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HYBRID PERFORMANCE AND STANDARD HETEROSIS FOR YIELD AND ITS CONTRIBUTING TRAITS IN SNAKE GOURD

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J. FERDOUSI[4] AND A. SATTAR[5]

Abstract

A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh in the experimental field of Horticulture Department during August to November, 2019. The experiment was laid out in a Randomized Complete Block Design with three replications to evaluate the yield and yield contributing characters as well as to estimate the standard heterosis of eight snake gourd hybrids selected from twenty one hybrids generated through a 7 × 7 half diallel cross during 2018. The earliest fruit harvest was from the cross $P_2 \times P_6$ (49.00 days) and the highest individual fruit weight was recorded in $P_2 \times P_6$ (217.67g). The cross $P_2 \times P_6$ (45.67) produced the maximum number of fruits per plant which was identical with the hybrid check 'Padma' (44.0) and the cross $P_3 \times P_7$ (45.33), followed by the cross $P_1 \times P_3$ (38.67). The cross $P_2 \times P_6$ registered significantly higher fruit yield (47.21 t/ha) than the standard hybrid check 'Padma' (33.79 t/ha) and other two check varieties of BU Chichinga-1 (31.12 t/ha) and BARI Chichinga-1 (21.90 t/ha). For early harvest the maximum significant negative heterosis was recorded in the cross $P_2 \times P_6$ (-9.81%) followed by $P_2 \times P_3$ and $P_4 \times P_7$ (-6.13% for each cross) and for individual fruit weight the maximum positive heterosis was noticed in the cross $P_2 \times P_6$ (22.06%), whereas insignificant positive heterosis for number of fruits per plant was recorded in the crosses $P_2 \times P_6$ (3.80%) and $P_3 \times P_7$ (3.02%). The four hybrids $P_1 \times P_3$, $P_2 \times P_3$, $P_2 \times P_7$, $P_4 \times P_6$, $P_4 \times P_7$ and $P_6 \times P_7$ showed significant negative heterosis for fruit yield per hectare. The cross $P_2 \times P_6$ had maximum significant positive heterosis for fruit length (19.50%), followed by $P_1 \times P_3$ (11.87%) and BARI Chichinga-1 (10.17%), while the highest positive heterosis was found for fruit diameter in the cross $P_3 \times P_7$ (34.84%) followed by BU Chichinga-1 (32.26%) and $P_2 \times P_6$ (28.06%). The maximum significant positive heterosis was noticed for fruit flesh thickness in the cross $P_6 \times P_7$ (32.07%), followed by $P_1 \times P_3$, $P_2 \times P_3$, $P_2 \times P_6$ and $P_4 \times P_6$ (13.21% for all 4 crosses). $P_2 \times P_6$ showed maximum positive traits like early fruit harvest, and maximum number of fruit/plant, fruit yield, fruit length, individual fruit weight and maximum duration of harvest. However, based on all the evaluated parameters and standard heterotic performance, the best F_1 combinations of $P_2 \times P_6$, $P_1 \times P_3$, $P_3 \times P_7$ and $P_6 \times P_7$ may be tested through multi-location trials for their stability and selection of best commercial hybrids.

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Keywords: Snake gourd, *Trichosanthes cucumerina var anguina*, standard heterosis, F_1 hybrids.

Introduction

Snake gourd [*Trichsanthes cucumerina* var. *anguina* (L.) Haines; 2n = 2x = 22], a member of the Cucurbitaceae family, is popularly known as 'chichinga' in Bangladesh, which is an important summer vegetable grown through the country. Snake gourd is thought to have originated in India or the Indo-Malayan region of tropical Asia (Adebooye, 2008). It is cultivated all across south and south-east Asian countries like India, Nepal, Bangladesh, Pakistan, Indonesia, Sri Lanka, Myanmar, Malaysia and China. It grows well round the year except extreme cold winter months because of its day neutral type of habit. This vegetable is regarded as nutrient-dense from a nutritional standpoint (Gopalan *et al.*, 1982) and its soft fruits are eaten as edible vegetables, healthy complement to meals (Devi and Mariappan, 2013). About 140 types of winter and summer vegetables grow in Bangladesh. But there is an unequal distribution of these vegetables between winter and summer seasons. Typically, summer vegetables cover 48.14% of the total land area, while winter vegetables occupy 51.86% of the total area under vegetable cultivation (Anon., 2020). Production wise 56.29% of vegetables are produced in the winter and 43.71% in the summer (Anon., 2020).

Only 4.58 million tonnes vegetables are produced in Bangladesh (Anon., 2020) against the requirement of 17.0-18.0 million tonnes. The vegetable requirement of our country is increasing day by day and is estimated to be 30.00 million tonnes by 2050 because the population is expected to reach 202 million people by 2050 (https:// www .the world counts .com/populations/countries/bangladesh).

Due to heterozygous nature of snake gourd and virtually obligatory outcrossing because of its monoecious nature, open-pollinated as well as hybrid varieties could be developed (Banik, 2003). In Bangladesh two improved open-pollinated snake gourd var. BARI Chichinga-1 (Mondal *et al*., 2014) and var. BU Chichinga-1 (https://bsmrau.edu.bd /dres /varieties-released/bu-chichinga-1) have been released by Bangladesh Agricultural Research Institute (BARI) and Bangabandhu Sheikh Mujibur Rahman Agricultural University, respectively and one hybrid snake gourd variety, namely 'Padma' (https://successfarmbd.com/product/hybrid–snake–gourd–padma) has been developed by Lal Teer Private Seed Company. Due to lack of enough suitable snake varieties, farmers are mainly cultivating local varieties. Therefore, there is no alternative way but to develop high yielding improved as well hybrid varieties of snake gourd. For getting new hybrids, it is important to evaluate the selected F_1s with check varieties. Nowadays, heterosis breeding is one of the most effective tools to exploit the heterotic response for several traits (Ahmed, 2016). Hybrid vigour with the magnitude of individual yield components may have an additive of synergistic effect on the final product. Heterosis can play a vital role in increasing the yield and quality of snake gourd. For developing superior varieties, it is necessary to improve the earliness and yield of snake gourd. This can be achieved through effective utilization of germplasm resources and integration of genomic tools to impart efficiency and pace to breeding processes (Banga, 2012). Exploitation of heterosis in crop plants is one of the most attractive achievements in boosting up the production and productivity of snake gourd. A comprehensive analysis of the combining ability involved in the inheritance of quantitative traits and in the phenomenon of heterosis is necessary for evaluation of various breeding procedures (Allard, 1960) for the development of hybrid varieties. The experiment was therefore, carried out to study the performances of some selected hybrids and identify the best standard heterotic effect on selected hybrids of snake gourd in Bangladesh.

Materials and Methods

The experiment was carried out at the experimental farm of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during August to November 2019. The location of the site is 24.09^0N latitude and 90.26^0E longitude with an elevation of 8.2 m from sea level under agro-ecological zone AEZ-28. Eight hybrids were selected based on their performance in terms of earliness and high yielding capacity, different horticultural traits, combining ability and heterobeltiosis from twenty one hybrids generated from the crossing performed in 7 x 7 half diallel fashion during 2018. The selected hybrids were $P_1 \times P_3$, $P_2 \times P_3$, $P_2 \times P_6$, $P_2 \times P_7$, $P_3 \times P_7$, $P_4 \times P_6$, $P_4 \times P_7$, $P_6 \times P_7$ and check varieties were also used, which were ‘Padma’ (hybrid) and two varieties, namely BARI Chichinga-1 (OP) and BU Chichinga-1 (OP). The hybrid variety ‘Padma’ was used for working out standard heterosis of eight snake gourd hybrids and two check varieties, and BARI Chichinga-1 and BU Chichinga-1 were used for comparison of mean performances of eight hybrids under study. The diverse snake gourd genotypes viz., TC 01 (P_1), TC 05 (P_2), TC 24 (P_3), TC 33 (P_4), TC 02 (P_5), TC 46 (P_6) and TC 53 (P_7) were used as parents for developing the above eight snake gourd hybrid varieties. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Fourteen days old seedlings were transplanted on 25 August 2019, in well prepared pits in an experimental plot. A total of 33 (11 × 3) unit plots were required, each measuring 15 m × 1.5 m accommodating 10 plants in single row of 15.0 m in length with row and plant spacing of 1.5 m and 1.5 m, respectively.

Fertilizers were applied @ 5000-50-24-40-14-1.5-1.0 kg/ha of cowdung-N-P-K-S-Zn-B according to Fertilizer Recommendation Guide (FRG (2012). The sources of N, P, K, S, Zn, and B were Urea, Triple Super Phosphate (TSP), Muriate of

Potash (MoP), Gypsum, Zinc Sulphate and Boric Acid (Laboratory Grade). During the final land preparation, the entire amount of cowdung, P, S, Zn, B and one-third of K, as well as 1/3rd N and the remaining part of K and N were applied in four equal installments at 7, 21, 35 and 49 days after transplantation. The observations were recorded on days to 1^{st} male flower opening, days to 1^{st} female flower opening, node number of 1^{st} male flower, node number of 1^{st} female flower, main vine length (m), number of nodes on main vine, number of primary branches per plant, days to 1^{st} harvest, duration of harvest, number of fruits per plant, fruit yield both per plant (kg) and per hectare (ton), individual fruit weight (g), fruit length (cm), fruit diameter (cm), fruit flesh thickness (cm) and locules per fruit.

Statistical Analysis

Estimation of standard heterosis

Percent standard heterosis (S) for each character was calculated as follows:

H (S) = $\frac{\overline{F1}-\overline{CV}}{\overline{CV}} \times 100$, Where, F_1 = Mean value of each hybrid and CV = Mean value of the check variety (standard variety) (Ene *et al*., 2019). Mean error variance from the combined analysis of variance of check variety and F_1s were used for calculating the SE of difference. The mean values over replications were used for comparison. For standard heterosis, the difference between F_1 and the check variety hybrid 'Padma' used for estimation of standard heterosis was taken into account crosswise. When the difference was greater than CD (critical difference), it was considered significant and vice versa. Critical difference (CD) = SE × t at 5% and 1%. For analysis of means of different recorded characters, Statistix 10 software was used and mean separation was done by Tukey's honesty significant different test.

Results and Discussion

Analysis of variance for genotypes i.e. crosses and check varieties showed highly significant differences for the maximum number of characters studied (Table-1).The evaluation of hybrids and estimates of percent standard heterosis observed in F_1 generation over standard variety 'Padma' are presented in Tables 2a, 2b, 3a and 3b.

Table 1. Analysis of variances for treatments (crosses and check varieties)

Source of variation	Degrees of Freedom	Mean sum square (characters)								
		Days to 1st male flower opening	Days to 1st female flower opening	Node number at the 1st male flower initiation	Node number at the 1st female flower initiation	Main vine length (m)	Primary branches per plant (no.)	Nodes on main vine (no.)	Days to 1st fruit harvest	Duration of harvest (days)
Replication	2	0.64	1.45	3.85	2.58	1.32	0.21	64.48	4.48	1.09
Treatment	10	77.61**	3.99**	26.14**	6.47**	0.29	0.24	17.88*	7.35**	9.27**
Error	20	2.47	1.09	1.75	1.2	0.17	0.24	7.28	2.25	1.99

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

Table 1. Continued

Source of variation	d.f.	Mean sum square (characters)							
		Individual fruit weight (g)	Fruits per plant (no.)	Fruit yield per plant (kg)	Fruit yield (t/ha)	Fruit length (cm)	Fruit diameter (cm)	Fruit Flesh thickness (cm)	Locules per plant (no.)
Replication	2	60.48	9.3	0.63	11.63	3.27	0.004	0.0003	0.0
Treatment	10	559.89**	141.95**	7.08**	130.95**	132.81**	0.40**	0.011**	0.07
Error	20	83.21	3.3	0.16	3.05	2.47	0.04	0.001	0.07

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

Performance of selected hybrids and check varieties

Significant variability in the hybrids was observed for days to 1st male flower opening in the snake gourd (Table 2a.). The days to 1st male flower opening ranged from 28 to 45 days. All the crosses significantly showed early male flower opening compared to the check hybrid variety 'Padma' (45 days) except the cross $P_3 \times P_7$ (45 days) which was identical with 'Padma' for this trait. But the earliest male flower opening was recorded in the cross $P_2 \times P_7$ (28 days) among the eight crosses. Moreover, the cross $P_2 \times P_7$ was significantly earlier blooming than the varieties BARI Chichinga-1 and BU Chichinga-1. Ahsan *et al.* (2014) found some crosses SG06 × SG18 and SG10 × SG18 (71.66 days for each cross) in snake gourd, in which early male flower opened. These findings were different from the findings of present study that may be due to the genotypic variation. Banik (2003) reported that the crosses $P_2 \times P_3$ and $P_2 \times P_4$ exhibited the earliest male flower opening in snake gourd where the range of days to male flower opening were 39 days to 40 days, which supports the present study. Among the hybrids under study a little difference was observed in days to 1st female flower opening, where the range of days to 1st female flowering was 40 to 44 days (Table 2a.). The earliest female flower opening was observed in the cross $P_4 \times P_7$ (40.00 days) whereas, no significant difference was observed in 7 crosses along with BARI Chichinga-1 and BU Chichinga-1 and the check 'Padma' with regard to days to 1st female flowering. Days to 1st female flower opening in the range of 74 to 82 days was reported by Ahsan *et al.* (2014). The results vary with these reported findings, which may be due to environmental and genetic constitutes of the genotypes. The present findings supported the result of Banik (2003) who obtained days to female flower opening in the range of 38 days to 51 days.

Significant variation was obtained in node number at the 1st male flower initiation which ranged from 7.67 to 16.00 (Table 2a.). The lowest node number at the 1st male flower initiation was noticed in the crosses $P_2 \times P_6$ and $P_4 \times P_7$ (7.67 for each cross) followed by $P_4 \times P_6$ (8), $P_1 \times P_3$ (8.33) and $P_2 \times P_3$ (8.67). This is in agreement with the results of Ahsan *et al.* (2014) who recorded the node number for the 1st male flower opening in the range of 6.33 (SG-01 × SG-18)to16.00 (SG-06 × SG-25). Banik (2003) reported a node number for 1st male flower opening in the range of 7.00to 13.00, which is in consonance with the result of the present investigation. Statistically significant variation was observed in snake gourd hybrids with regard to node number at the 1st female flower initiation which ranged from 15.00 to 19.67 (Table 2a.). The lowest node number at the 1st female flower initiation was recorded in $P_2 \times P_6$ (15) followed by $P_2 \times P_3$ (15.67). This is in consonance with the results of Ahsan *et al.* (2014) who reported that node number for the 1st female flower opening ranged from 15.66 (SG-10 × SG-06) to 23.66 (SG-01 × SG-26). Banik (2003) recorded node number at the 1st female flower initiation from 15.00 ($P_2 \times P_6$) to 25.33 ($P_2 \times P_3$), which is more or less close to the present investigation.

Main vine length at last harvest did not differ significantly, however its range was from 5.73 to 6.78 m (Table 2a.). Ara *et al.* (2013) was also found wide variability in the vine length for snake gourd genotypes. Banik (2003) also found variation in the length of the vines among 15 crosses of snake gourd where the range of main vine length was from 4.45 to 6.15 m. In the crosses, the primary branches per plant varied from 4.33 to 5.17 (Table 2a.). Ahsan *et al.* (2014) was found significant variation in the primary branches per plant for snake gourd genotypes, and it ranged from 7.33 to 11.33. In the crosses, nodes on the main vine significantly varied from one another and it ranged from 44.00 ($P_1 \times P_3$) to 52.67 ($P_6 \times P_7$) (Table 2a.). Banik (2003) reported that nodes on the main vine varied from 33 to 44, which is lower than the present study. This variation might be due to the difference in plant materials.

There was no remarkable difference found in the trial among the crosses (except $P_2 \times P_6$) and two open pollinated varieties and check variety 'Padma' in respect of days to 1st harvest, and it ranged from 49 ($P_2 \times P_6$) to 54 days ($P_4 \times P_6$) but substantial difference was noticed between $P_2 \times P_6$ and the hybrid check 'Padma" (Table 2a.). Ara *et al.* (2013) reported that days to 1st harvest varied from 77-90 days, which differs from the present study. There was a significant difference found with regard to the duration of harvest which ranged from 37 to 43 days (Table 2a.). Except $P_2 \times P_3$ and P_2 x P_7 no significant difference was found among the 6 crosses, two OP varieties along with hybrid check 'Padma'. However, the cross $P_2 \times P_6$ (43 days) had the longest duration of harvest closely followed by $P_1 \times P_3$ (42 days). Numerically the crosses $P_2 \times P_6$ and $P_1 \times P_3$ exhibited a longer duration of harvest than check variety 'Padma' which is desirable.

Significant differences were noticed in individual fruit weight where individual fruit weight varied from 167.33 to 217.67g (Table 2b.). The cross $P_2 \times P_6$ (217.67g) recorded the maximum individual fruit weight followed by BU Chichinga-1 (194.00). Ahsan *et al.* (2014) recorded the highest individual fruit weight in SG-04 × SG-26 (210g) and the lowest in SG-10 × SG-25 (110g). Banik (2003) reported that individual fruit weight ranged from 158.33 to 341.67g. These results are in line with the findings of Banik (2003) and close to the results of Ahsan *et al.* (2014). The number of fruits per plant ranged from 24.00 to 45.67 (Table 2b.), with the highest number of fruits per plant found in $P_2 \times P_6$ (45.67) followed by Padma (44.00), and the lowest number of fruits per plant was recorded in $P_4 \times P_7$ (24). Banik (2003) also found fruit numbers per plant in snake gourd ranging from 9.0 to 25.33, while Ahsan *et al.* (2014) reported the number of fruits per plant in snake gourd in the range of 14.66 to 51.66. The results of the present study corroborate the results of Ahsan *et al.* (2014) but the results were higher than Banik (2003).

This might be due to the difference in genetic constitution of plant material used in the reported experiment.

The eight crosses and three checks differed significantly in respect of fruit yield per plant which ranged from 4.31 to 9.93 kg/plant (Table 2b.). The maximum fruit yield per plant was found in $P_2 \times P_6$ cross (9.93 kg) followed by 'Padma' (7.86 kg), $P_3 \times P_7$ (7.57 kg) and BU Chichinga-1 (7.23 kg) and the lowest fruit yield in $P_4 \times P_7$ (4.31 kg). Ahsan *et al*. (2014) found that the cross SG-10 × SG-25 had the highest fruit yield per plant (9.77 kg), while Banik (2003) was found the fruit yield of hybrids in the range of 1.53 and 5.92 kg/ plant. The fruit yield per hectare differed significantly among the eight hybrids and three check varieties (Table 2b.). The maximum fruit yield per hectare was recorded in the cross $P_2 \times P_6$ (42.71 t/ha) followed by 'Padma' (33.79 t/ha), $P_3 \times P_7$ (32.57 t/ha) and BU Chichinga-1 (31.12 t/ha). The hybrid $P_2 \times P_6$ showed higher yield per hectare than all other check varieties, which makes the hybrid desirable for developing a new high yielding hybrid variety.

Significant variation was noted for fruit length and diameter of various hybrids and check varieties of the snake gourd (Table 2b.). Fruit length ranged from 27.67 and 47.00 cm. The maximum fruit length was observed in $P_2 \times P_6$ cross (47.00 cm) closely followed by $P_1 \times P_3$ (44.00 cm) and BARI Chichinga-1 (43.33 cm) whereas, the fruit diameter ranged from 3.10 to 4.18 cm and the highest fruit diameter was found $P_3 \times P_7$ (4.18 cm) which was statistically similar to the rest of all hybrids except $P_1 \times P_3$ (3.27 cm) The variety BU Chichinga-1 also gave identical fruit diameter like other hybrids except $P_1 \times P_3$ (3.27 cm). Ahsan *et al.* (2014) reported the highest length of fruit in hybrid combination of SG-04 × SG-26 (33.75 cm) and the lowest length in SG-10 × SG-18 (21.85 cm) and the highest fruit diameter was recorded in SG-18 × SG-01 (5.06 cm) and the lowest diameter (3.51 cm) in SG-10 × SG-25. Banik (2003) was obtained the fruit length ranging from 24.67 to 40.00 cm and fruit diameter ranging from 3.05 to 4.80 cm in snake gourd hybrids. The results of the present study regarding fruit length and diameter are more or less close to Banik (2003) and partially corroborate the findings of Ahsan *et al.* (2014). This may be due to the difference in genotypes or environmental conditions. Fruit flesh thickness also significantly varied among the hybrids and check varieties and it ranged from 0.50 to 0.70 cm (Table 2b.). The maximum fruit flesh thickness was observed in cross $P_6 \times P_7$ (0.70 cm) whereas, it was the lowest in $P_3 \times P_7$, BARI Chichinga-1, and BU Chichinga-1 (0.50 cm for each genotype). Fruit flesh thickness of most of the hybrids was higher than that of check varieties. Locule number per fruit did not differ significantly and it ranged from 2.7 to 3.3 (Table 2b.). Most of the hybrids and check varieties contained three locules except $P_3 \times P_7$ which gave 2.7 locules per fruit.

Table 2a. Mean performance of hybrids and check varieties of snake gourd with reference to vegetative growth, flowering and harvesting characteristics

Hybrids and checks	Days to 1st male flower opening	Days to 1st female flower opening	Node number at the 1st male flower initiation	Node number at the 1st female flower initiation	Main vine length (m)	Primary branches per plant (no.)	Nodes on main vine (no.)	Days to 1st fruit harvest	Duration of harvest (days)
$P_1 \times P_3$	32cd	43ab	8.33cd	16.33b-d	5.73	4.5	44.00b	52ab	42ab
$P_2 \times P_3$	33bc	42ab	8.67cd	15.67cd	5.98	4.5	49.00ab	51ab	38bc
$P_2 \times P_6$	32cd	41ab	7.67d	15.00d	6.38	5.16	49.67ab	49b	43a
$P_2 \times P_7$	28d	42ab	10.33cd	19.67a	6.07	4.83	47.33ab	52ab	37c
$P_3 \times P_7$	45a	44a	15.33ab	19.00ab	6.35	4.83	50.67ab	52ab	39a-c
$P_4 \times P_6$	35bc	43ab	8.00cd	16.67a-d	5.77	4.83	45.33ab	54a	40a-c
$P_4 \times P_7$	38b	40b	7.67d	16.33b-d	6.78	4.67	49.33ab	51ab	39a-c
$P_6 \times P_7$	35bc	41ab	11.67bc	18.67a-c	6.25	4.5	52.67a	52ab	39a-c
BARI Chichinga-1	35bc	43ab	10.00cd	17.67a-d	6.52	5.0	50.00ab	52ab	40a-c
BU Chichinga-1	36bc	43ab	9.00cd	16.67a-d	6.12	4.33	50.00ab	54a	41a-c
Padma	45a	44a	16.00a	16.33b-d	6.23	5.17	48.67ab	54a	41a-c
F-test	**	*	**	**	ns	ns	*	**	**
CD (0.05)	2.21	1.47	1.86	1.54	0.59	0.69	3.80	2.11	2.57
CD (0.01)	3.24	2.15	2.73	2.26	0.86	1.01	5.57	3.10	3.65
CV (%)	4.35	2.47	9.19	6.41	6.73	9.24	5.53	2.88	3.54

** Significant at 1% level, * Significant at 5% level;

BARI Chichinga-1 (OP), BU Chichinga-1 (OP) and Padma (hybrid) are check varieties.

Means having same letter(s) in a column, did not differ significantly by Tukey's honesty significant different test

Table 2b. Mean performance of hybrids and check varieties of snake gourd with reference to yield, yield attributes and fruit characteristics

Hybrids and checks	Individual fruit weight (g)	Fruits per plant (no.)	Fruit yield per plant (kg)	Fruit yield (t/ha)	Fruit length (cm)	Fruit diameter (cm)	Fruit flesh thickness (cm)	Locules per fruit (no.)
$P_1 \times P_3$	177.67b	38.67bc	6.86bc	29.50bc	44.00ab	3.27c	0.60b	3.0
$P_2 \times P_3$	175.00b	29.33de	5.14d	22.09d	39.67b-d	3.65a-c	0.60b	3.0
$P_2 \times P_6$	217.67a	45.67a	9.93a	42.71a	47.00a	3.97a	0.60b	3.3
$P_2 \times P_7$	181.67b	36.67c	6.66c	28.64c	30.00fg	3.87ab	0.57bc	3.0
$P_3 \times P_7$	167.33b	45.33a	7.57bc	32.57bc	29.00g	4.18a	0.50c	2.7
$P_4 \times P_6$	182.33b	37.00c	6.74bc	28.99bc	33.67ef	3.93a	0.60b	3.0
$P_4 \times P_7$	179.33b	24.00e	4.31d	18.52d	37.00de	3.93a	0.53bc	3.0
$P_6 \times P_7$	180.33b	37.33c	6.74bc	29.00bc	27.67g	3.97a	0.70a	3.0
BARI Chichinga-1	170.00b	30.00d	5.09d	21.90d	43.33a-c	3.33bc	0.50c	3.0
BU Chichinga-1	194.00ab	37.33c	7.23bc	31.12bc	31.44fg	4.10a	0.50c	3.0
'Padma'	178.33b	44.00ab	7.86b	33.79b	39.33cd	3.10c	0.53bc	3.0
F-test	**	**	**	**	**	**	**	ns
CD (0.05)	12.85	2.56	0.57	2.46	2.21	0.27	0.04	0.36
CD (0.01)	18.83	3.75	0.84	3.60	3.25	0.40	0.06	0.53
CV (%)	5.01	4.93	6.02	6.02	4.3	5.11	5.5	8.61

** Significant at 1% level, * Significant at 5% level;

BARI Chichinga-1 (OP), BU Chichinga-1 (hybrid) and 'Padma' (hybrid) are check varieties

Means having same letter (s) in a column, did not differ significantly by Tukey's honesty significant different test

Table 3a. Percent standard heterosis over variety (Padma) with reference to flowering, vegetative growth and harvesting characteristics

Hybrids and checks	Days to 1st male flower opening	Days to 1st female flower opening	Node number at the 1st male flower initiation	Node number at the 1st female flower initiation	Main vine length (m)	Primary branches per plant (no.)	Nodes on main vine (no.)	Days to 1st fruit harvest	Duration of harvest (days)
$P_1 \times P_3$	-28.68**	-1.53	-47.94**	0.0	-8.03	-12.96	-9.6	-4.29	2.44
$P_2 \times P_3$	-25.72**	-4.58	-45.81**	-4.04	-4.01	-12.96	0.68	-6.13*	-7.32*
$P_2 \times P_6$	-28.68**	-5.36*	-52.06**	-8.14	2.41	-0.19	2.05	-9.81**	4.88
$P_2 \times P_7$	-37.50**	-3.07	-35.44**	20.45*	-2.57	-6.58	-2.75	-4.29	-9.76*
$P_3 \times P_7$	-1.46	0.0	-4.19	16.35*	1.98	-6.58	4.11	-4.29	-4.88
$P_4 \times P_6$	-22.06**	-1.53	-50.00**	2.08	-7.38	-6.58	-6.86	-1.21	-2.44
$P_4 \times P_7$	-16.17**	-8.40**	-52.06**	0.0	8.83	-9.67	1.36	-6.13*	-4.88
$P_6 \times P_7$	-22.06**	-6.11*	-27.06*	14.33*	0.32	-12.96	8.22	-4.29	-4.88
BARI Chichinga-1	-22.06**	-2.29	-37.50**	8.21	4.65	-3.29	2.73	-4.29	-2.44
BU Chichinga-1	-19.85**	-2.29	-43.75**	2.08	-1.77	-16.25	2.73	0.0	0.0
‘Padma’	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

** Significant at 1% level, * Significant at 5% level; BARI Chichinga-1 (OP), BU Chichinga-1 (OP) and ‘Padma’ (hybrid) are check varieties.

Table 3b. Percent standard heterosis over hybrid variety (Padma) with reference to yield, yield attributes and fruit characteristics

Hybrids and checks	Individual fruit weight (g)	Fruits per plant (no.)	Fruit yield per plant (kg)	Fruit yield (t/ha)	Fruit length (cm)	Fruit diameter (cm)	Fruit flesh thickness (cm)	Locules per fruit (no.)
$P_1 \times P_3$	-0.37	-12.11*	-12.72*	-12.70*	11.87*	5.48	13.21*	0.0
$P_2 \times P_3$	-1.87	-33.34**	-34.61**	-34.63**	0.86	17.74*	13.21*	0.0
$P_2 \times P_6$	22.06**	3.80	26.34**	26.40**	19.50**	28.06**	13.21*	11.0
$P_2 \times P_7$	1.87	-16.66**	-15.27*	-15.24*	-23.72**	24.84**	7.55	0.0
$P_3 \times P_7$	-6.17	3.02	-3.69	-3.61	-26.26**	34.84**	-5.66	-11.0
$P_4 \times P_6$	2.24	-15.91**	-14.25*	-14.21*	-14.39**	26.77**	13.21*	0.0
$P_4 \times P_7$	0.56	-45.45**	-45.17**	-45.19**	-5.92	26.77**	0.0	0.0
$P_6 \times P_7$	1.12	-15.16**	-14.25*	-14.18*	-29.65**	28.06**	32.07**	0.0
BARI Chichinga-1	-4.67	-31.82**	-35.24**	-35.19**	10.17*	7.42	-5.66	0.0
BU Chichinga-1	8.79	-15.16**	-8.02	-7.9	-20.06**	32.26**	-5.66	0.0
Padma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

** Significant at 1% level, * Significant at 5% level;

BARI Chichinga-1 (OP), BU Chichinga-1 (OP) and Padma (hybrid) are check varieties

Magnitude of standard heterosis

The estimation of percent standard heterosis observed in F_1 generations over hybrid variety is presented in Tables 3a. and 3b. Hybrid var. Padma was mainly used as a check for hybrids to measure standard heterosis. All the crosses manifested earlier male flowering than the check variety 'Padma' and the negative standard heterosis ranged from -1.46 to -37.50% over check variety 'Padma' (Table 3). The highest significant negative heterosis was observed in the cross $P_2 \times P_7$ (-37.50%) which was followed by $P_1 \times P_3$ and $P_2 \times P_6$ (-28.68% for each cross). Among the cross combinations, nine crosses had earlier female flowering than their check variety 'Padma' and the negative standard heterosis ranged from -1.53 to -8.40% over check variety 'Padma' (Table 3a.). The maximum significant negative heterosis was observed in the cross $P_4 \times P_7$ (-8.40%) which was followed by $P_6 \times P_7$ (-6.11%) and $P_2 \times P_6$ (-5.36%), indicating desirable combinations for early female flowering because the negative standard heterosis illustrates earlier female flowering. These negative heterosis with reference to days to male flower and female flower opening were also reported, Sonavane *et al.* (2013) in sponge gourd and Nagadevi *et al.* (2022) in ridge gourd.

All the crosses except $P_3 \times P_7$ showed significant negative standard heterosis for earlier node number at the 1st male flower initiation opening which ranged from -4.19 to -52.06%. The cross combinations $P_2 \times P_6$ and $P_4 \times P_7$ (-52.06% for each cross) depicted the highest significant negative standard heterosis for the node number at the 1st female flower initiation opening which indicated earliness. These results are in conformity with the findings of Lodam *et al.* (2014), Bairwa *et al.* (2017) and Nagadevi *et al.* (2022) in ridge gourd. The standard heterosis varied from -8.14% to 20.45% for node number at the 1st female flower initiation (Table 3a). However, the cross combination $P_2 \times P_6$ (-8.14%) depicted the highest non-significant negative heterosis, followed by $P_2 \times P_3$ (-4.04%). These results are not similar to the findings of Lodam *et al.* (2014), Bairwa *et al.* (2017), Nandhini *et al.* (2018) and Nagadevi *et al.* (2022) in ridge gourd because of different cucurbit crops.

None of the cross combinations performed significant standard heterosis for main vine length (Table 3a.). However, the standard heterosis for main vine length ranged from -8.03 to 4.65%. These results are not similar to the findings of Devi *et al.* (2017) in snake gourd due to differences in plant genetic material (Table 3a.). In case of number of primary branches per plant, all the cross combinations showed non-significant negative standard heterosis and it ranged from -0.19 to -16.25% (Table 3a.). All the hybrids exhibited non-significant standard heterosis with regard to nodes on main vine. However, the range of positive standard heterosis for this trait was 0.68 to 8.22%.

