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GROWTH AND DRY MATTER PARTITIONING IN SELECTED SOYBEAN (*Glycine max* L.) GENOTYPES

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Abstract

The experiment was conducted at the experimental site of Agronomy Department, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur during the period from January to June 2011 to evaluate twenty selected soybean genotypes in respect of growth, dry matter production and yield. Genotypic variations in plant height, leaf area index, dry matter and its distribution, crop growth rate and seed yield were observed. The plant height ranged from 40.33 to 63.17 cm, leaf area index varied from 3.01 to 8.13 at 75 days after emergence, total dry matter ranged from 12.25 to 24.71 g per plant at 90 days after emergence (DAE). The seed yield ranged from 1745 to 3640 kg per hectare. The genotypes BGM 02093, BD 2329, BD 2340, BD 2336, Galarsum, BD 2331 and G00015 yielded 3825, 3447, 3573, 3737, 3115, 3542 and 3762 kg per hectare, respectively and gave higher than others contributed by higher crop growth rate with maximum number of filled pods. Seed yield of soybean was positively related to total dry matter at 45 DAE (Y = 632.19 + 659.31X, R^2= 0.46) and 60 DAE (Y= 95.335 + 405.53X, R^2 = 0.48). The filled pods per plant had good relationship with seed yield (Y = 1397 + 41.85X, R^2 = 0.41) than other components.

Keywords: Growth, dry matter, soybean, seed yield.

Introduction

Soybean (*Glycine max* L.) is one of the most nutritious crops (*Yaklich et al*., 2002) and widely used for both food and feed purpose. Its seed contain 42-45% protein and 22% edible oil (Mondal *et al*., 2001). Moreover, it contains minerals such as Fe, Cu, Mn, Ca, Mg, Zn, Co, P and K. Vitamins B1, B2, B6 and isoflavones are also available in soybean grains (Messina, 1997). Soybean oil is rich in polyunsaturated fatty acids, including the two essential fatty acids (linoleic and linolenic). In Bangladesh, human consumption of soybean is very little. Recently, soybean has become an important crop in Bangladesh for its increasing demand as an ingredient of poultry and fish meal. Therefore, a huge amount of soybean is imported every year. Soybean has become one of the stable and economic kharif crops in greater Noakhali areas of Bangladesh, but the yield is lower. Availability of high yielding and stable genotype of soybean suitable for

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different agro-climatic regions is one of the major constraints of soybean cultivation in Bangladesh. The yield of a crop is related to its various agronomic traits such as growth, development and photo synthetically active leaf area. Differences in dry matter accumulation and their distribution in different plant parts are the important determinants for selecting high yielding genotypes (Hossain and Khan, 2003). The crop growth largely depends on genetical inheritance and prevailing environment. This study was therefore, undertaken with 20 genotypes of soybean to observe the genotypic performance in respect of growth, dry matter partitioning and seed yield.

Materials and Method

The experiment was conducted at the research field of the department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh during the period from January to June, 2011. Twenty soybean genotypes viz. BARI Soybean-5 (check), BARI Soybean-6 (check), G00342, BD 2338, BD 2355, BD 2329, BD 2340, BD 2342, AGS 95, G00056, AGS 129, BD 2336, BGH 02026, BGM 02093, Galarsum, BD 2350, G00084, BD 2331, G00003 and G00015 were tested. These genotypes were selected based on their better performance in agronomic traits as observed in previous study (Khan, 2013). The experiment was laid out in a RCB design with three replications. The unit plot size was 2.4 m x 2.5 m. The soil was silty clay in texture with pH of 6.5. The seeds were sown on 12 January 2011 with 30 cm apart lines maintaining 5 cm plant to plant distances. Fertilizers were applied at the rate of 28-30-60-18 kg/ha of NPKS in the form of urea, TSP, MoP and Gypsum, respectively (FRG, 2005). Half of urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining half of urea was top dressed at flowering stage followed by irrigation. A light irrigation was done on the soil for uniform emergence. Additional three irrigations were given to the crop at trifoliate vegetative (V_3), beginning bloom (R_1) and full pod stage (R_4). Admire 200SL @ 1 ml/liter of water was sprayed at 10 and 25 DAE to control Jassids and white flies. Belt 4g/liter of water and Ripcord 10 EC @ 1 ml/liter of water was sprayed at 45 and 60 DAE, respectively to control leaf roller and pod borer. Five plants were collected from each plot at 15 days interval for different growth parameters like leaf area, total dry matter (TDM) and crop growth rate (CGR). Plants were cut at base and separated into stem, petiole, leaves and reproductive part. Then the leaf area was measured by an automatic leaf area meter (LI 3100 C, LI-COR, USA). The plant samples were oven dried at 70º C to a constant weight to measure dry matter of different plant parts. CGR was calculated using the following equation (Radford, 1967): CGR (g /m^2 /day^1) = (DW_2 – DW_1) / (t_2-t_1), where, DW_1 and DW_2 are the dry matter of the crop from unit ground area (g /m^2) collected at different days t_1 and t_2 ($t_2 > t_1$), respectively. The crop was harvested from 3 May to 14 May, 2011. Yield contributing characters were recorded from linearly collected 5 plants and yield were recorded from an area of one square meter. Data were analyzed and means were compared using Least Significant Difference (LSD).

Results and Discussion

Plant height

Plant height of different soybean genotypes varied appreciably over time (Fig. 1). Plant height increased slowly till 30 DAE and rapidly thereafter. Difference in plant height was apparent across the genotypes at different growth stages. The tallest plant was observed in genotype BD 2336 (63.17 cm) at 90 DAE which was identical with the height of BGM 02093 (61.00 cm) and followed by BD 2355 (58.50 cm) and BGH 02026 (58.33 cm). These genotypes also maintained increasing trend of height up to 90 DAE. The shortest plant was recorded in BARI Soybean-5 (40.33 cm) irrespective of growth stages. Rasaily *et al.,* (1986) and Ghatge and Kadu (1993) reported high variability in plant height of soybean varieties. Aduloju *et al.,* (2009) reported significant influenced in plant height by the genotypes.

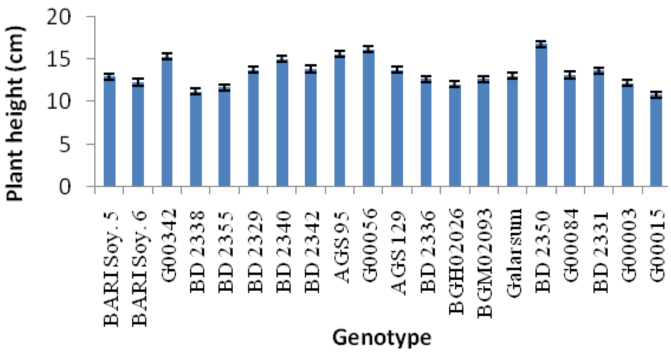


Fig.1a. Plant height of soybean genotypes at 30 DAE.

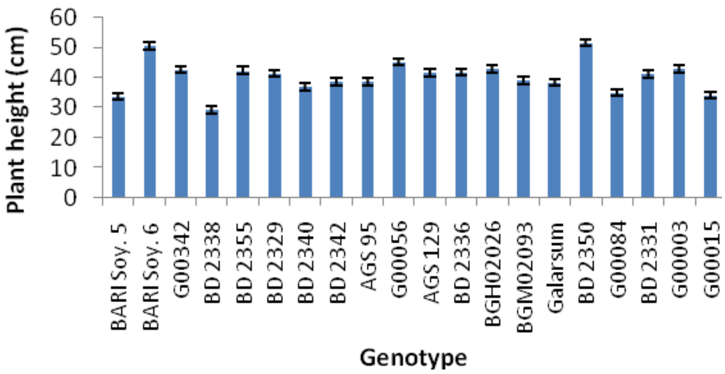


Fig.1b. Plant height of soybean genotypes at 60 DAE

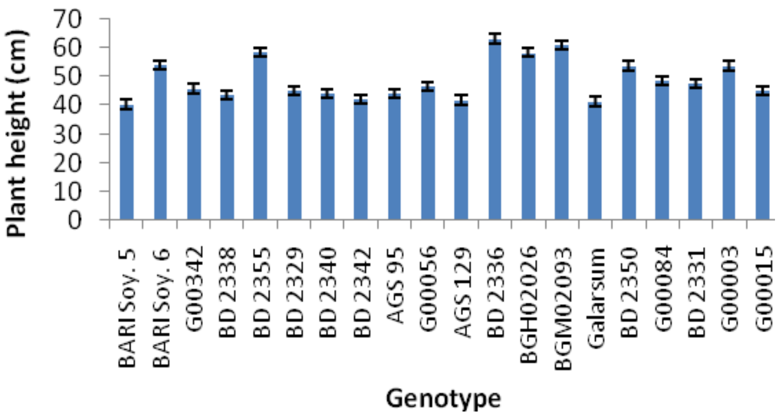


Fig.1c. Plant height of soybean genotypes at 90 DAE.

Leaf area index

Leaf area index (LAI) increased sharply from 30 DAE and reached maximum at 75 DAE and then declined sharply (Table 1). The decrease in leaf area index at later period may be attributed to the onset and senescence of the leaves. Among the genotypes, BGM02093 (4.22) showed maximum leaf area index at 45 DAE (blooming stage) followed by the index of genotypes BARI Soybean-6 (4.12), BD 2355 (3.70), BD 2329 (3.51), BD 2340 (4.21), G00056 (4.19), AGS 129 (3.64), Galarsum (4.21), BD 2331 (3.73) and G00003 (3.51). The increased leaf area index in soybean genotypes might be due to higher number of leaves per plant. The lowest leaf area index was obtained from BD 2342 (3.01) at 45 DAE. Board and Harville (1992) reported that attaining LAI of 3.5 to 4.0 by blooming stage (R_1) is necessary to optimize yield.

Total dry matter

Total dry matter (TDM) production of soybean genotypes increased progressively over time (Table 2). However, the total dry matter accumulation varied depending on genotypes and the stage of growth. The TDM production rate was minimum up to 45 DAE, and then increased sharply. At 90 DAE, the maximum TDM was recorded in G00015 (24.71 g /plant) followed by the TDM of genotypes BARI Soybean-6 (18.43 g/ plant), G00342 (18.28 g/ plant), BD 2338 (18.22 g/ plant), BD 2340 (16.34 g/ plant), BD 2331 (16.12 g/ plant) and G00003 (16.57 g/ plant). The lowest TDM was recorded in Galarsum (12.25 g/ plant) at 90 DAE. Hossain *et al.*, (2004) reported that soybean genotypes were varied in total dry matter production and seed yield. The seed yield was positively correlated with total dry matter production.

Table 1. Leaf area index of soybean genotypes at different days after emergence (DAE).

Genotype	Leaf area index					
	15 DAE	30 DAE	45 DAE	60 DAE	75 DAE	90 DAE
BARI Soybean-5	0.08	0.46	1.94	2.34	4.44	2.41
BARI Soybean-6	0.10	0.57	4.12	4.20	4.94	1.86
G00342	0.14	0.77	3.27	3.52	7.12	2.61
BD 2338	0.05	0.53	3.07	3.35	9.29	5.30
BD 2355	0.14	0.71	3.70	4.04	6.77	5.85
BD 2329	0.07	0.67	3.51	3.71	3.96	1.77
BD 2340	0.09	0.80	4.21	4.37	4.25	2.84
BD 2342	0.08	0.65	2.77	2.87	3.01	0.61
AGS 95	0.10	0.81	2.64	2.95	3.43	2.17
G00056	0.14	0.72	4.19	4.52	4.35	0.83
AGS 129	0.09	0.76	3.64	3.89	5.12	2.00
BD 2336	0.09	0.57	3.04	3.31	4.93	2.57
BGH02026	0.08	0.69	3.34	4.62	5.98	1.50
BGM02093	0.09	0.69	4.22	4.76	5.88	1.30
Galarsum	0.10	0.71	4.21	4.60	4.15	2.14
BD 2350	0.13	0.60	3.09	4.83	4.34	4.31
G00084	0.10	0.75	3.55	3.93	3.75	2.47
BD 2331	0.10	0.93	3.73	4.93	5.01	2.21
G00003	0.14	0.48	3.51	5.92	8.13	5.38
G00015	0.12	0.53	3.20	3.56	5.23	5.56
SE (±)	0.01	0.03	0.14	0.19	0.36	0.36
Mean	0.10	0.67	3.40	4.01	5.20	2.78

Total dry matter and their distribution in percent

Total dry matter and their distribution (%) of the plant of the respective soybean genotypes at 90 DAE is presented in Table 3. The genotypes varied according to their dry matter distribution (%) in different plant parts. Though the genotypes BARI Soybean-6, G00342, BD 2338, BD 2340, BD 2331, G00003 and G00015 produced maximum dry matter, BARI Soybean-6 distributed 21.66% in stem, 4.83% in petiole, 9.24% in leaf blade and 64.27% in pods; G00342 distributed 19.04% in stem, 2.86% in petiole, 10.29% in leaf blade and 67.81% in pods; BD 2338 distributed 17.27% in stem, 6.57% in petiole, 22.01% in leaf blade and

54.06% in pods; BD 2334 distributed 15.56% in stem, 5.34% in petiole, 14.75% in leaf blade and 64.35% in pods; BD 2331 distributed 20.915 in stem, 4.14% in petiole, 11.84% in leaf blade and 63.11% in pods; G00003 distributed 21.50% in stem, 6.9% in petiole, 18.75% in leaf blade and 52.85% in pods; G00015 distributed 16.21% in stem, 7.03% in petiole, 21.54% in leaf blade and 55.22% in pods. Among the genotypes, G00056 distributed the highest dry matter in pods (69.50%) with lowest in petiole (1.99%) and leaf blade (5.25%). Varietal differences in dry matter accumulation with their partitioning in mustard are in agreement with Khan *et al.*, (2006).

Table 2. Total dry matter production of soybean genotypes at different days after emergence (DAE).

Genotype	Total dry matter (g/plant)					
	15 DAE	30 DAE	45 DAE	60 DAE	75 DAE	90 DAE
BARI Soybean-5	0.10	0.53	2.30	4.66	14.89	15.20
BARI Soybean-6	0.13	0.67	3.56	7.37	18.21	18.43
G00342	0.18	0.86	3.46	6.37	17.87	18.28
BD 2338	0.07	0.58	2.40	6.49	18.14	18.22
BD 2355	0.17	0.79	3.21	6.21	11.58	15.02
BD 2329	0.10	0.61	3.27	6.62	11.86	15.21
BD 2340	0.13	0.89	4.03	7.19	12.27	16.34
BD 2342	0.10	0.72	3.18	6.57	9.38	12.56
AGS 95	0.13	0.66	2.91	5.88	11.41	13.23
G00056	0.18	0.85	4.10	7.95	13.73	14.52
AGS 129	0.13	0.72	3.93	7.61	13.58	13.77
BD 2336	0.12	0.64	4.05	7.75	14.23	14.72
BGH02026	0.10	0.59	4.05	7.81	12.61	13.34
BGM02093	0.11	0.76	4.30	8.48	13.67	14.12
Galarsum	0.12	0.68	3.90	8.31	11.84	12.25
BD 2350	0.17	0.76	3.77	7.16	12.01	13.12
G00084	0.17	1.45	4.01	6.87	12.45	13.69
BD 2331	0.13	0.79	4.06	8.08	14.48	16.12
G00003	0.17	0.53	2.80	6.65	13.64	16.57
G00015	0.16	0.60	4.31	8.88	18.32	24.71
SE (±)	0.01	0.04	0.14	0.23	0.57	0.64
Mean	0.13	0.73	3.58	7.15	13.81	15.47

Table 3. Total dry matter and their distribution in different plant parts at 90 days after emergence of soybean genotypes.

Genotypes	Stem (%)	Petiole (%)	Leaf blade (%)	Pods (%)	TDM (g/plant)
BARI Soybean-5	18.15	4.71	15.98	61.15	15.20
BARI Soybean-6	21.66	4.83	9.24	64.27	18.43
G00342	19.04	2.86	10.29	67.81	18.28
BD 2338	17.27	6.57	22.10	54.06	18.22
BD 2355	20.04	7.72	27.10	45.13	15.02
BD 2329	17.89	3.83	11.15	67.13	15.21
BD 2340	15.56	5.34	14.75	64.35	16.34
BD 2342	24.65	2.65	6.45	66.25	12.56
AGS 95	18.27	4.76	17.34	59.63	13.23
G00056	23.26	1.99	5.25	69.50	14.52
AGS 129	22.71	4.22	14.36	58.71	13.77
BD 2336	22.55	4.84	13.43	59.18	14.72
BGH02026	26.83	3.11	7.81	62.25	13.34
BGM02093	24.70	2.55	6.19	66.56	14.12
Galarsum	23.80	4.42	15.47	56.31	12.25
BD 2350	17.87	4.87	19.88	57.39	13.12
G00084	25.03	6.02	18.75	50.20	13.69
BD 2331	20.91	4.14	11.84	63.11	16.12
G00003	21.50	6.90	18.75	52.85	16.57
G00015	16.21	7.03	21.54	55.22	24.71
SE(±)	0.73	0.36	1.33	1.44	0.64
Mean	20.90	4.67	14.38	60.05	15.47

Crop growth rate (CGR)

Crop growth rate of the soybean genotypes varied appreciably over the time (Fig. 2). At early stages, CGR was very slow till 30 DAE and thereafter increased rapidly and the differences among the soybean genotypes persisted throughout the growth period. Regardless of genotypes, CGR reached peak at 75 DAE and thereafter declined in all genotypes. Maximum utilization of environmental resources reached the plant at maximum CGR at the reproductive phase. After 75 DAE natural senescence of leaves might have tended to decline in CGR. At 45 DAE, CGR was maximum in genotype G00015 (16.51 $g/m^2/day$) which was at par in BGM02093 (15.74 $g/m^2/day$) and followed by the growth rate of genotypes BD 2336 (15.17 g/m^2/day), BD 2326 (15.36 g/m^2/day) and BD 2331(14.57 g/m^2/day). At 75 DAE it reached the highest in genotype BD 2338 (51.78 g/m^2/day) which was at par with genotypes G00342 (51.11 g/m^2/day) and BARI Soybean-6 (48.19 g/m^2/day). At 90 DAE, the maximum CGR was recorded in genotype G00015 (28.40 g/m^2/day) followed by genotypes BD 2340 (18.10 g/m^2/day), BD 2355 (15.27 g/m^2/day), BD 2329 (14.89 g/m^2/day) and BD 2342 (14.13 g/m^2/day) genotypes.

