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HETEROSIS STUDIES IN SNAKE GOURD (*TRICHOSANTHES CUCUMERINA* VAR. *ANGUINA* L.)

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Abstract

An investigation was carried out on snake gourd at the research farm of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh during March to June 2019. Significant heterosis was observed for most of the characters studied to find out high heterotic combination for better hybrids. Both positive and negative heterosis were found for different characters of the F_1 hybrids over better parents. The best better parent heterotic performance was exhibited by early flowering and fruit fly infestation in P_2 x P_7 and P_6 x P_7, respectively while P_3 x P_7 for higher individual fruit weight; P_1 x P_3, P_2 x P_6, P_3 x P_7, P_4 x P_6 for number of fruit bearing; P_1 x P_3, P_2 x P_3, P_2 x P_7, P_3 x P_7, for higher fruit yield per plant and hectare; P_1 x P_3, P_2 x P_3, P_2 x P_6, P_3 x P_7 for maximum fruit length P_2 x P_6, P_4 x P_6, P_4 x P_7 for fruit diameter as well as for increasing 100-seed weight the cross combinations were P_2 x P_3, P_4 x P_6. Based on all the characters and heterotic performance, the crosses combinations viz., P_1 x P_3, P_2 x P_6, P_3 x P_7 and P_6 x P_7 can be selected to exploit improved hybrid lines.

Keywords: Snake gourd, heterosis, heterobeltiosis, genotypes, hybrids.

Introduction

Snake gourd (*Trichosanthes cucumerina* var. *anguina* L.) is an annual, day-neutral climbing type herbaceous vegetable crop and belongs to the cucurbitaceae family. It is grown throughout Bangladesh and is a popular summer vegetable in this region. At the end of winter and early summer seasons, there is a lean period when there is always a shortage of vegetables in this region. During that gap time, vegetable shortage can be mitigated to some extent through improvement of cucurbitaceous crops such as snake gourd. There is a diversified cultivars of snake gourd in this country with a wide range of variability in fruit size, shape and color (Rashid, 1993). In Bangladesh, vegetable production has increased five times in the past 40 years which has scored third in global vegetable production, next to China and India (FAO, 2015). Summer vegetables typically cover about 44 percent of the total vegetable area, of which snake gourd is a prominent vegetable crop in this country (BBS, 2020). Snake gourd is monoecious in nature and heavily cross-pollinated. Such

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pollination mechanism can be exploited for the development of hybrid variety. Heterosis or hybrid vigor can play a pivotal role in increasing the yield and quality of vegetable crops. Focused on the above opinions, heterosis studies are considered as excellent tools in any breeding programme. These include the desired genetic explanation relating to crop improvement or heterotic commercial advantage exploitation. Diallel analysis was also used to be properly informed about the heterosis in crosses to generate a suitable segregating population for selection (Glover, 2005 and Singh and Asati, 2011). Several workers have documented heterosis in cucurbits for various characteristics (Banik, 2003 and Rahman, 2004). There is minimal information available on the extent and existence of heterosis for yield and yield contributing characters in snake gourd as it is an underutilized crop. Due to monoceous , much scope for exploitation of heterosis in snake gourd exists virtually. The F_1 hybrids offer many benefits, such as earliness, high yield, uniformity, broader adaptability, and also help to establish dominant genes for disease and pest resistance (Riggs, 1988). Therefore, the main purpose of the present study was to select a high heterotic parental combination to produce hybrid lines with good quality fruits.

Materials and Methods

The experiment was performed at the experimental farm of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh, during March to June 2019. Seven diverse genotypes were selected based on their performance with respect to different horticultural traits, genetic diversity, and heritability. The parental genotypes TC 01, TC 05, TC 24, TC 33, TC 02, TC 46 and TC 53 were identified as P_1, P_2, P_3, P_4, P_5, P_6 and P_7 respectively. The seven parents were grown and crossed in all possible combinations, excluding reciprocals during August to November, 2018. The parents were grown together with their F_1s during March to June 2019. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Fifteen days old seedlings were transplanted on 20 March 2019, in well-prepared pit in an experimental plot. A total of 84 (28 × 3) unit plots were found, each measuring 7.5 m × 1.5 m plots hosted 5 plants with row spacing of 1.5 m and 1.5 m, respectively. It was carefully designed to have better drainage, beds, and pits. Approximately 25 cm deep drain was dug around the plot for proper drainage. Fertilizers were applied @ 5000-50-24-40-14-1.5-1.0 kg/ha of cowdung-N-P-K-S-Zn-B according to FRG (2012). The N, P, K, S, Zn and B origins 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 N and the remaining part of K were applied in four equal installments at 7, 21, 35 and 49 days after transplantation. Days to male flower open, days to female flower open, node number to first male flower open, node number to first female flower open, vine length (cm), nodes on main vine, primary branches per plant, days to 1st harvest, fruit fly infestation (%), fruits per plant, fruit yield/plant (kg), fruit yield/hectare (ton), fruit weight (g), fruit length (cm), fruit diameter (cm), fruit flesh thickness (cm), locules per fruit, seeds per fruit, 100-seed weight (g). Percent better parent heterosis (BP) for each character was calculated as follows H (BP) = $\frac{\overline{F1}-\overline{BP}}{\overline{BP}} \times 100$; Where, BP is the mean value of the better parents in a particular cross. Mean error variance from the combined analysis of variance of parents and F_1s were used for calculating the SE of difference. The mean values over replications were used for comparison. For heterosis, the difference between F_1 and the parent used for estimation of heterosis was taken into account cross wise. When the difference was greater than CD, it was considered significant and vice versa. Critical difference (CD) = SE × t at 5% and 1%.

Results and Discussion

The estimation of better parent heterosis as identified in the F_1 generation are presented in Table 1 to 4. Among the cross combinations, fifteen crosses were earlier than their better parents for days to 1st male flower anthesis (Table 1). Negative heterosis ranged from -0.66 to -35.81% over better parents. The highest significant negative heterosis observed in the cross P_2 x P_5 and P_5 x P_7 (-35.81% for each cross) followed by P_5 x P_6 (-34.93%), P_3 x P_5 (-27.95%) and P_1 x P_5 (-22.27%). However, the cross P_3 x P_4 (19.75%) showed the highest significant positive heterobeltiosis for days to 1st male flower anthesis followed by P_1 x P_3 (18.82%) and P_1 x P_4 (14.12%). These results are in consonance with the results of Banik (2003) in snake gourd and Ahmed (2016) in pumpkin who observed negative better parent heterosis for early male flower open. Among the cross combinations, eleven crosses for days to 1st female flower open were earlier than their better parents (Table 1). Negative heterosis ranged from -1.20 to -32.17% over better parents. The highest significant negative heterosis observed in the cross P_2 x P_5 (-32.17%) followed by P_3 x P_5 (-30.87%), P_5 x P_6 (-30.87%), P_5 x P_7 (-28.26%) and P_1 x P_5 (-26.96%), indicating desirable combinations. On the other hand, the cross P_3 x P_4 (11.59%) showed the highest significant positive heterobeltiosis for days to 1st female flower anthesis followed by P_2 x P_4 (10.84%) and P_4 x P_7 (10.30%). These results are in agreement with the findings of Banik (2003) and Varghese (1991) in snake gourd and Ahmed (2016) in pumpkin who found negative heterobeltiosis for early female flowering. Out of twenty-one crosses, eleven were earlier than their better parents for earlier node order to 1st male flower initiation (Table 1). From all the hybrids eleven performed significant heterosis. Heterosis for earlier node order to 1st male flower initiation varied from -2.08 to -51.06%. The cross combination P_5 x P_6 (-51.06%) exhibited the highest significant negative heterosis for this trait followed by P_2 x P_5 (-44.68%) and P_1 x P_7 (-37.50%), P_6 x P_7 (-29.17%), P_2 x P_7 (-25.00%), P_3 x P_5 (-19.15%) and P_5 x P_7 (-18.75%). On the contrary, the highest significant positive heterosis was observed in the cross P_3 x P_4 (58.33%) followed by P_1 x P_3 (41.03%) and P_1 x P_6 (30.77%). These results corroborate with the findings of Banik (2003) in snake gourd and Ahmed (2016) in pumpkin who found negative heterobeltiosis for node number to 1st male flower initiation. Out of twenty one crosses, eleven were earlier than their better parents for node order to 1st female flower initiation (Table 1). From all the crosses, seven hybrids performed significant heterosis. Heterosis for earlier node order to 1st female flower initiation varied from -1.89 to -17.46%. The cross combination P_1 x P_4 (-17.46%) exhibited the highest significant negative heterosis for this trait. However, the highest significant positive heterosis was observed in the cross P_4 x P_5 and P_4 x P_7 (47.17% for each cross) followed by P_2 x P_4 (33.96%) and P_2 x P_3 (31.82%). These results support the reports of Banik (2003) in snake gourd and Ahmed (2016) in pumpkin who found negative better parent heterosis for node number to 1st female flower emergence.

Table 1. Percent heterosis over better parent for flowering characters in snake gourd

Crosses	Days to 1st flower open		Node number to 1st flower initiation	
	Male	Female	Male	Female
P_1 x P_2	-1.18	-3.13*	15.38	14.29*
P_1 x P_3	18.82**	0.52	41.03**	15.87*
P_1 x P_4	14.12**	2.08	2.56	-17.46*
P_1 x P_5	-22.27**	-26.96**	0.00	-9.52
P_1 x P_6	2.35	-9.38**	30.77**	-12.7
P_1 x P_7	-17.06**	-6.77**	-37.50**	-4.76
P_2 x P_3	-4.32*	3.01*	-11.11	31.82**
P_2 x P_4	-2.01	10.84**	-14.29	33.96**
P_2 x P_5	-35.81**	-32.17**	-44.68**	-1.89
P_2 x P_6	-3.29	-1.20	10.34	-3.77
P_2 x P_7	-6.71**	-1.20	-25.00**	-1.89
P_3 x P_4	19.75**	11.59**	58.33**	11.32
P_3 x P_5	-27.95**	-30.87**	-19.15*	-1.89
P_3 x P_6	-8.02**	4.27**	-8.33	-9.43
P_3 x P_7	1.83	8.48**	-2.08	1.89

Table 1. Cont'd

Crosses	Days to 1st flower open		Node number to 1st flower initiation	
	Male	Female	Male	Female
P_4 x P_5	-14.85**	-13.04**	14.89	47.17**
P_4 x P_6	-0.66	1.23	5.71	13.21
P_4 x P_7	7.93**	10.30**	18.75*	47.17**
P_5 x P_6	-34.93**	-30.87**	-51.06**	-9.43
P_5 x P_7	-35.81**	-28.26**	-18.75*	-3.77
P_6 x P_7	-6.71**	2.42	-29.17**	7.55

** Significant at 1% level, * Significant at 5% level, without star indicates non-significant

Among twenty-one cross combinations, ten hybrids performed significant heterosis for main vine length (Table 2). Positive heterosis for main vine length varied from 1.09 to 55.69%. The highest significant positive heterosis was found in the cross P_4 x P_6 (55.69%) followed by P_4 x P_5 (39.02%), P_1 x P_4 (38.21%), P_4 x P_7 (31.71%), P_3 x P_5 (28.95%), P_2 x P_4 (23.98%) P_5 x P_6 (23.50%), P_3 x P_4 (21.95%) and P_2 x P_3 (20.00%). The present study is in consonance with the results of Banik (2003) in snake gourd who got positive better parent heterosis for long vine. Among all the cross combinations, only four hybrids performed significant heterosis for primary branches per plant (Table 2). The positive heterobeltiosis varied from 8.33 to 80.00%. The highest significant positive heterosis found in the cross P_2 x P_3 (80.00%) followed by P_1 x P_3 (40.00%) and P_3 x P_7 (27.27%). The only significant negative heterosis found in the cross P_3 x P_6 (-27.27%). The present study is in agreement with the report of Banik (2003) in snake gourd who appeared positive better parent heterosis for the increasing number of primary branches per plant. For nodes on main vine seven hybrids exhibited significant positive heterosis (Table 2). Heterobeltiosis was the highest positive in the cross P_2 x P_3 (28.46%) followed by P_4 x P_6 (27.42%), P_4 x P_5 (16.67%) and P_2 x P_4 (16.13%). The range of positive heterosis was 1.92 to 28.46% for this character. The highest significant negative heterosis was found in the cross P_5 x P_7 (-40.79%) followed by P_2 x P_7 (-13.82%). The present study corroborates with the findings of Banik (2003) in snake gourd, who illustrated positive better parent heterosis for the increasing number of nodes on main vine. Among the cross combinations, fourteen crosses were performed earlier harvest than their better parents (Table 2). Negative heterosis ranged from -0.94 to -16.37% over better parents. The highest significant negative heterosis was observed in the crosses P_2 x P_5 and P_3 x P_5 (-16.37% for each cross) followed by P_2 x P_7 (-12.05%), P_5 x P_7 (-9.29%), P_1 x P_5 (-8.41%), P_2 x P_6 (-7.59%) and P_5 x P_6 (-6.19%), indicating desirable combinations for early harvest. On the other hand, the cross P_1 x P_3 (5.07%) showed the highest significant positive heterobeltiosis for days to 1st harvest followed by P_1 x P_4 and P_1 x P_7 (4.15% for each cross). Varghese (1991) in snake gourd noticed the extent of negative heterosis for days to first fruit harvest which supports the present findings. These results support the reports of Islam (2008) in hyacinth bean who found negative better parent heterosis for early harvest. Negative heterosis ranged from -0.77 to -60.77% over better parents for minimum fruit fly infestation (Table 2). The highest significant negative heterosis observed in the crosses P_1 x P_4 (-60.77%) followed by P_3 x P_7 (-38.10%), indicating desirable combinations for minimum fruit fly infestation. On the other hand, the cross P_4 x P_5 (86.08%) showed the highest significant positive heterobeltiosis for this trait followed by P_2 x P_5 (56.19%) and P_4 x P_6 (36.92%).

Table 2. Percent heterosis over better parent for growth, harvest and fruit fly infestation (%) characters in snake gourd

Crosses	Vine length (m)	Primary branches per plant	Nodes on main vine	Days to 1st harvest	Fruit fly infestation (%)
P_1 x P_2	-14.00	10.00	0.00	1.79	10.79
P_1 x P_3	10.74	40.00**	-0.82	5.07**	13.82
P_1 x P_4	38.21**	-16.67	13.98*	4.15**	-60.77**
P_1 x P_5	18.42	8.33	-6.25	-8.41**	-7.73
P_1 x P_6	1.09	-9.09	-10.9	-4.61**	9.76
P_1 x P_7	2.70	9.09	-9.21	4.15**	0.68
P_2 x P_3	20.00*	80.00**	28.46**	0.89	17.27
P_2 x P_4	23.98**	8.33	16.13**	-5.36**	-17.27
P_2 x P_5	1.97	0.00	-6.92	-16.37**	56.19**
P_2 x P_6	-4.37	18.18	4.49	-7.59**	-29.5
P_2 x P_7	-21.62**	9.09	-13.82*	-12.05**	-12.24
P_3 x P_4	21.95**	-8.33	3.23	0.00	-0.77
P_3 x P_5	28.95**	-8.33	13.28	-16.37**	-3.61
P_3 x P_6	-12.57	-27.27*	-7.69	-0.94	22.5
P_3 x P_7	10.81	27.27*	15.79*	-1.90	-38.10*
P_4 x P_5	39.02**	16.67	16.67**	0.00	86.08**
P_4 x P_6	55.69**	0.00	27.42**	-2.36	36.92*
P_4 x P_7	31.71**	-8.33	13.44*	-3.30*	17.01
P_5 x P_6	23.50**	8.33	8.33	-6.19**	1.03
P_5 x P_7	-4.32	-8.33	-40.79**	-9.29**	11.34
P_6 x P_7	7.57	-9.09	1.92	-3.30*	40.82

** Significant at 1% level, * Significant at 5% level, Without star indicates non-significant.

Nine out of twenty-one crosses showed significant positive and seven hybrids showed significant negative heterosis individual fruit weight (Table 3). Positive heterosis was ranged from 2.41 to 25.00% over better parents. Maximum positive heterosis was observed in the cross P_3 x P_7 (25.00%) followed by P_4 x P_5 (20.73%), P_5 x P_6 (15.81%), P_3 x P_5 (15.41%), P_5 x P_7 (15.41%). However, the cross P_1 x P_7 (-25.60%) showed the highest significant negative heterobeltiosis for individual fruit weight followed by P_1 x P_4 (-23.74%) and P_1 x P_5 (-16.05%). The present study is in agreement with the findings of Banik (2003) in snake gourd, Jha *et al.* (2009) and Ahmed (2016) in pumpkin as well as Pandey *et al.* (2005) in ash gourd, who obtained positive better parent heterosis for increasing fruit weight.

Table 3. Percent heterosis over better parent for fruit and yield characters in snake gourd

Crosses	Fruit			
	Weight (g)	Number/ plant	Fruit yield/ plant (kg)	Fruit yield/ ha (t)
P_1 x P_2	4.64	7.20	12.19*	12.19*
P_1 x P_3	7.43**	18.12**	40.26**	40.27**
P_1 x P_4	-23.74**	-23.03**	-28.84**	-28.85**
P_1 x P_5	-16.05**	-3.20	-18.84**	-18.83**
P_1 x P_6	-5.70*	-21.50**	-12.62**	-12.63**
P_1 x P_7	-25.60**	11.20	-17.22**	-17.23**
P_2 x P_3	-10.23**	21.01**	20.13**	20.12**
P_2 x P_4	-12.78**	-23.03**	-21.73**	-21.73**
P_2 x P_5	2.41	24.00**	27.27**	27.30**
P_2 x P_6	10.09**	7.00	29.70**	29.67**
P_2 x P_7	-14.35**	44.80**	24.20**	24.20**
P_3 x P_4	10.95**	-21.71**	-13.01*	-13.02*
P_3 x P_5	15.41**	8.70	39.55**	39.55**
P_3 x P_6	-4.54	-17.00**	-20.98**	-21.00**
P_3 x P_7	25.00**	13.04*	41.20**	41.20**
P_4 x P_5	20.73**	7.89	30.22**	30.23**
P_4 x P_6	13.46**	-38.00**	-29.77**	-29.79**
P_4 x P_7	-0.50	-44.08**	-44.25**	-44.24**
P_5 x P_6	15.81**	-22.50**	-10.25*	-10.28*
P_5 x P_7	15.41**	16.13**	76.46**	76.42**
P_6 x P_7	-4.38	-21.50**	-24.99**	-25.01**

** Significant at 1% level, * Significant at 5% level, Without star indicates non-significant.

Six crosses exhibited significant positive and nine hybrids showed significant negative heterosis for fruits per plant (Table 3). Positive heterosis ranged from 7.00 to 44.80% over better parents. The highest positive heterosis was found in the cross P_2 x P_7 (44.80%) followed by P_2 x P_5 (24.00%), P_2 x P_3 (21.01%) and P_1 x P_3 (18.12%). On the other hand, the cross P4 x P7 (-44.08%) showed the highest significant negative heterobeltiosis for fruits per plant followed by P_4 x P_6 (-38.00%), P_1 x P_4 (-23.03%), P_2 x P_4 (-23.03%), P_5 x P_6 (-22.50%), P_3 x P_4 (-21.71%) and P_6 x P_7 (-21.50%). These results support the findings of Banik (2003) and Varghese (1991) in snake gourd, Hussien *et al.* (2015) and Jahan *et al.* (2012) in pumpkin as well as Pandey *et al.* (2005) in ash gourd who displayed positive better parent heterosis for improving fruits per plant. Among the snake gourd cross combinations, ten hybrids showed significant positive and eleven showed significant negative heterosis for yield of fruits per plant (Table 3). Positive heterosis ranged from 12.19 to 76.46% over better parents. The maximum positive heterosis was observed in the cross P_5 x P_7 (76.46%) followed by P_3 x P_7 (41.20%), P_1 x P_3 (40.26%), P_3 x P_5 (39.55%), P_4 x P_5 (30.22%), P_2 x P_6 (29.70%), P_2 x P_5 (27.27%), P_2 x P_7 (24.20%) and P_2 x P_3 (20.13%). On the contrary, the cross P_4 x P_7 (-44.25%) showed the highest significant negative heterobeltiosis for yield of fruits per plant. These results are in consonance with the findings of Podder *et al.* (2018) and Ahmed *et al.* (2000) in snake gourd, Kumari *et al.* (2020) in bitter gourd who recorded positive better parent heterosis for enhancing fruit yield per plant.

Out of twenty-one snake gourd crosses, ten hybrids showed significant positive and eleven showed significant negative heterosis for yield of fruits per hectare (Table 3). Positive heterosis ranged from 12.19 to 76.42% over better parents. The highest positive heterosis was observed in the cross P_5 x P_7 (76.42%) followed by P_3 x P_7 (41.20%), P_1 x P_3 (40.27%), P_3 x P_5 (39.55%), P_4 x P_5 (30.23%) P_2 x P_6 (29.67%), P_2 x P_5 (27.30%), P_2 x P_7 (24.20%) and P_2 x P_3 (20.12%). On the contrary, the cross P_4 x P_7 (-44.24%) showed the maximum significant negative heterobeltiosis for yield of fruits per hectare followed by P_4 x P_6 (-29.79%), P_1 x P_4 (-28.85%), P_6 x P_7 (-25.01%), P_2 x P_4 (-21.73%) and P_3 x P_6 (-21.00%). The present study corroborates with the findings of Podder *et al.* (2010) in snake gourd, Chauhan *et al.* (2018) in sponge gourd, Ene *et al.* (2019) and Mule *et al.* (2012) in cucumber who illustrated positive better parent heterosis for increasing yield of fruits per hectare. Fourteen snake gourd crosses showed significant negative heterotic effect but three combination exhibited non-significant positive heterosis for fruit length (Table 4). The combination P_1 x P_7 (-38.10%) had the highest significant negative heterobeltiosis for fruit length followed by P_1 x P_5 (-28.57%), P_1 x P_4 (-27.89%), P_2 x P_7 (-22.48%), P_3 x P_7 (-15.93%), P_1 x P_6 (-15.65%), P_6 x P_7 (-15.38%), P_3 x P_4 (-15.04%). These results are in agreement findings of Banik (2003) in snake gourd. Out of twenty-one crosses, only two hybrids showed significant positive and six showed significant negative heterosis for fruit diameter (Table 4). Positive heterosis ranged from 0.41 to 11.11% over better parents. The maximum positive heterosis was observed in the cross P_4 x P_7 (11.11%) followed by P_2 x P_5 (7.88%). On the contrary, the cross P_3 x P_6 (-15.60%) showed the highest significant negative heterobeltiosis for fruit diameter followed by P_5 x P_6 (-11.35%), P_1 x P_6 (-9.93%), P_1 x P_5 (-9.40%), P_6 x P_7 (-7.80%) and P_2 x P_6 (-6.38%). The present study is in agreement with the findings of Podder *et al.* (2018) in snake gourd, Quamruzzaman *et al.* (2019) in bottle gourd, Hussien *et al.* (2015) in pumpkin, who obtained both positive and negative better parent heterosis for fruit diameter. Among all the crosses, only two hybrids showed significant positive and four exhibited significant negative heterosis for fruit flesh thickness (Table 4). Positive heterosis ranged from 0 to 23.53% over better parents. The maximum positive heterosis was observed in the cross P_1 x P_7 (23.53%) followed by P_5 x P_6 (20.00%). On the other hand, the cross P_2 x P_4 (-22.22%) showed the highest significant negative heterobeltiosis for fruit flesh thickness followed by P_1 x P_5 (-17.65%), P_4 x P_5 (-16.67%), and P_4 x P_7 (-16.67%). The present study corroborates with the findings of Ahmed (2016) in pumpkin, who illustrated positive better parent heterosis for increasing fruit flesh thickness. Among twenty-one the crosses, only one hybrid P_2 x P_5 (33.33%) showed significant positive and three P_1 x P_4, P_4 x P_5, P_4 x P_6 (-18.18% for each hybrids) exhibited significant negative heterosis for locules per fruit (Table 4). The rest of the crosses showed insignificant heterosis for this trait. Positive heterosis is desirable to increase locules per fruit. Among the cross combinations, eight crosses performed lower number of seeds than their better parents for number of seeds per fruit (Table 4). Negative heterosis ranged from -1.13 to -32.57% over better parents. The highest significant negative heterosis observed in the crosses P_3 x P_4 (-32.57%) followed by P_2 x P_3 (-23.12%) and P_5 x P_7 (-17.84%), indicating desirable combinations for minimum seeds per fruit. On the other hand, the cross P_2 x P_4 (45.70%) showed the highest significant positive heterobeltiosis for seeds per fruit followed by P_4 x P_5 (35.14%), P_1 x P_4 (28.25), P_4 x P_7 (24.26%), and P_3 x P_6 (21.14%). These results are in consonance with the findings of Banik (2003) in snake gourd, who recorded negative better parent heterosis for reducing number of seeds per fruit. Three of the crosses showed significant positive heterotic effect for 100-seed weight and the combination P_4 x P_6 had maximum 100-seed weight (32.10%) followed by P_3 x P_4 (26.88%) and P_2 x P_3 (25.69%). Positive heterosis ranged from 0.22 to 32.10%. However, the combination P_1 x P_4 (-19.20%) had the only significant negative heterobeltiosis for 100-seed weight. Banik (2003) reported similar results in snake gourd for 100-seed weight for increasing the seed weight.

Table 4. Percent heterosis over better parent for fruit and seed characters in snake gourd

Crosses	Fruit				Seeds	
	Length (cm)	Diameter (cm)	Flesh thickness (cm)	Locules	Number/ fruit	100-seed weight (g)
P_1 x P_2	-0.68	0.41	0.00	10.00	-1.61	1.85
P_1 x P_3	-9.52**	5.04	0.00	-10.00	5.08	-2.74
P_1 x P_4	-27.89**	-4.76	-5.56	-18.18*	28.25**	-19.20*
P_1 x P_5	-28.57**	-9.40**	-17.65**	-10.00	3.78	-7.01
P_1 x P_6	-15.65**	-9.93**	0.00	0.00	-9.03	1.38
P_1 x P_7	-38.10**	-4.92	23.53 **	0.00	-1.13	-0.45
P_2 x P_3	-8.53**	-1.24	-11.76	11.11	-23.12**	25.59**
P_2 x P_4	-14.73**	-2.38	-22.22 **	9.09	45.70**	-0.68
P_2 x P_5	-13.18**	7.88*	0.00	33.33**	6.45	-7.54
P_2 x P_6	3.10	-6.38*	-5.88	11.11	2.15	-1.93
P_2 x P_7	-22.48**	-2.46	5.88	11.11	-6.99	1.58
P_3 x P_4	-15.04**	5.16	0.00	9.09	-32.57**	26.88**
P_3 x P_5	-7.08*	5.88	6.67	0.00	8.11	2.97
P_3 x P_6	4.42	-15.60**	0.00	0.00	21.14**	0.22
P_3 x P_7	-15.93**	1.64	12.5	0.00	8.57	-0.71
P_4 x P_5	-2.02	-2.38	-16.67 **	-18.18*	35.14**	-8.75
P_4 x P_6	4.81	-4.96	5.56	-18.18*	0.00	32.10**
P_4 x P_7	-13.13**	11.11**	-16.67 **	9.09	24.26*	-8.48
P_5 x P_6	-0.96	-11.35**	20.00 **	0.00	-10.27	-6.5
P_5 x P_7	-6.45	-1.64	0.00	11.11	-17.84*	-9.17
P_6 x P_7	-15.38**	-7.80**	6.25	11.11	15.60	-3.14

** Significant at 1% level, * Significant at 5% level, Without star indicates non-significant.

Conclusion

Heterosis study can play a pivotal role in increasing the yield and quality of vegetable crops. So, to find out high heterotic combination for better hybrids, significant heterosis was observed for most of the characters of snake gourd. Considering days to 1st female flower open, fruit weight, fruits per plant, fruit yield per plant, fruit yield per hectare, fruit length and fruit diameter, the best heterotic crosses were P_1 x P_3, P_2 x P_6, P_3 x P_7 and P_6 x P_7. Such crosses could also be used for the exploitation of better parent heterosis and evaluation in the desirable direction for developing improved hybrids.

References

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

Ahmed, M. S., M. G. Rasul, M. K. Bashar and A. S. M. Mian. 2000. Variability and heterosis in snake gourd *(Trichosanthes anguina* L.). *Bangladesh J. Pl. Breed. Genet.* **13**(1): 27-32.

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

BBS. 2020. Yearbook of Agricultural Statistices-2019. Bangladesh Bureau of Statistics. Ministry of Planning. Govt. of the Peoples Republic of Bangladesh. Dhaka.

Chauhan, V. B. S., D. K. Singh and H. Choudhary. 2018. Studies on heterosis for yield and its contributing traits in sponge gourd (*Luffa cylindrica* Roem.). *Int. J. Curr. Microbiol. App. Sci.* **7**(12): 223-230.

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

FAO. 2015. Food and Agriculture Data. Food and Agricultural Organization, Rome, Italy.

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

Glover, M. A., D. B. Willmot, L. L. Darrah, B. E. Hibbard and X. Zhu. 2005. Diallel analyses of agronomic traits using Chinese and US maize germplasm. *Crop Sci.* **45**(3):1096–1102.

Hussien, A. H. and A. A. Hamed. 2015. Diallel analysis for studying heterosis and combining ability of some economical yield traits in pumpkin. *J. Pl. Prod.* **6**(3): 261-270.

Islam, M. S. 2008. Genetic diversity, combining ability and heterosis in hyacinth bean. PhD Dissertation. Department of Horticulture. BSMRAU, Gazipur, Bangladesh.

Jahan, T. A., A. K. M. A. Islam, M. G. Rasul, M. A. K. Mian and M. M. Haque. 2012. Heterosis and qualitative and quantitative characters in sweet gourd (*Cucurbita moschata* Duch ex. Poir.). *African J. Food Agril. Nutri. Dev.* **12**(3): 6186-6198.

Jha, A., S. Pandey, M. Rai, D. S. Yadav and T. B. Singh. 2009. Heterosis in relation to combining ability for flowering behavior and yield parameters in pumpkin. *Veg. Sci.* **36**(3 suppl.): 332-335.

Kumari, M., J. Kumar, K. Kant, B. K. Singh, C. K. Bagchi, A. Kumari, R. kumari, M. Kumar, V. K. Singh, S. Shree, A. Bhardwaj and A. Kumar. 2020. Heterosis in bitter gourd (*Momordica charantia* L.) for yield and yield related traits. *J. Pharmacogn. Phytochem.* **9**(1): 1235-1239.

Mule, P. N., V. Khandelwal, V. A. Lodam, D. A. Shinde, P. P. Patil and A. B. Patil. 2012. Heterosis and combining ability in cucumber (*Cucumis sativus* L.). Madras Agric. J. **99**(7-9): 420-423.

Pandey, S., M. Rai, B. Singh and A. K. Pandey. 2005. Heterosis and combining ability in ash gourd (*Benincasa hispida*). *Veg. Sci.* **32**(1): 33-36.

Podder, R., A. K. M. Aminul Islam, M. G. Rasul, M. A. K. Mian and J. U. Ahmed. 2018. Heterosis in snake gourd (*Trichosanthes cucumerina* L.). *Ann. Bangladesh Agric.* **22** (1): 29-35.

Podder, R., M. G. Rasul, A. K. M. A. Islam, M. A. K. Mian and J. U. Ahmed. 2010. Combining ability and heterosis in snake gourd (*Trichosanthes cucummina* L.). *Bangladesh J. Pl. Breed. Genet.* **23** (2): 01-06.

Quamruzzaman, A. K. M, M. M. R. Salim, L. Akhter, T. Hasan, K. Mazed and M. A. Z. Chowdhury. 2019. Genetic architecture of yield in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *Agril. Sci.* **10**: 567-576. [https://doi.org/10.4236/as.2019.104045].

Rahman, A. K. M. M. 2004. Genotype-environment interaction, heterosis and sex modification in snake gourd (*Trichosanthes anguina* L.). PhD Dissertation. Department of Genetics and Plant Breeding, BSMRAU, Salna, Gazipur, Bangladesh.

Rashid, M. M. 1993. Shabjibiggyan (In Bengali). 2nd ed. Rashid Publishing House, 94, Old DOHS, Dhaka-1206. p.344.

Riggs, T. J. 1988. Breeding F_1 hybrid varieties of vegetables. *J. Hort. Sci.* **63**: 362-69.

Singh, A. K. and B. S. Asati. 2011. Combining ability and heterosis studies in tomato under bacteria wilt condition. *Bangladesh J. Agril. Res.* **36**(2): 313–318.

Varghese, P. 1991. Heterosis in snake gourd (*Trichosanthes anguina* L.). MS Thesis. Kerala Agril. Univ. Kerala. India.

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GROWTH, YIELD AND PROFITABILITY OF SUMMER COUNTRY BEAN (*LABLAB PURPUREUS* L.) AS INFLUENCED BY EXOGENOUS APPLICATION OF PLANT GROWTH REGULATORS

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Abstract

A field experiment on summer country been (var. BARI Shim-7) was conducted at the Research Field of Plant Physiology Section of Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur, during the summer season of 2018 and 2019 to study the effect of exogenously applied plant growth regulators (PGRs) on growth, yield and profitability of the crop. The experiment was consisted *of* four levels of NAA (15, 30, 45 and 60 ppm), three of CCC (200, 300 and 400 ppm), two of GA_3 (20 and 30 ppm) and tap water as control. Average results of two years showed that all growth regulators performed better in respect of all characters studied over control. At 1st fruit set vine length (3.15 m) and number of leaves/plant (327.96), at last harvest stem girth (24.53 mm) and vine length (4.89 m), and plant dry matter (17.24%), number of pods/cluster (6.41), pod length (8.78 cm), number of pods/plant (351.30), individual pod weight (6.26 g) and pod set (38.13%) were the maximum in 60 ppm NAA followed by 45 ppm NAA and 200 ppm CCC. The maximum mean pod yield (10.65 t/ha) was obtained with the application of 60 ppm NAA closely followed by 45 ppm NAA (10.50 t/ha). Application of 200 ppm CCC also produced higher pod yield (8.75 t/ha) than that of control. Application of 60 ppm NAA also gave the maximum gross return (Tk. 532500/ha), gross margin (Tk. 3361248/ha) and BCR (3.11).

Keywords: Country bean, *Lablab purpureus,* PGRs, yield, BCR.

Introduction

Country bean or hyacinth bean [*Lablab purpureus* (L.) Sweet] belonging to the family *Fabaceae* is a tropical vine crop and one of the most important protein rich vegetables grown in Bangladesh during both summer and winter seasons. It is popularly known as 'shim' in our country. The pods (fruits) are consumed as vegetables in its immature stage. The pods and seeds contain large amount of various vitamins and minerals.

During summer season some problems such as delayed and erratic flowering and low pod set are frequent in country bean. Hazra and Som (1991) reported that 75-

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90 % flower shedding occurs in country bean. Kolle (2010) reported that country bean is faced with problem of flower shedding which is a major constraint for yield in this crop and about 10-20% of the flowers only develop into mature pods. Sometimes farmers/growers face the problems that heavy flower dropping occurs in plants of country bean var. BARI Shim-7 and pod set percent in the inflorescence is not up to the mark. BARI has developed 10 high yielding varieties (HYVs) of country bean, among which BARI Shim-7 is a popular summer country bean variety.

Application of plant growth regulators (PGRs) is known as one of the most effective tools in agriculture for increasing horticultural crop production. Moreover, PGRs are known to improve physiological efficiency including photosynthetic ability of plants and offer a significant role in realizing higher crop yield. The PGRs are also known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates, thereby increasing the productivity of the crop (Khan and Mazed, 2018).

Application of plant growth regulators has been widely recommended to overcome problems such as low flowering and poor pod set in vegetable crops (Arora *et al*., 1992; Resmi and Gopalakrishnan, 2004). Maheshbhai (2006) was obtained the highest yield of country bean with the spray of NAA @ 40 ppm. The present study was; therefore, undertaken to evaluate the effect of selected plant growth regulators on vegetative growth, fruit set, pod yield and profitability of summer country bean.

Materials and Methods

The experiment was conducted at the field of Plant Physiology Section of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh during summer seasons of 2018 and 2019. The treatments consisted of four levels of NAA concentrations (15, 30, 45 and 60 ppm), three of CCC (200, 300 and 400 ppm), two of GA_3 (20 and 30 ppm) and control (where only tap water was sprayed). At first some review of literatures were collected about plant growth regulators (PGRs) (NAA, GA_3 and CCC) influence on legume crops including country bean. Based on their better results the doses of each PGR were selected (Arora *et al*., 1992; Rajani *et al.,* 2016; Noor *et al*., 2017; Rahman *et al.,* 2018; Shah and Prathapasenan, 1991; Maheshbhai, 2006; Ullah *et al*., 2007). Using electronic balance 250 mg each of gibberellic acid and naphthalene acetic acid were accurately weighed out and dissolved in a few ml of ethyl alcohol (95%) separately. The two solutions thus prepared were transferred to two 250 ml volumetric flasks. Then the volume of the solutions were made upto 250 ml with distilled water to get the 1000 ppm stock solution of GA_3 and NAA. On the other hand, 2 ml of CCC (50% aqueous solution) was accurately measured by using 5 ml pipette and dissolved in 100 ml distilled water in a 1000 ml volumetric flask and then the volume of the solution was made upto 1000 ml with distilled water to get the 1000 ppm CCC stock solution. Finally, the required lower concentrations of NAA (15, 30, 45 and 60 ppm), GA_3 (30 and 40 ppm) and CCC (200, 300 and 400 ppm) were prepared from the above three stock solutions by using the formula: V_1 x S_1 = V_2 x S_2; where, S_1: concentration of stock solution (1000 ppm) of NAA or GA_3 or CCC, V_1 = volume of stock solution NAA or GA_3 or CCC (which we have to be calculated), S_2: concentration of NAA or GA_3 or CCC needed and V_2: amount of solution of NAA or GA_3 or CCC required for spray. Then calculated amount (V_1) of NAA or GA_3 or CCC was taken from stock solution and poured into three separate volumetric flasks of known volume and then required amount of distilled water was added into these three flasks.

The experiment was laid out in a Randomized Complete Block Design with three replications. The unit plot size was 2.00 m x 1.80 m (3.6 m^2) having 2 plants. Each unit plot had single row of 2.0 m long with plant to plant space of 1.0 m. Horizontal trellises were made with bamboo separately for support of the two plants. The variety used in the experiment was BARI Shim-7. Thirteen and 12 day-old seedlings were transplanted on 19 April 2018 and 07 April 2019, respectively. Aqueous solutions of different NAA, CCC and GA_3 were prepared and sprayed as per treatment thrice on the plants i.e. 2 weeks after transplanting, at 1st flowering and three weeks after 1st flowering. Seedlings were raised in poly bag (6 cm x 7 cm). First flowering was appeared at 44 and 42 days after seed sowing during 2018 and 2019, respectively. Liquid soap was added in the solutions as surfactant for uniform spread of chemicals and moisture on leaves. Fertilizers were applied as recommended by Nasreen *et al.* (2015) along with cowdung @ 5 t/ha. Weeding was done when required. To control insects and diseases, protection measures were taken as necessity.

Pods were harvested during 24 June,29 August in 2018 and 25 June,16 August in 2019.The data were recorded on stem girth at last harvest (mm), vine length at 1st fruit set (m) and last harvest (m), number of leaves/plant at 1st suit set leaf length (cm), leaf breadth (cm), plant dry matter at last harvest % (with roots, leaves, stems and branches), soil plant analysis development (SPAD) value, number of pods/cluster, pod length (cm), pod width (cm), individual pod weight (g), number of pods/plant, pod set (%) and pod yield/plant (g). The data on SPAD value was taken at fruiting stages of each year with a SPAD meter (Brand: Minolta 502). Recorded data were statistically analyzed by MSTAT-C software and mean separation was done by LSD test at 5% level of probability. Benefit cost analysis was also done.

Results and Discussion

Growth characters and relative chlorophyll content (SPAD value)

Significant variations due to exogenously application plant growth regulators were found in respect of vine length at 1st fruit set, number of leaves/plant at 1st fruit set, leaf length, leaf breadth, stem girth at last harvest, vine length at last harvest, plant dry matter at last harvest, plant dry matter and SPAD value (Table 1). Application of NAA @ 60 ppm gave the maximum vine length at 1st fruit set (3.19 m in 2018 and 3.10 m in 2019) and vine length at last harvest (4.90 m in 2018 and 4.87 m in 2019) and spraying of CCC of all concentrations showed inhibitory effect on vine length. Number of leaves /plant at 1st harvest (330.92 in 2018 and 325.00 in 2019), leaf length (16.22 cm in 2018 and 15.72 cm in 2019) and leaf breadth (14.25 cm in 2018 and 13.78 cm in 2019) were found the maximum when NAA @ 60 ppm was sprayed whereas, the lowest from control. The maximum stem girth at last harvest was obtained from 60 ppm NAA (24.45 mm in 2018 and 24.61 mm in 2019) which was significantly better than other treatments followed by 45 ppm NAA (23.15 mm in 2018 and 23.40 mm in 2019). The stem girth was lowest in control (17.50 mm in 2018 and 17.46 mm in 2019). Plant dry matter at last harvest was the maximum from 60 ppm NAA (18.03% in 2018 and 16.45% in 2019) followed by 45 ppm NAA (17.41% in 2018 and 15.89% in 2019) and the minimum from 15 ppm NAA (15.14% in 2018 and 13.82% in 2019). The maximum SPAD value was recorded from CCC @ 200 ppm (38.34 in 2018 and 38.35 in 2019) followed by 300 ppm CCC (38.11 in 2018 and 38.12 in 2019) and 400 ppm CCC (38.08 in 2018 and 39.09 in 2019). Shah and Prathapasenan (1991) obtained the maximum chlorophyll content (47.18 SPAD value) over control in field pea from the foliar spray of cycocel at 500 ppm. Pramoda and Sajjan (2018) also obtained the highest plant height and SPAD value with the application of 40 ppm NAA in bushy type country bean. On contrary, Kumanan *et al.* (2020) also recorded the highest plant height from the foliar spray of 100 ppm NAA followed by 50 ppm NAA in bushy country bean.

Table 1. Effect of plant growth regulators on growth characters and leaf SPAD value of summer country bean var. BARI Shim-7 during 2018 and 2019

Treatment	Vine length at 1st fruit set (m)		Number of leaves/plant at 1st fruit set		Leaf length (cm)		Leaf breadth (cm)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_0	2.52	2.30e	278.94	270.50	14.26	13.82	12.51	11.97
T_1	2.57	2.46	282.85	274.32	14.61	14.17	12.61	12.15
T_2	2.70	2.60	289.53	280.51	15.35	14.88	12.78	12.27
T_3	2.88	2.80	314.09	309.58	15.40	14.94	13.87	13.23
T_4	3.19	3.10	330.92	325.00	16.22	15.72	14.25	13.78
T_5	2.49	2.35d	309.06	303.22	15.44	14.98	13.01	12.95
T_6	2.47	2.32e	305.62	301.69	15.25	14.78	13.36	12.76
T_7	2.30	2.21f	304.14	299.60	15.00	14.54	14.02	13.37
T_8	2.74	2.66	288.94	308.54	15.46	15.00	14.05	13.40
T_9	2.78	2.77	313.99	275.65	15.64	15.17	14.21	13.57
LSD (0.05)	0.11	0.13	9.51	10.20	0.68	0.57	0.15	0.16
CV (%)	3.74	3.22	4.89	5.01	3.56	3.74	2.90	2.84

T_0 = control, T_1 = 15 ppm NAA, T_2 = 30 ppm NAA, T_3 = 45 ppm NAA, T_4 = 60 ppm NAA, T_5 = 200 ppm CCC, T_6 = 300 ppm CCC, T_7 = 400 ppm CCC, T_8 = 20 ppm GA_3, T_9 = 30 ppm GA_3, Y_1 = 2018, Y_2 = 2019.