All the cross combinations performed negative standard heterosis for days to 1st harvest compared to check hybrid variety 'Padma' and the range of negative heterosis was from -1.21 to -9.81% over the check varieties. The highest significant negative heterosis was observed in the cross $P_2 \times P_6$ (-9.81%) which was followed by $P_2 \times P_3$ and $P_4 \times P_7$ (-6.13% for each cross), indicating desirable combinations for early fruit harvest. The negative heterosis for the 1st fruit harvest was also reported by Nagadevi *et al.* (2022) in ridge gourd. With regard to duration of harvest, two crosses $P_2 \times P_3$ (-7.32%) and $P_2 \times P_7$ (-9.76%) manifested significant negative standard heterosis, while non-significant positive standard heterosis range was 2.44 to 4.88% over check 'Padma' with regard to duration of harvest.

Only one cross $P_2 \times P_6$ showed significant positive standard heterosis for individual fruit weight and the positive heterosis range was 0.56 to 22.06% over check 'Padma' (Table 3b.). Maximum positive standard heterosis was observed in the cross $P_2 \times P_6$ (22.06%) for individual fruit weight. This result was comparable with the earlier findings reported by Nagadevi *et al.* (2022) in respect of individual fruit weight in ridge gourd. In case of number of fruits per plant**,** only two crosses $P_2 \times P_6$ (3.80%) and $P_3 \times P_7$ (3.02%) exhibited non-significant positive standard heterosis (Table 3b.). The results are not similar with those of Nagadevi *et al.* (2022) in ridge gourd. This dissimilarity may be due to variations in cucurbit crop. All the hybrids showed significant negative standard heterosis for fruit yield per plant except the cross $P_2 \times P_6$ (26.34%) which depicted significant positive standard heterosis for that character desirable for the improvement of fruit yield per plant (Table 3b.). The same trend was also observed in the case of fruit yield per hectare. All hybrids showed significant negative standard heterosis for fruit yield per hectare except the cross $P_2 \times P_6$ (26.40%) which showed significant positive standard heterosis for that character (Table 3b.). However, the cross $P_4 \times P_7$ (-45.19%) showed the highest significant negative heterosis for fruit yield per hectare, followed by BARI Chichinga-1 (-35.19%) and $P_2 \times P_3$ (-34.63%). The cross combination $P_2 \times P_6$ exhibited significant positive standard heterosis over the check 'Padma', which is expected to increase fruit yield per hectare. The results were comparable with those of Nagadevi *et al.* (2022) in ridge gourd.

Three cross combinations for fruit length and all cross combinations for fruit diameter showed a significant positive standard heterotic effect over the check variety 'Padma'. The combination $P_2 \times P_6$ had maximum positive standard heterosis for fruit length (19.50%), followed by $P_1 \times P_3$ (11.87%) and BARI Chichinga-1 (10.17%), whereas for fruit diameter, the maximum positive heterosis was observed in the cross $P_3 \times P_7$ (34.84%) followed by BU Chichinga-1 (32.26%), $P_2 \times P_6$ (28.06%), $P_6 \times P_7$ (28.06%), $P_4 \times P_6$ (26.77%), $P_4 \times P_7$ (26.77%), $P_2 \times P_7$ (24.84%) and $P_2 \times P_3$ (17.74%) (Table 3b.). These findings are in consonance with those of Hedau and Sirohi (2004) and Nagadevi *et al.* (2022) for fruit length in ridge gourd and with Nagadevi *et al.* (2022) in ridge gourd for that character.

Among all the crosses, five hybrids, namely $P_1 \times P_3$, $P_2 \times P_3$, $P_2 \times P_6$, $P_4 \times P_6$ and $P_6 \times P_7$ showed significant positive standard heterosis for fruit flesh thickness (Table 3b.). For fruit flesh thickness positive standard heterosis ranged from 7.55 to 32.07% over check variety 'Padma' with the maximum significant positive heterosis was observed in the cross $P_6 \times P_7$ (32.07%) followed by $P_1 \times P_3$, $P_2 \times P_3$, $P_2 \times P_6$ and $P_4 \times P_6$ (13.21% for each cross), which is desirable for enhancing fruit flesh thickness in snake gourd. Among all the crosses, only one hybrid $P_2 \times P_6$ (11.00%) depicted non-significant positive heterosis which is desirable. One hybrid $P_3 \times P_7$ (-11.00%) exhibited non-significant negative standard heterosis for locules per fruit over 'Padma' (Table 3b.). The rest of the crosses showed no heterosis for this trait.

Conclusion

Standard heterosis studies can contribute to the development of high-yielding vegetable crops that would be of better quality than standard check varieties. Considering the above results and discussion of early flowering, duration of harvest, individual fruit weight, number of fruits per plant, fruit yield per hectare, fruit length and fruit diameter as well as percentage of standard heterosis analysis, the hybrids $P_1 \times P_3$, $P_2 \times P_6$, $P_3 \times P_7$ and $P_6 \times P_7$ showed the best performance compared to the commercial hybrid 'Padma', and other two check varieties of BARI Chichinga-1 (OP) and BU Chichinga-1 (hybrid). Before recommendation for commercial exploitation, the above four hybrids, namely $P_1 \times P_3$, $P_2 \times P_6$, $P_3 \times P_7$, and $P_6 \times P_7$ might be subjected to further evaluation through multi-location trials.

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References

Adebooye, O. C. 2008. Phytoconstituents and anti-oxidant activity of the pulp of snake tomato (*Trichosanthes cucumerina*). *Afr. J. Tradit. Complement. Altern. Med* .**5**: 173–179.

Ahmed, B. 2016. Combining ability and heterosis in pumpkin (*Cucurbita moschata* Duch Ex Poir.). PhD Dissertation. Department of Horticulture, BSMRAU, Salna, Gazipur, Bangladesh.

Ahsan, F. N., A. K. M. A. Islam, M. G. Rasul, M. A. K. Milan and M. M. Hossain. 2014. Genetic variability in snake gourd (*Trichosanthes cucumerina* L.). *J. Agril. Technol.* **10** (2): 356-366.

Allard, R. W. 1960. Principles of plant Breeding. John Wiley and Sons. Inc., U.S.A. p.485.

Anonymous. 2020. Yearbook of Agricultural Statistics 2019. Bangladesh Bureau of Statitics (BBS), Statistics and Informative Division (SID), Ministry of Planing, Govt. of the Peopl's Republic of Bangladesh. www.bbs.gov.bd

Ara, N., M. F. Hossain and B. Akhter. 2013. Characterization and evaluation of snake gourd (*Trichasanthes anguina* L.) genotypes. *Wudpecker J. Agril. Res.* **2**(12): 330 – 334.

Bairwa S. K., A. K. Soni and A. S. Shekhawat. 2017. Heterosis studies in ridge gourd (*Luffa acutangula* (Roxb.) L.). *Int. J. Current Microb. Applied Sci.* **6**(11): 1572-1576.

Banga, S. S. 2012. Germplasm Enhancement in Indian Mustard: Some Exiting New Developments. In: "*Souvenir of XIX Annual AICRP Group Meet on Rapeseed-Mustard*", Birsa Agricultural University, Ranchi, India, pp. 29-34.

Banik, B. R. 2003. Variability, gene action and heterosis in snake gourd (*Trichosanthes anguina* L.). Ph.D Dissertation. Department of Genetics and Plant Breeding, BSMRAU, Salna, Gazipur, Bangladesh.

D'Croz, D. M., J. R. Bogard, T. B. Sulser, N. Cenacchi, S. Dunston, M. Herrero and K. Wiebe. 2019. Gaps between fruit and vegetable production, demand, and recommended consumption at global and national levels: an integrated modelling study. The Lancet Planetary Health. **3**(7): 318-319. https://www.sciencedirect.com/journal/the-lancet-planetary-health. https://doi.org/10.1016/S2542-5196(19)30095-6.

Devi, D., S. Mariappan and T. Arumugam. 2017. Heterosis in snake gourd (*Trichosanthes cucumerina* L.) for growth and earliness. *Int. J. Current Microb. Appled Sci.* **6**(3): 387-393.

Devi, N. D. and S. Mariappan. 2013. Studies on genetic diversity in snake gourd (*Trichosanthes anguina* L.). *African J. Agril. Res.* **8**(42): 5221-5225 [DOI: 10.5897/AJAR2013.7298].

Ene, C.O., P. E. Ogbonna, C. U. Agbo and U. P. Chukwudi. 2019. Heterosis and combining ability in cucumber (*Cucumis sativus* L.). *Inf. Process. Agric*. **6**: 150–157.

FRG. 2012. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council (BARC). Farmgate, Dhaka 1215. p.274.

Gopalan, C., B. V. Rama Sastri and S. C. Balasubramanian. 1982. Native value of Indian food. Indian Council of Medical Research, National Institute of Nutrition, Hyderabad.

Hedau, N. K. and P. S. Sirohi. 2004. Heterosis studies in ridge gourd. *Indian J. Hort* .**61**(3):236-239.

https://bsmrau.edu.bd/dres/varieties-released/bu-chichinga-1, Accessed: 30.11.2020.

https://www.theworldcounts.com/populations/countries/bangladesh.

https://successfarmbd.com/product/hybrid–snake–gourd–padma.

Lodam, V. A., P. P. Patil and D. T. Desai. 2014. Exploitation of hybrid vigour in ridge gourd (*Luffa acutangula* (L.) Roxb.). *Electronic J. Pl. Breed.* **5**(4):792-796.

Mondal, M. R., M. K. Sultan, S. Nur, M. Z. U. Sarker, M. S. Alam. and M. H. Rahman. Krishi projukti hatboi (Handbook on agro-technology), 6th edition, BARI. Gazipur, Bangladesh. 204. p. 491.

Nagadevi, S. A., M. R. Babu, D. Aparna, M. P. Rao and K. Umakrishna. 2022. Studies on heterosis in ridge gourd (*Luffa acutangula* (L.) Roxb.). *The Pharma Innov. J.* **11**(8): 1305-1311.

Nandhini, D., M. Ananthan, V. Krishnamoorthy and G. Anand. 2018. Studies on heterosis in ridge gourd [*Luffa acutangula* (L.) Roxb.]. *Int. J. Current Microb. Appled Sci.* **7**(5): 3126-3130.

Sonavane, P. N., M. N. Bhalekar, P. K. Pawar and S. O. Bawkar. 2013. Studies on heterosis and combining ability for earliness and yield in sponge gourd. *Bioinfolet.* **10**(2B): 662- 666.

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INFLUENCE OF DIFFERENT LEVELS OF NITROGEN ON GREEN POD YIELD AND NUTRIENT UPTAKE OF TWO VARIETIES OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.)

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Abstract

Two field experiments were carried out during two consecutive *rabi* (November-March) seasons of 2016-17 and 2017-18 at the Horticulture Research Centre of the Bangladesh Agricultural Research Institute (BARI), Gazipur, to evaluate the effects of different levels of nitrogen pod yield and nutrient uptake by the crop French bean (*Phaseolus vulgaris* L.). The treatments consisted of five N levels (0, 75, 100, 125 and 150 kg/ha) which were tested on two varieties (BARI Jharsheem-1 and BARI Jharsheem-2). Both varieties of french bean took up the highest N, P and K from soil in presence of 125 kg N/ha. BARI Jharsheem-1 recorded the higher fresh pod yield at 150 kg/ha (19.48 t/ha), which was identical with the same variety at 125 kg/ha (19.27 t/ha), followed by BARI Jharsheem-2 at 150 kg/ha (18.08 t/ha). Therefore, farmers might be advocated to use the variety BARI Jharshim-1 & 2 and nitrogen @ 125 kg/ha with other nutrients of 40 -80 -10 -1.98-0.84 kg/ha of P-K-S-Zn-B along with cowdung at 5 t/ha for french bean cultivation in Bangladesh.

Keywords: Cowdung, Chhiata soil series, French bean varieties, N, P & K uptake, Madhupur Tract.

Introduction

French bean (*Phaseolus vulgaris* L.), a member of the Fabaceae family, is an important leguminous vegetable across the world including Bangladesh. It is also known as kidney bean, snap bean, common bean, haricot bean, tepary bean and bush bean, and in Bangladesh it is called Jharsheem. It is used as vegetable when pods are immature and tender. The raw green pods of french bean is a good source of protein (1.83%), carbohydrate (6.97%), calcium (37 mg/100 g), iron (1.03 mg/100 g), phosphorus (38 mg/100 g and vitamins (Vit. A-35 πg/100 g, Vit. C-12.2 mg/100 g, Vit. K-14.4 πg/100 g and Vitamin B (Vit. B_1-0.082 mg/100 g, B_2-0.104 mg/100 g and B_3-0.734 mg/100 g) (Anonymous, 2021; Sharma *et al*., 2013).

Genetic constitution of a variety makes a great contribution to growth, yield and pod quality of french bean. Improved varieties, in general, give higher yields if supplied with optimum amount of deficient nutrients and are grown under

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favourable conditions (Farkade and Pawar, 2002). French bean, being a shy nodulator, responds well to the application of higher nitrogen for realizing higher yield potential (Kushwala, 1991). Its response to applied nitrogen is as high as 120 kg/ha (Projapoti *et al*., 2004), 124 kg/ha (Rana *et al*., 1998) and even as high as 180 kg/ha (Siddiqui, 2010).

The growth and yield performance of a crop are a function of the status of soil nutrients (especially N) (Mengel *et al*., 2006). Yield increase may respond to additional N supply and increased N utilization efficiency for yield production. Physical and chemical availability of nutrients and plant physiological factors affect the rate of nutrient absorption in plants (Agele *et al*., 2008). Potential availability of nutrients for plant uptake is a function of its solubility in the growing media and its physical location in the root zone.

Remobilization of nitrogen from photosynthesizing leaves can be stopped or reduced by supplemental nitrogen application. Nitrogen is critically deficient in most of the soils of Bangladesh. Practically, a number of research work was carried out on the effects of nitrogen on pod yield of french bean in Joydebpur condition, but there is a scarce information regarding research work on the influence of nitrogen on nutrient uptake as well as fresh pod yield of this crop in this area. The present study was, therefore, undertaken to find out the optimum nitrogen dose on nutrient uptake and fresh pod yield of two varieties of french bean in Joydebpur condition.

Materials and Methods

Two field experiments were conducted during *rabi* season (November –March) of 2016-17 and 2017-18 at the Research Field of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur which is located at 23º56′ N longitude and 90º24′ E Latitude at an altitude of 9 meter above the sea level. The two years' average of soil status for total N was 0.06 % and available P, S, Zn and B were 10.4, 16, 0.92 and 0.30 µg/g, respectively, and exchangeable K was 0.17 meq/100 g soil. The soil was clay loam, acidic (pH 6.0) and non- saline (EC 0.078 dS/m) in character. The research field belongs to Chhiata Soil Series under Modhupur Tract (AEZ-28). There were 10 treatment combinations comprising 5 levels of nitrogen, *viz*., 0.0, 75, 100, 125 and 150 kg/ha designated as N_0 (control), N_1, N_2, N_3 and N_4, respectively and two varieties of French bean, namely BARI Jharsheem-1 and BARI Jharsheem -2 designated as V_1 and V_2, respectively.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The size of each plot was 3.0 × 1.0 m. Autostin (@ 2.5 g/kg seed) treated seeds were sown by hand during second fortnight of November in both years at a rate of two seeds/hill with a spacing of 25 x 10 cm. After 15 days after sowing (DAS) thinning was done keeping one healthy seedling/hill. Two hand weeding were done at 15 and 50 DAS. A uniform dose of P (40 kg/ha), K (80 kg/ha), S (10 kg/ha), Zn (1.98 kg/ha), B (0.84 kg/ha), and cowdung (decomposed) (5 t/ha) was used in this experiment (FRG, 2012; Sen *et al*., 2010). The full dose of P, K, S, Zn, B, cowdung, and one-third of N as per treatment was applied during final land preparation and the rest half of N was top dressed in two equal installments between two rows at 20 and 35 DAS. The macro-nutrient contents of the applied decomposed cowdung were N (1.13%), P (0.48%), K (0.89%) and S (0.14%). The organic manure cowdung was applied to all plots.The source of N, P, K, S, Zn, and B were urea, TSP, MoP, gypsum, zinc sulphate (monohydrate) and boric acid (lab grade), respectively. In addition to pre-sowing irrigation, four additional irrigations were given to the crop. Tender green pods were picked out at regular intervals over 3-4 weeks from mid-January for recording plot-wise yield and a total of five pickings were done in both years from each plot. Pods were harvested at regular intervals from the five tagged plants and pod number and weight were calculated. From each harvest ten pods were randomly selected and weighed.

The N, P and K concentration of plants (five plants sampled in each plot, dried in an oven at 5^{o}C for 24 hours and ground) were determined following micro-Kjeldahl method for N (Jackson, 1973), by a Colorimetric Method for P and Flame Photometer Method for K Jackson, 1973). The uptake values of N, P and K obtained by multiplying total per cent of nutrient content of plants with the corresponding total dry matter, expressed as kg/ha. Data were analyzed with the help of MSTAT-C computer package and mean comparisions were done by LSD test at 5% level of probability.

Results and Discussion

Effects of different levels of N on fresh pod yield of French bean varieties

In 2016-17, BARI Jharsheem-1 treated with 150 kg N/ha ($V_1 \times N_4$) recorded the maximum green pod yield (19.53 t/ha) being identical with green pod yield produced by the same variety treated with 125 kg N/ha ($V_1 \times N_3$) (19.32 t/ha) (Table 1) while, in case of BARI Jharsheem-2, application of N @ 150 kg/ha ($V_2 \times N_4$) produced the second maximum green pod yield (18.05 t/ha) that was identical with 125 kg N/ha ($V_1 \times N_3$) (17.98 t/ha). In 2017-18, the highest green pod yield (19.42 t/ha) was found from BARI Jharsheem-1 in combination with 150 kg N/ha ($V_1 \times N_4$) closely followed by the same variety combined with 125 kg N/ha ($V_1 \times N_4$) (19.21 t/ha) and BARI Jharsheem-2 with 150 kg N/ha ($V_2 \times N_4$) (18.11 t/ha).

Table 1. Combined effects of varieties and nitrogen levels on fresh pod yield of french bean

Treatment	Green pod yield (t/ha)		
	2016-17	2017-18	Mean
$V_1 \times N_0$	5.78f	5.74f	5.76g
$V_1 \times N_1$	12.09e	12.01e	12.05f
$V_1 \times N_2$	15.80c	15.70c	15.75d
$V_1 \times N_3$	19.32a	19.21ab	19.27ab
$V_1 \times N_4$	19.53a	19.42a	19.48a
$V_2 \times N_0$	4.29g	4.31g	4.30h
$V_2 \times N_1$	11.57e	11.60e	11.58f
$V_2 \times N_2$	14.17d	14.22d	14.19e
$V_2 \times N_3$	17.98b	18.04b	18.01c
$V_2 \times N_4$	18.05b	18.11ab	18.08c
LSD (0.05)	1.13	1.31	1.22

V_1=BARI Jharsheem-1, V_2 = BARI Jharsheem-2; N_0 = 0 kg N/ha, N_1=75 kg/ha, N_2 = 100 kg/ha, N_3= 125 kg/ha and N_4 = 150 kg/ha

Considering mean data, the maximum green pod yield was obtained from BARI Jharsheem-1 combined with 150 kg N/ha ($V_1 \times N_4$) (19.48 t/ha) followed by the same variety with 125 kg N/ha ($V_1 \times N_4$) (19.27 t/ha). In case of BARI Jharsheem-2, no significant difference was observed between 150 and 125 kg N/ha with regards to green pod yield per hectare. Higher number as well as higher weight of green pods/plant (data were not presented) might have influenced higher green pod yield at higher levels of N (125 and 150 kg N/ha). Both the varieties in both years gave the lowest green pod yield when urea-N was not applied. These results are in agreement with Singh (2000) and Srinivas and Naik (1990) who recorded the maximum pod yield of French bean at 125 kg N/ha and 160 kg N/ha, respectively; the latter was identical with 120 kg N/ha. Siddiqui (2010) reported that BARI Jharsheem-1 gave the highest green pod yield of 16.38 t/ha at 150 kg N/ha. Rahman *et al.* (2018) observed that BARI Jharsheem-2 (22.7 t/ha) gave higher yield than BARI Jharsheem-1(16.67 t/ha), when N @ 120 kg/ha was supplied. Shahid *et al*. (2015) obtained the highest pod yield from the application of 120 kg N/ha in french bean.

Effects of different levels of N on N, P & K uptake by French bean varieties

Both varieties of french bean showed differential response in uptake of N and K (Table 2). BARI Jharsheem -1 showed the maximum N uptake in both years

(2016-17 and 2017-18) compared to BARI Jharsheem -2 while reverse was true for BARI Jharsheem -2 in 2016-17. No significant difference was found between two varieties of BARI developed Jharsheem with regard to P uptake. Higher nitrogen uptake was recorded by N_3 (74.21 kg/ha in Y_1 and 75.84 kg/ha in Y_2) treatment which was statistically similar with N_2 (70.58 and 72.60 kg/ha in Y_1 and Y_2, respectively) and N_4 (70.68 and 72.72 kg/ha in Y_1 and Y_2, respectively) Mean data revealed that higher N uptake (75.03 kg/ha) was recorded by N dose of 125 kg/ha (N_3) followed by N_4 (71.70 kg/ha) and N_2 (71.59 kg/ha). Phosphorous uptake was recorded maximum (31.69, 37.63 and 32.63 kg/ha) in 125 kg/ha (N_3) in Y_1 and Y_2 and mean data, respectively (Table 2). Similarly, the application of N significantly influenced the plant to uptake K from soil. Significantly higher K uptake (40.82 and 41.12 kg/ha) was recorded in the treatment N_3 in Y_1 and Y_2. The uptake trend was similar in mean data. However, the lowest N, P & K uptake was recorded for N_0 (no nitrogen) in both years.

The variety and nitrogen dose in combination put significant effect on uptake of N, P and K (Table 2). The maximum N uptake was observed in $V_1 \times N_3$ combination (77.74 kg/ha in 2016-17, 74.39 kg/ha in 2017-18 and mean 76.06 kg/ha) which was closely followed by $V_1 \times N_2$, $V_1 \times N_4$, $V_2 \times N_2$ and $V_2 \times N_3$ in 2017-18. In 2016-17, P uptake was recorded the highest (33.63 kg/ha) in $V_1 \times N_3$ closely followed by $V_2 \times N_3$ whereas, in 2017-18, P uptake was found maximum (32.15 kg/ha) followed by $V_1 \times N_3$ (31.22 kg/ha). Considering two years' average data, the maximum P uptake was demonstrated by $V_2 \times N_3$ (32.85 kg/ha) followed by $V_1 \times N_3$ (32.42 kg/ha).

In the first year, the K uptake was found highest in $V_2 \times N_3$ (40.67 kg/ha) closely followed by $V_1 \times N_4$ (37.23 kg/ha), next better uptake of K in $V_1 \times N_3$ (37.42 kg/ha). Whereas, in the second year maximum K uptake was recorded in $V_2 \times N_3$ (41.28 kg/ha) combination closely followed by $V_1 \times N_3$ (40.96 kg/ha) combination and the same trend was also followed in mean data. Lower N, P & K uptake was recorded in $V_1 \times N_0$ and $V_2 \times N_0$ combinations in 2016-17 and 2017-18, respectively.

Nutrient uptake increased significantly with the increasing rates of N up to 125 kg/ha which was due to luxuriant crop growth, pod yield and yield attributes. These findings are supported by Prajapati *et al*. (2004) in French bean where N, P and K uptake increased with the increase of N rate up to 120 kg N/ha. Sultana *et al*. (2014) reported that N uptake increased with the increase of N up to a certain limit**.** AVRDC (1990) reported that French bean (bushy type) removed N, P and K at the rate of 80, 30 and 100 kg/ha from the soil for12 kg/ha fresh pod yield.

Table 2. Nutrient uptake of two varieties of French bean as influenced by nitrogen levels

Variety/N treatment	Nitrogen			Phosphorous			Potassium		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean
Variety (V)									
V_1	67.63a	64.24a	65.93	27.31	25.46	26.39	31.39a	35.77	33.58
V_2	66.96b	63.63b	65.30	27.05	26.11	26.58	35.49b	36.12	35.80
LSD (0.05)	0.51	0.49	-	ns	ns	-	1.10	ns	-
Nitrogen (N)									
N_0	42.41c	43.10c	42.75	14.81c	14.99d	14.90	26.02d	26.28c	24.61
N_1	61.81b	63.81b	62.81	26.28b	26.48c	26.38	36.03c	36.55c	35.09
N_2	70.58a	72.60a	71.59	27.93b	29.04b	28.49	38.04b	38.41b	37.12
N_3	74.21a	75.84a	75.03	31.69a	32.63a	32.16	40.82a	41.12a	40.08
N_4	70.68a	72.72a	71.70	28.24b	29.27b	28.75	37.24bc	37.12bc	36.55
LSD (0.05)	2.98	2.50	-	2.11	1.95	-	1.94	1.87	-
Interaction (N×V)									
$V_1 \times N_0$	44.28c	42.72d	43.50	15.30d	14.74e	15.02	20.02d	26.15d	23.08
$V_1 \times N_1$	66.29b	62.19c	64.24	27.02c	26.40d	26.71	31.71c	36.19bc	33.95
$V_1 \times N_2$	74.84a	71.00ab	72.92	30.33b	27.37cd	28.85	33.85b	38.29b	36.07
$V_1 \times N_3$	77.74a	74.39a	76.06	33.63a	31.22b	32.42	37.42b	40.96a	39.19
$V_1 \times N_4$	74.99a	70.91b	72.95	30.27b	27.59cd	28.93	33.93b	37.25bc	35.59
$V_2 \times N_0$	43.32c	42.10d	42.71	15.07d	14.87e	14.97	25.89a	26.41e	26.15
$V_2 \times N_1$	65.32b	61.43c	63.38	26.34c	26.15d	26.25	35.87b	36.59cd	36.23
$V_2 \times N_2$	74.43a	70.16b	72.29	29.98b	28.50c	39.24	37.78b	38.54c	38.16
$V_2 \times N_3$	77.21a	74.04a	75.63	33.54a	32.15a	32.85	40.67a	41.28a	40.98
$V_2 \times N_4$	74.54a	70.44b	72.49	30.34b	28.88c	29.61	37.23a	37.79cd	37.51
LSD (0.05)	3.48	3.12	-	2.31	2.08	-	2.01	1.96	-

V_1=BARI Jharsheem-1, V_2 = BARI Jharsheem-2 ; N_0 = 0 kg N/ha, N_1=75 kg/ha, N_2 = 100 kg/ha, N_3= 125 kg/ha and N_4 = 150 kg/ha; Y_1 = 2016-17, Y_2 = 2017-18

Conclusion

Application of nitrogen along with other nutrients increased nutrient uptake (N, P & K) and fresh pod yield of two french bean varieties, namely BARI Jharsheem-1 and BARI Jharsheemm-2. Nitrogen applied @ 125 kg/ha recorded maximum uptake of N,P & P in both varieties. BARI Jharsheem-1 treated with 150 kg N/ha gave maximum green pod yield (19.48 t/ha) being identical with the combination of 125 kg N/ha with the same variety (19.27 t/ha). BARI Jharshim-2 in combination with both 125 and 150 kg N/ha gave fair pod yield (18.01-18.08 t/ha) of both the varieties. Therefore, french bean fertilized at N @ 125 kg/ha with other nutrients might be recommended for securing sustainable green pod yield of this crop.

References

Agele, S.O., I. E. Adeniji, I. A. Alabi and Olabomi, A. 2008. Responses of Growth, Yeild and N use efficiency of selected tomato cultivars to variations in the hydrothermal regimes of the cropping seasons in a rainforest zone of Nigeria. *Journal of Plant Interactions*. **2**.273-285.

Anonymous. 2021. French Beans. Health Benefits, Nutrition, Recipes, Side Effects. https://www.netmeds.com/health-library/post/french-beans-health-benefits-nutrition recipies-side-effects.

AVRDC. 1990. "Vegetable Production Training Manual". Asian Vegetable Research and Development Centre, Shanhua, Tainan. 226 pp.

Farkade, B.K. and W.S. Pawar, 2002. Growth performance and yield of French bean varieties as influenced by different fertilizer levels. J. *Soils & Crops*. **12**:142-144.

FRG. 2012. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, New Airport Road, Farmgate, Dhaka-2015.p. 121. http://www.barcapps.gov.bd/ documents /books /Fertilizer%20Recommendation%20Guide%20-%202012.pdf

Jackson, M. L. 1973. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 498

Kushwala, B.L. 1991. Response of winter French bean at varying levels of nitrogen and phosphorus in north Indian plains. *Indian J. Pulses Res*. **4**:217-218.

Mengel, K., C. A. Kirkby, H. Kosegarten and T. Appel. 2006. Principles of Plant Nutrition. 5th Edition, Springer Publishers, New York, 849 p.

Prajapati, M. P., H. A. Patel, B. M. Prajapati and L. R. Patel. 2004. Studies of nutrient uptake and yield of French bean (*Phaseolus vulgaris* L.) as affected by weed control methods and nitrogen levels. *Legume Res.***27** (2): 99-102.

Rahman, M. S., M. A. Kabir , B. C. Halder, M. E. Haque and M. A. Rahman. 2018. Response of French bean (*Phaseolus vulgaris* L.) varieties to phosphorus levels in the active Tista Flood Plain. *Int. J. Agron. Agri. Res.***12** (1): 20-25.

Rana, N. S., R. Singh and I. P. S. Ahlawat. 1998. Dry matter production and nutrient uptake in French bean (*Phaseolus vulgaris* L.) as affected by nitrogen and phosphorous application. *Indian J. Agron*. **43** (1): 114-117.

Sen, R., M. A. Rahman, A. K. M. S. Hoque , S. Zaman and S. Noor. 2009. Response of different levels of nitrogen and phosphorus on the growth and yield of French bean. *Bangladesh J. Sci. Ind. Res*. **45 (2):** 169-172. Available online at www.banglajol.info

Shahid, M., A. A. Malik, A. Rehman, M. S. Khan and S. K. Zakaria. 2015. Effect of various levels of nitrogen, phosphorus and potash on the Yield of French bean. *Journal of Natural Sciences Research*. **5** (11): 50-52.

Sharma, B. K., S. S. Kushwah, K.S. Verma and O. P. Singh. 2013. Studies on french bean (*Phaseolus vulgaris* L.) varieties under different N, P, K and S levels for growth, yield and economics. J. *Hortl. Sci.* **8** (2):268-270.

Siddiqui, N. A. 2010. Response of bush bean to applied nitrogen and phosphorus. Ph.D. Dissertation in Agronomy. BSMRAU, Salna, Gazipur. 205pp.

Singh, R. V. 2000. Response of French bean (*Phaseolus vulgaris* L.) to plant spacing, and nitrogen, phosphorous fertilization. *Indian J. Hort.* 57 (4): 338-341.

Srinivas, K. and L. B. Naik. 1990. Growth, yield and nitrogen uptake in vegetable french bean (*Phaseolus vulgaris* L.) as influenced by nitrogen and phosphorous fertilization. *Haryana J. Hort. Sci*. **19** (1-2): 160-167.

Sultana, M. M., M. A. Haque, M. S. A. Rez and M. A. H. Chowdhury. 2014. Performance of Rhizobia and nitrogen on nodulation, yield and N Uptake by Soybean in Saline Soil. *J. Environ. Sci. & Natural Resources*. **7**(1): 215-226.