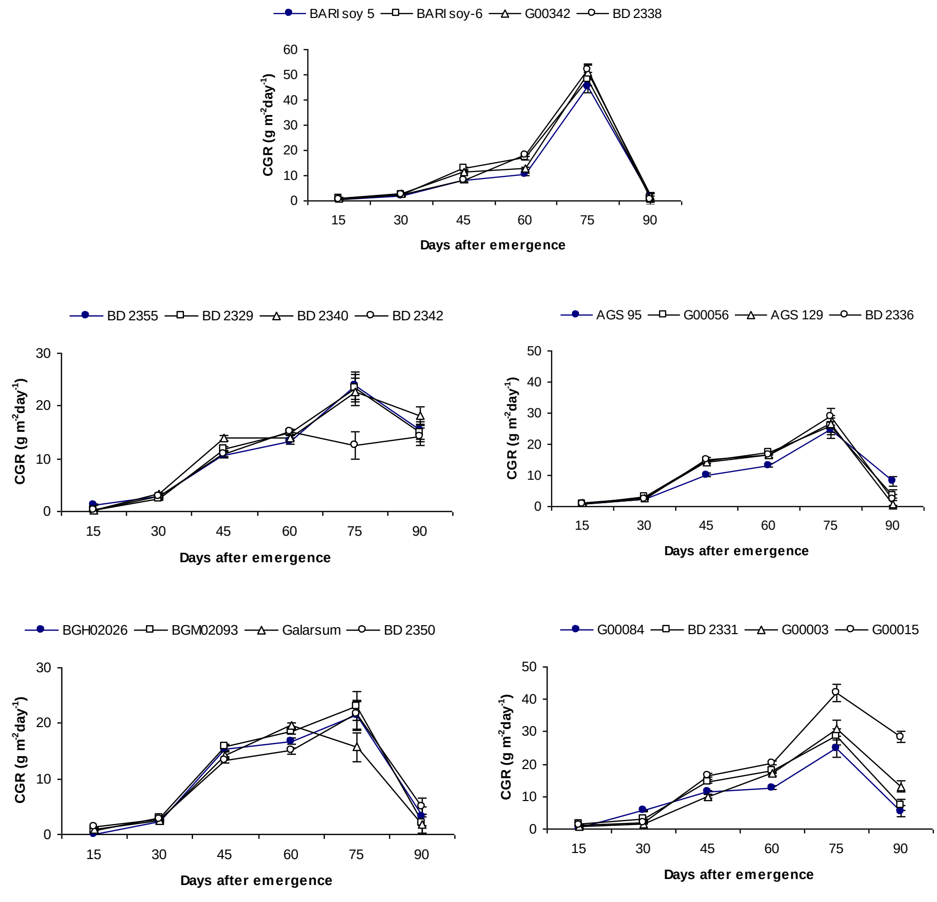


Fig. 2. Crop growth rate (CGR) of soybean genotypes at different growth stages.

Yield and yield attributes

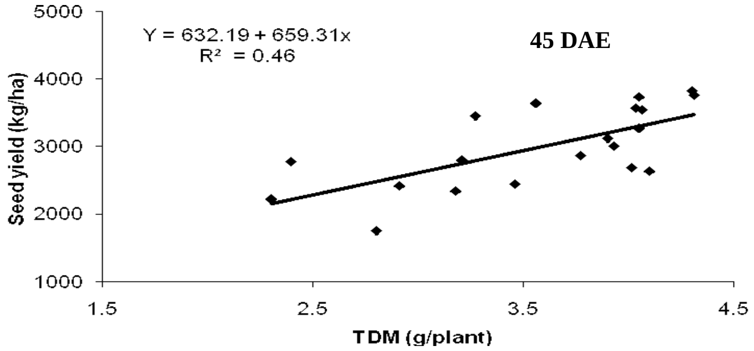
Plant population /m^2, plant height, number of branches per plant, filled pods per plant, unfilled pods per plant, 100-seed weight and seed yield of soybean showed significant variations across the genotypes (Table 4). The maximum plant population was obtained in genotype BD 2329 (67.6 /m^2) and it was statistically identical with the population of genotypes BARI Soybean-5 (63.6 /m^2), BARI Soybean 6 (64.0 /m^2), G00342 (63.9 /m^2), BD 2355 (66.4 /m^2), BD 2340 (66.4 /m^2), BD 2342 (59.8 /m^2), AGS 95 (67.3 /m^2), G00056 (61.1 /m^2), AGS 129 (66.7 /m^2), BD 2336 (61.3 /m^2), BGH02026 (58.4 /m^2), BGM02093 (62.9 /m^2), Galarsum (60.2 /m^2), BD 2350 (62.5 /m^2), BD 2331 (65.1 /m^2), G00003 (60.1 /m^2) and G00015 (60.4/m^2). The lowest population was recorded in genotype G00084 (50.7 /m^2). The tallest plant was obtained from genotype BD 2336 (63.17 cm) which was statistically identical with genotypes BD 2355 (58.50 cm), BGH02026 (58.33 cm), BGM02093 (61.00 cm). The shortest plant was obtained in BARI Soybean-5 (40.33 cm). Significantly the highest number of branches was recorded in BD 2350 (6.7 /plant) which was at par with genotypes BARI Soybean-6 (4.7 /plant), G00342 (5.0 /plant), BD 2338 (4.7 /plant), BD 2355 (5.7 /plant), BD 2340 (4.7 /plant), BD 2336 (6.0 /plant), BGH02026 (5.0 /plant) and BGM02093 (6.3 /plant). The lowest number of branch recorded in genotype Galarsum (3.0 /plant). Among the genotypes, BD 2336 and BGM 02093 produced the maximum number of filled pods (55.7/ plant) followed by BARI Soybean-6 (45.7/plant), BD 2340 (45.7 /plant) and BGH 02026 (45.7 /plant). Genotype G00056 produced the lowest number of filled pods (23.0 /plant). The highest number of unfilled pods was recorded in BARI Soybean-5 (10.7 /plant) and it was statistically at par with genotype BD 2342 (7.3 /plant). The lowest unfilled pod was recorded in genotypes BD 2329 and G00084. The heavier seed weight (16.52 g) was recorded in genotype G00056 followed by G00015 (14.81 g). The lighter seed weight was recorded in BD 2336 (6.81 g) which was at par with genotypes BGH 02026 (6.86 g) and BGM 02093 (7.12 g). Seed yield was also varied significantly due to genotypic variations. The highest seed yield was obtained from genotype BGM 02093 (3825 kg/ha) and it was statistically identical with genotypes BARI Soybean-6 (3640 kg/ ha), BD 2329 (3447 kg/ ha), BD 2340 (3573 kg/ ha), AGS 129 (3004 kg/ ha), BD 2336 (3737 kg/ ha), BGH 02026 (3267 kg /ha), Galarsum (3115kg/ ha), BD 2350 (2869 kg/ ha), BD 2331(3542 kg/ ha) and G00015 (3762 kg/ ha). The highest seed yield was attributed by the higher number of plant population/ m^2, filled pods/ plant and 100-seed weight. The lowest seed yield was obtained from genotype G00003 (1745 kg/ ha). Malik *et al.,* (2006) also observed high variability for seed yield in soybean genotypes.

Relationship between TDM at different growth stages and seed yield were estimated to find out the stages which one is more representative to seed yield and to predict required TDM of irrespective stages for attaining the optimum seed yield of soybean (Fig. 3). There was negative and weak relationship between TDM and seed yield at 15 DAE ($Y = 3643.6 – 4899.4X$, $R^2 = 0.07$) and 30 DAE ($Y = 3020.1 – 36.90X$, $R^2 = 0.01$). The relations were positive but weak at 75 DAE ($Y = 2315.3 + 49.09X$, $R^2 = 0.04$) and 90 DAE ($Y = 2177.7 + 52.70X$, $R^2 = 0.06$). Seed yield of soybean was more positively related to TDM at 45

DAE (Y = 632.19 + 659.31X, R^2 = 0.46) and 60 DAE (Y= 95.335 + 405.53X, R^2 = 0.48) DAE (Fig. 3). The filled pods /plant had significant relationship with seed yield (Y = 1397 + 41.85X, R^2 = 0.41) than other components (Fig. 4). The strong relationship between filled pods /plant and seed yield revealed that pods /plant had greater contribution to seed yield of soybean. A similar result of highly positive association between seed yield and number of filled pods was also reported by Arshad *et al.*, (2006).

Table 4. Yield contributing characters and yield of soybean genotypes.

Genotypes	Plant popn /m^2 (no.)	Plant height (cm)	Branches /plant (no)	Filled pods /plant (no.)	Unfilled pods /plant (no.)	100 seed weight (g)	Seed yield (kg/ha)
BARI Soybean-5	63.6	40.33	3.7	40.0	10.7	9.95	2222
BARI Soybean-6	64.0	54.00	4.7	45.7	4.7	10.40	3640
G00342	64.0	45.73	5.0	34.0	7.3	12.47	2443
BD 2338	57.6	43.50	4.7	42.0	2.3	8.91	2775
BD 2355	66.4	58.50	5.0	31.7	1.3	10.91	2799
BD 2329	67.6	45.17	4.3	38.0	1.0	10.76	3447
BD 2340	66.4	44.07	4.7	45.7	7.0	10.92	3573
BD 2342	59.8	42.00	3.7	27.3	2.7	9.87	2345
AGS 95	67.3	44.17	4.0	42.3	4.3	9.98	2421
G00056	61.1	46.50	4.0	23.0	3.7	16.52	2639
AGS 129	66.7	41.83	4.3	37.0	3.3	10.11	3004
BD 2336	61.3	63.17	6.0	55.7	2.0	6.81	3737
BGH02026	58.4	58.33	5.0	45.7	3.0	6.86	3267
BGM02093	62.9	61.00	6.3	55.7	3.3	7.12	3825
Galarsum	60.2	41.33	3.0	36.0	6.7	9.93	3115
BD 2350	62.4	53.83	6.7	37.7	2.3	11.13	2869
G00084	50.7	48.50	3.7	24.0	1.0	13.37	2691
BD 2331	65.1	47.50	4.0	38.3	2.3	10.46	3542
G00003	60.9	53.67	3.3	27.7	2.3	11.64	1745
G00015	60.4	45.10	4.0	35.0	2.0	14.81	3762
LSD (0.01)	9.18	8.44	2.3	11.7	3.6	0.68	967
CV (%)	6.65	7.79	23.15	13.69	44.42	2.86	14.59



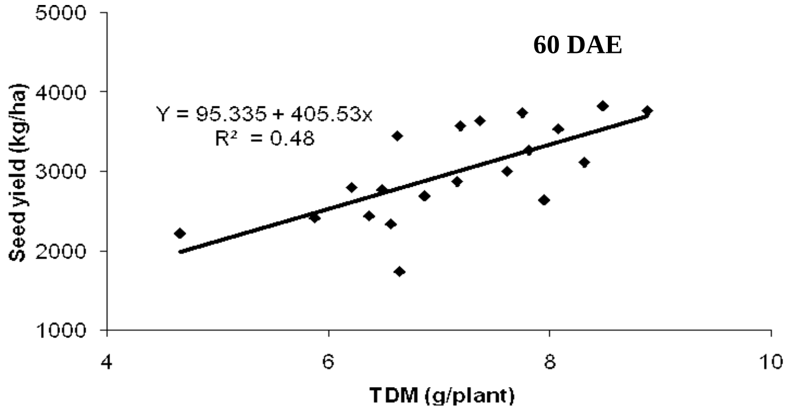


Fig. 3. Relationship between TDM and seed yield at different growth stages (45 and 60 DAE).

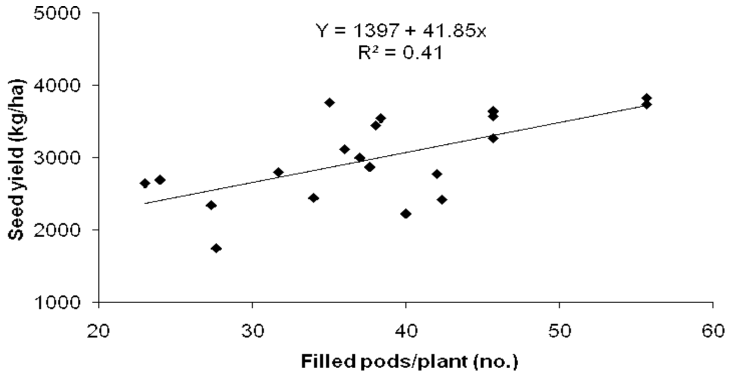


Fig. 4. Relationship between filled pods/plant and seed yield of soybean.

Conclusion

Plant height, leaf area index, dry matter distribution in different parts, crop growth rate and seed yield showed variation among the genotypes. The genotypes BGM 02093, BD 2329, BD 2340, BD 2336, Galarsum, BD 2331 and G00015 performed better in respect of higher accumulation of total dry matter and seed yield. The selected genotypes should further be incorporated in breeding trials to develop high yielding soybean varieties.

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FARMERS LAND TENURE ARRANGEMENTS AND TECHNICAL EFFICIENCY OF GROWING CROPS IN SOME SELECTED UPAZILAS OF BANGLADESH

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Abstract

There are different land tenure arrangements in crop cultivation in Bangladesh. It is needed to detect how farmers could maximize the benefits from proper utilization of their resources and technologies in these prevailing different land tenure arrangements in crop cultivation. The main quest of this study is to analyze the actual production level and how much is deviated from maximum attainable production level in terms of technical efficiencybased on average gross revenue of output ha-^{1} in the cultivated various types of crops among different categories of farmers and identifies the impact of the factors associated with technical efficiency.In search of this research question a case study was conducted in two Upazilas (Sub districts) in Bangladesh based on cross section data. This data were collected from January to March, 2013. Age of the household head, education, farm size, off-farm income and other concerned issues were assessed. Maximum likelihood estimation and ordinary least square regression techniques were used to estimate the parameters of the stochastic production frontier.Ordinary least square regression was used to identify the factors associated with technical efficiency. The study reveals that the technical efficiency varied among different categories of farmers. But land rent (0.0575) and weed management (0.0838) had significant positive impact on technical efficiency. This detects the potentiality to improve the technical efficiency by taking proper measures in land tenure arrangements in consideration of land rent andprovide required weed management support for the farmers.

Keywords: Stochastic frontier approach, Maximum likelihood estimation, ordinary least square regression method, land tenure, agricultural production.

Introduction

Bangladesh is an agricultural developing country. The total area of Bangladesh is 144,000 sq. km, population is 150 million having cultivable area of 8.44 million hectare (ha), the contribution of agriculture sector in the share of gross domestic product is 23.50%, and this sector ensures 52% of the total employment of the

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country(BBS, 2011).The major cultivated cereal crops in Bangladesh areHYV Boro, T. Aman and B. Aman. The average yield of these crops are 3.90, 2.26 and 1.90 Ton ha-^{1} (BBS, 2011).The following three farming categories are observed in the country based on share cropping, fixed rent and mortgaging tenancy arrangements:(a) Owner farming (b) Owner cum tenant farming(c) Tenant farming.

Farming category in the study areas

In Bangladesh, the percentages of owner, owner cum tenant and tenant farmers are 65%, 22% and 13% respectively(BBS , 2011).Where as these percentages of owner, owner cum tenant and tenant farmers in the study areas are 44.5%, 33.5% and 22% respectively (DAE, 2013).

Owner farmers cultivate owned land and mortgaged land in owner farming. In cultivating this owned land, owner farmers get the whole amount of the produced crop as net revenue after deducting the production cost. In the case of mortgaged land, cultivators need not to pay any share of the produced output to the land owner but need to pay a certain amount of mortgaged money and duration of this mortgaged land persist until the mortgaged money can be repaid by themortgagor(who mortgaged out the land).

Owner cum tenant farmers cultivate owned land, mortgaged land, fixed rentedland and share cropped land. In cultivation of this fixed rented land, a fixed amount of money is needed to payannually to the land owners by the cultivators(who rented in the land in fixed renting system).The terms and conditions of mortgaged land in owner cum tenant farming are as same as mortgaged land in owner farming. In most cases, share cropping system of cultivation has been found inefficient in terms of low resource use, low productivity and deprivation from land lords.ThereforeBangladesh government passed the land reform ordinance 1984 in order to protect the interest of tenant or share croppers from landlords as well as to increase crop productivity at farm level through efficient use of resources.

According to this land reform ordinance of Bangladesh, tenant will provide labor, land will be provided by the land owner and rest other input costs will be shared between the land owner and tenant farmers in 50:50 ratio, and the produced output will be shared based on the same ratio between the land owner and tenant farmers to get proper incentive in agricultural production(LRB, 1982). But in practice, output sharing is conducted according tothis legal provision but input costs sharing is not practiced properly(Ullah, 1996). Again,this crop sharing arrangement is applied in case of share cropped land of the owner cum tenant farmers also.

Measuring technical efficiency is one of theapproachesfor understanding how farmers could maximize the benefits from the proper utilization of existing resources and technologies.This approach can be conducted using production, cost or profit function. The first approach is called technical efficiency(Battese and Coelli,1995).

