab	0.39cb
K ₁₀₅	10.30a	0.090a	26.49a	5.05a	70.77b	0.38b	0.52b
K ₁₄₀	9.97b	0.070b	18.77cd	4.71bc	123.20a	0.37b	0.68a
K ₁₇₅	9.18c	0.057c	16.48de	3.63d	116.00a	0.32c	0.71a
Level of significance	**	**	**	**	**	**	**
CV (%)	1.80	11.56	7.97	4.78	9.39	21.48	8.74

Means bearing same letter (s) do not differ significantly at 1 % level of probability by DMRT.

** 1% level of probability.

β carotene

β carotene content of tomato had significantly varied due to the influence of different levels of potassium (Table 2). The maximum β carotene (0.090 mg/100 g) was found in K₁₀₅ and it was followed by K₇₀ (0.072 mg/100 g) while the lowest β carotene content was found in K₀ (0.050 mg/100 g).

Ascorbic acid

Significant variation was observed of the content of ascorbic acid in tomato due to the effect of different levels of potassium (Table 2). The maximum ascorbic acid (26.49 mg/100 g) was found in K₁₀₅ which was statistically similar with K₇₀ (22.68 mg/100 g) While it was minimum (14.30mg/100 g) in of K₀. The reason of increased content of ascorbic acid might be that K played a key role in proper carbohydrates metabolism and formation of ascorbic acid (Majumdar *et al.*, 2000).

Total sugar

The percentage of total sugar significantly varied due to the effect of potassium (Table .2). The highest content of total sugar (5.05%) was found in K₁₀₅ which was statistically similar with P₇₀ (4.94%). On the other hand, the lowest total sugar content was found in K₀ (3.62%). This might happen due to the fact that potassium played a key role in carbohydrate metabolism and photosynthesis and as a consequence, an optimum potassium supply determine better sugar content into sink organs (Marschner, 1995).

Iron

Significant variation of iron content of tomato was found due to the effect of K (Table 2). The highest content of iron (123.20 ppm) was found in K₁₄₀ which was statistically alike with K₁₇₅ (116.00 ppm) and it was followed by T₁₀₅ (70.77 ppm) while it was the lowest in K₀ (23.75 ppm). It was observed that iron content of tomato increased with the increase of potassium upto K₁₄₀.

Calcium

Calcium had significant influence on calcium content of tomato (Table 2). The maximum calcium (0.42%) was found in K₃₅ which was statistically similar with K₀ (0.40%) and K₇₀ (0.40%). However, K₁₀₅ (0.38%) and K₁₄₀ (0.37%) showed the intermediate Ca content and it was lowest in K₁₇₅ (0.32%). The result also indicated that increase of potassium rate decreased the Ca content. It might be due to the negative interaction between Ca and K in tomato. Malvi (2011) reported that Ca and K ions are quite similar in size and charge. So, high K reduces plants ability to absorb Ca due to their antagonistic nature.

Potassium

The highest content of potassium (0.71%) was found in K₁₇₅ follower by K₁₄₀ (0.68%), K₁₀₅ (0.52%) and K₇₀ (0.39%) while it was lowest in K₀ (0.33%). It was observed that increased the rate of K increased the K content of tomato. Kaviani *et al.*, (2004) reported that increasing the K level increased the K uptake in plant.

Response equation

Regression analysis was done to quantify the relationship of applied potassium with yield (kg ha⁻¹) of tomato. A quadratic relationship between yield and K was observed (Fig. 2). The estimated relationship reveal that fruit yield would be increased with the application of K up to 95.31 kg per hectare and beyond that dose, the yield may be declined. From the regression equation ($y = -3.339x^2 + 636.5x + 42606$ for K) the optimum doses of K was 95.31 kg ha⁻¹ and its corresponding yield was 71.96 t ha⁻¹.

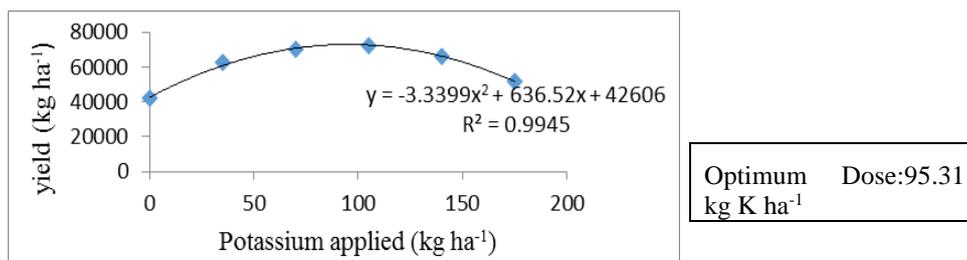


Fig. 2. Response of yield of tomato to potassium fertilizer.

Conclusion

The tomato plant treated with potassium @ 105 kg ha⁻¹ produce maximum plant height, number of fruits plant⁻¹, fruit diameter, fruit length, weight of fruit plant⁻¹, fruit yield ha⁻¹ dry matter, firmness, shelf life, TSS, β carotene, ascorbic acid and total sugar. On the other hand, maximum weight loss was found in K₀. Iron content increased upto 140 kg ha⁻¹ and potassium content increased with the increasing level of potassium but reverse effect was found in case of calcium. Based on regression equation, the optimum doses of K for tomato production was 95.31 kg ha⁻¹ in salna series of shallow red brown terrace soil.

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**EVALUATION OF PLANT EXTRACTS, FUNGICIDES, BIO-AGENT
AND SOIL AMENDMENTS AGAINST FOOT AND ROOT ROT
DISEASE OF BETELVINE CAUSED BY *SCLEROTIUM ROLFSII*
UNDER FIELD CONDITION**

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A. LATIF⁴ AND S. NAHAR⁵

Abstract

The studies were carried out on the management of foot and root rot disease caused by *Sclerotium rolfsii* Sacc. of betelvine (*Piper betle* L.) during April, 2017 to April, 2018 in a betelvine orchard (baroj) in the experimental farm of Sher-e-Bangla Agricultural University, Dhaka. There were 10 treatments, namely Provax 200, Tilt 250 EC, Score 250 EC, Pencozeb 80 WP, Garlic clove extract, Allamanda leaf extract, Poultry waste, Vermi-compost, *Trichoderma harzianum* and Control. The *in-vivo* evaluation, plant was inoculated by *S. rolfsii* after six month of plantation. The evaluation revealed that the lowest disease incidence of 8.33% was found in Provax 200 whereas the highest disease incidence of 91.67 was recorded under the untreated control treatment. The maximum of 90.91% reduction in disease incidence over control was found under Provax 200, which was significantly higher compared to all other treatments. Among the treatments, Provax 200 was noted as the most effective fungicide followed by Score 250 EC. The highest yield (7.57 t/ha) at 120 days after inoculation was found in case of Provax 200 which was 330.1% increased over untreated control. Stem and soil treated with Provax 200 including spraying at 3 days after inoculation, then sprayed at 7 days' intervals minimized disease incidence and increased yield. Among the eco-friendly approach, Garlic clove extract, *Trichoderma harzianum* and soil amended with Vermi-compost also showed better performance in controlling foot and root rot disease of betelvine as compared to control.

Keywords: Betelvine, disease management, foot and root rot, *Sclerotium rolfsii*.

Introduction

Betelvine (*Piper betle* L.), vernacularly known as 'Pan', is a kind of dioecious perennial creeper vine belonging to the family Piperaceae. It is cultivated largely for its leaves. It is an important cash crop of Bangladesh. Betel leaves have a strong pungent aromatic flavor and are widely used as masticatory. Mature leaves are used for chewing with smeared hydrated lime and catechu, arecanut,

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cardamom, clove, etc. Betelvine leaf chewing is considered as a good and cheap source of dietary calcium. Usually the people of South-Asia, South-east Asia, Gulf States and Pacific Islands chew betel leaves. All classes of people of Bangladesh chew not only as a habit but also as an item of rituals, etiquette and manners. There are about 100 varieties/cultivars of betelvine in the world (Guha and Jain, 1997). Among the cultivars, Desi Bangla, Bangla, Kali Bangla, Jhali, Sanchi, Goyeshi, Bhabna, Mitha, Geso, Bonhoogly, etc., are found to be widely grown in Bangladesh. Total cultivated area under the crop in Bangladesh in 2016-17 was about 23,803.20 hectares and the total annual production was about 2,14,252 metric tons. The average yield per hectare is 9.0 metric tons (BBS, 2018). Pan leaf is usually plucked throughout the year but maximum production obtained in the months of July to October.