Table 1. Cont'd

Treatment	Stem girth at last harvest (mm)		Vine length at last harvest (m)		Plant dry matter (%)		SPAD value	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_0	17.50	17.46	4.10	4.08	15.68	14.31	33.42	33.46
T_1	17.62	17.65	4.00	4.22	15.14	13.82	33.31	33.22
T_2	18.40	18.50	4.30	4.28	15.37	14.02	34.46	34.35
T_3	23.15	23.40	4.60	4.56	17.41	15.89	35.52	35.43
T_4	24.45	24.61	4.90	4.87	18.03	16.45	35.95	35.90
T_5	17.58	17.49	3.98	3.80	16.85	15.38	38.34	38.35
T_6	17.35	17.26	3.95	3.90	15.91	14.52	38.11	38.12
T_7	17.20	17.24	3.72	3.71	16.13	14.72	38.08	38.09
T_8	17.58	17.62	4.40	4.35	16.52	15.08	34.50	34.43
T_9	17.70	17.67	4.50	4.46	16.96	15.48	34.52	34.50
LSD (0.05)	0.10	0.12	0.09	0.11	0.13	0.14	0.12	0.13
CV (%)	3.29	4.01	10.61	9.05	4.61	4.25	5.32	5.01

T_0 = control, T_1 = 15 ppm NAA, T_2 = 30 ppm NAA, T_3 = 45 ppm NAA, T_4 = 60 ppm NAA, T_5 = 200 ppm CCC, T_6 = 300 ppm CCC, T_7 = 400 ppm CCC, T_8 = 20 ppm GA_3, T_9 = 30 ppm GA_3, Y_1 = 2018, Y_2 = 2019.

Yield attributes

Application of different growth regulators showed significant influence on number of pods/cluster, pod length, pod width, individual pod weight, number of pods/plant and pod set (%) (Table 2). The maximum number of pods/cluster was harvested with the application of 60 ppm NAA (6.58 in 2018 and 6.25 in 2019) which was statistically similar to 45 ppm NAA (6.54 in 2018 and 6.21 in 2019 and the minimum number from the control (5.13 in 2018 and 4.87 in 2019) (Table 2). The maximum pod length was obtained from NAA @ 60 ppm (8.82 cm in 2018 and 8.73 cm in 2019) which was statistically identical to 45 ppm NAA (8.81 cm in 2018 and 8.72 cm in 2019). The lowest pod length was noticed from control (7.78 cm in 2018 and 7.76 cm in 2019). Application of 200 ppm CCC produced the maximum pod width (3.25 cm in 2018 and 3.18 cm in 2019) which was statistically identical to CCC @ 300 ppm (3.21 cmin 2018 and 3.14 cm in 2019) and CCC @ 400 ppm (3.20 cm in 2018 and 3.14 cm in 2019) and the lowest value with control (2.40 cm in 2018 and 2.35 cm in 2019). Application of NAA @ 60 ppm produced the maximum individual pod weight (6.42 g in 2018 and 6.10 g in 2019), which was statistically similar to NAA @ 45 ppm (6.41 g in 2018 and 6.08 g in 2019) and GA3 @ 30 ppm (6.20 g in 2018 and

5.89 g in 2019) and GA3 @ 20 ppm (6.15 g in 2018 and 5.84 g in 2019). The lowest individual pod weight was with control (5.20 g in 2018 and 4.94 g in 2019). The maximum pod set was noticed in 60 ppm NAA (39.09% in 2018 and 37.17% in 2019) followed by NAA @ 45 ppm (38.08% in 2018 and 36.21% in 2019). Application of GA_3 @ 30 ppm (38.06% in 2018 and 36.18% in 2018) gave identical pod set percentage like 45 ppm NAA. The lowest pod set was recorded in control (31.51% in 2018 and 29.97% in 2019) (Table 2). The maximum number of pods/plant was recorded with NAA @ 60 ppm (369.80 in 2018 and 332.80 in 2019) closely followed by NAA @ 45 ppm (365.80 in 2018 and 329.20 in 2018) and the lowest with control (240.90 in 2018 and 216.80 in 2019). Kumanan *et al*. (2020) also reported that maximum pod number/plant from spraying of 100 ppm NAA; whereas, Pramoda and Sajjan (2018) reported highest pod number/plant in country bean with the application of 40 ppm NAA. Shah and Prathapasenan (1991) obtained the highest pod number/plant over control in mung bean from the foliar spray of cycocel at 1000 ppm.

Table 2. Effect of plant growth regulators on yield and yield attributes of summer country bean var. BARI Shim-7 during 2018 and 2019

Treatment	Pods/cluster (no.)		Pod length (cm)		Pod width (cm)		Individual pod weight (g)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_0	5.13	4.87	7.78	7.76	2.40	2.35	5.20	4.94
T_1	5.44	5.17	7.90	7.82	2.71	2.65	6.18	5.87
T_2	5.47	5.20	8.20	8.11	2.72	2.66	6.25	5.92
T_3	6.54	6.21	8.81	8.72	2.82	2.76	6.41	6.08
T_4	6.58	6.25	8.82	8.73	2.83	2.77	6.42	6.10
T_5	6.35	6.03	8.42	8.33	3.25	3.18	5.53	5.25
T_6	6.20	5.89	7.97	7.89	3.21	3.14	5.70	5.41
T_7	5.33	5.06	7.80	7.72	3.20	3.14	5.60	5.32
T_8	5.53	5.25	8.18	8.10	2.80	2.74	6.15	5.84
T_9	5.78	5.49	8.25	8.17	2.84	2.78	6.20	5.89
LSD (0.05)	0.10	0.11	0.15	0.17	0.18	0.17	0.29	0.30
CV (%)	7.81	6.29	3.72	3.14	3.65	2.81	3.40	3.32

T_0 = control, T_1 = 15 ppm NAA, T_2 = 30 ppm NAA, T_3 = 45 ppm NAA, T_4 = 60 ppm NAA, T_5 = 200 ppm CCC, T_6 = 300 ppm CCC, T_7 = 400 ppm CCC, T_8 = 20 ppm GA_3, T_9 = 30 ppm GA_3, Y_1 = 2018, Y_2 = 2019.

Table 2. Cont'd

Treatment	Pod set (%)		Pods/plant (no.)		Pod yield/plant (g)		Pod yield (t/ha)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_0	31.51	29.97	240.90	216.80	1168.60	864.07	7.15	3.29
T_1	33.97	32.30	247.20	222.50	1437.50	1227.07	8.62	5.04
T_2	33.07	31.45	281.30	253.20	1640.20	1409.00	9.84d	5.77
T_3	38.08	36.21	365.80	329.20	2227.20	1881.40	13.36	7.64
T_4	39.09	37.17	369.80	332.80	2255.50	1908.30	13.53	7.77
T_5	36.98	35.16	347.30	312.60	1883.60	1542.60	11.3	6.20
T_6	36.30	34.52	312.50	281.30	1692.90	1430.50	10.15	5.88
T_7	33.01	31.39	218.80	196.90	1165.00	984.70	6.99	4.00
T_8	36.32	35.18	250.40	225.40	1462.50	1237.40	8.77	5.05
T_9	38.06	36.18	278.80	250.92	1642.70	1389.30	9.86	5.66
LSD (0.05)	0.71	0..73	8.85	7.98	58.45	59.32	1.21	1.25
CV (%)	4.34	4.19	3.95	5.12	4.22	4.81	6.21	5.89

T_0 = control, T_1 = 15 ppm NAA, T_2 = 30 ppm NAA, T_3 = 45 ppm NAA, T_4 = 60 ppm NAA, T_5 = 200 ppm CCC, T_6 = 300 ppm CCC, T_7 = 400 ppm CCC, T_8 = 20 ppm GA_3, T_9 = 30 ppm GA_3, Y_1 = 2018, Y_2 = 2019.

Pod yield

The maximum pod yield/plant was recorded with NAA @ 60 ppm (2255.50 g in 2018 and 1908.30 g in 2019) which was statistically similar to 45 ppm NAA (2227.20 g in 2018 and 1881.40 g in 2019) and followed by 200 ppm CCC (1883.60 g in 2018 and 1542.60 g in 2019) (Table 2). The minimum pod yield/plant was noticed in control (1168.60 g in 2018 and 864.07 g in 2019). Ullah *et al.* (2007) recorded the maximum pod yield/plant in cowpea with the application of NAA @ 50 ppm. Dahmardeh *et al*. (2010) reported that application of planofix (NAA) helped in maintaining balance of endogenous hormones within the legume plants that decreased flower dropping in beginning and thereby resulted in increasing yield of faba bean. Application of 100 ppm NAA at the beginning of flower open in the first inflorescence was reported to improve fruit set and consequently yield (Anon. (2013).

Different growth regulators significantly influenced the pod yield/ha in both years (Table 2). In 2018, application of NAA @ 60 ppm produced the maximum pod yield (13.53 t/ha) which was statistically similar to NAA @ 45 ppm (13.36 t/ha) and the lowest in control (7.15 t/ha). In 2019, the maximum pod yield was in NAA @ 60 ppm (7.77 t/ha) which was statistically identical to NAA @ 45 ppm (7.64 t/ha). In 2018, the crop was good without any insects and diseases and 9 times pod harvest was possible; whereas, in 2019, the crop was attacked by insects and diseases which lowered pod yield/ha. Two years results indicate that pod yield/ha increased with the increasing of NAA levels. Pod yield also increased with the increase of GA_3 concentrations. Application of NAA @ 60 ppm, NAA @ 45 ppm and CCC @ 200 ppm gave 47.15, 46.48 and 36.72% higher yield over control in 2018 and 57.66, 56.94 and 44.05% higher yield over control in 2019, respectively (Table 2). Promada and Sajjan (2018) obtained the maximum pod yield /ha in bushy type hyacinth bean with the application of 100 ppm NAA followed by 45 ppm NAA, whereas Kumanan *et al*. (2020) obtained the highest pod yield/ha from the spray of 40 ppm NAA in bushy type hyacinth bean. On the other hand, Sahu and Verma (2020) obtained the highest pod yield/ha in 45 ppm NAA in yard long bean.

Economics

The maximum gross return was obtained from NAA @ 60 ppm (Tk. 5,32,500/ha) followed by NAA @ 45 ppm (Tk 5,25,000/ha) and CCC @ 200 ppm (Tk. 4,37,500.00/ha), CCC @ 300 ppm (Tk. 4,00,750/ha) and the minimum from the control (Tk. 2,61,000/ha) (Table 3). Gross margin was found the highest from NAA @ 60 ppm (Tk. 3,61,248/ha) followed by NAA @ 45 ppm (Tk. 3,53,871/ha) and CCC @ 200 ppm (Tk. 2,63,740/ha) while, the lowest in control (Tk. 90,240/ha). The maximum benefit cost ratio was obtained from NAA @ 60 ppm (3.11) followed by NAA @ 45 ppm (307) and CCC@ 200 ppm (2.52) while the minimum was in control (1.45).

Table 3. Benefit cost analysis of summer country bean production with the application NAA, CCC and GA_3 (Average of 2018 and 2019)

Treatment	Mean pod yield (t/ha)	Gross return (Tk./ha)	Cost of treatment Tk./ha)	Total cost of cultivation (Tk./ha)	Gross margin (Tk./ha)	Benefit-cost ratio (BCR)
T_0	5.22	261000	0.000	170760	90240	1.53
T_1	6.83	341500	0.123	170883	170617	2.00
T_2	7.81	390250	0.246	171006	219244	2.28
T_3	10.50	525000	0.369	171129	353871	3.07
T_4	10.65	532500	0.492	171252	361248	3.11
T_5	8.75	437500	3.000	173760	263740	2.52
T_6	8.02	400750	4.500	175260	225490	2.29
T_7	5.50	274750	4.000	174760	99990	1.57
T_8	6.91	345500	4.940	175700	169800	1.97
T_9	7.76	388000	7.410	178170	209830	2.18

T_0 = control, T_1 = 15 ppm NAA, T_2 = 30 ppm NAA, T_3 = 45 ppm NAA, T_4 = 60 ppm NAA, T_5 = 200 ppm CCC, T_6 = 300 ppm CCC, T_7 = 400 ppm CCC, T_7 = 20 ppm GA_3, T_7 = 30 ppm GA_3; Basic cost of cultivation: 170.76 thousand Tk:;1 kg produce: Tk 50.00.

Cost of PGRs;

1. Naphthalene Acetic Acid (NAA):Tk 2200.00/100 g
2. Cycocel (CCC)" Tk 2000.00/100 ml
3. Gibberellic acid: 500.00/g

Conclusion

Two years results revealed that application of growth regulators offers a scope for obtaining higher yield of summer country bean. However, spray of NAA @ 60 ppm at 2 weeks after transplanting i.e. 4 weeks after sowing, 1st flowering and 3 weeks after 1st flowering might be optimum for higher pod yield and economic return.

References

Anonymous. 2013. Dolichos bean-*Lablab purpureus* L. (Sweet.). University of Agricultural Sciences Bangalore, India. http://www.lablablab.org/html/ physiology.html.Accessed on 02.08. 2018.

Arora, S. K., M. L. Pandita and S. Pratap. 1992. Effect of plant growth substances on fruiting and yield of Indian bean (*Lablab purpureus* L.) cv. HD-18 and HD-60. *Haryana Agric. Univ. J. Res.* **22**:159-164.

Dahmardeh, M., M. Ramroodi and J. Valijadeh. 2010. Effect of plant density and culticars on growth, yield and yield component of Faba bean (*Viciafaba* L.). *Afri. J. Biotech*. **9** (50): 8643-8647.

Hazra, P. and M. G. Som.1991. Study of flower shedding and pod setting in dolichos bean [*Lablab purpureus* (L) Sweet]. *Bangladesh J. Bot*. **20** (1):85-86.

Khan, K. and M. Mazed. 2018. Chick pea responses to application of plant growth regulators, organics and nutrients. *Adv. Plant Agric. Res.***8** (3) 259-273.

Kolle, S. 2010. Effect of inorganic and organic fertilizers on growth and yield of dolichos lablab (*Lablab purpereus*). Project report. University of Nairobi College of Agriculture and Veterinary sciences, Faculty of Agriculture, Department of Crop Science and Crop Protection. 20pp.

Kumanan, K., M. Manikandan and. T. Saraswathi. 2020. Impact of plant growth regulators in Lablab (*Dolichos lablab* L.) on yield and yield contributing characters. *The Pharma Info. J*. **9** (12): 27-29.

Maheshbhai, N. V. 2006. Effect of triacontanol, NAA and GA_3 on growth and yield of Indian bean (*Lablab purpeureus*) cv. NavasariPapadi Selection 1. M.Sc Thesis. Horticulture Department, N. M. College of Agriculture, Navasari, Agriculture University. [http: // krishikosh .egranth.ac .in/handle /1/5810048448. Accessed on 03.08.2018].

Nasreen, S., M.A. Siddiky and R. Ahmed. 2015. Yield response of summer country bean to boron and molybdenum fertilizer. *Bangladesh J. Agril. Res*. **40** (1): 71-76.

Noor, F., F. Hossain and U. Ara. 2017. Effects of gibberellic acid (GA_3) on growth and yield parameters of French bean (*Phaseolus vulgaris* L.). *J. Asiat. Soc. Bangladesh Sci*. **43**(1): 49-60.

Pramoda and A.S. Sajjan. 2018. Effect of season and plant growth regulators on crop growth and yield in Dolichos bean [*Lablab purpureus* (L) Sweet] *Int. J. Pure App. Biosci*.**6** (4): 423-430. [Doi. http: // dx. Doi. org/10.18782/2320-7051-6507].

Rahman, M. M., A. Khan, M. M. Hasan, L.A. Banu, and M.H.K. Howlader. 2018. Effect of foliar application of gibberellic acid on different growth contributing characters of mungbean. Progressive *Agriculture*. **29** (3): 233-238.

Rajani, D., A. M. Rao, D. S. Hari and S. K. Karnam. 2016. Effect of plant growth regulators on growth, yield and yield attributes of French bean (*Phaseolus vulgaris* L.) CV. ArkaKomaL. *Andhra Pradesh J Agril*. Sci :**2** (4): 256-259.

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

Sahu, D. K. and A. Verma. 2020. Effect of plant growth regulators on growth and yield of yard long bean (*Vignaunguiculata* L.) var. Shefali. *Int. J. Chem. Stud.***8** (6): 1736-173. [DOI: https : // doi . org / 10.22271/ chemi. 2020. v8. i6y. 11016]

Shah and Prathapasenan. 1991. Effect of CCC on the growth and yield of mung bean (*Vignaradiata*[wilzeck var. Guj-20). *J. Agron. Crop Sci.* 166:40-47.

Ullah, M. J., Q.A. Fattah and F. Hossain. 2007. Response of growth, yield attributes and yield to the application of KNap and NAA in cowpea (*Vignaunguiculata*(l.) walp.). *Bangladesh J. Bo*t. **36**(2): 127-132.

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DISPOSAL PATTERN OF COLD AND HOME STORED POTATO IN SOME SELECTED AREAS OF BANGLADESH

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Abstract

A questionnaire survey was conducted with 600 growers in six potato growing areas of Bangladesh viz. Munshiganj, Barisal-Patuakhali, Dinajpur-Thakurgaon, Joypurhat, Jamalpur-Sherpur and Jashore-Chuadanga to collect a detailed information about potato storage at home and in cold storages along with their disposal pattern. The survey revealed that 55.2% growers store their potatoes in the cold storages. Due to the proximity of cold storages (within 1-10 km from the home/field) majority potato growers of Munshiganj (82%), Dinajpur-Thakurgaon (81%) and Joypurhat (70%) stored in cold storages. On the other hand, majority growers of Barisal-Patuakhali (88%) and Jamalpur-Sherpur (73%) could not store due to lack or long distance of cold storages. The growers disposed up their cold stored potatoes mainly by selling to local *paikers* at cold storage gate or by using as seed. While considering all areas, 56.0 % farmers stored potatoes at home in the studied areas. Majority farmers in Dinajpur-Thakurgaon (91%), Joypurhat (98%) and Jamalpur-Sherpur (65.0%) areas stored potato at home. Farmers of these areas stored upto 150 days at home because of cultivation of local varieties. Regarding disposal of home stored potatoes, the growers mainly sold to local *paikers* or at local market or used for own family consumption or by other means.

Keywords: Potato, Scenario, Disposal pattern, Cold and home storage, Bangladesh.

Introduction

Potato production in our country is increasing day-by-day. During 2018-19, the total potato production raised upto 9.7 million metric tons and the area coverage raised upto 0.47 million hectares with an average yield of 20.6 t/ha (BBS, 2020). However, potato production in Bangladesh has increased manifolds but other facilities has not yet been developed like marketing system, storage facilities and awareness of the farmers regarding use of production inputs e.g. fertilizers, pesticides etc. As a result, cost of production increases and farmers do not get appropriate price of the produced tubers in the seasonal time (Hossain, 2016). They cannot even store the produced potato in the cold storage with a view to selling the tubers in off-season at a higher price. At present, 364 cold storages has in operation in the country with hardly a capacity of storing 2.8 million metric tons potatoes in those cold storages (Hoque *et al.*, 2018). Considering the total cold storage capacity and production of potato in the country, about 25-30% of

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the total produced potatoes can be preserved in the cold stores (Rabbani *et al*., 2010; Hoque and Akter, 2014). So, storing potato is now-a-days number one problem in the country because of inadequate cold storages. Therefore, the growers sale their maximum amount of potatoes immediately after harvest or they preserve the products in the field or in their houses; where, they can hardly store for 2 months, but quality deteriorates. Different disease and insect attacks and greening of tubers increases, which is very toxic for human consumptions. The growers, however, still prefer to store the tubers at home even during the hottest period (April-August) in order to sell them gradually, and consequently at a high price (Bhattacharjee *et al*., 2014). Regarding this issue, the Tuber Crops Research Centre (TCRC) of Bangladesh Agricultural Research Institute (BARI) has developed an improved technology of storing potatoes under natural condition where potatoes can be stored for 3-5 months with minimum loss and without deterioration of tubers quality (Hoque, 2014). Therefore, the present study was undertaken to generate information for the policy makers with a view to improving storage facilities of potato in Bangladesh.

Methodology

The present study was focused on the present status of potato storage at home and in cold storages in Bangladesh, emphasizing on amount stored, cost of storage, disposal pattern of stored potatoes, sale price and problem faced by the potato growers during storage etc. The study was consisting of interviewing potato growers of selected regions using a questionnaire. The questionnaire was first prepared in English bearing in mind the objectives of the study and then translated into Bengali for ease of the data collection. For convenience, availability of respondent farmers and better interpretation of findings, the following 6 areas of the country were selected for the study (Table 1).

Table 1. List of different study areas

Study regions	Area / District(s)	Upazilla
1	Munshiganj	Sadar and Tongibari
2	Barisal-Patuakhali	Babuganj and Golachipa
3	Dinajpur-Thakurgaon	Birol and Thakurgaon Sadar
4	Joypurhat	Kalai and Khetlal
5	Jamalpur-Sherpur	Bakshiganj and Sherpur Sadar
6	Jashore-Chuadanga	Jhikorgacha and Chuadanga Sadar

One hundred potato growers were purposively selected from each of 6 selected areas with the help of local DAE officers. Considering the land area under potato cultivation, the selected potato growers of 6 study areas were grouped into 3 categories, namely large, medium and small. The large potato growers had more than 2.00 acres of land under potato cultivation; medium growers had 0.51-1.99 acres; and small growers had less than 0.51 acres (Rabbani *et al.,* 2010). Six enumerators were recruited (one for each selected areas) from the students of the BSMRAU for collecting data from the potato growers, using the structured questionnaire. The recruited enumerators were oriented through a training programme at Munshiganj. The questionnaire was elaborately presented to the enumerators; where, scientists, DAE personnel's and some elite farmers were present. A discussion on the questionnaire was held among the participants and the comments and suggestions were recorded. Immediately after the training, pre-testing of the prepared questionnaire was done through collecting data from 2-3 farmers from Katakhali village of Munshiganj sadar upazilla by the selected enumerators. After pre-testing, the questionnaire was fine-tuned and was finalized. Information was collected by the enumerators using the finalized questionnaire during October 2017 from farmers of the selected areas through personal visit. Questions were asked in such a way as to create interest among the respondents avoid boring. In case of any inconsistency, data were rechecked and corrected through repeated visits or by mobile phone. Besides, secondary data like number of cold storages, total capacity and production etc. of different areas were collected from the respective offices of the Deputy Director, Department of Agricultural Extension (DD, DAE). The collected information was processed, compiled and analyzed using MS-Excel and SPSS-PC (Version 16.0).

Results and Discussion

The growers of Munshiganj area occupied the top most position to devote larger areas of land (>2.00 acres) for potato cultivation (64%) followed by Dinajpur-Thakurgaon area (37%). More than 50% farmers devoted to medium category in Dinajpur-Thakurgaon (58%), Joypurhat (72%) and Jashore-Chuadanga (57%) area. Small farmers those who devote to small category for potato cultivation, were the highest in Barisal-Patuakhali area (48%) and the lowest in Munshiganj (4%). On an average of all studied areas, large potato growers was 27%, medium was 50% and small was 23% (Table 2). Potato is the most important and dominating crop in the cropping patterns of Munshiganj district and cultivated commercially for long period compared to other areas. Farmers of Munshiganj are much more aware about potato cultivation than other areas.

Table 2. Distribution of potato growers under large, medium and small category

Study area	Number and percent of respondents		
	Large (>2.00 acres)	Medium (0.51-1.99 acres)	Small (<0.51 acres)
Munshiganj	64	32	4
Barisal-Patuakhali	17	35	48
Dinajpur-Thakurgaon	37	58	5
Joypurhat	14	72	14
Jamalpur-Sherpur	11	48	41
Jashore-Chuadanga	20	57	23
Total	163	302	135
(% of total)	(27)	(50)	(23)

Cold storage preservation

Number of cold storages, total capacity and production of potato in different areas are presented in Fig. 1. The highest number (69) of cold storages were in Munshiganj and the lowest (1) in Barisal-Patuakhali area. In the Joypurhat and Dinajpur-Thakurgaon areas, the total potato production is more than six times than that of total cold storage capacity. Production of potato in other areas were also much higher than the storage capacity. Since, potato planting and harvesting in the northern part of the country including these areas are completed more than a month ahead of the southern parts of the country; therefore, they get the opportunity to preserve their potato to the cold storages of other parts of the country. Among other causes, cold storage facilities are limiting the increase of potato areas.

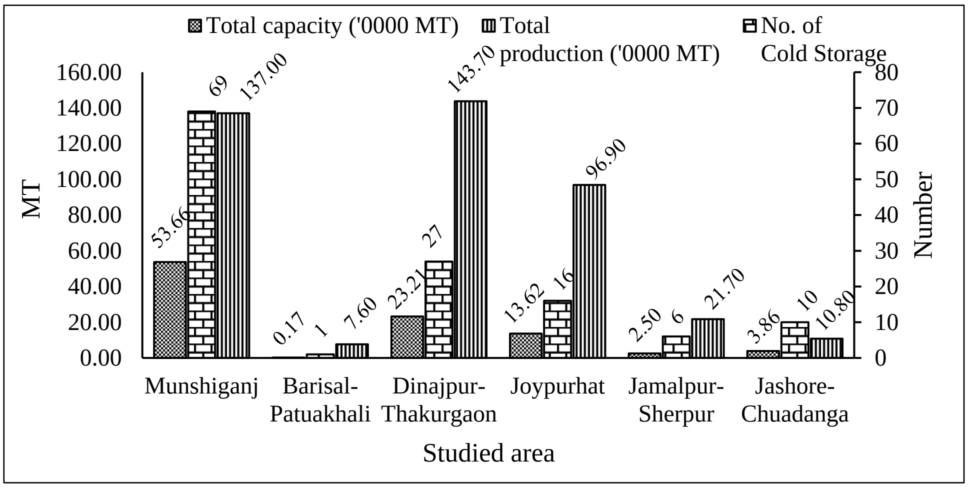

Fig. 1. Number of cold storage, total capacity and production of potato in studied areas in 2017.

Source: DAE office of respective district

Results regarding distribution of potato growers in different areas for amount preserved in cold storage are presented in Table 3. The table showed that maximum farmers of Barisal-Patuakhali (88%), Jamalpur-Sherpur (73%) and Jashore-Chuadanga (57%) did not store the potatoes in cold storage. Whereas, only a few farmers of Munshiganj (14%), Dinajpur-Thakurgaon (12%) and Joypurhat (25%) areas did not store at all in the cold storages in 2016-17 growing season. This was in agreement with the findings of Hossain (2016) who reported that 85.7% farmers of Munshiganj and 87.3% farmers of Bogura stored potato in cold storage. In general, it was observed that the areas where lower numbers of cold storages prevails where percentages of farmers not stored becomes higher in those areas. The availability and closeness of cold storages to the field in Munshiganj invigorated the farmers to store in cold storages (Table 3).

Table 3. Distribution of growers in different areas stored potato in cold storage

Amount (Kg)	Number/percentage of growers						All total (n=600)
	Munshiganj (n=100)	Barisal-Patuakhali (n=100)	Dinajpur-Thakurgaon (n=100)	Joypurhat (n=100)	Jamalpur-Sherpur (n=100)	Jashore-Chuadanga (n=100)	
Do not store	14	88	12	25	73	57	269 (44.8)
upto 4000	25	12	51	63	12	16	179 (29.8)
4001-20000	26	0	23	10	13	18	90 (15.0)
20001-40000	23	0	7	1	1	2	34 (5.7)
40001- 60000	4	0	5	0	0	3	12 (2.0)
60001- 80000	3	0	1	1	0	1	6 (1.0)
> 80000	5	0	1	0	1	3	10 (1.7)

Figures in the parentheses indicate percentage to total number of respondents.

Farmers in closed proximity of cold storage deposited potato in storage were maximum than distant proximities (10.1-20.0 km, 20.1-30.0 km and >30 km) (Table 4). Maximum farmers in Munshiganj (82%), Dinajpur-Thakurgaon (81%) and Joypurhat (70%) areas deposited potato in close proximity of cold storages that are situated within 1.0-10.0 km. All the farmers of Munshiganj, Dinajpur-Thakurgaon and Joypurhat areas had the opportunity to preserve in cold storage within 1.0-20.0 Km. For this reason, majority farmers of these areas preserved their potatoes in cold storages. In Jamalpur-Sherpur area, 27%; in Barisal-Patuakhali, 8% and in Jashore-Chuadanga, 4% farmers had to travel more than 30 km for preserving potatoes in cold storages (Table 4). A long travel from home/field to the cold storage uninspired the growers to store their produces.

Table 4. Distribution of farmers regarding proximity of cold storage

Distance	Number/percent of growers					
	Munshiganj (n=100)	Barisal-Patuakhali (n=100)	Dinajpur-Thakurgaon (n=100)	Joypurhat (n=100)	Jamalpur-Sherpur (n=100)	Jashore-Chuadanga (n=100)
Do not store	14	88	12	25	73	57
1.0-10.0 km	82	-	81	70	-	25
10.1-20.0 km	4	1	7	5	-	9
20.1-30.0 km	-	3	-	-	-	5
>30.0 km	-	8	-	-	27	4

In the study areas, average cost for carrying an 80 Kg bag of potatoes to cold storage ranged from Tk. 10/- to Tk. 250/-. The highest cost of Tk. 250/- to carry an 80 Kg bag was reported in Barisal-Patuakhali areas and the lowest cost Tk. 100/- . Similar trends was also for Jamalpur-Sherpur areas. The long distance of cold storages from field in these areas showed higher price. The lowest range of Tk. 10/- to Tk. 50/- was recorded in Jashore-Chuadanga area (Table 5).

Cold storage charge for an 80 Kg bag was also differed in different areas. The lowest charge of Tk. 200/- was recorded in Barisal-Patuakhali area and the highest of Tk. 370/- in Dinajpur-Thakurgaon and Joypurhat areas (Table 5). The highest charge in the studied areas did not vary considerably. Moazzem and Fujita (2004) reported a cold storage charge of Tk. 160.0 for an 80 kg bag of potato in 2000-2001 growing season. That means, the cold storages charges increased around 2 times over 16 years.

Storage period in preserving potatoes in the cold storage varies year to year or location to location. After storing potatoes, when the market price become higher farmers sale their potatoes. In 2016-17 growing season, farmers of Barisal-Patuakhali, Jamalpur-Sherpur and Jashore-Chuadanga preserved in cold storage for a maximum period of 10 months and in other locations this period was 9 months (Table 5). In a study at 6 important potato growing areas of Bangladesh, Hossain and Miah (2011) also found that farmers store their tubers in the cold storages for an average period of 9.3 months.

Table 5. Average carrying cost, storage fare and period of storing potatoes in cold storage in different areas

Potato growing area	Carrying cost (Tk/80 Kg bag)	Cold storage charge (Tk.)	Storage period (Months)
Munshiganj	25-150	300-350	06-09
Barisal-Patuakhali	100-250	200-350	08-10
Dinajpur-Thakurgaon	10-85	280-370	07-09
Joypurhat	20-50	220-370	04-09
Jamalpur-Sherpur	40-120	300-360	04-10
Jashore-Chuadanga	10-50	220-350	02-10

Average sale price of cold stored potatoes during 2016-17 was the maximum (Tk. 613/- per 40 kg maund) in Jamalpur-Sherpur area followed by Barisal-Patuakhali (Tk. 600/- per 40 kg maund), Joypurhat (Tk. 481/- per 40 kg maund) and Dinajpur-Thakurgaon (Tk. 419/- per 40 kg maund) area. Farmers in all studied areas sold to local *paikers* at cold storage gate. Except Barisal-Patuakhali area, farmers of all areas sold cold stored potatoes to other district *paikers* at cold storage gate. Growers of only in Jamalpur-Sherpur area sold their cold stored potatoes to the local markets at an appreciable high price (Tk. 641/- per 40 kg maund). Whereas, the growers of only Jashore-Chuadanga area sold their cold stored potatoes through commission agents but the price was lower (Tk. 325/- per 40 kg maund) than other selling (Table 6). Many other authors reported from their studies to have variable prices of potato in different areas (Hossain, 2016; Hossain and Miah, 2011; Hoque *et al.*, 2018 and Hossain, 2012).

Table 6. Average sale price of cold stored potatoes in different area

Place	Sale price (Tk/ 40 kg maund)					
	Munshiganj (n=86)	Barisal-Patuakhali (n=12)	Dinajpur-Thakurgaon (n=88)	Joypurhat (n=75)	Jamalpur-Sherpur (n=27)	Jashore-Chuadanga (n=43)
Local *paiker* at cold storage gate	339	600	462	557	596	362
Other district *paiker* at cold storage gate	325	-	375	405	600	350
Sale at local market	-	-	-	-	641	-
Through commission agent	-	-	-	-	-	325
Average	332	600	419	481	613	346

Table 7. Distribution of farmers about disposal of cold stored potatoes in different area

Channels*	Number of growers					
	Munshiganj (n=86)	Barisal-Patuakhali (n=12)	Dinajpur-Thakurgaon (n=88)	Joypurhat (n=75)	Jamalpur-Sherpur (n=27)	Jashore-Chuadanga (n=43)
Local *paiker* at cold storage gate	31 (36.0)	1 (8.3)	54 (61.4)	36 (48.0)	9 (33.3)	22 (51.2)
Other district *paiker* at cold storage gate	0 (0.0)	0 (0.0)	7 (8.0)	5 (6.7)	2 (7.4)	4 (9.3)
Sale at local market	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	7 (25.9)	0 (0.0)
Sale through *Arat*/ commission agent	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.3)	0 (0.0)	2 (4.7)
Use as seed	86 (100.0)	9 (75.0)	12 (13.6)	21 (28.0)	6 (22.2)	12 (27.9)
Own family consumption	19 (22.1)	8 (66.7)	14 (15.9)	24 (32.0)	6 (22.2)	8 (18.6)

*Some farmer respondent for more than one disposing channel.

Figures in the parentheses indicate percentage to total number of respondents of that area.

A disparity in distribution of farmers in the study areas concerning disposal of cold stored potatoes was observed. In Munshiganj, majority farmers (100%) disposed up their cold stored potatoes by using as seed; because, their own seed quality is better as they use lots of imported seed in the previous years. Of them, 36% farmers sold to local *paikers* at cold storage gate and 22.1% use for own family consumption. Farmers in all studied areas disposed up cold stored potatoes by own family consumption along with other disposal items. They also dispose by selling to local as well as other districts *paikers* (Table 7). The other district's *paikers* sometime store these potatoes to other districts cold storages. Hossain (2016) reported similarly that 20.8% potato growers in Munshiganj sold their produces to the *paikers*; whereas, Hajong *et al.* (2014) recorded 40.0% growers in Rangpur sold their potatoes to *paikers*.

Table 8. Distribution of potato growers in different studied areas according to their citation for problems for storing potato in cold storage

Problems*	Number and percent of Growers						
	Munshiganj (n=100)	Barisal-Patuakhali (n=100)	Dinajpur-Thakurgaon (n=100)	Joypurhat (n=100)	Jamalpur-Sherpur (n=100)	Jashore-Chuadanga (n=100)	All total (n=600)
Rot problem	13	7	64	8	19	25	136 (22.7)
Storing cost high	54	25	39	29	45	23	215 (35.8)
Lack of space/cold storage	49	64	15	27	31	35	221 (36.8)
No care by C/S owner	35	2	30	62	21	6	156 (26.0)
Others	7	0	10	0	0	0	17 (2.8)
No comments	8	18	11	9	21	31	98 (16.3)

*Some farmer respondent for more than one problem.

Figures in the parentheses indicate percentage to total number of respondents of that area.

At the time of interview, the maximum potato growers (36.8%) opined that the lacking of cold storage or space as a major problem irrespective of locations (Table 8). Although, the number of cold storages was the highest (69) in Munshiganj (Fig. 1) but they had a scarcity of space in the cold storages (39.12%). They opined that potato planting is somewhat late at Munshiganj due to the late removal of flood water compared to northern part of the country. As a result, harvesting also become late for more than a month and their potato reaches to the cold storages at the end of March or beginning of April. But the cold storages open in the February and potatoes from northern parts occupies the spaces of cold storages to a great extent. Hence, they do not get sufficient space.

They cited the storing cost (35.8%) as the 2nd most important problem followed by no care by cold storage owner (26.0%) and the rotting problem (22.7%). The potato growers of Munshiganj and Dinajpur-Thakurgaon area only cited some other problems like harassment by the middleman, poor management, misbehave by the cold storage personnel, giving less importance to the small farmers and delay entrance of bags within the storage etc. Organizing farmers' cooperative may be helpful to solve these sorts of problems as suggested by Hoque *et al.* (2018).

Home storage

Regarding home storage during 2016-17, farmers in different studied areas were distributed in a different manner. In Munshiganj, a few farmers (16%) stored potato at home but in Dinajpur-Thakurgaon, Joypurhat and Jamalpur-Sherpur, more than 60% farmers stored at home. While considering all areas, 56.0 % farmers stored potatoes at home (Fig. 2) in the studied areas. Majority farmers in Dinajpur-Thakurgaon (91%), Joypurhat (98%) and Jamalpur-Sherpur (65.0%) areas stored potato at home because of cultivation of local varieties as they have high storage capability under natural condition. In other areas, high yielding potato varieties are mainly cultivated that limited the home storage.

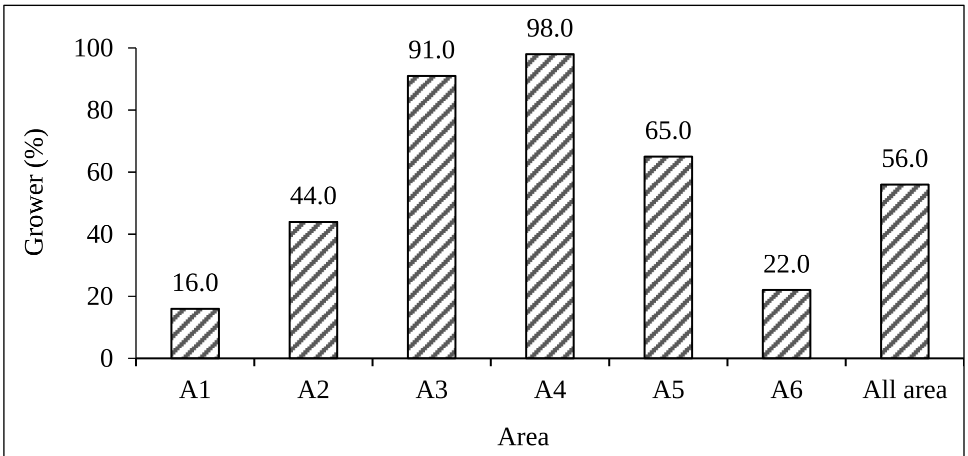

Fig. 2. Distribution of potato growers in different studied areas regarding home storage.

A_1= Munshiganj, A_2= Barisal- Patuakhali, A_3= Dinajpur-Thakurgaon, A_4= Joypurhat, A_5= Jamalpur-Sherpur and A_6= Jashore-Chuadanga.

In home storing methods, farmers of Munshiganj stored mainly in bags (16%) and in other areas, they stored mainly in heap. A few (5%) farmers in Munshiganj stored in field by covering with straw. In all areas, several farmers stored potatoes on *macha* made mainly by using bamboo. Hoque (2011) stored several high yielding varieties of potato under natural condition using different methods and obtained the best result when stored on bamboo made *macha* with 15-20 cm height of tubers. Farmers of Dinajpur-Thakurgaon (12%), Joypurhat (36%) and Jamalpur-Sherpur (12%) stored on *attic* (Table 9). The *attics* are specially made by the farmers in their living mud house that are available in those areas. In Munshiganj, the farmers store in the field for a month or more covering with straw or dried water hyacinth that they used as mulch. Sometimes they use polyethylene sheet to cover the potatoes to get rid from rain. In that case, rottage loss become higher as internal heat of the tubers increases due to respiration that creates suitable environment for micro-organism.

Table 9. Distribution of potato growers in different studied areas regarding method of home storage

Method*	Number and percent of growers					
	Munshiganj (n=16)	Barisal-Patuakhali (n=44)	Dinajpur-Thakurgaon (n=91)	Joypurhat (n=98)	Jamalpur-Sherpur (n=65)	Jashore-Chuadanga (n=22)
In heap	5	44	79	32	64	18
In bags	16	5	25	24	23	10
On *macha*	3	3	16	16	16	6
On *attic*	-	-	12	36	12	-
In field covered with straw	5	-	-	-	-	-

*Some farmer respondent for more than one method.

The survey result regarding distribution of potato growers for days of home storage in different areas revealed that farmers in all areas stored up to 120 days; although, the number of farmer was very low in Munshiganj (1.0), Barisal-Patuakhali (3.0) and Jashore-Chuadanga (3.0). Cultivation and storage of high yielding potato varieties in these areas might be a cause of shorter period preservation under ambient condition (Hoque *et al.*, 2018). Hoque (2011) suggested a method for preserving potatoes under natural condition; where, several HYV's of potato comparatively performed better upto 150 days of storage. In this method, a store house was made at Munshiganj using locally available materials like straw, bamboo etc. and potatoes were stored on bamboo made *macha* with 15-20 cm height of tubers. The method was then tested in other potato growing areas of the country and found effective (Hoque, 2014). Farmers in Dinajpur-Thakurgaon (3.3%), Joypurhat (8.2%) and Jamalpur-Sherpur (7.7%) areas stored even up to 150 days (Table 10). The reason behind this fact was that in these areas, indigenous potato varieties (IPV's) are grown in a large scale; which have a longer storability under natural condition compared to high yielding varieties (HYV's). The IPV's are stored in these areas for a longer period for using as seed in the next year; although, the tubers become shriveled or sprout come out of tubers. Sometimes, they use earthen pots for storing potatoes.

Table 10. Distribution of potato growers regarding storage period

Storage period (days)	Number of growers					
	Munshiganj (n=16)	Barisal-Patuakhali (n=44)	Dinajpur-Thakurgaon (n=91)	Joypurhat (n=98)	Jamalpur-Sherpur (n=65)	Jashore-Chuadanga (n=22)
1-30	3 (18.8)	12 (27.3)	35 (38.5)	24 (24.5)	12 (18.5)	6 (27.3)
31-60	10 (62.5)	18 (40.9)	22 (24.2)	30 (30.6)	18 (27.7)	10 (45.5)
61-90	2 (12.5)	11 (25.0)	18 (19.8)	24 (24.5)	20 (30.8)	3 (13.6)
91-120	1 (6.3)	3 (6.8)	13 (14.3)	12 (12.2)	10 (15.4)	3 (13.6)
121-150	0 (0.0)	0 (0.0)	3 (3.3)	8 (8.2)	5 (7.7)	0 (0.0)

Figures in the parentheses indicate percentage to total number of respondents of that area.

Table 11. Distribution of growers regarding loss during home storage of potatoes

Loss up to 90 days of storage	Number of growers					
	Munshiganj (n=16)	Barisal-Patuakhali (n=44)	Dinajpur-Thakurgaon (n=91)	Joypurhat (n=98)	Jamalpur-Sherpur (n=65)	Jashore-Chuadanga (n=22)
0- 10.0%	0 (0.0)	5 (11.4)	6 (6.6)	6 (6.1)	3 (4.6)	1 (4.5)
10.1- 20.0%	10 (62.5)	23 (52.3)	46 (50.5)	48 (49.0)	33 (50.8)	12 (54.5)
20.1- 30.0%	6 (37.5)	14 (31.8)	32 (35.2)	38 (38.8)	27 (41.5)	8 (36.4)
>30%	0 (0.0)	2 (4.5)	7 (7.7)	6 (6.1)	2 (3.1)	1 (4.5)

Figures in the parentheses indicate percentage to total number of respondents of that area.