The adaptation of proper variety and other socioeconomic factors had significant impact on technical efficiency (TE) in rice production of different farming system in Bangladesh,Barmon (2013)found that farmers producing modern variety of rice were more technically efficient than farmers producing rice in prawn gher(Area used for prawn cultivation) farming in the coastal region of Bangladesh.

The mean technical efficiency of Nepalese rice seed growers was 81% and it was found that there was a wide variation in technical efficiency due to education level and experience of the farmers in seed production (Khanal and Maharjan, 2013). The mean technical efficiency of rice cultivation in Bangladesh was 69%, indicating that there is a scope of 31% improvement in technical efficiency and availability of credit was found significant positive impact on technical efficiency (Ahmed, 2011). There are variations in the level of technical efficiency in agriculture within the sub- sectors of crop, livestock and fish cultivation. It is revealed that credit had a significant positive impact on the technical efficiency of all of these sub-sectors (Ahmed, 2010). The noted literatures clearly demonstrate that the stochastic frontier approach is widely used in agricultural economics studies. In case of Bangladesh, it was observed that fragmentation of land generates production inefficiency in agriculture sector (Wadud, 2003).In this study it was also found that farmers could increase their rice production by 9 to 39% if they could operate at full technical efficiency level with their existing resources and technology.

The pattern of land ownership affects gross revenue per hectare by affecting the efficient use of inputs. Considering the tenancy status of farm lands in Bangladesh, 58% of the land is operated by owner, 40% by owner cum tenant, and 2% by tenant farmers (Tenaw, *et al.*, 2009).

There are studies (Ahmed, 2012; Asadullah, 2005) about land tenure and tenancy system in Bangladesh refuting the claim about the significance of land leasing in and consequence enhancements in viability of small farms. It is cited evidence that the terms of tenancy in Bangladesh were very oppressive. In large portion of the cases the land owner exacted 50% of the produced crops as rent without sharing any parts of the cost and at least 5% of the cases the share of rent was more than 50%. Thus, when full cost accounting is applied the share croppers incurred a negative return (Ullah, 1996). The effect of land fragmentation on China’s agriculture was examined by Wan and Cheng (2001) and found that a new land tenure institution emphasizing consolidation significantly improves the production efficiency. The mean technical efficiency of Nigerian agriculture was 77%; it means that there is a scope of 23% improvement in technical efficiency (Idiong, 2007).

The productivity of agricultural production may varyamong different categories of farming due to discriminate use of various production inputs and managerial factors in Bangladesh, which needs proper evaluation through econometric model.There are some studies about various aspects of agricultural production in Bangladesh including technical efficiency based on different socioeconomic issues,but an updated study is needed on technical efficiency based on land tenure aspect to trace out the proper policy implication for the agricultural development in Bangladesh.Therefore, the present study was conducted with the following specific objectives.

Objectives of the study

- To analyze the technical efficiency of different categories of farmers in cultivating various cultivated crops in a cropping year to detect the actual production level and deviated from the maximum attainable production level of the farmers;
- To identify the impact of the factors influencing technical efficiency of different categories of farmers;
- To recommendfor betterment of agricultural production;

Materials and Method

(a) Description of the Study location and sampling technique adopted: This study was carried out at Basailupazila ofTangail district and TitasupazilaofComilla district in Bangladesh. The area of Basailupazila was 158 sq.km, and population was 76,002.The area of Titasupazila was 107.19 sq.km, and population was 183,425.These two Upazilas were selected as farmers of these twoUpazilas were getting proper agricultural support of the government due to location advantage, which can represent the overall farming characteristics of the country.The purposive stratified sampling technique was followed as the share of owner, owner cum tenant and tenant farmers were very disproportionate in the study areas(DAE, 2013).

(b) Method of data collection and period of study: Three hundred respondents were taken equally one hundred for each category and fifty respondents from each upazila.Data were collected in survey methodfrom January, 2013 - March, 2013 to trace out the proper factors oftechnical efficiency under different land tenure arrangements based on the cultivated crops in a cropping year. The major cultivated crops in the study areas were HYV Boro, T. Aman and B. Aman. Mustard, jute, wheat or pulses were cultivated as minor crops. Normally two or three crops were cultivated in each plot of land among these crops in a year.

(c) Analytical technique adopted: The collected data were analyzed by using STATA9.Stochastic frontier model was used to measure the technical efficiency of the different categories of farmers based on their average gross revenue of output ha-^{1}in the cultivated various types of land.This study considers the stochastic frontier approach with the assumption that the actual production cannotexceed the maximum possible production with the given input quantities and it is suggested to determine the factors responsible for inefficiency (Aigner *et al.*,1977 and Meeusen and van den Broeck,1977).

It was used in a two stage procedure. In the first stage,TE was computed and in the second stage socioeconomic variables of farm households were regressedagainst this TE using ordinary least square(OLS) regression method to identify their impact.Since the value of TE is $0<TE<1$,it justifies using OLS technique(Kalirajan,1999;Piya,Kiminami and Yagi,2012).The stochastic frontier model used in this study as follows:

$$Ln_{Yi} = _{\beta 0} + _{\beta} Lnxi + vi - ui \ldots \quad (1)$$

Where, logarithm Yi is theaverage gross revenue of output ha-^{1}in different types of cultivated land, $_{\beta}$is the vector of parameters to be estimated,xi presents inputs.

These inputs includes per hectare averagecost of labor, power tiller, chemical fertilizer andirrigation in various categories of cultivated land of the different tenure groups of farmers. Land rent was taken as a proxy indicator of surplus as ownership patterns as well as cultivated land categories were different among owner,owner cum tenant and tenant farmers. This land rent was taken at the rate of the cost of mortgaged land of the owner farmers based on their cultivated mortgaged land, but for the owner cum tenant and tenant farmers this land rent was taken at the rate of cost of cultivated share cropped land of the owner cum tenant and tenant farmers in the study areas.

It was found in the study areas that if half of the seed cost was provided to the tenant by the land owner then land owner claimed half of the produced by-product, and even sometimes without sharing this seed cost the half of the produced by- product was claimed also based on customary rule. To avoid this complexity, the price of by-product was not taken into account in estimating gross revenue as well as seed was not included due to this reason.v_i presents the error term accounting for random variation in gross revenue due to factors outside the control of farmers.

Another error term u_i presents error associated with farm level inefficiency and this is assumed to have 0 mean with variance $(\sigma u2)$and distributed half normally. Similarly,v_i is assumed to have zero mean and constant variance$(\sigma v2)$ and distributed normally with independent with each u_i. Both of these error terms are supposed to be uncorrelated with explanatory variables x_i.

The loglikelihood function for half normal model is given in equation (2).This likelihood function estimates whether the variation among the observation is due to inefficiency. From the likelihood function we get $\sigma 2$ and $\lambda 2$.

Where, $\lambda 2 = \sigma u2 + \sigma v2$ and$\lambda 2 = \sigma u2/\sigma 2$. If λ=0, it indicates there is no inefficiency effect and the variation in the data is due to random noise only.The higher the valueofλ the more will be inefficiency effects explained by the model.

$$Ln\ L(Yi|\beta, \sigma\lambda) = -\frac{1}{2} Ln(\pi\sigma 2) + \sum_{i=1}^{n} Ln\emptyset\{\frac{-\varepsilon i\lambda}{\sigma}\} - \frac{1}{2\sigma 2}\sum_{i=1}^{n} \varepsilon i2 \quad \ldots \quad (2)$$

Where, Yi is the vector log ofaverage gross revenue of output ha-[1] in different types of cultivated landεi=vi-ui=Ln Yi-xi β is the composite error and$\emptyset(xi)$ is a cumulative distribution functionof the standard normal variable evaluated at xi.

Empirical model:

Empirical model for production

$lnY_i = a + b_{1ln}X_1 + b_{2\ ln}X_2 + b_{3\ ln}X_3 + b_{4\ ln}X_4 + U_i$

Where,

Y= Average gross revenue of output (Takaha-^{1}) of different types of cultivated land in different types of farming

a, b_1, b_2, b_3, b_4= Parameters to be estimated

X_1=Average cost of labor (Taka ha-^{1})in different types of cultivated land

X_2= Average cost of power tiller (Taka ha-^{1})in different types of cultivated land

X_3= Average cost of chemical fertilizer (Taka ha-^{1})in different types of cultivated land

X_4= Average cost of irrigation (Taka ha-^{1})in different types of cultivated land

U_i= Error term

Empirical model for TE

The TE of the farmers in the context of stochastic frontier model can be expressed as:

$$TEi = \frac{Yi}{Y*} = f(xi;\beta)\exp(vi - ui)/f(xi;\beta)exp(vi) = exp(-ui) \quad \ldots \quad (3)$$

Where, $Y*$ is the maximum possible average gross revenue of output ha-[1] in different types of cultivated land,Yi,xi, $\beta, vi, TEi$and uiare as explained earlier.TEi measures the average gross revenue of output ha-[1] in different types of cultivated land of the farmers relative to the maximum possible average gross revenue ofoutput ha-[1] in different types of cultivated land that can be produced using the same cost of input vectors. This value of TEi is 0 to 1.

If TEi=1,Yi achieves the maximum value of $f(xi;\beta)exp(vi)$.IfTEi is less than 1,thatindicates the shortfall of gross revenue of output from the maximum possible level.Thissituation is characterized by stochastic elements,which vary among the farmers.The following equation (4) was used to identify the impact of socioeconomic variables on TE.

$$TEi = \delta_0 + \delta LnZi + \omega_i \quad \ldots(4)$$

Where, δ presents the parameters associated with socioeconomic variables(zi),and$\omega_i$is the error term.

The variables for the study were chosen considering both production theory and local context of the farmers.Analysis of variance (ANOVA) was used to analyze the mean difference of technical efficiency of the farmers.

Regression analysis was used to identify the impact of the factors associated with technical efficiency.In using this stochastic frontier model Wald chi^2 test showed significant result(P= 0.0000), that indicates the fitness of the model. All of these stochastic frontier model, ANOVA and regression analyses were used based on overall study areas.For the regression analysis OLS method was used, because OLS is easier to analyze mathematically than many other regression technique. It produces solution those are easily interpretable; OLS is the best unbiased linear estimator of the model coefficient.

Moreover, robust regression technique of this OLS model mitigates the problem of data variation. Before running this OLS model data were validated using Variance Inflation Factor(VIF) and robust regression method for multicollinearity and heteroskedasticity.

This OLS model was used in the many other similar studies including the study conducted by Ahmed (2012),on Agricultural Land Tenancy. This OLS model was also used in the study on Farm Productivity and efficiency in Rural Bangladesh: The role of Education Revisited(Asadullah,2005).

Results and Discussion

(1) Socioeconomic characteristics of respondent farmers

Table 1 presents the socioeconomic characteristics of the respondent farmers. The average year of education of head of the household (HHH[1]) were 4.65, 3.96

and 2.22 in owner, owner cum tenant and tenant farmers respectively. This year of education varied from 0 to 14 years, from 0 to 10 years, and from 0 to 5 years in owner, owner cum tenant and tenant farmers respectively.

The average farm size of owner, owner cum tenant and tenant farmers were 0.77, 0.74 and 0.70 ha respectively.This farm size varied in owner, owner cum tenant and tenant farmers from 0.23 to 4.08 ha, from 0.23 to 2.27 ha and from 0.23 to 2.72 ha respectively.

The mean land rents were BDT 18,010, 9,730 and 16,050 ha^{-1} among owner, owner cum tenant and tenant farmers respectively.This land rent varied from BDT 8,000 to 83,803, from BDT 5,000 to 39,696 and from BDT 3,000 to75,000, ha^{-1}respectively.

The percentages of adoption of new crop adopting farmers were 100, 100 and 87 among owner, owner cum tenant and tenant farmers respectively. But this percentage was 96 in overall.

The percentages of weed management adopting farmers were 100, 98 and 5 amongowner, owner cum tenant and tenant farmers, but this percentage was 68 in overall.

From the discussion of socioeconomic characteristics of the farmers, it is concluded that tenant farmers were in most dis-advantageous position in farming among these different tenure categories of farmers in consideration of farm size and all other socioeconomic aspects.

(2) Study variables

Table 2.1presentsthe mean and standard deviation of the study variables.The mean gross revenues of owner, owner cum tenant and tenant farmers were BDT 94,558, 93,941 and103,916ha^{-1}respectively.

Those varied from BDT15,845 to 234,650, BDT 25,641 to 395,200 and BDT 11,115 to 185,250

ha^{-1}inowner, owner cum tenant and tenant farmers respectively.The mean labor costs of owner, owner cum tenant and tenant farmers were BDT7,133,4,438 and 10,938ha^{-1}respectively. These labor cost varied in the range of BDT 2,205 to 16,540, BDT 2,205 to 11,026and BDT1,500 to 16,540 among owner, owner cum tenant and tenant farmers respectively.The mean power tiller costswere BDT 2,419,1,626 and 4,084 ha^{-1} in owner, owner cum tenant and tenant farmers respectively.

This power tiller cost varied from BDT 1,470 to 4,410, BDT1,143 to 4,410and BDT1,700to 4,940 ha^{-1}in owner, owner cum tenant and tenant farmers respectively.

Table 1. Socioeconomic characteristic of the sample households.

Variables	Owner farmers	Owner cum tenant farmers	Tenant farmers	Overall
Age of HHH[1](year)	51.43(9.98)	50.51(8.99)	43.77(9.69)	48.57(9.56)
Education (year)	4.65(3.5)	3.94(2.79)	2.22(1.97)	3.61(1.75)
Occupation of HHH[1] (1) (%)	42	76	72	63
Family labor(LFU[2])	3.65(0.83)	3.54(0.77)	3.13(0.89)	3.44(0.82)
Farm size(ha)	0.90(0.67)	0.80(0.33)	0.705(0.52)	0.80(0.50)
Off farm income (Taka)	69,640(76,944)	28,750(44,016)	26,020(18,958)	41,469(46,639)
Land rent	18,010(18,397)	9,730(6,589)	16,050(13,706)	14,596(14,183)
Extension (1) (%)	98	60	4	54
Saving (1) (%)	98	46	2	49
Credit (1) (%)	77	36	20	44
% of adoption of new crop	100	100	87	96
Weed management (1) (%)	100	98	5	68
Livestock nit(LSU[3])	3.06(1.21)	3.00(0.73)	2.32(0.91)	2.79(0.95)

Source: Field survey (2013) Note: Figures in the parentheses indicate Standard Deviation.

The mean fertilizer costs were BDT8,659, 4,942 and12,312 ha^{-1} in owner,owner cum tenant and tenant farmers respectively. This fertilizer cost varied from BDT 1,929 to 19,848, BDT653 to 6,076and BDT 3,193 to18,525 ha^{-1}in owner,owner cum tenant, and tenant farmers respectively.The mean irrigation costswere BDT 6,435, 3,795 and 9,316ha^{-1} in owner, owner cum tenant and tenant farmers respectively. This irrigation cost varied from BDT 1,874 to 11,026, BDT 1,176 to 7,351 and BDT 2,940 to 16,540 ha^{-1}in owner, owner cum tenant and tenant farmers respectively. This cost of production varied in different categories of farmers due to crop cultivation without tillage system and other concerned issues.

Table 2. Mean and standard deviation (SD) of the study variables use in stochastic frontier model.

Variables	Owner		Owner cum tenant		Tenant	
	Mean	SD	Mean	SD	Mean	SD
Yield(gross revenue Taka ha^{-1})	94,558	38,213	93,941	34,489	103,916	33,501
Labor (cost Taka ha^{-1})	7,133	1,937	4,438	1,080	10,938	3,791
Power tiller (cost Taka ha^{-1})	2,419	650	1,626	595	4,084	842
Chemicalfertilizer(cost Taka ha^{-1})	8,659	2,996	4,942	1,240	12,312	5,560
Irrigation/ IC^4(cost Taka ha^{-1})	6,435	1,571	3,795	1,223	9,316	4,063

Source: Field survey (2013) Note: The name of Bangladesh currency is Taka, BDT= Bangladesh Taka, 1 US Dollar=77.98 BDT.

(3) Factors Affecting Goss Revenue

Table 3 presents the findings from stochastic frontier model. The significant loglikelihood using the wald test signified the fitness of the model(P=0.0000). Moreover, the likelihood ratio test for the absence of inefficiency in the model criteria was rejected(P=0.000). Indicating that the inefficiency effect explained in the model was higher than random noise. It was also estimated marginal effects of the relevant input variables on gross revenue to complement the analysis and these marginal effects were used to discuss the average impact of inputs on gross revenueof the farmers. Labor and chemical fertilizerhadpositive effect. But power tiller and irrigation (IC^4) had negative effect on gross revenue. The marginal effect of labor was 0.226,indicates that 1% increase in labor cost leads to increase average gross revenue of output ha^{-1} by0.226%.The marginal effect of fertilizer was 0.103, indicates that 1% increment of fertilizer cost leads to increase the average gross revenue of output ha^{-1} by 0.103%. The marginal effect of power tiller was -0.452, indicates that 1% increase in power tiller cost leads to decrease the average gross revenue of output ha^{-1} by 0.452%. The marginal effect of irrigation was -0.052, indicates that 1% increment in irrigation cost leads to decrease the average gross revenue of output ha^{-1} by 0.052%.

Table 3. Maximum likelihood estimates and marginal effect.

Variables	Coefficients	P value	Marginal effects
Labor	0.306(0.000021)	0.000***	0.226
Power tiller	-0.690(0.000014)	0.000***	-0.452
Chemical fertilizer	0.138(0.000019)	0.000***	0.103
Irrigation(IC^4)	-0.072(0.000021)	0.000***	-0.052
Constant	14.36(0.00011)	0.000***	

Loglikelihood:-298.05***σ^2= 1.71ƛ =7.77 likelihood ratio= 2.7*** N= 300, *** indicates significant at 1% level of significance.