The acreage of betelvine is decreasing gradually due to infestation of disease and pest (Islam, 2005) and the extent of losses varies from 5-90 percent (Dasgupta and Sen, 1999; Dasgupta *et al.*, 2005). Among the diseases of betelvine foot and root rot caused by *Sclerotium rolfsii* is the most overwhelming disease which decreases the production of betel leaf to a great extent (Islam, 2005). Humid and moist shaded conditions are favorable for betelvine growth which also favor a variety of root and foliage disease development (Goswami *et al.*, 2002). The fungus can overwinter as mycelium in infected tissues or plant debris or as sclerotia near soil surface or buried in soil which serve as a major source of primary infection by germinating in response to alcohols and other volatile compounds released from decomposing plant material (Punja, 1985).

At present diseases are mainly managed by the use of chemicals such as fungicides. However, the indiscriminate use of chemicals not only hazardous to living being but also break the natural ecological balance by killing the beneficial and/or antagonist microorganisms. On the other hand, Botanical extracts, Plant growth promoting fungi (PGPF) and soil amended materials etc. suppress the pathogen and protect the plants that is environmentally safe, durable and cost effective alternative to chemicals (Mukhopadhyay, 1994) and avoid the development of resistant strains of the pathogen.

Hence, efforts have to be made to retain pathogen activity below economic threshold level by choosing different alternative methods. So, the present experiment was conducted to evaluate the efficacy of four fungicides [Provax 200 (Carboxin 17.5%+ Thiram 17.5%), Tilt 250 EC (25% Propiconazole), Score 250 EC (25% Difenconazole) and Pencozeb 80 WP (80 % Mancozeb)], two botanicals [Garlic clove extract (allicin), Allamanda leaf extract (allamandin)], two soil amendments [Poultry waste, Vermi-compost] and one bio-agent (*Trichoderma harzianum*) for controlling foot and root rot disease of betelvine caused by *S. rolfsii* in field condition.

Materials and Methods

The experiment was conducted in a betelvine orchard (baroj) in the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during April, 2017 to April, 2018. The experiment was laid out in RCBD with 4 replications maintaining plot size (0.30 x 0.60) m² and plant to plant spacing 20 cm. One hill with three plants were used for each treatments. Altogether 10 treatments comprising fungicides, botanicals, bio-agent and soil amendments were tested in the experiment. The treatments were T₁ = Provax 200 @ 0.25%, T₂ = Tilt-250 EC @ 0.1%, T₃ = Score 250 EC @ 0.05%, T₄ = Pencozeb 80 WP @ 0.45%, T₅ = Garlic clove extract @ 15%, T₆ = Allamanda leaf extract @ 15%, T₇ = Vermicompost @ 30g/plant, T₈ = Poultry manure @ 30g/plant, T₉ = *Trichoderma harzianum* @ 5g/plant and T₁₀ = Control.

(a) Growing of betelvine cuttings

A piece of medium high land with well drainage system was selected and deep ploughing was done during early summer at the end of April month in 2017. After ploughing, upper soil is left exposed in the sun for two months. During the first week of June, three times ploughing was done for well pulverized good tilth condition of soil. Weeds and stubbles were removed manually. Drainage trenches of 90 cm width by 15 cm depth were dugged in between two adjacent beds. A susceptible betelvine cultivar Misti pan cutting was collected from 3-5 years old betelvine orchard in Rajshahi. Forty centimeter long cuttings with three to five nodes were cut from the vine. For each treatment, twelve betelvine cuttings were treated deeply into suspension of fungicides, plant extracts and bioagent separately for 20 minutes. The cuttings were then drained off, air dried and planted in the field. For control treatment the cuttings were treated with plain water.

Treated vine cuttings were planted in the experimental field under partially shaded and humid environment in the betelvine baroj. Planting was done with the help of khurpi (a hand operated implement). For planting, a hole was made with khurpi, so that the internodes below the bud point is dipped in soil, but rest part of cutting must be touching with surface soil. The cuttings were planted in the furrows at 8-10 cm deep. The hole was compacted with the help of thumb finger. The planted cuttings were watered twice a day until the vines were established. Sticking of vines, irrigation and fertilization/manuring were done as per requirement of the orchard. Weeding was done regularly to ensure weed free clean cultivation.

(b) Inoculum preparation and inoculation of *S. rolfsii*

The isolate of *S. rolfsii* isolated from foot and root rot infected betelvine following tissue planting method (Mian, 1995) and multiplied on barley grains (Gupta and Kolte, 1982). Fresh barley grains were pre-soaked in 2% sucrose

solution overnight, drained off excess solution and boiled in fresh water for 30 minutes and drained off again. These were transferred into 250 ml conical flasks @ 80 g and autoclaved at 121.6°C temperature, under 1.1 kg/cm² pressure for 20 minutes. The conical flasks were allowed to cool at room temperature and were inoculated with 5 mm discs of 3 to 4 days old culture of *S. rolfsii* grown on PDA. Seven discs per flask were added and flasks were incubated for three weeks at 25±2°C.

After six months of plantation of betelvine the isolate of causal pathogen (*S. rolfsii*) were inoculated. The plants were prepared for inoculation by removing top soil around 5 cm of the stem to a depth of 2 cm. A table spoon (5 g) of inoculum was placed in direct contact of entire circumference of the exposed stem. Finally, the inoculum was lightly covered with top soil for infection.

(c) Collection and preparation of plant extracts

The plant leaf extracts were prepared by using the method of Ashrafuzzaman and Hossain (1992). For preparation of extracts, collected leaves were weighted in an electric balance and then washed in tap water and then in distilled water. After washing the big leaves were cut into small pieces. For getting extract, weighted plant parts were blended in an electric blender and then distilled water was added into the jug of the blender. For getting 1:1 (w/v) ratio 100 ml of distilled water was added with 100g plant parts. The pulverized mass was squeezed through 3 folds of fine cotton cloth. The extract was used as stock solution for the study. To prepare 15 % concentrations of plant extract, 15 ml of stock solution was mixed with 85 ml of sterilized water. The 15% concentrations of plant extract was used for application.

(d) Preparation of bio-agent

The fungal antagonist bio-agents, *Trichoderma harzianum* collected from the laboratory of Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI) and cultured on PDA. Inoculum of the bio-agent, *T. harzianum* was prepared using the method as described by Gupta and Kolte (1982). Fresh barley grains were pre-soaked in 2% sucrose solution overnight, drained off excess solution and boiled in fresh water for 30 minutes and drained off again. These were transferred into 250 ml conical flasks @ 80 g and autoclaved at 121.6°C temperature, under 1.1 kg/cm² pressure for 20 minutes. The conical flasks were allowed to cool at room temperature and were inoculated with 5 mm discs of 3 to 4 days old culture of *T. harzianum* grown on PDA. The inoculated flasks were incubated at 25±2°C for three weeks.

(e) Spraying of fungicides and plant extracts

Fungicides (Provax 200 @ 0.25%, Tilt-250 EC @ 0.1%, Score 250 EC @ 0.05%, Pencozeb 80 WP @ 0.45%) and plant extracts solutions were prepared

separately. The selected plant extracts and fungicides were sprayed at 3 days after inoculation at the base of the plant and plant base soil. Then sprayed at 7 days' intervals for three times by hand sprayer. Precautions were taken to avoid drifting of spray materials to neighboring plants.

(f) Application of bio-agent, poultry manure and vermi-compost

A table spoon (5 g) of cultured *T. harzianum* on barley grains were applied at the base and root zone of the plants before 10 days of *S. rolfsii* inoculation. Similarly, poultry manure 30g and vermi-compost 30g per plant were applied separately on different plant at the base and root zone before 10 days of *S. rolfsii* inoculation. Precautions were taken to avoid drifting of application materials to the neighboring plants.

(g) Data collection

The data on days required for appearance of disease symptom, disease incidence and yield of betel leaf were recorded.