While storing potatoes at home, data on distribution of farmers regarding loss up to 90 days of storage was taken and presented in Table 11. From the Table showed that majority farmers of the studied areas lost 10.1-20.0% of their stored tubers during home storage up to 90 days. Farmers those who had lost 20.1-30.0% tubers up to 90 days of storage included 37.5% in Munshiganj, 31.8% in Barisal-Patuakhali, 35.2% in Dinajpur-Thakurgaon, 38.8% in Joypurhat, 41.5% in Jamalpur-Sherpur and 36.4% in Jashore-Chuadanga areas (Table 11). Hossain (2016) reported to have 7.8% loss in home stored potatoes at Bogura; while, Hossain and Miah (2011) recorded a total of 31.5 % loss in home stored potatoes from 6 important potato growing areas of Bangladesh. Hoque *et al.* (2016) calculated 7.6% and Azad *et al.* (2017) calculated 18.7% loss in potato tubers of different varieties at 120 days after storage due to rot when stored under natural condition. Raghav and Singh (2003) involving 12 potato varieties under room temperature, also found various rottage percentages in their varieties.

Average sale price of home stored potatoes in different areas was found to be varied. In Dinajpur-Thakurgaon, Joypurhat and Jamalpur-Sherpur areas, the highest sale price for a 40 kg maund was recorded within 121-150 days after storage (DAS). In other locations, farmer did not store after 120 days at home (Table 12). The higher sale price after 120 days of storage might be due to the use of stored potatoes as seeds. Except this time duration of storage, the highest sale price for a 40 kg maund was recorded when the potatoes sold within 31-60 days of storage in Munshiganj (Tk. 345/ 40 kg maund), Jamalpur-Sherpur (Tk. 400/ 40 kg maund) and Jashore-Chuadanga (Tk. 550/ 40 kg maund). In other three areas, the highest price was recorded at 61-90 DAS. On an average, the farmers of Jamalpur-Sherpur area earned the highest money (Tk. 462.7/ 40 kg maund) from home stored potatoes. Price fluctuation of stored potatoes in different areas might be due to demand and availability of that localities.

Table 12. Average sale price of home stored potatoes in different studied areas

Storage duration	Sale price (Tk/40 kg Maund)						
	Munshiganj	Barisal-Patuakhali	Dinajpur-Thakurgaon	Joypurhat	Jamalpur-Sherpur	Jashore-Chuadanga	Average
Within 30 DAS	200.0	NR	350.0	356.5	420.0	481.0	361.5
Within 31-60 DAS	345.0	387.5	352.3	402.0	400.0	550.0	409.9
Within 61-90 DAS	265.0	450.0	440.0	416.9	390.0	345.0	384.5
Within 91-120 DAS	240.0	355.0	320.0	380.0	373.3	380.0	341.4
Within 121-150 DAS	NR	NR	800.0	755.0	730.0	NR	761.7
Average	262.5	402.5	452.5	462.1	462.7	439.0	413.5

DAS= Days after storage; NR= Not Reported.

Local *Pikers* plays an important role for dispose up of home stored potatoes in all studied locations. The highest number of respondents (87.5%) in Munshiganj area sold their home stored potatoes to local *Paikers* followed by Joypurhat (85.7%), Dinajpur-Thakurgaon (73.6%) and Barisal-Patuakhali (54.5%) areas. Majority of farmers in Munshiganj (31.3%) sold their home stored potatoes to other district *Paikers* in comparison to rest of the studied areas. In all studied areas, potato growers were found to sale their home stored tubers at local markets. Only the growers of Joypurhat (3.1%) and Jashore-Chuadanga (18.2%) area sold their home stored tubers through *Arat* or commission agents (Table 13). Growers of Munshiganj, Barisal-Patuakhali and Jashore-Chuadanga did not use the home stored potatoes as seed. This might be due to the storage of tubers of high yielding varieties that cannot be stored upto next season. In other areas, some farmers used the stored potatoes as seed; where, they stored local varieties that had longer storability. In case of disposal through own family consumption, it was found that most farmers in the studied areas used home stored potatoes for own family consumption. Availability and easy access to tubers when needed might be the reason behind this. Another reason might be like that when they sort the home stored potatoes, they discard some tubers which had been started to rot. These tubers were also used for family consumption. Hossain (2016) reported that 2.14% of total produced potatoes were used as family consumption in Bogura and Munshiganj. Among others- distribution to relatives, donation to local mosque/school/beggars, sale to *Faria* (Petty traders) or to hawkers for buying groceries, vegetables, spices or other goods that needed for daily consumption in a farm family were included. More than 90% farmers in all studied locations except Jashore-Chuadanga areas disposed up their stored potatoes by other means. This implies that the home stored potatoes play a vital role for maintaining the social norms of farm families.

Table 13. Distribution of farmers on disposal of home stored potatoes

Channels*	Number of growers					
	Munshiganj (n=16)	Barisal-Patuakhali (n=44)	Dinajpur-Thakurgaon (n=91)	Joypurhat (n=98)	Jamalpur-Sherpur (n=65)	Jashore-Chuadanga (n=22)
Sales to local *paiker*	14 (87.5)	24 (54.5)	67 (73.6)	84 (85.7)	11 (16.9)	9 (40.9)
Sales to other district *paiker*	5 (31.3)	0 (0.0)	7 (7.7)	8 (8.2)	1 (1.5)	1 (4.5)
Sale at local market	4 (25.0)	25 (56.8)	37 (40.7)	15 (15.3)	17 (26.2)	11 (50.0)
Sale through *Arat*/ commission agent	0 (0.0)	0 (0.0)	0 (0.0)	3 (3.1)	0 (0.0)	4 (18.2)
Use as seed	0 (0.0)	0 (0.0)	3 (3.3)	8 (8.2)	5 (7.7)	0 (0.0)
Own family consumption	16 (100.0)	38 (86.4)	85 (93.4)	87 (88.8)	49 (75.4)	18 (81.8)
Others	16 (100.0)	42 (95.5)	85 (93.4)	98 (100.0)	60 (92.3)	19 (86.4)

*Some farmer respondent for more than one disposing channel.

Figures in the parentheses indicate percentage to total number of respondents of that area.

Regarding distribution of potato growers in different studied areas according to their citation of problems for storing potato at home, it was estimated that 47.5% growers cited weight loss as a problem. Rot problem was cited by 41.3% growers among the studied areas. While working with 120 farmers at Bogura, Hossain (2012) reported that all the studied farmers mentioned the rot problem as a challenge in home stored potato. Hoque *et al.* (2016) quantified and recorded an average of 7.63% rotting loss and 18.5% cumulative weight loss at 150 DAS in 15 high yielding potato varieties irrespective of size. They also reported that large and medium sized potato could be stored under natural condition for 150 days with 13.9 and 5.9% total rotting loss, respectively. Disease as a problem for home stored potatoes was cited by 38.3% growers (Table 14). In Munshiganj, 80% growers cited the weight loss as a major problem for home stored potatoes. In Barisal-Patuakhali (46%) and Dinajpur-Thakurgaon (76%) areas, most growers cited the rot as major problem; while, majority growers of Joypurhat cited the rodent as major problem (56%). Disease as a major problem was cited by the growers of Jamalpur-Sherpur areas (93%) but the growers of Jashore-Chuadanga areas cited disease as well as insects as problem for storing potatoes at home. These sorts of discrepancies might be attributed due to prevailing weather condition of that area, places of home where the potatoes were stored and management followed by the growers during storage.

Table 14. Distribution of potato growers in different studied areas according to their citation of problems for storing at home

Problems*	Growers (%)						
	Munshiganj (n=100)	Barisal-Patuakhali (n=100)	Dinajpur-Thakurgaon (n=100)	Joypurhat (n=100)	Jamalpur-Sherpur (n=100)	Jashore-Chuadanga (n=100)	All (n=600)
Weight loss	80	32	52	1	24	96	285 (47.5)
Rot problem	12	46	76	14	6	94	248 (41.3)
Rodent	15	12	2	56	1	8	94 (15.7)
Disease	10	24	2	1	93	100	230 (38.3)
Insects	18	10	14	3	5	100	150 (25.0)

*Some farmer respondent for more than one problem.

Figures in the parentheses indicate percentage to total number of respondents of that area.

Conclusion

- More cold storages need to be constructed in Barisal-Patuakhali, Jamalpur-Sherpur, Jashore-Chuadanga and other areas.
- Farmers' cooperative may be organized involving DAE and Department of Agricultural Marketing (DAM) personnel to solve various problems in cold as well as home storage.
- Stored potatoes both in cold and home storage are at present disposed up mainly to the local *paikers* and the farmers do not get expected price of their products. Therefore, respective organization should take initiative to ensure a good price for the farmers.

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References

Azad, A.K., H. Kabir, T.E.J. Eaton and E.B. Soren. 2017. Storage potentialities of some exotic potato varieties at farmers' condition in Bangladesh. *Agricultural Sciences*, **8**: 183-193 [https://doi.org/10.4236/as.2017.82013].

BBS. 2020. Yearbook of Agricultural Statistics-2019. 31st Series, May 2020. Bangladesh Bureau of Statistics (BBS). Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh. pp: 367-374.

Bhattacharjee, A., T. S. Roy, M. M. Rahman, M. N. Haque and U. Rahima. 2014. Influence of variety and date of harvesting on post-harvest losses of potato derived from TPS at ambient storage condition. *Int. J. Sustain. Agril. Tech.* **10**: 08-15.

Hajong, P., M. Moniruzzaman, M.I.A. Mia and M.M. Rahman. 2014. Storage system of potato in Bangladesh. *Universal Journal of Agricultural Research*. **2**(1): 11-17 [DOI: 10.13189/ujar.2014.020102].

Hoque, M. A. 2011. Final Report on "Increasing storability of potato in natural storage and income generation through small scale processing of potato" Project, BARI, Munshiganj. May 2011. Krishi Gobeshona Foundation (KGF), Phase-I Project, Bangladesh Agricultural Research Council, Farmgate, Dhaka.

Hoque, M. A. 2014. Final Report on "Piloting for upscaling the technology of potato storage under natural condition" Project. Department of Horticulture, BSMRAU and Krishi Gobeshona Foundation (KGF), CGP Project, Bangladesh Agricultural Research Council, Farmgate, Dhaka.

Hoque, M. A. and K. T. Akter. 2014. Local improved method for home storage of potato (*In Bengali*). Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706 and and Krishi Gobeshona Foundation, BARC Campus, Farmgate, Dhaka. Pp. 1-16.

Hoque, M.A., A.S.M. Nahiyan, M.A. Siddique, L. Rahman and A. Raihan. 2018. Production, storage and marketing of table potatoes in selected areas of Bangladesh. ASRBC-ACI Agribusiness, Dhaka and BSMRAU, Gazipur. 36p.

Hoque, M.A., T. Yeasmin and N.U. Ahmed. 2016. Storability of different sizes of potato tubers under natural condition. *Annals of Bangladesh Agriculture*. **20**(1&2): 75-85.

Hossain, M.A. 2012. Postharvest challenges on potato in northern area of Bangladesh. An unpublished MS Thesis. Submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207.

Hossain, M.A. 2016. Value chain analysis of potato in selected areas of Bogra and Munshiganj districts of Bangladesh. An unpublished MS Thesis. Submitted to the BRAC Institute of Governance and Development, BRAC University, Bangladesh.

Hossain, M.A. and M.A.M. Miah. 2011. Assessment of post-harvest losses of potatoes in Bangladesh. Asia-Pacific Journal of Rural Development. **XXI**(2): 79-94.

Moazzem, K.G. and K. Fujita. 2004. The potato marketing system and its changes in Bangladesh: from the perspective of a village study in Cumilla district. *The Developing Economies.* **XLII**(1): 63-94.

Rabbani, M.G., M.A. Siddique, M.M. Islam and M.S. Islam. 2010. The Potato Sector in Bangladesh: Its Challenges and Opportunities. Katalyst, Dhaka, Bangladesh.

Raghav, M. and N.P. Singh. 2003. Differences among potato cultivars for their storability under room temperature. *Progressive Horticulture.* **35**: 196-198.

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CHARACTERIZATION AND EVALUATION OF *LILIUM* IN BANGLADESH

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Abstract

Thirty-seven genotypes of *Lilium* were collected and evaluated under *Lilium* shade at floriculture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur during 2017-21 to characterize different species of *Lilium* available in Bangladesh and collected from abroad. Notable variations in different qualitative and quantitative parameters were observed among the 37 genotypes under study. Among them, 31 genotypes were found suitable for cut flowers and six (06) suitable for pot culture. The longest stalk and rachis (94.3 cm and 36.0 cm, respectively) were produced by the genotype Lil-036. The maximum number of florets per stick (10.5) was produced by BARI Lilium-1. The maximum vase life was observed in Lil-007 and BARI Lilium-2 (11.0 days), whereas the minimum in Lil-022 and Lil-026 (5.0 days). The heaviest and the largest bulbs were produced by the genotype Lil-036 (72.4 g) and (6.6 cm) respectively. Considering *the* length of stalk and rachis, number of florets per stick, duration of vase life, average bulb weight, the genotypes, Lil-018, Lil-021, Lil-034, Lil-035 and Lil-036 were selected for further evaluation.

Keywords: *Lilium*, Cut Flower, Bangladesh, Asiatic Lilium, Oriental Lilium.

Introduction

Lilium (*Lilium* sp.) belongs to the Liliaceae family, has a high demand in the international flower trade. Commercially it is grown as a cut flower for its long-lasting (12-15 days) form with a wide range of colors and assortment. This lucrative flower has recently been introduced in Bangladesh due to its high demand and profitability. Among different types of *Lilium*, the Asiatic and Oriental hybrids have attractive flowers of different hues. Farmers are immensely keen on cultivating this flower. Mostly the northern region of Bangladesh has suitable climate condition for *Lilium* cultivation. One of the core constraints of *Lilium* flower cultivation in Bangladesh is the unavailability of *Lilium* bulbs during the growing season. To meet up the local demand, this flower is being imported to Bangladesh from other countries, especially from China and India. The imported bulb costs about Tk. 60-80 per bulb which is relatively a high value for our flower growers. If the bulb of this flower could be provided by the local market, more flower production would be possible and the price of the bulb

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would also be reduced. For this, the quality bulb should be produced locally. Furthermore, for the improvement of this flower species, diverse genetic resources should be collected. A wide diversity of *Lilium* resources will provide valuable genes for the breeding of novel varieties. Although flower growers in Bangladesh are cultivating this flower, there is a growing demand for new varieties with high attractiveness and productivity.

Considering this viewpoint, it is indispensable to collect *Lilium* germplasm and evaluate them for standardizing the production technology under the climatic conditions of Bangladesh. Therefore, the present experiment was undertaken to collect to characterize them different species of *Lilium* available in Bangladesh and also from abroad and to conserve the collected germplasm for future research.

Materials and Methods

The present investigation was carried out at the Floriculture Research Field of HRC, BARI, Gazipur during the *rabi* season of 2017-21. The prevailing average temperature of the growing season ranges from 20-26°C and humidity was 87-89%. During this period, two genotypes were released as varieties viz. BARI Lilium-1 and BARI Lilium-2. In this study 37 *Lilium* germplasm were used as treatments, along with BARI Lilium-1 and BARI Lilium-2 as control. Bulbs were planted under the shade houses made of UV poly film and agro-shade net from mid-October to mid-November of each year. The experimental land was well prepared by adding coco-dust (50:50 soil and coco-dust) and 10 t cow dung /ha. Chemical fertilizers were not applied up to 3 weeks of bulb planting. After 3 weeks of bulb planting, NPK @ 30:20:20g/m^2 was applied. Urea and MoP @ 100 kg/ha were top-dressed before the spike initiation stage and bulb lifting, respectively. No design was followed and spacing was maintained at 20 cm from row to row and 15 cm from plant to plant. When the lowermost buds showed color, the spikes were harvested. After collecting flowers, the plants keeping 25-30 cm stem were kept in the field for bulb development. Observations on various growth parameters were recorded after one month of planting bulbs. Before flower opening, vegetative parameters like plant height (cm), number of leaves, days to bud initiation were recorded. The height of the plant was recorded by measuring the length from the base of the rachis of the plant. Floral parameters were also recorded which included: spike length (cm), rachis length (cm), bud length (cm), bud diameter (cm), number of flowers per plant, flower diameter (cm), and vase life. When the leaves were brown and more or less damaged, the bulbs were lifted carefully and stored at 2.1-2.5ºC temperature with media containing coco-dust for future planting.

Results and Discussion

Wide variations in terms of qualitative parameters were observed (Table 1 & 2). Among the collected *Lilium* germplasm, 37 attractive colored and two types of flowers viz. Asiatic types and Oriental types have been found. There are 31 germplasms suitable for cut flowers and 6 germplasms suitable for pot culture among them. Attractive colors and variations were found in *Lilium* petals and tepals. Various spots were originated by the tepals of 19 *Lilium* genotypes and 18 genotypes did not show any spot in the tepal. Banba (1967) conducted an experiment where most *Lilium* hybrids had spots on their tepals due to the presence of anthocyanin. Regarding fragrance, Oriental type *Lilium* produces highly scented flowers whereas Asiatic *Lilium* has no fragrance. Each species in the genus *Lilium* possess great genetic diversity in its growth habit, flower color, form, shape, size, and as well as in persistence. This diversity in species of agronomic traits offers substantial germplasm and opportunities for the development of hardy and healthy varieties for variable climatic zones (Anderson *et al.*, 2010).

Table 1. Qualitative traits of some *Lilium* genotypes as cut flower

Genotypes	Types	Petal description	Anther color	Fragrance
BARI Lilium-1	Asiatic	Creamy white, greenish yellow midrib and sporadic dark spots are present at the base of the petal	Deep maroon	Absent
BARI Lilium-2	Asiatic	Yellow, no spots are present	Deep brown	Absent
Lil-002	Asiatic	Light orange, deep orange midrib is present at the base of the petal	Deep maroon	Absent
Lil-003	Asiatic	Deep orange, dark spots are present at the base of petal	Maroon	Absent
Lil-004	Asiatic	Deep Magenta	Brown	Absent
Lil-007	Asiatic	Deep orange, numerous dark spots are present at the base of the petal	Deep maroon	Absent
Lil-008	Asiatic	Reddish magenta, few dark spots are present at the base of the petal	Deep maroon	Absent
Lil-011	Asiatic	Pink at petal tips, burnt orange in the lower half of the petals and yellow in the center with some dark spots.	Deep maroon	Absent
Lil-012	Asiatic	Light orange, no spots are present	Deep maroon	Absent
Lil-014	Oriental	White curly petals, no spots are present	Deep maroon	Present
Lil-016	Asiatic	Greenish cream, green mid rib and few maroon spots are present at the base of the petal	Maroon	Absent
Lil-017	Oriental	White centered deep pink curvy petals surrounded by white color, no spots are available	Deep maroon	Present
Lil-018	Oriental	White broad petals, no spots are present	Maroon	Present

Table 1. Cont'd

Genotypes	Types	Petal description	Anther color	Fragrance
Lil-019	Oriental	Light pink curvy petals surrounded by white color, numerous dark spots are present at the base of the petal	Orange	Present
Lil-020	Oriental	Pink curvy petals surrounded by white color. Deep pink mid rib and numerous hairy spots are present	Maroon	Present
Lil-021	Asiatic	Pinkish maroon, few dark spots are present	Deep maroon	Absent
Lili-022	Asiatic	White petal surrounded by violet narrow markings. Numerous maroon spots are present at the base of petal	Deep maroon	Absent
Lil-023	Asiatic	Light orange with a glassy appearance. No spots are present	Maroon	Absent
Lil-024	Asiatic	Deep blackish maroon with a glassy appearance. Few black spots are present at the base of petals	Orange	Absent
Lil-025	Asiatic	Light yellow. No spots are present	Orange	Absent
Lil-026	Asiatic	Deep orange with a glassy appearance. No spots are present	Maroon	Absent
Lil-027	Asiatic	Pink with a glassy appearance. No spots are present	Maroon	Absent
Lil-028	Asiatic	Light maroon. Few spots are present at the base of the petals	Orange	Absent
Lil-029	Asiatic	Bright yellow, no spots are present	Deep maroon	Absent
Lil-031	Oriental	Pinkish white petal with numerous white hairy appearance at the base, no spots are present	Deep Orange	Present
Lil-032	Asiatic	Light maroon colored long petal with few dark spots at the base	Deep maroon	Absent
Lil-033	Oriental	Pink petals with some hairy appearance at the base and no spots are present	Deep Orange	Present
Lil-034	Oriental	Snow white colored petal along with slight greenish appearance at the base with no spots	Deep maroon	Present
Lil-035	Asiatic	Deep pink petal with whitish appearance at the base of the petal and few dark spots are present	Maroon	Absent

Table 1. Cont'd

Genotypes	Types	Petal description	Anther color	Fragrance
Lil-036	Oriental	Drooping type light pink curvy petals surrounded by white color along with whitish appearance at the base of the petal with no dark spots	Deep maroon	Present
Lil-037	Oriental	Snow white colored with some hairy appearance at the base of the petal and tinted with pink color on whole petal and no spots are present	Yellowish orange	Present

Table 2. Qualitative traits of *Lilium* genotypes as pot plant

Genotypes	Types	Petal description	Anther color	Fragrance
Lil-005	Asiatic	White, numerous pinkish red spots are present at the base of petal	Orange	Absent
Lil-006	Asiatic	Orange, numerous dark spots are present in the petal	Deep maroon	Absent
Lil-009	Asiatic	Orange, dark spots are present at the base of the petal	Deep maroon	Absent
Lil-013	Oriental	Deep magenta pink petals around a white center with dark spots	Deep orange	Present
Lil-015	Oriental	Thick white petals, white hair are present but no spots are available	Maroon	Present
Lil-030	Asiatic	Light orange petals with reddish spot	Maroon	Absent

Various growth and flowering parameters were influenced by the *Lilium* genotypes (Table 3) as cut flower. The longest plant (82.9 cm) was produced by the genotype Lil-034 and the shortest in Lil-016 (32.8 cm). Balode (2010) also reported the higher phenotypic variability for plant height in *Lilium* genotypes. The maximum number of leaves was recorded in Lil-022 (74.3) and the minimum in Lil-033 (35.2). Variation in the vegetative parameters of Asiatic *Lilium* was also reported similarly by Pandey *et al.* (2008); Deka *et al.* (2010) and Sindhu *et. al.* (2012). Differences in vegetative growth characters of different growth cultivars may be due to varied growth rate and their genetic makeup as a result, variations in phenotypic expression occur (Sankari *et al.* 2020). Similar results with vegetative characters were also reported by Mishra (1997). The minimum days were required for bud initiation after planting in Lil-017 and Lil-019 (26.0 days) whereas the maximum days in BARI Lilium-1(55.0 days). The findings of the present study are in close agreement with Dhiman (2003) and Sindhu *et al.* (2012) who observed significant variation among *Lilium*. The variation in the number of days taken for flowering was primarily due to the genetic constitution of various cultivars and prevailing environmental conditions during the period of crop growth (Sankari *et al.*, 2020).

The longest and the broadest bud were produced by the genotype Lil-037 (13.2 cm) and Lil-014 (3.7 cm), respectively. The shortest and the narrowest bud were produced by the genotype Lil- 003 (8.0 cm) and Lil-035 (2.3 cm), respectively.

The stalk length which is another important quality parameter significantly varied among Asiatic cultivars. The cost of a flower stalk is determined mostly by the number of florets per stalk. It is an important flowering characteristic for *Lilium* production as a cut flower. Variations were observed in case of flowering parameters of *Lilium* genotypes as cut flower (Table 3). The longest stalk and rachis (94.3 cm and 36.0 cm, respectively) were produced by the genotype Lil-036. The shortest stalk was produced by Lil-004 (30.0 cm) and minimum rachis length was found in Lil-016 (11.5 cm). Such varietal differences for sprouting have been also reported by Sindhu (2006).

The maximum number of florets per stalk (11.0) was produced by BARI Lilium-1 and the minimum number of florets in Lil-031 (1.6). The result corroborates with the findings of Deka *et al.* (2010), Srinivas (2002) and Srinivas (2003) who reported similar variation among *Lilium* cultivars concerning this parameter. Wide variation in floral parameters due to varieties has also been reported by Dhiman (2003).

The size of flowers also contributes to the quality of the flowering shoot and bigger buds on flowering stalks are always preferred **(**Sankari *et al.,* 2020). The largest flower was produced by Lil-036 (24.5 cm) and the size of the flower was minimum in Lil-004 (14.5 cm). Similar performance was found by De Hertogh (1996) where flower diameter ranged from 13.8 cm to 20.2 cm among some *Lilium* varieties and significantly large-sized flowers were recorded in Stargazer (20.6 cm) followed by Prato (20.2 cm) and PKLH-1 (19.3 cm) which could serve as a varietal trait. The vase life was recorded only for cut flowers, not for pot plants. The maximum vase life was observed in Lil-007 and BARI Lilium-2 (11.0 days) whereas the minimum was in Lil-022 and Lil-026 (5.0 days).

In case of pot plant (Table 4), maximum plant height was found in Lil-030 (24.0 cm) and the minimum in Lil-015 (10.2 cm). Maximum leaves were produced by Lil-005 (48.0 and minimum leaves in Lil-015 (24.0). Lil-006 took minimum days (27.0) whereas Lil-030 took maximum days (82.0) for bud initiation. The longest and broadest bud was produced by Lil-013 (9.3 cm and 3.3cm, respectively) and shortest and narrowest bud in Lil- 030 (5.0 cm and 1.5 cm, respectively).

Table 3. Vegetative and flowering parameters of different *Lilium* genotypes as cut flower

Genotypes	Plant height (cm)	No. of leaves/plant	Days to bud initiation	Bud length (cm)	Bud diameter (cm)	Stalk length (cm)	Rachis length (cm)	No, of florets/ stick	Floret diameter (cm)	Vase life (days)
BARI Lilium-1	73.6	67.0	55.0	10.4	3.3	80.0	26.0	11.0	17.0	10.0
BARI Lilium-2	50.1	64.0	33.0	9.9	2.7	60.0	18.5	7.5	20.0	11.0
Lil-002	43.0	40.0	45.0	10.5	3.2	48.0	14.0	2.0	17.0	7.0
Lil-003	33.0	45.0	37.0	8.0	2.5	35.0	14.0	4.0	15.0	8.0
Lil-004	34.0	48.0	45.0	7.5	2.7	30.0	14.0	4.0	14.5	7.0
Lil-007	34.2	70.0	30.0	8.4	2.5	46.0	17.7	4.0	16.7	11.0
Lil-008	43.4	70.0	27.0	7.9	2.7	50.0	17.1	4.4	19.0	8.0
Lil-011	45.1	65.0	30.0	8.5	2.4	46.0	15.5	4.6	18.1	10.0
Lil-012	46.0	60.0	32.0	8.9	2.5	55.0	16.9	2.0	21.5	8.0
Lil-014	36.6	37.0	37.0	11.4	3.7	36.2	12.7	4.0	21.9	8.0
Lil-016	32.8	48.0	34.0	8.8	2.5	31.8	11.5	2.0	20.1	6.0
Lil-017	39.1	51.0	26.0	12.0	3.5	73.3	20.5	3.0	21.2	8.0
Lil-018	48.4	37.0	27.0	10.7	2.9	85.8	23.8	4.0	21.6	7.0
Lil-019	40.2	36.0	26.0	9.7	3.3	70.4	20.8	3.0	20.1	6.0
Lil-020	67.8	36.6	33.0	12.2	3.1	36.5	16.3	2.3	24.0	6.0
Lil-021	53.9	54.0	35.0	9.6	2.7	36.0	29.3	7.2	20.8	6.0
Lil-022	76.0	74.3	32.0	9.6	2.9	55.4	27.3	3.8	20.0	5.0
Lil-023	44.0	55.5	36.0	9.8	2.7	29.4	15.9	2.0	18.0	6.5
Lil-024	60.4	48.0	35.0	9.8	2.7	42.5	20.3	4.8	21.1	5.5

Table 3. Cont'd.

Genotypes	Plant height (cm)	No. of leaves/plant	Days to bud initiation	Bud length (cm)	Bud diameter (cm)	Stalk length (cm)	Rachis length (cm)	No, of florets/ stick	Floret diameter (cm)	Vase life (days)
Lil-025	48.4	53.0	35.0	9.1	2.4	35.5	25.9	7.0	18.7	6.0
Lil-026	51.2	54.0	34.0	10.1	2.5	41.1	31.9	6.4	20.1	5.0
Lil-027	65.3	80.0	33.0	9.9	2.7	46.8	27.1	3.6	21.7	5.5
Lil-028	58.4	58.2	32.0	9.9	2.6	33.4	14.3	3.2	19.9	6.0
Lil-029	67.1	51.5	34.0	10.7	3.5	48.0	21.1	3.4	20.7	6.5
Lil-031	49.3	35.6	45.0	10.3	3.1	45.5	16.6	1.6	18.0	7.0
Lil-032	61.9	59.1	36.0	9.16	2.9	58.7	18.5	2.6	18.0	8.5
Lil-033	51.0	35.2	46.0	12.5	3.5	48.6	19.5	2.0	18.5	8.0
Lil-034	82.9	58.1	37.0	11.8	3.4	92.2	26.8	3.5	23.5	9.5
Lil-035	65.6	56.4	46.0	8.5	2.3	79.8	17.5	3.0	18.5	7.5
Lil-036	76.9	56.1	38.0	12.7	3.1	94.3	36.0	3.9	24.5	6.0
Lil-037	62.8	53.7	35.0	13.2	3.1	55.0	21.7	4.5	21.0	7.5
Mean	53.0	53.4	35.6	10.0	2.9	52.4	20.3	4.0	19.7	7.3
STD	14.1	12.0	6.67	1.4	0.3	18.7	6.02	2.0	2.3	1.6
CV (%)	26.7	22.6	18.6	14.6	13.3	35.6	29.6	50.1	12.0	22.5

Table 4. Vegetative and flowering parameters of different *Lilium* genotypes as pot plant

Genotypes	Plant height (cm)	No. of leaves/plant	Days to bud initiation	Bud length (cm)	Bud diameter (cm)	Stalk length (cm)	Rachis length (cm)	Florets/stick	Floret diameter (cm)
Lil-005	15.5	48.0	52.0	5.9	2.1	19.0	8.5	4.0	12.60
Lil-006	16.6	41.0	27.0	5.7	2.0	19.0	7.6	2.0	13.40
Lil-009	16.8	45.0	30.0	6.5	2.	18.0	7.5	2.0	13.6
Lil-013	18.6	33.0	52.0	9.3	3.3	20.8	9.6	3.0	17.6
Lil-015	10.2	24.0	40.0	6.4	2.6	28.9	10.0	4.3	14.3
Lil-030	24.0	40.0	82.0	5.0	1.5	36.0	10.0	3.0	8.0
Mean	19.7	44.0	67	5.4	1.8	27.5	9.2	3.5	10.3
STD	6.01	5.6	21.2	0.6	0.4	6.01	0.5	0.3	1.6
CV (%)	30.4	12.8	31.6	12.6	26.1	21.8	5.4	10.1	15.7

The genotypes that are suitable as pot plants (Table 4) produced comparatively shorter stalk (18.0cm to 36.0 cm) and rachis (7.5 cm to 10.0 cm). The maximum number of florets was produced by Lil-015 (4.3) while the minimum in Lil-006 and Lil-009 (2.0). Lil-013 had the largest floret diameter (17.65 cm), while Lil-030 had the smallest (8.0 cm). Sheikh *et al.* (2015) also reported that a wide range of variation was found regarding spike and rachis length (54.0-74.5 cm and 14.9-17.4cm, respectively) and also florets number per flower stick (3.0-8.7).

Like vegetative and flowering parameters, bulb and bulblet production were also influenced by the various *Lilium* genotypes (Table 5). The maximum bulb weight (72.4 g) was found in the genotypes Lil-036 while the minimum bulb weight (15.3g) in Lil-002. Similarly, Lil-036 also produced the largest bulb (6.6c m). The maximum number and weight of bulblet per plant were produced by Lil-009 (8.0 and12.0 g, respectively) and the minimum in Lil-013 (2.4 g) and Lil-035 (1.2 g) respectively. Similarly, wide variation was also observed by Sheikh *et al.* (2015) who reported that all *Lilium* genotypes produced 1.0 daughter bulb per bulb and the range of bulblet production was 3.30-22.30 per bulb. Significant differences in the various bulb and bulblet characteristics of Asiatic *Lilium* cultivars were also reported by Sindhu (2006) and Deka *et al.* (2010). Noticeable differences among the cultivars of Asiatic lily and the cultivars of Oriental lily for all the characters studied were also reported by Gupta (2002) and Gupta (2003).

Table 5. Bulb and bulb-let production influenced by *Lilium* genotypes

Genotypes	Single bulb wt. (g)	Bulb diameter (cm)	Bulb-let no./plant	Bulb-let wt./plant (g)
BARI Lilium-1	16.2	3.4	4.0	5.6
BARI Lilium-2	30.0	4.5	3.0	2.3
Lil-002	15.3	3.5	3.0	1.9
Lil-003	18.9	4.0	5.0	2.6
Lil-004	20.0	4.5	4.0	3.4
Lil-005	20.0	3.6	7.0	10.0
Lil-006	40.5	4.7	4.0	5.0
Lil-007	60.0	6.0	5.4	2.4
Lil-008	34.0	4.8	4.3	2.8
Lil-009	30.0	4.0	8.0	12.0
Lil-011	38.0	4.7	4.3	2.8
Lil-012	60.0	5.5	4.0	3.2
Lil-013	49.0	4.9	2.4	1.6
Lil-014	26.0	4.6	3.0	3.0
Lil-015	50.0	5.3	3.6	7.5
Lil-016	33.0	4.8	4.5	6.0

Table 5. Cont'd.

Genotypes	Single bulb wt. (g)	Bulb diameter (cm)	Bulb-let no./plant	Bulb-let wt./plant (g)
Lil-017	40.0	5.3	6.0	5.5
Lil-018	48.0	5.6	2.6	1.7
Lil-019	48.0	5.3	3.8	2.1
Lil-020	25.0	3.6	2.7	2.5
Lil-021	22.0	3.9	2.5	2.2
Lil-022	40.6	5.3	3.6	3.1
Lil-023	22.8	3.7	4.0	3.7
Lil-024	53.8	5.1	4.5	3.8
Lil-025	30.8	4.3	3.0	3.5
Lil-026	23.6	3.5	3.5	4.1
Lil-027	27.2	3.9	4.1	4.5
Lil-028	26.2	3.7	2.9	3.0
Lil-029	40.4	5.3	3.0	3.2
Lil-030	25.0	3.4	3.2	3.0
Lil-031	38.4	4.6	3.6	3.2
Lil-032	28.6	5.2	3.4	3.1
Lil-033	46.5	5.4	2.6	3.1
Lil-034	36.5	4.4	4.3	4.3
Lil-035	44.4	5.9	3.5	1.2
Lil-036	72.4	6.6	5.5	2.1
Lil-037	40.8	5.2	2.5	2.3
Mean	28.5	4.3	3.2	3.9
STD	17.3	1.2	1.0	2.3
CV (%)	60.8	29.1	32.6	58.0

Conclusion

Lilium genotypes exhibited wide-range variations in all qualitative and quantitative parameters considered. After evaluating the performance of collected genotypes, two varieties (BARI Lilium-1 and BARI Lilium-2) have been released in 2020 for their noticeable productivity and attractiveness. Considering the length of stalk and rachis, number of florets per stick, duration of vase life, average bulb weight of the genotypes, Lil-018, Lil-021, Lil-034, Lil-035 and Lil-036 were selected for further evaluation. Subsequently, with the collection and evaluation procedure, conservation of these germplasm should be a vital concern for *Lilium* researchers and the proper bulb preservation techniques are indispensable to preserve these bulbs for the next season. Equal emphasis should be given to quick multiplication through tissue culture to meet the intensifying demand of this flower species in the local market of Bangladesh.

References

Anderson, N.O., A. Younis, Y. Sun. 2010. Intersimple sequence repeats distinguish genetic differences in Easter lily 'Nellie White' clonal ramets within and among bulb growers over years. *J. Amer. Soc. Hort. Sci.*, **135:**445-455.

Balode, A. 2010. Phenotypic analysis of hybrids and their parents in *Lilium* spp. breeding. Annual 16th International Scientific Conference Proceedings. Research for Rural Development, **1:** 65-70.

Banba H. 1967. Pigments of lily flowers 1. Survey of anthocyanin (in Japanese), *J. Jap. Soc. Hort. Science,* **36:**61-65

De Hertogh A. A. 1996. Marketing and research requirements for *Lilium* in North America, *Acta Horticulture,* **414:** 17-24.

Deka, R. Kumar, C. Bidyut and V. V. Patel. 2010. Evaluation of Asiatic *Lilium* under sub-tropical mid hills of Meghalaya. *J. Ornam. Hort.,* **13**(4):257-260.

Dhiman, M.R. 2003. Evaluation of hybrid lily under Kullu conditions. *J. Ornam. Hort.,* **6**(2): 154-155.

Gupta, R. 2002. Evaluation of *Lilium* under Bajaura conditions. Abstract, National Symposium on Indian Floriculture in the New Millennium, Feb.25-27, pp. 52.

Gupta, R. 2003. Performance of various Asiatic and Oriental hybrid cultivars of *Lilium* under mid-hill zone of Himachal Pradesh. Abstract, National Symposium on Recent Advances in Indian Floriculture. Nov. 12-14, 87.

Mishra, H.P. 1997. Performance of gladiolus genotypes under calcareous soil for North Bihar. *Indian J. Hort.*, **14**(1): 77-92.

Pandey, R.K., Dogra, Sheetal, J.P. Sharma and Jamwal, Shivani. 2008. Evaluation of Asiatic hybrid lily cultivars under subtropical conditions of Jammu region. *J. Plant Sci. & Res.*, **24**(2): 213-214.

Sankari, A., M. Anand, B. Anita and R. Swarna Priya. 2020. Correlation and Coefficient Studies in *Lilium* (*Lilium* spp.). *Int.J.Curr.Microbiol.App.Sci*. **9**(02): 3073-3079.

Sindhu SS, JP Singh and RK Singh. 2012. Evaluation of *Lilium* cultivars under northern plains. *Int. J. Agril. Sci.,* **8**(2) 460-461.

Sindhu, S.S. 2006. Evaluation of *Lilium* cultivars under North Indian conditions. *Haryana J. Hort. Sci.*, **35**(3&4) : 270 plains.

Srinivas, M. 200). Response of Asiatic lilies to open cultivation. Abstract, Natioal Symposium on Indian Floriculture in the New Millennium. Feb.25-27, 50-51.

Srinivas, M. (2003). Performance of *Lilium* under Bangalore condition. Abstract, National Symposium on Recent Advances in Indian Floriculture. Nov, 12-14, 17.

Sheikh M. Q., Z. A. Bhat, M. A. A. Siddique. Tarak Nath Saha, K. P. Singh and Mast Ram Dhiman. 2015. Lilium. ICAR-DFR Bulletin No. 18. ICAR- Directorate of Floricultural Research, College of Agriculture Campus, Shivajinagar, Pune-411005 (Maharashtra), India.

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HOMESTEAD VEGETABLE PRODUCTION: A MEANS OF LIVELIHOOD AND NUTRITIONAL SECURITY FOR RESOURCE POOR HOUSEHOLDS IN BANGLADESH

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Abstract

Justifiable, nutritious and safe food productions are main challenges for food safety which reduce starvation, meets dietary needs and food preferences for a healthy life. Home gardens can play a significant role in providing better food supply and diversity of food. Studies on niche-based homestead gardening were carried out at FSRD site Atia, Tangail under On-Farm Research Division of Bangladesh Agricultural Research Institute during 2018-19 and 2019-20 to utilize the homestead resources for producing vegetables and fruits and to enhance nutritional security for the farm families. A total of 12 households were selected from marginal (0.021–0.20 ha), small (0.21–1.0 ha) and medium (1.0-3.0) farmer groups and seven production niches were intervened for year-round production following the Palima model. Results revealed that homestead area could be capable of harvesting sufficient and diversified vegetables round the year by utilizing all possible homestead nieches. After intervention, the number of vegetables was produced by medium farmers (630 kg/year) followed by small (510 kg/year) and marginal (408 kg/year) farmers. Yearly vegetable requirements of farmers were largely met by homestead garden with a supply between 30-58 kg/head/year compared with bench mark level of 5-12 kg/head/year. Results suggested that farmers consumed lion share of their products that could meet up nutrition. Utilization of farm resources available in the farm that increased nutritional security, income and improved livelihoods as well. The up scaling of the production model based on ecosystem in different poverty-stricken regions of Bangladesh is recommended to attain food security and lessening malnutrition.

Keywords: Homestead, Palima model, poverty, Malnutrition, Productivity and livelihood.

Introduction

Bangladesh government has long been striving to increase food safety and to diminish poverty and malnutrition. In this respect, home gardens can play a significant role in providing enhanced food supply and augmented diversity of

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food to some extent. Bangladesh is an emerging country of about 182 million people living in its 147,570 km^2 area and is mainly an agriculturally based economy (BBS, 2020). About 20.5% people in Bangladesh live below the food consumption-based poverty line and they could not afford sufficient food to meet a diurnal diet of 2122 kcal/day/person (ADB, 2021). Vitamin-A deficiency badly affects about 25% women of reproductive stage and nearly 20% preschool aged progenies (WHO, 2009). Dey *et al.,* (2012) reported that 93% family in Bangladesh is suffering from vitamin-C deficiency, 85% in riboflavin, 81% in vitamin-A and calcium, 60 % in protein and 59 % in calorie requirement.

There are about 20 million farm households in Bangladesh most of them live in rural areas having a homestead. These homesteads are the most effective and common production units for supplying food, fuel, timber and other family needs and employing family labour. There are 8,77,045 ha homestead area in Bangladesh among which only 11% homestead area is under vegetable cultivation (BBS, 2020). Rural consumption of leafy and non-leafy vegetables has remained more or less same over the past two decades after increasing over the past 30 years. Global food demand is growing rapidly double and sustaining food production at this level are major challenges for worldwide food security (Tilman *et al.*,2011). Home gardens are an integral part of local food systems and the agricultural landscapes of developing countries all over the world have endured the test of time (Galhena *et al.,* 2013). These home gardens can play a vital role in the production of vegetables and fruits throughout the year and can promote household food self-sufficiency. The homestead garden provides multiple products to the household and meets the diversified needs including food, nutrition and energy securities producing a wide variety of fruits, vegetables and spices. It also contributes to household income and saving through sales of vegetables and fruits.

Most of the farmers at the Farming Systems Research and Development (FSRD) site Atia, Tangail, Bangladesh is having poor resources. In this region, arable land is a scarce resource and is generally operated for growing field crops. Most of the farmers have homestead area, but utilized only for growing small number of vegetables for their own consumption. Moreover, the productivity of the homestead garden is low due to inadequate scientific knowledge of crop production and unavailability of good quality seeds and saplings. These improperly managed homesteads would be effective to bring under year-round production for improving the family nutrition and income generation of small holders (OFRD, 1993). On an average, Bangladeshi people consume a total of 126 g of vegetables and fruit from an average national per capita per day consumption of 23 g leafy vegetables, 89 g non-leafy vegetables and 14 g fruit. This intake is far below the minimum recommended daily consumption of 400 g of vegetables and fruit (Ferdous *et. al*., 2016). To address the problems of household food insecurity and malnutrition On-Farm Research Division (OFRD) of the Bangladesh Agricultural Research Institute (BARI) initiated a homestead vegetable production model known as "Palima model" in 1998. The model was subsequently modified based on the existing ecosystems (niches) of each homestead where different fruits were also included along with vegetables (Ali *et al*., 2006). The impact of home gardens on improving nutrition and household income and the quantity of the household's food production has been widely studied in Bangladesh (Schrein emachers *et al*., 2015). However, scientific evidence for the development of a year-round production model and the utilization of this model for producing fresh vegetables and fruits to enhance the nutritional supplies for the family throughout the year is still limited in Bangladesh.