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GENOTYPE AND SPACING ON GROWTH, YIELD AND PROFITABILITY OF YARDLONG BEAN

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Abstract

A field experiment was conducted at the Regional Agricultural Research Station, Jashore to investigate the effect of genotype and plant spacing on the growth, yield and profitability of dwarf yardlong bean over vine type during the period from 15 March 2019 to 14 August 2019. The experiment consisted of two yardlong bean genotypes, namely VU (p)-01 (BARI Borboti-01) (vine type) and VU (d) Jas -02 (dwarf type) and five levels of spacing *viz.*, (i) 40 cm x 30 cm (ii) 40 cm x 40 cm, (iii) 50 cm x 40 cm (iv) 50 cm x 50 cm and (v) 60 cm x 60 cm. The factorial experiment was laid out in randomized complete block design with three replications. Complete harvesting of young pods took 152 days in vine type genotype, whereas, in dwarf genotype, that took 69 and 70 days from 1st and 2nd cultivation, respectively. In the case of dwarf type genotype, the data of plant height at different days after sowing (DAS), number of branches/plant at different DAS, canopy spread per plant at different DAS, days required to 1st flowering and 50% flowering, days required to 1st and last harvesting, pod length and diameter were averaged over two times cultivation, but individual pod weight, weight of pods per plant and pod yield per hectare were sum up of two growing cycles. The obtained results showed that all the characters were markedly influenced by two genotypes at different spacing. In genotype VU (d) Jas-02, among spacing treatments significantly higher number of primary branches plant^{-1} (4.40 at 60 DAS), canopy spread (54.86 cm at 60 DAS), pods plant^{-1} (39.61), pod length (34.90), pod diameter (9.27 mm), pod weight plant^{-1} (718.62 g) were recorded with wider spacing of 60 cm x 60 cm. In this genotype, maximum plant height (65.82 cm at 60 DAS) and yield (31.50 t ha^{-1}) were recorded with the closer spacing of 40 cm x 30 cm. In the genotype VU (p) -01, maximum number of canopy spread (81.63 cm at 140 DAS), pods plant^{-1} (23.30), pod length (54.36 cm), pod diameter (8.13 mm), pod weight plant^{-1} (365.23 g) were recorded with wider spacing of 60 cm x 60 cm. Maximum plant height (415.92 cm at 140 DAS) and yield (15.69 t ha^{-1}) were recorded with the closer spacing of 40 cm x 30 cm. The economic analysis revealed that, in the case of the VU (p) -01 genotype, the 40 cm x 40 cm spacing gave the highest BCR of 1.42, whereas, in VU (d) Jas -02 genotype, that narrower spacing accrued maximum BCR of 3.96. Considering the above findings the dwarf genotype [VU (d) Jas-02] with 40 cm x 30 cm plant spacing may be recommend for yardlong bean cultivation in Bangladesh.

Keywords: Pod yield, Yardlong bean, vine type and dwarf type, Spacing, BCR.

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Introduction

Yardlong bean (*Vigna unguiculata ssp. Sesquipedalis* L.) of Fabaceae family is one of the most important leguminous tropical vegetable crops. It is also known as long-podded cowpea, Chinese long bean, bodi/boda (West Indies), daugok (China), pole sitao (Philippines), snake bean, pea bean, asparagus bean, body bean due to its long slender pods (Painginker *et al*., 2021). In Bangladesh it is popularly known as 'borboti' grown throughout the country. Yard long bean is considered to be originated in Central Africa and widely distributed in India, Indonesia, Philippines and Sri Lanka including Bangladesh. According to Verdcourt (1970), cowpea has five sub- species, which are *cylindrical*, *Sesquipedalis, dekindtiana, unguiculata and manensis*. Among them, *cylindrical*, s*esquipedalis* and *unguiculata* are cultivated species, whereas *dekindtiana and menensis* are wild. It is highly self-pollinated, vigorous climbing annual, cultivated for its strikingly long draping pods which are used as vegetables. The fleshy pendulous pods which may be white, light green, dark green, brownish red or purple are usually harvested while they are immature and eaten as green vegetables (Resmi and Gopalakrishnan, 2001). The average temperature required for its optimum growth and development during the growth period is 20ºC to 30°C and it prefers full sunshine during growth and development, whereas cloudy and rainy weather cause low yield due to poor fruit set and dropping of young pods (Painginkar *et al*., 2021). The pod production of yardlong bean in Bangladesh is much lower than in other Asian countries with a national average yield of 4.65 t ha^{-1} (Anon., 2022b). Bangladeshi farmers cultivated different local, BARI-released and other yardlong bean varieties of other organizations, which are low-yielding and trailing type. In yardlong bean, it is reported that two growth habit types exist well in forms of dwarf and climbing, and the latter takes longer time to commence its pod production than the former, but the latter is more common as a commercial crop (Nooprom and Santipracha, 2015). Traditional varieties (vine type) of yardlong beans are generally grown with the support of 'A' shaped structure and its preparation by long sticks made with bamboo slices or branches is laborious and costly. Besides, during early summer, high-speed wind poses a risk to its cultivation by breaking its staking sticks. In contrast, the dwarf yardlong bean is relatively a short duration photo insensitive crop which may be comparable to replacing the traditional ones, regarding the problem faced during its cultivation (Biswas, 2017). So variety selection is one of the most important decisions for yard long bean cultivation. Plant breeders have produced its varieties to suit for every climate, garden site, and taste so that farmers must carefully select the certain yard long bean varieties in order to gain high productivities and easily grow in local areas. At present farmers of the country are cultivating dwarf yard longbean collecting seeds from different sources (Anon., 2020 & 2022a).

Among the factors that affect yield and quality of yardlong bean, population or plant density is one most important elements. Suitable plant spacing can lead to optimum yield whereas too high or low plant spacing could result in relatively lower yield and quality. Manjesh *et al*. (2019) opined that the actual yield of this crop is low due to following inappropriate spacing and mentioned that the plant density and arrangement of plants in a unit area greatly determines (i) resource utilization such as sunlight, nutrients and water (ii) the rate, extent of vegetative growth and development of crop (iii) yield components (iv) invasion of diseases and pests. The density of plant population changes the interception of light, canopy structure, dry matter production, and crop yield (Parwar *et al.,* 2007). In addition, spacing has a significant influence on various growth parameters, yield, and yield attributing characters as well as different flowering behaviors of yardlong beans (Dandile *et al.*, 2017). The recommended spacing for cultivation of pole (vine) type yardlong bean is available in the literature. The spacing recommended by various authors/researchers for climbing yardlong bean ranges from 30 cm to 15 cm between plants and 90 cm to 45 cm between rows (Painginkar *et al*., 2021; Manjesh *et al*., 2019). But it has not yet been determined which spacing is more suitable and profitable for dwarf yardlong bean cultivation. We get information from You Tube from a farmer's interview that 45 cm x 25 cm or 45 cm x 20 cm spacing is suitable for dwarf yardlong bean cultivation (Anon, 2020 & 2022a). The plant spacing for dwarf yardlong bean cultivation appeared in Annual Research Reports of Horticulture Research Centre (HRC) generally ranges from 40 cm to 50 cm between plants and 50 cm to 60 cm between rows (Anon., 2018 & 2019). Based on these conditions, five plant spacing *viz*., 40 cm x 30 cm, 40 cm x 40 cm, 50 cm x 40 cm, 50 cm x 50 cm and 60 cm x 60 cm are chosen for the experiment.

From You Tube we come to know that cultivation of dwarf yardlong bean is profitable because no support/trellises are required for its cultivation like vine type yardlong bean (Anon., 2022a). Besides, it takes only 65-70 days for complete harvesting of young pods of dwarf yardlong bean whereas in case of trailing type, complete harvesting of young pod needs 120-150 days. Therefore, in the same areas of land where vine type is cultivated once for pod purpose, dwarf type is cultivated twice. In view of the above facts, the present investigation was carried out to determine the optimum plant spacing for better growth, pod yield and profitability of dwarf yard long bean in comparison to vine type.

Materials and Methods

The present experiment was conducted at the Regional Agricultural Research Station (RARS), Jashore, Bangladesh from March 15 to August 14, 2019. The experimental place was situated at 24°51′ N latitude and 89°22' E longitudes and 15 m above sea level. The soil texture of the RARS, Jashore experimental site was classified as clay loam with 2.4 % organic matter and a pH of 7.0 (Islam *et al.,* 2017).

To find out suitable genotype and spacing, two yardlong beans [VU (p)-01 (BARI Borboti-1) and VU (d) Jas-02] and five spacings (S_1: 40 cm × 30 cm, S_2: 40 cm ×

40 cm, S_3: 50 cm × 40 cm, S_4: 50 cm × 50 cm, S_5: 60 cm × 60 cm) were used as treatments. Two yardlong bean genotypes were designated as G_1 = VU (p)-01 (BARI Borboti-1) and G_2 = VU (d) Jas-02. The genotype G_1 was cultivated one time and G_2 was cultivated two times for this experiment along with all spacing treatments in the same field. In case of climbing yardlong bean (G_1 genotype) complete harvesting of young pods needed 152 days whereas complete harvesting of young pods of G_2 genotype needed 69 days for the 1st time and 70 days for the 2nd time. Therefore, two times cultivation of G_2 genotype was possible in the same field within the same cropping period of G1 genotype. The duration of cultivation of G_1 was from March 15 to August 14, 2019 (152 days). On the contrary, the duration of 1st cultivation of G_2 was from 15 March 2019 to 23 May 2019 (70 days) and 2nd cultivation was from 01 June 2019 to 08 August 2019 (69 days). The factorial experiment was carried out in Randomized Complete Block Design (RCBD) with three replications. The unit plot was 6.0 m × 6.0 m (36 m^2) in size with block to block distance of 1.0 m and plot to plot distance was 0.5 m. In total, there were 30 experimental plots. Thus, each unit plot accommodated 300, 225, 180, 144, and 100 plants, respectively for each yardlong bean genotype. Seeds of yardlong bean genotypes were used as planting material. Seeds were soaked overnight in water before sowing to enhance germination. Also, seeds were treated with Provex-200 @ 2 g kg^{-1} of seeds before sowing. Seeds were sown in rows according to the treatments by hand at 3 cm depth on 15 March 2019 (1st cultivation with G_1 and G_2) and 1st June 2019 (2nd cultivation with G_2). Two seeds were placed per hole and the hole was covered with fine soil to ensure uniform germination. After a few days of germination, a single healthy plant was considered for cultivation and another plant was removed from the hole. Insecticide Proclaim® was applied @ 1 g L^{-1} 3 times at an interval of 10 days starting soon after the advent of infestation to control bean pod borer *Maruca vitrata* (Fabricius). In addition, Bildor® was sprayed @ 2 ml L^{-1} 3 times at an interval of 10 days to control bean aphids (*Aphis fabae* Scopoli). No fungicide was sprayed for this trial to control the fungal diseases. For G_1, trellising was done 28 days after sowing and twigs were tied with stalks regular basis to maintain the proper growth of the plants. Detopping was done in the plants of G_2 genotype 21 DAS to enhance the number of twigs and keep the plants in the dwarf stage to increase pod yield. Irrigation was given as per requirement and weeding was done when as necessary. The manures and fertilizers that were used (Cowdung: 5 t ha^{-1}, Urea: 27 kg ha^{-1}, TSP: 86 kg ha^{-1}, MoP: 31 kg ha^{-1}, respectively) as suggested by Nahid (2018). The full amount of well-decomposed cowdung, triple super phosphate (TSP), ½ murate of potash (MoP) and 1/3 of urea were applied as basal doses during final land preparation and the rest 2/3 amount of the urea and ½ MoP were applied in two equal splits *viz.*, 15 and 30 DAS for G_2. In the case of G_1, the rest 2/3 amount of the urea and ½ MoP were applied in three equal splits *viz.*, 30, 60 and 90 DAS. The application procedure of other maures and fertilizers was similar to the previous one. The Urea and MoP were mixed properly and applied around the individual plant maintaining

a safe distance from the main stem and immediately top dressed after each application.

Data were gathered from inner plants within each row to avert border effects. Data are required on plant height, number of branches per plant and canopy spread per plant, days required to first and 50 % flowering, days required to first and last harvesting, pod length, pod diameter, number of pods per plant, individual pod length, weight of pods per plant and weight of pods per plot. Per hectare yield was calculated from plot yield. In the case of G_2, the data of plant height at different days after sowing (DAS), number of branches/plant at different DAS, canopy spread per plant at different DAS, days required to 1^{st} flowering, days required to 50% flowering, days required to 1^{st} and last harvesting, pod length and pod diameter were averaged over two times cultivation, but individual pod weight, weight of pods per plant and pod yield per hectare were sum up of two growing cycles. . Canopy spread was measured by calculating the canopy area in the north-south and east-west directions of leaves and averaging both values to get the actual canopy spread.

Recorded data were analyzed statistically using the GLIMMIX procedure of SAS and mean separation was done with Tukey's HSD test at $p \leq 0.05$ (SAS software Version 9.4, SAS Institute Inc, Cary, NC). Economic analysis was also done.

Results and Discussion

Effects of genotype and plant spacing on growth characters

Plant height

The combined effects of genotype and spacing were found to be significant for plant height at various days after sowing (DAS) (Table 1). Plant height at different DAS was found to be decreased with the increased plant spacing irrespective of the genotypes. In the case of genotype VU (p)-01, plant spacing of 40 x 30 cm produced significantly taller plants at 20 DAS (42.29 cm), 40 DAS (143.37 cm) and 60 DAS (221.40 cm) than those of the spacing of 50 cm x 40 cm (39.38 cm at 20 DAS, 137.01 cm at 40 DAS and 213.06 at 60 DAS), 50 cm x 50 cm (38.20 cm at 20 DAS, 131.27 cm at 40 DAS 203.32 cm at 60 DAS) and 60 x 60 cm (37.21 cm at 20 DAS, 123.67 cm at 40 DAS and 192.38 cm at 60 DAS). No significant difference was found between 40 cm x 30 cm and 40 cm x 40 cm spacing in respect of plant height at different DAS in genotype VU (p)-01. Plant height of the genotype VU (p)-01 at 80, 100, 120 and 140 DAS were not analyzed. At these DAS, plant height was also decreased with the increase of plant spacing. In case of the genotype VU (d) Jas-02, similar result was found in spacing treatments with regard to plant height. The maximum plant height was found in the closer spacing of 40 cm x 30 cm (36.51 cm at 20 DAS, 66.85 cm at 40 DAS and 75.87 cm at 60 DAS) closely followed by 40 cm x 40 cm (36.04 cm at 20 DAS, 66.51 cm at 40 DAS and 75.11 cm at 60 DAS) and the lowest plant height

Table 1. Combined effect of genotype and plant spacing on plant height of yardlong bean at different days after sowing

Treatment combination		Plant height (cm) at DAS						
Genotype (G)	Spacing (S)	20	40	60	80*	100 *	120*	140 *
G_1	S_1	42.29a	143.37a	221.40a	319.92	372.98	395.36	415.92
	S_2	41.74a	141.51a	219.18a	315.35	368.13	391.41	410.51
	S_3	39.38b	137.01b	213.06b	306.62	355.25	378.02	397.66
	S_4	38.20bc	131.27c	203.32c	289.93	339.11	360.86	379.72
	S_5	37.21cd	123.67d	192.38d	274.33	319.55	341.26	359.14
G_2	S_1	36.51cd	66.85e	75.87e	-	-	-	-
	S_2	36.04d	65.51e	75.11ef	-	-	-	-
	S_3	33.96e	63.26f	73.50f	-	-	-	-
	S_4	32.78e	59.85f	69.52g	-	-	-	-
	S_5	31.24f	56.40g	65.82h	-	-	-	-
CV (%)		5.13	6.89	4.32	-	-	-	-

Means followed by the same letters within a column do not differ significantly by Tukey's HSD test at $p<0.05$. G_1 = VU (p)-01(BARI Borboti-1), G_2 = VU (d) Jas-02, S_1 = 40 cm × 30 cm, S_2 = 40 cm × 40 cm, S_3 = 50 cm × 40 cm, S_4 = 50 cm × 50 cm and S_5 = 60 cm × 60 cm. For G_2, plant height was averaged over 2-growing cycles (two times cultivation), DAS- days after sowing, '*' marked data within columns were not analyzed.

was observed at the wider spacing of 60 cm x 60 cm (31.24 cm at 20 DAS, 56.40 cm at 40 DAS and 65.82 at 60 DAS). There were no significant differences between 50 cm x 40 cm and 50 cm x 50 cm spacing in respect of plant height at different DAS (20, 40 and 60 days). This increase in plant height might be due to the greater competition for space and light, thereby forcing the plants to grow taller. Increase in the number of plants per unit area coupled with high plant to plant competition. Due to this, lower amount of light intercepted by a single plant resulting into increased inter nodal length and also under higher plant density there might be comparatively low solar interception through crop canopy and under increased inter and intra row spacing probably the reduced interplant competition for light might have resulted in such variation in plant height. Similar observations were also reported by Manjesh *et al.* (2019), Shrikanth *et al.* (2007) and Darwesh and Fayza (2012) and Moniruzzaman *et al*. (2002 & 2003) in yardlong bean (vine type), hyacinth bean, cowpea and lady's finger, respectively. Manjesh *et al.* (2019) obtained the highest plant height (294.29 cm) at 45 DAS from the closer spacing of 45 cm x 30 cm spacing among eight spacing treatments (45 cm x 30 cm, 45 cm x 45 cm, 45 cm x 60 cm, 45 cm x 75 cm, 60 cm x 30 cm, 60 cm x 45 cm, 60 cm x 60 cm, 60 cm x 75 cm). Anon., (2019) reported that plant height (25.07 cm at 20 DAS, 56.81 cm at 40 DAS & 66.27 cm at 50 DAS) was observed in VU (d) Jas-02 genotype at 50 cm x 40 cm spacing whereas plant height (26.23 cm at 20 DAS, 160.17 cm at 20 DAS and 310.33 cm at 50 DAS) was recorded in VU (p)-01 (BARI Borboti-1) genotype at the same spacing.

Number of branches per plant

Main effect of genotype and plant spacing was found significant, but insignificant effect was found in combined effects of genotype and number of branches plant^{-1} in respect of number of branches plant^{-1} (Table 2). The genotype VU (d) Jas-02 recorded higher number of branches plant^{-1} (3.13 at 20 DAS, 4.54 at 40 DAS and 4.78 at 60 DAS) than that of the genotype VU (p)-01 (1.42 at 20 DAS, 2.52 at 40 DAS and 3.27 at 60 DAS). The genotype VU (p)-01 produced 4.92, 8.45, 12.64 and 15.56 primary branches plant^{-1} at 80, 100, 120 and 140 DAS.

Number of branches plant^{-1} was significantly influenced due to different levels of spacing. The number of branches plant^{-1} was increased with the decrease in plant density. The highest primary branches plant^{-1} (2.98 at 20 DAS, 3.92 at 40 DAS and 4.40 at 60 DAS) were produced at the lowest plant density of 27778 plants ha^{-1} (60 cm x 60 cm) and the lowest primary branches plant^{-1} (1.49 at 20 DAS, 2.95 at 40 DAS and 3.68 at 60 DAS) were produced at the highest plant density of 83333 plants ha^{-1} (45×30 cm). This is due to the fact that, as plant density decreased ample resources become available for each plant that enhances the lateral vegetative growth of the crop. The increased number of branches at the wider plant spacing could also be attributed to more interception of sunlight for photosynthesis, which may have resulted in production of more assimilates for partitioning towards the development of higher branches. This result corroborates the findings of Manjesh *et al.* (2019) and Painginkar *et al.* (2021), Shrikanth *et al.* (2007), Pawar *et al.* (2007), Reddy and Reddy (2011) and Moniruzzaman *et al*. (2009) in yard long bean (vine type), hyacinth bean, French bean, cluster bean and French bean, respectively. Manjesh *et al*. (2019) obtained the highest primary branches plant^{-1} (12.25) from 60 cm x 75 cm and the lowest from the closest spacing of 45 cm x 30 cm (9.71) in field condition at 45 DAS. Painginkar *et al.* (2021) reported that maximum number of branches plant^{-1} was recorded in wider spacing of 90 cm x 45 cm (17.77) and the lowest from closer spacing of 90 cm x 15 cm (12.70) at 120 DAS in vine type yardlong bean. Anonymous (2018) reported that 4.27 branches plant^{-1} at 68 DAS was produced in VU (d) Jas-02 genotype from 60 cm x 40 cm spacing.

Table 2. Main effect of genotype and plant spacing on the number of branches per plant of yardlong bean at different days after sowing

Treatment	Number of branches plant^{-1} at DAS						
	20	40	60	80	100	120	140
Genotype (G)							
G_1	1.42 b	2.52 b	3.27 b	4.92	8.45	12.64	15.56
G_2	3.13 a	4.54 a	4.78 a	-	-	-	-
Spacing (S)							
S_1	1.49 c	2.95 c	3.68 c	-	-	-	-
S_2	1.56 c	3.23 bc	3.79 c	-	-	-	-
S_3	1.85 bc	3.35 abc	3.85 bc	-	-	-	-
S_4	2.55 b	3.88 a	4.36 a	-	-	-	-
S_5	2.98a	3.92 a	4.40 a	-	-	-	-
G XS	ns	ns	ns	-	-	-	-
CV (%)	9.3	8.09	3.95	-	-	-	-

Means followed by the same letters within a column do not differ significantly by Tukey's HSD test at $p<0.05$. G_1 = VU (p)-01 (BARI Borboti-1), G_2 = VU (d) Jas-02, S_1 = 40 cm × 30 cm, S_2 = 40 cm × 40 cm, S_3 = 50 cm × 40 cm, S_4 = 50 cm × 50 cm and S_5 = 60 cm × 60 cm, For G_2, number of branches plant^{-1} was averaged over 2-growing cycles (two times cultivation), DAS- days after sowing.

Canopy spread per plant

The combination of genotype and spacing exerted significant influence on canopy spread plant^{-1} at different DAS (Table 3). Canopy spread increased with the increase of plant density or planting distance irrespective of the genotype. In the case of VU (p)-01 genotype, maximum canopy spread (14.96 cm at 20 DAS, 20.73 cm at 20 DAS and 37.15 cm at 60 DAS) was produced at the lowest plant density of 27778 plants ha^{-1} (60 cm x 60 cm) and the lowest canopy spread (12.23 cm at 20 DAS, 16.88 cm at 40 DAS and 30.92 cm at 60 DAS) were produced at the highest plant density of 83333 plants ha^{-1} (45×30 cm). Canopy spread at 80, 100, 120 and 140 DAS in genotype VU (p)-01 was not analyzed. At these DAS, canopy spread increased with the decrease of plant density i.e. with the increase of planting distance In the case of the genotype VU (d) Jas -02, maximum canopy spread (39.23 cm at 20 DAS, 46.87 cm at 40 DAS and 54.86 cm at 60 DAS) was also recorded from the wider spacing of 60 cm x 60 cm closely followed by 50 cm x 50 cm (38.83 cm at 20 DAS, 45.06 cm at 40 DAS and 52.11 cm at 60 DAS) and the lowest (30.63 cm at 20 DAS, 37.83 cm at 40 DAS and 44.29 cm at 60 DAS) from the closest spacing of 40 cm x 30 cm which was closely followed by 40 cm x 40 cm spacing (33.93 cm at 20 DAS, 38.53 cm at 40 DAS and 44.29 cm at 60 DAS). This might be due to the fact that, as plant density decreased i.e. planting distance increased sufficient resources become available for each plant that enhances the lateral vegetative growth of the crop. The increased number of branches at the wider plant spacing could also be attributed to more interception of sunlight for photosynthesis, which may have resulted in production of more assimilates for partitioning towards the development of higher branch and as a result canopy spread of the plant increased. This is in perfect agreement with the findings of Moniruzzaman *et al*. (2010), Moniruzzaman and Islam (2006), Moniruzzaman *et al.* (2008) and Moniruzzaman *et al*. (2009b) in lady's finger, lettuce, broccoli and French bean, respectively.

Effects of genotype and plant spacing on flowering and harvesting related parameters

Flowering parameters

The combined effects of genotype and spacing were found to be significant for days required to 1st flowering and 50% flowering (Table 4). Days required to 1st flowering was found to be decreased with the increased plant spacing irrespective of genotype. In the case of VU (p)-01 genotype, it took maximum days (33.85 days) to initiate flowering at the wider spacing of 60 cm x 60 cm) which was closely followed by 50 cm x 50 cm (33.50 days) and minimum days (30.25 days) were required to reach at 1st flowering stage at the closer spacing of 40 cm x 30 cm, which was statistically similar to 40 cm x 40 cm spacing (30.65 days).

The closer spacing of 40 cm x 30 cm took significantly lesser number of days (41.25 days) for 50 per cent flowering than wider spacing of 60 cm x 60 cm (47.51 days) for 50 per cent flowering being statistically identical with 50 cm x 50 cm spacing (46.90 days) in VU (p)-01 genotype. Similar results were also found in VU (d) Jas -02 genotype. The closer spacing of 40 cm x 30 cm also took significantly lesser number of days (26.78 and 31.12 days for 1st and 50 per cent flowering, respectively) for flowering than wider spacing of 60 cm x 60 cm (32.36 and 40.50 days for 1st and 50 per cent flowering, respectively). The low population

Table 3. Combined effect of genotype and plant spacing on canopy spread per plant of yardlong bean at different days after sowing

Treatment combination		Canopy spread plant^{-1} (cm) at DAS						
Genotype (G)	Spacing (S)	20	40	60	80 *	100 *	120 *	140*
G_1	S_1	12.23 g	16.88 d	30.92 d	38.70	48.91	57.74	68.43
	S_2	13.42 f	17.09 d	31.03 d	40.22	50.16	60.29	71.80
	S_3	13.63 f	19.82 c	34.12 cd	42.53	53.82	64.55	74.78
	S_4	14.76 e	20.43 c	36.30 c	45.34	58.90	68.92	78.25
	S_5	14.96 e	20.73 c	37.15 c	46.13	60.24	69.75	81.63
G_2	S_1	30.63 d	37.83 b	44.29 b	-	-	-	-
	S_2	33.93 cd	38.53 b	45.62 b	-	-	-	-
	S_3	35.73 bc	39.33 b	48.36 ab	-	-	-	-
	S_4	38.83 ab	45.06 a	52.11 a	-	-	-	-
	S_5	39.23 a	46.87 a	54.86 a	-	-	-	-
CV (%)		4.60	5.07	3.95	-	-	-	-

Means followed by the same letters within a column do not differ significantly by Tukey's HSD test at $p<0.05$. G_1 = VU (p)-01(BARI Borboti-1), G_2 = VU (d) Jas-02, S_1 = 40 cm × 30 cm, S_2 = 40 cm × 40 cm, S_3 = 50 cm × 40 cm, S_4 = 50 cm × 50 cm and S_5 = 60 cm × 60 cm, For G_2, canopy spread was averaged over 2-growing cycles (two times cultivation), '*' marked data within columns were not analyzed, DAS = Days after sowing

Table 4. Combined effect of effect of genotype and plant spacing on flowering, harvesting and number of pods plant $^{-1}$ of yardlong bean

Treatment combination		Days required to 1st flowering	Days required to 50 % flowering	Days required to first harvesting	Days required to last harvesting	Number of pods plant^{-1}
Genotype (G)	Spacing (S)					
G_1	S_1	30.25e	41.25d	57.23c	147.20c	16.53i
	S_2	30.65e	41.87c	57.85c	147.89c	17.19i
	S_3	32.89b	44.85b	58.35c	148.93b	20.11h
	S_4	33.50a	46.90a	60.58b	149.00b	22.13g
	S_5	33.85a	47.51a	62.25a	152.00a	23.30f
G_2	S_1	26.78h	31.12h	43.24f	66.87g	28.10e
	S_2	26.85h	31.56h	43.56f	66.98g	29.22d
	S_3	29.56g	35.56g	45.23e	68.56e	34.18c
	S_4	31.57d	38.54f	47.02d	68.38e	37.62b
	S_5	32.36c	40.50e	48.12d	70.00d	39.61a
CV (%)	-	6.76	5.92	7.49	6.51	5.83

Means followed by the same letters within a column do not differ significantly by Tukey's HSD test at $p<0.05$. . G_1 = VU (p)-01(BARI Borboti-1), G_2 = VU (d) Jas-02, S_1 = 40 cm × 30 cm, S_2 = 40 cm × 40 cm, S_3 = 50 cm × 40 cm, S_4 = 50 cm × 50 cm and S_5 = 60 cm × 60 cm. For G_2, days required to first and 50 % flowering, first and last harvesting were averaged over 2-growing cycles (two times cultivation), and number of pods plant^{-1} was the summation of 2-growing cycles (two times culvation).

density delayed the maturity due to higher number of branches, canopy spread and leaves, and higher availability of nutrients lead to profuse vegetative growth which delayed the reproductive phase. This result of flower initiation (days to 1st flowering) is in line with the results of Manjesh *et al.* (2019) and Painginkar *et al*. (2021) who reported that plants in closer spacing took minimum days in vine type yard long bean. The findings of 50 per cent flowering are in conformity with Manjesh *et al.* (2019) and Painginkar *et al*. (2021), Hatam *et al.* (2000), Deka *et al*. (2015) and Mozumder*et al.* (2007) who reported that plants in closer spacing took minimum days to 50 per cent flowering in yardlong bean (vine type), cluster bean, faba bean and hyacinth bean, respectively whereas wider spacing enhanced vegetative growth and caused a delay in maturity. Anon. (2019) reported that 45 and 34 days were required for VU (p)-01 and VU (d) Jas-02 genotypes to reach at 50% flowering stage, respectively when plant spacing of 50 cm x 40 cm was maintained. At 60 cm x 40 cm spacing, days to 1st flowering recorded in the dwarf genotype was 31 days (Anon., 2018).

Harvesting parameters

Days required to 1st and 50% harvesting were significantly influenced by the combined effect of genotype and spacing treatments (Table 4). Days required to 1st and 50% harvesting increased with the decrease of plant density irrespective of the genotypes. The wider spacing of 60 cm x 60 cm took significantly higher number of days (62.25 and 152 days for 1st and last harvesting of pods, respectively) for harvesting than closer spacing of 40 cm x 30 cm (57.23 and 147.20 days for 1st and last pod harvesting, respectively) in VU (p)-01 genotype. This result corroborates the result of Painginkar *et al.* (2021) in vine type yardlong bean. But in VU (d) Jas-02 genotype, the wider spacing of 60 cm x 60 cm took significantly higher number of days (48.12 and 70 days for 1st and last harvesting of pods, respectively) for harvesting than closer spacing of 40 cm x 30 cm (43.24 and 66.87 days for 1st and last pod harvesting, respectively). Anon. (2019) reported that 58 and 45 days were required for VU (p)-01 and VU (d) Jas-02 genotypes to reach at 1st harvesting stage, respectively when plant spacing of 50 cm x 40 cm was maintained.

Effects of genotype and plant spacing on yield attributes and yield

Number of pods per plant

Influence of genotypes and various spacing levels on yield and yield attributing characters was found to be significant (Table 4). The number of pods plant^{-1} increased with the decrease in plant density irrespective of the genotypes. In genotype VU (p)-01, the highest number of pods plant $^{-1}$ (23.30) was recorded at the lowest plant density of 27778 plants ha^{-1} (60 cm × 60cm) and the lowest number of pods plant^{-1} (16.53) was recorded at the highest plant density of 83333 plants ha^{-1} (40 cm × 30 cm). Similar result was also noticed in VU (d) Jas-02 at various spacing. In genotype VU (d) Jas-02, number of pods plant^{-1} was the summation of pods plant^{-1} produced from two times cultivation. Maximum number of pods plant^{-1} (39.61) was obtained from the lowest plant density of 27778 plants ha^{-1} (60 cm × 60cm) and its lowest value was obtained from the highest plant density of 83333 (40 cm x 30 cm). The decrease in the number of pods plant $^{-1}$ with the increase in plant density could be due to increased intra row competition which eventually might have caused reduction in the number of pods per plant. Furthermore, the increase in the number of pods plant^{-1} with decreased plant density might be due to increase in the number of pods per node as a result of higher net assimilation rate and reduction of competition in wider spacing and also nutrient, moisture and light. These results are in conformity with the findings of Manjesh *et al.* (2019) and Painginkar *et al*. (2021), Sahariar *et al.* (2015) and Moniruzzaman *et al*. (2009), Mozumder *et al.* (2007) and Moniruzzaman *et al.* (2010) in vine type yard long bean, French bean and hyacinth bean, respectively. Anon., (2018) and Anon., (2019) reported that 35.27 and 29 pods plant^{-1} were produced in VU (d) Jas-02 genotype at 60 cm x 40 cm and 50 cm x 40 cm spacing, respectively whereas 35 pods plan^{-1} was given by VU (p)-01 (BARI BOrboti-1) genotype at 50 cm x 40 cm spacing .