The incidence of the disease was computed based on the following formula:

$$\% \text{ Disease incidence} = \frac{\text{Number of infected plant in the area covered}}{\text{Number of inspected plant}} \times 100$$

The yield increase was calculated using the following formula:

$$\% \text{ yield increase over control} = \frac{x - y}{y} \times 100$$

Where x = Mean under treatments ($T_{n, n=1-9}$) and y = Mean under control (T_{10})

(h) Statistical analysis

The data were statistically analyzed by using computer package program (Statistix 10). The significant differences of the treatment means were compared by Duncan's Multiple Range Test (DMRT) at 1% level of significance.

Results and discussion

(A) Days required for appearance of disease symptom

Appearance of foot and root rot disease in inoculated betelvine varied from 10 to 95 days among the treatments (Table 1). Disease symptom appeared at 10 days in the control treatment while it ranged from 29 to 95 days among the treated plots. The result indicated that the appearance of foot and root rot disease could be deferred or delayed by the application of different treatment with fungicides, botanicals, bio-agent and soil amendments.

(B) Disease incidence

The highest disease incidence ranging from 58.33 to 91.67% was observed in control treatment at 30 through 120 DAI (Table 1). The disease incidence increased gradually with the progress of duration after inoculation showing the maximum of 91.67% at 105 and 120 DAI. Application of different treatments significantly reduced the disease incidence over control.

No visible symptoms of foot and root rot of betelvine appeared at 30 DAI, in case of fungicides, botanicals, bio-agents and soil amendments. Though poultry manure and control treated plot showed the disease incidence 16.67% and 58.33%, respectively.

At 45 DAI, the minimum of 16.67% disease incidence was recorded in case of treatment T₇ followed by T₈. At 60 DAI, the disease incidence was absent under T₁, T₂, T₃, T₅, T₆ and T₉. No disease incidence was observed at 75 DAI in T₁, T₂, T₃, T₅ and T₉. At that stage the lowest incidence of 16.67% was recorded from T₆ which was statistically similar to T₄ but significantly higher as compared to T₇ and T₈. At 90 DAI, only T₁ and T₅ showed no incidence of disease. At that stage the disease incidence under T₂, T₄, T₇ and T₈ were statistically similar but significantly higher as compared to T₆ and T₉ (Table 1). At 105 DAI, minimum of 8.33% foot and root rot incidence of betelvine was found under T₁, which were statistically similar to T₃ and T₉.

At 120 DAI, the lowest disease incidence of 8.33% was recorded from T₁, which was statistically similar to only T₃ (16.67%) but significantly higher as compared to other treatments. The disease incidence was 33.33% in the treatments T₂, T₅ and T₉, 49.99% under T₆, 58.32% in T₇ and 66.66% in T₄ and T₈ (Table 1).

At 120 days after inoculation (DAI), the maximum of 90.91% reduction in disease incidence over control was found under T₁, which was statistically similar to only T₃ (81.82%) but significantly higher as compared to all other treatments (Fig. 1). The lowest reduction was found under T₄ (18.95%) followed by T₈, T₆ and T₇. The disease incidence was 63.64 under treatments T₂, T₅ and T₉ which were significantly higher as compared to T₄, T₆, T₇ and T₈. Among the treatments, T₁ i.e. Provax 200 was noted as the most effective fungicide followed by T₃ i.e. Score 250 EC in controlling foot and root rot disease of betelvine.

(C) Yield

The per hectare yield of betel leaf at 120 days after inoculation was 7.57, 7.24, 7.16, 7.14 and 6.59 tons under the treatments of Provax 200 (T₁), Score 250 EC (T₃), *T. harzianum* (T₉), Garlic clove extract (T₅) and Tilt-250 EC (T₂), respectively (Table 2). The lowest yield of 1.76 t/ha was found under control (T₁₀) followed by Poultry manure (T₈), Allamanda leaf extract (T₆).

Application of Provax 200, Tilt-250 EC, Score 250 EC, Garlic clove extract and *Trichoderma harzianum*, produced increased yield over control ranged from 274.4 to 330.1%. These five treatments were noted as effective treatments to control the disease.

The results of the present investigation were in agreement with findings of many other researchers. Carboxin (Provax 200/ Vitavax 200) reported to be effective in controlling collar rot of Sunflower and Sunhemp caused by *S. rolfsii* (Pal and Choudhary, 1983). Others reported that Garlic clove extract found effective both *in-vitro* and *in-vivo* in controlling foot and root rot of betelvine (Yasmin, 2016; Shahiduzzaman, 2015). As a bio-agent *T. harzianum* and *T. viride* were also proved to be highly promising against soil borne pathogen, *S. rolfsii* (Rekha *et al.*, 2012; Parvin *et al.*, 2016).

Table 1. Effect of fungicides, plant extracts, bio-agent and soil amendments on the incidence of foot and root disease of betelvine under field condition

Treatments	DDI	Percent disease incidence (PDI) at different days after inoculation (DAI)						
		30 DAI	45 DAI	60 DAI	75 DAI	90 DAI	105 DAI	120 DAI
T ₁ = Provax 200	95	0.00 c (0.083)	0.00 d (0.083)	0.00 c (0.083)	0.00 d (0.083)	0.00 e (0.083)	8.33 e (8.57)	8.33 e (8.57)
T ₂ = Tilt- 250 EC	76	0.00 c (0.083)	0.00 d (0.083)	0.00 c (0.083)	0.00 d (1.59)	33.33 bc (34.02)	33.33bcd (34.02)	33.33 cd (34.17)
T ₃ = Score 250 EC	86	0.00 c (0.083)	0.00 d (0.083)	0.00 c (0.083)	0.00 d (0.083)	16.66 d (17.05)	16.67 de (17.05)	16.67 de (17.05)
T ₄ = Pencozeb 80 WP	47	0.00 c (0.083)	0.00 d (0.083)	8.33 c (9.70)	24.99 bc (25.53)	33.33 bc (34.02)	58.33 b (48.10)	66.66 b (52.80)
T ₅ = Garlic clove extract	91	0.00 c (0.083)	0.00 d (0.083)	0.00 c (0.083)	0.00 d (0.083)	0.00 e (0.083)	24.99 cd (25.53)	33.33 cd (34.01)
T ₆ = Allamunda extract	70	0.00 c (0.083)	0.00 d (0.083)	0.00 c (0.083)	16.67 cd (17.05)	24.99 cd (25.53)	41.66 bc (38.71)	49.99 bc (43.41)
T ₇ = Vermi-compost	44	0.00 c (0.083)	16.67 c (17.05)	33.33 b (34.02)	41.66 b (38.71)	49.99 b (43.41)	58.33 b (48.10)	58.32 bc (48.10)
T ₈ = Poultry manure	29	16.67 b (17.05)	33.33 b (34.02)	41.66 b (38.71)	49.99 b (43.41)	49.99 b (43.41)	66.66 b (52.80)	66.66 b (52.80)
T ₉ = <i>T. harzianum</i>	87	0.00 c (0.083)	0.00 d (0.083)	0.00 c (0.083)	0.00 d (0.083)	16.66 d (17.05)	16.67 de (17.05)	33.33 cd (30.22)
T ₁₀ = Control	10	58.33 a (51.91)	66.66 a (56.60)	74.99 a (65.11)	74.99 a (65.11)	83.33 a (69.81)	91.67 a (78.32)	91.67 a (78.31)
LSD	-	14.48	13.67	15.69	18.45	16.57	18.95	18.04

Figures within same column having common letter(s) do not differ significantly at 1.00% level of significance.

Data within parenthesis are arc-sine transformed values. DDI: Days to disease initiation.