(4) Farm specific technical efficiency of the farmers

Tables (4.1, 4.2) present frequency distribution and mean difference of technical efficiency among owner, owner cum tenant and tenant farmers. From the tables it is found that there was a variation among the number of farmers as well as significant mean difference of technical efficiencyamong owner, owner cum tenant and tenant farmers.

Table 4.1 Frequency distribution of farm specifictechnical efficiency of the farmers.

Rage of TE	Owner(%)	Owner cum tenant(%)	Tenant(%)
< 0.50	29	70	50
0.51- 0.60	28	12	28
0.61- 0.70	18	06	09
0.71- 0.80	06	08	03
0.80^+	19	04	10

Table 4.2 Farm specific technical efficiency of the farmers.

Farming category	Technical efficiency	P value
Owner	0.603(0.211)	0.0000***
Owner cum tenant	0.444(0.184)	
Tenant	0.527(0.192)	

Note: Number of observation: 300 ***Significant at 1% level of significance, figures in the parentheses indicate Std. Dev.

The result shows that there was 60% mean technical efficiency of owner farmers that varied from 7.9% to 99.9%. Indicates that owner farmers could improve technical efficiency by 40%.This mean technical efficiency in owner cum tenant farmers was 44% that varied from 3.8% to 99.9%, indicates that owner cum tenant farmers could improve technical efficiency by 56%. Again average technical efficiency of tenant farmers was 52.7% in the range of 5.8% to 99.9%, which indicates that tenant farmers could improve technical efficiency by 47.3%.

(5) Factors affecting technical efficiency of the farmers

Table 5 presents the summary result of the impact of socioeconomic variables.We tested fourteen socio economic explanatory variables against technical efficiency in OLS regression. From the analysis, it was found that the direction of the response of the variables land rent andweed management were as per the hypothesis and these variables hadsignificant positive impact on technical efficiency.Indicate that1% increment of land rent leads to increase TE by 5.75%.This might be for the better incentive of land rent as a surplus in farming. Proper use of weed management leads to increase TE by 0.0838%. This might be better utility of weed management in farming.Education, farm status, farm size and adoption of new crop were significant but did not show expected sign.

Table 5. Measurement unit, expected sign and parameter estimates of the OLS model.

Variables	Measurement unit	Expected sign	Coefficients	P value
Age of the HHH[1]	Year	+	0.0015(.001)	0.264
Education	Year of formal education	+	-0.0128(.004)	0.003***
Occupation	1= primary, 0= secondary (dummy)	+	-0.0146(.030)	0.634
Farm status (Owner cum tenant)	2= owner cum tenant	+	-0.0797(.032)	0.015**
Farm status(Tenant)	3= tenant	+	0.0431(.059)	0.467
Family labor(LFU[2])	LFU[2]	+	0.0110(.015)	0.466
Ln farm size	Hectare	+	-0.0857(.023)	0.000***
Ln off- farm income	BDT	+	-0.0212(.016)	0.198
Ln land rent	BDT	+	0.0575(.019)	0.003***
Extension services	1 = Yes, 0= No (dummy)	+	0.0452(.035)	0.208
Saving	1 = Yes, 0= No (dummy)	+	0.0392(.037)	0.296
Credit	1 = Yes, 0= No (dummy)	+	0.0386(.032)	0.233
Adaptation of new crop	1 = Yes, 0= No (dummy)	+	-0.1202(.061)	0.053*
Weed management	1 = Yes, 0= No (dummy)	+	0.0838(.039)	0.034**
Livestock unit (dummy)	LSU[3]	+	-0.0205(.015)	0.196
Cons	BDT	+	0.1812(.261)	0.488

Note: Farm status:1= owner, 2= owner cum tenant, 3= tenant (dummy) Number of observation: 300 R-squared = 28 Root MSE= 0.176 Figures in the parentheses indicate Std. Err. ***, ** and * Significant at 1%, 5% and 10% level of significance respectively.

In case of education, this might be the provided education was not properly oriented in farming. For the case of farm status of owner cum tenant farmers, this might be due to extensive use of owned land of owner cum tenant farmers. For farm size, this might be due to extensive use of owned land of the owner farmers as well as owner cum tenant farmers. In the case ofadoption of new crop, this might be the existing cultivation of crop is economically more viable than adoption of new crop based on the socioeconomic context of the farmers.Other variables did not show significant impact on technical efficiency.

Conclusion and recommendation

In this study technical efficiency of different categories of farmers was estimated using stochastic frontier model and analyzed the estimated technical efficiency using ANOVA.It was found that there was a statistically significant difference from zero in the level of technical efficiency among owner, owner cum tenant and tenant farmers.It was alsofound significantly positive influence of landrent and weed management on technical efficiency.

From the discussions it can be discerned that, there is a potentiality for the enhancement of technical efficiency in ensuring change by taking measures in land tenure arrangements in proper implementation of the land reform ordinance 1984 that will ascertain higher surplus for the share croppersin share cropped land and provide weed management support for the farmers.Those might lead to attain higher technical efficiency. This study recommends the government to take necessary measures on that direction.

End Note:

(1) HHH stands for household head.

(2) Labor force unit(LFU) is the measurement of family labor where people from 15-59 years regardless of sex were categorised 1 person=1 LFU, but in the case of children 10-14 and elderly people more than 59 years old 1 person= 0.5 LFU.

(3) Livestock unit(LSU) is the aggregate of different types of livestock kept at household standard unit calculated using following equivalents;

1 adult buffalo = 1 LSU,1 immature buffalo= 0.5 LSU 1 cow= 0.8 LSU, 1sheep or goat= 0.2 LSU and 1 poultry or pigeon=0.1 LSU (Khanal and Maharjan,2013).

(4) IC stands for irrigation cost. This irrigation cost is paid in kind as one fourth of the total produced crop.

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FACTORS AFFECTING THE ADOPTION OF IMPROVED VARIETIES OF MUSTARD CULTIVATION IN SOME SELECTED SITES OF BANGLADESH

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Abstract

Mustard is a leading oil crop in Bangladesh. Relevant data and information on the adoption of improved mustard varieties is very scanty and sporadic in Bangladesh. Therefore, an attempt was made to assess the extent of adoption of improved mustard varieties and their management practices at farm level. The study used data from 540 mustard growing farmers under Manikgonj, Rajshahi and Dinajpur districts. Probit regression model along with other descriptive statistics were used to analyze the collected data. Analysis revealed that the farm level adoption of different production practices were not encouraging as most farmers did not follow the recommendations made by Bangladesh Agricultural Research Institute (BARI) for mustard cultivation. The variety adoption scenario was also discouraging since only 40% of the farmers cultivated improved mustard varieties. However, farmers showed positive attitude towards adoption of improved mustard varieties since about 53% of the adopters wanted to increase area under improve mustard cultivation in next growing season considering the high yielding ability, low cultivation cost, high profit, and less labour requirements. Although mustard is considered to be a profitable crop, many farmers showed negative attitude towards its production due to some drawbacks. Non-availability of improved mustard seed was also found to be a barrier to its adoption at farm level.

Keywords: Improved mustard, variety adoption, farmers' attitude, production practices.

Introduction

Rapeseed and mustard are popularly called 'Mustard' which is a leading oilseed crop, covering about 80% of the total oilseed area and contributing to more than 60% of the total oilseed production in Bangladesh. It is a cold loving crop which is grown during Rabi season.

The total area and production of mustard is 276.11 thousand hectare and 262.00 thousand tons (Fig 1). The present mustard yield (0.95 t/ha) is very low as compared

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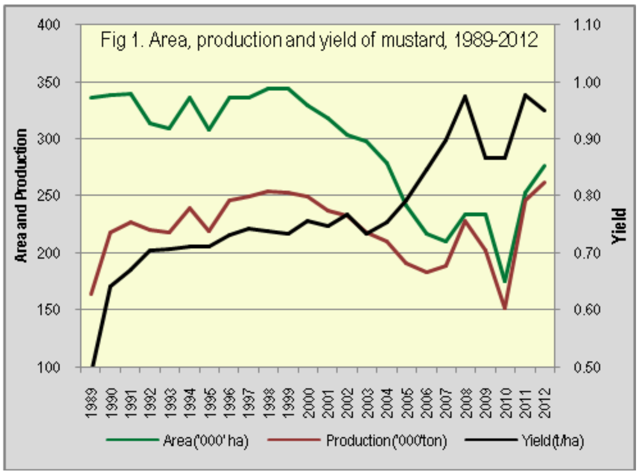
to other oilseeds growing countries in the world. The main reasons of lower yield are lack of good quality seed and inadequate adoption of improved production technologies developed by different research institutes (Miah *et al.*, 2014).



Source: Using data from various issues of BBS

Bangladesh is moving towards self-sufficiency for different agricultural commodities, such as rice, wheat and potato with the higher level of adoption of modern technologies generated by different research institutes. The country is producing about 0.36 million tons of edible oil per year as against the total requirement* of 1.4 million tons (Mallik, 2013). There has been a big gap between supply and demand of edible oils, which has been met through imports incurring a huge amount of foreign exchange (Bangladesh Bank, 2012) every year. In view of the importance of crops, due attention has been given to increase oilseeds production for reducing the huge shortage of cooking oil in the country. Research institutes (mainly BARI) developed a number of improved varieties of mustard and disseminated those for farm level cultivation. But many farmers have not adopted these technologies at all for various reasons which need to be identified. However, the area under improved mustard varieties is gradually increasing and the area under Tori-7 is decreasing year after year (Table 1).

Relevant information on the adoption of improved mustard varieties is very scanty and sporadic in Bangladesh. (Akter *et al.*, 2010) assessed the adoption status of BARI released mustard varieties and evaluated the impact of blocks demonstration on adoption using limited number of samples from Pabna, Tangail and Jamalpur district. Miah and Alam (2008) conducted another study to assess the extent of technology adoption, relative profitability and farmer's attitude toward BARI mustard cultivation. (Anwarul *et al.*, 2007) estimated the status of

* Total requirement = 22g/capita/day x 153 million people.

resource allocation in mustard production and measured the technical efficiency of the mustard farmers at Jamalpur district. Fariduzzaman (1996) compared the financial benefits of improved mustard varieties cultivation under improved and traditional management in some areas of Bangladesh.

Table 1. Area under different mustard varieties at national level (61 districts).

Variety	2010-2011		2009-2010		2008-2009	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
A. Improved	**1,30,445**	**30.0**	**1,15,041**	**29.4**	**1,00,582**	**23.9**
BINA Mustard (3-6)	4,807	1.1	4,853	1.2	1,944	0.5
BARI Mustard (2-13)	1,02,572	23.6	96,961	24.8	90,041	21.4
BARI Mustard 14	13,390	3.1	7,418	1.9	5,457	1.3
BARI Mustard 15	9,666	2.2	5,104	1.3	3,135	0.7
BARI Mustard 16	10	0.0	705	0.2	5	0.0
B. BARI old variety	**2,85,437**	**65.8**	**2,60,379**	**66.5**	**3,00,620**	**71.6**
Tori-7 (Improved)	2,85,437	65.8	2,60,379	66.5	3,00,620	71.6
C. Local	**18,017**	**4.2**	**15,957**	**4.1**	**18,803**	**4.5**
All variety	4,33,899	100	3,91,377	100	4,20,005	100

Source: Estimated using data from district level DAE Offices, 2012.

However, farm level adoption of improved mustard technologies is very much important since it is expected that farmers will benefit through receiving higher yield and income, utilizing vast current fallow land between T. Aman and Boro rice and save a lot of foreign currency through less importation. The policy makers and researchers will also be benefited through the findings of this study. Therefore, the present study was undertaken with the following objectives;

a) To study the adoption status of improved varieties of mustard and its recommended production practices at farm level;

b) To find out the factors associated with adoption of improved varieties of mustard at farm level;

c) To know farmers’ experience with and attitudes towards improved mustard cultivation.

Materials and Method

Study locations and sampling technique: Multi-stages sampling procedure were followed to select sample farmers. In the first stage of sampling, study areas were selected purposively based on the area coverage of mustard during cropping season 2008-2009. Thus, three mustard growing districts, namely Manikgonj, Rajshahi, and Dinajpur consisting high (covered ≤10% of total mustard area), medium (≤5 to >10% area), and low (>5% area) mustard growing areas were selected for the study. In the second stage, in all nine Upazilas under three selected districts were purposively selected taking three Upazila from each district. Before selecting Upazilas, data on the area and production of mustard were collected from Upazila DAE offices and the highest three mustard growing Upazilas were selected for the study. Thirdly, three agricultural blocks were also purposively selected in consultation with Agricultural Officer of the respective Upazila. Finally, a total of 540 mustard growing households (3 districts × 3Upazilas × 3 Blocks × 20 HHs) were randomly selected from a complete list of mustard growing farmers.

Method of data collection and period of study: Data and relevant information were collected through personal interview with sampled farmers using a pre-tested structured interview schedule. The researchers and trained enumerators collected data and information for this study. Data and information were collected during the period from October 2011 to October 2012.

Analytical techniques: For assessing the level of adoption of crop management technologies, respondent farmers were grouped into three categories such as high, medium, and low adopter based on the percent of farmers followed recommended practice with respect to each technology. A higher percentage indicates a higher level of adoption, while a lower percentage indicates a lower level of adoption of a technology. Adoption level was categorized as (70-100%) as high, (50-69%) as medium, and <50% as low. This category of adoption was followed by different authors (Islam *et al*., 2013; Salam *et al*., 2011; Miah *et al.*, 2010; Akter *et al*., 2010) in the past.

Probit and Logit models have been used extensively by agricultural production and farming systems economists for studying and analyzing farmers' adoption and diffusion of agricultural interventions. In Pakistan, Malik *et al*., (1991) and Heisey *et al.*, (1990) used Probit model to examine the role of credit in agricultural development and to identify the determinants of adoption of wheat varieties. Traxler and Byerlee (1992) also used this analysis to identify the characteristics of insecticide farmers. In the present study, Probit regression model was used to find out the factors of adoption and non-adoption of improved varieties of mustard. In order to ascertain the probability of adoption of improved mustard varieties, the following empirical Probit model was employed. Since the dependent variable is dichotomous, Ordinary Least Square (OLS) method is not suitable. Therefore, MLE method was followed to run the Probit model using STATA software. The empirical probit model was as follows:

$$A_i = \alpha + \beta_i X_i + \ldots\ldots.. + U_i$$

Where,

A_i = Farmers adopting improved mustard variety (If adopted = 1; Otherwise = 0), α = Intercept, X_i = Explanatory variables, β_i = Coefficients of respective variables, and U_i = Error term

The adoption of improved mustard variety is likely to be influenced by different explanatory variables. The variables are X_1 = Farm size (in decimal), X_2 = Family labour (in No./ha), X_3 = Training received on oilseed (in No.), X_4 = Availability of improved seed (score), X_5 = Influence of neighbouring farmers (score), X_6 = Influence of SAAO (score), X_7 = Cosmopolitness of the farmer (score), and X_8 = Extension contact of the farmers (score).

The procedures of measuring qualitative variables included in the model are briefly discussed below.

Influence of neighbouring farmers and SAAO: These variables were measured based on the level of influences of neighbouring farmers and SAAO in adopting improved mustard variety. Zero value was assigned for 'no influence' and 4 for 'strong influence'. Therefore, the possible scores of these variables ranged from 0 to 4.

Availability of improved seed: The availability of improved mustard seeds was assigned different values ranging from 0 to 4 (0 = not available, 4 = plenty) and these values were considered as score.

Cosmopolitness: Different values (0 for no visit and 3 for frequent visit) were assigned, based on frequency, for different places of visit. The actual score was then calculated by adding all the values. Possible scores ranged from 0 to 9.

Extension contact: Ten different extension Medias were considered in this study. All these Medias were assigned different values (0 for no contact and 4 for regular contact) according to their importance. The actual score was measured by adding all the values. The possible scores for extension contact were ranged from 0 to 40.

Results and Discussion

Adoption of mustard varieties in the study locations

The farm level adoption of mustard varieties mostly depended on the dissemination process of BARI in association with the Department of Agricultural Extension (DAE). So far BARI has developed and disseminated 16 improved rapeseed and mustard varieties to the farmers. Adoption of mustard varieties at household levels has been discussed below.

Household level adoption revealed that about 40.2% mustard farmers adopted improved varieties and almost 60% adopted BARI old variety (Tori-7). The national level data on mustard area also revealed that Tori-7 is the dominant variety across the country which covered 68.15% mustard area (Table 1). Short duration and to some extent tolerant to biotic and abiotic stresses are the main characteristics that make Tori-7 popular to most of the farmers in the study areas. Among improved varieties, BARI Mustard-15 and BARI Mustard-9 were the highly adopted varieties in the study areas, but area covered by these two varieties is very low at national level. However, BAU Sampod, BARI Mustard-9 and BARI Mustard-15 were the highly adopted varieties in Dinajpur, Rajshahi, and Manikgonj district respectively (Table 2).

Table 2. Level of adoption of different mustard varieties in different study locations.

Variety	% of farmers adopted the variety			
	Manikgonj	Rajshahi	Dinajpur	All area
A. Improved	**40.0**	**30.0**	**50.5**	**40.2**
BARI Mustard-9	5.6 (10)	16.7 (30)	8.3 (15)	10.2 (55)
BARI Mustard-14	16.1 (29)	2.8 (5)	1.1 (2)	6.7 (36)
BARI Mustard-15	17.2 (31)	10.6 (19)	12.2 (22)	13.3 (72)
BARI Mustard-16	1.1 (2)	--	--	0.4 (2)
BAU Sampod	--	--	17.8 (32)	5.9 (32)
Indian Mustard	--	--	11.1 (20)	3.7 (20)
B. BARI old variety	**60.0**	**70.0**	**49.5**	**59.8**
Tori-7	60.0 (108)	70.0 (126)	49.5 (89)	59.8 (323)
All varieties	100 (180)	100 (180)	100 (180)	100 (540)

Note: Figures in the parentheses indicate the number of respondent farmers.