Considering the above facts, the research work was undertaken with the objectives i) to utilize homestead resources in scientific way for producing fresh vegetables and fruits over space and time, ii) to meet up the food and nutritional requirements of the farmers' family and improved their livelihood and iii) to create employment opportunity particularly women and children and income generation throughout the year.

Materials and Methods

The study was conducted at the FSRD site Atia, Tangail, Bangladesh during 2018-19 and 2019-20 cropping seasons in the homestead of 12 selected farmers. Only marginal, small and medium farmers were the target group therefore, four marginal (0.021-0.20 ha), four small (0.21-1.0 ha) and four medium (1.o1-3.0 ha) farmers were selected purposively. (BBS, 2020). Soils in general have good water holding capacity. The area receives an annual rainfall of around 2123 mm with relatively early onset and late cessation. The homestead resources, needs and choice assessments were performed with the active participation of the family members of the selected households. At each homestead, seven production niches were identified and brought under cultivation following the Palima model. The niches were open sunny place, roof top, trellis, tree support, partially shady place, backyard and slightly marshy land (Table 1). Group meeting of farmers was organized to orient them on the utilization pattern and production practices of the homestead vegetables and fruits.

Table 1. English name, Scientific name, Family and cropping season of homestead garden plant species used by the farmers at FSRD site Atia, Tangail, Bangladesh during 2018-19 and 2019-20

Name of Crop*	Scientific name	Family	Cropping period	Uses
Radish	*Raphanus sativus*	Cruciferae	Mid Oct–Mid Mar	Open sunny space
Tomato	*Solanum Lycopersicum*	Solanaceae	Mid Oct–Mid Mar	Open sunny space
Okra	*Abelmoschus esculentus*	Malvaceae	Mid Mar– June	Open sunny space
Indian spinach	*Basella alba*	Basellaceae	July–Mid Oct	Open sunny space
Brinjal	*Solanum melongena*	Solanaceae	Mid Oct–Mid Mar	Open sunny space
Red amaranth	*Amaranthus gangeticus*	Amaranthaceae	Mid Mar–Mid Oct	Open sunny space
Spinach	*Spinacia oleraceae*	Chenopodiaceae	Mid Jun–Mid Oct	Open sunny space
Kang Kong	*Ipomoea aquatica*	Convolvulaceae	Mid Jun-Mid Oct	Open sunny space
French bean	*Phaseolus vulgaris*	Leguminosae	Mid Nov–Mid Feb	Open sunny space
Stem amaranth	*Amaranthus lividus*	Amaranthaceae	Mid Mar-Mid Jun	Open sunny space
Bottle Gourd	*Lagenaria siceraria*	Cucurbitaceae	Mid Oct–Mid Mar	Roof top/ trellis
Ash gourd	*Benincasa hispida*	Cucurbitaceae	Mid Mar–Mid Oct	Roof top/ trellis
Sponge gourd	*Luffa cylindrica*	Cucurbitaceae	Mid Jun–Mid Oct	Trellis/Tree support
Bitter gourd	*Momordica charantia*	Cucurbitaceae	Mid Oct–Mid Mar	Trellis /Fence
Snake gourd	*Trichosanthis cucumerina uraanguina*	Cucurbitaceae	Mid Mar–Mid Oct	Trellis
Country bean	*Lablab purpureus*	Leguminosae	Mid Oct–Mid Mar	Tree support
Yam	*Dioscorea sp.*	Dioscoreaceae	Mid Mar–Mid Dec	Tree support
Ginger	*Zingiber officinale*	Zingiberaceae	Round the year	Partial shady place
Turmeric	*Curcuma longa*	Zingiberaceae	Round the year	Partial shady place
Panikachu	*Colocasia esculenta*	Araceae	Round the year	Marshy land
Banana	*Musa sp.*	Musaceae	Round the year	Backyard
Lemon	*Citrus lemon*	Rutaceae	Round the year	Backyard
Giant taro	*Alocasia indica*	Araceae	Round the year	Backyard

*English name

The vegetable pattern was initiated from *kharif*-2 (mid-June to mid-October) and plantation of a quick growing fruit tree (papaya) was started afterward. Locally adaptable and culturally acceptable vegetables and fruit trees were selected based on year-round production potential with better nutritional value and market demand. The production units of the homestead crops and trees that were utilized and nourished in these homesteads in available spaces are presented in Table 2. Farmers were encouraged to apply organic fertilizers such as cow dung, poultry manure, compost, kitchen ash, vegetable refuse, crop residues and tree litters from their own sources. Irrigation was provided as and when required for normal growth of the crops. Pests were controlled mainly by mechanical ways without any pesticide application unless severe infestations were observed. Before executing of the activities, a household survey was carried out and detailed information of the selected households was documented. Therefore, a work plan for each of the selected household was prepared considering its available resources, needs and choice. The participated farmers of each farm group were provided orientation separately on the program activities prior to execution. Site working group meeting, review workshop, field day cum field visit and training for farmers and field staffs were organized during the implementation of study activities. Many stakeholders were selected as networking group members from different public and private organizations for proper execution of the activities.

Table 2. Production units of Palima model used by the farmers at the FSRD site Atia, Tangail, Bangladesh during 2018-19 and 2019-20

Niche/space		Round the year homestead vegetables production pattern		
		Rabi (October-March)	*Kharif*-I (April-June)	*Kharif*-II (July-September)
1. Open sunny space	Bed 1	Tomato/Radish	Okra	Indian spinach
	Bed 2	Brinjal+Red amaranth	Indian spinach	Okra+Red amaranth
	Bed 3	Spinach	Kang kong	Kang kong
	Bed 4	Bush bean	Stem amaranth	Indian spinach
2. House roof		Bottle gourd	Ash gourd	Ash gourd
3. Trellis		Bottle gourd	Ash gourd	Sponge gourd
		Bottle gourd	Bitter gourd	Snake gourd
4. Tree support		Country bean	Potato yam	Potato yam
		Country bean	Sponge gourd	Sponge gourd
5. Partial shady place		Ginger and turmeric		
6. Marshy land		Panikachu (Latiraj)		
7. Backyard		Banana, Lemon and Arum		

Socio-agro-economic data of all the selected households were collected, analyzed and presented based on the average of each farmer group. The year-round total vegetable production data were collected after harvesting of each crop from each production niche. A pre-designed schedule was used in this purpose and regular monitoring was also ensured. The nutrient contribution from vegetables and fruits was calculated by converting the total edible yield. Means and percentages were used for interpretation of the data by using MS Excel software.

Results and Discussion

Year-round homestead vegetable pattern

A total of 10 vegetables were selected for year-round vegetable cultivation and were planted in four beds under the open sunny place (Table 2). The year-round vegetable patterns under the seven production niches were divided into three cropping seasons including *rabi* (mid-October to mid-March), *kharif*-I (mid-March to mid-June) and *kharif*-II (mid-June to mid-October). Some vegetables under each production niche were grown only in one season, some were grown in two seasons and some were grown round the year. In contrast, banana and lemon under the backyard, panikachu under the marshy land and ginger and turmeric under the partially shady place were grown throughout the year. Bottle gourd, French bean and bitter gourd were planted in *rabi* whereas ash gourd, snake gourd and sponge gourd were grown in both *kharif*-I and *kharif*-II on the roof top and trellis, respectively.

Baseline survey revealed that intake of vegetables by farmers was only 4.92-11.60 kg/head/year before conducting the study. After applying the Palima model, the farmers gained knowledge on the year-round homestead gardening and their consumption increased 29.69 to 57.72 kg/head/year (Table 6). Thus, home gardens can contribute to ensure better livelihood and nutritional security. These results are in agreement with Ferdous *et al.* (2016) who reported that the target farmers were able to fulfill their daily requirement of vegetables in most parts of the year by following the Rangpur model. The Palima model of year-round production helped enhance food security and access to safe and nutritious food among the studied farmers of Tangail region in Bangladesh.

Year round vegetable production by farmers group

The season wise vegetables production was the highest in *rabi* (220.6, 263.1 and 294.6 kg/farm in marginal, small and medium respectively) followed by *kharif*-II 116.2, 148.5 and 204.4 kg/farm in marginal, small and medium, respectively (Table 3, 4 and 5). The lowest amount of vegetables were produced in *kharif*-I season due to poor vegetative growth and production. It was observed that more crops and production units were covered in *rabi* season than *kharif*. Except the open sunny space, it was observed that niche wise vegetable production was the highest in the roof top followed by the trellis for marginal and small farmers group (Tables 3, 4 and 5). In medium farmers group, the highest amount of vegetables was produced in the roof top followed by the partial shady place. The minimum amount of vegetable was produced in marshy land regardless of the farmers group.

The highest amount of vegetable production before intervention was 76 kg in medium farmers group followed by small (57 kg) farmers (Table 6). The lowest (39 kg) was found with marginal farmers. After intervention under the production model, the highest amount of vegetables (630 kg) was produced by medium farmers group followed by small (510 kg) and marginal (408 kg) farmers (Table 6). This suggests that vegetable production declined towards poor farmers probably due to partial involvement of those farmers in other income generating activities to ensure the daily expenses to some extent. By growing their own households' vegetables were able to supplement their income by lessening the need to purchase food from the local market and used this extra income for other purposes. Berning *et al*. (2008) and Khan *et al.* (2009) are also supported the findings of the study. Talukder *et al.* (2000) reported that the number of varieties and vegetable production was three times higher in the developed garden than traditional garden and child consumption was also 1.6 times higher. When farmers produce higher number of vegetables in their farms their intake of vegetables increase per family and at the same time they rely on less marketing of vegetables from the market. Each farm family sold a portion of their produce to the local market to meet their daily necessities.

Use of Farm Resources

Most of the farmers did not use resources in systematic way during the pre-intervention period. Farmers conserved the kitchen wastes, manures, crop residues, animal waste, poultry litter, cow dung etc. at their farm level systematically in integrated farming system. They used these recourses properly in homestead production units which eventually helped to improve soil fertility and reducing environmental pollution. Homestead garden benefits are family nutrition, increase household income and protect habitats. Nevertheless, after intervention full use of both physical and other resources available in the farm were mobilized for food security, income generation and upgrading their livelihoods. All these benefits have significant role towards poverty mitigation.

Utilization pattern of vegetables by farmers group

The consumption of vegetables varied among the farm categories. The total consumption was the highest in medium (288 kg/year) followed by small (269 kg/year) and marginal (193 kg/year) farmers (Tables 3, 4 and 5). The vegetable intake/head/year was similar in small (57.72 kg) and medium (57.60 kg) farmers and marginal farmers intake (29.69 kg) per head/year (Table 6). This is probably because of family size and selling greater proportion of vegetables by marginal farmers in the market to meet their family needs compared with small and medium farmers. The intake of vegetables/head/year before intervention was the maximum (11.60 kg) among medium farmers followed by small (9.66 kg) and marginal (4.92 kg) farmers (Table 6). It is noted that the intake of vegetables/head/year after intervention followed the same trends. However, the intake of vegetables increased almost more than six times higher after utilization of Palima model compared with vegetable intake before intervention. The average vegetables intake per year per farm family was 250 kg after intervention and the increment was 456 %, whereas intake was only 45 kg per farm family per year before intervention. Vegetable intake was increased remarkably and it was about 137 g/head/day. The highest amount of vegetables was distributed by medium farmers (39.0 kg/year) followed by small (35 kg/year) and marginal farmers (25 kg/year) (Table 6). All of the farmers distributed a portion of their produce to the neighbors and relatives to maintain a social relationship. Each farm family sold some vegetables in the market to meet their family needs. The highest quantity of vegetables was sold by medium farmers (303 kg/year) followed by small (206 kg/year) and marginal farmers (190 kg/year) (Table 6). This pattern indicates that selling of vegetables increased towards marginal to medium farmers. Resource poor farmers in some cases might not have selling large amount of vegetables due to meet their family demands compared with resource rich farmers. The overall results suggest that the production, intake, distribution and selling of vegetables increased with increasing farm sizes. It was observed that 49 % of the harvested vegetables were consumed by the farm families followed by sale (45 %) and the lowest amount (6 %) of vegetables was distributed to relatives and neighbours (Fig. 1). Similar results was found with Shaheb *et al*., (2014) who declared that farmers consumed their harvested vegetables, sale some of them and also distributed to other to strengthen social relation. The better utilization of homestead area with optimum management by effective farm family labour can be achieved for optimum vegetable production and subsequent intake, distribution and sell.

Income divergence

Result revealed that there was great scope and potentiality of increasing yields of short-term cash crops, like vegetables produced and sold in the nearest urban areas. The income from those activities in the homestead could be used to have access food and improve their livelihood. Homestead production of vegetables delivers the household with direct access to vital nutrients that may not be readily available or within their economic reach. Shaheb *et al.*, (2014) stated that additional income generated by selling of surplus vegetables was utilized to purchase extra food items, in turn increase the divergence of family's diet. Bibliographical evidence advocates that home gardens subsidize to income generation, improved livelihoods and household monetary welfare as well as endorsing entrepreneurship and rural development (Calvet-Mir *et al*., 2012).

Table 3. Round the year vegetables production from different niches and disposal pattern by marginal group of farmers at the FSRD site Atia, Tangail, Bangladesh (average of 2018-19 and 2019-20)

Niches		Vegetable Production (kg)			Total (kg)	Disposal pattern of vegetable (kg)		
		Rabi	*Kharif*-I	*Kharif*-II		Consumption	Distribution	Sale
1. Open sunny place	Bed 1	24.3 ± 2.4	16.0 ±2.0	21.2 ± 2.3	61.5 ±5.2	32.5 ± 0.6	3.5 ± 0.3	25.5 ± 0.8
	Bed 2	15.0 ± 2.7	14.0 ±2.7	24.3 ± 6.1	53.3 ± 8.4	27.5 ± 0.3	2.0 ± 0.4	23.8 ±1.5
	Bed 3	25.0 ± 3.5	10.0 ±2.5	12.0 ± 2.3	47.0 ±7.6	17.2 ± 1.6	4.0 ± 0.7	25.8 ±2.7
	Bed 4	26.0 ± 3.5	07.0±2.3	06.1 ±1.2	39.1 ± 4.8	16.0 ± 0.3	2.0 ± 0.2	21.1 ±1.8
2. Roof top		40.0 ± 5.5	06.0 ±1.2	11.0 ± 0.7	57.0 ±7.2	28.8 ± 1.3	3.5 ± 0.5	24.7 ± 1.5
3. Trellis		26.5 ± 4.6	09.0 ±1.8	10.3 ± 0.8	45.8 ±5.3	23.0 ± 4.1	3.0 ± 1.4	19.8 ±2.5
4. Tree support		08.0 ± 2.6	05.0 ±1.2	08.0 ±1.5	21.0 ±4.6	10.0 ± 5.1	1.0 ± 0.2	10.0 ±2.3
5.Partial shady place		24.0 ± 2.1	04.2 ±1.1	11.3 ±3.2	39.5 ± 7.7	21.5 ± 3.8	2.0 ± 1.2	16.0 ± 2.1
6. Marshy land		09.3 ± 1.9	-	-	09.3 ± 2.5	04.2 ± 3.1	1.0 ± 0.5	04.1 ±0.8
7. Backyard		22.5 ± 3.2	-	12.0 ± 2.3	34.5 ± 4.4	12.3 ± 3.6	3.0 ± 0.9	19.2 ±2.5
Total		220.6	71.2	116.2	408	193	25	190

Table 4. Round the year vegetables production from different niches and disposal pattern by small group of farmers at the FSRD site Atia, Tangail, Bangladesh (average of 2018-19 and 2019-20).

Niches		Vegetable Production (kg)			Total (kg)	Disposal pattern of vegetable (kg)		
		Rabi	*Kharif*-I	*Kharif*-II		Consumption	Distribution	Sale
1. Open sunny place	Bed 1	27.3 ± 3.8	24.1 ± 3.1	21.3 ± 2.9	72.7 ± 3.5	39.2 ± 1.9	3.5 ± 0.4	30.0 ± 3.1
	Bed 2	27.6 ± 1.8	17.2 ± 2.1	26.2 ± 2.2	71.0 ± 2.8	37.0 ± 1.3	3.5 ± 1.0	30.5 ± 3.1
	Bed 3	26.0 ± 1.4	12.0 ± 1.7	11.7 ± 0.8	49.7 ± 3.9	25.7 ± 2.9	4.0 ± 2.1	20.0 ± 3.9
	Bed 4	19.3 ± 2.2	9.0 ± 0.7	4.0 ± 0.8	32.3 ± 3.3	16.3 ± 1.4	3.0 ± 0.8	13.0 ± 1.2
2. Roof top		47.0 ± 4.3	10.3 ± 1.1	15.1 ± 0.5	72.4 ± 5.9	36.4 ± 2.3	5.0 ± 0.8	31.0 ± 1.6
3. Trellis		23.5 ± 1.8	11.2 ± 2.1	13.2 ± 0.6	47.9 ± 4.1	25.4 ± 1.7	4.0 ± 0.9	18.5 ± 2.8
4. Tree support		5.5 ± 0.5	8.3 ± 0.7	9.0 ± 1.4	22.8 ± 1.2	12.3 ± 4.1	2.5 ± 1.6	08.0 ± 3.4
5.Partial shady place		41.6 ± 4.3	6.3 ± 1.2	25.8 ± 2.7	73.7 ± 8.1	40.2 ± 4.7	3.5 ± 0.8	30.0 ± 1.8
6. Marshy land		19.0 ± 2.5	-	-	19.0 ± 2.5	9.0 ± 2.5	2.0 ± 1.2	08.0 ± 2.5
7. Backyard		26.3 ± 2.2	–	22.2 ± 2.5	48.5 ± 2.7	27.5 ± 4.9	4.0 ± 0.8	17.0 ± 2.1
Total		263.1	98.4	148.5	510	269	35	206

Table 5. Round the year vegetables production from different niches and disposal pattern by medium group of farmers at the FSRD site Atia, Tangail, Bangladesh (average of 2018-19 and 2019-20)

Niches		Vegetable Production (kg)			Total (kg)	Disposal pattern of vegetable (kg)		
		Rabi	*Kharif*-I	*Kharif*-II		Consumption	Distribution	Sale
1. Open sunny place	Bed 1	28.5 ± 2.6	30.2 ±3.4	33.5 ± 3.9	92.2 ±4.1	40.2±0.4	5.0 ± 1.0	47.0 ±0.8
	Bed 2	30.2 ± 2.5	24.5 ±1.4	35.2 ± 3.6	89.9 ±3.6	40.4 ± 0.3	4.0 ± 0.5	45.5 ±1.2
	Bed 3	28.3 ± 0.8	16.0 ±0.8	23.6 ± 1.7	67.9 ±2.2	26.9 ± 2.3	5.0 ± 0.5	36.0 ±1.0
	Bed 4	32.2 ± 3.1	11.0 ±1.1	15.5 ± 1.2	58.7 ±3.2	25.2 ± 0.9	3.0 ± 0.4	30.5 ±2.6
2. Roof top		54.0 ± 3.6	13.2 ±1.6	13.1 ± 0.2	80.3 ±2.4	34.3 ± 0.8	5.0 ± 0.4	41.0 ± 1.1
3. Trellis		25.0 ± 1.5	14.4 ±1.5	14.3 ± 0.9	53.7 ±3.1	30.2 ± 3.2	4.0 ± 1.1	19.5 ±2.1
4. Tree support		7.70 ± 0.5	12.3 ±0.9	18.7 ± 1.2	38.7 ±2.3	15.2 ± 4.1	4.0 ± 1.1	19.5 ±2.5
5.Partial shady place		35.5 ± 4.1	9.4 ± 1.2	25.1 ± 3.3	70.0 ±4.4	33.0 ± 2.1	3.0 ± 1.0	34.0 ±1.7
6. Marshy land		24.2 ± 1.1	–	–	24.2 ±1.2	10.2 ± 2.7	2.0 ± 1.6	12.0 ±2.2
7. Backyard		29.0 ± 2.8	–	25.4±2.6	54.4 ±3.4	32.4 ± 5.2	4.0 ± 1.1	18.0 ±1.1
Total		294.6	131	204.4	630	288	39	303

Table 6. Disposal pattern and intake by different farm categories before and after intervention at the FSRD site Atia, Tangail, Bangladesh during 2018-19 and 2019-20).

Farm Category	Average family size	Before intervention (2017-18)					After intervention (2018-2020)				
		Total production (kg)	Disposal pattern (kg)			Intake/ head/ year (kg)	Total production (kg)	Disposal pattern (kg)			Intake/ head/ year (kg)
			Intake	Distribution	Sale			Intake	Distribution	Sale	
Marginal	6.50	39	32	02	05	4.92	408	193	25	190	29.69
Small	4.66	57	45	04	08	9.66	510	269	35	206	57.72
Medium	5.00	76	58	04	10	11.60	630	288	39	303	57.60
Mean	5.39	56	45	3.33	7.67	8.35	516	250	33	233	46.38

Before intervention data were collected by interviewing the concerned farmers at the FSRD site Atia, Tangail.

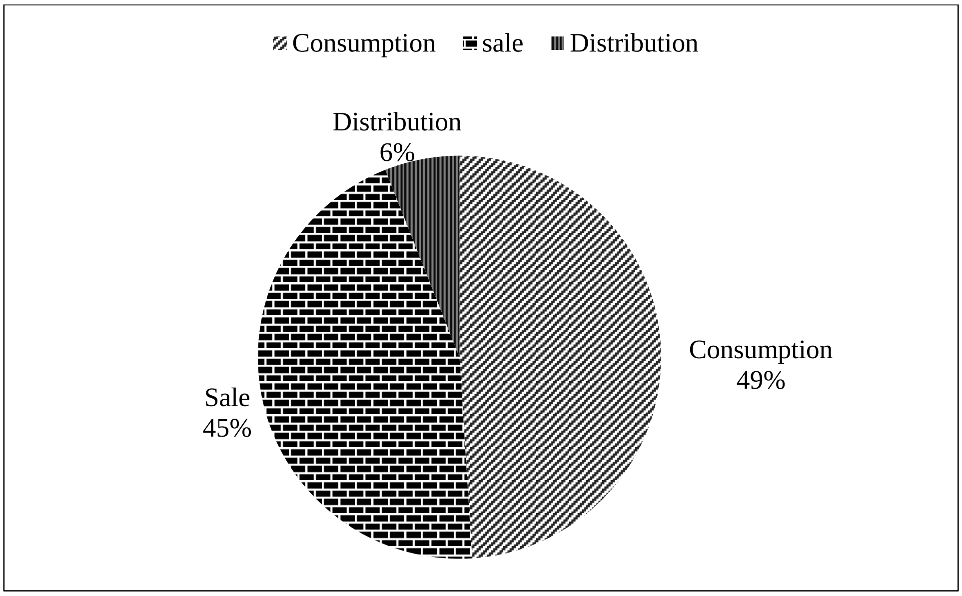

Fig 1. Disposal pattern of vegetables harvested by the farm households.

Nutrient contribution

The highest quantity of vegetables (55, 67 and 77 kg) was produced in the month of December from marginal, small and medium farmers, respectively followed by January (45, 56 and 70 kg) and May (40, 53 and 65 kg) and the lowest (19, 23 and 34 kg) in October (Table 7). It might be due to more production of winter vegetables in *rabi* season. Uddin *et al.* (2009) reported that the recommended dietary allowances (RDA) of vegetables is 220 g/person/day. The highest quantity of vegetables (79, 106 and 118 % of RDA) was intake in the month of December followed by January (59, 82 and 88 % of RDA), while the lowest amount of vegetables was consumed in October (29, 35 and 47 % of RDA) compared to RDA (Table 7). It is also mentionable that 62, 97 and 126% more vegetables produced in the month of December compared to recommended RDA of that month followed by January (32, 65 and 106 %) of RDA from marginal, small and medium farmers. Shaheb *et al*. (2014) declared that children consumed more vitamin 'A' rich foods, such as green leafy vegetables and yellow fruits more frequently from homestead garden than did children in households without a garden or with a traditional garden. It was evident from the literature that home gardens are a part of agriculture and food production systems in many developing countries are widely used as a remedy to lessen hunger and malnutrition (Johnson *et al*., 2000).

Table 7. Month wise vegetables production and intake against RDA by different farmers group at FSRD site Atia, Tangail during 2018-19 and 2019-20 (average of 2 years)

Months	Marginal farmers			Small farmers			Medium farmers		
	Production (kg)	Intake (kg/family)	% Intake over RDA	Production (kg)	Intake (kg/family)	% Intake over RDA	Production (kg)	Intake (kg/family)	% Intake over RDA
January	45	20	59	56	28	82	70	30	88
February	40	18	58	47	24	77	58	25	81
March	27	13	38	34	18	53	46	21	62
April	25	12	36	30	17	52	39	17	52
May	40	19	56	53	28	82	65	27	79
June	37	17	52	45	23	70	49	21	64
July	34	15	44	40	21	62	43	20	59
August	30	14	45	44	23	68	55	26	76
September	22	11	33	27	14	42	38	17	52
October	19	10	29	23	12	35	34	16	47
November	34	17	52	44	25	76	56	28	85
December	55	27	79	67	36	106	77	40	118
Total	408	193	48	510	269	67	630	288	72

Profits from homestead gardening

After intervention, the maximum. cash income from selling vegetables was recorded by medium farms (Tk. 3098/year) followed by small (Tk. 2168/year) and marginal farms (Tk. 1944/year) whereas before intervention the cash income of medium, small and marginal farmers was Tk.130, 104 and 65 per year, respectively. The mean cash income was 23 times higher than before intervention (Table 8). It is revealed that among the seven production units, the highest gross return (Tk. 6446, 5216 and 4181) and gross margin (Tk. 4529, 3420 and 2833) were recorded from medium, small and marginal farmers, respectively. After intervention, marginal, small and medium farmers gross return were 723, 603 and 552 % higher, respectively over before intervention, while the gross margin also followed the similar trend (Table 8). The findings of the study are conformed by finding of Khan *et al*. (2009). The mean vegetables yield (516 kg/year), gross return (Tk. 5281/year) and gross margin (Tk. 3594/year) was received by three groups of farmers (Table 8). The annual income levels of the beneficiary farmers improved after execution of the year-round homestead vegetable production model. Women are the main caretakers of the home gardening activities which empower them resulting in better utilization of the income and improvement in family welfare.

Table 8. Monetary benefit by different farm groups before and after intervention at FSRD site Atia, Tangail, Bangladesh during 2018-19 and 2019-20

Farm category	Before intervention (2018-19)				After intervention (2019-20)			
	Cash Income (Tk.)	Gross return (Tk.)	TVC (Tk)	Gross margin (Tk.)	Cash income (Tk.)	Gross return (Tk.)	TVC (Tk.)	Gross margin (Tk.)
Marginal	65	508	160	348	1944	4181	1348	2833
Small	104	742	214	528	2168	5216	1796	3420
Medium	130	988	256	732	3098	6446	1917	4529
Mean	99	746	210	536	2403	5281	1687	3594

Household labour use and women empowerment

Results indicated that homestead production system gave an opportunity for female employment and empowerment. The idle family labour was mostly used in home garden production system. Male farmers participated more in hard working such as land preparation, planting, weeding, fencing and crop protection while female had a good involvement in intercultural operation, harvesting and marketing of vegetables. Children were also participated in all the works and helped their parents (Table 9). Shaheb *et al*. (2014) reported about more participation of male compared to female while Khan *et al*. (2009) reported that participation of male and female labour was almost equal in home gardening. So, it was found that homestead gardening has created a good opportunity to utilize idle family labour properly. The higher participation of women in agricultural activities made positive impact on equity issues within the family and also in the community as well.

Table 9. Household labour participation in homestead vegetables production at FSRD site Atia, Tangail during 2018-19 and 2019-20

Work area	Male (%)	Female (%)	Children (%)
Land preparation	63	33	4
Seed/seedling	66	34	0
sowing/planting	54	39	7
Intercultural operations	42	54	4
Harvesting	56	42	2
Marketing	76	21	3
Cooking	0	99	0
Mean	51	46	3

Conclusion

The results of the study highlighted the status of utilization of homestead by year-round vegetable production in Bangladesh for marginal, small and medium farm households. There is sufficient scope available to bring the remaining homesteads of Tangail region under proper and effective usage following the Palima model. Farmers usually grow diverse vegetables and fruits in the adjacent area of their households in unplanned and traditional system. The "Palima model" for homestead vegetable production was developed on local conditions and cultural context and intervention could be a sustainable means to improve household food and nutrition security. Homestead vegetable production program can be implemented successfully and cost-effectively on a national-scale using a collaborative model that fits local conditions. The findings of the study would positively help the scientists, extension personnel, policy makers etc. to articulate livelihood enhancement, food and nutrition security related sustainable agricultural program at farm level.

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References

ADB (Asian Development Bank). 2021. Asian Development Bank. Basic Statistics. 2021.

Ali, M. A., M. A. Momin, M. R. Alam, M. S. H. Mollah, F. I. Ivy and M. A. Hossain. 2006. Goyespur Vegetable Production Model (a Bengali Booklet), On-Farm Research Division, Bangladesh Agricultural Research Institute, Pabna, Bangladesh.

BBS. 2020. Statistical Year Book of Bangladesh. Statistics Division, Ministry of Planning. Government of the People's Republic of Bangladesh.P. 113.

Berning, C., C. Bradley, K. Sirman, and F. Sosa. 2008. Homestead Food Production in Barisal, Bangladesh: Capstone report. M A Candidates, International Development Studies, The Elliott School of International Affairs, The George Washington University, 79

Calvet-Mir L., E. Gomez-Bagetthun and V. Reyes-Garcia. 2012. Beyond food production: Home gardens ecosystem services. A case study in VallFosca, Catalan Pyrenees, northeastern Spain. Ecol. Econ. **74:** 53-160.

Dey, S., U. K. Sarker and M. A. Awal. 2012. Year round homestead vegetable production: reduction of nutritional deficiency and income generation for small household. Bangladesh J. Progress. Sci. Technol. **10:**187–190.

Ferdous, Z., A. Datta, A. K. Anal, M. Anwar, A. S. M. M. R. Khan. 2016. Development of home garden model for year-round production and consumption for improving resource poor household food security in Bangladesh. Wageningen J. Life Sci. 78:103-110. http://dx.doi.org/10.1016/j.njas.2016.

Galhena, D. H., R. Freed and K. Maredia. 2013. Home gardens: a promising approach to enhance household food security and wellbeing, Agric. Food Sec. **2:** 8. http://www.agriculture and food security.com

Johnson, W. C., B. Alemu, T. P. Msaki, M. Sengendo, H. Kigutha and A. Wolff. 2000. Improving Household Food Security: Institutions, Gender and Integrated Approaches. Davis CA, USA: Paper prepared for the Broadening Access and Strengthening Input Market Systems (BASIS) Collaborative Research Support Project (CRSP).

Khan, M.A.H., M.Y. Ali, M. A. Quayyum, M. I. Nazrul, and M. J. Hossain. 2009. Year-Round Homestead Vegetables Production: A Means of Reducing Poverty and Nutritional Deficiency for Small Farm. Bangladesh J. Agril. Res. **34**(1): 169-174.

OFRD (On-Farm Research Division). 1993. Homestead Vegetable Production: Training Manual, OFRD of Bangladesh Agricultural Research Institute, Gazipur.

Schreinemachers, P., M. A. Patalagsa and M. R. Islam. 2015. The effect of women's home gardens on vegetable production and consumption in Bangladesh, Food Sec. **7:** 97–107.

Shaheb, M. R., M. I. Nazrul and A. Sarker. 2014. Improvement of livelihood, food and nutrition security through homestead vegetables production and fruit tree management in Bangladesh. J. Bangladesh Agril. Univ. **12**(2): 377–387.

Talukder, A., D. P. Saskia, A. Taher, A. Hall, R. M. Pfanner and M. W. Bloem. 200. Improving Food and Nutrition Security Through Homestead Gardening in Rural, Urban and Peri-Urban Areas in Bangladesh. Helen Keller International, Bangladesh

Tilman, D., C. Balzer, J. Hill, and B. L. Befort. 2011. Global Food Demand and the sustainable Intensification of Agriculture. Proceedings of the National Academy of Sciences of the United States of America, **108:** 20260–20264.

Uddin, M. J., A. T. M. Masud L. Aktar, M. A. Rashid and A. Haque. 2009. Improved Variety of Sweet Gourd and Production Technology (Booklet). Published by Bangladesh Agricultural research Institute, Gazipur, Bangladesh, 1-18.

WHO (World Health Organization). 2009. Global prevalence of vitamin A deficiency in populations at risk 1995–2005 in: Database on Vitamin A Deficiency.

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INFLUENCE OF FOLIAR APPLICATION OF GROWTH REGULATORS ON VEGETATIVE GROWTH AND FLOWERING OF CHRYSANTHEMUM

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S. M. SHARIFUZZAMAN[4] AND M. A. SADIA[5]

Abstract

The pot experiment was conducted at the Floriculture field of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during August 2020 to May 2021 to evaluate the foliar spray of gibberellic acid (GA_3), benzyl adenine (BA) and naphthalene acetic acid (NAA) on growth and flowering traits of chrysanthemum (*Chrysanthemum morifolium*). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Four weeks old seedlings of chrysanthemum genotype CM-019 (flower class: Pompon and flower colour: Orange yellow) were transplanted in pot keeping under natural sunlight. The aqueous solution of GA_3, BA and NAA @ 100 and 200 ppm of each were sprayed on the flower plants at monthly interval starting after one month of transplantation of seedlings along with control (water). The results revealed that vegetative growth and flowering parameters were significantly influenced by plant growth regulators. Maximum number of leaves per plant (50.0) and leaf area per plant (7.5 cm^2) were recorded from the spraying of BA @ 100 ppm closely followed by BA @ 200 ppm (48.0 and 7.0 cm^2/plant) and GA_3 @ 100 ppm only for number of leaves (47.0/plant). Spraying of GA_3 @ 100 ppm produced the tallest plant (70.0 cm) and the highest plant spread (23.0 cm). Number of flowers (26.0/plant), flower size (7.8 cm), average weight of stalk (37.0 g) and vase life (15.0 days) were also found maximum from the application of GA_3 @ 100 ppm, closely followed by GA_3 @ 200 ppm (23.5/plant, 7.2 cm, 36.0 g, 14.0 days) and NAA @ 100 ppm (18.5/plant, 7.0 cm, 36.0 g, 13.0 days) and irrespective of concentrations, BA failed to improve these characters. GA_3 @ 100 ppm recorded maximum length of stalk (37.5 cm) and rachis (29.0 cm), which was identical with GA_3 @ 200 ppm (34.6 cm and 25.0 cm), and BA @ 100 ppm gave the lowest length of stalk and rachis. GA_3 also caused faster initiation of flowering, whereas NAA and BA delayed it. GA_3 @ 100 ppm took the minimum days to flowering (50.0 days) was observed when plants were sprayed with GA_3 @ 100 ppm whereas it was maximum (69 days) from BA @ 100 ppm treatment. It can be concluded that GA_3 @ 100 ppm provided the best results for obtaining better vegetative growth of plants, maximum number of cut blooms with longer stalk as well as bigger flower size with prolonged vase life in chrysanthemum.

Keywords: Chrysanthemum, GA_3, BA, NAA, Phenology, Vase life.

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Introduction

Chrysanthemum (*Chrysanthemum morifolium* Ramat.) belongs to the family *Asteraceae* and is a very popular commercial flower grown for as cut flowers for vases, as loose flowers for garland making, general decoration, hair adornments, religious functions and interior decorations at ceremonies, as well as pot plants all over the world including Bangladesh. Chrysanthemums are native to East Asia and northeastern Europe and most of the species originate from East Asia and the center of diversity is in China (Liu *et al.*, 2012). There are more than 5000 different varieties with different names, grown all around the world. In some countries, it ranks next to rose in value of the crop produced. The agro-ecological conditions of the country are favorable for the culture and survival of chrysanthemum. For this, the flower growers of Bangladesh are very much interested in cultivating chrysanthemum instead of the traditional flower crops that usually do not give much return to them. As a result, recently chrysanthemum is becoming attractive to the growers as well as users, as it has great potential for local and export market.

Plant Growth Regulators (PGRs) such as auxins, gibberellins, cytokinins, abscisic acid, ethylene, brassinosteroids, salicylates, jasmonates etc. are available in synthetic forms, which are commonly used in ornamental industry for nursery production, ornamental foliage plant and several other flowering crops (Arteca, 1996; Sanap *et al*., 2000). Gibberellic acid (GA_3) is a well-recognized synthetic gibberellins, which has been used for desirable plant growth, flower size, flower number and flower induction in many herbaceous flower crops. The flowering habit of long day or long short day plant can be controlled by regulating the endogenous level of gibberellins-like substances through the use of such growth promoter. The beneficial effects of GA_3 on growth and flowering has been reported in chrysanthemum (Patel *et al*., 2010; Alhajhoj, 2017; Aparna *et al*., 2018; Sajid *et al*., 2018; Farag *et al*., 2018; Sing and Bala, 2018; Singh *et al.*, 2018), in calendula (Khudus *et al*., 2017) and in china aster (Mishra *et al*., 2018). Naphthalene acetic acid (NAA) is a syntheticauxins, which has various physiological roles viz., encouraging cell division and cell enlargement. This PGR can enter into plants through leaves, branches and tender skin etc. and can influence plant growth, flowering and other properties. The beneficial effects of NAA on growth and flowering has been reported in chrysanthemum (Sahu *et al.*, 2021) and in calendula (Khudus *et al.,* 2017). Benzyl adenine has recently been used as one of other sources that can maintain or increase the quality of various ornamental plants (Buban, 2000; Han, 2001) and on many other physiological and developmental processes, including leaf senescence, leaf chlorosis, increase the vase life, delaying senescence of cut carnation by inhibiting ethylene biosynthesis (Cook *et al*., 1985), nutrient mobilization, apical dominance, the formation and activity of shoot apical meristems, floral development, combating drought stress in plants (Waterland *et al*., 2010). El-Ghait *et al*. (2018) recorded increased plant height and highest number of branches and leaves per plant, number of flowers per plant and maximum vase life in chrysanthemum from the application of Kinetin (a synthetic cytokinin) @ 75 ppm. Singh and Bala (2018) obtained maximum vase life in chrysanthemum from the application of BA @ 200 ppm. Nambiar *et al*. (2012) reported that application of Benzyl adenine @ 200 ppm on dendrobium orchid were found to increase maximum inflorescence%, hastens inflorescence emergence, inflorescence size (length x width), number of leaves per plant, number of flowers per inflorescence and flower size. Application of proper doses of plant growth regulators may not only ensure better yield and quality of chrysanthemum, as well as minimize the wastage of growth regulators and cost. In Bangladesh, a few studies were done regarding the use of plant growth regulators, especially plant growth retardants for growth and flowering of chrysanthemum. The present study was, therefore, conducted to find out the optimum concentration of GA_3, BA and NAA to improve vegetative growth and flowering traits of chrysanthemum.

Material and Methods

The experiment was conducted at the field of Landscape, Ornamental and Floriculture Division of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during August 2020 to May 2021. Four weeks old seedling of chrysanthemum (CM-019) were collected from HRC, BARI and transplanted in 10 x 12 cm earthen pot in the month of October 2020. The pompon type genotype (CM-019) was used . The pots were filled with a mixture of media that consists of one part coarse sand, one part garden soil, one part cocodust, one part cowdung, a quarter part of wood ashes and two table spoonful’s of bone meal. Subsequently, 10 g TSP, 6 g MoP, 0.10 g B as solubor (%) per pot were applied. Urea @ 2, 3 and 2 g per pot was applied at 30, 50 and 70 days after transplanting, respectively. The pots were kept under natural sunlight and distance were maintained 6 cm apart from one pot to another pot. The experiment was laid out in Randomized Completely Block Design (RCBD) with 5 replications (one pot considered as one replication). The experiment consists of 7 treatments viz. BA, GA_3 and NAA @ 100 ppm and 200 ppm of each and control. The growth regulators were sprayed on plants in the morning at monthly interval starting after one month of seedling transplantation. Control treated plants were sprayed with water. All the cultural operations such as weeding, mulching, watering, disbudding, pinching, staking etc. were done as per the need of the crop. Ridomyl Gold (a.i. Metalaxyl & Mancozeb) was sprayed on the plants @ 2.0 g/L H_2O thrice at 15 days interval starting from 20 days after transplanting as protective measures against the incidence of diseases such as leaf spot and powdery mildew. Ripcord (a.i. Cypermethryn) was also sprayed on the plants @ 2.0 ml/L H_2O thrice at 15 days interval starting from 30 days after transplanting as protective measures against the attack of insects such as aphids, thrips, leaf miners etc.

The data were recorded on plant height, number of leaves per plant, plant spread, leaf area per plant, days to flower initiation, number of flowers per pot, stalk length, rachis length, flower size, average weight of stalk after maturity indices of chrysanthemum flower. For observing post-harvest life of the cut flowers of chrysanthemum, GA_3, BA and NAA treated and untreated cut stems were collected from the field in the morning to avoid excessive heat and brought to the laboratory in a bucket containing 3-4 liters of water. Before placing cut stems in the vase water, stems were cut (slanting) to a uniform length of 25 cm and leaves near the bottom of the cut stems were removed except for few leaves below the inflorescence. Cut stems were placed in 250 ml conical flasks containing 200 ml of distilled water and kept in laboratory conditions at a room temperature of 18±2ºC and relative humidity of 70±5% under continuous illumination of florescence light. Five flowers were taken randomly and vase life was recorded from all the treatments by counting number of days from the time, when the cut flowers lose their decorative value after complete opening or shedding of petals. The recorded data were statistically analyzed with the help of computer base MSTAT software and treatment means were separated by Duncan's Multiple Range Test (DMRT) at 1% level of probability.

Results and Discussion

Vegetative growth parameters

Plant height

The tallest plant (70.0 cm) was recorded from the treatment GA_3 @ 100 ppm, whereas the minimum plant height (52.0 cm) from BA @ 100 ppm which was closely followed by that of BA @ 200 ppm (55.0 cm) (Table 1). Patel *et al.* (2010), Singh *et al*. (2018) and Sharifuzzaman *et al.* (2011) obtained the tallest plant from GA_3 @ 150 ppm in chrysanthemum. On the other hand, Farag *et al.* (2018) and Sahu *et al.* (2021) were obtained the tallest plant from GA_3 @ 200 ppm in chrysanthemum. Aparna *et al.* (2018), Alhajhoz (2017) and Sajid *et al*. (2018) was obtained highest plant height when the chrysanthemum plants treated with GA_3 @ 400 ppm, GA_3 @ 300 ppm and GA_3 @ 250 ppm, respectively. Talukder and Paswan (1998) was also obtained maximum value for this same trait from the spraying of GA_3 @ 40 ppm. Foliar application of GA_3 at a proper concentration might have influenced plant height by stimulating cell division and elongation at internodal region, which resulted in more number of cells and increase in cell length. The shortest plant height with application of BA might be due to counteracting the apical dominance.