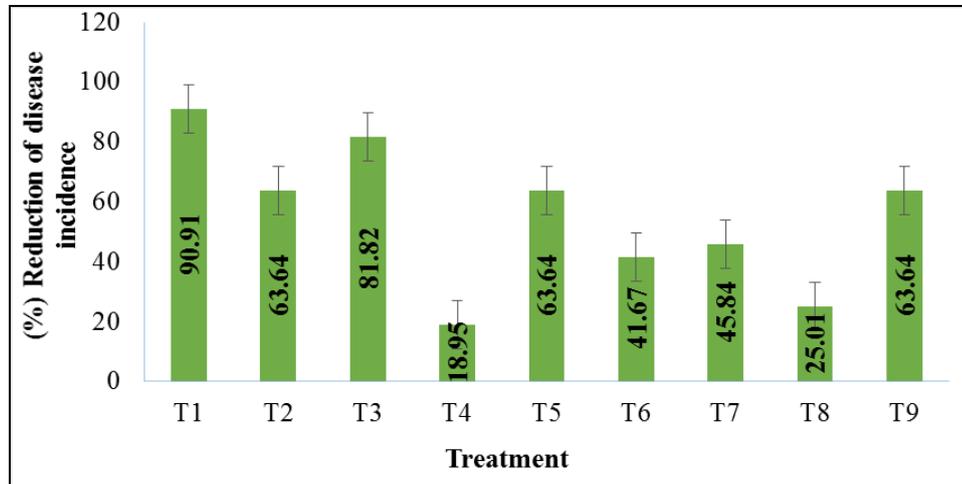


Figure 01. Percent reduction of incidence of foot and root rot disease of betel vine due to different treatments over control at 120 days after inoculation.

[T₁ = Provox 200, T₂ = Tilt- 250 EC, T₃ = Score 250 EC, T₄ = Pencozeb 80 WP, T₅ = Garlic clove extract, T₆ = Allamanda leaf extract, T₇ = Vermi-compost, T₈ = Poultry manure, T₉ = *Trichoderma harzianum* and T₁₀ = Control (No chemicals, plant extract, bio-agents and soil amendments)].

Table 2. Effect of fungicides, plant extracts, bio-agents and soil amendments on yield of beteleaf under field condition

Treatments	Yield (t/ha) at 120 days	Yield increase (%) over control [£]
T ₁ = Provox 200	7.57 a	330.1
T ₂ = Tilt- 250 EC	6.59 abc	274.4
T ₃ = Score 250 EC	7.24 a	311.4
T ₄ = Pencozeb 80 WP	5.94 bcd	237.6
T ₅ = Garlic clove extract	7.14 ab	300.5
T ₆ = Allamanda extract	5.59 cde	218.0
T ₇ = Vermi-compost	5.29 de	201.0
T ₈ = Poultry manure	4.48 e	154.5
T ₉ = <i>T. harzianum</i>	7.16 a	306.8
T ₁₀ = Control	1.76 f	-

Conclusion

Foot and root rot caused by *Sclerotium rolfsii*, the most devastating disease of betelvine in Bangladesh, reduced the yield and quality of betel leaves every year. Based on results of the *in-vivo* evaluation, Garlic clove extract, Provox-200 & Score 250 EC fungicides, *T. harzianum* and soil amendments with Vermi-

compost were found to be most effective against *S. rolfsii* which could be used as IPM components for increasing the yield of betel leaf under baroj conditions.

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SPECIES DIVERSITY AND RICHNESS OF ANT (*Hymenoptera, formicidae*) IN BHAWAL NATIONAL PARK OF BANGLADESH

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Abstract

Ant community serves as an bioindicator on the assumption that the extent of ant diversity reflects broader ecosystem change. Bangladesh with varied agro ecosystem providing broad ecological niche of diversified ant community. The study of ant community is a way to measure the recent transformation of agro ecosystems in Bangladesh to provide information about management and conservation of agricultural landscape. The present study was conducted in Bhawal National Park to delve deeper into the diversity and richness of ants as they work as ecological indicators of an ecosystem. Being a conservation site with natural resources, Bhawal National Park can serve as study site with species diversity due to having sites with similar vegetation and soil type, but different ecological parameters. The objective of the study was to identify local ant fauna in forest agroecosystem to understand the impact on human disturbance to ant communities of the study area. Total 399 individuals were identified from 42 species of 17 genera belonging to 6 subfamilies. Sampling was performed using Time unit sampling (TUS) and pitfall trap in two different areas, viz, area 1 and 2. The most dominant subfamily of the study area was Myrmicinae. The highest number of species were found from the genus *Camponotus*. The Shannon-Wiener's Diversity Index showed that area 1 had higher species diversity due to favorable living conditions with less animal intervention and higher density of vegetation playing key role. However, the species dissimilarity in different study areas were relatively low due to similar vegetation and soil type. The study provided an inventory of Bangladesh as well as identification system of ants. This is the first comprehensive list of ants from forest ecosystem of Bangladesh.

Keywords: Ant diversity, Bhawal National Park, bioindicator, forest ecosystem

Introduction

Ant is a eusocial species that plays a crucial role in ecological systems as soil engineers, competitors, predators, scavengers, mutualists, gardeners, and biological agents of insect pests in agriculture (Pal, 2006). In tropical regions, 10-15% animal biomass in different biotopes constitute of ants making them one of the most abundant insect groups (Agosti *et al.*, 2000). From top of the tall trees to the soil and litters of forests, in almost all territory-based ecosystems, a broad range of 15,000 ants can be found (Andrade *et al.*, 2007). Ants participate in

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various natural cycles that help to reduce climate change hence, considered to be bio-indicators of the quality of forests (Nguyen and Nguyen, 2016). Ant species have been used as soil indicators of mine site rehabilitation (Andersen *et al.*, 2003). They also contribute to modify the physical and chemical properties of soil increasing its drainage and aeration (Dostál *et al.*, 2005) and responsible for altering temperature and other micro climatic variables (Jenkins *et al.*, 2011). High diversity in taxonomy and association with specific settlements make ants a good object in monitoring studies. Thus, ants are usually chosen to compare species diversity at different habitats.

Numerous researches have been conducted recently (Szewczyk and McCain, 2016, Arnan *et al.*, 2017, Belskaya *et al.* 2017) on ant diversity and functions for ecosystem management. However the association of ant community with agroecosystems needs more detailed study in the tropics.

In Bangladesh, no research was conducted to monitor ant diversity as a tools of bio-indicator in the natural system due to lack of taxonomic information and method for measuring human disturbance. Therefore, the present study was conducted to analyze the diversity of local ant fauna, understand the prevalent ecosystem by correlating it with the presence of ants found in the study area and shed light on the differences in the various ecosystems with the interfering effects in the study area and how it impacts the ant biomass.

Methodology

Study Area

The study was conducted in Bhawal National Park (24°01'N, 90°20'E) during June 2015 to November 2015. The park is situated about 40 km north of Dhaka, the capital city of Bangladesh, at the heart of Gazipur city. Along with the forest, the park covers 5,000 ha area (Kabir and Ahmed, 2005). Its coverage of this huge area contributes to its biological diversity in both flora and fauna.

Habitat Characterization

The forest area of the park is a mix of different habitats dominated by Sal forests and rice fields. The topology is classified as low hills that raise 3.0-4.5 m above the surrounding paddy fields (Kabir and Ahmed 2005). The tree that dominates the forest is Sal (*Shorea robusta*) covering 90% of the area. A total of 221 species consisting of 27 grass species, 24 climber species, 3 palm species 105 herb species, 19 shrubs species, and 43 tree species have been identified here. Plants include *Careyaa rborea*, *Dillenia pentagyna*, *Terminalia belerica*, *Milius avelutura* etc. Among vegetation, *Lantala*, *Melostoma*, etc. are commonly found here. Few mammals including *Vulpes bengalensis*, *Canis aureus*, *Viverricula indica* etc. can be seen (Kabir and Ahmed, 2005).

Although it was a reserve forest, the forest have several ecological properties. Some part of this forest is open with foraging fields where people and cattle

move frequently. This area is bounded by lakes and some aquatic feature as well. Paddy fields are observed in the periphery of this area. The other side is occupied by deep vegetation and relatively undisturbed areas. No such lakes or aquatic environment are observed. For this study, for measuring the diversity and functions of ants, we categorized the two areas as Area 1 and Area 2, respectively based on the type of vegetation and management approaches. The perimeter of both the areas were about 372 m. The two areas are: Open Forest containing foraging fields and lakes that has been mentioned as Area 1 and Deep Forest containing higher vegetation and limited intervention, termed as Area 2 in this paper.