Pod size (pod length and pod diameter)

The combination of genotype and spacing significantly influenced pod length and diameter (Table 5). Both pod length and diameter increased with the decrease in plant density (planting distance) irrespective of the genotypes. In the genotype of VU (p)-01, maximum pod length (54.36 cm) and diameter (8.13 mm) was recorded from the wider spacing of 60 cm x 60 cm and the lowest pod length (47.50 cm) and pod diameter (7.06 mm) from the closest spacing of 40 cm x 30 cm). There were no significant differences between 40 cm x 30 cm, 40 cm x 40 cm and 50 x 40 cm spacing with regard to pod length and diameter. Similar results were also observed in VU (d) Jas-02 genotype. In VU (d) Jas-02 genotype, wider spacing of 60 cm x 60 cm) produced maximum pod length (34.90 cm) and pod diameter (9.27 mm) and the closer spacing of 40 cm x 30 cm) gave minimum pod length (32.25 cm) and pod diameter (8.06 mm). The reason for longer pods and more pod diameter may be due to availability of favourable conditions, i.e. moisture, light, nutrients and less competition of plants among themselves in wider spacing. Similar findings were also reported by Manjesh *et al*. (2019), Moniruzzaman *et al.* (2010a), Sahariar *et al*. (2015) and Alam *et al.* (2011) in yardlong bean (vine type), hyacinth bean, French bean and faba bean, respectively. Anon. (2019) reported that 54.0 cm and 34.0 cm pod length was recorded in VU (p)-01 and VU (d) Jas-02 genotypes, respectively at 50 x 40 cm spacing and, pod diameter 6.5 and 6.6 mm was observed in VU (p)-01 and VU (d) Jas-02 genotypes, respectively at the same spacing. Anon. (2018) reported that pod diameter 8.1 mm was recorded from VU (d) Jas-02 genotype at 60 cm x 40 cm spacing.

Table 5. Combined effect of genotype and plant spacing on pod size, individual pod weight, pod weight plant^{-1} and pod yield of yardlong bean

Treatment combination		Pod length (cm)	Pod diameter (mm)	Individual pod weight (g)	Pod weight plant^{-1} (g)	Pod yield (t/ha)
Genotype (G)	Spacing (S)					
G_1	S_1	47.50c	7.06h	15.19f	188.32g	15.69e
	S_2	47.88c	7.25gh	16.91ef	218.01g	13.63ef
	S_3	48.84c	7.61fg	17.92de	270.28fg	13.51f
	S_4	51.28b	7.67efg	19.17cd	318.17ef	12.73f
	S_5	54.36a	8.13de	20.90c	365.23e	10.15g
G_2	S_1	32.25e	8.06def	17.94de	378.09e	31.51a
	S_2	32.60e	8.27cd	18.80cde	412.00c	25.75b
	S_3	33.22d	8.68bc	19.60cd	502.45c	25.12c
	S_4	33.88d	8.75b	21.17b	597.31b	23.89c
	S_5	34.90d	9.27a	24.19a	718.62a	19.96d
CV (%)	-	4.72	7.28	2.65	8.14	7.85

Means followed by the same letters within a column do not differ significantly by Tukey's HSD test at $p<0.05$. . G_1 = VU (p)-01(BARI Borboti-1), G_2 = VU (d) Jas-02, S_1 = 40 cm × 30 cm, S_2 = 40 cm × 40 cm, S_3 = 50 cm × 40 cm, S_4 = 50 cm × 50 cm and S_5 = 60 cm × 60 cm. For G_2, pod length and pod diameter were averaged over 2-growing cycles (two times cultivation), and individual pod weight, weight of pods plant^{-1} and pod yield were the summation of 2-growing cycles (two times cultivation).

Individual pod weight

Individual pod weight was significantly influenced by the combined effects of genotype and spacing (Table 5). Individual pod weight increased with the increase of planting distance irrespective of the genotypes. In the genotype of VU (p)-01, the highest individual pod weight (20.90 g) was recorded from the widest spacing of 60 cm x 60 cm closely followed by 50 cm x 50 cm (19.17 g) and the lowest individual pod weight (15.19 cm) from the closest spacing of 40 cm x 30 cm) closely followed by 40 cm x 40 cm spacing (16.91). Similar result was also noticed in VU (d) Jas-02 at various spacing. The genotype VU (d) Jas-02 gave maximum individual pod weight (24.19 g) at wider spacing of 60 cm x 60 cm) and the lowest individual pod weight (17.94) was found at the closer spacing of 40 cm x 30 cm closely followed by 40 cm x 40 cm spacing (18.80 g). This is due to maximum pod length and diameter at wider spacing, and minimum pod length and diameter at closer spacing. This result corroborates the findings of Moniruzzaman *et al.* (2002 & 2003) and Moniruzzaman *et al.* (2010b) in lady's finger, and Moniruzzaman *et al.* (2010a) in hyacinth bean. Anon.(2019) reported that VU (p)-01 (BARI Borboti-1) and VU (d) Jas-02 genotypes gave 23.20 and 12.90 g individual pod weight (one time cultivation), respectively at 50 cm x 40 cm spacing. Anon. (2018) obtained individual pod weight 10.07 g (one time cultivation) from VU (d) Jas-02 genotype when plant spacing 60 cm x 40 cm was maintained.

Pod weight per plant and yield per hectare

The combination of genotype and plant spacing had significant influence on pod weight plant^{-1} (Table 5). Pod weight plant^{-1} decreased with the increase in plant density irrespective of the genotypes. Maximum pod weight plant^{-1} was recorded at a wider spacing of 60 cm x 60 cm (365.23 g) which was significantly higher than closer spacing of 40 cm x 30 cm (188.32 g) in VU (p) -01. In VU (d) Jas-02, pod weight plant^{-1} was the summation of pod weight plant^{-1} produced from two times cultivation. In this genotype similar result was found and maximum pod weight^{-1} was recorded from the wider spacing of 60 cm x 60 cm (718.62 g) and its lowest value was obtained from the closer spacing of 40 cm x 40 cm (378.09 g). The spacing of 40 cm x 40 cm, 50 cm x 40 cm and 50 cm x 50 cm gave pod weight plant^{-1} of 412.00, 502.45 and 597.31 g, respectively in VU (d) Jas -02 genotype. The reason for the higher pod weight plant^{-1} may probably be due to less competition for light, nutrients, water and space in wider row-spacing compared to closer ones. The findings are in agreement with the results of Manjesh *et al*. (2019), Moniruzzaman *et al*. (2010a), Moniruzzaman *et al*. (2009) and Shahriar *et al*. (2015), and Alam *et al.* (2011) in yardlong bean (vine type), hyacinth bean, French bean and sweet paper. Anon. (2019) reported that VU (p)-01 (BARI Borboti-1) and VU (d) Jas-02 genotypes produced 584.67 and 287.33 g (one time cultivation) pod weight plant^{-1}, respectively at 50 cm x 40 cm spacing. Anon. (2018a) reported that VU (d) Jas-02 recorded pod weight (355.17 g plant^{-1} from one time cultivation) and Anon. (2018b) reported VU (p)-01 produced 375.2 g pod plant^{-1} at 60 cm x 50 cm spacing.

The combination of genotype and plant spacing had significant effect on the pod yield ha^{-1} (Table 5). In VU (p) -01 genotype, it was observed that significantly higher pod yield (15.69 t ha$^{-1)}$ was recorded with the closer spacing of 40 cm x 30 cm closely followed by 40 cm x 40 cm spacing and the lowest yield (10.15 t ha^{-1}) with the wider spacing of 60 cm x 60 cm (Table 5). The spacing of 50 cm x 40 cm and 50 cm x 50 cm produced 13.51 and 12.73 t ha^{-1}, respectively in VU (p)-01 genotype. In the case of this genotype, there were no significant differences among 40 cm x 40 cm, 50 cm x 40 cm and 50 cm x 50 cm with regard to pod yield ha^{-1}. In VU 9d) Jas-02 genotype, pod yield ha^{-1} was the summation of yield ha^{-1} produced from two times cultivation of this genotype. In this dwarf genotype, maximum pod yield (31.51 t ha^{-1}) was recorded from the closer spacing (40 cm x 30 cm) followed by 40 cm x 40 cm (25.75 t ha^{-1}) and the lowest pod yield (19.96 t ha^{-1}) from the wider spacing (60 cm x 60 cm). The spacing of 50 cm x 40 cm and 50 cm x 50 cm spacing produced 25.12 and 23.89 t ha^{-1} pod yield, respectively in VU (d) Jas-02 genotype. This might be due to higher plant population per unit area at narrower spacing. Similar findings have been reported by Manjesh *et al*. (2019), Deka *et al.* (2015), Satodiya *et al.*(2015), Mozumder *et al.* (2007) and Shahriar *et al*. (2015) in yardlong bean (vine type), cluster bean, vegetable cowpea, hyacinth bean and French bean, respectively. Manjesh *et al.* (2019) obtained the highest pod yield of vine type yardlong bean (15.31 t ha^{-1}) from 45 cm x 30 cm spacing and the lowest pod yield (9.69 t ha^{-1}) from 60 cm x 75 cm spacing. Anon. (2019) reported that 14.66 t ha^{-1} and 9.21 t ha^{-1} (one time cultivation) pod was produced from VU (p)-01 and VU (d) Jas-02 genotypes, respectively at 50 cm x 40 cm spacing. Anon. (2018a) reported that VU (d) Jas-02 gave pod yield of 14.80 t ha^{-1} (one time cultivation) at 60 cm x 40 cm and Anon. (2018b) reported that 12.50 t ha^{-1} pod was obtained from VU (p)-01 genotype at 60 cm x 50 cm spacing. It is mentioned that the pod yield of BARI Borboti-2 was 17-18 t ha^{-1} (Anon., 2021). BARI Borboti-2 was released as a dwarf variety of yardlong bean from VU (d) JAS-02 genotype by Bangladesh Agricultural Research Institute (BARI).

Economics

Table 6 shows that plant spacing of 40 cm x 30 cm in genotype VU (d) Jas-02 gave the highest gross return (Tk. 882280.00 ha^{-1}) and gross margin (Tk. 647410.33 ha^{-1}) followed by 40 cm x 40 cm spacing (Tk. 721000.00 ha^{-1}and Tk. 521072.00 ha^{-1}). The highest benefit-cost ratio (BCR) was obtained from 40 cm x 30 cm spacing in VU (d) Jas-02 (3.76) which was followed by 40 cm x 50 cm and 50 cm x 50 cm in the same genotype (3.66). This might be due to higher total green pod yield of yardlong bean recorded in closer spacing of 40 cm x 30 cm) in VU (d) Jas-02. In VU (p) -01 genotype, the spacing of 40 cm x 30 cm recoded the highest gross return, gross margin followed by 40 cm x 40 cm spacing. But in this genotype, 40

Table 6. Benefit-cost analysis of yardlong bean cultivation as influenced by two genotypes and five spacing

Treatment combination		Pod yield ($t\ ha^{-1}$)	Gross return ($Tk.\ ha^{-1}$)	Total cost of cultivation ($Tk.\ ha^{-1}$)	Gross margin ($Tk.\ ha^{-1}$)	Benefit-cost ratio (BCR)
Genotype (G)	Spacing (S)					
G_1	S_1	15.69	439320.00	324198.07	115121.93	1.36
	S_2	13.63	381640.00	269394.40	112245.60	1.42
	S_3	13.51	378280.00	269301.40	108978.60	1.40
	S_4	12.73	356440.00	257807.40	98632.60	1.38
	S_5	10.15	284200.00	236616.96	47583.04	1.20
G_2	S_1	31.51	882280.00	234869.67	647410.33	3.76
	S_2	25.75	721000.00	199928.00	521072.00	3.61
	S_3	25.12	703360.00	192373.00	510987.00	3.66
	S_4	23.89	668920.00	182909.00	486011.00	3.66
	S_5	19.96	558880.00	166141.89	392738.11	3.36

G_1 = VU (p)-01(BARI Borboti-1), G_2 = VU (d) Jas-02, S_1 = 40 cm × 30 cm, S_2 = 40 cm × 40 cm, S_3 = 50 cm × 40 cm, S_4 = 50 cm × 50 cm and S_5 = 60 cm × 60 cm, For G_2, pod yield was the summation of two growing cycles (two times cultivation), selling price of 1 kg pod =28 Tk.

cm x 40 cm spacing gave the maximum BCR (1.42) followed by 50 cm x 40 cm spacing (1.40). From the economic results (Table 6), it is observed that cultivation cost of the genotype VU (p)-01 was more than that of the genotype VU (d) Jas-02 because the former genotype was involved in costs of trellising, more labours due to pesticide spraying and weeding compared to the latter genotype. The savings in inputs costs (trellising, labor, insecticides, weeding) would increase more to this cost-efficacy for the genotype VU (d) Jas-02. The dwarf genotype (VU (d) Jas-02) did not need any trellises for vines, as a result bamboo purchasing costs along with labour costs for making trellises were saved. In addition, the dwarf genotype had fewer pest infestation compared to the vine type traditional cultivar reduced insecticides cost as well as minimized the labor cost of spraying those chemicals. Moreover, fewer weeds were observed in the dwarf yardlong field which cut down labor costs considerably. For this reason the dwarf genotype (VU (d) Jas-02) was more profitable than vine type genotype (VU (p)-01. In addition to less cultivation cost, short duration crop cycle (69-70 days) of this dwarf genotype played a great role in increasing profitability of this genotype because two times cultivation of this dwarf genotype had been possible due to its short duration crop cycle for green pod production and maximum pod yield was recorded in VU (d) Jas-02 genotype.

Conclusion

In the present study, the cultivation of yardlong bean of both vine type and dwarf type in five spacing had given significant results. The higher productivity was recorded in closer spacing of 40 cm x 30 cm spacing irrespective of the genotypes. Among five spacing and two genotypes, the dwarf genotype VU (d) Jas-02 with spacing treatment of 40 cm x 30 cm gave the highest profitability of yardlong bean. Maximum gross margin (Tk. 647410.33 ha^{-1}) and the highest BCR of 3.76 were found from the dwarf yardlong bean genotype (VU (d) Jas - 02) at the narrower spacing. Hence, 40 cm x 30 cm spacing may be recommended for dwarf yardlong bean cultivation in field condition of Bangladesh.

References

Alam, M. S., S. R. Saha, M. A. Salam and M. K. Alam. 2011. Effect of sowing time and plant spacing on the yield and yield attributes of sweet pepper (*Capsicum annuum*). *Bangladesh J. Agric. Res*. **36**: 271-278.

Anonumous. 2019. Regional yield trial of dwarf yardlong bean germplasm. Research report on Horticultural Crops (2018-19). Vegetable crops. Olericulture Division, HRC, BARI, Gazipur. pp. 127-128.

Anonymous. 2018a. Evaluation of dwarf yard long bean germplasm. Research Report on Horticultural Crops (2017-18). Vegetable crops. Olericulture Division, HRC, BARI, Gazipur. pp. 123-124.

Anonymous. 2018b. Regional yield trial of dwarf yardlong bean germplasm. Research Report on Horticultural Crops (2017-18). Vegetable crops. Olericulture Division, HRC, BARI, Gazipur. pp. 121-122.

Anonymous. 2020. Khato Jater Borbotti Chash. You Tube, Interviewing with the farmer, Nobodip Mollik by M. M. Hossain, Upozilla Krishi Officer, Dumuria, Khulna; 7:25 min video. (Accessed on 15 July, 2022).

Anonymous. 2021. Udvabito Krisi Projukti 2019-20. Borbotir Jat, BARI Borboti-2. Bangladesh Agricultural Research Istitute (BARI). Joydebpur, Gazipur -17001. pp. 35-36.

Anonymous. 2022a. Khato Jater Borbotti Chash (Dwarf yardlong bean production). You tube, Interviewing with the farmer, Nihar Mollik, vill. Borati by M. M. Hossain, Upozilla Krishi Officer, Dumuria, Khulna; 17:18 min video. (Accessed on 15 July, 2022).

Anonymous. 2022b. Yearbook of Agricultural Statistics-2021. 33rd series. Bangladesh Bureau of Statistics (BBS), Ministry of Planning, Govt. of the People's Republic of Bangladesh. p. 312.

Biswas, S. C. 2017. Research activities on yardlong bean in BRAC Bangladesh. https: // www slidesharenet/DrSitesh Biswas/research-activities-on-yardlong-bean-in-bracbangladesh 81042839. (Accessed November 11, 2019).

Dandile, H. 2017. Study on effect of spacing and nitrogen levels on growth and yield of yard long bean (*Vigna unguiculata* sub Sp. *sesquipedalis* (L.) verdcourt). M.Sc. (Horti), thesis submitted to Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, India.

Darwesh and M. A. Fayza, 2012. Cowpea (*Vigna unguiculata*) productivity as affected by combination effect between sowing dates and plant population. *J. Plant Production*. Mansoura Univ. **3** (11): 2711-2722.

Deka, K.K., R. D. Milu, P. Bora and N. Mazumder. 2015. Effect of sowing dates and spacing on growth and yield of cluster bean (*Cyamopsis tetragonoloba*) in subtropical climate of Assam, India. *Indian J. Agric. Res*. **49** (3): 250-254.

Hatam, M. K. M., Khattak, Manullah, A. M. 2000. Effect of sowing date and sowing geometry on growth and yield of faba bean (*Vicia faba* L.). *FABIS News Letter*. **24**:26-28.

Manjesh, M., N. Adivappar, V. Srinivasa, G. K. Girijesh and Sharanabasappa. 2019. Effect of plant densities and different environments on productivity and profitability of yardlong bean (*Vigna unguiculata sub sp. sesquipedalis*). *Legume Res.* **42** (3). 348-353. DOI: 10.18805/LR-3958file:///C:/Users/Win10/Downloads/Nagarajappa_Adivappar_Leg_Res%20(1).pdf

Moniruzzaman, M and M. R. Islam. 2006. Effects of plant spacing and nitrogen levels on the growth and yield of lettuce. *Bangladesh J. Agril. Research*. 31 (1):119-127.

Moniruzzaman, M, M. Z. Uddin, S. N. Mozumder and M. R. Islam. 2002 & 2003. Response of plant spacing and picking interval of green fruit of okra (*Abelmoschus esculentus* (L) Moench) cv. BARI Dheros-1 in hill agriculture. *Bangladesh J. Agri***. 27 & 28**:113-120.

Moniruzzaman, M., G. M. A. Halim and Z. A. Firoz. 2009. Performances of French bean as influenced by plant density and nitrogen application. *Bangladesh J. Agril. Research*. **34** (1): 105-111.

Moniruzzaman, M., J. Hasan, N. U. ahmed, Z. A. Firoz and A. Q. M. Kamruzzaman. 2010a. Effect of date of planting and spacing on the yield attributes and yield different varieties of country bean (*Lablab purpureus* L. (Sweet)]. *Bangladesh J. Agril Research*. **37** (4): 573-584.

Moniruzzaman, M., N. U. Ahmed and S. M. M. Hossain. 2010b. Effects of spacing and variety on fruit yield of okra okra (*Abelmoschus esculentus* (L) Moench). *Bangladesh J. Agri.* **35** (1):63-68.

Moniruzzaman, M., S. N. Mozumder and G. M. A. Halim. 2008. Response of broccoli (*Brassica oleracea*) to spacing and seedling age in hilly areas. Bangladesh J. Agri. 33 (2): 49-58.

Mozumder S. N. and M. Moniruzzaman, S. M. M. Rahman, P. C. Sarker and N. C. Basak. 2007. Influence of support systems and spacing on hyacinth bean production in the eastern hilly area of Bangladesh. *Legume Res*. 3**0** (1):1-9.

Nooprom, K. and Q. Santipracha. 2015. Effect of varieties on growth and yield of yard long bean under Songkhla Conditions, Southern Thailand. *Modern Applied Science*. **9** (13: 247-251. doi:10.5539/mas.v9n13p247 URL: http://dx.doi.org/10.5539/mas.v9n13p247

Painginkar, S. S., Y. R. Parulekar, N. V. Dalvi and R. V. Dhopavkar. 2021. Standardization of spacing and nitrogen dose for yard long bean (*Vigna unguiculata sub sp. sesquipedalis* L. *Verdcourt*) under Konkan agro- climatic conditions. *The Pharma Innovation Journal*. **10** (9): 167-171.

Parwar, S., M. Kharwade and H. Awari. 2007. Effect of plant density on vegetative growth and yield performance of different varieties of French bean under irrigated condition. *Karnataka J. Agric. Sci.* **20**: 684-685

Reddy, M. A. and S. B. Reddy. 2011. Effect of planting geometry and fertility level on growth and seed yield of cluster bean under scarce rainfall zone of Andhra Pradesh. *Legume Res*. **34** (2): 143-145.

Resmi, R. and T. R. Gopalakrishnan. 2004. Effect of plant growth regulators on the performance of yard long bean (*Vigna unguiculata var. sesquipedalis L.*). *Kerala J. Trop. Agric. Sci.* **42** (1-2):55-57.

Sahariar, M. S. , M. R. Karim, M. A Nahar, M. Rahman, M. U. Islam. 2015. Influence of mulching and plant spacing on growth and yield of French bean (*Phaseolus vulgaris* L.). *Progressive Agriculture.* **26**: 129-135.

Satodiya, B. N., H. C. Patel and N. V. Soni. 2015. Effect of planting density and integrated nutrient management on flowering, growth and yield of vegetable cowpea (*Vigna unguiculata* walp). The *Asian J. Hort*. **10**(2): 232-23.

Shrikanth, M. N., A. S. Merwade, C. S. Tirakannanavar, C. P. Mallapur, C. P., Hosamani. 2007. Effect of spacings and fertilizer levels on crop growth and seed yield in lablab bean (*Lablab purpureus)*. *Karnataka J. Agric. Sci*. **21**(3): 440-443.

Verdcourt. 1970. Kew bulletin. 24(2):235-307.

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EFFECT OF PLANT SPACING ON GROWTH, SEED YIELD AND QUALITY OF GYPSOPHILA (*Gypsophila paniculata* L.)

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Abstract

Spacing is significant for determining desired plant population to achieve higher yields. Appropriate plant spacing makes more efficient use of nutrient and light leading to faster canopy establishment resulted in reducing moisture evaporation and weed growth. Hence, an experiment was conducted at the open research field of Floriculture Division, Horticulture Research Centre, BARI, Gazipur during 2019-20 and 2020-21 to determine the suitable plant spacing for growth, yield attributes, yield and quality of gypsophila. The experiment consisted of six plantspacing's viz. broadcast (farmer's practice), 20 cm × 05 cm, 20 cm × 10 cm, 20 cm × 15 cm, 30 cm × 05 cm and 30 cm × 10 cm.The experiment was arranged in a randomized complete block design with three replications.BARI Gypsophila-1 was used as a variety.The blanket doses of fertilizers were N:100 kgha^{-1}, P:40 kg ha^{-1}, K:60 kg ha^{-1}, S:20 kg ha^{-1}, Zn:3 kg ha^{-1}and B:1.5 kg per hectare was applied in the form of urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. The results exhibited that the highest seed yield (1308 kg ha^{-1}) was obtained from the wider spacing of 30 cm × 10 cm. The same plant spacingachieved higher yield increment (8.28%) over farmer'spractice. The performance of growth and yield parameters were found better in the spacing of 30 cm × 10 cm. Economic analysis revealed that the highest gross margin and benefit cost ratio (2.21) wereachieved under the spacing of 30 cm × 10 cm.So, spacing 30 cm × 10 cm may be suitable for gypsophila cultivation but further research with wider spacing is needed for getting a conclusive result.

Keywords: *Gypsophila paniculata L.*, spacing, profitability, yield attributes, relative yield.

Introduction

Gypsophila (*Gypsophila paniculata*L.) is an important flower found in Eurosia, Africa, Australia and the Pacific Islands (Amini *et al*., 2018). Turkey has mainly high diversity of Gypsophila (Özdemir *et al*., 2010). The genus name is from the Greek gypsos (gypsum, calc) and philos (loving). Plants of this genus are known commonly to baby'sbreath. A few species are commercially cultivated for several uses, including floristry, herbal medicine and food (Korkmaz and Özçelik, 2011). The gypsophila is most commonly used in

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flower arrangements such as bouquets (Poornima *et al*., 2021). It is also used as cut flower and has great economic value in trade because of its prettiness (Wahome *et al.*, 2011).

The seed yield ofgypsophila could be increased by using improved management practices like plant spacing. Most of the farmers of Bangladesh are practicing broadcast seed sowing. It is well known that broadcast seed sowing always resulted in non-uniform plant spacing in crop field which reduced the crop yield. However, the yield and vase life of gypsophila areimproved byusing appropriate plant spacing as well as plant density. Plant spacing/planting density plays a vital role for producing quality of flowers and protects the incidence of diseases and pests (Poornima *et al*., 2021). Plant spacing is an important agronomic factor which influenced light capture during photosynthesis and increased nutrient availability (Nain *et al*., 2017). Appropriate plant spacing facilitated the good proliferation of photosphere and rhizosphere and for adequate air, light, moisture and plant nutrient uptake which ultimately improved the plant growth, yield and flower quality (Manimaran and Ganga, 2022; Khan *et al*., 2003; Ibeawuchi *et al*., 2008; Rafiei, 2009). There is little information on plant spacing for gypsophila cultivation in Bangladesh. Hence, the present study was undertaken to determine the optimum plant spacing for growth, yield, quality and profitability of gypsophilacultivation.

Materials and Methods

Experimental location and soil

The field experiment was conducted during the winter season of 2019-20 and 2020-21 at the research field of Floriculture division, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur. The terrace soils of Gazipur is medium high land with fine-textured (clay loam) and belongs to *Chhiata* soil series under the agro-ecological zone- Madhupur Tract (AEZ-28) (Shil *et al*., 2016). The particle and bulk density of the soil was 2.51 g/cm^3 and 1.36 g/cm^3, respectively having the porosity of 46.2% and field capacity (FC) of 25.7%. Before beginning the experiment initial soil (0-15 cm) sample was collected from the field and analyzed for chemical properties by following the standard methods outlined by Page *et al*. (1982) which are presented in the Table 1.

Table 1. Nutrients status of the experimental soil

Properties	pH	OM	Ca	Mg	K	Total N%	P	S	Zn	B
		%	meq 100 g^{-1}				μg g^{-1}			
Nutrient level	6.4	1.24	4.52	1.49	0.12	0.065	13.4	20.0	0.84	0.19
Critical level	-	-	2.0	0.50	0.12	0.12	7	10	0.6	0.20
*Interpretation	-	Low	Opt	Opt	Low	Very low	Optimum	Medium	Low	Low

*Anonymous, (2018)

Climatic condition: The site atmosphere was subtropical, humid, and subject to monsoons. The daily average temperatures was 13.0 to 36.1°C and yearly mean rainfall varied from 1500 to 2200 mm. Monthly minimum and maximum average temperature, and rainfall data of the experimental period of 2019-20 and 2020-21 were recorded from a meteorological station located about 369 m from the experimental field (Figure 1a, 1b).

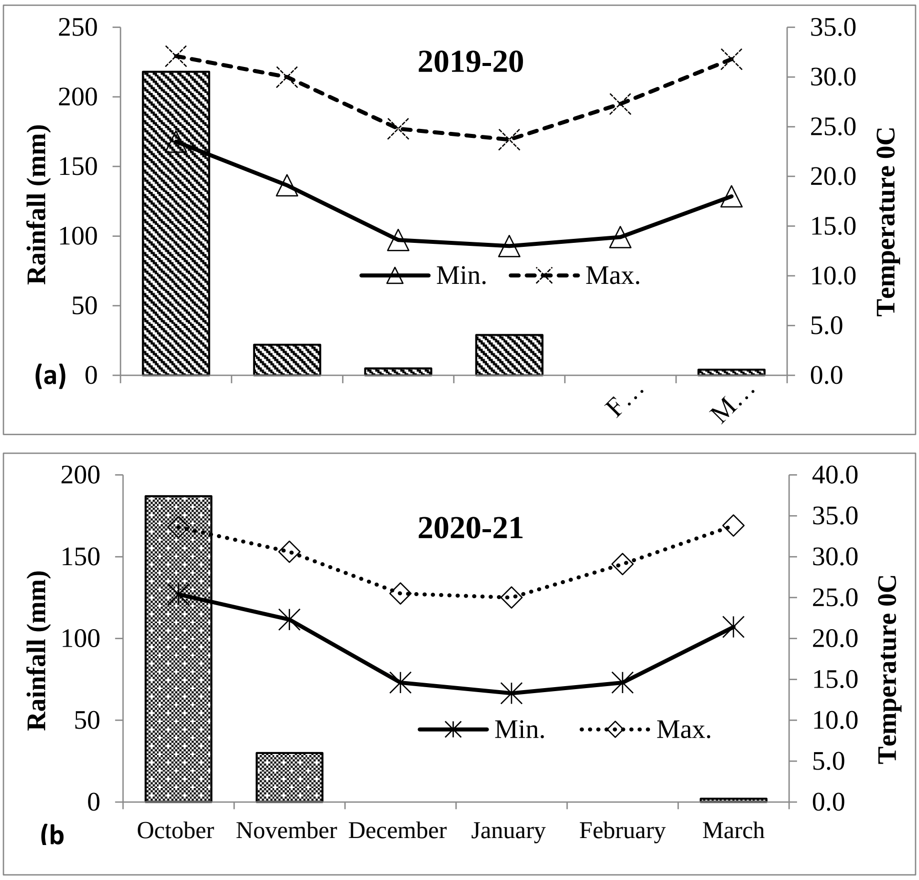

Fig. 1. Monthly mean minimum and maximum temperature ^{0}C and rainfall (a, b) during the experiment period of 2019-20 and 2020-21.

Land preparation, layout of experiment and planting material: The land was prepared with a tractor driven plough by 4 passes and it was leveled with a tractor driven rotavator. Weeds and stubble were eradicatedand cleaned manually.The experimental treatment was planned with six plant spacing such as S_1 (Farmer's broadcasting practice), S_2 (20 cm × 05 cm), S_3 (20 cm × 10 cm), S_4 (20 cm × 15 cm), S_5 (30 cm × 05 cm) and S_6 (30 cm × 10 cm). The experiment was laid out in a randomized complete block design with three replications.The unit plot size was 2 m × 2 m separated from each other by an alley of 50 cm widthThe doses of fertilizers were N:100 kgha^{-1}, P:40 kg ha^{-1}, K:60 kg ha^{-1}, S:20 kg ha^{-1}, Zn:3 kg ha^{-1}, B: 1.5 kg ha^{-1}in the form of urea, TSP, MoP, gypsum zinc sulphate and boric acid, respectively and cowdung@ 5t ha^{-1}were applied and incorporated into the soil (Quddus *et al*., 2021). The tested variety was BARI Gypsophila-1 released from Floriculture Division, Horticulture Research Centre, BARI, Gazipur.

Fertilizer application and seed sowing: Thefull dose of triple super phosphate (TSP), gypsum, zinc sulphate, boric acid, decomposed cowdung, 1/3 MoP and 1/3 urea were applied during final land preparation. Healthy seeds of gypsophila (var. BARI Gypsophila-1) were sown @ 2.5 kg ha^{-1}as per plant spacing continuously in rows on 12December 2019 and on 13 December 2020, respectively.

Intercultural management: Light irrigation was applied immediately after seed sowing by plastic hose pipe.After two days of seed sowing,irrigation was done twice in a week up to 40 days of seed sowing then it was applied single in a week before maturity.Hand weeding as well as thinning were done at 20 days after sowing maintaining the distances of treatment plant spacing (plant to plant and row to row). Second hand weeding was done at 40 days after sowing. The rest 2/3 Urea and 2/3 of MoP was applied in two equal splits. First split was applied at 20 days after sowing (DAS) and second split was applied 40 DAS.Seedlings were protected from disease (rot) by use of the fungicide Dithane M-45 for two times at the rate of 2 g L^{-1} water at 25 and 35 days after sowing.The crop was harvested on 15 March 2020 and on 16 March 2021.The maturity sign of gypsophila was determined when old stems with branches became brown in colour and about 80% capsules (fruits) became light black in colour. In this time some flowers still were present on top of the plants.