Number of leaves per plant

The maximum number of leaves (50.0) per plant was recorded from BA @ 100 ppm, which was identical with BA @ 200 ppm (48.0/plant) and GA_3 @

100 ppm (47.0/plant), whereas the minimum number of leaves per plant (39.0) from control. The maximum number of leaves per plant with application of BA @ 100 ppm might be due to higher number of suckers per plant. Sahu *et al.* (2021), El-Ghait *et al.* (2018) and Sajid *et al.* (2018) also reported that maximum number of leaves per plant was observed from the plants sprayed with treatment containing GA_3 @ 200 ppm, GA_3 300 ppm and GA_3 @ 100 ppm, respectively. Aparna *et al*. (2018) reported that the result of higher number of leaves per plant might be due to GA_3 application at a proper concentration enhanced biosynthesis of protein and carbohydrates leading to enhancement of initiation of leaf primordial growth and consequently production of more leaves.

Table 1. Effect of BA, GA_3 and NAA on vegetative growth parameters of chrysanthemum

Growth regulators (ppm)	Plant height (cm)	Number of leaves/ plant	Leaf area (cm^2)/plant	Plant spread (cm)
BA @ 100 ppm	52.0 d	50.0 a	7.5 a	14.9 bc
BA @ 200 ppm	55.0 cd	48.0 ab	7.0 ab	14.4 bc
GA_3 @ 100 ppm	70.0 a	47.0 ab	6.4 bc	23.0 a
GA_3 @ 200 ppm	65.0 b	44.8 b	6.0 bc	20.0 ab
NAA @ 100 ppm	63.0 bc	42.3 bc	5.9 bc	17.0 b
NAA @ 200 ppm	61.0 bc	42.0 bc	5.8 bc	15.0 bc
Control	58.0 c	39.0 c	5.5 c	12.0 c
CV (%)	8.7	7.5	9.5	9.2

In a column mean values with common letters do not differ significantly at 1% level of probability by DMRT.

Leaf area per plant

The maximum leaf area per plant (7.5 cm^2) was recorded from BA @ 100 ppm closely followed by that of BA @ 200 ppm (7.0 cm^2/plant), whereas, the minimum leaf area per plant (5.5 cm^2) in control. This might be due to production of higher number of leaves per plant, when plants are treated with benzyl adenine at a specific concentration. On the contrary, Farag *et al.* (2018) obtained maximum leaf area per plant through application of GA_3 @ 200 ppm, closely followed by GA_3 @ 100 ppm, though they obtained increased leaf area per plant from BA @ 200 and 100 ppm compared to control. These results of GA_3 might be attributed to the role of gibberellic acid at a proper concentration on stimulation of cell division and cell elongation of the leaves or on increasing the number of leaves per plant, or all of them, consequently the leaf area per Chrysanthemum plant could be increased reported by Farag *et al.*, (2018).

Plant spread

The maximum plant spread (23.0 cm) was noticed in GA_3 @ 100 ppm which was statistically similar to GA_3 @ 200 ppm (20.0 cm) and the minimum plant spread (12.0) in control (Table 1). Singh *et al.* (2018) and Patel *et al.* (2010) also obtained maximum plant spread in chrysanthemum from GA_3 @ 150 ppm closely followed by GA_3 @ 100 ppm among three GA_3 concentrations (50, 100 and 150 ppm). Alhajhoj (2017) reported that application of GA_3 @ 300 ppm produced maximum plant spread in chrysanthemum. Sahu *et al*. (2021) reported that maximum spread of plant was noticed from the chrysanthemum plants sprayed with treatment containing GA_3 @ 200 ppm. Patel *et al.* (2010) explained that higher plant spread might be due to GA_3 which enhanced cell division and cell enlargement, promotion of protein synthesis coupled with dry matter accumulation.

Flowering parameters

Days to flower initiation

There was a significant difference in days to flowering among the different treatments. The minimum days (50) required for flower initiation was observed in GA_3 @ 100 ppm which was closely followed by GA_3 @ 200 ppm (52 days) (Fig. 1). Application of BA @ 100 ppm took maximum days (69) to initiate flowers followed by control (66 days) and BA @ 200 ppm (64 days). Application of NAA @ 100 ppm took 58 days required for flower imitation followed by NAA @ 200 ppm (56 days). Singh *et al*. (2018) also reported that minimum number of days required for first flower bud appearance was recorded with 100 ppm concentration of GA_3 in chrysanthemum. It is evident that GA_3 @ 100 ppm and GA_3 @ 200 ppm reduced time to initiate flower by 16 and 14 days, respectively for early bloom compared to control. Irrespective of concentrations, NAA also took less time to initiate flower compared to control, but BA @ 100 ppm took more time to initiate flower compared to control, whereas BA @ 200 ppm reduced time only by two days compared to control. GA_3 decreased the concentration of abscisic acid in plant shoot, which might enhance flower initiation and early flowering. Moreover, as the leaf numbers were increased in present study, which improved photosynthetic activity to enhance early flowering. These findings are confirmed by those reported by Sajid *et al*., (2018), Sharifuzzaman *et al*. (2011) and Patel *et al*. (2010) who observed that plant treated with GA_3 took minimum time to initiate flower in chrysanthemum.

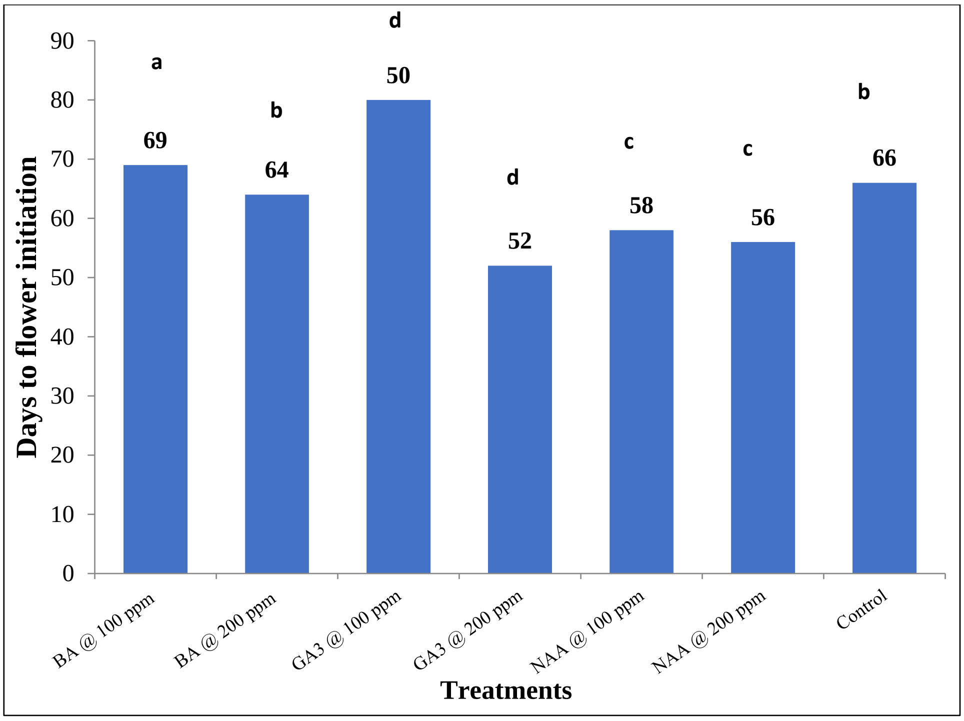

Fig. 1. Effect of BA, GA_3 and NAA on flower initiation in chrysanthemum. Mean values on top of the bars with uncommon letter(s) are significantly different at 1% probability by DMRT.

Stalk length and rachis length

From marketing point of view, length of flower stalk is an important parameter of flower growth. Using GA_3 at 100 ppm concentration gave the maximum stalk length (37.5 cm) and rachis length (29.0 cm), compared with other PGR (BA and NAA) concentrations and control, which were statistically similar to those of GA_3 @ 200 ppm (34.6 cm and 25.0 cm). Minimum stalk length (26.5 cm) and rachis length (18.0 cm) were observed in BA @ 100 ppm closely followed by BA @ 200 ppm and NAA @ 100 ppm and control. This is in close conformity with the result of Singh *et al.* (201) who obtained maximum stalk length using GA_3 @ 150 ppm being identical with GA_3 @ 100 ppm in chrysanthemum. The increased stalk length with GA_3 @ 100 ppm treatment might be due to rapid internodal elongation, rapid cell division and cell elongation in the intercalary meristem. Singh *et al.* (2018) opined the reason of increased stalk might be that the flowers stalk length due to redirecting the movement of organic metabolism and in establishing sink. The increase in rachis length with GA_3 @ 100 ppm might be due to increased activity of growth promoting enzymes by synthesizing more nucleic acid and other compounds. Whereas, the minimum rachis length with BA @ 100 ppm might be due to BA showed reduced plant height and stalk length, which directly influenced the rachis length.

Table 2. Effect of plant growth regulators on flowering parameters of chrysanthemum

Treatments	Stalk length (cm)	Rachis length (cm)	Flower number/plant	Flower size (cm)	Av.weight of stalk (g)
BA @ 100 ppm	26.5 c	18.0c	15.0 c	6.7 ab	25.5 c
BA @200 ppm	30.0 bc	20.8 bc	19.0 bc	6.8 ab	26.8 bc
GA_3 @100 ppm	37.5 a	29.0 a	26.0 a	7.8 a	37.0 a
GA_3 @200 ppm	34.6 ab	25.0 ab	23.5 ab	7.2 ab	36.0 ab
NAA @100 ppm	31.8 bc	21.5 bc	18.5 ab	7.0 ab	29.0 ab
NAA @200 ppm	32.5 b	22.0 bc	20.0 b	7.1 ab	31.0 b
Control	30.0 bc	22.7 b	17.0 bc	6.0 b	26.5 bc
CV (%)	7.5	7.2	8.6	6.9	8.7

In a column mean values with common letters do not differ significantly at 1% level of probability by DMRT

Number of flowers per plant

Plants treated with GA_3 @ 100 ppm concentration produced maximum number of flowers per plant (26.0) which was identical with GA_3 @ 200 ppm (23.5/plant) and NAA @ 100 ppm (18.5/plant), but BA @ 100 ppm treatment produced the lowest number of flowers per plant (15.0) being identical with BA @ 200 ppm (19.0/plant) and control treatment (17.0/plant) (Table 2). The increase in flower numbers by GA_3 with a specific concentration might be due to increase in leaf numbers and leaf area, which might have boosted the production and accumulation of assimilates that were translocated from source to sink for flower production.

Alhajhoj (2017) also reported that application GA_3 @ 300 ppm gave maximum number of flowers per plant which was identical with that of GA_3 @ 200 ppm. Patel *et al*. (2018) obtained the highest number of flowers per plant from GA_3 @ 150 ppm being identical with GA_3 @ 100 ppm. Sharifuzzaman *et al*. (2011) and Singh *et al*. (2018) obtained maximum number of flowers per plant from the spraying of GA_3 @ 150 ppm which was significantly higher than GA_3 @ 150 ppm. Sahu *et al.* (2021) and Sajid *et al*. (2016) reported maximum number of flowers per plant was from GA_3 @ 200 ppm and GA_3 @ 250 ppm, respectively.

Flower size

Maximum size of flower (7.8 cm) was observed with GA_3 @ 100 ppm concentration which was statistically similar to GA_3 @ 200 ppm (7.2 cm), NAA (100 and 200 ppm) and BA (100 and 200 ppm) and the lowest flower size was observed in control (Table 2). Singh *et al.* (2018) and Sharifuzzaman *et al.* (2011) obtained maximum flower size from GA_3 @ 150 ppm. Frag *et al*. (2018) and Sajid *et al.* (2016) reported that using GA_3 @ 200 ppm gave the maximum flower size, whereas Alhajhoj (2017) was found flower size maximum from GA_3 @ 300 ppm treated plant. The result of increased flower size with GA_3 was probably due to that using gibberellic acid at a proper concentration led to extend the length of ray florets, or promote more initiated florets per capitulum or both of them, accordingly the flower size of chrysanthemum plant would be increased (Frag *et al*.,2018). Singh *et al*. (2018) opined regarding the cause of increased flower size with GA_3 at a specific concentration that it may have been due to a close parallelism between vegetative growth and flowering and it is possible that stimulatory effect of GA_3 on vegetative growth associated with efficient mobilization capacity.

Weight of stalk (Average)

The average fresh weight of stalk (37.0 g) was recorded to be the maximum with treatment involving GA_3 @ 100 ppm closely followed by 36.0 g weight with GA_3 @ 200 ppm and NAA @ 100 ppm (29.0 g). The minimum weight (25.5 g) in stalk harvested from the pot where plants were sprayed with BA @ 100 ppm which was identical with normal water (control) (26.5 g). Singh and Bala (2018) obtained increased stalk weight compared to control when GA_3 was applied at the rate of 50, 100 and 150 ppm. However, they obtained maximum stalk weight from GA_3 @ 150 ppm being identical with GA_3 @100 ppm. Increase in weight of stalk might be due to increased activity of enzymes which are involved in cell division and elongation process.

Vase life

Treatment consisting of GA_3 @ 100 ppm significantly produced maximum vase life (flower life) (15 days) which was closely followed by that of GA_3 @ 200 ppm (14 days) and minimum vase life in control treatment (10 days) (Fig. 2). It is observed that flower life was increased by 5 days when the solution of GA_3 @ 100 ppm was used. This is in agreement with the results of Sajid *et al.* (2018) and Sharifuzzaman *et al.* (2011) who obtained maximum vase life from the chrysanthemum plants treated with 100 ppm GA_3 closely followed by 150 ppm GA_3. Talukder and Paswan (1998) also reported that application of GA_3 at 40 ppm concentration increased vase life by 9 days in chrysanthemum.

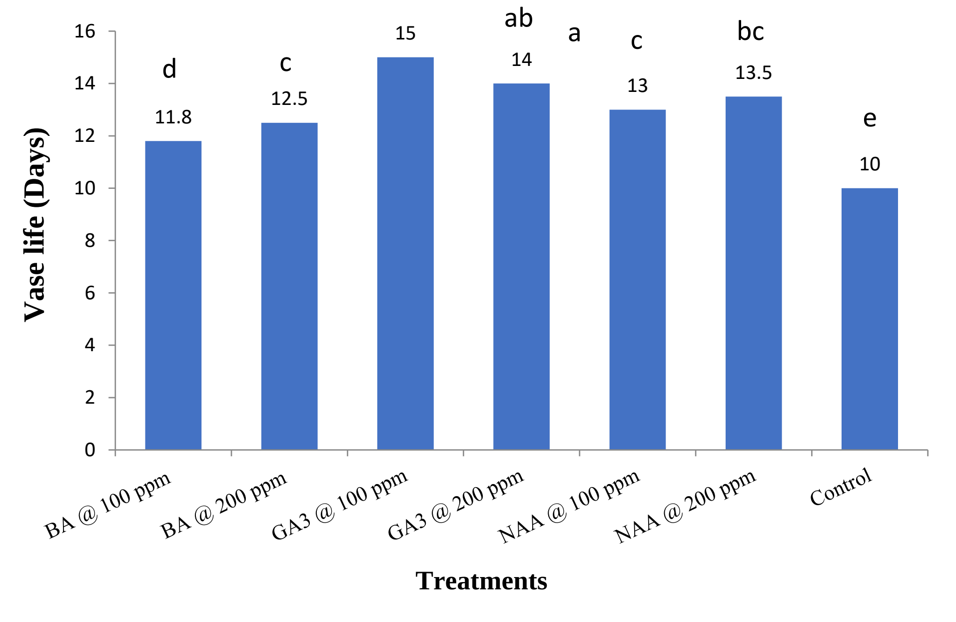

Fig. 2. Effect of BA, GA_3 and NAA on vase life in chrysanthemum. Mean values on top of the bar with uncommon letter(s) are significantly different at 1% probability by DMRT.

Sajid *et al*. (2018) explained that the vase life could be correlated with ethylene production which is inhibited by the foliar application of GA_3, because it may had retarded the onset of senescence in whole cut inflorescence stalk by containing higher amount of RNA content. Farag *et al*. (2018) gave the same opinion that the increased vase life was probably due to that using GA_3 at a suitable concentration led to delay the flower's senescence and reduce ethylene production in the cut flowers, consequently the flower duration in the vase could be increased.

Conclusion

Vegetative growth and flowering parameters of chrysanthemum as well as vase life of flowers were influenced by the application of plant growth regulators, namely GA_3, BA and NAA in chrysanthemum. GA_3 @ 100 ppm was superior regarding plant height and plant spread and all flowering traits and reduced time to flower initiation by 16 days for early bloom. The same treatment also increased vase life of flowers by 5 days. From the present study, it is concluded that foliar application of GA_3 @ 100 ppm was superior for obtaining better vegetative growth of plants, maximum number of flowers with longer stalk as well as bigger flower size with prolonged vase life in chrysanthemum

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References

Alhajhoj, M. R. 2017. Effects of foliar application of plant growth regulators on growth and flowering characteristics of chrysanthemum CV. Paintball. *Pak. J. Life Soc. Sci*. 15(2): 114-119. http://www.pjlss.edu.pk/pdf_files/2017_2/114-119.pdf.

Aparna, V., K. Prakash, M. Neema, A. Ajay, N. Kumar and M. Singh. 2019. Effect of gibberellic acid on plant growth and flowering of chrysanthemum CV. Thai Chen Queen under short day planting conditions. *Int. J. Agric. Sci.* 10 (11): 6274-6278. https://www.researchgate.net/publication/335978277.

Arteca, R. N. 1996. Plant growth substances: Principles and applications. Chapman and Hall Publishers, London, UK. pp. 32-40.

Buban, T. 2000. The use of benzyl adenine in orchard fruit growing: A mini review. *Plant Growth Reg*. **32:** 381-390.

Cook, D., M. Rasche and W. Eisinger. 1985. Regulation of ethylene biosynthesis and action in cut carnation flower senescence by cytokinins. *J. Amer. Soc. Hort. Sci*. **110:** 24- 27.

El-Ghait, A., M. Eman, A. O. Gomaa, A. S. M. Yousuf and A. M. El- Nemr. 2018. Effect of kinetin and GA_3 treatments on growth and flowering of *Dendranthema grandiflorium* CV. Art Queen plants. *Middle East J. Agric.* 7 (3): 801-815.https://www.curresweb.com /mejar /mejar/2018/801-815.pdf.

Farag, G., M. Khattab and A. El- Naggar. 2018. Effect of benzyl adenine and gibberellic acid on the vegetative growth and flowering of chrysanthemum plant. *Alex. J. Agric. Sci.* **63** (1): 29-40.

Han, S. S. 2001. Benzyl adenine and gibberellins improve postharvest quality of cut Asiatic and Oriental lilies. *Hort. Sci*. **36**(4): 741 – 475.

Khudus, S., V. M. Prasad and S. M. Jogdand. 2017. Effect of plant growth regulators on growth and flower yield of calendula (*Calendula officinalis* L.) CV. Bon Bon. *Chem. Sci. Rev. Lett.* 6(22) : 1290-1294. https://chesci.com/wp content/uploads/2017/07/V6 i2296_ CS072048052 _ SM_Jogdand 1290-1294.pdf.

Liu, P. L., Q. Wan, Y. P. J. Guo, Yang and G. Y. Rao. 2012. Phylogeny of the genus *Chrysanthemum* L.: Evidence from single-copy nuclear gene and chloroplast DNA Sequences. *PLOS One*. 7(11): e48970. doi:10.1371/journal.pone.0048970.

Mishra, P. P., G. Pandey, A. Kumura, R. Naik and L. P. Pujahari. 2018. Effect of foliar application of gibberellic acid (GA_3) concentrations and spraying frequencies on vegetative and floral attributes of China aster [*Callistephu schinensis* (L.) Nees.]. *Int. J. Curr. Microbiol. App. Sci.* 7(01): 1889-1894. doi: https :// doi. Org /10 . 20546/ ijcmas. 2018.701.227.

Nambiar, N., T. C. Siang and M. Mahmood. 2012. Effect of 6-benzylaminopurine on flowering of a Dendrobium orchid. *AJCS.* 6(2):225-231.https: // www. researchgate .net/profile / Nisha-Nambiar/publication/268349587.

Patel, S. R., N. S. Parekh, A. B. Parmar and H. C. Patel. 2010. Effect of growth regulators on growth, flowering and yield of chrysanthemum (*Chrysanthemum morifolium* Ramat.) cv. “IIHR-6” under middle Gujarat conditions.*Int.J.Agril.Sci.*.6(1):243-245. http:// researchjournal. co.in/upload/assignments/6_243-245.pdf

Sahu, J. K., S. K. Tamrakar, R. Lakpale and T. Tirke. 2021. Effect of planting geometry and Plant Growth Regulators on Growth and Flowering of Chrysanthemum. *Agriways.* 9 (1): 17-20.http://www.agriwaysjournal.com/wpcontent/uploads/journals/ volume9.1/effectofplantinggeometry.pdf.

Sajid, M,, A. Rab and I. A. Khan, I. Jan, N. Ul. Amin, A. Moteen, h. Usman, M. Alam and S. T. Shah. 2018. The pre-harvest foliar application influenced the flower quality and vase life of chrysanthemum cultivars. *Hort.Int. J.* 2(4):145-152. DOI: 10.15406/hij.2018.02.00043.

Sanap, P. B., B. A. Patil and B. V. Gondhali. 2000. Effect of growth regulators on quality and yield of flowers in tuberose (*Polianthes tuberosa* L.) CV. Single. *Orissa J. Hort*. **28:** 68-72.

Sharifuzzaman, S. M., K. A. Ara, M. H. Rahman, K. Kabir. and M. B. Talukdar . 2011. Effect of GA_3, CCC and MH on vegetative growth, flower yield and quality of chrysanthemum. *Int. J. Expt. Agric*. **2**(1): 17-20. http://ggfjournals.com/assets/uploads.

Singh, J., R. Nigam, R. Singh, A. Kumar and A. Kumar. 2018. Effect of gibberellic acid and cycocel on growth, flowering and yield of chrysanthemum (*Dendranthema grandiflora* Ramat) CV. Birbal sahni. J. Pharmacog. and Phytochem. 2018; SP1: 2753-2758. https :// www.phytojournal .com/archives /2018/vol7issue1S/PartAO/SP-7-1-776.pdf.

Singh, T. and M. Bala. 2018. Effect of foliar spray of benzyl adenine, gibberellic acid and putrescine on post-harvest keeping quality of chrysanthemum. *Agric. Res. J*. 55 (2) : 386-388. DOI No. 10.5958/2395-146X.2018.00073.X.

Talukdar, M. C. and L. Paswan. 1998. Effect of GA_3 and CCC on growth and flowering of standard chrysanthemum. *J. Orna. Hort.***1:** 11-16.

Waterland, N. L., J. J. Finer and M. L. Jones. 2010. Benzyl adenine and gibberellic acid application prevents abscisic acid-induced leaf chlorosis in pansy and viola. *Hort. Sci.* **45**(6): 925–933.

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COMBINING ABILITY AND HETEROSIS STUDY FOR GRAIN YIELD AND YIELD CONTRIBUTING TRAITS OF MAIZE (*Zea mays* L.)

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Abstract

The nature of combining ability and heterosis were studied in an 8×8 diallel cross excluding reciprocals in maize for grain yield and yield contributing characters. Significant estimates of general combining ability (GCA) and specific combining ability (SCA) variances suggested the importance of both additive and non-additive gene actions for the expression of the traits studied. The variances for GCA Was found significant for days to pollen shedding, days to silking, plant height, ear height, 1000- grain weight and yield. SCA was significant for all the characters except yield. Non-significant SCA variance for yield suggests that this trait was predominantly controlled by additive type of gene action. Variances due to GCA were much higher in magnitude than SCA for all the characters indicating preponderance of additive gene effects for the inheritance of these traits. Parents CML431 (P_4) and CML285 (P_6) were the best general combiner for both high yield and parent CLG1837 (P_7) and CML429 (P_8) for earliness and dwarf plant type. Seven crosses CL02450×CML451 (P_1×P_5), CL02450×CLG1837 (P_1×P_7), CML551×CML431 (P_2×P_4), CML223×CML451 (P_3×P_5), CML431×CML451 (P_4×P_5), CML431× CML429 (P_4×P_8) and CML285× CLG1837 (P_6× P_7) exhibited positive SCA effects for grain yield. Considering, BARI Hybrid Maize-9 (BHM-9) as check, the percent heterosis for grain yield varied from -46.17 to 12.14%. Two crosses CML551×CML431 (P_2×P_4) and CML285× CLG1837 (P_6× P_7) exhibited significant and positive heterosis 12.14 and 10.77%, respectively over the check BHM-9 suggested their benefit cost ratio (BCR) study for developing high yielding hybrid varieties.

Keywords: Maize (*Zea mays* L.), combining ability, GCA, SCA, heterosis, yield.

Introduction

Maize is one of the most important food grains in the world as well as in developing countries like Bangladesh. It is the highest yielding grain crop having various uses. A great combination of high market demand with relatively low production cost, ready market and high yield has generated great interest among the farmers in maize cultivation in Bangladesh. Day by day it is gaining popularity in the country due to vast demand, particularly for poultry industry. In

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2019-20, maize was cultivated in 11.66 lac acre of land in Bangladesh and production was 40.15 lac M.tons (BBS, 2021).

Combining ability analysis is of special importance in cross-pollinated crops helps to identifying potential parents that can be used for producing hybrids and synthetics (Vasal, 1998).

Combining ability and heterosis prerequisite for developing good economically viable hybrid variety in maize. Combining ability analysis is one of the powerful tools in identifying the better combiners which may be hybridized to exploit heterosis and to select better crosses for direct use or further breeding work. Selection of parents based on *per se* performance with good GCA effect is the high approach to assess the nature of gene action involved in the inheritance of character (Vasal, 1992). Parents showing a high average combining ability in crosses are considered to have good GCA while if their potential to combine well is bounded to a particular cross, they are considered to have good SCA. Therefore, it is important to select parent with good GCA and better crosses with good SCA for development of hybrids. Hence, the investigation was undertaken to study the estimates of GCA and SCA and heterosis to develop high yielding hybrid varieties.

Materials and Methods

Eight diverse maize inbred lines *viz.* P_1(CL02450), P_2(CML551), P_3(CML223), P_4(CML431), P_5(CML451), P_6(CML285), P_7(CLG1837) and P_8(CML429) were collected from CIMMYT, India and crossed in a diallel fashion excluding the reciprocals during the *rabi* season in 2015-16. The resulting 28 F_1's were evaluated along with one check (BHM-9) in RCBD with two replications at BARI, Gazipur in the following rabi season of 2016-17. Each entry was planted in two rows of 4 m long plot. The spacing between rows was 60 cm and plant to plant distance was 25 cm.

One plant per hill was maintained after proper thinning. Data were recorded on ten randomly selected plants from each plot for plant height (cm), ear height (cm), days to pollen sheddding and silking and 1000- grain weight. Grain yield was recorded at 14% grain moisture and finally converted to ton/hectare (t/ha). Data were analyzed and the mean performances of all characters were analyzed using PB Tools software. The combining ability analysis was carried out Method IV (one set of F_1's but neither parents nor reciprocal F_1's is included) described by Griffing (1956). The mean squares for GCA and SCA were tested against error variance using the mean data of all the single cross hybrids and check variety, was estimated and tested according to Singh and Singh (1994). Percent heterosis was calculated by using the following formula:

Standard heterosis (%) = $[(\overline{\mathrm{F}}_1 - \overline{\mathrm{CV}})/\overline{\mathrm{CV}}] \times 100$

Where, $\overline{F}_1$ and $\overline{CV}$ represented the mean performance of hybrid and standard check variety. The significance test for heterosis was done by using standard error of the value of check variety.

Results and Discussion

The magnitude of mean squares for GCA and SCA for studied characters (Table 1) indicated significant differences among the GCA as well as SCA effects. This also suggested presence of notable genetic variability among the genotypes for the characters studied. Highly significant differences for most of the sources of variation were also reported by Narro *et al.* (2003). The significant differences for GCA and SCA variances for different traits in maize have been reported earlier (Mathur and Bhatnagar, 1995). The mean squares of genotypes were highly significant for all the traits. This indicated an adequate amount of variability present in the materials for these traits. Further, analysis of variance for combining ability showed that estimates of mean squares due to GCA and SCA were highly significant for all the characters. This indicated importance of both additive and non-additive components of genetic variance in controlling these traits. This was supported by Debnath and Sarker (1990) and Derera *et al.* (2007) who reported similar results for yield and yield components in maize. Importance of both additive and non-additive gene effects in maize was also reported by Rokadia and Kaushik (2005).

Table 1. Mean squares due to general and specific combining ability (GCA and SCA) for six characters of maize

Sources of variation	df	Mean of squares					
		DP	DS	PH (cm)	EH (cm)	TGW (g)	GY (t/ha)
Genotype	27	18.97**	16.91**	354.92**	220.12**	1355.60**	10.50**
GCA	7	25.15**	22.11**	351.28**	225.32**	386.53**	14.76**
SCA	20	4.00**	3.67**	116.62**	65.34**	779.74**	1.92
Error	27	2.11	2.02	69.52	8.54	85.21	0.52
GCA: SCA		6.28	6.02	3.01	3.44	0.49	7.68

DP= Days to 50% pollen shedding, DS= Days to 50% silking, PH=Plant height, EH= Ear height, TGW= 1000 grain weight (g), GY= Grain Yield (t/ha). *, ** indicated at 5% and 1% level of significance, respectively.

In the present study, variances due to GCA were much higher in magnitude than SCA for all the characters indicating preponderance of additive gene effects for the inheritance of these traits. Malik *et al.* (2004) in their study also found higher GCA variances than SCA for days to pollen shedding, plant height, ear height, 1000-kernel weight and grain yield. Predominance of additive gene action for various quantitative traits in maize was also reported by Ahmed *et al.* (2008).

General combining ability (GCA) effects

The estimates of general combining ability effects of the parents are presented in Table 2. For days to pollen shedding and silking, negative estimates are considered desirable as those were observed to be associated with earliness. Data showed that the parents P_7 and P_8 showed significant and negative GCA effects for these traits. In case of plant height and ear height, negative estimates are desirable since they are correlated with shorter plant height. Parent P_7 and P_8 were good combiner having significant and negative GCA effects both for plant and ear height. According to Singh and Singh (1979), generally earliness is associated with days to silk and the shorter plants with low ear height are associated with resistance to lodging. Parents P_4 and P_6 were the best general combiner for yield and also possessed significant and positive GCA effect. This was supported by Singh *et al.* (1995) and Hussain *et al.* (2003). The overall study of GCA effects suggests that parents P_7 and P_8 were excellent general combiner for earliness, short stature and P_4 and P_6 for grain yield. These parents with desirable GCA for particular trait could be used in future breeding program to improve maize yield with desirable trait.

Table 2. General combining ability (GCA) effects for different characters

Parent	DP	DS	PH (cm)	EH (cm)	TGW(g)	GY (t/ha)
P_1	2.12**	1.72**	2.77	1.29	1.97	-0.16
P_2	-0.62	-0.60	7.02*	-2.60	-10.10**	1.22
P_3	1.12	1.39	0.02	14.07**	6.56	-1.31
P_4	0.12	0.31	9.93*	-2.32	1.97	2.37**
P_5	-0.12	-0.10	-2.22	-6.82**	11.14**	-0.73*
P_6	2.79**	2.47**	3.85	-2.54	5.31	0.77**
P_7	-3.29**	-3.18**	-8.97**	-7.85**	-7.18*	0.48
P_8	-2.12**	-2.02**	-12.39**	-8.93**	-9.68**	-2.63**
SE (gi)	0.55	0.54	3.18	3.02	3.52	0.27
LSD $_{(5\%)}$	1.08	1.06	6.23	5.92	6.90	0.53
LSD $_{(1\%)}$	1.42	1.39	8.20	7.79	9.08	0.70

*, ** indicated at 5% and 1% level of significance

Specific combining ability (SCA) effects

The SCA effects of the crosses for six characters are presented in Table 3. For days to 50% pollen shedding, three crosses exhibited significant negative SCA effects and for days to 50% silking four crosses showed significant and negative SCA, indicates early flowering of the hybrids. Considering yield, among 28 hybrids seven crosses performed significant and positive SCA effects for grain yield (Table 3). Out of 28 crosses, seven crosses $P_1 \times P_5$, $P_1 \times P_7$, $P_2 \times P_4$, $P_3 \times P_5$, $P_4 \times P_5$, $P_4 \times P_8$ and $P_6 \times P_7$ showed significant and positive SCA effects for yield. The significant and positive SCA effect involved parents where one or both the parents were related to good combiners, indicating GCA of the parental lines plays a key role for high yield. Xingming *et al.* (2002) also reported similar conclusion. Vasal (1998) also suggested to include one good combiner (especially female parent) during crossing to obtain higher heterosis.

Table 3. Specific combining ability (SCA) effects for different characters in 8×8 diallel cross in maize

Crosses	DP	DS	PH (cm)	EH (cm)	TGW (g)	GY (t/ha)
$P_1 \times P_2$	1.32	1.00	-16.20*	-18.49**	32.32**	-0.79**
$P_1 \times P_3$	-2.42*	-2.5*	17.79*	-3.49	-34.34**	-0.27
$P_1 \times P_4$	1.07	1.08	-14.11*	4.90	45.23**	-1.02**
$P_1 \times P_5$	-1.67	-1.5	12.54	-7.60	-21.42**	0.93**
$P_1 \times P_6$	-1.09	-1.08	1.96	10.45	-23.09**	0.07
$P_1 \times P_7$	1.49	1.08	-0.70	1.73	-10.59**	0.70**
$P_1 \times P_8$	1.32	1.91	-1.28	2.51	11.90**	0.37
$P_2 \times P_3$	0.32	-0.16	-3.95	-1.94	-22.26**	-0.11
$P_2 \times P_4$	1.32	1.41	-6.86	-2.88	2.32	0.74**
$P_2 \times P_5$	-0.42	-0.66	9.79	19.95	13.15**	0.04
$P_2 \times P_6$	2.65	2.75	2.21	-4.66	-21.01**	0.31
$P_2 \times P_7$	-3.26**	-2.58*	12.54	2.29	-1.01	-0.17
$P_2 \times P_8$	-1.92	-1.75	1.46	-4.27	-3.51	-0.01
$P_3 \times P_4$	-0.92	1.08	-5.36	2.45	5.65	-1.21**
$P_3 \times P_5$	2.32	2.33	0.29	7.95	-13.51**	1.82**
$P_3 \times P_6$	-2.09	-1.25	5.21	0.01	42.32**	0.41
$P_3 \times P_7$	1.99	1.91	-9.95	3.95	-15.17**	-0.32

Table 3. Cont'd

Crosses	DP	DS	PH (cm)	EH (cm)	TGW (g)	GY (t/ha)
$P_3 \times P_8$	0.32	0.75	-4.03	-8.94	37.32**	-0.31
$P_4 \times P_5$	-0.67	-1.08	-14.88*	-21.33**	-13.92**	0.98**
$P_4 \times P_6$	-3.09*	-2.66*	0.79	-0.60	-35.59**	-0.01
$P_4 \times P_7$	1.99	2.50*	-0.36	10.01	1.90	-1.43**
$P_4 \times P_8$	0.32	-0.16	21.04**	7.45	-5.59	1.94**
$P_5 \times P_6$	1.15	0.75	-14.03**	-15.56*	42.73**	-3.38**
$P_5 \times P_7$	-0.76	-0.58	-5.70	-2.49	27.73**	-0.21
$P_5 \times P_8$	0.07	0.75	-7.78	-2.05	-34.76**	-0.19
$P_6 \times P_7$	0.82	0.33	-8.21	-15.77**	-1.42	2.92**
$P_6 \times P_8$	1.65	1.16	-4.3	-5.01	-3.92	-0.32
$P_7 \times P_8$	-2.26	-2.66**	-5.03	0.29	-1.42	-1.40**
SE(ij)	1.22	1.20	7.04	6.70	3.52	0.27
LSD $_{(5\%)}$	2.39	2.35	13.80	13.13	6.90	0.53
LSD $_{(1\%)}$	3.15	3.10	18.16	17.29	9.08	0.70

*, ** indicated at 5% and 1% level of significance; DP = Days to 50% shedding, DS = Days to 50% silking, PH = Plant height, EH = Ear height, TGW = Thousand grain weight, GY = Grain yield.

The desirable significant SCA effects observed for different characters were exhibited by the crosses involved high × average, high × low and low × low general combining parents. High SCA effects manifested by different crosses were of good combiner parents might be attributed to sizeable additive × additive gene action. The high × low combinations, besides expressing the favorable additive effect of the high parent, manifested some complementary gene interaction effects with a higher SCA. An appreciable amount of the SCA effects expressed by low × low crosses might be attributed to dominance × dominance type of non-allelic gene action produced over dominance and are non-fixable. It appears that superior performance of most hybrids may be largely due to epistatic interaction. The SCA effects of the crosses exhibited no specific trends in cross combinations between parents having high, medium and low GCA effects. So, the crosses which showing desirable SCA effects can be used in future breeding program.

Heterosis

The standard heterosis expressed by the F_1 hybrids over the standard check BHM-9 for different characters are presented in Table 4. The percent of heterosis in F_1 hybrids varied from character to character and from cross to cross.

Days to pollen shedding (DP) and days to silking (DS)

Days to pollen shedding and silking determine the earliness of flowering of the hybrid. Negative heterosis is desirable for these characters. Considering hybrid BHM-9 as a check, two crosses showed significant and negative heterosis for days to pollen shedding and ranged from -4.88 to 10.98%. For days to silking, two crosses showed significant and negative heterosis and ranged from -4.71 to 10.59% (Table 4).

Plant height (PH) and ear height (EH)

Negative heterosis is desirable for plant height and ear height which helps for developing short statured plant leads to less lodging. Considering hybrid BHM-9 as a check all of the 28 crosses exhibited significant and negative heterosis for plant height indicates dwarfness of the hybrids which ranged from -35.03 to -8.47% (Table 4). For ear height, twelve crosses showed significant and negative heterosis (Table 4).

1000- grain weight (TGW)

Positive heterosis is also desirable for bold grain hybrids. Considering grain weight, five crosses expressed significant and positive heterosis ranged from -14.01 to 9.24% (Table 4).

Table 4. Percent heterosis over the check variety BHM-9 for different characters in 8×8 diallel crosses of maize

Crosses	DP	DS	PH (cm)	EH (cm)	TGW (g)	GY (t/ha)
$P_1×P_2$	8.54**	7.06**	-23.73**	-32.76**	2.24	-23.00**
$P_1×P_3$	7.32**	4.71**	-8.47**	1.72	-11.76**	-40.40**
$P_1×P_4$	8.54**	8.24**	-20.90**	0.00	9.24**	-15.07**
$P_1×P_5$	6.10**	4.71**	-12.43**	8.62*	-7.00**	-24.98**
$P_1×P_6$	9.76**	8.24**	-15.25**	13.79**	-8.96**	-19.38**
$P_1×P_7$	4.88**	3.53**	-23.73**	3.45	-8.96**	-16.45**
$P_1×P_8$	6.10**	5.88**	-25.99**	-10.34**	-3.36*	-46.17**
$P_2×P_3$	6.10**	4.71**	-18.08**	-18.97**	-11.76**	-27.05**
$P_2×P_4$	6.10**	5.88**	-14.12**	8.62*	-6.16**	12.14**
$P_2×P_5$	3.66**	2.35**	-11.86**	3.45	-0.56	-20.71**
$P_2×P_6$	10.98**	10.59**	-12.43**	-3.45	-11.76**	-5.34**
$P_2×P_7$	-3.66**	-2.35**	-13.56**	3.45	-9.80**	-12.06**
$P_2×P_8$	0.00	-1.18	-22.03**	-12.07**	-11.20**	-37.64**

Table 4. Cont'd.

Crosses	DP	DS	PH (cm)	EH (cm)	TGW (g)	GY (t/ha)
P_3×P_4	4.88**	4.71**	-17.51**	0.00	-0.56	-32.90**
P_3×P_5	8.54**	9.41**	-20.90**	-31.03**	-3.36*	-21.02**
P_3×P_6	7.32**	8.24**	-14.69**	3.45	5.04**	-26.27**
P_3×P_7	4.88**	4.71**	-30.51**	-32.76**	-8.96**	-35.23**
P_3×P_8	4.88**	4.71**	-29.38**	-22.41**	5.04**	-38.76**
P_4×P_5	4.88**	3.53**	-12.99**	24.14**	-4.76**	-2.67
P_4×P_6	4.88**	4.71**	-11.86**	6.90	-12.61**	1.81
P_4×P_7	3.66**	3.53**	-19.77**	5.17	-5.60**	-13.09**
P_4×P_8	2.44**	2.35**	-9.60**	12.07**	-8.40*	-10.77**
P_5×P_6	9.76**	8.24**	-27.12**	-24.14**	7.84**	-43.15**
P_5×P_7	0.00	0.00	-29.38**	-37.93**	3.64**	-29.29**
P_5×P_8	2.44**	2.35**	-32.77**	-43.10**	-14.01**	-37.90**
P_6×P_7	6.10**	3.53**	-18.08**	-10.34**	-5.60**	10.77**
P_6×P_8	7.32**	5.88**	-27.12**	-34.48**	-7.00**	-40.14**
P_7×P_8	-4.88**	-4.71**	-35.03**	-32.76**	-9.80**	-36.09**
Mean	5.05	4.41	-19.97	-8.99	-4.96	-22.53
Min	-4.88	-4.71	-35.03	-43.10	-14.01	-46.17
Max	10.98	10.59	-8.47	24.14	9.24	12.14
SE	0.71	0.66	1.42	3.53	1.24	3.03
$CD_{(0.05)}$	1.46	1.36	2.91	7.24	2.55	6.21
$CD_{(0.01)}$	1.96	1.83	3.93	9.78	3.45	8.38

*, ** indicated at 5% and 1% level of significance, DP = Days to 50% shedding, DS = Days to 50% silking, PH = Plant height, EH = Ear height, TGW = Thousand grain weight, GY = Grain yield.

Grain yield (GY)

The percent heterosis for kernel yield varied from -46.17 to 12.14%. Talukder *et al*. (2016) also found -51.39 to 12.53% heterosis in their study. It showed that among the 28 F_1s, two crosses exhibited significant and positive heterosis for grain yield (Table 4). The highest heterosis was exhibited by the cross P_2×P_4 (12.14%) and followed by P_6×P_7 (10.77%).

Conclusion

Parents with positive GCA for high yield (P_4 and P_6), for early flowering and short duration, short plant and ear height (P_7 andP_8) and for bold grain weight (P_5) can be used as donor for combining high yield with desirable traits. Seven crosses $P_1 \times P_5$, $P_1 \times P_7$, $P_2 \times P_4$, $P_3 \times P_5$, $P_4 \times P_5$, $P_4 \times P_8$ and $P_6 \times P_7$ exhibited positive SCA effects for grain yield. Two crosses ($P_2 \times P_4$ and $P_6 \times P_7$) showed significant and positive heterosis for yield compared to the check variety BHM-9. The cross combinations manifested significant high SCA effects coupled with *per se* performance and could be more rewarding in a hybrid breeding program after intensive investigation at different agro ecological zones.

References

Ahmed, S., F. Khatun, M.S. Uddin, B.R. Banik and N.A. Ivy. 2008. Combining ability and heterosis in maize (*Zea mays* L.). *Bangladesh J. Pl. Breed. Genet*. **21**(2): 27-32.

BBS. 2021. Statistical year book of Bangladesh. Statistic Division, Ministry of Planning, Dhaka, Bangladesh. P.141.

Debnath, S.C. and K.R. Sarker. 1990. Combining ability analysis of grain yield and some of its attributes in maize (*Zea mays* L.). *Indian J. Genet*. **50:** 57-61.

Derera, J.P., P. Tongoona, B.S. Vivek and M.D. Laing. 2007. Gene action controlling grain yield and secondary traits in southern African maize hybrids under drought and non-drought environments. *Euphytica*. **162:** 411-422.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Australian. J. Biol. Sci*. **9:** 463-493.