Sampling

Sampling of ants were done using Time-Unit Sampling (Ogata, 2001) and by setting pitfall trap. In Time-Unit Sampling method, the whole operation was divided into four time-units. Each unit lasted for 15 minutes at stretch. Two persons conducted the operation in $30+\alpha$ minutes (α signifies the gap between two time-units). Ants were searched on the ground, in/under shelters, on lower vegetations and collected using forceps. The key idea in this method is to collect as many ants as possible within a single 15-minute time unit. Each of the time unit samples is independent, so the samples were preserved in their own vials with their own serial code. These vials were prepared beforehand using 70% ethanol. For pitfall trap method, small containers were placed on the ground with their tops on the surface level. The containers were filled with ethylene glycol. Ants that fell into the trap while roaming around were collected from the containers afterwards for further processing.

Cleaning and Sorting

Collected specimens were cleaned using brush dipped in water to remove any dirt or other materials. After cleaning, the samples were washed in alcohol and sorted into similar groups. Each group were put in separate vial and labeled accordingly.

Dry Preservation

The collected specimens were preserved on a dry basis using card points and card mounts. Small triangular pieces of white cardboard, points were made using scissors. Each point was mounted on a macro-pin inserted near the base of the triangle. Using water-soluble glue, the samples were glued to the tip of the point. Multiple ants from same group were placed on one macro-pin.

Identification and Labeling

Samples were inspected under electronic microscope and identified with their taxonomic keys (Bolton, 1994). The identified ants were properly labeled and

preserved in the museum of Department of Entomology of Bangabandhu Sheikh Mujibur Rahman Agricultural University for future references.

Statistical Analysis

For measuring the diversity of ants, few renowned methodology were followed:

1. Shannon-Wiener Diversity Index:

Shannon-Wiener Diversity Index (H') (Krebs, 1999) was calculated to determine the species diversity in each study area. It measures the amount of order (or disorder) contained in a system (Margalef, 1958). The value is given by:

$$H' = \sum_{i=1}^s p_i \ln(p_i)$$

where,

s= Number of Species

p_i = Proportion of the Total Sample Belonging to the i -th Species

2. The Evenness Index:

The Evenness Index (J') (Krebs 1999) was calculated to determine the equal abundance of ants in each study area. The value is given by:

$$J' = \frac{H'}{H'_{\max}}$$

where,

H' = Observed Index of Species Diversity

H'_{\max} = Maximum Possible Index of Diversity

3. Effective Number of Species:

Effective Number of Species (ENS) (Jost, 2006) was calculated using the Shannon-Wiener Diversity Index (H') to find the true diversity of the areas in question. This helped us to find an actual measure to compare and contrast the two study areas. The value is given by:

$$ENS = e^{H'}$$

where,

H' = Observed Index of Species Diversity

4. Bray-Curtis Dissimilarity:

Bray-Curtis Dissimilarity (*BC*) (Bray and Curtis 1957) was calculated to quantify the compositional dissimilarity between two areas. The result is often multiplied by 100 and treated as percentage. The value is given by:

$$BC = 1 - \frac{2|X \cap Y|}{|X| + |Y|}$$

where,

$|X \cap Y|$ = Number of species common in both areas

$|X|$ = Total number of species in area 1

$|Y|$ = Total number of species in area 2

5. Statistica Package:

Statistica Package R was used for generating the graph on species diversity in two areas.

Results and Discussion

A total of 399 individuals of 42 species in 17 genera distributed among 6 subfamilies were collected from two areas using time-unit sampling and pitfall traps. The detailed checklist can be found in Table 1. Among the subfamilies, Myrmicinae thrives having 215 samples from 8 genera consisting of 20 different species followed by Ponerinae and Dorylinae, respectively. The highest number of ants were identified from *Pheidole* followed by *Camponotus* and *Dolichoderus*. Both the areas were dominated by 6 different species from the the genus *Camponotus*.

The most dominant species in both the areas of Bhawal National Park is *D. affinis* occupying 7.27% of the identified samples, followed by *P. binghami* and *M. brunnea* (Table 2). Area 2 was found more diverse with species richness than that of Area 1. Thirty Four species of ants in 16 genera were found in Area 2, while, 27 species of ants in 14 genera were identified in Area 1. This can be attributed to diverged vegetation pattern incorporated with the lack of human intervention and no foraging activity in Area 2. Bhawal National Park is dominated by deciduous Sal tree. The leaves of these trees fall off every year. Fallen leaves are decomposed by microorganisms resulting in higher nutrient content. This is why ants seek refuge in places with high vegetation. Moreover, limited human access and lack of foraging activities facilitate free movement of ants. This has made the place an ant sanctuary. On the contrary, Area 1 is facilitated with lakes and crop fields that allow intervention of cattle and human along with some aquatic insectivores. These make the area less suitable for ants.

Table 1. Species diversity of different ant fauna in Bhawal National Park

Subfamily	Genera	Number of Species	Total Individuals
Dolichoderinae	<i>Dolichoderus</i>	2	41
Dorylinae	<i>Camponotus</i>	6	55
	<i>Cerapachys</i>	1	5
Formicinae	<i>Oecophylla</i>	1	21
	<i>Crematogaster</i>	3	35
	<i>Meranoplus</i>	2	29
Myrmicinae	<i>Myrmica</i>	2	11
	<i>Myrmicaria</i>	2	32
	<i>Pheidole</i>	5	65
	<i>Solenopsis</i>	1	14
	<i>Tetramorium</i>	2	13
	<i>Trichomyrmex</i>	3	16
	<i>Anochetus</i>	2	8
Ponerinae	<i>Diacamma</i>	3	22
	<i>Leptogenys</i>	3	9
	<i>Odontoponera</i>	1	4
Pseudomyrmecinae	<i>Tetraponera</i>	3	19
Total		42	399

Table 2. Relative abundance of listed ant species in two areas

Genus	Species	Area 1	Area 2	Total	Occurrence (%)
<i>Dolichoderus</i>	<i>D. affinis</i>	9	20	29	7.27%
	<i>D. taprobanae</i>	0	12	12	3.01%
<i>Camponotus</i>	<i>C. angusticollis</i>	4	2	6	1.50%
	<i>C. festinus</i>	7	11	18	4.51%
	<i>C. fulvopilosus</i>	4	3	7	1.75%
	<i>C. oblongus</i>	3	5	8	2.01%
	<i>C. rufoglaucus</i>	0	6	6	1.50%
	<i>C. siemsseni</i>	0	10	10	2.51%
<i>Cerapachys</i>	<i>C. sulcinodis</i>	0	5	5	1.25%
<i>Oecophylla</i>	<i>O. smaragdina</i>	11	10	21	5.26%

Genus	Species	Area 1	Area 2	Total	Occurrence (%)
<i>Crematogaster</i>	<i>C. abdominalis</i>	9	5	14	3.51%
	<i>C. binghamii</i>	4	8	12	3.01%
	<i>C. rufa</i>	3	6	9	2.26%
<i>Meranoplus</i>	<i>M. laeviventris</i>	7	0	7	1.75%
	<i>M. rothneyi</i>	0	22	22	5.51%
<i>Myrmica</i>	<i>M. indica</i>	4	4	8	2.01%
	<i>M. rugosa</i>	0	3	3	0.75%
<i>Myrmicaria</i>	<i>M. brunnea</i>	0	22	22	5.51%
	<i>M. fodiens</i>	0	10	10	2.51%
<i>Pheidole</i>	<i>P. binghamii</i>	0	25	25	6.27%
	<i>P. feae</i>	13	3	16	4.01%
	<i>P. indica</i>	8	0	8	2.01%
	<i>P. roberti</i>	0	7	7	1.75%
	<i>P. noda</i>	4	5	9	2.26%
<i>Solenopsis</i>	<i>S. geminata</i>	0	14	14	3.51%
<i>Tetramorium</i>	<i>T. belgaense</i>	3	0	3	0.75%
	<i>T. indicum</i>	4	6	10	2.51%
<i>Trichomyrmex</i>	<i>T. criniceps</i>	3	4	7	1.75%
	<i>T. destructor</i>	0	7	7	1.75%
	<i>T. mayri</i>	2	0	2	0.50%
<i>Anochetus</i>	<i>A. cryptus</i>	0	3	3	0.75%
	<i>A. rufus</i>	4	1	5	1.25%
<i>Diacamma</i>	<i>D. assamense</i>	4	0	4	1.00%
	<i>D. ceylonense</i>	0	6	6	1.50%
	<i>D. indicum</i>	7	5	12	3.01%
<i>Leptogenys</i>	<i>L. assamensis</i>	0	4	4	1.00%
	<i>L. falcigera</i>	3	0	3	0.75%
	<i>L. roberti</i>	1	1	2	0.50%
<i>Odontoponera</i>	<i>O. denticulata</i>	4	0	4	1.00%
<i>Tetraponera</i>	<i>T. binghami</i>	3	7	10	2.51%
	<i>T. nigra</i>	3	2	5	1.25%
	<i>T. rufonigra</i>	4	0	4	1.00%