Source: Field survey, 2011-12.

The respondent farmers were found to be very much enthusiastic towards BARI Mustard-14 and 15 due to their short life cycle (80-85 days) and high yielding potentials. But the rate of adoption of these two varieties was not satisfactory in the study areas mainly due to lack of knowledge about these varieties and non-availability of seed. The same reasons of low adoption of improved rice varieties were also stated in the study conducted by Jabber and Alam (1993). However, the adoption rates of these two varieties may be higher in other mustard growing areas. Experienced farmers and extension personnel opined that the availability of seeds of short duration T. Aman rice (e.g. BINA Dhan-7), BARI Mustard-14, and BARI Mustard-15 could bring revolution in mustard cultivation in Bangladesh.

Table 3. Percent of adoption of crop management technologies used in mustard cultivation.

Technology	Manikgonj *(n= 180)*	Rajshahi *(n= 180)*	Dinajpur *(n= 180)*	All area *(n=540)*	Adoption level
Ploughing and laddering (No.)					
Recommended no. (4-5)	10.0 (18)	3.3 (6)	40.6 (73)	18.0 (97)	Low
Below recommendation (2-3)	90.0 (162)	96.7 (174)	45.0 (81)	77.2 (417)	
Above recommendation (>5)	--	--	14.4 (26)	4.8 (26)	
Seed sowing period					
*(Mid October-mid November)	98.3 (177)	90.0 (162)	33.9 (61)	74.1 (400)	High
Above recommendation	1.7 (3)	10.0 (18)	66.1 (119)	25.9 (140)	
Seed sowing method					
Broadcasting	100.0 (180)	100.0 (180)	92.8 (167)	97.6 (527)	High
Line sowing	--	-	7.2 (13)	2.4 (13)	
Seed rate (kg/ha)					
Recommended rate (6-7)	13.3 (24)	5.6 (10)	10.6 (19)	9.8 (53)	Low
Below recommendation(1-5.4)	2.8 (5)	0.6 (1)	8.9 (16)	4.1 (22)	
Above recommendation (>7)	83.9 (151)	93.9 (169)	80.6 (145)	86.1 (465)	
No. of irrigation					
Recommended (2 times)	36.7 (66)	--	2.8 (5)	13.1 (71)	Low
Below recommendation	30.6 (55)	3.3 (6)	42.8 (77)	25.6 (138)	
Above recommendation	5.6 (10)	--	--	1.9 (10)	
No. of weeding					
Recommended (2 times)	--	--	--	--	Low
Below recommendation	10.6 (19)	3.9 (7)	--	4.8 (26)	
Above recommendation	--	--	--	--	
Pest control					
Do not use pesticides	73.9 (133)	75.0 (135)	41.1 (74)	63.3 (342)	--
Used pesticides	26.1 (47)	25.0 (45)	58.9 (106)	36.7 (198)	

Note: Figures in the parentheses indicate number of farmers responded.

*Indicate recommended period; Adoption level: 70-100% as high; 50-69% as medium; & <50% as low.

Source: Field survey, 2011-12.

Technology used in mustard cultivation

Land preparation includes ploughing, laddering and other operations needed to make the soil suitable for sowing seeds. The mustard growing farmers in the study areas ploughed their lands using power tiller. The number of plowing and laddering varied from farm to farm and location to location. Only 18% mustard farmers followed recommended number of ploughing (4-5 times). Most of them (77.2%) ploughed their lands 2-3 times. Therefore, land preparation secured low level of adoption. The highest percentage of mustard growing farmers (96.7%) at Rajshahi district ploughed lands with the below recommendation level (Table 3).

In the case of mustard, the recommended period of seed sowing is mid October to mid November. 74.1% mustard farmers sown seeds within recommended period and 25% farmers sown seed within the 1^{st} & 2^{nd} week of October. The highest percentages (98%) of farmers at Manikgonj district followed the recommended period of sowing. The time of seed sowing was highly adopted because farmers found it convenient to sow during the available range of time. Two types of sowing method were followed for mustard production. Most of the farmers (98%) followed broadcast method for sowing mustard seed. The recommended seed rate for mustard is 6-7 kg/ha. About 86.1% farmers used higher amount of seed than the recommendation level (Table 3).

Two times irrigation, one is after 15-20 days of seed emergence and the other one is during flowering stage, is recommended for achieving higher productivity of mustard. Most of the sample farmers of Dinajpur district (72.8%) were found to irrigate their crop. About 97% farmers of Manikgonj district did not irrigate their crop because of rainfall initiated in the early stage of production. The majority of mustard farmers under all the study locations did not weed their crop. About 37% farmers used pesticides to control insects like aphid and cutworm. The highest proportion of (65%) farmers in Dinajpur district applied pesticide to control insects (Table 3).

Farmers' responses on the use of manure and fertilizer in Tori-7 and improved mustard cultivation are presented in Tables 4 and 5. The recommended fertilizer doses are different for Tori-7 and improved varied mustard cultivation. The use of manure and fertilizers by sample farmers varied from location to location. Mustard growing farmers often do not follow the recommendations in applying manure and fertilizers. They tended to use manure and fertilizers either in excess or in very small quantities. In the study areas, both adopter and non-adopter of improved mustard growing sample farmers applied different chemical fertilizers such as Urea, TSP, MoP, Gypsum, and Boric acid in lower quantity compared to the recommended doses. Only zinc oxide was applied in excess quantity than the recommended dose. Therefore, the level of overall adoption of chemical fertilizers was low at farm level. Again, about 7% respondent mustard growing farmers used manure (cowdung) following recommended dose, whereas 37.3-42.1% sample farmers applied manure lower quantity compared to the recommended level. Therefore, the level of adoption of manure was found to be low at farm level (Table 4 and 5).

Table 4. Farmers' practice on using manure and fertilizer in improved variety mustard cultivation.

Particular	% of farmers used manure and fertilizers				Adoption level
	Manikgonj (n=72)	Rajshahi (n=54)	Dinajpur (n=91)	All area (n=217)	
Cowdung (ton/ha)					
*8-10 ton/ha	13.2 (12)	1.4 (1)	3.7 (2)	6.9 (15)	Low
Below recommendation	38.5 (35)	16.7 (12)	63.0(34)	37.3 (81)	
Above recommendation	26.4 (24)	--	--	11.1 (24)	
Urea (kg/ha)					
*250-300 kg/ha	7.0 (5)	--	2.1 (2)	3.2 (7)	Low
Below recommendation	86.1 (62)	98.1 (53)	90.1 (82)	91.7(199)	
Above recommendation	7.0 (5)	1.8 (1)	5.4 (5)	5.1 (11)	
TSP (kg/ha)					
*170-180 kg/ha	4.2 (3)	--	1.1 (1)	1.8 (4)	Low
Below recommendation	41.7 (30)	42.6 (23)	61.5 (56)	50.2(109)	
Above recommendation	34.7 (25)		18.7 (17)	19.3 (42)	
MoP (kg/ha)					
*85-100 kg/ha	5.6 (4)	5.5 (3)	19.8 (18)	11.5 (25)	Low
Below recommendation	37.5 (27)	66.7 (36)	40.7 (37)	46.5(101)	
Above recommendation	12.5 (9)	9.3 (5)	54.9 (50)	29.5 (64)	
Gypsum (kg/ha)					
*150-180 kg/ha	--	5.6 (3)	4.3 (4)	2.8 (6)	Low
Below recommendation	33.3 (24)	35.2 (19)	29.7 (27)	32.3 (70)	
Above recommendation	6.9 (5)	3.7 (2)	8.8 (8)	6.9 (15)	
Zinc (kg/ha)					
*5-7 kg/ha	4.2 (3)	1.8 (1)	1.1 (1)	2.3 (5)	Low
Below recommendation	1.4 (1)	--	5.4 (5)	2.8 (6)	
Above recommendation	5.6 (4)	5.6 (3)	26.4 (24)	14.3 (31)	
Boron (kg/ha)					
*10-15 kg/ha	5.6 (4)	1.8 (1)	9.9 (9)	6.5 (14)	Low
Below recommendation	8.3 (6)	9.3 (5)	16.4 (15)	12.0 (26)	
Above recommendation	1.4 (1)	5.6 (3)	3.3 (3)	3.2 (7)	

Note: Figures in the parentheses indicate number of farmers responded

*Recommended dose; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

Source: Field survey, 2011-12.

Table 5. Percent of non-adopters used manure and fertilizer in mustard cultivation.

Particular	Manikgonj (n=108)	Rajshahi (n=126)	Dinajpur (n=89)	All area (n=323)	Adoption level
Cowdung (ton/ha)					
*8-10 ton/ha	22.5 (20)	0.9 (1)	0.8 (1)	6.8 (22)	Low
Below recommendation	50.6 (45)	9.3 (10)	64.3 (81)	42.1 (136)	
Above recommendation	46.1 (41)	--	--	12.7 (41)	
Urea (kg/ha)					
*200-250 kg/ha	39.8 (43)	4.0 (5)	7.8 (7)	17.0 (55)	Low
Below recommendation	46.3 (50)	93.7 (118)	89.9 (80)	76.8 (248)	
Above recommendation	13.8 (15)	1.5 (2)	1.1 (1)	5.5 (18)	
TSP (kg/ha)					
*150-170 kg/ha	7.4 (8)	0.7 (1)	3.3 (3)	3.7 (12)	Low
Below recommendation	51.6 (55)	34.1 (43)	78.6 (70)	52.0 (168)	
Above recommendation	23.1 (25)	1.6 (2)	12.4 (11)	11.8 (38)	
MoP (kg/ha)					
*70-85 kg/ha	30.6 (33)	19.8 (25)	12.4 (11)	21.4 (69)	Low
Below recommendation	39.0 (42)	44.4 (56)	31.5 (28)	39.0 (126)	
Above recommendation	21.3 (23)	6.3 (8)	46.1 (41)	22.3 (72)	
Gypsum (kg/ha)					
*120-150 kg/ha	4.6 (5)	6.33 (8)	1.1 (1)	4.3 (14)	Low
Below recommendation	25.0 (27)	2.8 (3)	1.1 (1)	23.5 (76)	
Above recommendation	11.1(12)	8.0 (10)	2.2 (2)	7.4 (24)	
Zinc (kg/ha)					
*5-7 kg/ha	--	--	--	--	Low
Below recommendation	--	0.8 (1)	4.5 (4)	1.5 (5)	
Above recommendation	11.1 (12)	13.5 (17)	27.0 (24)	16.4 (53)	
Boron (kg/ha)					
*10-15 kg/ha	5.6 (6)	3.2 (4)	6.7 (6)	5.0 (16)	Low
Below recommendation	5.6 (6)	7.1 (9)	20.2 (18)	10.2 (33)	
Above recommendation	2.8 (3)	3.2 (4)	2.2 (2)	2.8 (9)	

Note: Figures in the parentheses indicate number of farmers responded

*Recommended dose; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

Source: Field survey, 2011-12.

Determinants of adoption of improved mustard varieties

The adoption of improved mustard varieties was likely to be influenced by different socio-economic factors. Data in Table 6 show that farm size, family labor, training on oilseed, influences of neighbor, influences of SAAO, cosmopoliteness, and extension contact had positive and importantly influence on the adoption of improved mustard varieties in the study areas.

Marginal coefficient indicate that if farm size increased by 100%, the probability of adopting improved mustard varieties would increase at 0.017%. Again, if the number of family labor increased by 100% the probability of adopting improved mustard varieties would increase by 1.01%. The coefficients of seed availability, influences of SAAO, cosmopolitness, and extension contact were positive and significant. If these variables increase by 100% the probability of adopting improved mustard varieties would increase by 13.26%, 14.67%, 5.06%, and 1.18% respectively (Table 7).

Table 6. Maximum likelihood estimates of variable determining adoption of improved mustard varieties among respondent farmers.

Explanatory variable	Coefficient	Standard Error	z-statistic	Probability
Constant	-3.70295***	0.413278	-8.96	0.000
Farm size (decimal)	0.00045*	0.0002515	1.80	0.072
Family labour (number/ha)	0.02763***	0.0045008	6.14	0.000
Training on oilseed (number)	0.09835	0.1206966	0.81	0.415
Availability of HYV seed (score)	0.36302***	0.0902197	4.02	0.000
Influences of neighbour (score)	0.07377	0.0740819	1.00	0.319
Influences of SAAO (score)	0.40150***	0.0699717	5.74	0.000
Farmers' cosmopolitness (score)	0.13839**	0.0607972	2.28	0.023
Extension contact (score)	0.03230**	0.0150383	2.15	0.032

Note: Number of observation = 537; LR chi-square (8) = 321.6; Log likelihood = -190.47736;

'***' '**' & '*' represent significant at 1%, 5% and 10% level respectively

Higher score value represents the higher probability of improved variety adoption

Source: Field survey, 2011-12.

Table 7. Marginal effect of the variables determining adoption of improved mustard varieties among respondent farmers.

Explanatory variable	Dy/dx	Standard Error	z-statistic	Probability
Farm size (decimal)	0.000165*	0.00009	1.80	0.071
Family labour (number/ha)	0.010094***	0.00167	6.04	0.000
Training on oilseed (number)	0.035930	0.04414	0.81	0.416
Availability of HYV seed (score)	0.132622***	0.03307	4.01	0.000
Influences of neighbour (score)	0.026949	0.02699	1.00	0.318
Influences of SAAO (score)	0.146682***	0.02669	5.50	0.000
Farmers' cosmopolitness (score)	0.050557**	0.02218	2.28	0.023
Extension contact (score)	0.011799**	0.00551	2.14	0.032

Note: '***' '**' & '*' represent significant at 1%, 5% and 10% level respectively

Farmers' attitudes toward mustard cultivation

The respondent farmers were asked to mention the possibility of devoting more area for improved mustard cultivation. In the case of adopters, almost 52% of the mustard farmers showed their interest to increase mustard cultivation in the next year. In the case of non-adopters, 46.65% farmers showed their interest to expand mustard cultivation. About 48% adopter and 52% non-adopter indicated that they would not increase mustard area in the next year. Although mustard is a profitable crop, 50.19% farmers will not increase mustard cultivation in the next year due to various reasons (Table 8).

Table 8. Farmers' perceptions regarding further increase or decrease of area under mustard cultivation in the next year,

Particulars	% of farmers opined		
	Adaptor (*n=197)*	Non-adaptor (*n=343)*	All category (*n=540)*
1. Increase	51.78	46.65	48.52
2. Not increase	47.72	51.60	50.19
3. Decrease	0.51	1.75	1.30

Source: Field survey, 2011-12

The highest percentage of the sample mustard growing farmers mentioned their willingness to expand their mustard areas for the next year due to higher yield and good price of the produces. They also mentioned various reasons behind their eagerness to increase mustard cultivation in future. The reasons were low cost but high profit, easy cultivation and needs les labour, available lands for mustard cultivation (Table 9).

Table 9. Farmers' reasons for increasing mustard cultivation in the near future.

Reasons for devoting more area	% of responses (*n=540)*
1. Higher yield and get good product price	38.9
2. Low cost but high profit	34.1
3. Easy cultivation and needs less labour	14.6
4. Availability of cultivable land	3.9
5. Others*	3.1

*Create new cropping pattern, invest mustard income on *Boro* cultivation, less attack of insects, early soil moisture, and family consumption.

Source: Field survey, 2011-12

Some adopters and non-adopters mustard farmers mentioned various reasons for not expanding their area in the next year. The important reasons were scarcity of cultivable land as they need to grow other crops. A very small percentage of respondent farmers mentioned about higher cost of production which is considered to be a barrier toward expansion of mustard cultivation in the next year. This reason is not significant because most farmers mentioned that mustard cultivation requires lower cost compared to other crops. About 10.2% farmers mentioned that mustard cultivation is less profitable compared to maize, onion, carrot and vegetables. Some farmers did not want to increase mustard cultivation because it hampers *Boro* rice cultivation due to lack of short duration improved variety (Table 10). A small number of adopter and non-adopter farmers also mentioned some reasons for decreasing their area for the next year. The reasons were scarcity of suitable cultivable land as they need to grow other crops.

Table 10. Reasons for not increasing oilseed cultivation in the next year.

Reasons for not increasing	% of responses (*n=540)*
1. Scarcity of cultivable land	19.6
2. Higher cost of production	2.6
3. Lack of irrigation facility	0.9
4. Scarcity of improved short duration seed	0.9
5. Increase rice cultivation	2.4
6. Others*	4.8

*Delay in *Boro* rice production, lack of short duration variety seed, foggy weather, decrease soil fertility due to use same cropping pattern repeatedly, increase rice cultivation, and lack of irrigation facility.

Source: Field survey, 2011-12.

Facility needed for increasing mustard cultivation

Some of the respondent farmers mentioned some facilities that need to be created for them to expand mustard area in the near future. Their demanded needs are displayed in Table 11.

The availability of cultivable land is very much important for growing or expanding area for mustard. About 20.4% farmers opined in favour of devoting area for mustard cultivation for the next year if they can manage more cultivable land through lease or mortgage. Availability of short duration improved mustard variety is a pre-requisite for expanding mustard cultivation throughout the country. Many farmers also demanded short duration T. Aman rice variety so that they can harvest Aman rice early and cultivate mustard in between T. Aman and Boro rice cultivation.

Good quality seeds, fertilizers and pesticides are important inputs for producing mustard profitably. Therefore, these inputs should be available to the farmers at lower price. A good segment of the sample farmers opined in favour of reducing the input price (Table 11).

Farmers need cash money at the time of cultivation. So, institutional credit facilities should be made available at the right time to the farmers to encourage them in producing more crops. Some mustard farmers wanted easy access to institutional credit facilities with easy terms and conditions since the rate of interest of non-institutional credit is very high.