Hussain, S.A., M. Amiruzzaman and Z. Hossain. 2003. Combining ability estimates in maize. *Bangladesh. J. Agril. Res*. **28:** 435-440.

Mathur, R.K. and S.K. Bhatnagar. 1995. Partial diallel cross analysis for grain yield and its component characters in maize (*Zea mays* L.). *Ann. Agric. Res.,* **16:** 324-329.

Malik S.I., H.N. Malik, N.M. Minhas and M. Munir. 2004. General and specific combining ability studies in maize diallel crosses. *Intl. J. of Agric. and Biology*. **6**(5): 856-859.

Narro, L., S. Pandey, J. Crossa, C.D. Leon and F. Salazar. 2003. Using line × tester interaction for the formation of yellow maize synthetics tolerance to acid soils. *Crop Sci*. **43:** 1717-1728.

Rokadia, P. and S.K. Kaushik. 2005. Exploitation of combining ability for heterosis in maize (*Zea mays* L.). *In:* Pixley, K. and S.H. Zhang (ed). Proc. 9th Asian Reg. Maize Workshop. Beijing, China, September 5-9, pp. 89-91.

Singh, S.P. and H.N. Singh. 1979. Genetic divergence in Okra (*Abelmoxhus esculentus* L. *Moerch*). *Indian J. Hort*. **36:** 166-170.

Singh, G., M. Singh and K.R. Dhiman. 1995. Genetic analysis of maize (*Zea mays* L.) in Sikkim. *Indian J. Agri. Sci.,* **65:** 293-294.

Sprague, G.F. and L.A. Tatum. 1942. General versus specific combining ability in single crosses of corn. *American. J. Soc. Agron.* **37:** 923-928.

Talukder, M.Z.A., A.N.M.S. Karim, S. Ahmed and M. Amiruzzaman. (2016). Combining ability and heterosis on yield and its component traits in maize (*Zea mays* L.). *Bangladesh J. Agril. Res*. **41**(3):565-577.

Vasal, S.K. 1998. Hybrid maize technology: Challenges and expanding possibilities for research in the next century. *In:* Vasal, S.K., C.F. Gonzalez and F. Xingming (ed). Proc. 7th Asian Reg. Maize Workshop. Los Banos, Philippines, February 23-27 pp. 58-62.

Vasal, S.K., G. Srinivasan.G.C. Han and C.F. Gonzalez. 1992. Heterotic patterns of eighty-eight white subtropical CIMMYT maize lines. *Maydica*. **37:** 319-327.

Xingming, F., J.Tan, Z. Chen and J. Yang. 2002. Combining ability and heterotic grouping of ten temperate, tropical and subtropical quality protein maize. *In:* Srinivasan, G., P.H. Zaidi, B.N. Prasanna, F.C. Gonzalez and K. Lesnick (ed). Proc. 8th Asian Reg. Maize Workshop. Bangkok, Thailand, August 5-8, pp. 10-18.

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EFFECT OF ZINC AND BORON ON YIELD AND NUTRIENT CONTENT OF CORIANDER

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Abstract

Micronutrient deficiency, especially zinc and boron deficiency, commonly occurs in Bangladesh soils. Nevertheless, common diets of this country's people are often deficient in zinc. Thus, application of zinc and boron has significant value in enhancing crop yield as well as zinc and boron content in crop. With this understanding, field experiments were conducted in two consecutive seasons of 2018-19 and 2019-20 at Bangladesh Agricultural Research Institute (BARI) farm, Gazipur under the agroecological zone 28 (Madhupur Tract). Texturally the soil was sandy clay loam with 6.2 pH, 1.26% organic matter, 0.99 mg kg^{-1} zinc and 0.13 mg kg^{-1} boron content. Treatments consisted of a factorial arrangement of three levels of zinc (0, 2, 4 kg ha^{-1}) and three levels of boron (0, 1, 2 kg ha^{-1}) in a randomized complete block design (RCBD) with three replications. Combined application of Zn and B significantly increased the foliage and seed yield as well as their (zinc and boron) contents. On an average, among the treatment combinations, Zn_4B_1 produced the highest foliage yield (4.55 t ha^{-1}) and Zn_2B_2 gave the highest seed yield (1.99t ha^{-1}). The highest zinc and boron contents were found in Zn_4B_2 treatment for both foliage and seeds. Agronomic biofortification of zinc in coriander could be possible without reducing yield through the use of Zn_4B_1 treatment for foliage purpose and Zn_2B_2 for seed purpose.

Keywords: Biofortification, Zinc, Boron, Coriander, Capital foliage and Capital foliage yield.

Introduction

Coriander (*Coriandrum sativum* L.; Bengali Dhonia) is a popular spice, which belongs to the family Apiaceae and usually cultivated in winter (*rabi*) season in Bangladesh. This spice is mainly used as culinary and medicinal purposes. It is a multifunctional herb grown mainly for its foliage and seeds, but all parts of the plant such as leaves, flower, fruit and seed can be used as medicinal purpose. Coriander seed is useful in flatulence, indigestion, vomiting and other intestinal disorders and both leaves and seeds are greatly valued as food mainly for its high Vit. A and Vit. C contents (Nadeem *et al*., 2013).

Among the micronutrients, the zinc and boron deficiency has arisen in Bangladesh mainly due to continuous mining of soil nutrients for increased

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cropping intensity (198% at present) (BBS, 2020). Zinc deficiency not only causes lower yield, the dietary Zn deficiency in cereals and vegetables may lead to malnutrition and chronic health problems in human. Increasing nutrient content of vegetable tissues during their growth period is known as biofortification. Biofortification is a good mechanism for human nutrition (Marschner, 2011; and Jahiruddin, 2020). Exogenous application of Zn might be a useful option to recover Zn deficiency in coriander. On the other hand, boron is essential for seed production of crops as it plays a vital role in the physiological processes of plants, such as cell elongation, cell maturation, meristematic tissue development and protein synthesis (Mengel and Kirkby, 1982). It influences absorption of N, P, and K. Boron deficiency causes poor seed quality (Jahiruddin, 2011).

Coriander growing areas in Bangladesh covers 7377 acres with a total yield of 5487 M. ton (leaves) and in case of seed production the area covers 50049 acres with a total production of 19295 M. ton (BBS., 2019Both Zn and B have vital role on the yield and quality of coriander. In such situation bio-fortification is a good solution to meet the demand. However, information on the response of coriander to application of Zn and B fertilizers is lacking. Therefore, the present study was undertaken to see the response of coriander crops to Zn and B application.

Materials and Methods

Experimental site and soil

The experiment was set up at the experimental field of Bangladesh Agricultural Research Institute (BARI), Gazipur during *rabi* season of 2018-19 and 2019-20. The site belongs to AEZ 28 (Madhuput Tract). Initial soil properties were: texture – sandy clay loam, pH – 6.2, OM – 1.26%, total N – 0.07%, exchangeable K – 0.18 me%, available S – 20.6 mg kg^{-1}, available P – 4.65 mg kg^{-1}, available zinc – 0.99 mg kg^{-1} and available boron – 0.13 mg kg^{-1}.

Treatments

The experiment was laid out in randomized complete block design (RCBD) with five treatment combinations having three replications, the unit plot size being 1.5 m × 2 m. Treatment combinations were made with three levels of zinc: 0, 2, 4 kg ha^{-1} and three levels of boron: 0, 1, 2 kg ha^{-1}. A basal application was made with 5 t ha^{-1} cowdung, 83 kg ha^{-1} N, 26 kg ha^{-1} P, 55 kg ha^{-1} K and 13 kg ha^{-1} S to all plots to support normal plant growth. Zinc as zinc sulphate heptahydrate (ZnSo4. 7H2o) and boron as boric acid H_3Bo_3 were added to soil during final land preparation. The full amount of cowdung, P from TSP, K from MOP, S from gypsum and half of N from urea were applied during final land preparation. Rest of the N from urea was top dressed after 35 days of sowing.

Set up of experiment

The seeds of coriander (var. BARI Dhonia-1) were rubbed and soaked in water for 24 hours to enhance germination. Before sowing the seeds were treated with Bavistin at 2 g kg^{-1} and sown it at 30 cm apart rows continuously by hand at 25 kg ha^{-1}. Seeds were sown on 28 November in both years of 2018 and 2019. The soils of all plots were kept moist with light irrigation for quick germination. Necessary intercultural operations viz. irrigation, weeding etc. were done throughout the cropping period. For foliage record, green plants were harvested before bolting. Ten plants were selected randomly in each plot for recording data on plant height, number of leaves $plant^{-1}$, foliage yield etc. On the other hand, plants cultivated for seed yield were harvested when 50% seeds turned brown color. Five plants were selected randomly from each plot for recording data on plant height, number of umbells $plant^{-1}$, number of umbellates $plant^{-1}$ etc. Seeds were dried in an oven at 70°C for 72 hours and the dry samples were analyzed for chemical analysis.

Chemical analysis

For initial soil analysis, pH was measured by a combined glass calomel electrode (Jackson, 1962). Organic carbon determination was done by wet oxidation method (Walkley and Black, 1934) and Total N by modified Kjeldahl method. Element P was determined by $NaHCO_3$ extraction (Olsen method), K by NH_4OAc extraction method, S and B (boron) by $CaCl_2$ extraction method, and Zn and B were determined by DTPA extraction method. Vitamin C was determined by classical titration method using 2, 6- dichlorophenol indophenols solution and expressed as 100 mg g^{-1} of fresh weight (Miller, 1998). Total carotenoids (μg 100 g^{-1}) were measured by spectrophotometer (T-40, PG Instrument Ltd.UK) at 451ɳm (Alasalvar *et al.*, 2005).

Statistical analysis

All field and lab. data were statistically analyzed by statistical package STATISTIX-10 to examine the treatment effects and mean comparisons were done by Tukey HSD test at 5% level of significence.

Results and Discussion

Effect of zinc and boron on foliage yield of coriander

Different parameters were significantly influenced by the combined effects of different levels of zinc and boron (Table 1). The highest plant height (15.9 cm) was found in T_4 treatment which was significantly higher except T_3 treatment (15.4 cm). The highest single plant weight (2.60 g) was also recorded in T_4 treatment. The maximum number of leaves plant^{-1} (6.50) was noted in T_4 treatment which was statistically identical to T_3 (6.30) and T_5 (5.70 g). Significant variation was also noticed in foliage yield of coriander. The T_4 treatment recorded the highest foliage yield (455 g m^{-2} fresh yield and 74.3 g m^{-2} dry yield). The application of 1 kg B ha^{-1} coupled with 5 kg Zn ha^{-1} gave higher foliage yield in coriander (Tania *et al*., 2018).

Table 1. Foliage yield and yield attributes of coriander as influenced by the different zinc and boron levels (Pooled) years)

Treatments	Plant height (cm)	Single plant weight (g)	No. of leaves plant^{-1}	Foliage fresh yield (g m^{-2})	Foliage dry yield (g m^{-2})	Foliage yield (t ha^{-1})
T_1 (Zn_0B_0)	12.7 b	1.4 c	4.8 b	236 c	38.9 d	2.36 c
T_2 (Zn_2B_1)	13.4 b	2.0 b	5.0 b	330 bc	54.0 c	3.30 bc
T_3 (Zn_2B_2)	15.4 a	2.5 a	6.3 a	369 ab	60.4 bc	3.69 ab
T_4 (Zn_4B_1)	15.9 a	2.6 a	6.5 a	455 a	74.3 a	4.55 a
T_5 (Zn_4B_2)	13.7 b	2.1 b	5.7 ab	392 ab	69.7 ab	3.92 ab
CV (%)	3.47	6.72	7.71	10.62	6.31	10.62

Means followed by same letter (s) in a column do not differ significantly at 5% level of significance by Tukey HSD test.

Effects of zinc and boron on seed yield of coriander

The combined effect of Zn and B had significant influence on the seed yield of coriander (Tables 2a and 2b). The highest plant height (82.2 cm),t number of primary and secondary branches plant^{-1} (4.2 and 10.7, respectively) were recorded in T_3 (Zn_2B_2) treatment. Similar trend was followed in case of umbels plant^{-1} (31.0).The maximum number of umbellates plant^{-1} (103) was in T_3 treatment which was statistically identical to T_4 (99.4) and T_2 (98.6) treatments. The T_2 (Zn_2B_1) treatment showed statistically the highest number of umbellates umbel^{-1} (3.59). Significant variation was recorded in seed yield and 1000-seed weight of coriander. Treatment T_3 exhibited the highest 1000- seed weight (5.25 g) and seed yield (1.70 t ha^{-1}). Kamrozzaman *et al*. (2016) also .recorded the maximum seed yield of coriander due to combined application of 2.2 kg Zn and 0.8 kg B ha^{-1}. Bepari *et al*. (2018) reported that application of 45 kg S ha^{-1} combined with 6 kg Zn ha^{-1} gave the maximum growth, seed yield and quality of coriander.

The results revealed that application of boron and zinc in all combinations positively influenced every plant parameter as compared with the control (No Zn or B applied). The result suggests that application of 4 kg Zn ha^{-1} + 1kg B ha^{-1} and 2 kg Zn ha^{-1} + 2 kg B ha^{-1} performed better in producing foliage and seed yields, respectively.

Table 2a. Plant height and yield attributes of coriander as influenced by zinc and boron levels (Pooled)

Treatments	Plant height (cm)	No. of primary branches $plant^{-1}$	No. of secondary branches $plant^{-1}$	No of umbels $plant^{-1}$	No. of umbellates $plant^{-1}$
T_1 (Zn_0B_0)	70.9 b	3.1 b	7.45 c	27.0 b	85.2 c
T_2 (Zn_2B_1)	73.9 b	3.8 ab	7.83 c	27.5 b	98.6 ab
T_3 (Zn_2B_2)	82.2 a	4.2 a	10.7 a	31 a	103 a
T_4 (Zn_4B_1)	81.3 a	4.0 a	9.8 ab	30.4 a	99.4 ab
T_5 (Zn_4B_2)	80.6 a	3.5 ab	8.57 bc	28.2 b	94.9 b
CV (%)	2.95	7.36	7.86	2.43	2.47

Means followed by same letter (s) in a column do not differ significantly at 5% level of significance by Turkey LSD test.

Table 2b. Seed yield and yield attributes of coriander (seed purpose) as influenced by zinc and boron levels (Pooled)

Treatments	No of umbellates $umbel^{-1}$	Seed yield (g m^{-2})	Seed yield (t ha^{-1})	1000- seed weight (g)
T_1 (Zn_0B_0)	3.16 c	129 d	1.29 d	3.99 c
T_2 (Zn_2B_1)	3.59 a	153 c	1.53 c	4.21 c
T_3 (Zn_2B_2)	3.33 b	199 a	1.99 a	5.25 a
T_4 (Zn_4B_1)	3.27 bc	170 b	1.70 b	5.03 ab
T_5 (Zn_4B_2)	3.37 b	185 a	1.85 a	4.40 bc
CV (%)	2	3.09	3.09	5.63

Means followed by same letter (s) in a column do not differ significantly at 5% level of significance by Turkey LSD test.

Vitamin C and β -Carotene content

Like many green leafy vegetables, coriander leaves are a rich source of vitamins (e.g. Vit. A and C) and minerals (e.g. iron). The highest Vit. C (121 mg 100 g^{-1}) and β -Carotene (5.2 mg 100 g^{-1}) were found in T_4 treatment (Table 3). β -carotene is a precursor of Vit. A. Chizoba (2015) reported that the green herbs contain vitamin C up to 160 mg100 g^{-1} and vitamin A up to 12 mg 100 g^{-1}.

Table 3. Quality character of coriander foliage as influenced by zinc and boron levels (Pooled)

Treatment	Vit. C (mg/100g)	β -Carotene (mg/100g)
T_1 (Zn_0B_0)	96	4.4
T_2 (Zn_2B_1)	108	4.8
T_3 (Zn_2B_2)	112	5.0
T_4 (Zn_4B_1)	121	5.2
T_5 (Zn_4B_2)	116	4.9

Table 4. Nutrient content of coriander leaves and seeds as influenced by the zinc and boron levels (Pooled)

Treatment	Coriander leaves			Coriander seeds		
	Zn conc. (ppm)	B conc. (ppm)	Increase in Zn concentration (%)	Zn conc. (ppm)	B conc. (ppm)	Increase in Zn concentration (%)
T_1 (Zn_0B_0)	61.4	22.5	-	69.4	27.3	-
T_2 (Zn_2B_1)	63.6	24.3	3.58	70.4	28.5	1.44
T_3 (Zn_2B_2)	64.8	25.5	5.54	70.7	30.8	1.87
T_4 (Zn_4B_1)	65.9	27.5	7.33	71.3	31.2	2.74
T_5 (Zn_4B_2)	66.4	30.2	8.14	71.6	31.8	3.17

Zinc and boron content of coriander leaves and seeds

Zinc and boron concentrations of coriander leaves ranged from 61.4 to 66.4 ppm and 22.5 to 30.2 ppm, respectively (Table 4). Treatment T_5 (Zn_4B_2) had the highest Zn and B concentrations and the T_1 (Zn_0B_0) control treatment lowest value. Similarly, treatment T_5 (Zn_4B_2) exhibited the highest Zn (71.6 ppm) and B (31.8 ppm) concentrations in coriander seeds, whereas control (Zn_0B_0) displayed the lowest values (69.4 ppm and 27.3 ppm, respectively). Zn concentration increased progressively with increasing rates of zinc application showing a range of 3.58% - 8.14% in case of coriander leaves and 1.44% - 3.17% in case of coriander seeds (Table 4). B concentration had increased up to 34.2% for coriander leaves and up to 16.5% for coriander seeds.

Conclusion

Application of zinc and boron enhanced the foliage and seed yields of coriander and positively influenced Zn and B enrichment and also Vit. C and β-carotene (precursor of Vit. A) contents. The results reveal that application of 4 kg Zn ha^{-1} + 1 kg B ha^{-1} significantly improved foliage yield whereas 2 kg Zn ha^{-1} + and 2 kg B ha^{-1} markedly increased seed yield of coriander. For Zn enrichment, coriander leaves and seeds Zn could be applied at 4 kg ha^{-1} along with boron at 2 kg ha^{-1}.

References

Alasalvar, C., M. Al-Farsi and F. Shahidi. 2005. Compositional charac-teristics and antioxidant of cherry laurel varieties and pekmez. *J. Food Sci*. **70:** S47–S52

Bepari, I. S. Naruka, K. C. Meena, A. Haldar, S. Nayma. 2018. Effect of sulphur and zinc on growth, and quality of coriander (*Coriandrum sativum* L.) *cv.* RCr-436. *Int J Chem Stud*, **6**(5): 2479-2483.

BBS. 2020. Statistical Year Book of Bangladesh. Government of the Peoples Republic of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Finance and Planning.

BBS. 2019. Statistical Year Book of Bangladesh. Government of the Peoples Republic of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Finance and Planning.

Chizoba, E. F. G. 2015. A Comprehensive Review on Coriander and its Medicinal properties. *International Journal of Scientific Research and Reviews*. **4**(2): 28 – 50

Jahiruddin, M. 2020. Biofortification of food crops: a novel strategy for reducing micronutrient. *Fundamental and Applied Agriculture* **5**(2): 133–146.

Jahiruddin, M. 2011. Screening, Selection and Molecular Characterization of Boron Efficient Wheat Genotypes. USDA Project Report, Dept. of Soil Science, BAU, Mymensingh Jackson M. 1962. Soil Chemical Analysis, 496. London: Constable and Co. Ltd.

Kamrozzaman, M. M., S. Ahmed and A. F. M. R. Quddus. 2016. Effect of fertilizer on coriander seed production. Bangladesh J. Agril. *Res*. **41**(2): 345-352.

Mengel, K., and E. Kirkby. 1982. Principles of Plant Nutrition, 446. Bern, Switzerland: International Potash Institute.

Miller, D. 1998. Food Chemistry: a Laboratory Mmanual. John Wiley & Sons Press.

Mathias, M.E. 1994. Magic, myth and medicine", Econ. Bot., Vol. 48, pp. 3-7.

Marschner, H. 2011. Mineral Nutrition of Higher Plants, 3rd edn. Academic Press, London

Nadeem M, FM Anjum, MI Khan, S Tehseen, A El-Ghorab, JI Sultan. 2013. Nutritional and medicinal aspects of coriander (*Coriandrum sativum* L.): *A review. Brit. Food J*. **115**(5):743-755

Tania,C., T. Basanta, R. Chatterjee and P.K. Chattopadhyay. 2018. Assessment for growth and yield of coriander (*Coriandrum sativum* linn.) with micronutrients. *Int. J. Curr. Microbiol. App. Sci* (2018) **7**(12): 336-339.

Walkley, A., and C. A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **37**(1): 29–38.

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EFFECT OF PLANT GROWTH REGULATORS ON SEED YIELD OF MUSTARD

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Abstract

An experiment was conducted at the research field of Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Cumilla during November 2019 to March 2021 to find out the effect of two plant growth regulators (PGR) of IAA and GA_3 on yield attributes and yield of mustard (Var. BARI Sarisha-17). There were seven treatments viz. T_1= IAA 50 ppm, T_2= IAA 75 ppm, T_3= IAA 100 ppm, T_4= GA_3 50 ppm, T_5= GA_3 75 ppm, T_6= GA_3 100 ppm, and T_7= Control. The PGRs was sprayed twice on mustard plant at 22 and 33 days after sowing. Plant height, branches plant^{-1}, siliqua plant^{-1}, 1000 -seed weight and seed yield ha^{-1} were influenced significantly by different levels of application of plant growth regulators. The highest plant height (115.9 cm), branches plant^{-1} (6.2), siliqua plant^{-1} (79.8), 1000- seed weight (4.1) and seed yield (1788.3 kg ha^{-1}) was obtained from T_5 (GA_3 - 75 ppm) treatment. The lowest seed yield was obtained from the control plants (T_7). Application of GA_3-50 ppm, GA_3-100 ppm, IAA-100 ppm, IAA-75 ppm, IAA-50 ppm gave statistical identical yield. The highest gross return (Tk. 89145 ha^{-1}), gross margin (Tk. 53215 ha^{-1}) and benefit cost ratio (2.47) were also obtained from GA_3 at 75 ppm followed by GA_3 at 50 ppm (2.43). Foliar application of GA_3 and IAA at the rate of 75 ppm could be used at early growth stage for obtaining higher seed yield and economic return.

Keywords: Giberellic acid (GA_3), Indole acetic acid (IAA), Yield, Benefit cost ratio (BCR), Mustard.

Introduction

Mustard (*Brassica sp*.) is one of the most important oil crops of global economic importance (Malek *et al.*, 2012). Its oil is used mostly for edible purpose and a partly finds for industrial applications. Oil cake is used as manure and rich animal food. About 12% of the annual edible oil supply contributed from mustard crop in the world (FAO, 2018). It has a remarkable demand for edible oil in Bangladesh. It covers about 72% of the total oilseed acreage with about 61% production. Bangladesh required 0.30 million tons of oil equivalent to 0.85 million tons of oil seeds to nourish the existing population. At present oilseed production is about 0.32 million tons which covers 30% domestic needs. In

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Bangladesh, seed yield of mustard is 1154 kg ha^{-1} (BBS, 2019) which is very low compared with other developed countries (2400 kg ha^{-1}). Improvements of existing oilseed crops by introduction of improved varieties with optimized cultural management need urgent attention for fast growing population of Bangladesh. There is a little scope for horizontal expansion of mustard. The attempt is made to increase the per unit production with attention to increase yield per unit area by adopting improved technologies and management. Scope exists for making breakthrough in yield improvement through changes of hormonal behaviors of variety.

Plant growth regulators could be an alternative to increase crop production. Spraying Plant growth regulators (PGR) at the right growth stage can improve stem quality, prevent lodging, and increase crop yields (Cailong *et al*., 2017). Plant growth regulators (PGRs) are being used as an aid to enhance crop yield (Mondal *et al*., 2016). Plant growth regulators are effective on several crop plants to balance the source sink relationship and thereby increasing them, they used as an aid to enhance in many crops. Indole acetic acid (IAA) and Gibberellic acid (GA_3) can manipulate a variety of growth and developmental phenomena in various crops. IAA has been found to increase the plant height, number of leaves per plant with consequent enhancement in seed yield in cotton and groundnut (Lee,1990). It also increases flowering, fruit set, total dry matter of crops (Gurudev and Saxena, 1991) likewise GA_3 stimulated stem elongation (Harington *et al*.,1996), increased dry matter accumulation and enhance total yield (Deotale *et al*.,1998). PGRs are the chemical substances, when applied in small amounts modify the growth of plants by stimulating or inhibiting part of the natural growth regulatory system. About 60 plant growth regulators at different groups are now commercially available and several of them have reached considerable importance in crop production. Gibberellin is a plant growth regulator which promotes cell elongation and induces cell division. It plays a great role in retarding abscission like that of IAA in lower concentrations. IAA influences plant growth by enlarging leaves and increasing photosynthetic activities in plant. Though plant growth regulators have great potentialities, its application and actual assessments etc. have to be judiciously planned in terms of optimal concentrations, stage of application, species specificity, season etc. for obtaining higher seed yield and quality (Kore *et al*., 2003). Keeping these views in mind, the present experiment was undertaken to study the effect of plant growth regulators on seed yield of mustard.

Materials and Methods

The experiment was conducted at Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Cumilla during *rabi* season of 2019-20 and 2020-21. The research plot is located in AEZ-19 (Old Meghna Estuarine floodplain). The study consisted of 7 plant growth regulators treatments viz., T_1=IAA 50 ppm, T_2= IAA 75 ppm, T_3= IAA 100 ppm, T_4=GA_3 50 ppm, T_5= GA_3 75, ppm, T_6= GA_3 100 ppm, and T_7= control. The experiment was laid out in randomized complete block design with three replications. The PGRs were applied twice pre-flowering (22 days after sowing) and post-flowering (33 days after sowing) stage with hand sprayer at 4 P.M. The solutions of 50 ppm, 75 ppm and 100 ppm of plant growth regulators (IAA and GA_3 each) were prepared by dissolving 50 mg, 75 mg and 100 mg in small quantity of acetone (5 ml) and dissolve all granules of PGR in acetone was made completely. The final volume of 1 litre by adding distilled water slowly. Finally the 50 ppm, 75 ppm and 100 ppm concentrations each of IAA and GA_3 were prepared. The soil of the experimental area is silty loam. The unit plot size was 3.0 m × 2.7 m. The variety was used in BARI Sarisha-17 as test crop. The seeds of mustard were hand sown in rows on 5 November 2020 in continuous sowing and row was 30 cm apart from each other. Seeds were placed at about 3-4 cm depth from the soil surface.

The seedlings were thinned after few days of germination 5 cm apart. Fertilizers were applied @ 120: 80: 60: 40: 4: 1 kg ha^{-1} of N: P: K: S: Zn and B from urea, TSP, MoP, gypsum, zinc sulphate and boric acid respectively. Half of the urea and all other fertilizers were applied during final land preparation. The remaining 50% urea was top dressed at 25 DAS at flower initiation stage followed by irrigation. The crop field was weeded once at 20 DAS. Two irrigations were provided to the crop during flower initiation (22 DAS) and fruit development stages (50 DAS). To control aphid, Malathion 57 EC was sprayed @ 2.0 ml L^{-1} of water at afternoon by using sprayer at late flowering and pod development stage. Rovral was sprayed @ 2.0 ml L^{-1} of water at afternoon by using sprayer at pod development stage to control leaf spot disease. Roguing was done at 40 and 55 DAS. The crop was harvested on 85 DAS. After threshing, cleaning and drying the seed yield was recorded at 12% moisture content at fresh weight basis. Economic performance of different treatment was calculated. The variable costs for each treatment were calculated based on the labor requirement for sowing, weeding and irrigation, manure and fertilizer cost, PGRs cost, spraying cost, seed cost and other input cost. The gross return was calculated based on the market price of seed of mustard. The gross margins of different treatments were estimated by deducting the production cost from the gross return. The benefit cost ratios (BCR) were calculated by dividing the gross return by total variable cost (production cost). At harvest ten plants were randomly selected from each plot for collecting yield contributing characters. The plot yield was taken and converted into kg ha^{-1}. The collected data were analyzed statistically following the analysis of variance (ANOVA) technique with the help of MSTAT-C software. The mean differences between the treatments were compared by Least Significant difference (LSD) test by this software.

Results and Discussion

The effect of foliar application of PGRs at different concentrations showed significant difference on plant height, branches plant^{-1}, siliqua plant^{-1}, 1000- seed weight and seed yield (t ha^{-1}) of mustard (Table 1). The maximum plant height (115.9 cm) was recorded in plants treated with GA_3 at 75 ppm (T_5) which was statistically similar to T_6, T_2, T_4, T_3 and T_1 treatments. The lowest plant height (102.3) was noted in control (T_7). The GA_3 and IAA treated plants showing increased plant height than control might be due to increased number of internodes or length of internodes because of increased cell number. Saied *et al.* (2018) also observed that application of GABA (PGR) in mustard plant increased plant height (8.3%).

The maximum branches plant^{-1} (6.2) was obtained from T_5 (GA_3-75) ppm and T_2 (IAA-75 ppm) treatments and it was statistically identical with T_1 (IAA-50 ppm), T_3 (IAA-100 ppm), T_4 (GA_3-50 ppm) and T_6 (GA_3-100 ppm) treatments. The results are in agreement with the findings of Samsuzzaman *et al.* (2004) who reported that branch number of mustard increased with PGRs application. The lowest number of branches (4.2) was recorded in control (T_7). The highest siliqua plant^{-1} (79.8) was recorded from GA_3 at 75 ppm (T_5) followed by IAA at 75 ppm (T_2) and the lowest (62.1) from control (T_7). Saied *et al.* (2018) also observed that application of GABA (PGR) in mustard plant increased leaf area (22.1%), total dry mass (22.2%) and absolute growth rate (9.43%) over the control. Similar result was also reported by Islam *et al.* (2007) for sesame crop.

Table 1. Effect of plant growth regulators on seed yield and yield attributes of mustard at RARS, Cumilla (pooled data of 2019-20 and 2020-21)

Treatment	Plant height (cm)	Branch plant^{-1} (no.)	Siliqua plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	1000- Seed weight (g)	Seed Yield (kg ha^{-1})
T_1 (IAA -50 ppm)	107.5	5.8	73.6	32.4	3.7	1670
T_2 (IAA -75 ppm)	112.8	6.2	78.7	33.1	3.9	1722
T_3 (IAA -100 ppm)	109.8	5.9	75.1	33.0	4.1	1692
T_4 (GA_3-50 ppm)	112.5	5.8	68.0	33.0	3.7	1711
T_5 (GA_3-75 ppm)	115.9	6.2	79.8	34.6	4.1	1788
T_6 (GA_3-100 ppm)	112.9	6.0	77.3	31.4	4.1	1706
T_7 (Control)	102.3	4.2	62.1	26.9	3.4	1480
CV (%)	3.90	11.04	7.7	8.7	3.25	5.57
LSD (0.05)	9.8	1.21	10.34	NS	0.22	167.7

Table 2. Cost and return analysis of mustard under different concentrations of two plant growth regulators (pooled data of 2019-20 and 2020-21)

Treatment	Gross return (Tk. ha^{-1})	Cost of production (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	Benefit cost ratio (BCR)
T_1 (IAA -50 ppm)	83505	35200	48305	2.37
T_2 (IAA -75 ppm)	86115	36200	49915	2.38
T_3 (IAA -100 ppm)	84575	37200	47375	2.27
T_4 (GA_3-50 ppm)	85530	35200	50330	2.43
T_5 (GA_3-75 ppm)	89415	36200	53215	2.47
T_6 (GA_3-100 ppm)	85285	37200	48085	2.29
T_7 (Control)	74015	33200	40815	2.22

Price of mustard seed: 50 Tk./kg.

The maximum 1000- seed weight (4.1g) was recorded from GA_3-75 (T_5) ppm, IAA-100 ppm (T_3), and GA_3-100 ppm (T_6) which was statistically similar to IAA-75 ppm (T_2) and the lowest from control plant (T_7). The maximum seed yield (1788 kg ha^{-1}) was obtained from T_5 (GA_3-75 ppm) treatment and it was statistically identical with to T_2 (IAA -75 ppm), T_4 (GA_3 -50 ppm), T_6 (GA_3-100 ppm), T_3 (IAA -100 ppm) and T_1 (IAA -50 ppm) treatments. The lowest seed yield (1480 kg ha^{-1}) was found in T_7 (control) treatment. The increase in yield due to application of plant growth regulators at different concentrations ranged from 12.8 to 20.8% over the control plants.

The maximum seed yield was recorded with GA_3 at 75 ppm probably due to higher siliqua plant^{-1}, as well as increased vegetative growth and balanced C/N ratio. This might have increased the synthesis of carbohydrate which ultimately promoted higher seed yield. Similar result was reported by Hernandez, (1997) in sunflower. Seed yield decreased beyond 75 ppm concentrations of IAA and GA_3 might be due to toxic effect for growth and development of plant. Similar result was reported by Rahim (2005) in soybean.

The economic performance of plant growth regulators at different levels/concentrations were presented in table 2. The highest gross return (Tk. 89415 ha^{-1}) was obtained from plants treated with GA_3 at 75 ppm (T_5). Maximum benefit cost ratio (2.47) was also obtained from plants treated with GA_3 at 75 ppm (T_5) followed by GA_3 at 50 ppm (T_4). Hence plants treated with GA_3 at 75 ppm would be economically profitable for seed yield of mustard.

Conclusion

Results revealed that, IAA and GA_3 offer a good scope for obtaining higher seed yield of mustard var. BARI Sarisha-17. It appears that, application of GA_3 at 75 ppm could be optimum for higher seed production and economic return.

References

BBS. 2019. Statistical Year Book of Bangladesh, Government of the Peoples of Republic of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning.

Cailong, X., Y. Gao, B. Tian, J. Ren, Q. Meng and P. Wang. 2017. Effects of EDAH, a novel plant growth regulator, on mechanical strength, stalk vascular bundles and grain yield of summer maize at high densities. *Field Crops Research*, **200:** 71-79.

Deotale, R.D., V.G. Maske, N.V. Sorte, B.S. Chimurkar and A.Z. Yerne. 1998. Effect of GA_3 and NAA on morpho-physiological parameters of soybean. *J. Soils Crops.* **8:** 91-94.

FAO. Production Year Book of 2021. Italy; **353:** 27.

Gurdev, S. and O.P. Saxena. 1991. Seed treatments with bio-regulators in relation to wheat productivity. In New Trends in Plant Physiology, Proceedings of National Symposium on Growth and Differentiation in Plants New Delhi, India 201-210.

Harrington, J.F., L. Rappaport and K.J. Hood. 1996. The influence of gibberellins on stem elongation and flowering on endive. *Science*. **125:**601.

Hernandez, P. 1997. Morphogenesis in sunflower as affected by exogenous application of plant growth regulators. *Agri. Scientia*., **13:** 3-11.

Islam, M. M. 2007. Effect of GABA on growth, yield and yield contributing characters of sesame Doctoral dissertation, Dept. Crop Bot., Bangladsh Agric. Univ., Mymensingh.

Kore, V. N., H. P. Khade, R. N. Nawale, R. S. Patil and A. V. Mane. 2003. Effect of growth regulators on growth, flowering and yield of bottle gourd variety Samrat under Konkan conditions. *J. Soils Crops*, **13:** 18-21.

Lee, H.S. 1990. Effects of pre-sowing seed treatments with GA_3 and IAA on flowering and yield components in groundnuts. *Korean J. Crop Sci.***35:**1-9.

Malek, M. A., Ismail, M. R., Monshi, F. I., Mondal, M. M. A., & Alam, M. N. (2012). Selection of promising rapeseed mutants through multi-location trials. *Bangladesh Journal of Botany*, **41**(1): 111-114.

Mondal, M., A. B. Puteh and N. C. Dafader. 2016. Foliar application of chitosan improved morpho-physiological attributes and yield in summer tomato (*Solanum lycopersicum*). *Pakistan Journal of Agricultural Sciences*, **53**(2).

Rahim, A. M. 2005. Effect of GABA on flowering pattern, floral abscission and yield attributes in soybean. Doctoral dissertation. Dept. Crop Botany, Bangladesh Agric. Univ., Mymensingh, Bangladesh.

Saied M.A, A.M.M. Momjurul and R.M. Shahidur. 2018. Foliar application of GABA improve growth and yield of mustard. *MOJ Curr. Res. & Rev*. **1**(3):119–122.

Samsuzzaman, M. 2004. Effect of NAA and GABA on growth and yield contributing characters of groundnut. Department of Crop Botany, Bangladesh Agricultural University, Mymemsingh, Bangladesh.

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RESPONSE OF MUNGBEAN VARIETIES TO BORON IN CALCAREOUS SOILS OF BANGLADESH

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Abstract

An experiment was conducted in calcareous soil at the research farm of Regional Pulses Research Station,Madaripur during 2014 and 2015 to determine the suitable dose of B for yield maximization of different varieties of mungbean (*Vigna radiata* L. There were 25 treatment combinations comprising five levels of boron (0, 1.0, 1.5, 2.0 and 2.5 kg ha^{-1}) and five varietiesof mungbean (BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and BARI Mung-6) along with a blanket dose of $N_{20}P_{25}K_{30}S_{10}Zn_2$ kg ha^{-1}. The experiment was laid out in factorial randomized complete block design with three replications. Main effect of boron indicated 1.5 kg ha^{-1} B was superior to other doses in respect of yield, protein content and yield traits of mungbean varieties. However, the highest yield increment (31.4%) over control was achieved from 1.5 kg B ha^{-1}. In interactions, the maximum seed yield was achieved from var. BARI Mung-6 with the application of B @ 1.5 kg ha^{-1}. As such cultivation of mungbean var. BARI Mung-6 with the application of boron @ 1.5 kg ha^{-1} along with $N_{20}P_{25}K_{30}S_{10}Zn_2$ kg ha^{-1} (blanket dose) could be found suitable for yield maximization of mungbean in calcareous soils of Bangladesh.

Keywords: Mungbean variety, boron, yield, protein content, yield traits.

Introduction

Mungbean (*Vigna radiata* L.) is one of the promising and important legume crops in Asia under *Fabaceae* family and known as green gram, cultivated during spring and autumn seasons (Hussain *et al*., 2016; Sadaf and Tahir, 2017). The crop is very important in the nutritional point of view containing 24.5% protein, 1.3 % fat and 60.4 % carbohydrate, 75 mg calcium, 8.5 mg iron and 49 mg β-carotene per 100 g split dhal (Quddus *et al*., 2010). The mungbean sprout is rich in vitamins and amino acids (Hussain *et al*., 2011; Saket *et al*., 2018). Mungbean crop also plays a key role in improving the soil fertility through biologically nitrogen fixation from 63 to 342 kg ha^{-1} (Sadaf and Tahir, 2017; Kaisher *et al*., 2010). The retention of mungbean biomass has significant

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effect in contributing residual nitrogen for succeeding crops and could add considerable amount of organic matter to increase soil fertility (Kumar and Yadav, 2018).

The average seed yield of mungbean in Bangladesh is much low (about 867 kg ha^{-1}) compared to potential yield (BBS, 2016). But seed yield can be improve by cultivation of modern high yielding variety with judicial application of macro and micro nutrients, particularly boron application (Uddin *et al*., 2009). Calcareous soils of Bangladesh are more or less deficient in boron as the soil contains sufficient amount of calcium carbonate which caused decrease in B-availability (Padbhushan and Kumar, 2014; Shaaban *et al.*, 2004). Boron application plays an important role in plant cell wall formation and membrane constancy (Bassil *et al.*, 2004). It facilitates to increase the flowering, germination of pollen, accelerates the growth of pollen tube, pod and seed setting and seed yield of legume (Qamar *et al*., 2016). Boron is useful in chlorophyll synthesis and carbohydrates metabolism (Laxmi *et al*., 2020). In addition, boron positively influences the uptake and acquisition of N, P and K nutrients by the plant.

Hence, using the suitable variety of mungbean with appropriate dose of B is essential for higher seed yield of mungbean. The present study was therefore undertaken to find out suitable mungbean variety and determine the suitable dose of boron for yield maximization of mungbean in calcareous soils of Bangladesh.

Materials and Methods

Field experiment was conducted in research field of Regional Pulses Research Station, Bangladesh Agricultural Research Institute (BARI), Madaripur during summer (Kharif-I) season of 2014 and 2015. The land of Madaripur is medium high with loamy textured calcareous soils. It belongs to Gopalpur series (Soil taxonomy: Aquic Eutrochrepts) under the agro-ecological zone Low Ganges River Floodplain (AEZ-12). The experimental area is characterized by moderately monsoon rainfall, high humidity, and high temperature during March to June. Long day with less clear sunshine, heavy rainfall (about 80% of the total rainfall) during June to October. The site having scanty rainfall, low humidity, and low temperature, short day and clear sunshine during October to March. Average temperature ranged from 12.0 to 38^0 C and average annual rainfall varied from 1500 to 5500 mm around the year

Soil samples (0-15 cm depth) were collected for laboratory analyses at the beginning of the experiment to know the basic soil properties of the experimental soil. The chemical properties of the initial soil are presented in Table 1.

Table 1. Initial soil nutrient status of the experimental field

Nutrient	Soil test value	Critical level	*Soil test interpretation	Method of analysis and reference
pH	7.4	-	Slightly alkaline	Glass electrode pH meter (Page *et al.*, 1982)
Organic carbon (g kg^{-1})	8.33	-	Low	Wet oxidation method (Page *et. al.*, 1982)
Ca (meq.100g^{-1} soil)	14.4	2.0	High	1N NH4OAc extraction (Page *et. al.*, 1982)
K (meq.100g^{-1} soil)	0.14	0.12	Low	1N NH4OAc method (Jackson, 1973)
Total N (g kg^{-1})	0.65	1.2	Very low	Microkjeldahl method (Page *et. al.*, 1982)
Available P (mg kg^{-1})	15	8	Medium	Olsen method (Page *et. al., 1982)*
Available S (mg kg^{-1})	15.3	10	Low	Turbidity method using $BaCl_2$ (Fox *et. al.*, 1964)
Available Zn (mg kg^{-1})	0.85	0.6	Low	DTPA method (Lindsay and Norvell, 1978)
Available B (mg kg^{-1})	0.15	0.2	Low	Azomethine-H method (Page *et. al.*, 1982)

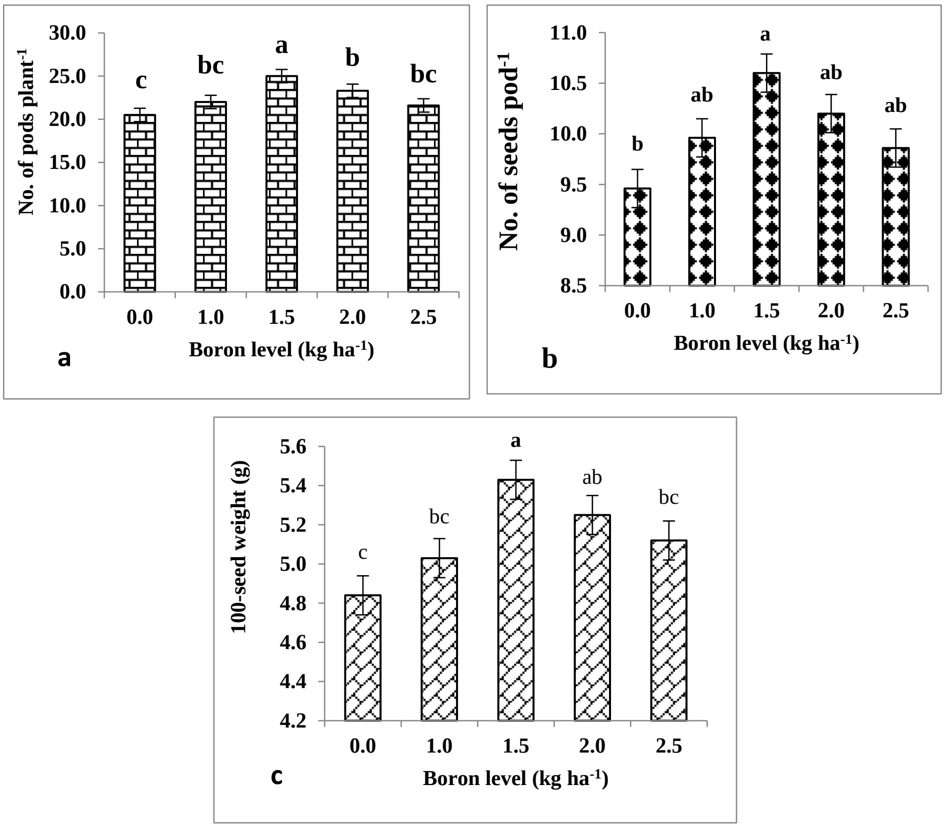
*Anonymous (2012).