Between the two areas, Area 2 scores higher Shannon-Wiener Diversity Index compared to Area 1. This result is shown in Table 3. These findings support previous phenomenon of higher abundance of species in Area 2. The evenness index of both areas are close to 1, denoting that in both areas the number of

species are close to each other. Evenness index works better when the number of sample is higher. However, it fails to capture the intricate difference between evenness of species for smaller sample sizes as shown in this case. For this reason, the effective number of species were calculated. It shows us the degree of unevenness or dominance of species in the area. It emphasizes the result of Shannon-Wiener Diversity Index as it weighs each species exactly according to its frequency. Even though there were 34 species found Area 2, the effective number of species is far lesser denoting the huge difference between the contribution of each species in the biomass of the area. The Bray-Curtis Dissimilarity between Area 1 and Area 2 is 0.377. That means the two areas have 37.7% dissimilarity between them. The reasoning behind this can be the similarity in vegetation of the two areas.

Table 3: Shannon-Wiener Diversity, Evenness Index and Effective Number of Species of the two areas

Area	Number of Species	Number of Samples	J'	H'	ENS
1	27	135	0.96	3.15	23
2	34	264	0.92	3.26	26

8 species from 7 genera were exclusive to area 1 whereas 15 species from 12 genera were exclusive to area 2, however, 11 species were common in both areas (Fig. 1).

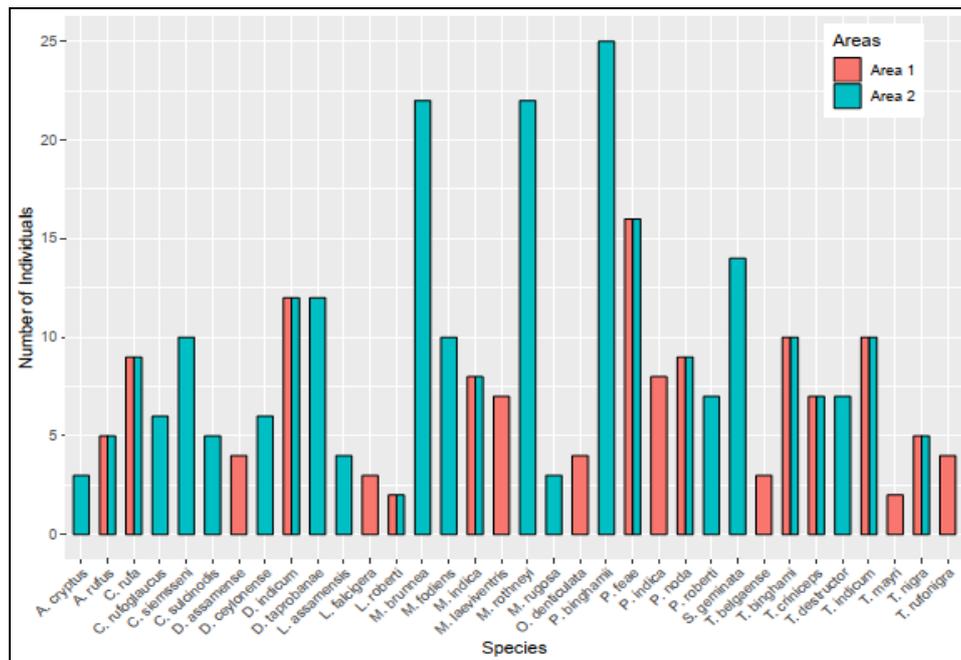


Fig. 1. Relative distribution of ant species in the two areas.

Conclusion

The diversity and richness of ants in Bhawal National Park was highlighted in this study. A total of 42 species from 17 genera distributed among 6 subfamilies were identified. The difference in species composition found can be attributed to the difference in the habitats of the study area. Higher density in vegetation and lack of animal intervention resulted higher diversity index. However, similarity in regions were found due to homogenous vegetation pattern. As ants are using to measure and monitor biodiversity in different agroecosystem, therefore, the findings of this study will be useful to evaluate recent biodiversity and the effects of agricultural intensification. This study of the ant community of Bhawal national park will be a way to measure the transformation of agroecosystems and can provide information about management and conservation of agricultural landscape by studying the impacts of disturbance on ant communities in agroecosystem of Bangladesh.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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**EFFECT OF FOLIAR SPRAY OF BIOREGULATORS AND
IRRIGATION ON DRY MATTER ACCUMULATION OF
MUSTARD (*Brassica juncea* L.)**

A. SINGH¹ AND R. S. MEENA²

Rapeseed and mustard is generally, affect by irrigation water. The rapeseed-mustard is the crop that has fewer requirements of the water (Aujla *et al.*, 2005). To alleviate the harmful effect of drought stress, bioregulators may be used to change the different metabolic and physiological activities of the plant for increasing the yield of mustard crop (Meena *et al.*, 2013). Thiourea containing one SH group and it's is a sulphhydryl compound. The SH group has been implicated in photosynthetic translocation in plants (Giaquinta, 1976). It is simply concerned in light activation of photosynthetic enzymes (Salisbury and Ross, 1986). The exogenous application of Salicylic acid (SA) has been reduced the negative effect of water stress (Khan *et al.*, 2015) and spray of SA improve the growth of the plant (Hayat *et al.*, 2010). Glycinebetaine an important ammonium compound, it considered to be one of the most pre-dominant and effective osmoprotectants. The exogenous application of glycinebetaine improved the drought tolerance in plants (Mahmood *et al.*, 2009; Meena *et al.*, 2018). Hence, the study was conducted to see the effect of bioregulators on dry matter accumulation of Indian mustard under different levels of irrigation.

The experiment was conducted during the *rabi* (winter) seasons of 2014-15 and 2015-16 at Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The experimental field has clay loam soil. The soil have pH 7.58, 7.60, organic carbon 0.44%, 0.46%, available nitrogen 217.3, 224.1 kg/ha, available phosphorus 20.28, 22.85 kg/ha, available potassium 219.2, 226.4 kg/ha and available sulphur 20.90, 21.85 mg/kg/ha during both the years, respectively. The field experiment was laid out in split plot design, where, main plot treatment: three irrigation levels (zero irrigation, one irrigation (at pre-flowering stage) and two irrigation (at pre-flowering and pod formation stage) and Sub-plots treatment: seven foliar spray of bioregulators (control, thiourea@1000ppm, thiourea@ 500ppm, salicylic acid @ 100ppm, salicylic acid @ 50ppm, glycinebetaine@ 100ppm and glycinebetaine @ 50ppm) and irrigation was applied @ 6 cm by V-notch method. Foliar spray was done at 50 per cent flower initiation and 50 per cent pod formation stage. Furrows were opened at a spacing of 45 cm × 15 cm for the sowing of Indian mustard variety 'Ashirwad' with seed rate of 5kg/ha. The sowing was done on 13th November 2014 in 2014-15 and 23rd

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November 2015 in 2015-16. The N, P, K and S were applied as 100, 50,50 and 40 kg/haby basal application. Nitrogen and phosphorus were applied through diammonium phosphate and urea, potash and sulphur through murate of potash and elemental sulphur, respectively. The ½ dose of N and full dose of P, K and S were applied at sowing and ½ dose of N given at the time of first irrigation as basal dressing but full dose of NPKS was applied at the time of sowing in zero irrigation treatment. The data were analyzed as per the standard procedure for “Analysis of Variance” (ANOVA) (Gomez and Gomez, 1976).