Data collection: Data ongrowth parameters like plant height (cm), number of branches per plant, number of internodesper plant and internode length (cm) were collected from 10 plants selected randomly from each unit plot and each data were averaged.Leaf chlorophyll content was measured by a soil-plant analysis development (SPAD) chlorophyll meter (Konica Minolta, model SPAD-502 plus, Tokyo, Japan) from randomly selected 10 plants of each treatment at 60 days after sowing. The SPAD readings were collected from mid-ribs of fully expanded individual leaves in each plant.Five plants from each treatment were randomly collected to record number of open and un-open flowers per plant. Five open flowers were detached from every plant of each treatment for measuring flower diameter and the data was averaged.Regarding number of filled and unfilled fruits per plant, 5 mature plants of gypsophila were randomly collected from the middle rows of each plot at the harvest time and the data were recorded and averaged. Filled fruits were detached from five plants and randomly selected five fruits from each treatment to record the number of seeds per fruit. Thousand seed weight (g) was determined by the counting of 500 seeds collected from composite seeds of each treatment and weighing through electronic balance and converting it into1000-seed weight.One square meter area of each treatment plot was selected for recoding the number of plants per plot (plant population) after 60 days of seed sowing. In the plot of farmer's broadcasting practice, all plants were considered as plant population, but flowers and fruits bearing plants were approximately 70%. In case of treatment plot S_2 (20 cm × 05 cm), flowers and fruits bearing plants were about 79%. Seed yield and straw yield were recorded on a whole plot basis and converted in kg ha^{-1}.

Relative data in percentage: For each plant spacing treatment, the value of relative data was presented as percentage relative to the farmer's broadcasting practice..

$$\textbf{Relative data}\ (\%) = \frac{\textbf{Treatment value} - \textbf{farmer broadcasting value}}{\textbf{farmer broadcasting value}} \times 100 \text{ --------- } (1)$$

Statistical analysis: Statistical analysis was done subjected to statistical analysis of variance (ANOVA) according to Statistix 10 software (www.statistix.com). The means of each treatment were compared using the least significant difference (LSD) at significant level $p \leq 0.05$ (Statistix-10, 1985).

Economic analysis: The seed yield was utilized to calculate the gross return. The gross return was measured by multiplying the marketable unit price of seed. Gross margin was calculated by subtracting management cost from gross return.Treatment wise management cost was calculated by adding the cost incurred for labours, ploughing and inputs of each treatment. Theshadow prices (land rent, straw cost etc.) were not considered. The BCR was calculated from gross return divided by total cost of cultivation.

Results and Discussion

Growth and flower attributes of gypsophila: Growth attributes of gypsophila were affected significantly by different plant spacing (Table 2).The maximum plantheight (71.4 cm) was found in spacing30 cm × 10 cm, which was statistically similar to spacing20 cm × 10 cm and Farmer's broadcasting practice. The minimum plantheight (61.3 cm) was observed in spacing 20 cm × 15 cm. The tallest plant in S_6treatment might be related with increasing in the space between row to row for getting more light, nutrients, air and moisture as compared toother treatments. The result is in agreement with the findings of Poornima *et al*. (2021) in gypsophila who noted that the tallest plant (96.0 cm) was recorded in wider spacing (50 cm × 50 cm) under poly house condition. Similar results were also observed by Manimaran and Ganga (2022) in *Jasminum nitidum* andNaik and Kumar (2014) in *Dendrobium* orchids. Different treatment contributed significantly to increase the number of branches per plant of gypsophila. The treatment S_6 resulted gave more number of branches (6.90) per plant, which was comparable to S_3, S_4 and S_5 treatments (Table 2).The probable reason of increased branches per plant might be due to proper plant space,availability of air, water, sunlight and nutrition for proper physiological process of the plant. Similar result was documented by Poornima *et al*. (2021) in gypsophila and Niranjan *et al.* (2018) in *Gladiolus grandiflorus.*The maximum number of internodes per plant (9.28) of gypsophila wasobservedinS_6 followed by S_4 and S_5 treatments. The internode length of gypsophila was significantly influenced by different plant spacing where the maximum internode length (6.30 cm) was measured from S_6(30 cm × 10 cm) followed by S_4 and S_5 treatments. The wider spacing allowed the appropriate number of plants to receive better soil moisture, and helped to uptake proper nutrient, light for photosynthesis toplant which ultimately increased the number of internodes and internode length of gypsophila.Similar view was also verified by Jain *et al*. (2018) in *Limonium sinuatum* who reported that the highest plant length (73.9 cm) as well as internode length was recorded in spacing 45 cm × 30 cm.In this experiment, themaximum number of opened flowers per plant (54.4) was recorded from S_6treatment, which was statisticallysimilar to S_3, S_4 and S_2 treatments. The treatment S_6gave more number of unopened flowers (43.1) as compared to other treatments. The S_6 treatment (30 cm × 10 cm) recorded higher number of flowers which might be due to wider spacing, however this spacing greatly favored the nutritional availability and amount of sunlight resulting in higher number of flowers. Similar findings were outlined by Niranjan *et al.* (2018) in *Gladiolus grandiflorus* and Gaurav *et al.* (2005) in gerbera. Themaximum diameter of flower (0.90 cm) was recorded from S_4 (20 cm × 15 cm) closely followed by S_6 treatment (Table 2).Wider plant spacing(20 cm × 15 cm) might have affected the flower diameter. Spacing playsa significant role for activation of photosynthetic system to enhance biological efficiency, allowinghigher photosynthesis to increase flower diameter. Lakshmi *et al.* (2014) reported that African marigold (*Tagetes erecta* L.) under wider spacing (40 cm × 60 cm) got higher flower diameter.Similar view was outlined by Poornima *et al*. (2021) in gypsophila. Leaf chlorophyll content in leaves was responded positively by different spacing. The maximum SPAD value (49.4) was recorded from the treatment S_6 which was statistically similar to S_4, S_3 and S_5 treatments. The lowest value was found in S_2 treatment (Table 2). Wider plant spacing (30 cm × 10 cm) might be associated with higher leaf chlorophyll due to availability of light, air and nutrient from soil. The function of chlorophyll in a plant is to absorb sunlight. The energy absorbed from light is transferred to energy-storing molecules (Pavlović *et al.*, 2014). However, proper density of plant (population) modifies the canopy structure and influence light interception for photosynthesis to produce dry matter (Khenizy *et al.*, 2014).

Table 2. Effect of plant spacing on growth and flower attributes of gypsophila (Pooled data of two years)

Treatment	Plant height (cm)	No. of branch plant^{-1}	No. of internodes plant^{-1}	Internode length (cm)	No. of opened flower plant^{-1}	No. of unopened flower plant^{-1}	Flower diameter (cm)	SPAD value
S_1 (Farmer's practice)	66.0a-c	5.37c	8.25c	4.12d	45.4c	34.5c	0.59e	47.5bc
S_2 (20 cm × 05 cm)	64.3bc	5.91bc	8.34bc	4.64cd	52.7ab	37.8b	0.76d	46.8c
S_3 (20 cm × 10 cm)	69.7ab	6.61ab	8.46bc	5.20bc	52.6ab	41.6a	0.82c	48.6ab
S_4 (20 cm × 15 cm)	61.3c	6.59ab	8.88ab	5.59ab	52.4ab	41.8a	0.90a	49.3a
S_5 (30 cm × 05 cm)	63.5bc	6.06a-c	8.92ab	5.82ab	49.1bc	37.6b	0.84bc	48.5ab
S_6 (30 cm × 10 cm)	71.4a	6.90a	9.28a	6.30a	54.4a	43.1a	0.86ab	49.4a
CV (%)	5.72	8.21	3.69	8.09	5.72	2.94	2.69	3.92

Values within the same column with a common letter do not differ significantly according to the least significant difference (LSD) test at $p \leq 0.05$.

Seed yield attributes of gypsophila

Yield attributes of gypsophila were affected by different plant spacing (Table 3). Maximum number of filled fruits per plant (73.4) was recorded from treatment S_6 which was significantly different from the other treatments but statistically alike with $S_3$and S_4 treatments (Table 3). The highest number of unfilled fruits per plant (26.9) was recorded inS_6treatment which was significantly higher than S_1 and S_2treatments, but statistically identical with S_5 andS_4 treatments. This increase in fruits per plant might be due to the minor competition among the plants for nutrient and water at wider spacing (30 cm ×

10 cm). Similar findings were recorded in different crops outlined by Nain *et al.* (2017) in African marigold; Kumar *et al.* (2012) in African marigold cv. PusaNarangi; Poornima *et al.* (2021) in gypsophila. Seeds per fruit are very important yield contributing character for achieving higher seed yield of any crop. However, different plant spacing contributed positively to achieve higher number of seeds per fruit over farmer's practice. Maximum number of seeds per fruit (16.8) was recorded from S_6 treatment that was statistically similar to S_5, S_4 and S_3 treatments and the lowest number of seeds per fruit was in S_1 treatment (Table 3). The 1000-seed weight (1.67 g) was found at par except farmer's practice (Table 3). Optimum plant density as well as spacing is very essential for higher number of seeds per fruit and getting heaviest seed for obtaining highest seed yield. Similar observation was also obtained by Niranjan *et al*. (2018) in gladiolus.

Table 3. Effect of plant spacing on seed yield attributes of gypsophila (Pooled data of two years)

Treatment	No. of filled fruit plant^{-1}	No. of unfilled fruit plant^{-1}	No. of seed fruit^{-1}	1000-seed wt. (g)
S_1 (Farmer's practice)	40.0d	15.9b	10.5b	1.48b
S_2 (20 cm × 05 cm)	46.7c	15.4b	11.2b	1.60a
S_3 (20 cm × 10 cm)	71.7ab	18.8b	15.1a	1.63a
S_4 (20 cm × 15 cm)	70.8ab	20.2ab	16.1a	1.67a
S_5 (30 cm × 05 cm)	67.2b	20.8ab	15.3a	1.61a
S_6 (30 cm × 10 cm)	73.4a	26.9a	16.8a	1.67a
CV (%)	5.07	19.5	6.73	2.74

Values within the same column with a common letter do not differ significantly according to the least significant difference (LSD) test at $p \leq 0.05$.

Yields of gypsophila: Seed yield is a vital reflection for seed production of a crop. Seed yield depends on the branches per plant, number of fruits per plant, seeds per fruit, and seed weight. In the experiment, farmer's broadcasting practice (S_1) treatment had maximum plants but about 70% plants were flowered as well as fruits bearer. Similarly closer spacing 20 cm × 05 cm(S_2) treatment had 2nd highest number of plants but about 79% plants were flowered as well as fruits bearer.However, the plant spacing had a significant effect on seed yield of gypsophila (Table 4). The highest seed yield (1316 kg ha^{-1}in 2019-20 and1300 kg ha^{-1} in 2020-21) was recorded in the treatment S_6(30 cm × 10 cm) which was comparable with S_3 and S_5treatments in both the years.

Maximum percent yield increment over farmers practice (8.28%) was achieved in spacing 30 cm × 10 cm (S_6) followed by spacing 20 cm × 10 cm (S_3) (Table 4). Wider spacing might have facilitated photosynthesis process due to get proper light, air and easily uptake the nutrient from soil.Wider spacing facilitates easy translocation of photosynthetic products to the seed for increasing enzymatic activitycausingseed yield increment. The result of this experiment agrees with the findings of a number of previous research activities involving other flower crops (Nain *et al*., 2017; Khenizy *et al.*, 2014; Kumer *et al*., 2012; Sharma *et al.*, 2012). The highest straw yield of gypsophila (1673 kg ha^{-1}in 2019-20 and1723 kg ha^{-1} in 2020-21) was exhibited in S_6 comparable with most of the treatment. Similar result was supported by Sing *et al* (2015) in marigold who reported that the highest yield was observed at 40 cm× 20 cm spacing. The lowest seed yield and straw yield of gypsophila werenoted in S_2 treatment (Table 4).

Table 4. Effect of plant spacing on seed yield and straw yield of gypsophila

Treatment	Seed yield (kg ha^{-1})			% Seed yield increment over farmer practice	Straw yield (kg ha^{-1})	
	2019-20	2020-21	Mean		2019-20	2020-21
S_1 (Farmer practice)	1270ab	1145b	1208	-	1588ab	1634ab
S_2 (20 cm × 05 cm)	1160b	1123b	1142	-5.46	1543b	1567b
S_3 (20 cm × 10 cm)	1260ab	1297a	1279	5.88	1681a	1699ab
S_4 (20 cm × 15 cm)	1190ab	1195b	1193	-1.24	1609ab	1607ab
S_5 (30 cm × 05 cm)	1240ab	1211ab	1226	1.49	1671a	1700ab
S_6 (30 cm × 10 cm)	1316a	1300a	1308	8.28	1673a	1723a
CV (%)	6.05	4.11	-	-	4.17	5.05

Values within the same column with a common letter do not differ significantly according to the least significant difference (LSD) test at $p \leq 0.05$.

Plant population of gypsophila: Plant population of gypsophila was influenced significantly by the different plant spacing (Figure 2). The maximum number (population) of plants per plot (485) was recorded from S_1 treatment and lowest was from S_4 treatment (Figure 2). The reason of maximum number of plants in S_1treatment (Farmer'sbroadcasting practice) plot might be due to non-uniform plant spacing.

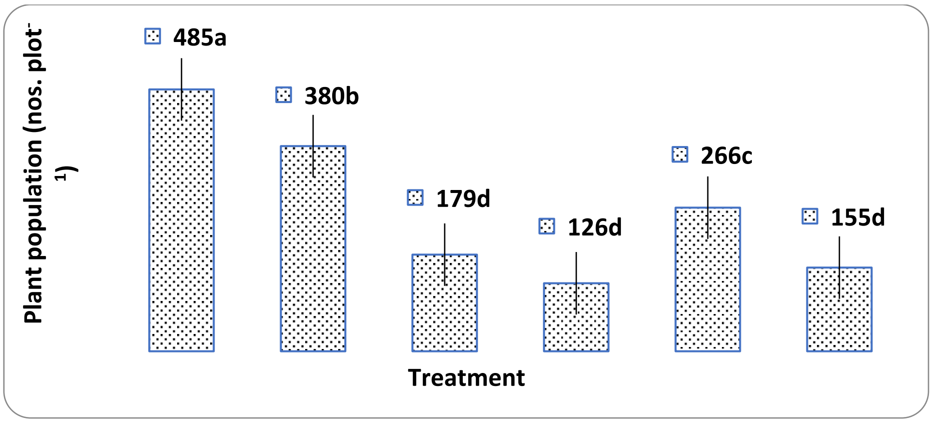

Fig. 2. Effect of plant spacing on number of plants (plant population) per plot (Pooled data of two years).

Means followed by the uncommon letter (s) are significantly different from each other by LSD test at $P \leq 0.05$.

Note: S_1 (Farmer's broadcasting practice), S_2 (20 cm × 05 cm), S_3(20 cm × 10 cm), S_4 (20 cm × 15 cm),

S_5 (30 cm × 05 cm)and S_6 (30 cm × 10 cm).

Cost and return analysis

Regarding the cost and return analysis, the maximum gross return Tk. 1569600 ha^{-1} wasrecorded from S_6 treatment followed by S_3. The minimum gross return was found from S_2 treatment. The highest gross marginwas also noted from S_6 treatment. The highest benefit cost ratio of 2.21 was obtained from S_6treatment followed by S_3. The lowest gross margin and benefit cost ratio were recorded from S_2 treatment (Table 5).

Table 5. Cost and return analysis of gypsophila due to different plant spacing (Pooled data of two years)

Treatment	Gross return (Tk. ha^{-1})	TC ((Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
S_1 (Farmer practice)	1449600	694500	755100	2.09
S_2 (20 cm × 05 cm)	1370400	708747	661653	1.93
S_3 (20 cm × 10 cm)	1534800	708747	826053	2.17
S_4 (20 cm × 15 cm)	1431600	708747	722853	2.02
S_5 (30 cm × 05 cm)	1471200	708747	762453	2.08
S_6 (30 cm × 10 cm)	1569600	708747	860853	2.21

Input prices: Urea= Tk.16 kg^{-1}, T.S.P= Tk. 24 kg^{-1}, MoP= Tk. 17 kg^{-1}, Gypsum= Tk.15 kg^{-1}, Zinc sulphate= Tk. 1400 kg^{-1} (lab grade), Boric acid= Tk. 1200 kg^{-1} (lab grade), Bavistin= Tk. 200 100^{-g}, Ribcord= Tk. 120 100^{-ml}, Gypsophila seed= Tk.1200 kg^{-1}, Ploughing= Tk. 1400 ha^{-1}(one pass), Cow dung= Tk. 2.0 kg^{-1}, Wage rate= Tk. 500 day^{-1}

Output price: Gypsophila seed price rate=Tk. 1200kg^{-1}

Gross returns were calculated on the basis of farm gate price of Gazipur, Bangladesh. TC = Total cost, BCR = Benefit cost ratio.

Conclusion

The gypsophila seed yield and yield traits were influenced significantly by plant spacing. The highest seed yield of gypsophila was achieved in the spacing of 30 cm × 10 cm. The highest benefit cost ratio and gross margin were also found from the same plant spacing. The result suggests that the wider plant spacing of 30 cm × 10 cm may be used for cultivation of gypsophila. Further research should be conducted on plant spacing including another wider spacing for confirmation of suitable plant spacing in maximizing seed yield of gypsophila.

Reference

Amini, E., Sh. Zarre and M. Assad. 2018. Leaf anatomical study of Gypsophila (Caryophyllaceae) and allied genera in Iran and its taxonomical implication. *Iran. J. Bot.* **24 (2):** 138-155.

Anonymous. 2018. Fertilizer recommendation guide-2018. Bangladesh Agricultural Research Council, Farmgate, Dhaka.

Gaurav, S.B., B.R.Singh, U.T. Desai, S.M. Katwale, D.S. Kakede, A.V. Dhane 2005. Effect of spacing on yield and quality of gerbera (*Gerber Jamesonii* Bolus ex hoof. f) under polyhouse. *J. Orna. Hortic. New series*.**8(1):**62-64.

Ibeawuchi, I.I., M.N. Edna, O. O. Miriam, A. P. Chinyere and V.N. Onyia. 2008. Plant spacing, dry matter accumulation and yield of local and improved maize cultivars. *The Journal of American Science*.**4(1):** 11-20.

Jain R, M.K. Singh, K. Swaroop, M.V. Reddy, T. Janakiram, P. Kumar, R. Pinder. 2018. Optimization of spacing and nitrogen dose for growth and flowering of statice (*Limonium sinuatum* Mill.). *Ind. J. Agric. Sci.* **88(7):**1108-14.

Kapczyńska, A. 2013. Effect of plant spacing on the growth, flowering and bulb production of four lachenalia cultivars. *South African Journal of Botany*.**88:**164-169.

Khan, M.A., M.K. Hasan, M.A.J. Miah, M.M. Alam and A.S.M.A. Masum. 2003.Effect of plant spacing on the growth and yield of different varieties of onion.*Pakistan Journal of Biological Sciences*.**6 (18):** 1582-1585.

Khenizy, S., A.Abd. El-Moneim and G.H. Abdel-Fattah.2014. Effect of natural extracts on vase life of gypsophila cut flowers. *Sci. J. Flowers and Orn. Plants.*1(1):1-16.

Korkmaz, M. and H. Özçelik. 2011. Economic importance of *Gypsophila* L., *Ankyro petalum* Fenzl and *Saponaria* L. (Caryophyllaceae) taxa of Turkey. *African J. Biotechnol.* **10(47):** 9533-9541.

Kumar, V., H.K. Singh, A. Kumar, A.K. Singh and Bhanupratap. 2012. Effect of planting distance and pinching on growth and flowering behavior of African marigold (*Tagetes erecta*) cv. PusaNarangi in Rainy season. *Curr. Adv. Agril. Sci*. **4 (1):** 79-81.

Lakshmi, R. K. Pandey, S. Dogra, N. Laishram, D. Bhat, A. Singh and S. Jamwal. 2014. Studies on effects of planting dates and spacing in African marigold (*Tagetes erecta*L.).*Progressive Horticulture*.**46 (1):** 149-152.

Manimaran, P and M. Ganga. 2022.Effect of different plant spacing on growth, flower yield and quality of Jasmine spp. (*Jasminum nitidum*).*The Pharma Innovation Journal*.**11(7):** 1531-1536.

Naik, R.M. and A.K. Kumar.2014. Effect of various plant growth promoters and growing conditions on flowering of dendrobium cv. Earsakul. *Int. J. Forest. and Crop improve*.5**(2):**30-36.

Nain S., B. S. Beniwal, R. P. S. Dalal and S. Sheoran. 2017.Effect of pinching and spacing on growth, flowering and yield of African marigold (*Tagetes erecta*L.) under semi-arid conditions of Haryana. *Journal of Applied and Natural Science.* **9 (4):** 2073 -2078.

Niranjan R, S. Saravanan, M. Shabi and A. N. Bander. 2018. Effect of different plant spacing and planting depth on growth and flower yield of Gladiolus (*Gladiolus grandiflorus* L.).*International Journal of Chemical Studies*.6(4): 3074-3078.

Özdemir, C., M. Mustafa Özkan and A. Kandemir. 2010. The morphological and anatomical properties of *gypsophila lepidio ides*boiss (caryophyllaceae) endemic to Turkey. *Int. Res. J. Plant Sci*. **1(4):** 069-074.

Page, A.L., R.H. Miller and D.R. Keeney (Eds.). 1982. Agronomy Series 9 ASA, SSSA. *Methods of Soil Analysis* (Part 2, 2nd ed., pp. 403-427). *Am. Soc. of Agron*., Madison, USA.

Pavlović D., B. Nikolić, S. Đurović, H. Waisi, A. Anđelković and D. Marisavljević. 2014.Chlorophyll as a measure of plant health: Agroecological aspects.Pestic. Phytomed. (Belgrade).**29(1):**21-34.

Poornima, S., P.M. Munikrishnappa, G.K. Seetharamu, R. Kumar, A. Taj, A. Kumar and M. Kumar. 2021.Effect of spacing and growing conditions on growth and quality of Gypsophila (*Gypsophila paniculata*L.) cut flower. *The Pharma Innovation Journal*. **10(8):** 1255-1258.

Quddus,M.A., K.A. Ara, M.A. Siddiky, M.J. Hussain and S.M. Sharifuzzaman. 2021. Fertilizer management of gypsophila (*Gypsophila paniculata*). *Bangladesh J. Agril. Res*.**46(1):** 23-34.

Rafiei, M. 2009. Influence of tillage and plant density on mungbean. *American-Eurasian Journal of Sustainable Agriculture*.**3:**877-80.

Sharma, A.K., S.V.S. Chaudhary and R.S. Bhatia. 2012. Efffect of spacing and pinching on regulation of flower-ing in African marigold under submontane low hill conditions of Himachal Pradesh. *Prog. Agri.* **12(2):** 331-336.

Shil, N.C., M. A. Saleque, M. R. Islam, and M. Jahiruddin. 2016. Soil fertility status of some of the intensive crop growing areas under major agro-ecological zones of Bangladesh.*Bangladesh J. Agril. Res*.**41(4):** 735-757.

Singh, A. K., U. Kumar and A. Kumer. 2015. Effect of planting date and spacing on performance of marigold (*Tageteserecta*Linn.) cv. PUSA NARANGI under North Bihar agro-ecological conditions. *Internat. J. Forestry & Crop Improv.***6 (1):**16-20.

Statistix 10. 1985. An Anlytical Software, Po Box 12185, Tallahassee, FL 32317, Copy right © 1985-2013

Wahome, P.K., T.O. Oseni, M.T. Masarirambi and V.D. Shongwe. 2011. Effects of different hydroponics systems and growing media on the vegetative growth, yield and cut flower quality of gypsophila (*Gypsophila paniculata*L.). *World J. Agr. Sci.*7(6): 692-698.

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EFFECT OF MANAGEMENT PRACTICES ON THE YIELD AND QUALITY OF MURTA PLANT (*Schumannianthus dichotomus*) IN JHALAKATI

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Abstract

The experiment was conducted at farmers' field of Kamdebpur village under Nalchity upazila of Jhalakati district of Bangladesh during 2019-2020 and 2020-2021 to develop suitable management package for increasing the yield and quality of murta. The treatments comprised of five management practices on existing murta plants viz., T_1 = Fertilizers (Inorganic + organic, 70-32-40 kg/ha N-P-K, respectively and compost 3 t /ha) + Pesticides application (on rhizome and plant parts) + Pruning (extra tillers and cleaning of dead plant parts), T_2 = Fertilizers (inorganic + organic) + Pruning, T_3 = Pesticides (insecticide + fungicide) + Pruning, T_4 = Pruning and T_5 = Farmers' practice (without management). The experiment was set up on 10 years old existing mutra plant. The experiment was laid out in randomized complete block design with three replications. Plant height, doga height, doga diameter, single doga weight, fresh doga yield and rating of doga quality varied significantly due to different management practices. The maximum fresh doga yield (32.37 t/ha) was found in T_1 treatment and it was statistically identical to that of T_2 treatment (26.66 t/ha). In terms of rating of doga quality (considering length, colour and strength of murta cane), treatment T_1 showed the highest quality (2.33) and it was at par to that of T_2 and T_3 treatments (3.33). The farmers' practice showed the lowest quality doga (4.67), which was similar to that of T_4 treatment (4.00). The results further revealed that treatment T_1 increased the doga yield of 68.35% over the farmers' practice. However, yield of doga for treatments T_2, T_3 and T_4 treatments were 38.64, 31.38 and 14.97% higher over farmers' practice, respectively. In terms of cost and return, treatment T_1 gave the highest gross margin (Tk. 98765/ha), it was slightly reduced in T_2 and T_3 treatments (Tk. 67663 and 66086/ha, respectively). Improved agronomic practices enhanced the growth and quality of murta stem. Considering the stem (doga) yield, quality and economic return, fertilizers (Inorganic + organic, 70-32-40 kg/ha N-P-K, respectively and compost 3 t /ha) + Pesticides application (on rhizome and plant parts) + Pruning (extra tillers and cleaning of dead plant parts) would recommended for murta cultivation in Jhalakati.

Keywords: Murta, management practices, stem yield, cane quality.

Introduction

The herbaceous plant from which shitalpati is made is called "murta" plant (*Schumannianthus dichotomus* L.). Murta is a shrub and perennial plant under the

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family of Marantaceae. Depending on the growing region, murta plant is also called as *paitra, mustaq, patibet, patipata, muktagach, patigacha, murtha, ratagacha, patijong, shitalpati* plant etc. The murta plants are usually grown in the low-lying and wetland areas of Sylhet, Sunamganj, Moulvibazar, Habiganj, Chattogram, Noakhali, Feni, Lakshmipur, Chandpur, Cumilla, Brahmanbaria, Barishal, Jhalokati, Pirojpur, Jashore, Munshiganj, Narsingdi, Tangail, Mymensingh, Natore, Sirajganj districts of Bangladesh since hundreds years ago. The stripe, collected from culm of the *Murta* plant is used for weaving the bed mat, which is traditionally known as s*hitalpati*. Once planted, good yields are obtained for about forty consecutive years (Chowdhury *et al*., 2007). However, research information on murta cultivation is very scanty in Bangladesh and abroad. It was reported that the average annual revenue of the Bangladesh government from the sale of murta is about five thousand US dollar during the period of 1981-91 (Banik, 2001). Murta can be easily grown on fallow lands around houses, ditches, canal, beels or ponds where the lands remain wet or damp (Alam, 2007). Murta plant can tolerate salinity and waterlogging. Due to its wide adaptability, the plant can be easily cultivated on any land up and down (Ahmed *et al*., 2007). This plant prevents soil erosion and the decaying leaves of the plant mix with the soil add organic matter and increase fertility of the soil. Murta plant flowers in March-April and fruit/seed matures in June-July (Merry *et al*., 1997). Murta plant can grow up to 3-5 meters in length. The main part of this plant for making mat is the long stem without node which tends to get shorter as the plant grows older (Mia *et al*., 2018). Plants are usually harvested twice in a year and the harvesting continues for about 40 years. The farmers of Jhalakati district have been practicing '*shitalpati*' weaving since about 500 years. The mat is used by people all over Bangladesh as a sitting mat, bedspread or prayer mat. Traditional art of *shitalpati* weaving of Sylhet has been included in The United Nations Educational, Scientific and Cultural Organization (UNESCO)'s Representative List of the Intangible Cultural Heritage (ICH) of Humanity in 2017 (*Annon.*, 2017). Moreover, *shitalpati* carries a glorious history for Bangladesh. *Shitalpati* of Sylhet was used to decorate the palace of British Queen Victoria (BSCIC, 2018). Both men and women participate in collecting and processing murta, where women being more involved in the weaving process. Moreover, *murta* has wonderful adaptation capacity to marshy land facilitating production in the waterlogged area and play a significant role in soil erosion control (Ahmed *et al*., 2007). The farmers in Jhalakati region generally do not apply any management practices for murta plant cultivation regarding nutrient management, weeding, pruning of extra tillers and cleaning of dead plant parts, insect-pest and disease management etc. That is why the yield and quality of murta plant products (stem or *doga, beti* etc.) are not satisfactory. Continuous harvesting of murta plants for 10 or more years leads to decrease in culm length. Recurrent harvesting of *murta* leads to nutrient imbalance and consequently the yield is reduced in the aged plantations. Limitations of nitrogen and phosphorus caused culm shortness in murta (Mia *et al*., 2018). It is possible that nutritional imbalance or deficiency, either singly or combined, might be responsible for culm shortness (Harpole *et al*., 2011). However, research on *murta* cultivation is very scanty in the country. In these circumstances, the experiment was designed to develop suitable management package for increasing the yield and quality of murta stem/doga.

Materials and Methods

The experiment was conducted at farmers' field of Kamdebpur village under Nalchity upazila of Jhalakati district of Bangladesh during 2019-2020 and 2020-2021 to develop suitable management package for increasing the yield and quality of murta stem. The experimental site is situated in the latitudes and longitudes of 22º33/31.518//N and 90º15/38.4618//E. The experimental site is located under the agro-ecological zone Ganges Tidal Floodplain (AEZ 13). The soil type was medium low land with siltly-clay texture in soil. The treatments of the experiment were five management practices on existing murta plants viz., T_1 = Plant nutrients (inorganic + organic, @ 70-32-40 kg/ha N-P-K, respectively and compost 3 t /ha) [Mia *et al*., 2018] + Pesticides application (on rhizome and plant parts) + Pruning (extra tillers and cleaning of dead plant parts like branch, leaf etc.), T_2 = Plant nutrients (inorganic + organic) + Pruning, T_3 = Pesticides (insecticide + fungicide) + Pruning, T_4 = Pruning and T_5 = Farmers' practice (without management). Pesticides like Autostin 50WDG and Proclaim 5 SG were used as per recommended doses in this experiment. The experiment was set up at farmers on 10 years old existing murta plant. The experiment was laid out in randomized complete block design with three replications. Unit plot size was 4.5 m × 3 m. The experimental plots were fertilized as per the treatment specifications. Before setting up the experiment, the initial soil sample was collected for chemical analysis in the laboratory for determining the available plant nutrients. The collected soil sample was analyzed in the Regional Laboratory of Soil Resource Development Institute (SRDI), Barishal and analytical results were given below:

Table 1. Analytical results of the soil sample (2019-2020)

Soil pH	Salinity (dS/m)	Organic matter (%)	Nitrogen (%)	Potassium (meq /100g soil	Phosphorus (µg/g soil)	Sulphur (µg/g soil)	Boron (ppm)	Zinc (ppm)
7.40	0.71	0.82	0.012	0.15	17.12	2.13	0.51	1.01

The samples of murta plant were also collected randomly and sent to the Soil Science Laboratory of Bangladesh Agricultural Research Institute (BARI), Gazipur for determining nutrient status. Analytical results have been presented in Table 2. The murta crop (stem/doga) was harvested in the month of January in 2020 and 2021. Data were collected on different parameters such as plant height, number of stem (doga)/m^2, doga height, doga diameter, single doga weight, doga weight/plot and rating of doga quality. The plot wise doga weights were then converted into ton/hectare. The quality of harvested doga (considering length, colour and strength of murta cane) was rated based on 1-7 scale, where 1 = Excellent quality, 2 = Very good, 3 = Good, 4 = Moderate, 5 = Poor, 6 = Very poor, and 7 = Not useable/worst quality. Besides, the existing local market prices of product and by-product were collected for making economic analysis for murta cultivation. Data were analyzed through Statistix10 computer software and the mean differences were adjudged with Duncan's Multiple Range Test (DMRT) following Gomez and Gomez (1984).