There were 25 treatment combinations comprising five levels of boron (0, 1.0, 1.5, 2.0 and 2.5 kg ha^{-1}) and five varieties (V_1=BARI Mung-2, V_2= BARI Mung-3, V_3= BARI Mung-4, V_4=BARI Mung-5 and V_5= BARI Mung-6) along with a blanket dose of $N_{20}P_{25}K_{30}S_{10}Zn_2$ kg ha^{-1}. The experiment was laid out in factorial randomized complete block design with three replications. The land was prepared by 3-4 passes with a tractor driven chisel plough and leveled with tractor driven rotavator. Weeds and stubbles were removed manually. Boron was applied as boric acid (17% B). The source of N, P, K, S and Zn were urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively. Full amount of all fertilizers except boric acid as per treatment were applied during final land preparation. Healthy seeds of mungbean varieties lviz., BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and BARI Mung-6 were sown @ 30-35 kg seed ha^{-1} with a spacing of 40 cm × 10 cm on 11 March 2014 and 12 March 2015. Two hand weeding were done at 20 and 40 days after sowing. The insects (thrips and pod borer) were controlled by spraying Karate @ 0.2% three times started at flowering with an interval of 10 days. Only one pre-sowing light flood irrigation was done to ensure proper seed germination. The matured crop was harvested duly and seed yield (kg ha^{-1}) was measured. Plant samples (seed) against each treatment were oven-dried at 70°C for 48 h and finely ground using CyclotecTM 1093 sample Mill (Made in Sweden). An amount of 0.1 g ground sample (seeds) was analyzed for N using the Kjeldahl method FOSS (Persson *et al*., 2008). The protein content was estimated by multiplying the %N content of mungbean with constant factor 6.25 that means %N × 6.25 (Hiller *et al*., 1948). The collected data were compiled and analyzed statistically with the help of a computer package program MSTAT-C and the mean differences were adjusted by Duncan's New Multiple Range Test (Gomez and Gomez, 1984). The optimum dose of boron was calculated using the formula: $Y= a + bx + cx^2$ and By = - b/2c (Gomez and Gomez 1984).

Results and Discussion

Main effects of boron application

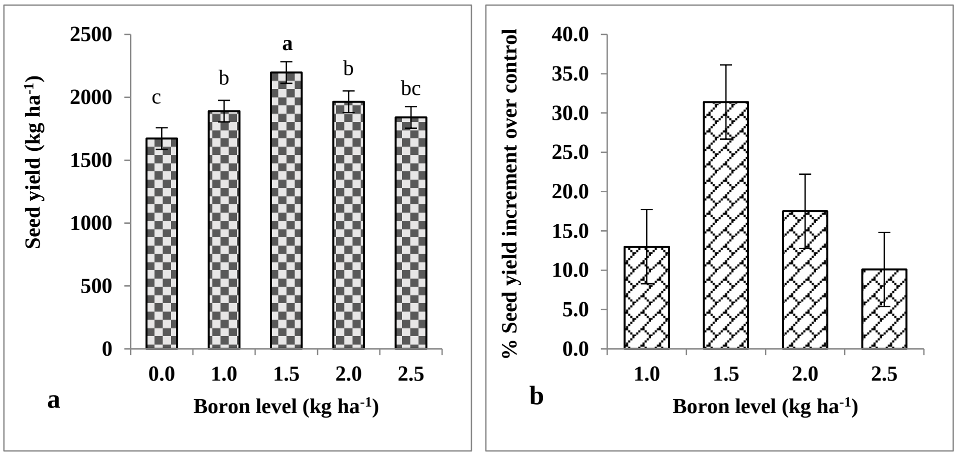
Yield traits viz., pods per plant, seeds per pod and 100-seed weight of mungbean varieties varied significantly due to application of boron (Figure 1a, b, c). The maximum pods per plant (25.0) was recorded from application of B @ 1.5 kg ha^{-1} and the minimum pods per plant (20.5) from control treatment (Figure 1a). Boron application @1.5 kg ha^{-1} has led to attain the highest increment (21.9%) of pods per plant of mungbean over control treatment. Boron helps the formation of more flowers, pollen germination, and speed up the growth of pollen tube, facilitating better pod setting in plant thus resulting increased number of pods per plant under B application @ 1.5 kg ha^{-1}. Similar statement was reported by Qamar *et al*. (2016); Padbhushan and Kumar (2014). The maximum seeds per pod (10.6) was obtained from application of 1.5 kg B ha^{-1} that was comparable to treatments of 2.0, 2.5 and 1.0 kg B ha^{-1} (Figure 1b). Tania *et al*. (2019) also reported similarly that boron application increased the pods per plant and seeds per pod in mungbean. Similar results were also corroborates by Alam *et al*. (2017) in chickpea production. The highest 100-seed weight (5.43 g) was obtained from application of 1.5 kg B ha^{-1} which was 12.2% higher over t control treatment (Figure 1c). Boron enhanced the crop cell division, carbohydrate metabolism, sugar and starch formation which ultimately improved the seed size and seed weight of mungbean. The comparable result was also outlined by Padbhushan and Kumar (2014).



Values followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \leq 0.05$.

Fig. 1. Main effect of boron on (a) number of pods per plant, (b) number of seeds per pod and (c)100-seed weight of mungbean varieties (Pooled)

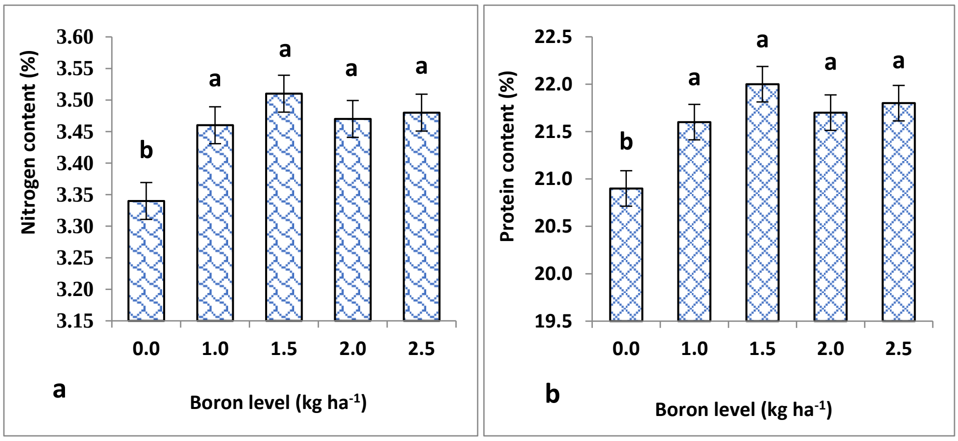
Boron application had positively influenced the seed yield of mungbean varieties (Figure 2a). Seed yield of mungbean was increased due to increase in boron application rate up to 1.5 kg ha^{-1} and then decline up to 2.5 kg ha^{-1}. However, the highest seed yield (2197 kg ha^{-1}) was produced from application of 1.5 kg B ha^{-1} which was significantly higher than other treatments (Figure 2a). Verma *et al.* (2004) also reported that seed yield of mungbean improved with increasing the boron availability in soil. Boron influences the proper function of cell membranes and the transport of K to guard cells for the proper control of internal water balance, encouraged to works the xylem vessels and root hair tips and finally improves the plant growth and yield (Ahmed *et al.* 2020). Percent yield increment of mungbean over B control was highest (31.4%) from B application @1.5 kg ha^{-1} and lowest (10.1%) from B application @ 2.5 kg ha^{-1} (Figure 2b).



Values followed by the same letter are not significantly different according to DMRT at $p \leq 0.05$.

Fig. 2. Main effect of boron on (a) seed yield of mungbean varieties and (b) percent seed yield increment over control (Pooled).

The N and protein content in mungbean was influenced significantly by the B application (Figure 3a, b). The highest N (3.51%) and protein contents (22.0%) were recorded in the treatment 1.5 kg B ha^{-1}.. Maqbool *et al.* (2018) also reported similarly that B application increases the protein content of mungbean. The lowest N and protein content was found in B control treatment (Figure 3a, b). Boron influences the absorption of N, P and K and played a positive role for protein synthesis (Quddus *et al.*, 2018).

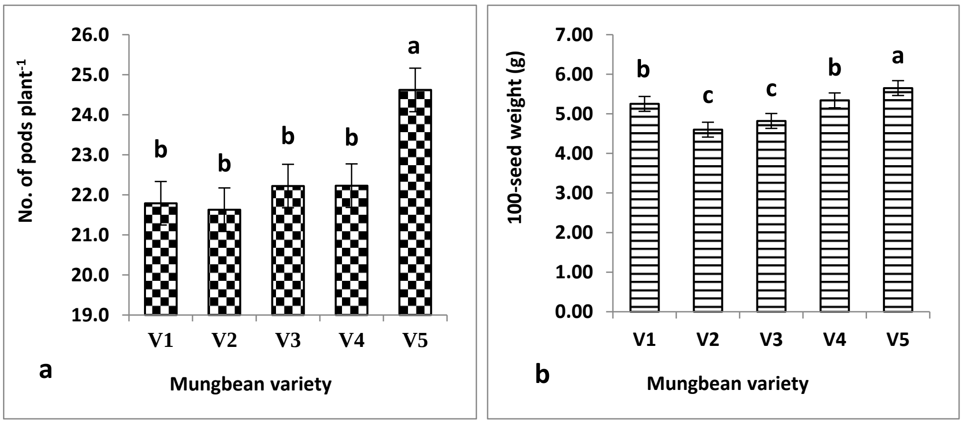


Values followed by the same letter are not significantly different according to DMRT at $p \leq 0.05$.

Fig. 3. Main effect of boron on (a) nitrogen content and (b) protein content in mungbean varieties (Pooled).

Main effects of varieties

Yield traits viz., pods per plant and 100-seed weight exhibited significant variation among mungbean varieties (Figure 4a, b) but number of seeds per pod was statistically similar.. The highest pods per plant (24.6) was obtained from BARI Mung-6 whereas minimum pods per plant was noted from BARI Mung-3 (Figure 4a). The highest 100-seed weight (5.65 g) was recorded from BARI Mung-6 and lowest 100-seed weight from BARI Mung-3 (Figure 4b). The pods per plant and seed weight showed highest in BARI Mung-6 might be related to the contribution of genetic divergence and superiority in nutrient uptake capacity than other mungbean varieties. Similar observation reported by Razzaque *et al.* (2016) in mungbean genotypes.

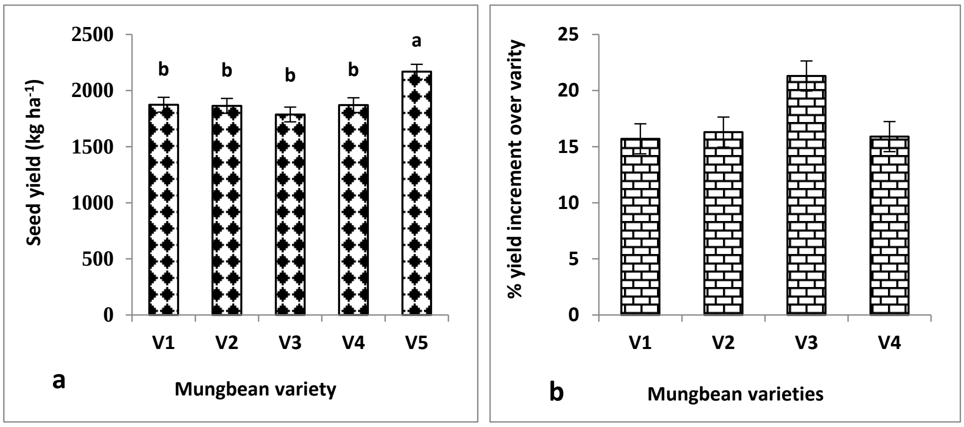


Values followed by the same letter are not significantly different according to DMRT at $p \leq 0.05$.

Fig. 4. Main effect of mungbean varieties on (a) number of pods per plant and (b) 100-seed weight (Pooled).

Note: V_1=BARI Mung-2, V_2= BARI Mung-3, V_3= BARI Mung-4, V_4=BARI Mung-5 and V_5= BARI Mung-6.

Variety had significant influence on seed yield of mungbean (Figure 5a). The highest seed yield (2168 kg ha^{-1}) was produced from BARI Mung-6 and lowest seed yield (1864 kg ha^{-1}) from var. BARI Mung-3 (Figure 5a). The varietal characters might result in higher seed yield of BARI Mung-6 than other varieties. Uddin *et al*. (2010) corroborated the similar findings. In present study, the yield increment of BARI Mung-6 over BARI Mung-2 was 15.7%, BARI Mung-3 (16.3%), BARI Mung-4 (21.3%) and BARI Mung-5 (15.9%) (Figure 5b). This yield increment of BARI Mung-6 over other varieties might be attributed due to pods per plant and heaviest seed weight in BARI Mung-6. Tania *et al*. (2019) and Hossain *et al*. (2016) alsostated that higher pods per plant variation might be due to genetic advantage that has contributed to higher seed yield in BARI Mung-6.

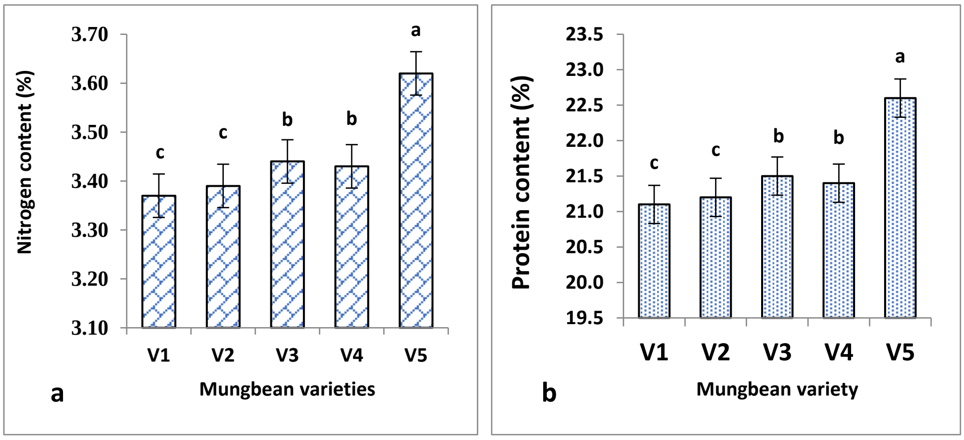


Values followed by the same letter are not significantly different according to DMRT at $p \leq 0.05$.

Fig. 5. Main effect of mungbean varieties on (a) seed yield and (b) % yield increment of BARI Mung-6 over varieties (Pooled).

Note: V_1=BARI Mung-2, V_2= BARI Mung-3, V_3= BARI Mung-4, V_4=BARI Mung-5 and V_5= BARI Mung-6.

Nitrogen and protein content exhibited significant variation among mungbean varieties (Figure 6a, b). Mungbean var. BARI Mung-6 accumulated the higher protein content (22.6%) than the other varieties (Figure 6b).



Values followed by the same letters are not significantly different according to DMRT at $p \leq 0.05$.

Fig. 6. Main effect of mungbean varieties on (a) nitrogen content and (b) protein content in mungbean (Pooled).

Note: V_1=BARI Mung-2, V_2= BARI Mung-3, V_3= BARI Mung-4, V_4=BARI Mung-5 and V_5= BARI Mung-6.

Regression analysis

Regression analysis exhibited positive and quadratic response to mean yield of mungbean varieties and application of B (Figure 7). The optimum dose of B calculated from the quadratic response function was 1.46 kg ha^{-1}. Using the optimum dose (1.46 kg ha^{-1}), the maximum seed yield (2053 kg ha^{-1}) of mungbean could be expected from B deficient soil.

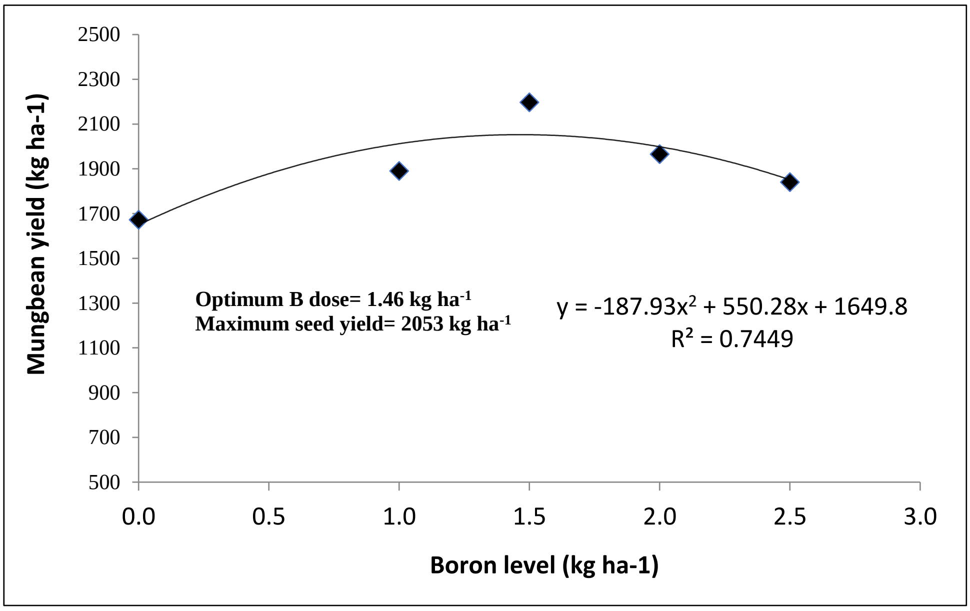


Fig. 7. Relationship between mungbean seed yield and dose of boron

Interaction effect of boron and mungbean varieties

The interaction of variety and level of boron exhibited significant variation in pods per plant, seeds per pod, 100-seed weight and seed yield of mungbean (Table 2).

The highest number of pods per plant (26.7) was documented from $B_{1.5}$ × BARI Mung-6 treatment combination and the lowest pods per plant from treatment combination of B_0 × BARI Mung-3. The maximum seeds per pod was recorded in the treatment $B_{1.5}$ × BARI Mung-6 comparable to $B_{2.0}$ × BARI Mung-6, $B_{1.0}$ × BARI Mung-6, $B_{1.5}$ × BARI Mung-5, $B_{1.5}$ × BARI Mung-4, $B_{1.5}$ × BARI Mung-3, and $B_{1.5}$ × BARI Mung-2. Seeds per pod were minimum in B_0 × BARI Mung-3 treatment (Table 2). The maximum 100-seed weight was found in $B_{1.5}$ × BARI Mung-6 treatment which was statistically identical to $B_{2.0}$ × BARI Mung-6 and $B_{1.5}$ × BARI Mung- (Table 2). Ceyhan and Onder (2007) reported significant variation in varietal response to different B rates. Tania *et al.* (2019) BARI Mung-6 with 1 or 1.5 kg B application performed better result in yield and yield traits. Mungbean var. BARI Mung-6 having the larger seed size with B application @ 1.5 kg ha^{-1} compared to 1.0 or 2.0 kg ha^{-1}Use of suitable variety and optimum dose of B nutrient along with other nutrients might have favored plant growth and development that finally resulted in getting higher seed yield of mungbean In interaction of variety and B application showed that the highest seed yield (2529 kg ha^{-1}) was obtained from t $B_{1.5}$ × BARI Mung-6 and lowest from B_0 × BARI Mung-5 treatment (Table 2). Boron application might have played a key role for getting higher seed yield of mungbean varieties. Ceyhan and Onder (2007) opined that B application has positive effect on pulse crop. The maximum N content (3.68%) and protein content (23.0%) was recorded from the treatment $B_{1.5}$ × BARI Mung-6 which was statistically similar with $B_{2.5}$ × BARI Mung-6, $B_{2.0}$ × BARI Mung-6 and $B_{1.0}$ × BARI Mung-6 treatments. The lowest N and protein content in seed was from B_0 × BARI Mung-2 treatment (Table 2).

Table 2. Interaction effect of boron and variety on yield traits, yield, N and protein content in mungbean (Pooled)

Boron level × Mungbean variety	Number of pods plant^{-1}	Number of seeds pod^{-1}	100-seeds wt. (g)	Seed yield (kg ha^{-1})	N content (%)	Protein content (%)
B_0 × BARI Mung-2	19.8jk	9.38fg	5.00f-j	1639hij	3.15g	19.6h
$B_{1.0}$ × BARI Mung-2	20.6hij	9.93b-g	5.16e-h	1837f-i	3.37ef	21.0efg
$B_{1.5}$ × BARI Mung-2	24.5bcd	10.5a-d	5.55bc	2131bcd	3.46de	21.7de
$B_{2.0}$ × BARI Mung-2	22.5d-h	10.1b-f	5.30c-f	1923d-g	3.41ef	21.3d-g
$B_{2.5}$ × BARI Mung-2	21.5f-j	9.97b-g	5.22d-g	1839f-i	3.47de	21.6de
B_0 × BARI Mung-3	18.5k	9.16g	4.37m	1648hij	3.30f	20.6g
$B_{1.0}$ × BARI Mung-3	20.9g-j	9.67c-g	4.46lm	1878efg	3.40ef	21.3efg
$B_{1.5}$ × BARI Mung-3	24.5bcd	10.3a-f	4.82ijk	2066b-e	3.45de	21.5de
$B_{2.0}$ × BARI Mung-3	22.8c-g	9.90b-g	4.67klm	1916d-g	3.40ef	21.3efg
$B_{2.5}$ × BARI Mung-3	21.5f-j	9.59d-g	4.70jkl	1815f-j	3.41ef	21.2efg
B_0 × BARI Mung-4	20.4ijk	9.55d-g	4.42lm	1620ij	3.39ef	21.1efg
$B_{1.0}$ × BARI Mung-4	22.2e-i	10.1b-g	4.69jkl	1767g-j	3.45de	21.6de
$B_{1.5}$ × BARI Mung-4	24.7bc	10.3a-e	5.15e-h	2034c-f	3.47de	21.8cde

Table 2. Cont'd.

Boron level × Mungbean variety	Number of pods plant^{-1}	Number of seeds pod^{-1}	100-seeds wt. (g)	Seed yield (kg ha^{-1})	N content (%)	Protein content (%)
$B_{2.0}$ × BARI Mung-4	23.3b-f	10.0b-g	4.97g-k	1797g-j	3.44de	21.5de
$B_{2.5}$ × BARI Mung-4	20.6hij	9.91b-g	4.88h-k	1719g-j	3.47de	21.6de
B_0 × BARI Mung-5	20.3ijk	9.47efg	5.09e-i	1607j	3.31f	20.7fg
$B_{1.0}$ × BARI Mung-5	22.2e-i	9.82b-g	5.28c-g	1848fgh	3.46de	21.7de
$B_{1.5}$ × BARI Mung-5	24.8b	10.6abc	5.66ab	2227bc	3.48c-e	21.8cde
$B_{2.0}$ × BARI Mung-5	23.1b-f	10.1b-f	5.37b-e	1918d-g	3.46de	21.6de
$B_{2.5}$ × BARI Mung-5	20.8g-j	9.66c-g	5.29c-g	1753g-j	3.44de	21.5def
B_0 × BARI Mung-6	23.6b-e	9.73c-g	5.31c-f	1846f-h	3.54b-d	22.1bcd
$B_{1.0}$ × BARI Mung-6	24.3bcd	10.3a-f	5.57bc	2119bcd	3.61a-c	22.5abc
$B_{1.5}$ × BARI Mung-6	26.7a	11.1a	5.94a	2529a	3.68a	23.0a
$B_{2.0}$ × BARI Mung-6	24.8b	10.7ab	5.92a	2269b	3.63ab	22.7ab
$B_{2.5}$ × BARI Mung-6	23.7b-e	10.2b-f	5.51bcd	2076b-e	3.64ab	22.8ab
CV (%)	4.68	4.74	4.34	6.02	3.89	3.97

Values within the same column with a uncommon letters differed significantly ($P \leq 0.05$) by DMRT.

Conclusion

All the varieties of mungbean used in the present investigation were found responsive to boron application but munjgbean var. BARI Mungbean-6 was more responsive to boron fertilizer. Among the varieties, BARI Mung-6 was the best on the basis of yield traits, protein content and seed yield. Again, the application of B @ 1.5 kg ha^{-1} along with a blanket dose of $N_{20}P_{25}K_{30}S_{10}Zn_2$ is found suitable dose for mungbean cultivation. Regression analysis of the yield data also indicates that the application of boron at 1.46 kg ha^{-1} is optimum and leads to maximize seed yield of mungbean in B deficient area. Thus to boost up seed yield of mungbean, BARI Mung-6 variety with B application @ 1.5 kg ha^{-1} could be recommended for Madaripur region.

References

Ahmed, A.A.M.A., Z.A. Dawood and W.K. Khalid. 2020. Role of Boron and Calcium on growth, flowering and yield of strawberry (*Fragaria* x *ananassa* Duch) var. Liberation D'Orleans. *Middle East J. Agric. Res.* **9** (1): 130-133.

Alam, M. S., K. J. Ali and A. Hoque. 2017. Yield and yield component of chickpea as affected by boron application. *Journal of Experimental Agriculture International,* **15**(2): 1-9; Article no.JEAI.8944. doi: 10.9734/JEAI/2017/8944

Anonymous. 2012. *Fertilizer recommendation guide*. Bangladesh Agricultural Research Council, Farmgate, Dhaka.

Bassil, E., H. Hu and P. H. Brown. 2004. Use of phenyl boronic acids to investigate boron function in plants : possible role of boron in transvacuolar cytoplasmic strands and cell-to-Wall adhesion. *Plant Physiol.,* **136:** 3383-3395.

BBS (Bangladesh Bureau of statistics). 2012. Bulletin of tropical legume Bangladesh. Stat. Div. Ministry Plann. Govt. People's Repub. of Bangladesh, 150-160.

BBS (Bangladesh Bureau of statistics). 2016. *Yearbook of Agriculture Statistics*-2016. Statistics and Information Division, Ministry of Planning, Government of the People's Republic of Bangladesh. www.bbs.gov.bd

Ceyhan, E., and M. Onder. 2007. Response of chickpea cultivars to application of boron in boron- deficient calcareous soils. *Communications in Soil Science and Plant Analysis.* **38:** 2381-2399.

Fox, R. L., R. A. Olsen, and H.F. Rhoades. 1964. Evaluating the sulphur status of soil by plant and soil test. *Soil Science Society of American Journal*, **28(**2), 243-246.

Gomez, K. A. and A.A. Gomez.1984. Statistical procedure for agricultural research, 2nd edition, John Wiley and Sons, Inc. Singapore, 324 p.

Halder, N.K., M. A. Hossain , M.A. Siddiky , N. Nasreen and M.H. Ullah , 2007. Response of Wheat Varieties to Boron Application in Calcareous Brown Floodplain Soil at Southern Region of Bangladesh. *Journal of Agronomy,* **6:** 21-24.

Hossain, M.M., M.M. Mahbub and B.J. Shirazy. 2016. Growth and yield performance of mungbean varieties in summer cultivation. *Scientia Agriculturae,* **16** (3), 2016: 79-82.

Hiller, A., J. Plazin, J. and D.D. Vanslyke. 1948. A study of conditions of Kjeldhal determination of nitrogen in proteins. *Journal of Biological Chemistry,* **176**(3), 1401-1420.

Huq S. M. I. and J. U. M. Shoaib, 2013. The Soils of Bangladesh, World Soils Book Series 1, Springer Science.

Hussain, F., A.U. Malik, M.A. Haji and A.L. Malghani. 2011. Growth and yield response of two cultivars of mungbean (*vigna radiata* L.) to different potassium levels. *Journal of Animal & Plant Sciences,* **21**(3): 622-625.

Hussain, F, M., M.R. Buriro, S. Nizamani, S. Ahmed, N.A. Rehman and Z. Huma. 2016. Growth and yield response of Mungbean to different levels of potassium. *International Journal of Agricultural and Environmental Research,* **2**(1):67-76.

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

Kaisher, M.S., M.A. Rahman, M.H.A. Amin, A.S.M. Amanullah and A.S.M. Ahsanullah. 2010. Effects of sulphur and boron on the seed yield and protein content of mungbean. *Bangladesh Research Publication Journal*, **3:**1181-1186.

Kumar, N. and A. Yadav. 2018. Role of pulses in improving soil quality and enhancing resource use efficiency. *Conservation Agriculture for Advancing Food Security in Changing Climate*, **2:**547-561.

Laxmi, S., R. Patel, S. Singh, B. Choudhary, R. Gadhwal, R. Meena and Y.V. Singh. 2020. Growth and yield response of mungbean as influenced by sulphur and boron application. *International Journal of Current Microbiology and Applied Sciences*, **9**(3): 2788-2794.

Lindsay, W. L., and W.A. Norvell. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal*, **42**(92), 421-428.

Mahbub, M.M., M.M. Rahman, M.S. Hossain, F. Mahmud and M.M.M. Kabir. 2015. Genetic variability, correlation and path analysis for yield and yield components in soybean. *Am-Euras. J. Agric. & Environ. Sci.*, **15**(2): 231-236.

Maqbool, R., W. Ali, M. A. Nadeem and T. Abbas. 2018. Boron application in clay-loam soil for improved growth, yield and protein contents of mungbean in water-stresses. *Sains Malaysiana*, **47**(1): 51-58.

Padbhushan, R. and D. Kumar. 2014. Influence of soil and foliar applied boron on green gram in calcareous soils. *International Journal of Agriculture, Environment & Biotechnology*, **7**(1): 129-136.

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

Persson, Jan-Ake, M. Wennerholm and S. O'Halloram. 2008. *Handbook for Kjeldahl Digestion*. Published by FOSS, DK-3400 Hilleroed, Denmark. ISBN 91-630-3471-9.

Qamar, J., A. Rehman, M.A. Ali, R. Qamar, K. Ahmed and W. Raza. 2016. Boron increases the growth and yield of mungbean. *Journal of Advances in Agriculture*, **6**(2): 922-924.

Quddus, M.A., M.A. Hossain, H.M. Naser, N. Naher and F. Khatun. 2018. Response of chickpea varieties to boron application in calcareous and terrace soils of Bangladesh. *Bangladesh J. Agril. Res*. **43**(4): 543-556.

Quddus, M.A., M.H. Rashid, A.T.M. Hossain, M.A. Hossain and M.A. Bakr. 2010. On-station and on-farm performance of six mungbean genotypes. *Bangladesh Journal of Agriculturist*, **3**(1): 27-33.

Razzaque, M.A., M.M. Haque, M.M. Rahman, M.M. Bazzaz and M.S.A. Khan. 2016. Screening of mungbean (V*igna radiata* L. wilczek) genotypes under nutrient stress in soil. *Bangladesh J. Agril. Res.* **41**(2): 377-386.

Sadaf, A. and M. Tahir. 2017. Effect of Potassium on Growth, Yield and Quality of Mungbean under Different Irrigation Regimes. *Bulletin of Biological and Allied Sciences Research*, **2**(4), 1-10.

Saket,K., S.J. Dan and S. Rajesh. 2018. Growth and Yield Response of Mung Bean (*Vigna radiata* L.) in Different Levels of Potassium. *Acta Scientific Agriculture,* **2**(6), 23-25.

Shaaban, M. M., M.M. El-Fouly and Abdel-Maguid. 2004. Zinc-Boron relationship in wheat plants grown under low or high levels of calcium carbonate in the soil. *Pakistan Journal of Biological Science* **7:** 633-639.

Tania, S.A., F.M.J. Uddin and M.A.R. Sarkar. 2019. Responses of selected mungbean (*Vigna radiata* L.) varieties to boron fertilization. *Fundamental and Applied Agriculture,* **4**(1): 655–660.

Uddin, F.M.J., M.A.R. Sarkar and A.A. Mamun. 2010. Effect of variety, date of planting and level of phosphorus on shoot dry matter and yield of mungbean. *Journal Agroforestry Environment,* **4:**121-124.

Uddin, M.A., A.K.M. Ruhul Amin, Md. Jafar Ullah and Md. Asaduzzman. 2009. Interaction effect of variety and different fertilizers on the growth and yield of summer mungbean. *Am-Euras. J. Agron*., **2**(3): 180-184.

Verma, C. B., B. Lallu and R. S. Yadav. 2004. Effect of B and Zn application on growth and yield of pigeonpea. *Indian J. Pulse Res*., **17:** 149- 151.

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EFFECT OF NITROGEN AND WATER USE ON YIELD AND STORABILITY OF ONION

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Abstract

A Field experiment was conducted at Regional Spices Research Centre, BARI, Gazipur and Spices Research Sub-Centre, BARI, Lalmonirhat to find out the water and nitrogen use efficiency of onion (*Allium cepa* L.) as influence by different levels of soil moisture regimes and nitrogen doses during *rabi* season of 2020-2021. The experiment was designed in Factorial Randomized Complete Block Design having three replications. The treatment composed of three soil moisture regiems (10%, 20% and 30% depletion of soil moisture over field capacity) and three nitrogen doses (150, 100 and 75 kg ha^{-1}). The individual as well as interaction effect of soil moisture and nitrogen levels showed significant effect on yield and yield contributing parameters, storability, nitrogen and water use efficiency except the TSS of onion. The highest bulb yield (21.49 t ha^{-1} in Gazipur & 22.79 t ha^{-1} in Lalmonirhat), marketable bulb yield (18.0 t ha^{-1} in Gazipur & 20.0 t ha^{-1} in Lalmonirhat), harvest index (598.0% in Gazipur & 607.9% in Lalmonirhat) were recorded when the crop irrigated at 10% depletion of field capacity and plant supplied with 100kg Nha^{-1}. Similarly, the maximum nitrogen use efficiency (54.74% in Gazipur & 61.38% in Lalmonirhat) and the maximum water use efficiency (105.76 kg ha^{-1} mm^{-1} in Gazipur & 108.06 kg ha^{-1} mm^{-1} in Lalmonirhat) were also observed from the above mentioned treatment combinations. Total PLW was higher (16.3% in Gazipur and 21.1% in Lalmonirhat) with irrigation was given applied at 10% depletion of field capacity and application of 150 kg N ha^{-1} during 120 days of storage.

Keywords: Onion, irrigation, nitrogen & water use efficiency and shelf-life.

Introduction

The popular spices crop, onion (*Allium cepa* L.) originated in Central Asia (Afghanistan, Iran and Pakistan), having remarkable medicinal and nutritional properties. The immature and mature bulbs, leaves and often inflorescences are consumed as spices and vegetables in all clans of people in Bangladesh (Yousuf *et al*., 2013). It ranks first in production among the spice crops grown in the country, covering 1.85 lakh hectares of land and produced 19.54 lakh Metric tons bulbs with a productivity of 10.56 t ha^{-1} (BBS, 2021), which is lower in comparison to the world average of 19.7 t ha^{-1}. Onion as fibrous and shallow rooted bulb crop, mostly cultivated during winter season and dormant bulbs are stored for year round

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consumption, except summer onion which is consumed immediate after harvest. Irrigation is indispensable in winter crops due to very little or no precipitation. Water is the most important natural resource especially for crops grown in winter and dry summer season. The soil moisture as natural solvent provides mobility or availability of soil nutrients for plants. Maintaining optimum soil moisture level in whole growing season of onion is elementary. On the other hand, nitrogen as a major constituents of chlorophyll, amino acids, proteins and nucleic acids, the increase in which improved photosynthesis leading to formation of protoplasm and new cells encouragement for growth, development and storability (Bangali *et al*., 2012 and Walle *et al.*, 2018). But farmers are unaware of soil-water-nitrogen-plant dynamics, especially the irrigation and nitrogen to crop needs (Tolossa, 2021 and Gebregwergis *et al.*, 2016). Water and nitrogen are two factors which, with optimum application, increase bulb yield and storability and, if left unchecked, caused huge yield reduction (Kumara *et al*., 2018). Moreover, Kumar *et al.* (2007) reported that the growth and yield parameters such as plant height, number of leaves per plant, biomass, individual bulb weight and bulb yield increased significantly with appropriate irrigation frequencies and nitrogen doses. Study showed that onion grown under water stress and nitrogen deficient condition resulted in bulb rots and early sprouting than anticipated during storage (Fatideh and Asil, 2012). Therefore, judicious application of irrigation and nitrogen fertilizer is of great concern in many parts of the world, like Bangladesh. An excessive use of nitrogen tends to promote severe environmental crisis like land & soil health degradation, eutrophication, cancer and blue baby syndrome. The aim of new agricultural strategy is to maximize crop production by utilizing of minimum resources like land, labor, fertilizers and water. Hence, the present study was undertaken to find out the optimum soil moisture level and nitrogen dose for higher bulb yield, longer storability and to assess nitrogen & water use efficiency of onion in sub-tropical climatic condition of Bangladesh.

Materials and Methods

The present investigation was conducted at the research fields of Regional Spices Research Center, BARI, Gazipur and Spices Research Sub-Centre, BARI, Lalmonirhat during *rabi* season of 2020-2021. The treatment comprises of three soil moisture regimes (Irrigation at 10%, 20% and 30% depletion of field capacity) with three levels of nitrogen *i.e.*, 150 (N_1), 100 (N_2) and 75 (N_3) kg ha^{-1}. The experiment was laid out in Factorial Randomized Complete Block Design with three replications**.** The test crop was onion cv. BARI Piaz-4. Seeds were soaked in water for 12 hours and treated with Autostin (*Carbendazim*) @ 2 g kg^{-1} before sowing to control primary seed-borne diseases. The seeds were sown @ 30 g per seed bed (3m x 1m) on 01 November 2020. Healthy seedlings of 40 days were transplanted into the main field maintaining10cm x10cm spacing on 11 December 2020. The unit plot size was 3.0 m x 1.2 m with 30 cm deck around the plot. Cowdung was applied @ 5 t ha^{-1} and other chemical fertilizers such as P, K, S, Zn and B @ 50, 100, 30, 3.5 and 1.5 kg ha^{-1} were applied as basal before final land preparation. Nitrogen was applied at two equal splits whereas, the 1st split was applied at 25 days after transplanting (DAT) and the second at 50 DAT. The intercultural operations like hand weeding was done thrice to control weed, spraying of Ridomil Gold (*Mancozeb* + *Metalaxyl*), Ruvral (*Iprodione*) @ 2.5 g l^{-1} in alternation with Admire (*Imidacloprid*) @ 2.0 m l^{-1} at 12 days interval for controlling disease and insect pest. The bulbs were harvested 10 days after 80% neck fall on 28 March 2021 in both locations. Data on plant height, number of leaves per plant, neck thickness, days to maturity, bulb size, individual bulb weight and bulb yield were recorded for each treatment from randomly selected 10 plants before harvest. The harvested bulbs were cured for three days in a well aerated shady place to make the bulb firm, dried and colored. Marketable bulb yield was determined by discarding bulb size smaller than 1.5 cm in diameter, injured, thick necked, bolted and rotten to total number of normal bulbs per plot. To enhance the shelf-life after curing, bulbs were cut at 5-7 cm above neck region for storing. Soils from the experimental fields were collected before final land preparation for estimating initial nutrient status and for calculating post-harvest nutrient status of soil. The soil samples were collected from each & every treatment immediately after harvest. The physiography and physico-chemical properties of soil in the experimental sites are described in Table 1a and 1b. About 10 kg of cured bulbs were stored in a plastic rack at room temperature to observe shelf-life. The data on physiological loss in weight were recorded at 30 days interval up to 120 days of storage. After harvesting 10 (ten) selected onion plants from each plot were uprooted, air-dried in the laboratory and finally oven-dried for 72 hours at 65^{0}C to estimate dry matter production. The dry matter was calculated by the following formula:

$$DM = [\{(DY/10) \times NP\} \times 10000)]/1000$$

Where,

DM = Dry matter (kg ha^{-1})

DY = Total dry matter yield of 10 plants per plot (g)

NP = Total number of plants per plot

For measuring the TSS, bulb tissue (20.0g) was homogenized in a blender and centrifuged for 20 min at 12000 rpm under 4^{0}C, the supernatant was analyzed at room temperature with a hand refractometer, expressed as ^{0}Brix.

Harvest index was calculated by the following formula:

$$HI = (EY / BY) \times 100$$

Where,

HI = Harvest index (%)

EY = Marketable bulb yield (kg)

BY = Biological yield (kg)

N uptake from the soil was calculated by using the formula:

N uptake = (A x Y) / 100

Where,

A = N content of plant (%)

Y = Total dry matter production (kg ha^{-1})

N use efficiency was calculated by using following formula:

NUE= (NU/NA) x 100

Where,

NUE = Nitrogen use efficiency (%)

NU = Total amount of nitrogen uptake (kg)

NA = Total amount of applied nitrogen (kg)

Soil moisture used by the crop throughout the growing period of the crop was determined by using the following formula:

$$Sm = \{(M_S – M_H) / 100\} \times \rho b \times D \times A$$

Where,

Sm = Soil moisture used by the crop (cm)

M_S = Soil moisture percentage at sowing (by weight basis)

M_H = Soil moisture percentage at harvest (by weight basis)

ρb = Bulk density (g cm^{-3})

D = Rooting depth (cm)

A = Area (m^2)

Data on rooting depth, total number of irrigation, common irrigation (transplanting to seedling establishment) and total amount of irrigation water are presented in Table 2.

Effective rainfall was determined by using the following equations:

$Pe = 0.8P – 25$ if $P > 75$ mm $month^{-1}$

$Pe = 0.6P – 10$ if $P < 75$ mm $month^{-1}$

Where,

Pe = Effective rainfall (mm)

P = Rainfall (mm)

The recorded data on different parameters were statistically analyzed by using the software, *R* 3.5.5 to find out the significance of variation resulting from the experimental treatments.