Irrigation is an important input for crop production. It helps increasing crop productivity to a great extent. Most of the study areas are facilitated with irrigation. But mustard farmers are often constrained by the frequent load shedding of electricity that hampers their crop production practices. Nevertheless, some farmers till do not have adequate irrigation facility. Therefore, they have demanded this facility in the study areas.

Product price is very much important to the mustard farmers for higher production. Some of adopter and non-adopter mustard farmers opined that they could not receive fair prices of their produces.

Training is an important tool that enhances knowledge and skill of the farmers. It is noted that a small percentage of mustard farmers approached for receiving hand-on training on oilseed production. Farmers also proposed some other facilities such as short duration variety of T. Aman rice (BINA Dhan-7); cooperation from extension personnel; crop threshing machine; low cost of plough; removal of water logging problem; and storage facility (Table 11).

Table 11. Facilities demanded by the sample farmers for increasing oilseed cultivation.

Facility	% of responses (*n=540)*
1. Availability of more cultivable land	20.4
2. Need short duration and improved varieties	17.0
3. Ensuring lower price of inputs (seed, fertilizer, pesticides & diesel)	12.0
4. Credit facility with easy term	5.7
5. Adequate irrigation facility	2.6
6. Ensuring fair price of the produces	5.2
7. Hand-on training on oilseed cultivation	3.7
8. Others*	9.4

* Short duration variety of *T.Aman* rice, cooperation from extension personnel, low cost of plough, removal of water logging problem, crop threshing machine, removal of labour scarcity, and storage facility.

Source: Field survey, 2011-12

Conclusion and Recommendation

The study assessed the level of adoption of improved mustard varieties along with management technologies at farm level and attitudes towards mustard cultivation. The study revealed the low level of adoptions of the improved mustard technologies at farm level. The lion share of the total mustard areas are planted to BARI old mustard variety (Tori-7). The adoption of improved mustard variety was very low. Different socioeconomic factors, such as family labour, availability of improved seed, farmers' cosmopolitness, and extension contact significantly influence farmers to adopt improved mustard varieties. The majority of the respondent farmers wanted to increase the cultivation of improved mustard varieties in the next year due to higher yield, low cultivation cost, higher profit, and less labour requirement.

In order to increase the adoption of improved mustard varieties at farm level, the Government should ensure the adequate supply of improved and short-duration seeds of mustard and *T-Aman* rice at farm level. Hand-on training on improved mustard cultivation and crop management practices for the mustard growing farmers is also an important factor of adoption and government should take care of it. Existing extension services should be strengthened for higher adoption of mustard technologies. Affordable price of the inputs, fair price of the output, and credit facilities with favourable terms & conditions influence mustard farmers to a greater extent to adopt improved technology. Therefore, Government should take appropriate steps on these aspects so that farmers become enthusiastic toward improved mustard cultivation.

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SOME BIOLOGICAL PARAMETERS OF BRINJAL SHOOT AND FRUIT BORER, *LEUCINODES ORBONALIS* GUENEE (LEPIDOPTERA: PYRALIDAE) ON POTATO IN LABORATORY CONDITION

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Abstract

Studies were made on the biology of brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee feeding on peeled potato tubers as host in the laboratory. It was observed that moths were active at night for mating, oviposition and adult emergence. Adult emergence started just after sunset and it was maximum (88.90%) during the first half of the night. Maximum mating occurred at late night where 90.80% mating occurred in the first night of adult emergence. Oviposition occurred in the second night of emergence when 86.62% of eggs were deposited during the first half of the night. A female laid 288.05 eggs in 2.65 days in summer and 185.55 eggs in 2.70 days in winter. The egg hatching and larval and pupal period of BSFB were 4.13, 10.40 and 6.60 days, respectively in summer and 6.90, 14.50 and 10.65 days in winter. BSFB needs 10.40 and 14.50 days to complete its larval period in summer and winter, respectively. Pupal period lasted for 5-13 days. Life cycle from egg to adult was 17-44 days. The longevity of male and female adult was 3.50 and 6.20 days in summer and 4.85 and 8.90 days in winter. Temperature in two seasons showed variations in the biology of BSFB.

Keywords: Biology, adult longevity, brinjal shoot and fruit borer, mating, oviposition, larval and pupal period.

Introduction

Brinjal (*Solanum melongena* L .) is one of the most popular and year-round vegetable, cultivated widely in Bangladesh and covers about 15% of the total vegetable area of the country (Rahman, 2005) with an average yield of 6.03 t/ha (Anon, 2009). It is the leading vegetable in the country and ranks first among summer and winter vegetables in terms of total acreage and cultivation by small farmers, low income consumers and commercial growers. Brinjal, an economically important commercial crop, is reported infestation by more than 36 pests (Regupathy *et al*., 1997) from the time of its planting to harvest. Among them brinjal shoot and fruit borer is considered to be the most serious pest of brinjal and it has become a very serious production constraint in all brinjal growing countries (Alam *et al*., 2003). It is very difficult to control as it feeds inside the shoots and fruits (Ghosh and Senapati, 2009). Sometimes, the yield

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loss caused by this pest has been estimated more than 85% (Rashid *et al*., 2003) in Bangladesh, 85.8% (Patnaik, 2000) and 75% (Singh *et al*., 2005) in India. Over 95% of farmers recognized BSFB as the most serious pest of brinjal and nearly all of them used only chemical insecticides to combat this pest (Alam *et al*., 2003).

Indiscriminate use of systemic insecticides makes the vegetables poisonous, ecologically unsafe and economically unviable. It is easy to replace the poisonous chemicals with the knowledge of the nature and behaviour of BSFB. Very few farmers had knowledge on the biology of BSFB. Insect control with insecticides and other methods is based on the availability of data on insect biology, ecology and population dynamics. It is important to know the life cycle of an insect so that control mechanisms may be incorporated at the most susceptible stage of the life cycle. It is necessary to understand the biology of BSFB for reducing crop damage. Therefore, the present study has been undertaken to know some biological parameters of BSFB.

Materials and method

The biology of BSFB was studied during March, 2008 to April, 2009 in the laboratory, Department of Entomology, BAU, Mymensingh, Bangladesh. Infested fruits were collected from the unsprayed brinjal field and were kept in tin made tray like open container with dried brinjal leaves (Plate 1). Through completing the larval stage the full fed larvae came out from the infested brinjal fruits and go to pupation in the dried brinjal leaves. A large number of pupae were collected from the tray (Plate 2) and left in a glass jar. The mouth of the glass jar was then covered with a small piece of mosquito net to allow the pupae to develop into adults (Plate 3). After adult emergence, the male and female adult moths were collected from the glass jars. A pair of adults (one male and one female) was transferred into a both side open cylindrical glass jar (Plate 4) containing a few pieces of green papers inside. The inner surface of the glass jar was wrapped with green papers to make the environment of the jar somewhat green like leaves of brinjal. Immediately after transferring the adults both the open ends were covered carefully with small pored net so that the moths were not injured during the process. Mating, adult behavior and oviposition were recorded in the twenty same cylindrical jars. BSFB usually lays eggs on the brinjal leaves and twigs both of which are rough surfaced. In preliminary observation it was also evident that BSFB female prefers to deposit its eggs in a place of rough surface. The fine meshed net was found to be a preferred surface for egg deposition of BSFB. This type of net was used to cover the cylinder with the objective to encourage the females to lay eggs on it. Sugar solution of 5% soaked in cotton was placed inside the cylinder to provide nourishment for the adults during the period of oviposition. The pair of moths was transferred to another similar jar after 24 hours and maintained following the same procedure. This was continued so long the moths survived. Twenty mated females were used separately as 20 replications for recording the egg laying trend. After removal of adults the green papers and the fine meshed net were checked thoroughly for the presence of BSFB egg.

Plate 1: Infested fruits with brinjal leaves.

Plate 2: Collected pupae from the tray.

Plate 3: : BSFB adult emerged from pupae in glass cylinder

Plate 4: One pair of adult (male and female) within the rearing chamber

Plate 5: Egg mass of BSFB

As expected the female laid all the eggs on the net. There was no trace of eggs on the green papers. The eggs on the net were very tiny and visualized properly with the help of magnifying glass. Then these were counted and it was continued until the death of the female. This counting was done at mid night and early in the morning as it was observed to lay eggs after sunset and no eggs were laid in day time. After counting, the net with eggs was placed in a plastic film container and allowed to hatch. For all the batches of eggs, the same procedure was maintained. All the batches of eggs of an individual were added to get the fecundity of the female. Twenty females were observed for laying their eggs (Plate 5). The age specific egg laying pattern of the female was determined. The eggs laid by a female per day from the 1st oviposition day to the last oviposition day were counted daily. The longevity of the adults was recorded also.

Net with eggs were cut into several pieces carefully with minimum damage and kept in plastic film container and allowed to hatch. The eggs were observed for hatching everyday. The time of egg hatching was also recorded. Counting of the number of egg hatching was done from early in the morning to till 2.00 PM. Once the eggs hatched into neonate larvae the duration of the incubation period was recorded. The mean incubation period and percentages of hatching were calculated. After hatching, 40 neonate larvae were released on whole peeled potato with the help of soft hair brush for feeding. Immediately after releasing on the peeled potato the newly hatched larvae were allowed to settle there. In earlier experiment laboratory rearing technique of BSFB on the peeled potato was developed. The development of larvae of each generation was observed. Peeled potato infested with neonate larvae was observed for the development of larvae. Once the larval period is about to be completed, they came out from the host potato. The larval duration was recorded. Pre-pupae were left in a tray with dry leaves of brinjal for pupation to provide favorable environment for pupation. The pre-pupae were observed carefully for any change to become a pupa. All the pre-pupae and pupae were left undisturbed in a tray until the adult emergence. The pupal period was recorded. The total development periods were also recorded. To study the behavior of the adult emergence a number of pupae were kept in a glass cylinder and observed for adult emergence. In a preliminary study in the laboratory it was found that adult started emerging from the pupae just after sunset and continued up to sun rising and no adults emerged in day time. Therefore, the number of adult emergence were recorded at two times viz., mid night and early in the morning. The percentage of adult emergence was calculated at first half and second half of night.

Results and discussion

Mating behavior

BSFB moths were found active at night when the mating took place. As revealed from the preliminary observation that maximum percentage of adult emergence (88.90%) occurred at first half of the night (Table 1). Mating frequency was found to vary with the adult emergence time. The percentage of mating was 90.80 in the night of adult emergence and it was 9.20 in the next night (Table 2). The mean of mating period was 35.02 minutes in summer and 43.27 minutes in winter (Table 3). Singh and Singh (2001a) reported mating more than once in the life span of female which occurred at night or very early hours in the morning. Yasuda and Kawashaki (1994) observed the copulation of male and female at 4.40 AM which lasted for 43 minutes. Das and Islam (1982) showed that the virgin 1-day old females began calling from 18:15 to 23.45 hours and duration was 33 minutes. Kavitha *et al.,* (2008) showed that mating took place on the same or next day after emergence. Prabhat and Johnsen (2000) reported that the feeding and mating activities occurred during night and mating lasted for about 16 minutes. The findings of the above authors supported the present investigation on mating behavior of adult moths of *orbonalis* L.

Table 1. Percentage of adult emergence and oviposition of brinjal shoot and fruit borer in different times of night.

Parameters	First half of the night		Second half of the night	
	Range	Mean± SE	Range	Mean± SE
Adult emergence (%)	84-95	88.90±1.07	5-16	11.10± 1.07
Egg laying (%)	73.83-96.33	86.62±2.53	3.67-26.17	13.38±2.53

Table 2. Percentage of mating and ovipositing female of brinjal shoot and fruit borer in two nights.

Parameters	First night		Second night	
	Range	Mean± SE	Range	Mean± SE
Mating (%)	88-94	90.80±0.59	6-12	9.20±0.59
Egg laying (%)	75-98	85.90±2.88	2-25	14.10±2.88

Oviposition behaviour

Egg laying always occurred at night. Generally oviposition started during the next night after emergence and mating. Maximum percentage of (86.62%) egg laying occurred at first half of the night and rest of them were in the second half of the night (Table 1). There were 85.90% females to start egg laying in the first night and 14.10% were in the second night (Table 2). Although females were found to survive about a week but effective egg laying period was first three days. The eggs were distributed in mass or singly in a scattered form. A range of 40-60 eggs were found in a mass. Singh and Singh (2001b) reported that the female laid eggs within a day or second day after mating. Singh and Singh (2001a) reported that the laying of eggs started on the same day of mating and continued till fourth day with an average preoviposition and ovipositional period 1.35 and 2.09 days, respectively. The number of eggs gradually decreased by each day. The egg laying activities of the female was reported by Prabhat and Johnsen (2000), Alam *et al.*, (2003) and Rahman (2005). The latter author reported that eggs were laid during the later part of the night to the early hours of the morning. Gupta and Kauntey (2007) reported that the average oviposition period of BSFB was 2.46 days. Harit and Shukla (2003) expressed the similar opinion indicating that the female BSFB moth starts laying eggs on the same day or a day after mating. The mean oviposition period was observed in this study was 2.65 days in summer and 2.70 days in winter (Table 3). Harit and Shukla (2003) and Gupta and Kauntey (2007) reported 2.1 and 2.46 days as oviposition period which was similar to the present study. However, all the findings showed that the oviposition period of BSFB is very short. This indicated that the female emerged with full compliment of eggs which were deposited in short time starting as early as possible.

Table 3. Different biological parameters of brinjal shoot and fruit borer in two seasons.

Parameters observed	Summer		Winter	
	Range	Mean± SE	Range	Mean ± SE
Preoviposition period (days)	1.15-1.24	1.21±0.32	1.08-1.21	1.10±0.52
Fecundity (eggs/female)	198-387	288.05±2.32	100-281	185.55±2.52
Oviposition period (days)	1-4	2.65±0.04	1-4	2.70±0.04
Egg hatching period (days)	3.5-4.21	4.13±0.01	5.0-8.0	6.90±0.05
Egg hatching (%)				
Morning	87-95	90.37±1.06	83-94	87.41±0.18
After morning to noon	5-11	9.63±1.06	4-9	12.59±0.18
Overall egg hatching (%)	80-100	94.05±0.30	28-77	60.80±0.68
Larval period (days)	8-16	10.40±0.11	11-25	14.50±0.18
Pupal period (days)	5-9	6.60±0.05	9-13	10.65±0.06
Life cycle (egg to adult) (days)	17-28	21.18±0.14	23-44	31.95±0.21
Longevity of adult (days)				
Male	2-5	3.50±0.05	3-7	4.85±0.06
Female	5-8	6.20±0.05	7-11	8.90±0.07
Mating duration (minutes)	33-45	35.02±2.05	28-50	43.27±1.07

Fecundity and egg viability

After mating the female moth of *L. orbonalis* laid a mean of 288.05 eggs in summer and 185.55 eggs in winter (Table 3). The overall mean percentage of egg hatching was 94.05 (ranged from 80-100%) in summer and 60.80 (ranged from 28-77%) in winter. The egg hatching period ranged from 3.5 to 4.21 ($\bar{x}$ = 4.13) days in summer and 5 to 8 ($\bar{x}$ = 6.90) days in winter. It is important to note that eggs hatched early in the morning. Usually in the morning 90.37% eggs hatched in summer (5.0-7.0 AM) and 87.41% in winter (7.0-9.0 AM). Rest of the eggs hatched at 7:00-14:00 hours in summer and 9:00-14:00 hours in winter (Table 3). Egg laying started just after sunset and no egg was laid during day time.

Singh and Singh (2001a) reported that on an average 174.95 eggs were laid by a female and the viability of eggs was 82.61%. Alam *et al.*, (2003) reported that the number of eggs laid by a female varies from 80 to 253. An adult female laid as few as 8 to as many as 295 eggs during its lifetime with an average of 118 eggs (PhilRice, 2007). Kavitha *et al.*, (2008) reported that the average number of eggs laid by an individual female was 170. The results of the present study showed that the number of eggs laid per female and percentage of egg hatching was higher in summer than the winter which might be due to higher temperature in summer. The number of eggs laid per female and percentage of egg hatching reported by the above authors were lower than that found in summer in present study. However, the data of fecundity in winter is similar to those of the above reports. Environmental conditions influence the biology of many insects including the fecundity.

Larval and pupal development

After hatching, the neonate larvae which were released on the potato tubers bored into the tubers. They completed their larval period on this host. The neonate larva completed its larval period in 10.40 days (8-16 days) during summer and 14.50 days (11-25 days) during winter (Table 3). Rahman (2005) showed that the larval period was 12-15 days during summer while it was 14-22 days during winter season. A larva of *L. orbonalis* completes its larval development in 15-20 days (Talekar *et al*., 1999). The average larval period was 18.66 days (Singh and Singh, 2001a), 12.80 days (Gupta and Kauntey, 2007) and 16.32 days (Kavitha *et al.,* 2008a). It is reported by several authors that BSFB larva completes its total development period in 5 instars. In the present study five larval instars were found during different activities. It became difficult to study the instar wise developmental period in potato host as the left exuvae were not clearly visible due to similarity with the color of potato. For this reason no attempt was made to conduct the study on instar wise development period. Variation of larval developmental period in summer and winter noticed in the present study was solely the influence of higher and lower temperature in these two seasons. The effect of different hosts such as potato used in the present study and different artificial diets used by different authors caused such variation of larval development.

The full fed larvae moved out of the potato tubers to pupate in the supplied dried brinjal leaves, the usual substrate for pupation. The pupal period was 6.60 days (5-9 days) in summer and 10.65 days (9-13 days) in winter (Table 3). Rahman (2005) showed that the pupal period was 7-10 days during summer while it was 13-15 days during winter. Almost similar pupal period was reported by Rahman (2005) and Kavitha *et al.,* (2008) and also by Gupta and Kauntey (2007). It is evident from the present study and reports of other authors that BSFB needs around a week for completion of its pupal period.