The pooled analysis showed that the Interaction effect of levels of irrigation and foliar spray of bioregulators were observed significant on dry matter accumulation (Table 1). The result indicated that the two irrigation was produce maximum dry matter accumulation (DMA) at 80, 100 DAS (days after sowing) and at harvest with the foliar spray of thiourea@1000ppm which was statistically at par with two irrigation with foliar spray of thiourea @ 500ppm. Therefore, the application of two irrigation with foliar spray of salicylic acid @ 100 ppm gave more dry matter than two irrigation with foliar spray of salicylic acid @ 50ppm. However, the application of two irrigation with foliar spray of glycinebetaine @ 100ppm was recorded higher dry matter over two irrigation with foliar spray of glycinebetaine @ 50ppm. The minimum dry matter accumulation at 80, 100 DAS and at harvest was recorded in zero irrigation + water spray, respectively. The maximum dry matter accumulation was recorded with the application of two irrigation (at pre flowering and pod formation stage). This might be due to the adequate soil moisture increase the availability of the nutrient in the soil for the plant to increase in growth parameters by cell elongation and cell division this ascribed due to higher activity of auxin in plant tissues and photosynthesis activity of plant so they produced more food (Mandal *et al.*, 2006; Meena *et al.*, 2019). The higher value of DMA was recorded with the foliar spray of thiourea @1000ppm which was found statistically at par with the application of thiourea @500 ppm. This may be ascribed due to the foliar application of thiourea motivating the photosynthetic carbon fixation mechanism that enhanced the canopy of the plant (Mehta and Sumeria; 2001, Meena *et al.*, 2020). Moreover, the favorable effect of foliar application of salicylic acid on dry matter accumulation might be due to increased photosynthetic efficiency by increased chlorophyll content, number of branches and leaf area index, which ultimately resulted in increased dry matter accumulation (Hassanein *et al.*, 2012; Meena *et al.*, 2017).

The significant improvement in Dry matter accumulation of Indian mustard could be achieved by application of two irrigation +foliar spray of thiourea @1000ppm followed by two irrigation + foliar application of thiourea @500ppm.

Table 1. Interaction effect of foliar spray of bioregulators and irrigation levels on DMA (g/plant) at different days after sowing (DAS) of Indian mustard (pooled)

Treatment	DMA (g/plant) at 80 DAS			DMA (g/plant) at 100 DAS			DMA (g/plant) at harvest		
	Zero irrigation	One irrigation	Two irrigation	Zero irrigation	One irrigation	Two irrigation	Zero irrigation	One irrigation	Two irrigation
Control (water spray)	23.83	31.41	33.00	25.32	34.31	36.20	26.86	36.23	37.79
Thiourea @ 500 ppm	33.72	38.36	39.76	37.05	42.56	44.22	39.03	44.81	46.72
Thiourea @ 1000 ppm	33.93	38.51	39.88	37.30	42.73	44.36	39.32	45.01	46.88
Salicylic acid @ 50 ppm	31.88	36.60	38.04	34.87	40.47	42.19	36.73	42.50	44.48
Salicylic acid @ 100 ppm	32.62	37.46	38.84	35.74	41.49	43.13	37.74	43.68	45.57
Glycinebetaine @ 50 ppm	29.97	34.79	35.88	32.60	38.33	39.62	34.67	40.03	41.52
Glycinebetaine @ 100 ppm	30.87	35.72	37.17	33.67	39.43	41.15	35.72	41.30	43.29
SEm±	0.16			0.20			0.24		
CD (<i>p</i> =0.05)	0.46			0.55			0.66		

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FARMER'S KNOWLEDGE, ATTITUDE AND PRACTICES ON SAFETY, QUALITY AND POST HARVEST MANAGEMENT OF BRINJAL AND TOMATO IN SOME SELECTED AREAS OF BANGLADESHM. KHATUN¹ AND M. S. RAHMAN²

Post harvest management is very important for horticultural crops. The safety and quality of horticultural crops specially vegetables largely depends on its post harvest management. Due to improper management farmers have to bear significant post harvest losses. Post harvest losses of fruits and vegetables are estimated at 5-20% in developed countries and 20-50% in developing countries (Mashav, 2010). In Bangladesh, post-harvest losses of fruits and vegetables amount to 16.73-43.5% which accounts for an annual loss of Tk. 34420 million (Hasan *et al.*, 2010; Kaysar *et al.*, 2016). The country like Bangladesh suffer much of the postharvest losses due to a number of factors such as lack of adequate knowledge and information, the unavailability of appropriate practices under funded research and development (Hasan *et al.* 2010 and Azad *et al.*, 2014). The quality and nutritional value of fresh vegetables are also affected by postharvest handling and storage condition (Sablani *et al.*, 2006). In order to reduce post harvest losses and to arrest higher profit vegetable producers in the tropics and subtropics relies heavily on chemicals such as fertilizers, pesticides and crop preservatives. Pesticide comes with a specific environmental concern due to their toxicity and persistence in the environment (Lamberth *et al.*, 2013). So, it not only advantages for crop yield but it also have a significant negative impacts.

Farmers directly involved in the handling of pesticides and insecticides and are at a high risk of exposure to these through contact with pesticide residues on treated crops, unsafe handling, storage and disposal practices (Koureas *et al.*, 2014; Manyilizu *et al.*, 2017). They are using a large number of insecticides during the entire period of growth of vegetables, even at fruiting stage. Sometimes they also ignored the recommended waiting period between the harvest and last spray. Improve post harvest practices reduce food losses, increase food quality, food safety and also higher profit for the grower and marketers. So, improve post harvest management is a very important component in reducing production loss of vegetables. Knowledge, attitude and practice (KAP) survey is an essential tool to know the existing post harvest management and farmers views on safety and quality of vegetables.

KAP are the components of human behavior which is responsible for any action in dealing everyday life. These three components are somewhat pre-requisite in

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adopting new knowledge on safe and quality vegetable production. Knowledge is the result of some activity such as generation, storage, dissemination and utilization of something that entails either information or data. It is usually based on learning, thinking, and proper understanding of the problem area (Azad, 2013). Attitude is defined by Ajzen and Fishbein (1980) as a person's degree of evaluative affect toward a target behavior. An individual may have multiple attitudes about an object, accessing different ones at different points in time (Wilson, 1998). Attitudes are relatively stable and once adopted, can provide a long-term effect (Olgyaiova *et al.*, 2005). Through changing attitude of farmers, it is possible to improve their performance in adoption and commercialization of horticultural products (Meena *et al.*, 2009).

A good number of researches on knowledge, attitude and practice of the farmers on different issues of crop production were carried out (Yuantari *et al.*, 2015; Azad *et al.*, 2014; Assis and Ismail, 2011; Muhammad *et al.*, 2012; Abbassy, 2017; Amponsah, *et al.*, 2018; Baksh *et al.* 2015; Adesuyi *et al.*, 2018; Mohamed *et al.*, 2018; Meena *et al.*, 2009) but unfortunately there is lack of information on KAP on safety, quality and post-harvest management of vegetables. Due to limited knowledge and information on these areas the present study was designed to demonstrate the status of tomato and brinjal grower's knowledge, attitude and current practices regarding safety, quality and post harvest management in some selected areas of Bangladesh. The study was conducted with a structured interview schedule in two Upazila from Jamalpur and Rangpur district of Bangladesh. They were selected based on intensive growing of tomato and brinjal. Total number of respondents was 100 taking 50 from each district.

Safety, quality and post-harvest management of tomato and brinjal cultivation

Farmers' knowledge

All the respondents under this study were using chemical fertilizers, insecticides, fungicides and pesticides. At the same time some farmers were using herbicides along with the chemical components as all they believe that these are mandatory for higher yield. These findings are similar to Zawiyah *et al.*, 2007 who indicated that insecticides were used by 98% of the farmers, followed by bactericides (79%), nematicides (24%), and herbicides (5%) and Mohamed *et al.*, 2018 who indicated that pesticides were indispensable for high crop yield (80%). Farmers were asked about the harmfulness of the chemical components used in brinjal and tomato cultivation. Among them 84.9% knew that these are very harmful The study also found that 2.7% of the respondents still have no idea on the harmful effect of chemical components used in brinjal and tomato cultivation.