Table 1a. Physiography and observed soil physical characteristics of experimental sites

Parameters	Analytical value		Analytical method
	Gazipur	Lalmonirhat	
Agro-ecological zone (AEZ)	28 (Madhupur Tract)	03 (Tista Meander Floodplain)	
General soil type	Grey Terrace soil	Non-calcareous Grey Floodplain soil	
Soil Oder	Inceptisols	Inceptisols	
Soil Series	Chhiata series	Gangachara series	
Geographical Coordinate	$23^0 98' 8''$ North Latitude & $90^0 40' 9''$ East Longitude	$25^0 92' 2''$ North Latitude & $89^0 43' 1''$ East Longitude	
Particle size distribution			Hydrometer method
% Sand	31.5	35.7	
% Silt	30.1	39.2	
% Clay	38.4	25.1	
Textural class	Clay loam	Loam	
Bulk density (g cm^{-3})	1.38	1.41	Core sampling method
Particle density (g cm^{-3})	2.65	2.68	Pycnometer method
Porosity (%)	47.9	47.4	
Field capacity (% by weight)	31.9	29.5	Gravimetric method
Initial moisture content (% by weight)	24.8	23.6	Gravimetric method

Table 1b. Observed soil chemical properties of the experimental site

Soil Chemical Properties	Analytical value		Analytical method
	Gazipur	Lalmonirhat	
Soil pH	6.2	5.9	Soil: water=1:2.5
Organic carbon (%)	0.89	1.12	Wet oxidation method
Total N (%)	0.08	0.09	Micro Kjeldhal Method
Available P (ppm)	7.78	7.33	Bray and Kurtz method
Exchangeable K (meq 100 g^{-1} soil)	0.08	0.09	N NH_4OAc Extraction method
Available S (ppm)	6.57	6.34	Calcium dihydrogen phosphate extraction method
Available B (ppm)	0.18	0.21	Calcium chloride extraction method
Available Zn (ppm)	0.57	0.63	DTPA Extraction method
Available Cu (ppm)	0.17	0.19	DTPA Extraction method
Available Mn (ppm)	0.75	0.78	DTPA Extraction method
CEC (meq 100 g^{-1} soil)	9.3	9.9	N NH_4OAc Extraction method

Table 2. Amount of irrigation water applied in different soil moisture levels of onion

No. of irrigation	Rooting depth (cm)	Amount of irrigation water (mm) at different soil moisture regimes and nitrogen levels																	
		I_1N_1		I_1N_2		I_1N_3		I_2N_1		I_2N_2		I_2N_3		I_3N_1		I_3N_2		I_3N_3	
		Gaz	Lal	Gaz	Lal	Gaz	Lal	Gaz	Lal	Gaz	Lal	Gaz	Lal	Gaz	Lal	Gaz	Lal	Gaz	Lal
1st	5	7.03	6.4	8.5	8.01	6.5	7.1	10.1	7.1	9.6	10.3	9.7	10.7	15.7	13.5	16.2	18.5	29.4	27.7
2nd	5	10.03	8.5	12.5	9.01	10.2	7.8	10.7	10.8	10.5	10.7	14.4	15.3	16.3	15.9	25.5	22.1	33.5	30.5
3rd	5	12.07	11.1	15.9	9.2	13.7	11.7	19.7	16.7	17.7	16.1	22.1	19.1	17.5	20.5	28.7	25.7	30.1	35.1
4th	7	15.01	15.9	16.3	14.5	16.1	17.1	20.5	19.5	19.9	21.1	26.1	20.1	25.5	24.1	28.5	28.8	29.2	35.4
5th	7	18.02	18.2	15.7	15.7	16.7	17.4	22.2	21.1	24.7	23.7	27.4	22.2	29.8	234.7	32.4	28.7	-	-
6th	7	19.02	19.7	18.7	18.1	20.5	19.2	21.5	20.5	24.8	25.7	28.7	21.7	30.2	25.0	-	19.5	-	-
7th	10	21.01	21.5	23.8	23.1	24.7	19.2	25.9	23.6	24.7	26.1	20.1	23.7	-	18.4	-	-	-	-
8th	10	22.7	23.8	27.5	25.7	26.9	20.1	24.5	21.7	25.8	27.5	-	23.5	-	-	-	-	-	-
9th	10	25.4	20.2	28.0	26.7	28.9	20.4	-	17.0	-	-	-	-	-	-	-	-	-	-
10th	12	20.21	19.5	-	21.18	-	23.5	-	-	-	-	-	-	-	-	-	-	-	-
11th	12	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common irrigation for plant establish		29	31	29	31	29	31	29	31	29	31	29	31	29	31	29	31	29	31
Total		199.5	204.2	195.9	202.2	193.2	194.5	184.1	189	186.7	192.2	177.5	187.3	164.0	173.1	160.3	174.3	151.2	159.7

Results and Discussion

Plant height

The individual as well as the interaction effects of irrigation regimes and nitrogen doses were significant for plant height of onion (Table 3-5). Considering the main effect of irrigation treatment the tallest plants (49.6 cm in Gazipur and 50.6 cm in Lalmonirhat) was recorded in irrigation at 10% depletion of field capacity (I_1). The application of N fertilizer significantly increased the plant height. The tallest plant (48.6 cm in Gazipur and 49.8 cm in Lalmonirhat) was recorded from the application of 150 kg N ha^{-1} (N_1) which was statistically similar with plants supplied with 100 kg N ha^{-1} (N_2). Due to interaction effects of irrigation regimes and nitrogen levels the highest plant height (52.4 cm in Gazipur and 53.3 cm in Lalmonirhat) was recorded from plot subjected to irrigation at 10% depletion of field capacity and application of 100 kg N ha^{-1} (I_1N_2). The lowest plant height (37.3 cm in Gazipur and 39.7 cm in Lalmonirhat) was recorded under irrigation at 30% depletion of field capacity and application of 50 kg N ha^{-1} (I_3N_3). The plant height might have increased due to the optimum availability of soil moisture and nitrogen, which enhanced cell division and elongation of the plant to attain maximum growth. Similar results were reported by Tolossa, 2021 and Tsegaye *et al*., 2016.

Number of leaves per plant

The number of leaves per plant was significantly influenced by individual as well as the combined effects of irrigation regimes and nitrogen doses for onion (Table 3-5). Taking into account as main effect of irrigation treatment, the maximum number of leaves per plant (14.2 in Gazipuar and 12.1 in Lalmonirhat) was recorded from irrigation at 10% depletion of field capacity (I_1). The application of N fertilizer also significantly increased the number of leaves per plant. The maximum number of leaves per plant (14.0 in Gazipur and 12.3 in Lalmonirhat) was noted from the application of 150 kg N ha^{-1} (N_1). When irrigation and nitrogen were applied in combination, the maximum number of leaves per plant (16.7 in Gazipur and 13.3 in Lalmonirhat) was found with irrigation at 10% depletion of field capacity and 150 kg N ha^{-1} (I_1N_1), while the minimum number of leaves per plant (9.7 in Gazipur and 9.3 in Lalmonirhat) was recorded in irrigation at 30% depletion of field capacity and 75 kg N ha^{-1} application. Water stress and nitrogen deficiency might have inhibited leaf expansion, reduced the amount of solar radiation, hampered cell turgor pressure, reduced CO_2 and nutrient uptake, photosynthesis and other biochemical processes, which ultimately affected the growth and development of onion. The transpiration and gas exchange also become limited due to stomatal closure, when crop grown under moisture and nutrient stress conditions. This result is in agreement with the findings of Tolossa, 2021 and Walle *et al*., 2018.

Neck thickness

The individual as well as the interaction effects of irrigation regimes and nitrogen doses on the neck thickness of onion were found significant (Table 3-5). In case of the main effect of irrigation treatment, the maximum neck thickness (0.95 cm in Gazipur and 0.87 cm in Lalmonirhat) was observed from irrigation at 10% depletion of field capacity (I_1). For the mean effect of N, the maximum neck thickness of onion (0.91cm in Gazipur and 0.84 cm in Lalmonirhat) was recorded under the application of 150 kg N ha^{-1} (N_1). The maximum mean neck thickness (1.12 cm in Gazipur and 1.0 cm in Lalmonirhat) was found from the plant grown with irrigation at 10% field capacity and application of 150 kg N ha^{-1}. Thick necked onions cannot be stored for the long time because these may have less capability of storing assimilates as well as vulnerable to rotting due to attack of pathogen. The results are in line with the findings of Nurga *et al*., 2020.

Days to maturity

The maturity sign of onion bulb commences by drying and fall of leaves at the neck which is called “neck fall”. If the goal is to store the onions in *kharif* season, rolling down onion tops encourages the onion to turn brown and stop taking up water, thus boosting the final process of ripening. Days to maturity referred to the number of days required from transplanting to 80% of the plant in a plot shows yellowing of leaves and neck fall. Results revealed that the individual as well as the interaction effects of irrigation regimes and nitrogen were significant for days to maturity of onion (Table 3-5). Considering the main effect as irrigation treatment, the maximum days required to mature onion bulb was (87.7 days in Gazipur and 90.1 days in Lalmonirhat) when irrigation applied at 10% depletion of field capacity (I_1). Application of N fertilizer significantly increased days to maturity. The maximum days required to mature of onion bulb (87.3 days in Gazipur and 87.4 days in Lalmonirhat) was observed by the application of 150 kg N ha^{-1}(N_1). Onion plants supplied with N 150 kg ha^{-1} and irrigation at 10% depletion of field capacity (I_1N_1) required maximum (92.3 in Gazipur and 95.3 in Lalmonirhat) days to mature while irrigation at 30% depletion of field capacity and 75 kg N ha^{-1} to onion plants required minimum (75.7 in Gazipur and 77.0 in Lalamonirhat) days to maturity. The results are in agreement with the findings of various researches who revealed that frequent and too much application of irrigation and nitrogen promoted excessive vegetative growth and delayed maturity (Nurga *et al*., 2020 and Tsegaye *et al*., 2016).

Table 3. Effect of irrigation regimes on vegetative growth parameters of onion

Treatment	Plant height (cm)		No. of leaves plant^{-1}		Neck thickness (cm)		Days to maturity	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
I_1	49.6a	50.6a	14.2a	12.1a	0.95a	0.87a	87.7a	90.1a
I_2	46.3b	49.7a	11.9b	10.7b	0.81b	0.74b	82.4b	82.8b
I_3	41.9c	43.3b	10.9c	10.0b	0.65c	0.66c	79.6c	79.1c
CV (%)	3.82	6.89	6.12	9.32	14.61	9.70	2.12	1.39

Table 4. Effect of nitrogen levels on vegetative growth parameters of onion

Treatment	Plant height (cm)		No. of leaves plant^{-1}		Neck thickness (cm)		Days to maturity	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
N_1	48.6a	49.8a	14.0a	12.3a	0.91a	0.84a	87.3a	87.4a
N_2	47.5a	49.8a	12.4b	11.8a	0.80a	0.77a	82.4b	84.4b
N_3	41.4b	44.0b	10.6c	9.7b	0.69b	0.66b	79.3c	80.1c
CV (%)	3.82	6.89	6.12	9.32	14.61	9.70	2.12	1.39

Table 5. Interaction effects of irrigation regimes and nitrogen levels on vegetative growth parameters of onion

Treatment	Plant height (cm)		No. of leaves $plant^{-1}$		Neck thickness (cm)		Days to maturity	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
I_1 X N_1	52.2a	53.0a	16.7a	13.3a	1.12a	1.0a	92.3a	95.3a
I_1 X N_2	52.4a	53.3a	14.7b	12.7ab	0.94ab	0.89ab	86.3b	91.3b
I_1 X N_3	44.1d	45.3cd	11.3de	10.3cd	0.79bcd	0.73cd	84.3b	83.7cd
I_2 X N_1	48.7b	51.7ab	13.3c	11.7abc	0.92ab	0.81bc	86.0b	85.3c
I_2 X N_2	47.7bc	50.3abc	11.7de	11.0bcd	0.82bc	0.74cd	83.3b	83.3cd
I_2 X N_3	42.7d	47.0bc	10.7ef	9.3d	0.67cd	0.66de	78.0cd	79.7ef
I_3 X N_1	44.7cd	44.7cd	12.0d	10.3cd	0.70cd	0.71cde	83.7b	81.7de
I_3 X N_2	43.7d	45.3cd	11.0de	10.3cd	0.65cd	0.68de	79.3c	78.7fg
I_3 X N_3	37.3e	39.7d	9.7f	9.3d	0.60d	0.59e	75.7d	77.0g
CV (%)	3.82	6.89	6.12	9.32	14.61	9.70	2.12	1.39

Legend: Irrigation levels: I_1=irrigation at 10%, I_2=20% and I_3=30% depletion of field capacity

Nitrogen levels: N_1=150 kg ha^{-1}, N_2=100 kg ha^{-1} and N_3=75 kg ha^{-1}

Bulb size

Onion bulb size refers to the length and diameter of the bulb. However, individual as well as the interaction effects of irrigation regimes and nitrogen doses showed significant variation for bulb size (Table 6-8). In case of the main effect of irrigation treatment, the biggest bulb (4.9 cm x 4.7 cm in Gazipur and 5.1cm x 4.8 cm in Lalmonirhat) was obtained from irrigation at 20% depletion of field capacity (I_1). The application of N fertilizer significantly increased the bulb size of onion. For that case, the biggest sized onion bulb (4.9 cm x 4.9 cm in Gazipur and 5.1 cm x 5.0 cm in Lalmonirhat) was obtained from the application of 100 kg N ha^{-1} (N_2). The maximum mean bulb length and diameter (5.1 cm x 5.2 cm in Gazipur and 5.5 cm x 5.2 cm in Lalmonirhat) was obtained from application of irrigation at 10% field capacity and N 100 kg ha^{-1}, whereas further increase had no significant effect. This result is in agreement with Nurga *et al.* (2020) and Tsegaye *et al.* (2016), who reported that optimum combinations of N and irrigation enhance the formation of bulb.

Single bulb weight

The single bulb weight of onion was significantly influenced by individual and interaction effect of irrigation regimes and nitrogen levels (Table 6-8). For the main effect of irrigation, the maximum single bulb weight (51.6 g in Gazipur and 52.9 g in Lalmonirhat) was obtained from irrigation at 20% depletion of field capacity (I_2), which was statistically similar to irrigation at 10% depletion of field capacity (I_1). The application of N fertilizer significantly increased the single bulb weight of onion. The maximum single bulb weight (51.3 g in Gazipur and 53.8 g in Lalmonirhat) was recorded due to the application of 100 kg N ha^{-1} (N_2). Optimum combination of irrigation regimes and nitrogen levels increased single bulb weight but deficit irrigation and over dose of N caused reduction in single bulb weight. However, for interaction effect, the treatment I_1N_2 (irrigation at 10% depletion of field capacity and application of 100 kg N ha^{-1}) gave the highest single bulb weight (55.1 g in Gazipur and 56.7 g in Lalmonirhat). Soil moisture and nitrogen help to translocate photosynthates form leaves to bulbs which might have resulted in single bulb weight. Similar kind of result was reported by Fatideh and Asil, 2012.

Total soluble solids (TSS)

Effect of irrigation regimes and nitrogen doses and their interactions were found to be non-significant for total soluble solid (TSS ^{0}Brix) content in onion (Table 6-8). Highest TSS values (12.99^{0}Brix in Gazipur and 13.3^{0}Brix in Lalmonirhat) were noted by applying irrigation at 10% depletion of field capacity (I_1) followed by I_2 and the lowest (12.60 ^{0}Brix in Gazipur and 13.1 ^{0}Brix in Lalmonirhat) from that of irrigation at 30 % depletion of field capacity (I_3). For main effect of N, the maximum TSS of onion (12.70^{0}Brix and 13.3^{0}Brixin Gazipur and Lalmonirhat

Location, respectively) was observed by the application of 150 kg N ha^{-1} (N_1). For the interaction effect, the maximum mean TSS (12.83^{0}Brix in Gazipur and 13.4^{0}Brix in Lalmonirhat) of onion was obtained from irrigation at 10% field capacity with application of 150 kg N ha^{-1}. These findings revealed that TSS is more likely influenced by the environmental factors. The results are in agreement with the findings of Walle *et al*., 2018.

Total bulb yield

Total bulb yield of onion was significantly influenced by the individual as well as the interaction effects of irrigation regimes and nitrogen levels (Table 9-11). Considering the main effect of irrigation, the maximum bulb yield (19.84 t ha^{-1} in Gazipur and 21.17 t ha^{-1} in Lalmonirhat) was obtained from irrigation at 10% depletion of field capacity (I_1). However, the maximum bulb yield of onion (19.9 t ha^{-1} in Gazipur and 21.13 t ha^{-1} in Lalmonirhat) was observed from the application of 100 kg N ha^{-1} (N_2). The combined effect of irrigation at 10% depletion of field capacity and application of 100 kg N ha$^{–1}$ gave the highest total bulb yield of onion (21.49 t ha^{-1} in Gazipur and 22.79 t ha^{-1} in Lalmonirhat). The lowest total bulb yield (14.46 t ha^{-1} in Gazipur and 16.02 t ha^{-1} in Lalmonirhat) was recorded from irrigation at 30% depletion of field capacity and application of 75 kg N ha$^{–1}$. Optimum irrigation and nitrogen levels might have increased the rate of metabolism which resulted in more synthesis of carbohydrate, translocation of metabolites and proper functioning of phytohormones and ultimately increased total bulb yield of onion. These results are in close conformity with Tsegaye *et al.*, 2016 and Fatideh and Asil, 2012.

Marketable bulb yield

The individual effect as well as the interaction effects of irrigation regimes and nitrogen levels on the marketable bulb yield of onion were significant (Table 9-11). For the main effect of irrigation, the highest marketable bulb yield of onion (16.6 t ha^{-1} in Gazipur and 18.4 t ha^{-1} in Lalmonirhat) were recorded from irrigation at 10% depletion of field capacity, whereas the minimum from (12.1 t ha^{-1} in Gazipur and 14.9 t ha^{-1} in Lalmonirhat) from irrigation at 30% depletion field capacity. Considering the main effect of nitrogen levels, the maximum marketable bulb yield (16.1 t ha^{-1} in Gazipur and 18.6 t ha^{-1} in Lalmonirhat) was obtained from 100 kg N ha$^{–1}$ and the minimum (13.8 t ha^{-1} in Gazipur and 15.7 t ha^{-1} in Lalmonirhat) from 50 kg N ha^{-1}. However, for the interaction effect, treatment I_1N_2 (irrigated at 10% depletion of field capacity and application of 100 kg N ha$^{–1}$) gave the highest marketable bulb yield (18.0 t ha^{-1} in Gazipur and 20.0 t ha^{-1} in Lalmonirhat) and the minimum value (10.6 t ha^{-1} in Gazipur and 13.6 t ha^{-1} in Lalmonirhat) were obtained in treatment I_3N_3 (irrigation at 30% depletion of field capacity and application of 50 kg N ha$^{–1}$). Similar results are depicted by Nurga *et al.* (2020), Fatideh and Asil (2012) and Nasreen *et al.* (2007).

Table 6. Effect of irrigation regimes on yield parameters and TSS of onion

Treatment	Bulb length (cm)		Bulb diameter (cm)		Single bulb weight (g)		TSS(^{0}Brix)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
I_1	4.7a	4.7b	4.6a	4.7a	50.8a	52.0a	12.99	13.3
I_2	4.9a	5.1a	4.7a	4.8a	51.6a	52.9a	12.64	13.2
I_3	3.8b	4.4c	3.9b	4.4b	41.0b	46.6b	12.60	13.1
CV (%)	9.84	4.15	6.82	3.80	4.69	3.67	NS	NS

Table 7. Effect of nitrogen levels on yield parameters and TSS of onion

Treatment	Bulb length (cm)		Bulb diameter (cm)		Single bulb weight (g)		TSS(^{0}Brix)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
N_1	4.6a	4.7b	4.3b	4.5b	49.0b	50.4b	12.70	13.3
N_2	4.9a	5.1a	4.9a	5.0a	51.3a	53.8a	12.59	13.2
N_3	3.9b	4.4c	3.9c	4.4b	43.0c	47.2b	12.64	13.3
CV (%)	9.84	4.15	6.82	3.80	4.69	3.67	NS	NS

Table 8. Interaction effect of irrigation regimes and nitrogen levels on yield parameters and TSS of onion

Treatment	Bulb length (cm)		Bulb Diameter (cm)		Single bulb weight (g)		TSS(^{0}Brix)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
I_1 X N_1	5.1a	5.1b	4.4b	4.6b	55.0a	55.0ab	12.83	13.4
I_1 X N_2	5.1a	5.5a	5.2a	5.2a	55.1a	56.7a	12.70	13.4
I_1X N_3	4.4abc	4.6cd	4.4b	4.5bc	45.0cd	49.3de	12.60	13.1
I_2 X N_1	4.7ab	4.7bc	4.4b	4.7b	51.7ab	52.0bcd	12.63	13.2
I_2 X N_2	5.1a	5.1b	5.1a	5.1a	52.0a	52.7bc	12.67	13.3
I_2 X N_3	4.3bc	4.4de	4.2b	4.4bcd	48.0bc	49.0de	12.50	13.1
I_3 X N_1	3.9c	4.4cde	4.1b	4.3cd	43.3d	46.7e	12.63	13.2
I_3 X N_2	4.4abc	4.7bc	4.3b	4.7b	43.7d	49.7de	12.67	13.3
I_3 X N_3	3.0d	4.1e	3.2c	4.2d	36.0e	43.3f	12.57	13.1
CV (%)	9.48	4.15	6.82	3.80	4.69	3.67	NS	NS

Legend: Irrigation levels: I_1=irrigation at 10%, I_2=20% and I_3=30% depletion of field capacity

Nitrogen levels: N_1=150 kg ha^{-1}, N_2=100 kg ha^{-1} and N_3=75 kg ha^{-1}

Biomass yield

The single as well as the interaction effect of irrigation regimes and nitrogen levels were significant variation for biomass yield (Table 9-11). For the main effect of irrigation, the maximum biomass yield (2.82 t ha^{-1} in Gazipur and 3.40 t ha^{-1} in Lalmonirhat) were obtained from irrigation at 10% depletion of field capacity (I_1). Considering the main effect of nitrogen, the maximum biomass yield (2.78 t ha^{-1} and 3.22 t ha^{-1} in Gazipur and Lalmonirhat Location, respectively) was recorded from the application of 100 kg N ha^{-1} (N_2). The highest biomass yield of onion (3.01 t ha^{-1} in Gazipur and 3.29 t ha^{-1} in Lalmonirhat) was recorded in treatment I_1N_2. Water and nitrogen availability in the root zone, leads to enhance plant growth and development (Tolossa, 2021; Bangali, 2012 and Kumar *et al*., 2007).

Harvest Index

The individual as well as interaction effects of irrigation regimes and nitrogen levels on harvest index of onion are presented in Table 9-11. Considering the main effect of irrigation, the maximum (588.65% in Gazipur and 599.35% in Lalmonirhat) from irrigation at 10% depletion of field capacity and the minimum value (555.05% in Gazipur and 568.70% in Lalmonirhat) was obtained from irrigation at 30% depletion of field capacity. For the main effect of nitrogen, the maximum harvest index (579.14% in Gazipur and 741.0% in Lalmonirhat) from 100 kg N ha^{-1} and minimum value (558.7% in Gazipur and 644.19% in Lalmonirhat) was recorded from 50 kg N ha^{-1}. The interaction effect of irrigation at 10% depletion of field capacity along with 100kg Nha^{-1} gave the maximum harvest index (598.0% in Gazipur and 607.9% in Lalmonirhat) and the minimum (517.07% and 541.83% in Gazipur and Lalmonirhat location, respectively) were noted in I_3N_3.

Nitrogen content

Nitrogen content per plant was significantly influenced by individual and interaction effects of irrigation regimes and nitrogen levels. (Table 12-14). Considering the main effect of irrigation, the maximum N content per plant (2.62% in Gazipur and 2.69% in Lalmonirhat) was recorded from irrigation at 10% depletion of field capacity (I_1), being significantly higher over rest of the irrigation level. Application of nitrogen fertilizer significantly increased the nitrogen content in onion plant. The maximum N content per plant (2.56% in Gazipur and 2.66% in Lalmonirhat) was noted with the application of 150 kg N ha^{-1} (N_1). It was observed that irrigation at 10% depletion of field capacity and application of 100 kg N ha^{-1} contributed to the maximum nitrogen content in plant (2.76% in Gazipur and 2.87% in Lalmonirhat), which was statistically similar to I_1N_2 (2.71% in Gazipur and 2.78% in Lalmonirhat). The minimum N content (1.99% in Gazipur and 2.05% in Lalmonirhat) was noted in I_3N_3 (irrigation at 30% depletion of field capacity and application of 75kg Nha^{-1}).

Table 9. Effect of irrigation regimes on bulb yield, biomass yield and harvest index of onion

Treatment	Total bulb yield(tha^{-1})		Marketable yield (tha^{-1})		Biomass yield (tha^{-1})		Harvest index (%)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
I_1	19.84a	21.17a	16.6a	18.4a	2.82a	3.40a	588.65	599.35
I_2	18.68b	19.85b	16.1a	17.6a	2.81b	2.93b	572.95	588.63
I_3	15.99c	17.18c	12.1b	14.9b	2.18c	2.38c	555.05	568.70
CV (%)	6.09	7.84	5.93	7.31	7.22	11.25	-	-

Table 10. Effect of nitrogen levels on bulb yield, biomass yield and harvest index of onion

Treatment	Total bulb yield(tha^{-1})		Marketable yield (tha^{-1})		Biomass yield (tha^{-1})		Harvest index (%)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
N_1	18.56b	19.48b	14.9b	16.62b	2.58b	2.98a	577.52	644.19
N_2	19.90a	21.13a	16.1a	18.6a	2.78a	3.22a	579.14	741.04
N_3	16.06c	17.60c	13.8c	15.7b	2.47c	2.51b	558.7	716.89
CV (%)	6.09	7.84	5.93	7.31	7.22	11.25	-	-

Table 11. Interaction effect of irrigation regimes and nitrogen levels on bulb yield, biomass yield and harvest index of onion

Treatment	Total bulb yield(tha^{-1})		Marketable yield (tha^{-1})		Biomass yield (tha^{-1})		Harvest index (%)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
I_1 X N_1	20.61ab	21.66b	16.3bc	18.1abc	2.79c	3.03b	584.23	597.36
I_1 X N_2	21.49a	22.79a	18.0a	20.0a	3.01a	3.29a	598.0	607.9
I_1X N_3	17.41d	19.07d	15.4c	17.2bc	2.67f	2.89c	576.78	595.16
I_2 X N_1	19.23c	20.14c	15.9bc	17.0c	2.77d	2.91c	574.01	584.19
I_2 X N_2	20.52b	21.73b	17.1ab	19.3ab	3.0a	3.27a	570.0	590.21
I_2 X N_3	16.30e	17.70e	15.4c	16.4cd	2.68e	2.81d	574.63	583.63
I_3 X N_1	15.84e	16.63f	12.4d	14.7de	2.18h	2.59e	568.81	567.57
I_3 X N_2	17.69d	18.88d	13.2d	16.4cd	2.32g	2.76d	568.97	594.20
I_3 X N_3	14.46f	16.02f	10.6e	13.6e	2.05i	2.51f	517.07	541.83
CV (%)	6.09	7.84	5.93	7.31	7.22	11.25	-	-

Legend: Irrigation levels: I_1=irrigation at 10%, I_2=20% and I_3=30% depletion of field capacity

Nitrogen levels: N_1=150 kg ha^{-1}, N_2=100 kg ha^{-1} and N_3=75 kg ha^{-1}

Nitrogen uptake

Nitrogen uptake by onion plant was varied due to single and as well as combined application of irrigation and nitrogen (Table-12-14). Considering the sole effect of irrigation, the maximum nitrogen uptake (73.88 kg ha^{-1} in Gazipur and 82.58 kg ha^{-1} in Lalmonirhat) was observed with irrigation at 10% depletion of field capacity (I_1) and the minimum value (48.4 kg ha^{-1} in Gazipur and 61.05 kg ha^{-1} in Lalmonirhat) was found from irrigation at 30% depletion of field capacity (I_3). Application of nitrogen fertilizer also influenced the uptake of nitrogen. The maximum nitrogen uptake (69.78kg ha^{-1} in Gazipur and 65.51 kg ha^{-1} in Lalmonirhat) were observed from 100 kg N ha^{-1} (N_2) and the minimum (47.18 kg ha^{-1} in Gazipur and 49.93 kg ha^{-1} in Lalmonirhat) were observed from the lowest dose of 75 kg N ha^{-1}. The interaction effect of irrigation and nitrogen levels on N uptake of onion was also varied appreciably. The highest nitrogen uptake (81.57kg ha^{-1} in Gazipur and 91.46kg ha^{-1} in Lalmonirhat) was observed in I_1N_2 (irrigation at 10% depletion of field capacity and application of 100 kg Nha^{-1}). This corresponds to early findings of El-Hadidi *et al*. (2016) and Nasreen *et al.* (2007).

Nitrogen use efficiency

Nitrogen use efficiency of onion varied due to irrigation regimes and nitrogen levels (Table-12-14). Among the main effect of irrigation treatments, the maximum of nitrogen use efficiency (46.96% in Gazipur and 52.49% in Lalmonirhat) was recorded with irrigation at 10% depletion of field capacity (I_1) and the minimum (30.76% in Gazipur and 38.80% in Lalmonirhat) at 30% depletion of field capacity (I_3). On the other hand, the maximum nitrogen use efficiency (46.83% in Gazipur and 43.97% in Lalmonirhat) was observed by the application of 100 kg N ha^{-1} (N_2). The interaction effect of irrigation and N levels on N use efficiency of onion was considerable. The highest nitrogen use efficiency (54.74% in Gazipur and 61.38% in Lalmonirhat) was obtained from irrigation at 10% depletion of field capacity along with application of 100 kg Nha^{-1}(I_1N_2). Similar results on nitrogen use efficiency of onion were reported by Kumara *et al.* (2018) and Nasreen *et al.* (2007).

Table 12. Effect of irrigation regimes on nitrogen use efficiency of onion

Treatment	N content per plant (%)		N uptake ($kgha^{-1}$)		N use efficiency (%)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
I_1	2.62a	2.69a	73.88	82.58	46.96	52.49
I_2	2.44b	2.54b	68.56	75.95	43.58	48.27
I_3	2.22c	2.33c	48.40	61.05	30.76	38.80
CV (%)	2.46	4.78	-	-	-	-

Table 13. Effect of nitrogen levels on nitrogen use efficiency of onion

Treatment	N content per plant (%)		N uptake ($kgha^{-1}$)		N use efficiency (%)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
N_1	2.58a	2.66a	66.56	68.63	33.45	34.49
N_2	2.51b	2.61a	69.78	65.51	46.83	43.97
N_3	1.91c	2.28b	47.18	49.93	38.05	40.27
CV (%)	2.46	4.78	-	-	-	-

Table 14. Interaction effect of irrigation regimes and nitrogen levels on nitrogen use efficiency of onion

Treatment	N content per plant (%)		N uptake ($kgha^{-1}$)		N use efficiency (%)	
	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat	Gazipur	Lalmonirhat
I_1 X N_1	2.76a	2.87a	77.0	86.96	38.69	43.69
I_1 X N_2	2.71ab	2.78ab	81.57	91.46	54.74	61.38
I_1X N_3	2.39d	2.41d	63.81	69.65	51.46	56.17
I_2 X N_1	2.61bc	2.63bc	72.30	76.53	36.33	38.46
I_2 X N_2	2.53c	2.62bc	75.90	85.67	50.94	57.49
I_2 X N_3	2.19e	2.38d	58.69	66.88	47.33	53.94
I_3 X N_1	2.38d	2.50cd	51.88	64.75	26.07	32.54
I_3 X N_2	2.29d	2.44cd	53.13	67.34	35.66	45.19
I_3 X N_3	1.99f	2.05e	40.80	51.46	32.90	41.50
CV (%)	2.46	4.78	-	-	-	-

Legend: Irrigation levels: I_1=irrigation at 10%, I_2=20% and I_3=30% depletion of field capacity

Nitrogen levels: N_1=150 kg ha^{-1}, N_2=100 kg ha^{-1} and N_3=75 kg ha^{-1}

Storability

Onion is a non-climacteric perishable crops producing low endogenous ethylene during storage and encounters 35-40% post-harvest losses during storage owing to decay, sprouting and physiological weight loss (Anbukkarasi *et al.*, 2013). The storability of onion depends on variety, bulb size, shape with content of TSS, maturity at harvest, production technologies, storage condition and climatic condition. The physiological loss of weight (PLW) of onion was increased both with water deficit and nitrogen deficiency conditions up to 120 days of storage (Fig. 1 & 2). Total PLW was higher (16.3% in Gazipur and 21.1% in Lalmonirhat) for I_1N_1 (irrigation at 10% depletion of field capacity and application of 150 kg N ha^{-1}) during 120 days of storage. On the other hand, the minimum storage loss (11.8% in Gazipur and 15% in Lalmonirhat) was recorded from I_2N_2 (irrigation at

20% depletion of field capacity and application of 100 kg Nha^{-1}) during 120 days of storage. Onion grown under higher soil moisture regimes and higher nitrogen levels usually produced bigger bulb and tends to loss more weight and increase susceptibility to diseases and early sprouting during storage. On the other hands, onion grown under lower soil moisture and lower nitrogen level produced smaller sized bulb and less physiological weight loss to keep well during the 120 days storage period than onion grown under optimum soil moisture (Irrigation at 20% depletion of field capacity) and nitrogen levels (100 kg N ha^{-1}). Irrigation should be stopped before 15-20 days before attaining maturity to improve the keeping quality of bulbs. Similar results were reported by Kumar *et al.* (2007); Fatideh and Asil (2012).

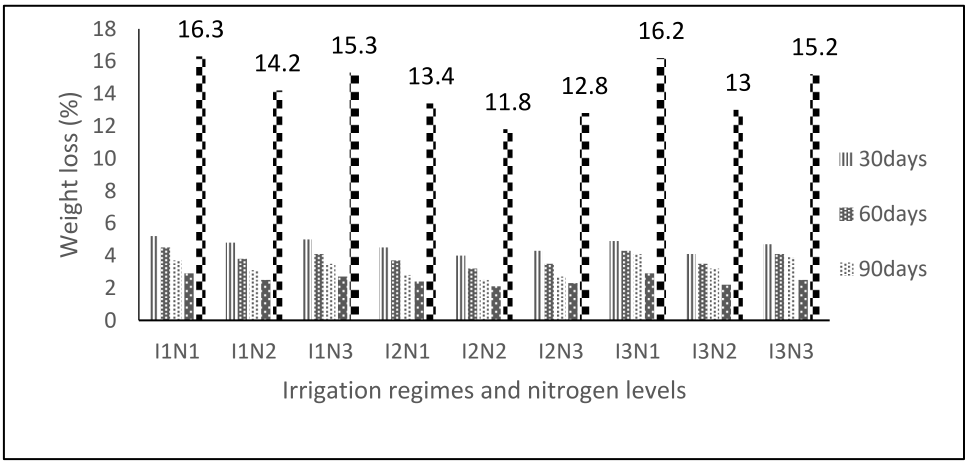

Fig. 1. Effect of irrigation and nitrogen levels on storability of onion at Gazipur.

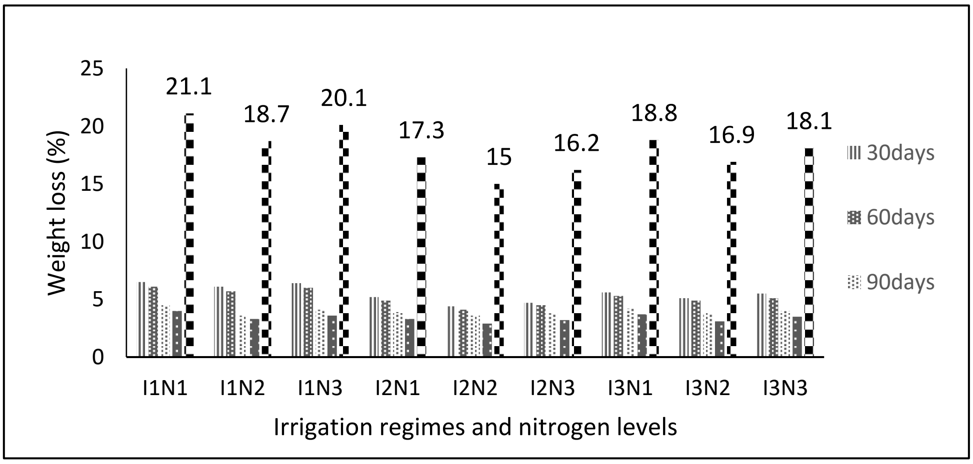

Fig. 2. Effect of irrigation and nitrogen levels on storability of onion at Lalmonirhat.

Table 15a. Total amount of irrigation water, soil moisture contribution and effective rainfall of onion affected by irrigation regimes and nitrogen levels

Treatment	Common irrigation (mm)		No. of irrigation		Amount of imposed irrigation water (mm)		Total amount of irrigation (mm)		Soil moisture contribution (mm)		Effective rainfall (mm)	
	A		-		B		C= A+B		D		E	
	Gazi	Lalmoni	Gazi	Lalmoni	Gazi	Lalmoni	Gazi	Lalmoni	Gazi	Lalmoni	Gazi	Lalmoni
I_1 X N_1	29.0	31.0	10	11	170.5	173.2	199.5	204.2	6.8	7.9	0	0
I_1 X N_2	29.0	31.0	9	10	166.9	171.2	195.9	202.2	7.3	8.7	0	0
I_1X N_3	29.0	31.0	9	10	164.2	163.5	193.2	194.5	8.7	10.5	0	0
I_2 X N_1	29.0	31.0	8	9	155.1	158.0	184.1	189.0	10.2	12.5	0	0
I_2 X N_2	29.0	31.0	8	8	157.7	161.2	186.7	192.2	12.9	12.6	0	0
I_2 X N_3	29.0	31.0	7	8	148.5	156.3	177.5	187.3	13.2	13.7	0	0
I_3 X N_1	29.0	31.0	6	7	135.0	142.1	164.0	173.1	13.7	13.7	0	0
I_3 X N_2	29.0	31.0	5	6	131.3	143.3	160.3	174.3	14.9	14.5	0	0
I_3 X N_3	29.0	31.0	4	4	122.2	128.7	151.2	159.7	15.2	14.9	0	0

Table 15b. Total consumptive use of irrigation water, water use efficiency of onion affected by irrigation regimes and nitrogen levels

Treatment	Total consumptive use of water (mm)		Water use efficiency (kg $ha^{-1}mm^{-1}$)	
	F = C + D + E		Total bulb yield / F	
	Gazipur	Lalamonirhat	Gazipur	Lalamonirhat
I_1 X N_1	206.3	212.1	99.90	102.12
I_1 X N_2	203.2	210.9	105.76	108.06
I_1X N_3	201.9	205.0	86.23	93.68
I_2 X N_1	194.3	201.5	98.97	99.95
I_2 X N_2	199.6	204.8	102.81	106.1
I_2 X N_3	190.7	201.0	85.47	88.06
I_3 X N_1	177.8	186.8	89.09	89.03
I_3 X N_2	175.2	188.8	100.97	100.0
I_3 X N_3	166.4	174.6	86.89	91.75

Legend: Irrigation levels: I_1=irrigation at 10%, I_2=20% and I_3=30% depletion of field capacity

Nitrogen levels: N_1=150 kg ha^{-1}, N_2=100 kg ha^{-1} and N_3=75 kg ha^{-1}

Consumptive use of water and water use efficiency

Irrigation water is the most crucial factor for onion cultivation. Bulb yield reduction should be compensated by maximizing water use efficiency. The effect of irrigation regimes and N levels on soil moisture contribution, total consumptive use of water and water use efficiency of onion was shown in Table 15a and Table 15b. The soil moisture contribution was the maximum in treatment I_3N_3 (15.2 mm in Gazipur and 14.9 mm in Lalmonirhat) and the minimum in I_1N_1 (6.8 mm in Gazipur and 7.9 mm in Lalmonirhat). The maximum consumptive use of water was noted in treatment I_1N_1 (206.3 mm in Gazipur and 212.1mm in Lalmonirhat). The minimum value was mentioned in treatment I_3N_3 (166.4 mm in Gazipur and 174.6 mm in Lalmonirhat). The maximum water use efficiency (105.76 kg ha^{-1} mm^{-1} in Gazipur and 108.06 kg ha^{-1} mm^{-1} in Lalmonirhat) was found in treatment I_1N_2 in both the locations. The results of these studies were in harmony to the findings of Tsegaye *et al*., 2016.

Conclusion

Onion was found responsive to both irrigation regimes and nitrogen doses. Both deficient water and nitrogen deficiency reduce bulb yield, biological yield, days to maturity, nitrogen uptake, nitrogen use efficiency, water productivity and storability of onion. Application of irrigation at 10% depletion of soil moisture over field capacity and 100 kg N ha^{-1} may be suitable for onion cultivation in the soils under AEZ-3 (Tista Meander Floodplain) and AEZ-28 (Madhupur Tract) in Bangladesh.

References

Anbukkarasi, V., P. Paramaguru, L. Pugalendhi, N. Ragupathi and P. Jeyakumar. 2013. Studies on pre and post-harvest treatments for extending shelf life in onion – A review. *Agric. Rev.* **(34)4:** 256-268.

Bangali, A.N., H.B. Patil, V.P. Chimmad, P.L. Patil and R.V. Patil. 2012. Effect of inorganics and organics on growth and yield of onion (*Allium cepa* L.). *Karnataka J. Agril. Sci.* **25(1):** 112-115.

Bangladesh Bureau of Statistics (BBS). 2021. Year book of Agricultural Statistics-2020. Ministry of Planning. Bangladesh.

El-Hadidi, E.M., M.M. El-Shazly and H.M.M. Hegazy. 2016. Effect of N, P and Cu fertilization on onion yield, quality and nutrients uptake. *J. Soil Sci Agric. Eng. Mansoura Univ.* **7(2):** 231-236.

Fatideh, M.M. and M.H. Asil. 2012. Onion yield, quality and storability as affected with different soil moisture and nitrogen regimes. *South West J. Hort. Bio. Environ.* **3(2):** 145-165.

Gebregwergis, F., K. Weldetsadik, Y. Alemayhu. 2016. Effect of irrigation depth and nitrogen levels on growth and bulb yield of onion (*Allium cepa* L.) at Alage, Central Rift valley of Ethiopia. *Intl. J. Res. Irri. Eng. Water Man.* **1(1):** 1–11.

Kumar, S., M. Imtiyaz, A. Kumar, R. Singh. 2007. Response of onion (*Allium cepa* L.) to different levels of irrigation water. *Agril. Water Manage*. **88:** 161-166.

Kumara, B.R., C.P. Mansur, S. Meti, S.L. Jagadeesh, G. Chander, S.P. Wani, R.K. Mesta, D. Satish, B. Allolli and S. Reddy. 2018. Potassium levels, sources and time of application on nutrient uptake and nutrient use efficiency of onion *(Aluum cepa* L). *Int. J. Curr. Microbiol. App. Sci.* **7(7):** 4214-4225.

Nasreen, S., M.M. Haque, M.A. Hossain and A.T.M. Farid. 2007. Nutrient uptake and yield of onion as influenced by nitrogen and sulfur fertilization. *Bangladesh J. Agri. Res.* **32**: 413-420.

Nurga, Y., Y. Alemayehu and F. Abegaz. 2020. Effect of deficit irrigation levels at different growth stages on yield and water productivity of onion (*Allium cepa* L.) at Raya Azebo Woreda, Northern Ethiopia. *Ethiop. J. Agric. Sci.* **30(3):** 155-176.

Tolossa T.T. 2021. Onion yield response to irrigation level during low and high sensitive growth stages and bulb quality under semi- arid climate conditions of Western Ethiopia, *Cogent Food Agric.* **7:** 1-25.

Tsegaye, B., T. Bizuayehu, A. Woldemichael and A. Mohammed. 2016. Yield and yield components of onion (*Allium cepa* L.) as affected by irrigation scheduling and nitrogen fertilization at Hawassa area Districts in Southern Ethiopia. *J. Medic. Bio. Sci. Res.* **2(2):** 15-20.

Walle, T., N. Dechassa and W.T. Kebede. 2018. Yield and yield components of onion (*Allium cepa* var. *cepa*) cultivars as influenced by population density at Bir Sheleko, North-Western Ethiopia. *Acda. Res. J. Agril. Sci. Res.* **6(3):** 172-192.

Yousuf, M.N., S. Akter, M.I. Haque, N. Mohammad and M.S. Zaman. 2013. Compositional nutrient diagnosis (CND) of onion (*Allium cepa* L.). *Bangladesh J. Agril. Res*. **38(2):** 271-287.

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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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