Table 2. Analytical data of murta sample (2019-2020)

Sample name	Ca	Mg	K	P	S	Cu	Fe	Mn	Zn	B
	%					ppm				
Peet	0.43	0.23	0.60	0.17	0.39	6.88	190.86	85.59	10.52	23
Ati	0.37	0.20	0.57	0.11	0.29	7.23	168.90	75.74	14.77	37
Chota	0.24	0.13	0.58	0.18	0.39	7.29	245.46	100.07	15.51	17
Buka	0.74	0.39	1.33	0.64	0.69	9.30	263.40	118.12	111.63	16
Whole plant	2.07	1.09	1.12	0.28	0.48	7.72	1977.00	886.55	44.60	44

Source: Soil Science Laboratory, BARI, Gazipur

Plant samples: Peet = Upper green part of murta stem, Ati = Lower part of peet, Chhota = Lower layer of ati, Buka = Inner soft pith, Whole plant = Peet, ati, chota and buka

Results and Discussion

Effect of management practices on yield of murta

The plant height, doga height, doga diameter, single doga weight, fresh doga yield and rating of doga quality varied significantly due to different management practices as imposed on murta plant (Table 2). In 2019-2020 (Y_1), treatment T_1 gave the tallest plant (385 cm), which was statistically similar to that of T_3, T_2 and T_4 gave statistically similar heights (360, 345 and 320 cm, respectively) but treatment T_5 produced the shortest plant (244 cm). Likewise, the longest plant (387 cm) was also obtained from found achieved from T_1 treatment in Y_2 (2020-2021). Statistically identical results were also found in T_3 and T_2 (385 and 360 cm, respectively). In average of two years, treatment T_1 produced the tallest plant (386 cm), which was statistically similar to that of T_3 treatment (373 cm) and T_2 treatment (353 cm). The shortest plant (245 cm) was obtained from farmers' practice (without management). The longest doga was found in T_1 (234 cm), which was statistically identical to T_3, T_2 and T_4 treatments (212, 208 and 206 cm, respectively) but the shortest doga (179 cm) was obtained from farmers' practice in Y_2. Average doga height showed the highest (224 cm) in T_1 treatment.

Statistically similar height was also observed in T_3, T_2 and T_4 treatments (213, 209 and 201 cm, respectively). The shortest height of doga (185 cm) was obtained from T_5 treatment. In Y_1, treatment T_1 showed the highest diameter (22.41 mm) of doga that was statistically at par to that of T_2 and T_3 treatments (21.10, 20.69 and 17.41 mm, respectively). In Y_2, treatment T_1 also gave the highest diameter (24.49 mm) of doga, which statistically similar to T_3 (21.79 mm). Treatment T_5 gave the lowest diameter in both the years (16.74 and 17.84 mm in Y_1 and Y_2, respectively). Average diameter showed the highest value (23.45 mm) in T_1 that was statistically similar to that of T_3 (21.24 mm) and T_2 (20.63 mm) treatments. The lowest average diameter (17.29 mm) was found in T_5 treatment. The highest weight of single doga (423 g) was obtained from T_1 treatment in Y_1. Statistically identical results were also found in T_3 (408 g), T_2 (377 g) and T_4 (348 g) treatments. In Y_2, T_1 gave the highest weight of single doga (505 g). In aveage, treatment T_1 produced the highest weight of single doga (464 g). Statistically similar weight was also obtained from T_3 and T_2 treatments (399 and 381 g, respectively). Farmers' practice (T_5) produced the lowest weight of single doga (327 g). In Y_1, treatment T_1 gave the highest fresh yield (30.91 t/ha) of doga that was statistically at par to that of T_2, T_3 and T_4 treatments (25.24, 24.21 and 22.62 t/ha, respectively). Treatment T_1 also gave the highest yield of fresh doga (30.91 t/ha) in Y_1, which was statistically similar to that of T_2 (28.07 t/ha) and T_3 (26.31 t/ha) treatments. Treatment T_5 gave the lowest yield in both the years (19.82 and 18.63 t/ha in Y_1 and Y_2, respectively). In average of two years, doga yield showed the highest (32.37 t/ha) in T_1 treatment and the results was statistically at par to that of T_2 treatment (26.66 t/ha). The lowest yield (19.23 t/ha) was found in farmers' practice (T_5). The results further revealed that treatment T_1 increased the doga yield of 68.35% over the farmers' practice. However, the increased yield of doga for T_2, T_3 and T_4 treatments were 38.64, 31.38%and 14.97%, respectively over the farmers' practice (T_5). Improved management practices like application of balanced fertilizers (inorganic + organic) along with pesticides application on rhizome or plant parts for preventing insect-pest and diseases, pruning of extra tillers and cleaning of dead plant parts produced created favourable environment for vigorous growth of murta plant that produced more number of stem, increased doga height, doga diameter and single doga weight over the farmers' practice. Cumulative effect of these parameters helped in getting higher yield and quality of murta doga. The results are in agreement with the findings of Mia *et al*. (2018) and they noted that a combined limitation of N and P was responsible for culm (stem) shortness and reduced growth in Murta. Combined application of organic and inorganic fertilizers particularly N, P and K increased generation of new plants. It was observed that long and wide diameter of doga is suitable for producing quality cane for shitalpati weaving.

Table 2. Effects of management practices on yield and quality of murta plant at farmers' field of Kamdebpur village, Nalchity, Jhalakati during 2019-2020 and 2020-2021

Treatment	Plant height (cm)			Stem (doga)/ m^2 (no.)			Doga height (cm)		
	Y_1	Y_2	Average	Y_1	Y_2	Average	Y_1	Y_2	Average
T_1	385a	387a	386a	7.21	6.65	6.92	215	234a	224a
T_2	345a	360ab	353ab	6.64	7.31	6.98	210	208ab	209ab
T_3	360a	385a	373a	5.99	6.71	6.35	215	212a	213a
T_4	320a	309bc	314b	6.56	6.22	6.39	197	206ab	201ab
T_5	244b	246c	245c	6.05	5.72	5.89	191	179b	185b
CV (%)	11.05	9.85	11.60	10.81	14.63	9.02	7.99	7.73	10.66
F-test	**	*	*	NS	NS	NS	NS	**	*

Table 2. Contd.

Treatment	Doga diameter (mm)			Single doga weight (g)			Stem (doga) fresh yield (t/ha)			Doga yield increase over control (%)
	Y_1	Y_2	Average	Y_1	Y_2	Average	Y_1	Y_2	Average	
T_1	22.41a	24.49a	23.45a	423a	505a	464a	30.91a	33.82a	32.37a	68.35
T_2	21.10a	20.17bc	20.63ab	377ab	385b	381ab	25.24ab	28.07ab	26.66ab	38.64
T_3	20.69a	21.79ab	21.24a	408ab	391b	399ab	24.21ab	26.31ab	25.26bc	31.38
T_4	17.41b	18.72bc	18.06bc	348ab	344b	346b	22.62ab	21.59b	22.10bc	14.97
T_5	16.74b	17.84c	17.29c	330b	325b	327b	19.82b	18.63b	19.23c	-
CV (%)	7.12	10.13	8.22	12.27	14.59	11.65	21.19	23.44	14.25	-
F-test	**	**	*	*	**	*	*	**	*	-

Note: Y_1 = Year 2019-2020 and Y_2 = Year 2020-2021

* and ** Significant at 5% and 1% level of probability, respectively; NS = Not significant

Management practices: T_1 = Fertilizer + Pesticide + Pruning; T_2 = Fertilizer + Pruning; T_3 = Pesticide + Pruning; T_4 = Pruning and T_5 = Farmers' practice

Effect of management practices on the quality of murta

Stem or doga quality (based on length, colour and strength of murta cane) varied significantly because of different management practices (Table 3). Treatment T_1 showed the highest quality (2.33) and it was at par to that of T_2 and T_3 treatments (3.33). The farmers' practice showed the lowest quality doga (4.67), which was similar to that of T_4 treatment (4.00). Application of improve management practices, enhanced the growth of murta plant that produced higher yield and improved quality of murta stem. It can be noted that longer and wide diameter of doga is more suitable for making good quality murta cane. Attractive natural colour and good strength of murta cane are also considered for weaving quality shitalpati. Long cane of murta stem is used for weaving big size of shitalpati without making any joint of the cane with one another. Demand and price of the unjointed shotalpati is comparatively high to the end user as well as in the local market.

Table 3. Effect of management practices on the quality of murta (2020-2021)

Treatment	Rating of murta (cane quality)			
	Length	Colour	Strength	Average
T_1	2.00	2.00	3.00	2.33c
T_2	3.00	3.00	4.00	3.33bc
T_3	3.00	3.00	4.00	3.33bc
T_4	4.00	5.00	3.00	4.00ab
T_5	6.00	5.00	3.00	4.67a
CV (%)	-	-	-	12.33
F-test	-	-	-	*

Note: * Significant at 5% level of probability

Rating of doga quality: 1 = Excellent, 2 = Very good, 3 = Good, 4 = Moderate, 5 = Poor, 6 = Very poor, and 7 = Not useable/worst quality

Economic return from different management practices of murta

The economic analysis was done based on the local market price of the product and by-product of murta plant. Economic analysis results revealed that gross return obtained from treatment T_1 was the highest (Tk. 173465/ha), while T_2 gave the return of Tk. 124863/ha (Table 3). Treatment T_3 and T_4 showed the gross returns of Tk. 118586 and 74647/ha, respectively. The lowest gross return (Tk. 61057/ha) was found in T_5 (farmers' practice). Similar trend was also observed in case of gross margin. Treatment T_1 showed the highest gross margin (Tk. 98765/ha). However, comparatively reduced gross margins were achieved from T_2 and T_3 treatments (Tk. 67663 and 66086/ha, respectively). On the other hand, the lowest gross margin (Tk. 31057/ha) was computed in T_5 treatment. The highest value of BCR (2.32) was computed in T_1, while the values in T_3, T_2 and T_4 were 2.26, 2.18 and 2.13, respectively. The farmers' practice showed the lowest value of BCR (2.04). Considering the stem (doga) yield, quality and economic return, treatment $T_{1=}$ Fertilizers (Inorganic + organic, 70-32-40 kg/ha N-P-K, respectively and compost 3 t /ha) + Pesticides application (on rhizome and plant parts) + Pruning (extra tillers and cleaning of dead plant parts) can be applied for murta cultivation in Jhalakati.

Table 3. Economic return from different management practices of murta (average of 2 years)

Treatment	Stem (doga) yield (t/ha)	By-product yield (t/ha)	Gross return (Tk/ha)	Total variable cost (Tk/ha)	Gross margin (Tk/ha)	Benefit cost ratio (BCR)
T_1	32.37	10.32	173465	74700	98765	2.32
T_2	26.66	9.83	124863	57200	67663	2.18
T_3	25.26	9.84	118586	52500	66086	2.26
T_4	22.10	7.83	74647	35000	39647	2.13
T_5	19.23	6.76	61057	30000	31057	2.04

Local market price of murta product: Stem (doga) for T_1 Tk. 5200, T_2 Tk. 4500, T_3 Tk. 4500, T_4 Tk. 3200 and T_5 Tk. 3000/t; By-product (dried stem as cooking fuel) price: Tk. 500/t

Conclusion

From two years study it might be concluded that application of inorganic and organic fertilizers @ 70-32-40 kg/ha N-P-K, respectively and compost 3 t /ha along with pesticide application on rhizome and plant parts and pruning (extra tillers and cleaning of dead plant parts like branch, leaf etc.) would be recommended in cultivating murta for achieving higher yield, quality and economic return of murta stem or doga.

References

Ahmed, R., A. N. M. F. Islam, M. Rahman and M. A. Halim. 2007. Management and economic value of *Schumannianthus dichotoma* in rural homesteads in the Sylhet region of Bangladesh. *Intl. J. Biodiversity. Sci. & Manage*. **3-4:** 252-258.

Alam, M. J., 2007. *Cultivation of Patipata and its use in Bangladesh (Bengali)*. Krishikotha, Agricultural Information Service, Dhaka, Bangladesh. pp. 359-360.

Annonymous. The *Daily Star, National Newspaper of Bangladesh,* December 7, 2017.

Banik, R. L. 2001. *Economic importance and future of Rattan and Patipata in Bangladesh*. In: Propagation and Cultivation of Rattan and Patipata in Bangladesh. Roshetko JM, Bose SK (eds). Proceeding of training courses held at the Bangladesh Forest Research Institute (BFRI), Chittagong, Bangladesh, pp. 25–28.

BSCIC (Bangladesh Small and Cottage Industries Corporation). 2018. Glory of Upazila, Balagonj, Sylhet, Bangladesh.

Chowdhury, M. S. H., M. S. Uddin, F. Haque, N. Muhammed and M. Koike. 2007. Indigenous Management of Patipata (*Schumannianthus dichotoma*) plantation in the rural homesteads of Bangladesh. *J. Subtrop. Agric. Res. and Dev.* **5**(1): 202–7.

Gomez, K.A. and A.A. Gomez. 1984. *Statistical Procedure for Agricultural Research*. John Willy and Sons. New York. 680 p.

Harpole, W. S., J. T. Ngai, E. E. Cleland, E. W. Seabloom, E. T. Borer, M. E. S. Bracken, J. J. Elser, D. S. Gruner, H. Hillebrand, J. B. Shurin and J. E. Smith. 2011. Nutrient co-limitation of primary producer communities. *Ecology Letter,* **14:** 852–862.

Merry, S. R., R. Ara and N. A. Siddiqi. 1997. Raising Seedlings of Patipata. *Bangladesh J. of Forest Sci*. **26**(1): 74-75.

Mia, S., E. Mustafa, M. M. Hasan, M. A. Kayum, N. U. Ahmed and M. H. Or-Rashid 2018. Co-limitation of nitrogen and phosphorus causes culm shortness in the aged *Murta* plantation, *Intl. J. of Innov. Res.* **3**(3): 94–99.

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SURVEY, IDENTIFICATION AND MANAGEMENT OF MAJOR DISEASES OF LATKAN IN SOME SELECTED AREAS OF BANGLADESH

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Abstract

Latkan (*Baccaurea* sp.), an underutilized minor fruit has drawn popularity because of its nutritional value in Bangladesh. Its cultivation, therefore, is gaining momentum . So, a survey on the health status and prevalence of diseases on Latkan was carried out at Shibpur upazilla of Narsingdi and Valuka upazilla of Mymensingh district during the cropping season 2019-2020. Growers of Latkan in the two Upazillas were interviewed to know about the occurrence of diseases of latkan and their management. Infected leaves, twigs and fruits were collected, and the pathogens were isolated and identified in the Plant Pathology Laboratory of BARI, Gazipur. Three diseases were identified viz. (i) gray leaf blight caused by *Pestalotiopsis* sp., (ii) die-back caused by *Diplodia* sp. and (iii) anthracnose caused by *Colletotrichum* sp. The prevalence of the diseases varied for location, age of the orchards and type of the disease. Anthracnose predominated in the old orchards compare to gray leaf blight and die-back. Field experiment was conducted for chemical management of anthracnose indicated that Tilt (Propiconazole @ 0.5ml/L) and Autostin (Carbendazim @ 1g/L) were effective measures to control the disease.

Keywords: Latkan, survey, disease, management.

Introduction

Latkan or Burmese grape (*Baccaurea*sp.) is one of the most popular and commercially important minor fruit crops of Bangladesh. It is evergreen, slow growing, dioecious, short to medium height, shade loving plant species with enormous nutritional value belonging to Euphorbiaceae family. The tree shows a good example for the fruits which grows directly from the main trunk (Hagens, 2000). It is an important unexploited fruit plant native to tropical and subtropical Southeast Asian region, which grows as wild as well as under farming, mainly in Nepal, India, Myanmar, Bangladesh, South China, Indochina, Thailand, Malaysia, Srilanka and some regions of Indonesia (Morton, 1987; Maniruzzaman, 1988; Subhadrabandhu, 2001). In recent time, latkan is commercially cultivated in some part of Bangladesh and has become popular among the people because of its excellent taste, vitamin and market value. It is a mild acidic fruit and mainly consumed as fresh.

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Among underutilized fruit crops, burmese grape is becoming a very potential fruit crop grown mostly in homestead condition in the region of Narsingdi, Mymensingh, Gazipur, Tangail, Sylhet, Dhaka, Chittagong hill tracts (Bhowmick, 2010). It flowers during summer month and fruits are matured during rainy season. Latkans have various uses such as seeds as dyeing agent (Raghavan and Ramjan, 2018), leaves, fruits, seeds, and stem bark for varied therapeutic potential the fruit as antiviral and antioxidant source and the stem bark of the plant was reported to have diuretic activity (Hasan *et al.,* 2009). It contains potassium twice as much as in bananas. So, the health benefits of latkan are significant. However, there are some diseases generally that affect the latkan such as- Anthracnose (*Colletotrichum* sp.), Leaf blight, Bacterial leaf spot, Black rot (*Guignardia bidwellii*), Scab (*Venturia inaequalis*), Mould rot (*Botrytis cinerea*), Foot rot (*Cylindrocarpon* sp.) and Dieback which threaten latkan production as well as income of the farmers (Karim *et al.*, 2010 and Hasan *et al.*, 2009). Hence, a keen observation on latkan is essential for generating details information on disease status and their management. Therefore, the present investigation was designed to assess the diseases of latkan and to find out the proper control measure of major diseases of latkan.

Materials and Methods

The field survey programs were conducted in two upazilla namely Shibpur of Narsingdi and Valuka of Mymensingh district during the cropping season 2019-2020. In each upazilla, 10 different latkan fruit orchards were surveyed and samples were collected based on visual symptoms. The symptoms of the disease were recorded according to description of Amador (2002), Ferguson (2002) and Reddy and Murthi (1990). Identification of all the fungal diseases was finally confirmed by isolation and identification of the associated fungal organism. Mass group of farmer's interaction was taken to know the detail scenario about the diseases of latkan by using questionnaire on disease problems, age of garden, intercultural operations, and management practices adopted by the latkan farmers.

Infected fruits as well as diseased plants parts of latkan were collected from the survey area and brought into the Plant Pathology Laboratory, Bangladesh Agricultural Research Institute for isolation and identification of causal organism. Pieces of the diseased sample of latkan were sterilized in 10% chlorox for 2-3 minutes, followed by several rinses with sterile distilled water. The samples were then placed separately on the blotter paper, water agar and potato dextrose agar (PDA) Petri plates and incubated at 25±1^{o}C for 5-12 days. After incubation, the vegetative and reproductive structures of fungi grew out of the inocula were examined under stereo as well as compound microscope. To prove that Koch's postulates were true, pathogenicity test was conducted on symptomless leaves and fruits of latkan.

An experiment with four different fungicides was conducted under natural infection condition in the established orchard of Horticulture Research Center, BARI, Gazipur during 2020-21for the management of anthracnose disease of latkan. The experiment was laid out in randomized complete block design with 3 replications. Each plant was considered as a replication. The treatments were T_1 = Autostin(Carbendazim) @1g/L, T_2 = Secure (Fenamidone + Mancozeb 600WG) @ 2g/L water, T_3 =Dithane M-45 (Mancozeb80%) @ 2g/L water, T_4 = Tilt (Propiconazole) @ 0.5ml/L water, and T_5 = Control. The spraying was started with the initiation of anthracnose disease on the latkan plants and a total of three sprays were done at an interval of 10-12 days. Data were recorded on the incidence of fruit rot disease of latkan and the percent data were transformed and analyzed statistically using 'R' program and the means were separated by least significance difference (LSD) test.

Results and Discussion

Outcome of questionnaire: Farmer's interaction by using questionnaire was the basis of details information on latkan cultivation and their disease management. The response of 50 latkan growers of Shibpur of Narsingdi and Valuka of Mymensingh districts respectively possessing 9-10 years old orchard were almost similar (Table 1). They rarely practiced disease management of latkan though there were fruit dropping and twig dying.

Table 1. Outcome of the questionnaire from both Narsingdi and Mymensingh districts

Parameters	Survey results of Shibpur, Narsingdi	Survey results of Valuka, Mymensingh
Number of farmers interviewed	50	50
Major diseases of latkan	Not specific, claims for fruit dropping, twig dying and fruit rot	Not specific, only claim for fruit dropping due to drought and dieback
Age of garden	Most of the gardens average age 10-11 years	Most of the gardens average age 8-9 years
Intercultural operation	Not practiced regularly	Not practiced regularly
Management option	Practice but little	Rarely practice

Isolation and Identification of the pathogens: From the survey area, three different diseases were identified from latkan fruit, leaves and twigs of the collected samples. The diseases were (i) Gray leaf blight (ii) Die-back and (iii) Anthracnose. Based on disease symptoms and morphological characteristics of the pathogens viz. mycelium coloration or pigmentation, presence or absence of septa, spore morphology etc., the diseases and pathogens were identified as gray leaf blight (*Pestalotiopsis* sp.), die-back (*Diplodia* sp.) and anthracnose (*Colletotrichum* sp.). The symptoms of the diseases recorded were as follows.

Gray leaf blight (*Pestalotiopsis* sp.): The symptoms started from tip of the leaf as light brown to dark brown necrosis that advanced towards both the margins of the leaf leading to complete necrosis of the affected leaves that dried up subsequently. Death of leaves on new shoots and a foliar blight were also observed. Some of the affected leaves showed sun scorched symptom.

Fig. 1. Leaf blight symptoms

Fig. 2. Conidia of *Pestalotiopsis* sp.

Die-back (*Diplodia* sp.): Die-back was characterized by progressive dying of twigs, and branches, starting at the tips that usually caused slower development and hindered uniformity throughout the crown. The tree in the dieback stage, however, showed localized symptoms such as apparently healthy twigs and branches adjacent to dead or dying twigs and branches that initiated at the top of a plant and progressed downward.

Fig. 3. Dieback symptoms

Fig. 4. Conidia of *Diplodia* sp.

Anthracnose (*Colletotrichum* sp.): Fruit infections were characterized by dark, brown to black, water-soaked spots or sunken lesions on green and ripe fruit that covered with spore masses. Large circular brown spots were formed around the damaged or punctured skin of the fruit. The spots darkened with age and centre started sunken with dark brown margins. In severe cases, the spots were eventually developed cankers on twigs and stems.

Fig. 5. Anthracnose symptoms

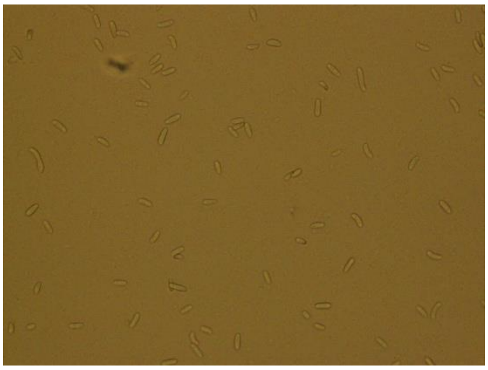

Fig. 6. Conidia of *Colletotrichum* sp.

Disease severity in Shibpur of Narsingdi district

The prevalence of diseases of latkan in Shibpur upazila of Narsingdi district was more in the old orchards as compared to that in the new orchards (Table 2). From the survey, it was found that (4%) and (15%) plants were infected with *Pestalotiopsis* sp. in new and old orchards, respectively. Similarly, only (5%) latkan plants of new orchards showed die-back disease symptom while (23%) infection was found in old orchards. On the other hand, the prevalence of anthracnose disease was lower (12%) in new orchards while (27%) in old orchards (Table2).

Table 2. Disease severity of latkan plant in Shibpur of Narshingdi district

Name of the disease	Causal organism	Percent Infection	
		New orchards	Old orchards
Gray leaf blight	*Pestalotiopsis* sp.	04	15
Die-back	*Diplodia* sp.	05	23
Anthracnose	*Colletotrichum* sp.	12	27

Disease severity in Valuka of Mymensingh district

The incidence of latkan diseases was higher in the old orchards of Valuka upazila under Mymensingh district in general (Table 3). From the survey it was found that (3%) plants of latkan in new orchards were infected with *Pestalotiopsis* sp. while (9%) infection was observed in the old orchards. Die-back disease prevalence was

(5%) and (14%) in new and old orchards, respectively. The incidence of anthracnose disease was higher (20%) in old orchards and lower (10%) in new orchards of Valuka upazila under Mymensingh district (Table 3).

Table 3. Disease severity of latkan plant in Valuka of Mymensingh district

Name of the disease	Causal organism	Percent Infection	
		New orchards	Old orchards
Gray leaf blight	*Pestalotiopsis* sp.	03	09
Die-back	*Diplodia* sp.	05	14
Anthracnose	*Colletotrichum* sp.	10	20

Efficacy of fungicides against anthracnose disease of latkan

The incidence of anthracnose disease of latkan was significantly (p = 0.05%) reduced by all the tested fungicides compared to control (Table 4). Among the fungicides, Tilt 250EC (Propiconazole) showed the lowest anthracnose disease incidence (4.67%) followed by Autostin (Carbendazim) treatment where the anthracnose disease incidence was (6.67%) (Table 4). The fungicides Secure (Fenamidone + Mancozeb 600WG) and Dithane M-45 (Mancozeb 80%) also gave significantly lower anthracnose disease incidence of (9.33%) and (9.67%), respectively. The highest anthracnose disease incidence of (37.67%) was recorded from the unsprayed control treatment. The maximum reduction (87.60%) of anthracnose disease incidence of latkan was recorded in case of Tilt 250EC (Propiconazole) followed by Autostin (Carbendazim) treatment where the reduction of anthracnose disease incidence was (82.29%) compared to unsprayed control. Besides, the fungicides Secure (Fenamidone + Mancozeb 600WG) and Dithane M-45 (Mancozeb 80%) reduced the anthracnose disease of latkan over control by (75.23%) and (74.33%), respectively (Table 4).

Table 4. Effect of fungicides on the incidence of anthracnose disease of latkan

Treatments	Anthracnose disease incidence (%)	Disease decreased over control (%)
T_1= Autostin (Carbendazim)	6.67 c(14.93)	82.29
T_2= Secure (Fenamidone + Mancozeb600WG)	9.33 b(17.75)	75.23
T_3= Dithane M-45 (Mancozeb 80%)	9.67 b(18.10)	74.33
T_4 = Tilt (Propiconazole)	4.67 d(12.47)	87.60
T_5= Control	37.67 a(37.85)	-
LSD (P = 0.05)	1.845	-

The anthracnose disease (Colletotrichum sp.) was considered as one of the ten most notorious pathogens in the world, causing heavy crop losses worldwide

(Dean *et al.*, 2012). The highest incidence (12% and 27%) in Narsingdi and (10% and 20%) in Mymensingh of anthracnose disease on latkan were observed during the survey. In a similar survey on mango, Onyeani and Amusa (2015) showed that 60% of mango trees surveyed were found to be infected with anthracnose and over 34% of fruits produced on those trees were severely infected with the disease incidence (45.90%) and severity (38.10%) of anthracnose. Anthracnose disease of latkan was a burning issue to the agriculturists as well as latkan farmers and effective control measure was not available in the country. A combination of the different strategies like chemical control, biological control, physical control and intrinsic resistance was recommended for managing the disease (Agrios, 2005). The chemical fungicides generally recommended for controlling anthracnose disease were based on copper compounds, Carbendazim, dithiocarbamates, benzimidazole and triazole compounds (Waller, 1992). Present findings agreed partially with the findings of Leroux and Gredt (1974), Pandey (1988), Oh and Kang (2002) and Everett *et al*. (2005) who found that Carbendazim (Derosal) gave better control of anthracnose disease of fruits caused by *C. gloeosporioides*.

Conclusion

Three different diseases viz. gray leaf blight, die-back and anthracnose diseases were identified from latkan leaves, twigs and fruits plant samples collected from Shibpur of Narsingdi and Valuka of Mymensingh district. Among these diseases anthracnose was predominant in both the locations. The management study revealed that Tilt (Propiconazole) and Autostin (Carbendazim) is found effectively controlled the anthracnose disease of latkan in the orchards.

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References:

Agrios, G. N. 2005. Plant Pathology. 5th Ed. Elsevier Academic Press, California, USA, 922p.

AlamM.S., M. G. Miah and M. K. Hasan 2007. Indigenous Production Technology of Latkan Practiced in Narsindi District, J Agric Rural Dev **5(1&2):** 173-175

Amador, J. M. 2002. Disease affecting localized part of trees. Texas Agricultural Extension Service. **56:** 576-759.

Bhowmick, N. 2010. Some lesser known minor fruits of Northern parts of West Bengal. acta horticulturae, 890. 61–64

Dean R., J. A. L. Van Kan,Z. A. Pretorius,K. E. Hammond-Kosack,A. Di Pietro, and P. D. Spanu. 2012. The Top 10 fungal pathogens in molecular plant pathology. *Mol. Plant Pathol.* 13, 414–430. 10.1111/j.1364-3703.2011.00783.x

Everett, K. R., S. G. Owen and J. G. M. Cutting. 2005. Testing efficacy of fungicides against postharvest pathogens of avocado (*Persea americana*cv. Hass). New Zealand Plant Protection **58:** 89-95.

Ferguson, J. J. 2002. Common pests, Disease and disorders of Dooryard citrus, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

Gogoi, B. 2017. *Baccaurea ramiflora* Lour: biochemical and ethno botanical value with scope for bio-prospection. *Ann. Plant. Sci* **6**(7):1649–1652

Hagens, R. M. A. P. 2000. Taxonomy, Phylogeny and Biogeography of Baccaurea distichiasis and Nothobaccaurea (Euphorbiaceae) *Blumea Supplement* 121-216.

Hasan, S.M., R. Hossain, M. M. Akter, R. Jamila, M. Mazumder, M. E. H. Rahman.2009. SDPPH free radical scavenging activity of some Bangladeshi medicinal plants. Journal of Medicinal Plants Research **3:** 875-879.

Karim, M. M., Arifunnahar, M and T. K. Dey. 2010-11. Bangladesh Agricultural Research Institute, Plant Pathology Research Annual Report. 2011-12: 18-20

Leroux, P. and M. Gredt. 1974. Study of the systemic activity of benomyl, carbendazim, thiophanate methyl and thiophamine, used as seed dressings for various herbaceous plant species. PhytiatriePhytopharmacie **23:** 51-68.

Maniruzzaman, F. M. 1988. *Bangladesh Falerchash (Fruit cultivation in Bangladesh)* (In Bengali). Bangla Academy, Dhaka, Bangladesh. 384p.

Morton, J. 1987. Fruit of warm climates, Miami, Florida, USA.

Nesa M. L, S. S. Karim, K. Api, M. M. R. Sarker, M. M. Islam, A. Kabir, and M. S. Munir. 2018. Screening of *Baccaurea ramiflora* (Lour.) extracts for cytotoxic analgesic anti-infammatory neuropharmacological and antidiarrheal activities. BMC Complement Altern. Med **18(1):**35

Oh, J. H. and N. W. Kang. 2002. Efficacy of fluazinam and iprodione+propineb in the suppression of *Diaporthe phaseolorum, Colletotrichum truncatum* and *Cercospora kikuchii*, the causal agents of seed decay in soybean. *J. Plant Pathol.* **18 (4):** 216-220.

Pal, R. K., N. Bhowmick, and C. P. Suresh. 2008. Latka (*Baccaurea sapida* Muell. Arg.) An under exploited minor fruit crop of West Bengal. Abstracted in 3rd Indian horticulture congress, new R&D initiatives in horticulture for accelerated growth and prosperity (p. 325), 6–9 November 2008 held at QUAT, Bhubaneswar. Organized by Horticultural Society of India

Pandey, R. R. 1988. Effect of foliar application on the phylloplane mycoflora and fungal pathogen of guava. *Ind. J. Phto. path* **123(1):** 52-62.

Raghavan, M., and M. Ramjan. 2018. Burmese grape (*Baccaurea ramiflora* Lour.): a promising fruit crop for future generations. *J. Med. Plant* **6(3):** 50–52.