Total development period

The total development period (egg-adult) ranged from 17.0 to 28.0 days ($\bar{x}$ =21.18) in summer and 23.0-44.0 days ($\bar{x}$ = 31.95) in winter (Table 3). Mathur *et al.,* (2000) showed that the total development period was found to be 28.2±1.2 days and 37±2.31 days in summer and winter, respectively. A range of 22 to 27 days as total developmental period of brinjal shoot and fruit borer was reported by PhilRice (2007) and a mean of 28.82 days was reported by Gupta and

Kauntey (2007). Singh and Singh (2001a) described the life cycle of the brinjal shoot and fruit borer and showed 26 to 39 days developmental period of BSFB with 10 generations in a year. It is clear from the data that BSFB requires 1.5 times higher periods to complete its development in winter than that of summer. Although the effect of temperature was not studied in this experiment the results indicated that the rate of development of BSFB seemed to be directly proportional to the temperature.

Adult emergence

Most of the adults (88.90%) emerged during the first half of the night and rest of the adults emerged in the second half of the night (Table 1). During the day adults remained inactive on the lower surface of the host leaf and were not usually seen. They were found to be active at night for their mating and oviposition purposes. At night they were mostly active from 20.00h to 22.00h (Alam *et al*., 2003).

Adult longevity

Longevity of male and female of BSFB moth is shown in Table 3. The longevity of female moth was higher than the male moth. The male adult survived in 2-5 days ($\bar{x}$ =3.50) in summer and 3-7 days ($\bar{x}$ =4.85) in winter. The female adult longevity was 5-8 days ($\bar{x}$ =6.20) in summer and 7-11 ($\bar{x}$ =8.90) days in winter (Table 3). Singh and Singh (2001a) reported that the male and female moth of *L. orbonalis* was found to survive on an average for 3.53 days (2-5 days) and 5.80 days (2-8 days). The longevity of male and female was 4.0 days and 7.5 days, respectively (Bang and Corey, 1991). On an average the longevity of adult was 4-8 days reported by PhilRice (2007). Kavitha *et al.,* (2008) reported that the longevity of male and female was 3.50 days and 5.70 days, respectively. Reports on the longevity of male and female BSFB moth by Kavitha *et al.,* (2008) was 3.5 and 5.70 days, respectively which is similar to the results of the present study. As per findings of Gupta and Kauntey (2007) the longevity of BSFB moth was very short which is different from the results of present study as well as reports of other authors. There might be some reasons for such short duration but no single individual moth lived for such short period in the environmental condition of the present study. Adult longevity was longer in winter than summer. Female longevity was about 2-fold higher than the male.

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EFFICACY OF FUNGICIDES IN CONTROLLING BOTRYTIS GRAY MOLD OF CHICKPEA (*Cicer arietinum* L.)

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Abstract

A field experiment was carried out at Regional Pulses Research Station (RPRS), Madaripur during Rabi season of 2011-12 and 2012-13 to evaluate the most effective fungicides in controlling Botrytis Gray Mold (BGM) of Chickpea. Five different fungicides e.g. Propiconazole (Tilt 250 EC), Carbendazim (Bavistin DF), Fenamidone+Mancozeb (Secure 600 WG), Difenoconazole (Score 250 EC), Tebuconazole (Folicure 250 EC) were evaluated under natural condition. Results revealed that among the five fungicides Fenamidone+Mancozeb (Secure 600WG) sprayed at the rate of 1g/L with 7 days interval gave the lowest BGM score of 3.80 and 4.00 in 1-9 scale during 2011-12 and 2012-13 and produced highest yield of 1547 and 1443 kg/ha, respectively. Besides, the highest BGM was scored by the untreated control plot (6.26 and 6.33) and produced the lowest yield of 988 and 853 kg/ha during the two consecutive years.

Introduction

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop in the world and seven most important pulse crops in Bangladesh as per production. Botrytis gray mold (BGM) caused by *Botrytis ceneria* is an important disease of chickpea in northern India, Nepal, Bangladesh and Pakistan. It was first reported in India in 1915 (Shaw and Ajrekar, 1915). Outside the Indian subcontinent the disease has been reported from Argentina (Carranza, 1965), Australia (Nene *et al.,* 1989), Canada (Kharbanda and Bernier, 1979), and Chile (Sepulveda and Alvarez, 1984). It was first documented in 1981 in Bangladesh (Annon., 1981). In Bangladesh, for high infestation of BGM, farmers are reluctant to grow chickpea that results declining of area and production of the crop. The pathogen of the disease is soil, seed and air borne. Different researchers had been taking many efforts to control the disease. Foliar application of fungicides is one of the most important management options to control the disease. Therefore, the experiment has been conducted to find out suitable fungicide to control BGM of chickpea.

Materials and Method

The experiment was conducted at Regional Pulses Research Station (RPRS), Madaripur, Bangladesh during Rabi season of 2011-12 and 2012-13. The experiment was laid out in Randomized Complete Block Design (RCBD) with

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three replications. The five fungicides viz- Propiconazole (Tilt 250 EC, 0.5 ml/L), Carbendazim (Bavistin DF, 2.0 g/L), Fenamidone+Mancozeb (Secure 600 WG, 1 g/L), Difenoconazole (Score 250 EC, 0.5 ml/L), Tebuconazole (Folicure 250EC, 2.0 ml/L) and untreated control were included in the study. The unit plot size was 2.4m × 3m and plant spacing was 50 cm × 10 cm. The seeds of BGM susceptible chickpea variety BARI Chola-1 (Nabin) was treated with Provax-200 to control fusarium wilt and sown on 16 November 2011 and 14 November 2012. Intercultural operations were done manually and herbicides application (Rahman and Miah, 1989). The experiment was monitored regularly to observe the first appearance of BGM. Spraying of fungicides was started when the disease appeared on the crop. Four sprays were applied at weekly interval on 8, 15, 22 and 27 February, 2012 and 3, 10, 17 and 24 February, 2013 respectively by the knapsack sprayer. Data on BGM disease was recorded on three frequencies (18, 25 and 30 February, 2012 and 13, 20 and 27 February, 2013). BGM of chickpea was graded on a 1-9 scoring scale (Singh, 1999). The scale described as 1= no infection on any part of the plant, 2= minute lesions on lower leaves, flowers and pods covered under dense plant canopy, usually not visible, 3= lesions on less than 5% of the leaves, flowers and pods covered and under dense plant canopy, 4= lesions and some fungal growth (conidiophores and conidia) can be seen on up to 15% of the leaves, flowers and pods and branches covered under dense plant canopy, 5= lesions and slight fungal growth on up to 25% of the leaves, flowers and pods, stems and brunches covered under dense plant canopy, 6= lesions and fungal growth on up to 40% of the leaves, flowers and pods, stems and branches defoliation, 25% of the plant killed, 7= large lesions and good fungal growth on up to 60% of the leaves, flowers and pods, stems and branches defoliation common, drying of branches and 50% of the plants killed, 8= large lesions and profuse fungal growth on up to 80% of the leaves, flowers and pods, stems and branches, severe defoliation, drying of branches and 75% of the plants killed, 9= large lesions, very profuse fungal growth on up to 100% of the flowers, pods, stems, branches, almost complete defoliation, drying of plants and 100% of the plants killed. The crop was harvested on 15 March 2012 and 18 March 2013 at matured stage. Data on yield contributing characters recorded from 10 randomly selected plants from each plot. Grain yield (kg/ha) were recorded from the whole plot. The Data were analyzed statistically through MSTAT-C.

Results and Discussion

The fungicides caused sharp variation in percent mortality and severity of botrytis gray mold disease of chickpea in Madaripur during 2011-12 (Table 1). Maximum percent mortality (15.35) was observed in Tebuconazole (Folicur 250EC) treated plot and minimum (7.65) in Difenoconazole (Score 250EC) treated plot. The BGM disease score was found minimum (3.80) in Fenamidone+Mancozeb (Secure 600 WG) treated plot and maximum (6.26) in control plot. The grain yield and yield contributing characters of chickpea were significantly influenced by the test fungicides during 2011-12 cropping season (Table 2). The highest number of branches (4.25) were recorded from Propiconazole (Tilt 250 EC), Fenamidone+Mancozeb (Secure 600 WG) and Tebuconazole (Folicur 250EC) treated plots and lowest (3.20) from Difenoconazole (Score 250 EC) treated plot. Similarly, the highest plant height (45.00cm) was recorded from Difenoconazole (Score 250 EC) treated plot and lowest (33.33 cm) from Tebuconazole (Folicur 250 EC) treated plot. There was no significant differences in pods/plant and seeds/pod due to the application of fungicides in chickpea. However, higher number of pods/plant was observed in case of fungicide treatment over untreated control plot. In case of seeds/pod, Fenamidone+Mancozeb (Secure 600 WG) treated plot produced maximum (1.78) while control plot produced lowest (1.53) seeds/pod. The effect of fungicide was statistically similar in respect of 100 seed weight but differed from the untreated control plot. The 100 seed weight ranged from 11.5-13.0 g among the fungicide treated plot and maximum (13.0 g) was in Fenamidone+Mancozeb (Secure 600 WG) treated plot and minimum (8.9 g) in control plot. Among the five fungicides Fenamidone+Mancozeb (Secure 600 WG) sprayed plot produced highest seed yield (1547 kg/ha) which was statistically similar to that of Propiconazole (Tilt 250 EC) and Difenoconazole (Score 250EC) while the lowest (988 kg/ha) yield was recorded in control plot (Table 2).

Table 1. Efficacy of different fungicides in controlling BGM of chickpea during 2011-12 at Madaripur.

Fungicides	Mortality (%)	BGM Scale (1-9)
Propiconazole (Tilt 250 EC)	9.45	4.73
Carbendazim (Bavistin DF)	8.36	4.76
Fenamidone+Mancozeb (Secure 600 WG)	9.82	3.80
Difenoconazole (Score 250 EC)	7.65	5.00
Tebuconazole (Folicur 250 EC)	15.35	5.33
Control	11.46	6.26
CV(%)	8.85	5.96
LSD (0.05)	5.80	0.53

Values within a column having same letter(s) do not differ significantly (p=0.05); BGM=Botrytis gray mould.

Table 2. Effect of different fungicides on the yield and yield contributing characters of chickpea through suppression of BGM during 2011-12 at Madaripur.

Fungicides	Branch per plant	Plant height (cm)	Pods per plant	Seeds per pod	100 seed weight (gm)	Yield (kg/ha)
Propiconazole (Tilt 250 EC)	4.25 a	41.33 b	47.53	1.73	12.0a	1514 ab
Carbendazim (Bavistin DF)	3.66 a	42.20 ab	41.80	1.33	12.5 a	1433 b
Fenamidone+Mancozeb (Secure 600 WG)	4.25 a	36.80 c	47.93	1.78	13.0 a	1547 a
Difenoconazole (Score 250 EC)	3.20 b	45.00 a	42.67	1.66	12.2 a	1492 ab
Tebuconazole (Folicur 250 EC)	4.25 a	33.33 c	46.33	1.56	11.5 a	1106 c
Control	3.80 a	36.80 c	38.53	1.53	8.9 b	988 d
CV(%)	7.71	10.32	11.13	12.41	8.05	4.07
LSD (0.05)	1.56	6.883	10.18	0.65	43.30	96.35

Values within a column having same letter(s) do not differ significantly (p=0.05).

Percent mortality and botrytis gray mould of chickpea varied among the fungicide treated plots during 2012-13 (Table 3). The mortality (%) was highest (14.63) in Tebuconazole (Folicur 250 EC) treated plot and lowest (7.80) in Propiconazole (Tilt 250 EC) treated plot. The BGM score was lowest (3.00) in Fenamidone+Mancozeb (Secure 600 WG) sprayed plot and where the maximum (6.33) disease severity was found in control plot. Yield and yield contributing characters of chickpea were significantly influenced by the application of fungicides during 2012-13 (Table 4). The number of branches per plant varied from 3.03 to 3.36 and plant height from 31.10 cm to 39.30 cm. The maximum number of branches (3.36) were recorded from Propiconazole (Tilt 250 EC) and maximum height (39.30 cm) was recorded from Carbendazim (Bavistin DF) treated plot. The highest no. of pods/plant (39.17) was observed in Fenamidone+Mancozeb (Secure 600 WG) sprayed plot and lowest (33.63) in control plot. Incase of seeds/pod, Fenamidone+Mancozeb (Secure 600 WG) treated plot produce maximum (1.33) and control plot produced minimum (1.00) number of seeds/pod. The maximum 100 seed weight (12.02 g) was recorded from Fenamidone+Mancozeb (Secure 600 WG) and minimum (10.30 g) from control plot. Among the fungicides Fenamidone+Mancozeb (Secure 600 WG) sprayed plot produced highest seed yield (1443 kg/ha) followed by Propiconazole (Tilt 250EC) and Tebuconazole (Folicur 250EC) with 1370 kg/ha and 1317 kg/ha respectively. The lowest seed yield (853 kg/ha) was produced by control plot (Table 4).

Table 3. Efficacy of fungicides in controlling BGM of chickpea during 2012-13 at Madaripur.

Fungicides	Mortality (%)	BGM scale (1-9)
Propiconazole (Tilt 250 EC)	7.80	3.67
Carbendazim (Bavistin DF)	13.17	4.33
Fenamidone+Mancozeb (Secure 600 WG)	8.34	3.00
Difenoconazole (Score 250 EC)	8.20	3.33
Tebuconazole (Folicur 250 EC)	14.63	5.67
Control	9.53	6.33
CV(%)	7.57	13.34
LSD (0.05)	1.33	0.99

Values within a column having same letter(s) do not differ significantly (p=0.05).

Table 4. Effect of different fungicides on the yield and yield contributing characters of chickpea through suppression of BGM during 2012-13 at Madaripur.

Fungicides	No. of branches /plant	Plant height (cm)	No. of pods/ plant	No. of seeds/ pod	100 seed wt. (g)	Yield (kg/ha)
Propiconazole (Tilt 250 EC)	3.36a	38.37a	38.10a	1.23 ab	12.00 a	1370 ab
Carbendazim (Bavistin DF)	3.23ac	39.30a	37.67a	1.23 ab	11.63 a	1175 bc
Fenamidone+Mancozeb (Secure 600 WG)	3.33ab	38.90a	39.17a	1.33 a	12.02 a	1443 a
Difenoconazole (Score 250 EC)	3.03d	38.47a	38.17a	1.27 a	11.83 a	1048 cd
Tebuconazole (Folicur 250 EC)	3.13cd	31.10c	33.77b	1.07 c	10.83 b	1317 ab
Control	3.33ab	33.30b	33.63b	1.00 c	10.30 b	853 e
CV(%)	2.91	2.43	2.72	6.40	3.62	8.79
LSD (0.05)	0.16	1.55	1.74	0.13	0.72	73.6

Values within a column having same letter(s) do not differ significantly (p=0.05).

Management of plant diseases successfully achieved through application of chemical fungicides. All the tested fungicides reduced the disease score and enhanced plant growth parameters and yield of chickpea in comparison with control plot. The lowest BGM disease score of 3.80 and 3.00 were recorded from the plots sprayed with Fenamidone+Mancozeb (Secure 600 WG) and the highest score of 6.26 and 6.33 were recorded from control plot during 2011-12 and 2012-13, respectively. In 2012-13, the yield of chickpea was less than that of 2011-12 due to attack of pod borer (*Helicoverpa armigera* Hubner). This results in less number of seed/pod in 2012-13. But the BGM infection was comparatively less in the second year due to unfavorable climatic conditions for BGM results in low scoring scale. However, foliar sprays, used at regular intervals with the first appearance of the disease, can control an epidemic in the crop (Pande *et al*., 2002), particularly when used in combination with a seed-dressing fungicide (Grewal and Laha, 1983). Effective fungicides used as a foliar spray 50 days after sowing or with the first sign of the disease include Captan, Carbendazim, Chlorothalonil, Mancozeb, Thiabendazole, Thiophanate-methyl, Thiram, Triadimefon, Triadimenol, or Vinclozolin (Singh and Kaur, 1990; Haware and McDonald, 1992; Bakr *et al*., 1993; Haware, 1998; Knights and Siddique, 2002; Pande *et al*., 2002; Davidson *et al*., 2004). Sometimes multiple sprays are recommended, although generally one spray at flowering followed by another 10 days later on a moderately resistant chickpea cultivar provides the best protection against BGM on chickpea (Pande *et al*., 2002).

Conclusion

Fenamidone+Mancozeb (Secure 600 WG) at 1 g/L water effectively controlled the BGM disease and produced higher yield of chickpea through four sprays at 7 days interval if applied at the first appearance of the disease.

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BRINJAL SHOOT AND FRUIT BORER INFESTATION IN RELATION TO PLANT AGE AND SEASON

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Abstract

Brinjal shoot and fruit borer infestation varied significantly in relation to plant age and season. The peak shoot infestation was 8.56% in the 10th week of transplanting. No infestation of BSFB was found up to 5 weeks of transplanting. The shoot infestation was initiated in the 6th week of transplanting which increased to a little higher level in the next week. Then it showed an exponential increase of shoot infestation up to 10th week after which it declined steadily. Flowering and fruit setting started in the 9th week of transplanting. Infestation of brinjal shoot and fruit borer (BSFB) shifted to fruits from shoots causing a steady declined in the trend of shoot infestation. Plant age had significant effect (r^2=0.87) on fruit infestation. The fruit infestation reached the highest level (38.56%) in 14th week of transplanting. However, the level of infestation at different ages of the plant may vary depending on the location, temperature, variety etc. The shoots and fruits of brinjal plant were found to be infested by BSFB throughout the year, although the level of infestation varied. Maximum shoot and fruit infestation was found in the month of September.