The knowledge level of brinjal and tomato farmer on safety, quality and post harvest management was shown by the following Table 1. It shows the number of respondents who answered the 18 statements as whether they know (Yes) means that they gave the correct answer or don't know (No) means that they gave

the false answer as previously done by Baksh et.al., (2015) and Yuantari et.al., (2015). It is evident from the mean frequencies that 74.61% of the sample farmers have sufficient knowledge on the safety, quality and post-harvest management of brinjal and tomato cultivation whereas the rest (25.39%) still unaware of this issue. Farmers had highest knowledge in response to “*Good management increases vegetables quality (100%)*”, “*The level of vegetables loss is more prominent for delay harvesting (98%)*”, “*Morning is the appropriate time for vegetable harvesting (98%)*” and “*The level of vegetable loss is more prominent at storage stage (96%)*”. Lowest knowledge was with respect to “*Idea on proper storage technique (32%)*” and “*It is very important to follow pre harvest interval rules (13%)*”.

Table 1. Farmers Knowledge on safety, quality and post harvest management of tomato and brinjal cultivation

Sl. No.	Statements	Extent of knowledge (% of respondents)	
		Yes	No
1.	Good management increases quality	100	0
2.	The level of loss is more prominent for delay harvesting	98	2
3.	Morning is the appropriate time for harvesting	98	2
4.	The level of loss is more prominent at storage stage	96	4
5.	Should collect after natural maturity	95	5
6.	Variety influences the post-harvest loss	93	7
7.	Should be free from disease	92	8
8.	Should be free from harmful insecticide and pesticide	85	15
9.	Good processing and packaging increases net revenue	79	21
10.	Large volume transport at a time increases post-harvest loss	76	24
11.	Idea on safety issues for human consumption	73	27
12.	Knowledge on sorting and grading	72	28
13.	Idea on optimum maturity	71	29
14.	Knowledge on pre and post-harvest handling	59	41
15.	Idea on proper transportation technique	58	42
16.	Should be washed after harvesting	53	47
17.	Idea on proper storage technique	32	68
18.	It is very important to follow pre harvest interval rules	13	87
	Summary (mean) knowledge	74.61	25.39

Source: Field survey, 2018.

Farmers Attitude

In order to measure farmers' attitude Table 2 enumerates ten statements on which farmers showed their opinions on two scales- agree and disagree as done by Yuantari *et al.* (2015). Majority of the respondents (82.78%) attitude was positive to the statement whereas 17.22% have negative attitude towards the statements means that they disagreed with the statement. Farmers agreed mostly with the statement, "Necessary to circulate more awareness building materials at the farmer level (100%)", "Ensuring the quality of insecticide and pesticide (100%)", "Should maintain proper management technique (96.8)" and "Use of pheromone trap and light trap (95.7)". Farmer were disagreed mostly with the statements "Use of bio pesticide and bio insecticide (50.7%)", "Pre harvest interval rules should follow (40.7%)" and "Clean the collected vegetables with hygienic water (37.5%)". It indicates that farmers have a strong believe on using chemical component to reduce insects and pests rather depend on bio pesticide and insecticide.

Table 2. Farmer's attitude towards safety, quality and post harvest management of brinjal and tomato cultivation

Sl. No.	Statements	Agree (%)	Disagree (%)
1.	Necessary to circulate more awareness building materials at the farmer level	100	0
2.	Ensuring the quality of insecticide and pesticide	100	0
3.	Should maintain proper management technique	96.8	3.2
4.	Use of pheromone trap and light trap to reduce insecticide and pesticide application	95.7	4.3
5.	Optimum use of chemical fertilizers	93.2	6.8
6.	Sources of pesticides and insecticides should be taken under strong monitoring	92.6	7.4
7.	Educate farmers on the optimum application of insecticide and pesticide	78.4	21.6
8.	Clean the collected vegetables with hygienic water	62.5	37.5
9.	Pre harvest interval rules should follow	59.3	40.7
10.	Use of bio pesticide and bio insecticide	49.3	50.7
	Summary (mean) attitude	82.78	17.22

Source: Field survey, 2018

Farmers Practices

Farmers practices has enumerated through Table 3. It shows seven practice statements of the study and farmers responses (%) as always, rarely and never as done by Yuantari *et al.* (2015). Majority (43.93%) of the respondents stated that they always practice these statements whereas a significant portion of the respondents (38.40%) opined that they never follow this statement in the cultivation of brinjal and tomato. Among the respondents 88.7% told that they timely apply quality pesticide and insecticide. But at the same time, 66.3% of the respondents always apply unnecessary insecticide and pesticide. This might be due to the knowledge gap of the farmers and their traditional attitude regarding safety and quality issues of brinjal and tomato cultivation.

Table 3. Farmer practices on safety, quality and post harvest management of brinjal and tomato cultivation

Sl. No.	Statements	Always (%)	Rarely (%)	Never (%)
1.	Farmer thinks about the safety and quality issue	10.8	22.6	66.6
2.	Farmer applies unnecessary insecticide and pesticide	66.3	8.5	25.2
3.	Farmer applies bio fertilizer and bio medicine	19.8	37.3	42.9
4.	Farmer uses pheromone trap, light trap and some other technology to destroy the harmful insect	53.4	28.7	17.9
5.	Farmer follows pre harvest interval rules	8.7	10.6	80.7
6.	Farmer timely applies quality insecticide and pesticide	88.7	2.3	9.0
7.	Farmer depends on natural maturity	59.8	13.7	26.5
	Summary (Mean) practices	43.93	17.67	38.40

Source: Filed survey, 2018

Attitude and perceptions towards safe and hygienic brinjal and tomato

Farmer attitude

Enumerates nine statements on farmers' attitude towards safe and hygienic tomato and brinjal. In each of the statements farmers showed their views as agree and disagree. Majority of the respondents (75.2%) showed positive attitude on the statements in Table 7. Farmers agreed mostly on "*Quality seed (100%)*", "*Variety should be high yielding (96.7)*" and "*Proper management of the crop*

field (92.3%)". Farmer showed disagreed on "Collected vegetables should be sun dried (65.4%)" and "Clean with fresh water (60.1%)".

Farmer perception

Farmers' perception towards safe and hygienic brinjal and tomato cultivation has enumerated in Table 4 where they answer in three different scales - always practice, rarely practice and never practice as done by Yuantari et.al. (2015). Most of the respondents were against the statements as maximum 40.93% never practiced during the cultivation of brinjal and tomato. Again 38.49% of the respondents had always practiced following by 20.58% as rarely practice in brinjal and tomato growing.

Table 4. Perception of brinjal and tomato farmers on safe and hygienic brinjal and tomato cultivation

Sl. No.	Statement	Always (%)	Rarely (%)	Never (%)
1.	Think about this issue	54.3	23.8	21.9
2.	Collect and sell quickly	86.0	14.0	0.0
3.	Cultivate high yielding variety	57.3	21.1	21.6
4.	Use bio fertilizer, insecticide and pesticide	12.2	21.7	66.1
5.	Follow pre harvest interval rules	15.9	31.4	52.7
6.	Make proper management of the crop field	89.4	8.6	2.0
7.	Clean with fresh water	14.5	15.7	69.8
8.	Clean with fresh piece of cloth	21.3	15.6	63.1
9.	Keep the collected tomato and brinjal in open sunlight	0.0	5.00	95.00
10.	Keep the collected tomato and brinjal in bare soil	34.0	48.9	17.1
	Summary (mean) perceptions	38.49	20.58	40.93

Source: Field survey, 2018

Tomato and brinjal farmers are practicing a good number of post harvest management. They had good level of knowledge and positive attitude towards safety and quality issues of tomato and brinjal. A significant number of tomato and brinjal growers were habituated with right practices regarding point of harvesting, packaging, transportation, grading, sorting and storing. They were well informed about the harmfulness of applying insecticide and pesticide in brinjal and tomato cultivation. Though they had enough knowledge on safety and

quality issues of tomato and brinjal but less than half of the farmers were practicing at farm level. So, still there is floor to improve their practices. In order to bridge the gap between knowledge and practice, new and update technology and information to improve their production performances should disseminate at farm level. Beside motivation training should follow up by the research institution and agricultural extension. This will be helpful for the farmer to come out of their normal trend of cultivation and enable them to use their knowledge without hesitation.

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