Reddy,G. S. and V. D. Murthi. 1990. Citrus disease and their control. The Indian Council of Agricultural Research. Pp. 5-50.

Subhadrabandhu, S. 2001. Underutilized Tropical Fruit of Thiland. RAP Publication 2001/26. Bangkok, Thiland.

Waller, J. M. 1992. *Colletotrichum* diseases of perennial and other cash crops, in *Colletotrichum:* Biology, Pathology and Control, eds Bailey J. A., Jeger M. J. (Wallingford: CAB International), 167–186.

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BIOLOGY AND MORPHOMETRICS OF FALL ARMYWORM, *SPODOPTRA FRUGIPERDA* ON MAIZE PLANT

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Abstract

The study was conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh to observe the biology and morphometrics of fall armyworm, *Spodoptra frugiperd* (Lepidoptera: Noctuidae) during winter (December-February) and summer (March-May) seasons. The fall armyworm larvae were collected from the maize field of BARI, Gazipur and SAU research fields. The collected larvae were brought to the laboratory and reared on maize plant at room temperature. The female moths laid eggs in clusters under or upper surface of the maize leaf which were hatched in 4.01 and 2.45 days at winter and summer, respectively. The larvae passed through six instars with the total larval period of 29.17 and 14.80 days, respectively at winter and summer. The pupa took 17.63 days in winter and 9.34 daysin summer for emergence into adult. During winter season the longevity of female and male moths were 15.47 and 13.98 days respectively. But in summer the adult longevity for female and male was 10.03 and 8.19 days, respectively. The male-female sex ratio in winter was 1:1and 1:2 in summer. The total life cycle was completed within 64.79 days (male) and 66.28 days (female) in winter and that was 34.86 days (male) and 36.70 days (female) in summer. Larva was gradually increased in size with instars having a square shaped four black spots on 8th and 9th abdominal segments and Y-shaped line on the frons. The male pupa (16.53 mm) was slightly larger than the female (15.81 mm) with a bit longer distance between genital opening and anal slot. Body length of the adult male measured 13.75 mm and that of the female was 12.77 mm. The percent of survival was maximum at 6thinstar larval stage (94.55 %) and least survival percent was at 1st instar larval stage (79.53%). On the other hand, percent of mortality was maximum at 1stinstar larval stage (20.47%) and least mortality was at 6th instar larval stage (5.45 %).

Keywords: Biology, Morphometrics, Fall Armyworm, *Spodoptra frugiperda*, Maize, *Zia mays.*

Introduction

Maize (*Zea mays* L.) of the family poaceae, is one of the most important worlds' widely grown cereal crops and contributes to food security in most of the developing countries. It has high yield potential, there is no cereal on the earth which has so immense potentiality and that is why it is called "queen of cereals. Maize is the 2nd most important crop in terms of area and production after rice in Bangladesh and in 2020-21 maize was produced 41.16 lakh metric tons from an area of 4.80 lakh hectares with average yield of 8.57 t/ha (Anonymous, 2022).

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Maize is the most important staple cereal crop grown of which, 90% of production is used as food, industrial material and major component of animal feed. The fall armyworm (FAW), *Spodoptera frugiperda* (J.E Smith), is the most important noctuid pest in North and South America and has recently become an invasive pest in Africa (Montezano *et al*., 2018). It has been spread around 38 courtiers till now and in Bangladesh, the caterpillar was first detected on two different crops, cabbage and maize in different districts (Palma, 2020). Fall armyworm larvae can feed on a large number of plant species, including maize, rice, sorghum, millet, sugarcane, vegetable crops and cotton, and can cause significant yield losses.

Fall armyworm is a polyphagous pest and numerous alternative hosts outside the production season of main crops. Larvae feed on the surface of leaves leaving only white papery patches on young maize called window panes. Older larvae consume more tissues, with stronger mandibles, cut large portions of plant tissues with high silica content and includes seedlings, foliage, tassels, cobs, husks, and developing kernels. Yield losses due to FAW in maize crops vary from 22 to 67% in different parts of the world (Day *et al*., 2017).

FAW has several generations per year, whose life cycle consists of egg, six larval instars, pupa, and adult (IITA, 2016). Information about biology and life table parameters of FAW such as survivorships, mortality rates, longevity, fecundity, life expectancy, the population distribution, economic importance, seasonal abundance, host plants, life history are essential for natural, cultural, genetic, and chemical controls of fall armyworm. These vary depending on the different stages in particular hosts and metrological parameter of the country. FAW can migrate long distances on prevailing winds, but it can also reproduce continuously in areas that are climatically suitable (Prasanna *et al.*, 2018). *S. frugiperda* has a high reproductive capability, a relatively short generation time and great disperse ability (Montezano *et al*., 2018) which has raised an extreme awareness against this insect that is threaten for food security. To prevent this enormous invasion, fundamental knowledge of its biology and morphological features are very crucial. However, obtaining that information seems to be complicated and still limited in Bangladesh context. Thus, the aim of this studyis to generate data on the biological and morphological parameters of *S. frugiperda* population growth under laboratory at room temperature-to know the growth and development of different stage of fall armyworm on maize and to determine morphometry at specific growth stage.

Materials and Methods

Collection and rearing of the insects

The study was conducted in the laboratory at ambient weather condition (Table1) in the Department of Entomology, Sher-e-Bangla Agricultural University during December, 2020 to May, 2021.

Infested maize plants (30 days after emergence) was collected from different locations *viz*. BARI research field, SAU research field and farmers field of Kalatia, Keranigonj, Dhaka during growing season (winter and summer). The collected larvae were brought to the laboratory and kept in plastic cages (18 cm height x 25 cm diameter) with sufficient soil for mass rearing. Some larvae were reared until pupation using maize leaves (variety MK 40). Pupae were observed daily until moths emerged. The cages were covered with a fine mesh net to prevent the moths from escaping. The maize leaves and stems were replaced every day and inspected for egg laying. All set-ups were kept under laboratory at room temperature.

Table 1. Monthly average room temperature and relative humidity during study period

Months	Average temperature (^{0}C)	Range	Relative humidity (%)	Range
Winter season				
December / 2020	17.53^{0}C	10^{0}C - 25^{0}C	60.00	57 – 62%
January / 2021	16.72^{0}C	10^{0}C - 25^{0}C	53.13	42 – 64%
February / 2021	18.66^{0}C	10^{0}C - 30^{0}C	45.11	41 – 49%
Summer season				
March / 2021	24.13^{0}C	14^{0}C - 35^{0}C	48.93	42 – 65%
April / 2021	26.80^{0}C	18^{0}C - 34^{0}C	59.10	55 – 63%
May / 2021	26.35^{0}C	20^{0}C - 33^{0}C	68.29	63 – 74%

Biology of fall armyworm

Life cycle of fall armyworm was observed in two seasonal conditions such as winter (December-February) and summer (March-May). An adult male and a female were confined in pair kept in plastic cages (21 cm height x 10 cm diameter). Ten pairs were prepared in this manner. The female moth was laid eggs on maize leaf. They were provided with soaked cotton pads in 10% sugar solution as food source in small plastic caps placed inside the cage and replaced daily. From the progeny of these parental stock, 10 neonates (newly-hatched) larvae were individually transferred to fresh maize leaves and reared in plastic cages (18 cm height x 25 cm diameter) containing moistened filter paper, a fresh maize leaf and required amount of soil until pupation. In each cage, pupae were observed daily until moths emerged. After that adult moth (male and female) were kept into the other plastic cage for further rearing with aforesaid manner to observe the developmental period at different stages of fall armyworm. In this study, eggs collected within 1 hr after oviposition were placed in plastic cages (19 cm height x 18 cm diameter) with moist filter paper maintained at room temperature. There were 4 replications with one egg mass for each cage. The morphological features of the different instars were observed and recorded along with incubation period, development period from the first instar to the sixth instar, pupal period, pre-oviposition period (the time adult female emerged to the time the first mass of eggs is laid), Oviposition period (egg laying period), post oviposition period (the time female stopped laying eggs till death), longevity of male and female adults (the time from adult emergence till their death), fecundity (number of egg-masses and number of eggs per egg-mass laid in the lifetime of adult females), hatchability of eggs and the number of neonates that hatched from all egg-masses laid by a female in her lifetime. All periods of observations were taken in days.

Morphometry of the different life stages

Morphometric measurements of the different life stages such as different instar larvae, pupae and adult length, width and weight were taken. The measurement of3rd, 4th, 5th, and 6thinstar larvae, pupae and adults were measured using a digital Slide Caliper. The measurement of1stand 2ndinstar larval length and width were also taken by using stereomicroscope. The length and width of the larvae was measured as well as the width of the head capsule. The male and female pupae were likewise measured from the tip of the head down to the tip of abdomen and the widest width of the body. Male and female adults were pinned, wings expanded and dried. The wing expansion of the forewings was measured and body length from the tip of the head to the tip of the abdomen was taken. The larvae, pupae and adults were weighted to use an electric balance. The measurement of each stage was done by using ten individuals for each stage.

Adult longevity

The study was conducted as a completely randomized design with 5 replications. Each cage represented one replication. After emergence, the adult male and female were confined separately for an hour and randomly selected and transferred into plastic cage (21 cm height x 18 cm diameter) covered with fine mesh net. Each cage contained 5 adults with soaked cotton pads in 10% sugar solution as food source in small plastic caps placed inside the cage and replaced daily. But in case of unfed condition, no food was provided.

Data Analysis

Data on biological parameters were analyzed by MS office excel 2016 and fed and unfed adults' data were analyzed by the R version 4.1.1 software. Mean separation of treatments was calculated by Fisher's LSD test at 5% level of probability.

Results and discussions

Female moth laid eggs in clusters under or upper surface of the maize leaf, base of the plant, in whorls and lid of plastic cage (Plates 1, 2). Newly laid eggs were pink to greenish grey in colour and become darker with age towards larval eclosion. Fall armyworm eggs were oblate-spheroidal shape, flattened and curve and also clearly marked with ridges. Eggs were covered with greyish scales by the female moth, giving them a downy appearance. Similar report was also reported by (Shylesha *et al*., 2018). On higher magnification, shining reticulated surface could be easily noticed. Incubation period ranged from 3.00–5.00 days with a mean of 4.01 days and ranged from 2.00–3.00 days with a mean of 2.45 days, at winter and summer, respectively (Table 2).

First instar larvae were greenish with a black head, and turned greenish brown in the second instar (Plate 4). The third instar was brownish with three dorsal and lateral white lines beginning to form. Fourth to sixth instar had a reddish-brown head, were mottled with white and the brownish body bears three white dorsal lines and a pale lateral line. Black tubercles were found dorsally on the body which bears spines. The arrangement pattern of black spots was square on 8th and trapezoidal on 9^{th} segment of larva (Plate 5). The frons had a white inverted Y-shaped line (Plate 6). Each larva passed through six distinct instars over a period ranged 24-33 days with a mean 29.17 days and ranged 11-18 days with a mean of 14.80 days (Table 2) observed at winter and summer respectively. Larvae are most active in the early morning and tend to hide themselves during the brightest time of the day. Duration the larval stage tends to be about 14 days in warm weather and 30 days in cool weather (Hardke *et al.* 2015). Sharanabasappa *et al.* (2018) also revealed that larva passed through six distinct instars over a period of 15.9 ± 1.45 days that also supports this result.

At the time of prepupal period the full-grown larva stopped feeding, turned greenish and the bright brown colour. Duration of the pupal period was 1.28 ± 0.28 in winter and 1.06 ± 0.31 days in summer (Plates 7, 8). Similar results were reported by Montezano *et al.* (2019), as they also claimed that the prepupal stage of *S. frugiperda* was completed in 1-3 days on different food diets. Duration of the pupal period was about 17.63 ± 1.65 days (range12.78 - 22.09 days) in winter and 9.34 ± 0.99 days (range 8.00 to 11.00 days) in summer (Table 2).The pupal period ranges between 8 - 9 days in summer and 20 - 30 days in winter was also reported by other researcher which is supported the present study. The distance between genital opening and anal slot was greater in female than the male (Plate 9, 10) which can be used to identify the female and male pupa of fall armyworm.


Plate 1. Egg mass


Plate 2. Egg mass (after 24h old)


Plate 3. Newly hatch larvae


Plate 4.1st to 6th instar larvae


Figure 5. 6th instar larva


Figure 6. 6thinstar larva

Plate7. Pre pupa

Plate8. Pupa

Plate9. Female Pupa

Plate10. Male Pupa

Plate 11. Male moth

Plate 12. Female moth

Male and Female moths can be identified by the forewing colour and spot. Forewing of male is shaded with gray and brown, with triangular white patch at the apical region and circular spot at the center of the wing (Plate11). These characters are similar as reported earlier by Sharanabasappa *et al.* (2018). The forewings of females are uniform grayish brown to a fine mottling of gray and brown (Plate12) in the present study. Adult hind wing is silver-white with a narrow dark border in both male and female. Pre-oviposition, oviposition and post oviposition period ranged 4-5, 5-8 and 4-5 days, respectively in winter and those ranged from 2-3, 4-5 and 2-3 days, respectively in summer (Table 2). The female adult longevity was 15.47 days with a range of 11-22 days compared to male 13.98 days with a range of 10-21 days in winter. On the other hand, the female adult longevity was 10.03 days with a range of 9-12 days compared to male 8.19 days with a range of 7-10 days in summer. The total life cycle of male and female ranged from 59-73 and 61-73 days, respectively in winter and 31-37 and 33-40 days, respectively in summer (Table 2). Adult male longevity was shorter than that of the female moths. Sharanabasappa *et al.* (2018) reported that the development cycle of *S. frugiperda* male and female takes 37.50 and 40.50 days on average at 27^0 C. This is also slightly slower than the total development period of 66.5 days at 18^0 C and 18.3 days at 35^0 C.

Table 2. Duration (in days) of the different developmental stages of *Spodoptera frugiperda* reared on maize leavesin laboratory at room temperature.

Developmental Stage (Days)	Winter		Summer	
	Mean ± SD	Range	Mean ± SD	Range
Incubation period	4.01 ± 0.79	3.00 – 5.00	2.54 ± 0.44	2.00 – 3.00
Larva				
I inster	4.19 ± 0.75	2.53- 7.00	2.40 ± 0.50	1.19 - 3.14
II inster	4.31 ± 0.77	3.00 - 7.00	2.03 ± 0.67	1.17 - 3.00
III inster	4.47 ± 0.53	4.00 - 6.00	2.13 ± 0.58	1.23 - 3.00
IV inster	4.45 ± 0.51	4.00 - 5.89	1.69 ± 0.53	1.00 - 3.00
V inster	4.98 ± 0.97	4.00 - 7.88	2.58 ± 0.97	1.00 - 4.21
VI inster	5.61 ± 0.99	5.00 - 8.00	2.75 ± 0.68	2.00 - 5.00
Pre-pupa	1.28 ± 0.28	1.00 - 2.00	1.06 ± 0.31	1.00 - 1.97
Total larval period	29.17 ± 0.97	24.00 - 33.00	14.80 ± 0.93	11.00 - 18.00
Pupal period	17.63 ± 1.65	12.78 - 22.09	9.34 ± 0.99	8.00-11.00
Male adult longevity	13.98 ± 2.95	10.00 - 21.00	8.19 ± 0.91	7.00-10.00
Female adult longevity	15.47 ± 2.89	11.00 - 22.00	10.03 ± 0.92	9.00-12.00
Pre oviposition period	4.78 ± 0.43	4.00 – 5.00	2.97 ± 0.46	2.00 – 3.00
Oviposition period	6.51 ± 0.94	5.00 – 8.00	4.61 ± 0.41	4.00 - 5.00
Post oviposition period	4.95 ± 0.13	4.00 - 5.00	2.16 ± 0.38	2.00 – 3.00
Total life cycle (egg-adult) Male	64.79 ± 3.45	59.00 -73.00	34.86 ± 1.61	31.00 - 37.00
Female	66.28 ± 2.79	61.00 -73.00	36.70 ± 1.56	33.00 - 40.00

The female moth laid eggs ranged from 690-819 eggs and 893–1261 eggs in winter and summer respectively (Table 3). The mean number of eggs production was 789.29 ± 33.67 eggs/ female and 1071.08 ± 95.07 eggs/ female in winter and summer, respectively (Table 3). Usually, egg mass covered with a protective, hair-like layer of scales (setae) from the female abdomen. The number of egg masses laid per female ranged from 4-9 egg masses and 6-9 egg masses in winter and summer, respectively. The mean number of eggs/egg mass was recorded as 105.35 ± 14.60 and 121.65 ± 30.96 at winter and summer, respectively. In another study, the eggs of *S. frugiperda* are laid in groups or clusters of 20-350 and total egg production per female average about 1500, with a maximum of over 2000.

Table 3. Number (mean ± SD) of eggs/ female, egg masses/ female, number of eggs/egg mass, % egg hatch number of egg layer/ egg mass and sex ratio of *S. frugiperda* on maize

Different Stages (Number)	Winter		Summer	
	Mean ± SD	Range	Mean ± SD	Range
Number of eggs $female^{-1}$	789.29 ± 33.67	690- 819	1071.08 ±95.07	893 - 1261
Number of egg mass $female^{-1}$	7.13 ± 1.72	4 – 9	8.00 ± 0.92	6 -9
Number of eggs egg $mass^{-1}$	105.35 ± 14.60	46 – 165	121.65 ± 30.96	76 – 201
% Egg hatching	88.51 ± 11.95	65.00 - 96.88	91.63 ± 3.68	80.65 - 99.41
Number of egg layer egg $mass^{-1}$	2.13 ± 0.87	1 – 4	2.20 ± 0.9	1 – 4
Sex ratio (M: F)	1:1		1:2	

Mean percent of egg hatching was 88.51 ± 11.95 and 91.63 ± 3.68 in winter and summer, respectively. The female deposits eggs in egg masses ranged from 1-4 layers both winter and summer (Table 3). Three to four layers of egg in an egg mass was observed in the present study. The sex ratio was observed 1:1(M: F) and 1:2(M: F) in winter and summer, respectively. Ahir *et al*. (2019) observed less male population than female (1:1.30 male and female sex ratio) of the fall armyworm. Environmental factors could have influenced on seasonal variations of male and female sex ratio fall armyworm. Lekha *et al*. (2020) earlier mentioned that biology of fall armyworm was influenced by growing temperature, relative humidity, host, artificial diet.

Life cycle of fall armyworm was observed under two seasonal conditions such as winter (December-February) and summer (March-May). Average temperature was found 17.5^{0}C, 16.7^{0}C and 18.6^{0}C for January, February and March, respectively as well as humidity ranged from 41- 64%. On the other hand, average temperature was 24.1^0, 26.8^{0}C and 26.3^{0}C for March, April and May, respectively and the humidity ranged from 42-74% (Table 1) during this period. Variation of weather parameters might be influenced on the life cycle of fall armyworm. Lekha *et al*. (2020) mentioned that biology of fall armyworm was influenced by temperature, relative humidity, host, artificial diet.

Morphometry of the different life stages

Data on morphometry of different developmental stages of *S. frugiperda* have been demonstrated in Table 4. Width of head capsule as well as body length, width and weight of different instars of larvae were increased with instars. The width of head capsule of the six larval instars were 0.24 mm, 0.36 mm, 0.62 mm, 0.94 mm 1.48 mm and 2.09 mm, respectively in first, second, third, fourth, fifth and sixth instar. The width of head capsules of the larvae was a slowly increased during first, second and third instar and significantly increased during the fourth, fifth and sixth instars. Larval body length was gradually increased with instars. Similarly, width and weight of larvae was markedly increased with instars and the highest width (1.15 mm) and weight (359.02 mg) were observed for sixth instar larva. The average body length of male and female pupae was 16.53 mm and 15.81 mm, respectively (Table 4). Male pupae little bit longer than female pupa. Similar findings were also reported by Marcela and Mario (2020).

Adult male body length was 13.75 mm with a wing expanse of 33.46 mm and body weight was 83.52 mg. Female body length was 12.77 mm with a wing expanse of 34.14 mm and body weight was 75.66 mg. The male was slightly bigger than the female although the general trend in arthropods is that males are smaller. But adult female wing expanse is slightly bigger than the male. These characters are more or less similar as reported earlier (Marcela and Mario,2020), who recorded13.33mm body length with a wing expanse of 32.66mmfor male and body length 12.20 mm with a wing expanse of 32.81 mm for female. Zeeshan (2021) reported that male and female body length was more or less similar (16.3±0.39 mm and 16.52±0.25mm for male and female, respectively) which is different from present study**.**

Table 4. Morphometric measurements (mm) of larval instars, pupae and adults of *Spodoptera frugiperda* reared on maize under laboratory in room temperature

Developmental Stage	Parameter	Mean ± SD	Range
Larva- 1st instar			
Head capsule	Width (mm)	0.24 ± 0.06	0.18 - 0.36
Body	Length (mm)	1.54±0.17	1.11 - 1.73
	Width (mm)	0.24±0.04	0.18 - 0.30
	Weight (mg)	8.28 ±0.39	7.00 - 8.90

Developmental Stage	Parameter	Mean ± SD	Range
2nd instar			
Head capsule	Width (mm)	0.36 ±0.04	0.33 - 0.49
Body	Length (mm)	3.03 ±0.15	2.71 - 3.71
	Width (mm)	0.41±0.03	0.34 - 0.48
	Weight (mg)	19.44 ±0.66	18.30 - 20.40
3rd instar			
Head capsule	Width (mm)	0.62±0.01	0.60 - 0.63
Body	Length (mm)	6.75±0.54	5.75 - 7.90
	Width (mm)	0.85±0.031	0.77 - 0.89
	Weight (mg)	139.39±1.18	136.89 - 141.55
4th instar			
Head capsule	Width (mm)	0.94±0.01	0.92 - 0.95
Body	Length (mm)	14.69±0.53	12.95 - 15.19
	Width (mm)	0.91±0.044	0.84 - 0.99
	Weight (mg)	191.49±2.66	185.89 - 194.71
5th instar			
Head capsule	Width (mm)	1.48±0.04	1.40 - 1.56
Body	Length (mm)	27.84±1.49	25.25 - 30.54
	Width (mm)	1.04±0.06	0.98 - 1.15
Weight (mg)	280.48±2.67	275.88 - 283.92	
6th instar			
Head capsule	Width (mm)	2.09±0.18	1.00 - 2.16
Body	Length (mm)	34.28±1.30	32.27 - 36.79
	Width (mm)	1.15±0.16	0.18 - 1.23
	Weight (mg)	359.02±15.77	322.99 - 378.64
Pupa			
Male	Length (mm)	16.53±0.14	16.25 - 16.75
	Width (mm)	5.02 ± 0.08	4.90 - 5.15
	Weight (mg)	181.441±19.18	170.61 - 250.79
Female	Length (mm)	15.81 ± 0.10	15.65 - 15.95
	Width (mm)	4.92 ± 0.07	4.80 - 5.05

Developmental Stage	Parameter	Mean ± SD	Range
	Weight (mg)	174.16 ± 9.62	167.91- 209.38
Adult			
Male	Length of body (mm)	13.75 ± 0.09	13.59 - 13.88
	Body weight (mg)	83.52 ± 5.25	70.00 - 90.00
	Wing expanse (mm)	33.46 ± 0.45	32.87 - 34.50
Female	Length of body (mm)	12.77 ± 0.05	12.69 - 12.86
	Body weight (mg)	75.66 ± 2.12	72.00 - 79.21
	Wing expanse (mm)	34.14 ± 1.81	28.00 - 39.35

The percent survival and mortality varied at different growth stages of fall armyworm (Figure 1). Figure expressed that, 152 eggs from a single egg mass were fully fresh but number of alive 1st instar larvae were 127 out of 152 that means egg mortality was (16.45%), whereas the percent of mortality was maximum found in (20.47%) 1st instar larva. Minimum percent of mortality (5.45%) was observed at 6thinstar larva then also found 4th and 5th instar larva which were 12.5% and 12.70% respectively. On the other hand, maximum percent of survival was found (94.55%) at6thinstar larval stage and least survival was recorded at 1stinstar larval stage (79.53%).

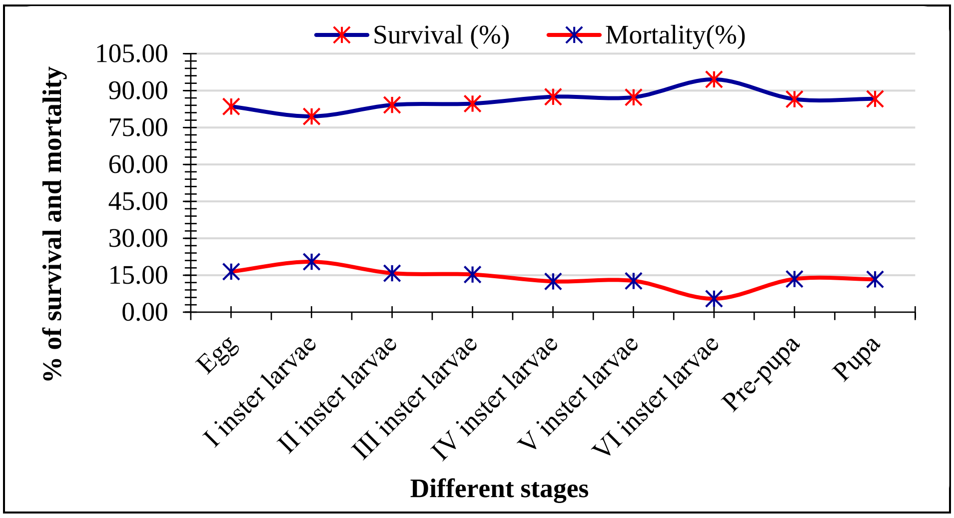

Fig. 1. Different stage-specific percent of survival and mortality of *S. frugiperda* onmaize.

Similar trend of different stage-specific survival and mortality was reported by Ashok *et al*. (2020) with maximum mortality of FAW in the first instar larva and egg stage, whereas mortality reduce in later larval instar with minimum mortality recorded in 6th larval instar. Another results of these studies of FAW conducted by Priyanka *et al*. (2021) under laboratory conditions reveals that the maximum apparent mortality of 33.82% in the 1st larval instar, whereas minimum mortality was recorded in pupae, 4th, 5rd, and 6th larval instars. Unfed adult longevity was much shorterthan fed adult, as shown in (Figure 2). The average longevity of the fed female and male moths was recorded as 16.08 days and 14.12days, respectively and that was4.69 days and 3.95 days, respectively for unfed female and male moths of fall armyworm. Lekha *et al.* (2020) observed an adult male and female longevity of 4.50-8.00 and 7.00-10.33 days on different hosts; while Kalyan *et al*. (2020) observed this as 10.67- 13.00 days.

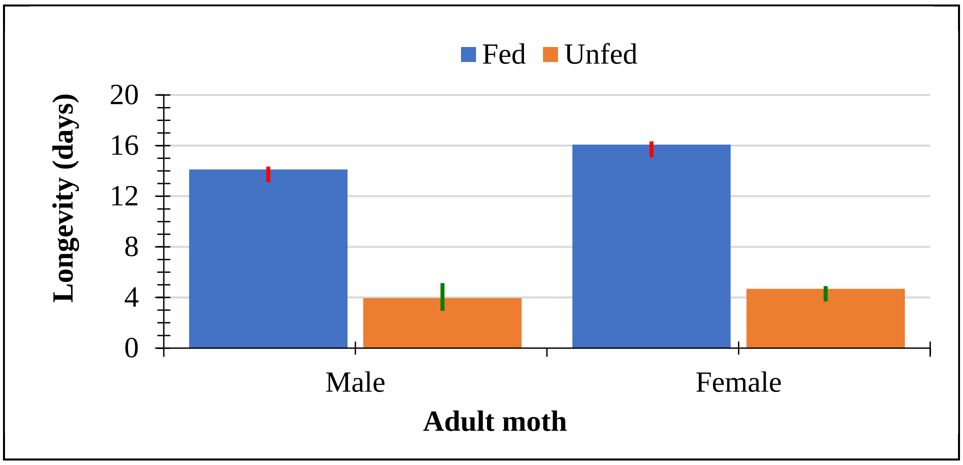

Fig. 2. Longevity (days) of fed and unfed adults of fall armyworm (*Spodoptera frugiperda*).

Conclusion

The results on biology and morphometry of fall armyworms revealed that fall army worm had four stages such as egg larva, pupa and adults in its life cycle. Eggs are laid in cluster which consisted higher number of eggs in summer than winter. The incubation period, duration of different developmental periods and total life cycle were longer in winter than summer. Larva transformed into pupa through six instars and the size of larva was gradually increased with instars. Larva had a white inverted Y-shaped line on frons and a square of black spots on 8th and trapezoidal on 9th segment. Male pupa was slightly bigger than female one with longer distance between genital opening and anal slot. Adult male was also a bit larger than female and adult moths feeding with sugar solution lived more days than unfed moths.

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References

Ahir, K.C., M.K. Mahla, R. Swaminathan and N.L. Dangi. 2020. Biology of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on maize (*Zea mays* L.). *J. Entomol. R*.**44**: 429-432.

Anonymous. 2022. Year Book of Agricultural Statistics. 33rd series. Bangladesh Bureau of statistics (BBS), Ministry of Planning, Govt. of the People’s Republic of Bangladesh. www.bbs.gov.bd. p. 41.

Ashok, K., J.S.Kennedy, V.P. Geethalakshmi, N. Sathiahand V. Balasubramani.2020.Lifetable study of fall army worm *Spodoptera frugiperda* (j. E. Smith) on maize. *Indian J. Entomol.* **82**(3): 574-579.

Day, R., Abrahams, P.Bateman, M.Beale, T.Clottey, V. Cock, M.Colmenarez, Y.Corniani, N.Early, R. Godwin, J. Gomez, J.Moreno, P.G.Murphy, S.T.Oppong-Mensah, B. Phiri, N.Pratt, C.Silvestri and S.Witt. 2017. Fall armyworm: impacts and implications for Africa. *Outlooks Pest Manag.* **28**:196–201.

Hardke, J. T., G. M. Lorenz & B. R. Leonard. 2015. Fall armyworm (Lepidoptera: Noctuidae) ecology in Southeastern cotton. *J. IntegratedPest Manage.***6**(1), 10. doi:https://doi.org/10.1093/jipm/pmv009.

IITA. 2016. International Institute of Tropical Agriculture. Maize. [http://www.iita.org/maize] site visited on 7/8/2018.

Kalyan, D., M. K. Mahla, S. R. Babu, R. K. Kalyan and S. Swathi. 2020. Biological Parameters of Spodoptera frugiperda (J.E. Smith) under Laboratory Conditions. *Intl. J. Current Microbiol. Appl. Sci.* **9**(5): 2972-2979.

Lekha, M.K., H. Swami, A.K. Vyas and K.C. Ahir. 2020. Biology of fall armyworm, *Spodoptera frugiperda* (JE Smith) on different artificial diets. *J. Ent. Zool. Study*. **8**: 584-586.

Marcela, M. N and V. N. Mario. 2020. Life cycle, morphometry and natural enemies of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on *Zea mays*L. In the Philippines. *J. ISSAAS.* **26**(2): 17-29.

Montezano, D.G., A. Specht, D.R. Sosa-Gomez, V.F. Roque-Specht, J.C. Sousa-Silva, S.V. De Paula Moraes, J.A. Petersonand and T. E. Hunt. 2018. Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. *African Entomol.* **26**(2): 286-300.

Priyanka, M., P. Yasodha and C.G.L. Justin. 2021. Life table evaluation of *Spodoptera frugiperda* on maize at room temperature. *Pharm. Innov. J.*,**10**(10): 1318-1323.

Palma, P. 2020. New threat to crops. The Daily Star; 2018. (Accessed 1 May 2020) Available at https://www.thedailystar.net/back page/news/new-threat-crops-1672021.

Prasanna B. M., E. H. Joseph, E. Regina, M. P. Virginia, Ed.2018. Fall Armyworm in Africa: A guide for integrated pest management. Proceedings of CIMMYT Workshop, Entebbe, Uganda.16 - 17 September 2017, pp. 107

Sharanabasappa, D., C.M.Kalleshwaraswamy, M.S. Maruthiand and H.B. Pavithra. 2018.Biology of invasive fall army worm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on maize. *IndianJ. Entomol.* **80**(3): 540-543.

Shylesha A N, S.K. Jalali, A. Gupta, R.Varshney, T. Venkatesan, P. Shetty, R. Ojha, P. C. Ganiger, O.P. Navik, K. Subaharan, N. Bakthavatsalam, C.R. Ballal. 2018. Studies on new invasive pest Spodoptera frugiperda (J. E. Smith) (Lepidoptera: Noctuidae) and its natural enemies. *J. Biol. Control.* **32**(3): 2018.

Zeeshan, B., M.A.Agha, K. Imran, R. Qurba, R. Shahjahan, T. Mehvish and Y. Harrison. 2021. First report of morphometric identification of *Spodoptera frugiperda* J.E Smith (Lepidoptera: Noctuidae) an invasive pest of maize in Southern Sindh, Pakistan. Department of Entomology, Faculty of Crop Protection, Sindh Agriculture University. *Asian J. Agril.Biol*. **1**:169.

ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 47(2): 241-255, June 2022

ECONOMIC FEASIBILITY OF SOLAR IRRIGATION PUMPS IN SOUTHERN REGION OF BANGLADESH

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Abstract

This study presents the economic suitability of solar pump in the southern region of Bangladesh. Field survey was conducted during 2018-19 at Kalapara and Galachipa Upazila of Patuakhali district, Borguna Sadar and Amtoli Upazila of Borguna district, Charfassion and Lalmohon Upazila of Bhola district. BARI developed large and mini solar pumps and were tested in those areas for irrigation in vegetables. Two water saving irrigation techniques (Drip and alternate furrow) and one conventional irrigation practice were used for cultivating tomato, brinjal, watermelon and chili. The internal rate of return of all irrigation systems were greater than the bank interest rate. Solar powered drip and alternate furrow irrigation system was found more profitable than low lift pump for cultivation of vegetables. The benefit-cost ratio of mini and large solar systems were found 1.50 and 1.42, respectively. So, solar pump may be recommended for irrigation vegetables in the southern region of Bangladesh.

Keywords: Benefit cost ratio, low lift pump, net present value, payback period, solar pump. vegetables.

Introduction

In Bangladesh, 187188 LLP (Low lift pump), 1357532 STW (Shallow tube well), 37634 DTW (Deep tube well) and 5500 solar pumps are in operation of 1.58 million irrigation pumps. There is about 65.08% irrigation coverage of which 78.45% operate on a diesel engine and 21.55% on electric motor and solar energy operated pumps (BADC, 2020). Bangladesh government has already decided to generate 1.5 GW electricity from solar within 2021 (SREDA, 2021). Solar based irrigation systems are innovative and environment friendly solution for the agro-based economy of Bangladesh. Farmers normally use pumps for 115-120 days of a year for irrigation, while the rest of the year the pumps remain off when solar electricity has no use. Bangladesh Rural Electrification Board (BREB) plans to install 2000 solar irrigation pumps allowing farmers to sell their unconsumed electricity to the national grid when irrigation is no longer required. Hossain *et al.* (2015) conducted a base-line survey in 2010 at different locations of Bangladesh to know the status of solar pumps. There were about 150 solar pumps in Bangladesh among them 65% were used for supplying drinking water to the poor people of the locality and about 35% solar pumps were used for irrigation

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purposes. Statistics from a draft report of SREDA (Sustainable and Renewable Energy Development Authority) on National Solar Energy Roadmap 2021-41 shows that so far 1872 solar irrigation pumps were installed across the country by different organizations. Of these, BREB installed 40, IDCOL (Infrastructure Development Company Limited) 1523, BADC (Bangladesh Agricultural Development Corporation) 137, Barind Multipurpose Development Authority (BMDA) 106, RDA (Rural Development Academy) 15, and other authorities 51, which have installed power generation capacity is 43.178 MW. Islam and Hossain (2022) reported that small solar pump in Bangladesh is more profitable than large solar pump. Large solar pump is run by 'fees for service model' and small solar pump is run by ‘fees for ownership model' and it is more profitable due better management.

To achieve the government dictum Bangladesh Agricultural Research Institute (BARI) has started working on solar irrigation cum solar home system from the late 90s. Therefore, this study was executed to assess the technical and economic feasibility of BARI developed different solar irrigation system for vegetable cultivation over low lift pump in southern areas of Bangladesh.

Materials and Methods

Experimentation

Two types of solar pumps were fabricated at Farm Machinery and Pos-tharvest Process Engineering (FMPE) Division, Bangladesh Agricultural Research Institute (BARI), Gazipur for surface water lifting. The large and mini solar pumps were selected and installed at Patuakhali, Borguna and Bhola districts of southern Bangladesh for irrigating vegetables in *Rabi* season. The large solar pump (910W dc motor, 180 L/min discharge) was designed and fabricated for large and medium farmers. The mini solar pump (280W dc motor, 40 L/min discharge) was designed and fabricated considering affordability of small farmers. The large solar pump had inlet and outlet diameters of 51 mm and the mini solar pump had inlet and outlet diameter of 25 mm. Field experiments were conducted at Galachipa and Kalapara Upazilla of Patuakhali district, Amtali, Borguna Sadar Upazilla of Barguna district, Lalmohon and Charfasson Upazila of Bhola district during *Rabi* season of 2019-2020 and 2020-2021 with the solar pumps for irrigating tomato, brinjal, chili and watermelon. Drip irrigation, alternate furrow irrigation and conventional method (Every furrow/ring basin) irrigation treatments were applied through randomized complete block design.Drip irrigation, alternate furrow/ring basin irrigation treatments were applied through randomized complete block design for executing watermelon experiments. The experiment information is given in Table 1.

Table 1. Description of field experiments during Rabi season of 2019-20 and 2020-21

District	Upazila	Year	Vegetables	Area (m^2)
Patuakhali	Kalapara	2019-20	Brinjal	264
		2020-21	Brinjal	216
	Galachipa	2019-20	Tomato	521
			Brinjal	264
		2020-21	Tomato	216
			Brinjal	240
			Chili	300
			Watermelon	924
Borguna	Sadar	2019-20	Tomato	472
			Brinjal	472
		2020-21	Tomato	250
			Brinjal	216
			Watermelon	360
	Amtali	2019-20	Tomato	336
			Brinjal	524
		2020-21	Watermelon	534
			Brinjal	400
Bhola	Lalmohon	2019-20	Tomato	360
			Brinjal	236
		2020-21	Tomato	584
	Charfassion	2019-20	Brinjal	326
		2020-21	Brinjal	400
			Tomato	120

Plant height (cm), fruit diameter (cm), fruit length (cm), number of fruits per plant, unit fruit weight (g) and yield (t/ha) data were collected. . Two types of solar pump were tested and recorded different cost parameters for installation and operations of all pumps. The relevant costs of LLP (3.0 kW diesel engine, 660 L/min discharge and 76.20 mm outlet diameter) were also collected from direct interviewing from the local service providers.

Financial analysis

Total operating cost of two types of solar pumps and diesel engine operated LLP for crop production is the sum of total fixed cost and total variable cost. Fixed cost is the sum of capital consumption, shelter/taxes/insurance and interest of investment. The life cycle cost (LCC) of any piece of equipment is the total "lifetime" cost to purchase, install, operate, maintain, replacement and dispose of that equipment. LCC analysis is a management tool that can help the owner to minimize waste and maximize energy efficiency for pumping system. LCC is calculated using the following formulae (Anonymous, 2001).

LCC = Total investment cost + Fixed cost + variable cost + replacement and disposal cost.

Total Investment cost = Purchase price of pump/panel + Installation cost + Cables and accessories cost

Fixed cost = Capital consumption + interest of investment + shelter

Variable cost = Repair & maintenance + labor cost + fuel cost + oil/lubrication cost

Operating cost =Fixed cost + variable cost

Repair and maintenance = 3% of purchase price of pump/engine

Salvage value = 10% of purchase price of pump/solar panel (Sv)

Shelter =2% of purchase price of pump/engine

$$\text{Capital Consumption} = \{(\text{TIc} - \text{Sv}) * \text{CRF}\} + (\text{Sv} * \text{i})$$

Where,	TIc	=	Total investment cost
	Sv	=	Salvage value
	CRF	=	Capital recovery factor
	i	=	interest (10%)

Where, TIc is the sum of purchase price of pump/solar panel, installation cost, cables, accessories and pipes and fitting cost.

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1}$$

Where,	i	=	Interest (10%)
	L	=	Economic life of system

Marginal benefit cost ration for pump was calculated by the following equation

$$\text{MBCR} = \frac{\text{Gross Return}}{\text{Annual Operating Cost}}$$

Where,	Gross return ($/year)	=	Area under irrigation × irrigation charge per year/ season
	Operating cost ($/year)	=	Fixed cost + variable cost

Benefit cost ration for crop was calculated by the following equation

$$BCR = \frac{\text{Gross Return}}{\text{Total Cultivation Cost}}$$

Where,	Net return ($/year)	=	Gross return – cultivation cost
	Cultivation cost ($/year)	=	Fixed cost + Variable cost

Payback period for was calculated by the following equation

$$PBP = \frac{\text{Total Investment Cost}}{\text{Gross Return}}$$

Depreciation is often defined as the annual loss in value due to use, wear, tear, age, and technical obsolescence. Several methods or equations can be used to compute annual depreciation. Straight line method was used in this study to calculate depreciation. The straight line method of calculating depreciation is widely used. The useful life of solar pump and diesel engine-operated pump was assumed to be 20 years and 10 years, respectively. Annual interest rate was considered 10 % of the capital price of the pump.

Net present value (NPV) was calculated by using the following equation

NPV= PW of benefit at 10% DF – PW of cost at 10% DF

Where,	PW	=	Present worth
	DF	=	Discounted factor

To investigate investment prospects of PV water pumping applications, internal rate of return (IRR) is used as an indicator of project profitability. Internal rate of return is defined as the interest rate at which present worth of the cash flows of a project are zero. Internal rate of return higher than the market interest rate means profitable investment.

Present worth income = present worth (disbursements) then IRR = i

Results and Discussion

Base line information

Irrigation status of the selected Upazila of Patuakhali, Borguna and Bhola districts were given in Table 3. In all locations farmers used diesel operated LLP. Only 11.54 to 34.48% farmers used their own irrigation system. Rest of the farmers (65.52 to 88.46%) used the irrigation system as hiring basis. The engine horse power varied from 4.5 to 10.50 hp depending on the head of water source.

Table 3. Irrigation status in the selected areas in Patuakhali, Borguna and Bhola districts

Items		Patuakhali		Borguna		Bhola	
		Kolapara	Galachipa	Sadar	Amtoli	Charfassion	Lalmohon
Pump	LLP (%)	100	100	100	100	100	100
	Diesel (%)	100	100	100	100	100	100
	Engine (hp)	6.5	7.3	5.33	4.5	8.32	10.50
	Owner (%)	19.23	34.48	11.54	17.39	17.25	10.35
	Hire (%)	80.77	65.52	88.46	82.61	82.75	89.65
	Fuel consumption (Lh^{-1})	1.03	1.21	0.872	0.792	1.22	1.5
	Operating time (h)	8.5	9.5	10	9	9.85	10.35
Source of irrigation water	Canal (%)	85	73	90	65	87	74
	Pond (%)	15	27	10	35	13	26
Water available in dry season (m)		3.04	2.90	1.59	1.15	1.48	1.27

Fuel consumptions of the used engines were 0.79 to 1.5 L/h depending on the engine power. The operating time of those engines were varied from 8.5 to 10.35 h depending on the cultivated crop. Most of the southern farmers (65-90%) used canal water for irrigation and the head of available water sources varied from 1.15 to 3.04 m.

Financial analysis

Different cost components for two solar pumps and LLP are given in Table 4 . A large solar pump comprised of 1.3 kW photovoltaic panel and 1.2 hp centrifugal pump with 180 L/min discharge capacity and a mini solar pump comprised of 0.50 kW photovoltaic panel and 0.40 hp centrifugal pump with 40 L/min discharge capacity were selected for economic analysis. A 4.5 hp diesel engine operated centrifugal pump with 250 L/min discharge capacity LLP was also selected for economic analysis. Life of solar panel was assumed 20 years and life of DC motor was assumed five years. The command area of two selected solar pumps were 1.6 ha and 0.8 ha, respectively and was used in whole season. The command area of selected LLP was 2.94 ha. From Table 4 it is observed that the total cost (Cost of panel, cost of pump, cost of motor, installation and fitting cost) of large solar pump, mini solar pump and LLP were USD 940.80, 303.30 and 314.40 respectively. From Table 3, it is also observed that there was no installation cost for LLP. There was no fixed structure for LLP at the southern region of Bangladesh. Farmers usually keep LLP at home and transfer it in the field during the time of irrigation. The fitting cost of solar pump was higher than LLP. Solar pump need wiring and accessories for fitting with the solar panel but LLP does not require such type of wiring cost.

Table 4. Cost Components of two solar pumps and low lift pump

Item	Power	Cost of panel (USD)	Cost of pump associated with prime mover (USD)	Installation cost (USD)	Fittings cost (USD)	Total cost (USD)
Large solar pump	Panel:1300 W_p motor: 910 W	514.80	270.00 (dc motor with pump)	36.00	120.00	940.80
Mini solar pump	Panel: 365 W_p motor: 280 W	153.30	12.00 (dc motor with pump)	36.00	102.00	303.30
LLP	2984 W	-	240.00 (Engine with pump)	-	74.40	314.40

It can be illustrated from Table 5 that the investment cost and fixed cost were much higher in two types of solar pump than LLP. The purchase price (USD 0.40 per watt) of solar panel was much higher than LLP in Bangladesh. On the other side variable cost and operating cost were observed higher in LLP than the solar pumps. Variable cost included repair and maintenance, labor cost, fuel cost and oil cost. No fuel and oil cost were required for solar pump operation. The labor cost was not as much of in solar pump operation. In case of LLP, engine needs overhauling almost every year. Life of diesel engine and pump were considered five years. After five year new engine and pump would be required for LLP but for solar pump only pump would be required.

Table 5. Life cycle costs of two solar pumps and low lift pump

Cost Item	Large solar pump	Mini solar pump	LLP
Investment cost (USD)	940.80	411.30	314.40
Fixed cost (USD)	167.90	74.21	24.12
Variable cost (USD)	155.70	78.66	727.99
Operating cost (USD)	323.60	152.87	752.11
Life cycle cost (USD)	1588.00	717.03	1818.62

In case of solar pumps, only the motor and pump need to be changed after five years because the life of solar panel was assumed 20 years (Table 6). Hossain *et. al.* (2015) also found from a survey in Bangladesh that a 4.0 hp submergible solar pump was more cost effective than a 4.0 hp diesel engine operated shallow tube well.

Table 6. Capacity, operation and fuel used in LLP at six upazila in Patuakhali, Borguna and Bhola districts

Cost Item	Unit	Average value
Fuel consumption	Liter/hour	1.00
Fuel cost	USD/Liter	0.78
Daily use	Hour	8.00
Yearly use	Day	60.00
Annual use	Hour	480.00
Total energy cost	USD/year	374.40
Oil & lubrication (15% of total fuel cost)	USD	56.16
Area under irrigation	Hectare	2.94
Irrigation cost	USD/ha/season	287.42

Costs and benefit of solar pumps and LLP for vegetable cultivation

Table 7 gives different cost components regarding tomato, brinjal, watermelon and chili cultivation through drip, alternate furrow and every furrow irrigation using large solar pump. Among all three irrigation practices, drip irrigation required higher cost for all types of vegetables cultivation due to its high installation cost. Here input cost included land preparation cost, fertilizer cost, seed cost, insecticide and pesticide cost and labor cost. Irrigation cost included pipes, tank and other fitting costs. The variable cost is the sum of input cost and irrigation cost. The cultivation cost is the sum of variable cost and fixed cost. The input cost was varied due to the labor usage varied at different irrigation methods. In that case of, every furrow irrigation required higher labor cost than other irrigation practice. The cost of pump and fixed cost remained same at all irrigation method.

Table 7. Costs of Vegetable cultivation under different irrigation methods for large solar pump

Crop	Irrigation method	Fixed cost ($)/ha	Input cost ($)/ha	Irrigation cost ($)/ha	Total variable cost ($)/ha	Total cultivation cost ($)/ha
Tomato	Drip	73.99	1142.78	961.61	2104.39	2178.38
	AFI	73.99	1294.27	144.00	1438.27	1512.26
	EFI	73.99	1541.27	300.00	1841.27	1915.26
Brinjal	Drip	73.99	3890.24	1215.66	5105.90	5179.89
	AFI	73.99	4075.49	210.00	4285.49	4359.47
	EFI	73.99	4353.36	420.00	4773.36	4847.35
Watermelon	Drip	73.99	1184.98	711.36	1896.34	1970.32
	RBI	73.99	1302.30	80.03	1382.33	1456.32
	EFI	73.99	1671.97	80.03	1752.00	1825.99
Chilli	Drip	73.99	3942.52	1130.98	5073.49	5147.48
	AFI	73.99	4347.19	264.00	4611.19	4685.18
	EFI	73.99	4841.18	540.00	5381.18	5455.17

Table 8 describes different cost components regarding tomato, brinjal, watermelon and chili cultivation through drip, alternate furrow and every furrow irrigation using mini solar pump. Among all three irrigation practices, drip irrigation required higher cost for all types of vegetables cultivation due to its high installation cost. Here input cost included land preparation cost, fertilizer cost, seed cost, insecticide and pesticide cost and labor cost. Irrigation cost included pipes, tank and other fitting costs. The variable cost was the sum of input cost and irrigation cost. The cultivation cost was the sum of total variable cost and fixed cost. The input cost was varied due to the labor usage varied at different irrigation practices. In that case, every furrow irrigation required higher labor cost than other irrigation practice. The cost of pump and fixed cost remained same in all irrigation system.

Table 8. Costs of Vegetable cultivation under different irrigation methods for mini solar pump

Crop	Irrigation method	Fixed cost ($)/ha	Input cost ($)/ha	Irrigation cost ($)/ha	Total variable cost ($)/ha	Total cultivation cost ($)/ha
Tomato	Drip	42.01	1142.78	961.61	2104.39	2146.40
	AFI	42.01	1294.27	144.00	1438.27	1480.28
	EFI	42.01	1541.27	360.00	1901.27	1943.27
Brinjal	Drip	42.01	3890.24	1215.66	5105.90	5147.91
	AFI	42.01	4075.49	180.00	4255.49	4297.49
	EFI	42.01	4353.36	420.00	4773.36	4815.37
Watermelon	Drip	42.01	1184.98	474.24	1659.22	1701.22
	RBI	42.01	1302.30	80.03	1382.33	1424.33
	EFI	42.01	1431.97	160.06	1592.03	1634.03
Chilli	Drip	42.01	3342.52	1215.66	4558.18	4600.19
	AFI	42.01	4347.19	144.00	4491.19	4533.20
	EFI	42.01	4841.18	300.00	5141.18	5183.19

Table 9 shows different cost components regarding tomato, brinjal, watermelon and chili cultivation through drip, alternate furrow and every furrow irrigation using LLP. Among all three irrigation practices drip irrigation required higher irrigation cost, variable cost and cultivation cost at all types of vegetable cultivation due to its high installation cost. Here input cost included land preparation cost, fertilizer cost, seed cost, insecticide and pesticide cost and labor cost. Irrigation cost included pipes, tank and other fitting costs. The variable cost was the sum of input cost and irrigation cost. The cultivation cost was the sum of total variable cost and fixed cost. The input cost was varied due to the labor usage varied at different irrigation methods. In that case, every furrow irrigation required higher labor cost than other irrigation methods. The cost of pump and fixed cost remained same in all irrigation systems.

Table 9. Costs of Vegetable cultivation under different irrigation methods for low lift pump

Crop	Irrigation method	Fixed cost ($)/ha	Input cost ($)/ha	Irrigation cost ($)/ha	Total variable cost ($)/ha	Total cultivation cost ($)/ha
Tomato	Drip	24.12	830.78	961.61	1792.39	1816.51
	AFI	24.12	1414.27	144.00	1558.27	1582.39
	EFI	24.12	1181.27	360.00	1541.27	1565.39
Brinjal	Drip	24.12	3374.24	1215.66	4589.90	4614.02
	AFI	24.12	4195.49	180.00	4375.49	4399.61
	EFI	24.12	4101.36	420.00	4521.36	4545.48
Watermelon	Drip	24.12	1184.98	474.24	1659.22	1683.34
	RBI	24.12	1302.30	80.03	1382.33	1406.45
	EFI	24.12	1431.97	80.03	1512.00	1536.12
Chilli	Drip	24.12	3342.52	1215.66	4558.18	4582.30
	AFI	24.12	4347.19	144.00	4491.19	4515.31
	EFI	24.12	4721.18	300.00	5021.18	5045.30

Table 10 demonstrates that the gross return was comparatively high at drip and alternate furrow irrigation over every furrow irrigation. High gross margin was found in alternate furrow irrigation which was followed by drip irrigation and every furrow irrigation for tomato, brinjal, watermelon and chili cultivation at the selected locations of the southern districts. Two improved irrigation technologies gave highest return than every furrow irrigation for all types of vegetable cultivation.

Table 10. Gross margin of two solar pump and LLP under different irrigation methods for vegetable cultivation

Crop	Irrigation method	Yield (t/ha)	Selling price ($/t)	Large solar pump ($)/ha	Mini solar pump ($)/ha	Low lift pump ($)/ha
Tomato	Drip	44.29	122.04	3226.77	3258.75	2860.65
	AFI	38.41	122.04	3175.30	3207.28	2377.17
	EFI	37.69	122.04	2684.43	2656.41	2306.31
Brinjal	Drip	47.71	300.00	9133.11	9165.09	6108.39
	AFI	44.62	300.00	9026.53	9088.51	5581.20
	EFI	44.04	300.00	8364.65	8396.63	5296.13
Watermelon	Drip	44.69	148.44	4663.46	4932.56	4222.46
	RBI	40.33	148.44	4530.27	4562.25	3852.15
	EFI	38.70	148.44	3918.64	4110.59	3480.52
Chilli	Drip	12.50	960.00	6852.52	7399.81	6689.71
	AFI	12.40	960.00	7218.82	7370.80	6660.70
	EFI	11.72	960.00	6266.43	6538.41	5948.30

It is shown in Table 11 that the marginal benefit cost ratio was higher in mini solar pump (1.51) and large solar pump (1.42) than LLP (1.12). Though it could be observed from Table 11 that the gross return was found high in LLP but the variable cost and operating costs were much higher in LLP operation than solar pumps (Table 5). So that the MBCR became lower in LLP. Biswas and Hossain (2013) also reported that a 10 hp solar operated pump became more economic than a 10 hp diesel engine operated pump after 10 years of operation. Abu-Aligah (2013) reported that for long-term irrigation project (more than five years) solar pump is more economic than same sized-diesel pump.

Table 11. Gross return, gross margin , BCR and payback period of two solar pumps and low lift pump

Benefit Item	Large solar pump	Mini solar pump	Low lift pump
Gross return (USD)	460.80	230.40	844.80
Gross margin (USD)	137.20	77.53	92.69
Marginal benefit cost ratio	1.42	1.51	1.12
Payback period	6.86	5.30	3.39

From the above discussion, it could be stated that the solar pump was more economical than diesel operated pump for vegetable cultivation. Though the investment cost was high in solar pump irrigation system but the variable cost and operating cost were much lower in comparison with diesel operated LLP. Generally, farmers of Bangladesh use LLP as hire basis for irrigation. In that case, farmers would have to bear the fuel cost and operation cost for the benefit of the pump owner. In the survey area, irrigation water was applied through 4.5 hp diesel engine operated LLP. Only 18% people were the owner of those pumps and the rest 82% people used the pumps for irrigation as hiring basis. The irrigation cost per hectare was calculated 287.42 USD per season in the selected survey area (Table 5). However, in case of solar pump there was no fuel cost. Therefore, the irrigation rent would be less in solar irrigation system than LLP. In case of benefit cost ratio, for each type of vegetable cultivation, alternate furrow irrigation and ring basin irrigation gave highest BCR than other two-irrigation practices. It could be stated from the Table 12 that the improved irrigation techniques were more suitable than conventional practice.

Net present value (NPV), benefit cost ratio (BCR), and internal rate of return (IRR) at 10% discounted factor was calculated for project analysis. Discounted measures of project were used for financial analysis since undiscounted measures of project worth is quite unable to be taken into consideration the timing of benefits and costs. From Table 13, it is pointed that the solar pumps and LLP were profitable for the owners in using irrigation practice. A cash flow chart was prepared for project analysis in making comparison between large solar pump, mini solar pump and LLP. The project analysis was calculated for 20 years project period. The project cost was the sum of capital cost and operating cost of solar PV pumping system. The cash inflow of the project came from custom hire of irrigation service to the farmers. The hire rate was equal for both diesel pump and solar pump. In Table 13, the large solar pump cash out flow it was stated that the NPV, BCR, IRR and DPBP was 968.62 USD, 1.33, 14% and 14.28, respectively. Whereas for mini solar pump cash out flow stated that the NPV, BCR, IRR and DPBP was 560.65, 1.40, 25% and 16.48, respectively. Once more for LLP the cash out flow stated that the NPV, BCR, IRR and DPBP was 433.01, 1.06, 17% and 16.61, respectively. The NPV indicates that the solar irrigation system was considered financially sound and the project may be financially viable because the highest IRR (20%) of solar irrigation system was greater than the bank interest rate. Therefore, solar PV system for using irrigation purpose in vegetable cultivation is more risk free than other irrigation system.

Table 12. Benefit cost ratio of solar pumps and LLP under different irrigation system for vegetable cultivation

Crop	Irrigation method	Large solar pump	Mini solar pump	Low lift pump
Tomato	Drip	1.48	1.52	1.12
	AFI	2.10	2.17	1.03
	EFI	1.40	1.37	1.01
Brinjal	Drip	1.76	1.78	1.14
	AFI	2.07	2.11	1.09
	EFI	1.73	1.74	1.00
Watermelon	Drip	2.37	2.90	1.75
	RBI	3.11	3.20	1.80
	EFI	2.15	2.52	1.54
Chilli	Drip	1.33	1.61	1.26
	AFI	1.54	1.63	1.27
	EFI	1.15	1.26	1.03

Table 13. Comparison of NPV, BCR, IRR and DPBP for two solar pumps and low lift pump

Item	Large solar pump	Mini solar pump	Low lift pump	Remarks
NPV (USD)	968.62	560.65	433.01	If greater than zero, accepted
BCR	1.33	1.40	1.06	If greater than unity, accepted
IRR	14%	25%	17%	If greater than prevailing interest rate, Accepted
DPBP	14.28	16.48	16.61	If less than economic life, accepted

3.4 Cost and benefit of large and small solar irrigation system including solar home system

Life cycle cost in Table 14 and Table 15 described the gross and net returns, BCR and payback period of two solar irrigation system including solar home system. In case of large solar pump investment cost, fixed cost, variable cost, operating cost and life cycle cost increased about 358.80, 61.25, 180.00, 241.25 and 841.30 USD, respectively. On the other hand, for mini solar pump investment cost, fixed cost, variable cost, operating cost and life cycle cost increased about 358.80, 61.25, 90.00, 151.25 and 661.31 USD, respectively.

Table 14. Life cycle costs of two solar pumps including solar home system

Cost item	Large solar pump	Mini solar pump
Investment cost (USD)	1299.60	770.10
Fixed cost (USD)	229.15	135.46
Variable cost (USD)	335.70	168.66
Operating cost (USD)	564.85	304.12
Life cycle cost (USD)	2429.30	1378.34

Though the expenses were increased gradually at all cost items, the returns also increased thoroughly. The gross return was increase USD 367.20 for large and mini solar pumps. The gross margin was increased USD 493.15 and 215.95, respectively for large and mini solar pumps. It was observed that the solar irrigation system including solar home system provided higher marginal benefit cost ratio than solar irrigation system excluding solar home system. The pay back period was observed less in solar irrigation system including solar home system.

Table 15. Gross return, net return, BCR and payback period of two solar pumps

Benefit Item	Large solar pump	Mini solar pump
Gross return (USD)	828.00	597.60
Gross margin (USD)	630.35	293.48
Marginal benefit cost ratio (MBCR)	2.12	1.97
Pay back period (PBP)	2.06	2.62

Social benefits of solar pump

Solar irrigation is potential for increasing agricultural productivity and income due to improved access to water (additional cropping season, diversification of cropping pattern, higher value crops). From Table 6, it is observed that the farmers could save 374.40 USD per year as fuel cost by using solar irrigation system, which will save carbon dioxide emission. A single unit solar irrigation system could save 1.29 tons carbon dioxide emission per year over diesel engine operated low lift pump.

Farmers could save on an average USD 28.8 per year in domestic use (electricity) andabout USD 14 per year in homestead watering (bathing, clothing, cleaning and livestock watering etc.). Solar irrigation is time saving technology due to replacement of labor-intensive manual irrigation, which can lead to other income-generating activities. Women and/or children might profit from time not spent on watering anymore and potential for job creation in the renewable energy sector, which reduced dependence on energy exports. Energy subsidies for fossil fuels can be reduced while offering an alternative to farmers and rural communities whose livelihoods would otherwise be negatively affected.

Conclusion

In all selected locations, 1.91 m depth of water was always available in dry season at all water sources. With this available water, about 4.5 hp power diesel operated low lift pump is used. Solar pumps (Large and mini) were found suitable in terms of technical and financial performance over LLP. The solar irrigation system for vegetable cultivation was found profitable. The installation cost of solar irrigation system was high but the economic life, labor cost, fuel cost, oil cost and repair maintenance cost of solar irrigation system were lower than the LLP. Entrepreneurs can save fuel cost, oil cost and repair maintenance cost in operation of solar pump. The BCR was found 1.50 and 1.42 for mini and large solar pumps respectively. The solar irrigation system was not familiar to the farmers and the service providers of the study areas. A solar irrigation system owner or local service provider (LSPs) can start this business, which would be a profitable scheme for an entrepreneur. To extend the benefits of solar irrigation system among the farmers and custom hire service providers, appropriate adoption and dissemination programs must be launched all over Bangladesh. After fulfilling own demand, service providers can trade excess electricity to others through grid line, charging batteries, charging mobile phones and charging battery operated vehicles.

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Reference

Anonymous. 2001. Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems. Collaboratively published by the Hydraulic Institute, Europump, and the US Department of Energy's Office of Industrial Technologies (OIT). DOE/GO-102001-1190.

BADC. 2020. Minor Irrigation Survey Report 2018-19 (Rabi Season). Digitalization of Survey & Monitoring for Development of Minor Irrigation Project, Bangladesh Agricultural Development Corporation. 22, Manikmia Avenue, Shere-e-Bangla Nagar, Dhaka-1207.

Biswas, H. and H. Hossain. 2013. Solar Pump: a possible solution of irrigation and electric power crisis of Bangladesh. *Int J. Comput Appl*. **62(16):** 1-5.

Hossain, M. A., M. S. Hassan, M. A. Mottalib, and M. Hossain. 2015. Feasibility of Solar Pump for Sustainable Irrigation in Bangladesh. *International Journal of Energy & Environmental Engineering* **6(2):** 147-155.

SREDA. 2021. Energy Efficiency and Conservation Master Plan up to 2030. Power Division, Ministry of Power, Energy and Mineral Resources, Government of the People's Republic of Bangladesh.

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Ahmed, F. and M. Z. Alam. 1993. Mango leaf consumption by *Cricula trifenestrata* Heifer (Lepidoptera: Saturnide) larvae under field conditions. *Bangladesh J. Entomol.* **31:** 9-17.

Cano, H., N. Gabas and J. P. Canselier. 2001. Experimental study on the ibuprofen crystal growth morphology in solution. *J. Crystal Growth* **224:** 335.

De Beer, G. R.1940. Embryology and Taxonomy. *In: The New Systematics.* (Ed. Huxely, J.). Oxford Univ. Press, London. pp. 365-393.

Dockery, D. J. and C. A. Pope, 1994. Acute respiratory effects of particulate air pollution. *Ann. Rev. Public Health* **15:** 107-110.

Edmonds, J. and K. M. Karp. 1997. Theoretical improvements in Algorithmic Efficiency for network flow problems. *J. Assoc. Comput. Mach.* **19:** 248-264.

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