Keywords: Brinjal shoot and fruit borer, *Leucinodes orbonalis*, infestation, plant age, seasonal fluctuation.

Introduction

Brinjal is a versatile and economically important vegetable among small-scale farmers and low income consumers of the entire universe (FAO, 2000). It is the leading vegetable in the country and ranks first among summer and winter vegetables in terms of total acreage. Asia has the largest brinjal production which comprises about 90% of the total production area and 87% of the world production (FAO, 2000). Brinjal, an economically important commercial crop, is reported variedly to be infested by more than 36 pests (Regupathy *et al*., 1997) from the time of its planting to harvest. Among them, brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee is considered to be the most serious pest of brinjal and it has become a very serious production constraint in all brinjal growing countries (Alam *et al*., 2003). The brinjal shoot and fruit borer is the key insect pest of brinjal in Bangladesh (Alam and Sana, 1964), India (Tewari and Sardana, 1990) and other countries of the world (Dhankar, 1988). The fruit infestation by this pest may be as high as 67% (BARI 1991). It is very difficult to control since it feeds inside the shoots and fruits (Ghosh and Senapati, 2009).

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Over 95% farmers recognized BSFB as the most serious pest and nearly all of them used only chemical insecticides to combat (Alam *et al*., 2003). Sometimes, the yield loss caused by this pest has been estimated more than 85% (Rashid *et al*., 2003) and 86% (Ali *et al.,* 1996) in Bangladesh, 85.8% (Patnaik, 2000), 75% (Singh *et al*., 2005) and 95% (Naresh *et al.,* 1986) in India. Brinjal production is seriously affected by damage caused by brinjal shoot and fruit borer (AVRDC, 2001). The management practices mainly include spraying different insecticides which cause several pesticide related complications and leave toxic residues in the fruits, reduce the beneficial arthropods and create pollution of the environment. The vegetable growers of Jessore region spray insecticide almost every day or every alternate day in the brinjal field with as many as 84 times in a season (BARI, 1994). It is now urgently required to find out an alternative and non-insecticidal method for controlling this pest. Frequent use of systemic insecticides makes the vegetables poisonous, ecologically unsafe and economically unviable. It is easy to replace the poisonous chemicals with knowledge through transplanting the seedlings at appropriate time and understanding the knowledge of seasonal fluctuation of temperature and other abiotic factors. Very few farmers had knowledge on the infestation status of BSFB in relation to plant age and seasonal fluctuation of temperature. Therefore, the present study was undertaken to know the effects of plant age of brinjal and seasonal variation on the infestation of BSFB.

Materials and method

An experiment was conducted in the field of Entomology Division, Bangladesh Agricultural University, Mymensingh during September 2008 to October 2009 on the incidence of BSFB in relation to plant age and season. The seedlings were raised in a seed bed. Variety was BARI Begoon 8. The land was prepared by ploughing and laddering and fertilized with organic manure such as cow dung @ 10 m ton/ha, 7 days before final land preparation and chemical fertilizer Urea @ 150 kg/ha, TSP @ 100 kg/ha and MP @ 150 kg/ha. The whole TSP and MP and $^{1}/_{3}$ of Urea were applied during the final land preparation. Rest of the Urea was applied in two splits- one 30 days and other 50 days after planting. The individual plot size was 4.5m × 4.2m. The seedlings were planted in September 2008 and March 2009 with spacing 75 cm in between lines and 60 cm in between plants. Irrigation and other cultural operations were done as and when necessary. Ten plots were made for recording data and each plot was treated as one replication. No control measure was taken except the removal of shoots and fruits at the time of data collection. Infestation of BSFB to the shoots and fruits was monitored weekly after establishment of the plant in the field and continued to the last harvest of the brinjal fruits. Shoot damage was recorded by counting the infested shoots from 10 randomly selected plants. Percentage of shoot damage was calculated from damaged and healthy shoots. The number of infested and healthy brinjal fruits per plot were recorded at each harvest. The percentage of infestation by number was calculated using the number of infested and total brinjal fruits. At each count the affected shoots and fruits were removed and harvested. Incidence of BSFB in different months was calculated from the pooled weekly data. The correlations between seasonal incidence and environmental factors such as temperature, humidity and rainfall were determined.

Results and Discussion

Infestation level of BSFB with plant age: After transplanting the brinjal seedlings, it was monitored weekly for BSFB infestation. Infestation by BSFB was different in plant of different ages (Figure 1). The peak shoot infestation was 8.56% in the 10th week of transplanting. No infestation of BSFB was found up to 5 weeks of transplanting. The shoot infestation was initiated in the 6th week of transplanting which increased to a little higher level in the next week. Then it showed an exponential increase of shoot infestation up to the 10th week after which it declined steadily. Flowering and fruit setting started in the 9th week. Infestation of BSFB shifted to fruits from shoots causing a steady decline in the trend of shoot infestation. There was no significant correlation (r^2=0.17) between plant age and shoot infestation.

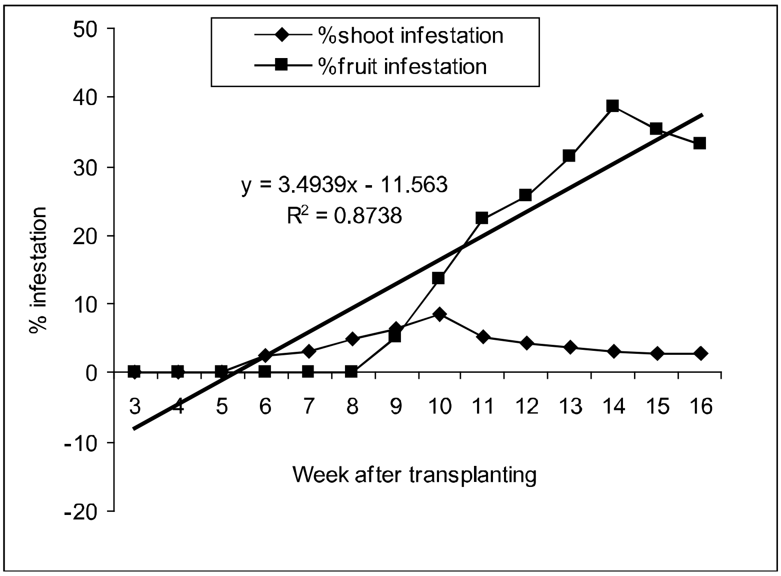

Figure 1. Effect of plant age on the infestation of *L. orbonaliS*

On the other hand, plant age had significant effect (r^2=0.87) on fruit infestation which started in 9th week of transplanting and showed 5.13% infestation. Then the fruit infestation increased rapidly showing a distinct increasing trend. The fruit infestation reached to its highest level (38.56%) in 14th week of transplanting. Thereafter, a little decline of fruit infestation was observed. It is evident that older plants suffered far more from the attack of BSFB and caused higher damage to the brinjal plants especially to the fruits. However, the level of infestation at different ages of the plant may vary depending on the location, temperature, variety etc. Therefore, in the early stage of the plant growth the pest BSFB is not a serious problem to brinjal cultivation. The management option should be selected depending on the level of BSFB infestation. In general, the brinjal growers may not need to adopt any chemical control measures until the plant reaches its maximum vegetative stage or pre-flowering stage as the commencement of infestation is noticed during that stage.

Several authors reported that the infestation of BSFB depends on plant age. Hossain *et al.*, (2002) reported that plant age had significant effect on the incidence of brinjal shoot and fruit borer. They showed the highest infestation (32.80%) of BSFB at 70 days after transplanting which was statistically different from the infestation (5.18%) at 40 days after transplanting. They also reported that the rate of infestation gradually increased with the increase of plant age and then decreased in 100 days (31.70%) after transplanting. Naik *et al.*, (2008) showed the initial infestation of BSFB at 51 days after transplanting and thereafter the infestation gradually increased from 10.2 to 82.4% of shoot damage. It required 74 days after transplanting to reach a peak incidence of BSFB. Thereafter declined gradually with rise in temperature. In the present study the maximum shoot damage was found as 8.56% while Sharma and Chhibber (1999) reported that shoot damage was 15.89% at 29 days after transplanting of brinjal. The present finding on BSFB shoot infestation is different from the reports of Sharma and Chhibber (1999). It is noted that BSFB needs good vegetative growth of the plants for its infestation.

The level of BSFB infestation reported by Hossain *et al.*, (2002) was 31.70% at 100 days after transplanting which is similar to the results of present study as it was recorded 31.25% fruit infestation at 91 days (13 weeks) after transplanting. The initial infestation of BSFB reported by Naik *et al.*, (2008) was 51 days after transplanting which was near to 42 days (6 weeks) in the present study. The maximum shoot infestation was observed at 70 days (10 weeks) after transplanting in the present study which was also supported by Naik *et al.*, (2008) although the level of infestation was different.

The results of the present study and the findings of above authors clearly indicate that the infestation of BSFB has relationship with the plant age showing higher pest incidence with the progress of plant growth. In other words, it can be said that infestation level is higher with sufficient vegetative growth of the plant and the presence of fruiting bodies.

Seasonal incidence of *L. orbonalis*

The seasonal incidence of BSFB throughout the year in terms of shoot and fruit infestation is shown in Figure 2. Observation on the seasonal incidence of BSFB started in the month of September 2008 and continued up to October 2009. It was found that the level of fruit infestation was always higher than that of shoot infestation. The shoots and fruits of brinjal plant were found to be infested by BSFB throughout the year although the level of infestation varied. The shoot infestation was only 1.33% in January which was very similar in February. Then it started to increase steadily up to the month of September when maximum shoot infestation was observed. Then a marked decline was observed in October which showed a further slow decline thereafter up to the month of December.

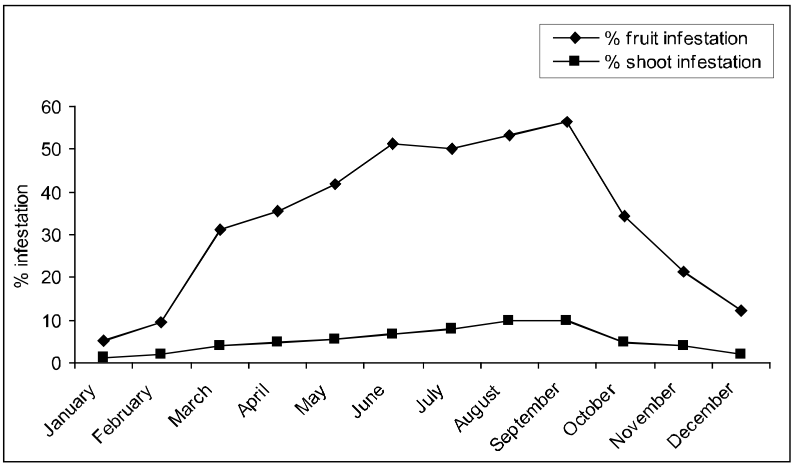

Figure 2. Seasonal incidence of *L. orbonalis* in unsprayed brinjal field

The incidence of BSFB in fruits was calculated on the basis of the infestation of marketable size of the fruits. The fruit infestation was found 5.26% in the month of January which was minimum. Then a slight increase was found in the month of February which followed a sharp increase in March reaching 31.27%. Thereafter the infestation of fruit was found to show a more or less steady increase up to the month of September when it reached its peak (56.38%). Then a certain drop of infestation level occurred in the next month and reached to a significantly lower level as the winter progressed. In the month of December the level of infestation was found 12.25%.

In addition, it was observed that a large number of flowers, flower buds and very young fruits were infested and damaged totally which were not included in the data. If they were included the level of fruit infestation would be much higher as it is evident in the Figure 3. The variation of BSFB infestation in shoots and fruits might be due to several abiotic and biotic factors. The temperature and rainfall had significant effect on the infestation level of brinjal shoot and fruits (Figure 4 and 5), although relative humidity had no significant effect.

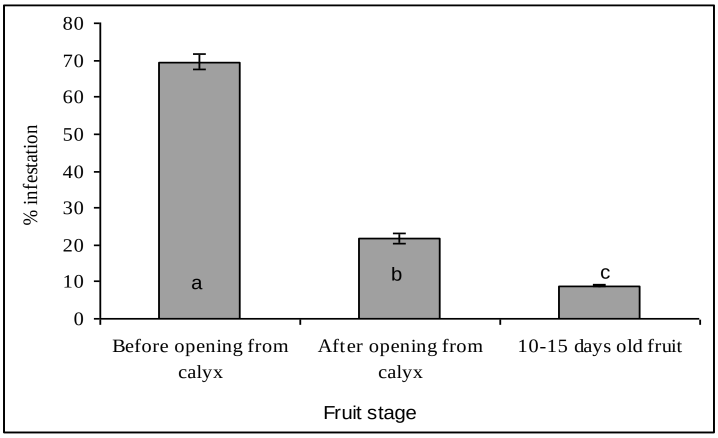

Figure 3. Percentage of BSFB infestation at different fruiting stages. Vertical bars represent ±SE. Different letter(s) in different bars represent the significant difference (p≥ 0.01)

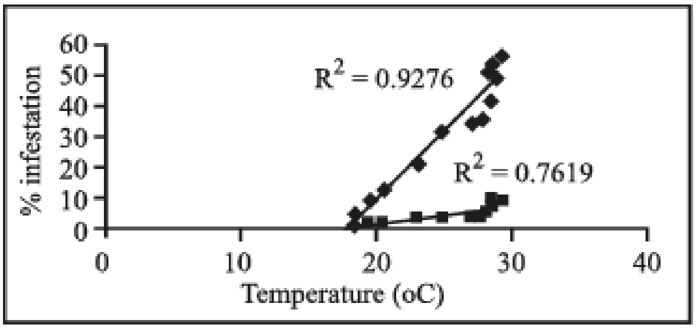

Figure 4. Relationship between temperature and the level of infestation of brijal shoots and fruits.

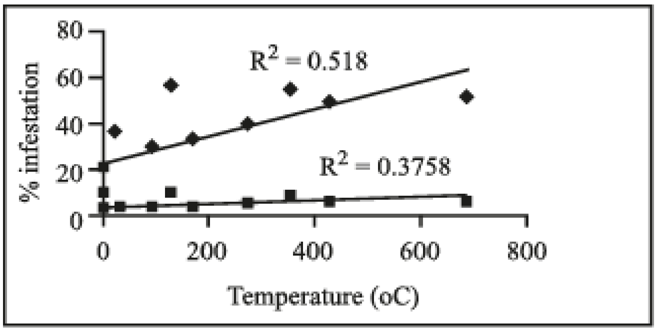

Figure 5. Relationship between rainfall (mm) and the level of infestation of brinjal shoots and fruits.

Naik *et al.,* (2008) reported that incidence of *L. orbonalis* in terms of shoot infestation starts in February and there was no significant relationship of BSFB infestation with the temperature, RH and rainfall. Singh *et al.,* (2000) reported that BSFB infestation was more serious on shoots during September to October ranging 73.33% to 86.66% with an intensity of 2.09 borers/plant when it reached the peak. They demonstrated a continuous decline of shoot infestation even to zero level in the month of October. This decline was related to the initiation of flowering and at this critical stage the borer infestation shifted from 33.33% to 66.66% in flowers and shoots which subsequently showed a greater decrease with the advent of winter season. Mahesh and Men (2007) reported that the infestation commenced from August with 21.2% infestation and reached its peak during mid-October with 35.3% infestation at temperatures ranging between 21.4 and 33.0^0 C, relative humidity of 45-86% with 2.7 mm rain and hot sunshine.

Although it was revealed that BSFB was prevailing in the brinjal field throughout the year, the level of infestation varied with the months and seasons of the year. The borer infestation was found to be very low during the winter months (December-February) which increased markedly in the summer months which was supported by Alam *et al.,* (2006). They reported that summer brinjal crops suffered much greater pest damage than winter crops. Rashid *et al.,* (2003) reported that *L. orbonalis* is difficult to control in the open field during summer time. The maximum level of borer infestation was found from June to September ranging from 51.35 to 56.38% when the average temperature, RH and rainfall were 28.74^0C, 87.77% and 400.28 mm, respectively.

The trend of BSFB infestation found in present investigation has similarity with the findings of Singh *et al.,* (2000) and Mahesh and Men (2007) although the level of infestation was different. The seasonal variation of the pest level is common in many insects mostly for their poikelothermic developmental nature i.e., the development is directly proportional to the environmental temperatures. The variation of level of pest incidence in summer and winter may have the relationship with the biotic factors especially some parasitoids of BSFB. Although no attempt was made to investigate the synchronization between the pest and parasitoids in different environmental conditions, it was assumed that the tiny parasitoids were not able to withstand in the environmental condition when the rainfall was high during the month of June to September.

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PROFITABILITY OF BETEL LEAF (*Piper betle* L.) CULTIVATION IN SOME SELECTED SITES OF BANGLADESH

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M. S. Hoq[4] and Moniruzzaman[5]

Abstract

The study was conducted in four betel leaf growing areas, namely Barisal, Chittagong, Rajshahi and Kustia district during 2013-14 to assess the cultivation practices, physical productivity, profitability, and to explore the constraints to betel leaf cultivation. The study has been designed to investigate the economics of betel leaf production considering intensive cultivated areas for recent information in Bangladesh. From each district, two upazilas were selected considering the concentration of betel leaf growers and easy access. Also from each upazila, two blocks and from each block 20 farmers were selected with the consultation of Upazila Agriculture Officer and Sub Assistant Agriculture Officer. The study revealed that betel leaf cultivation was profitable in the study areas, although BCR in the first and second years was below one which was due to high initial cost. The highest yield and gross return of betel leaf cultivation were in the fifth year. The benefit cost ratio was found highest in 6-10 year followed by 5th and 11-15 year. The benefit cost ratio at 12%, 15% and 20% rate of interest were 1.27, 1.25 and 1.21 respectively. Internal rate of return (IRR) was calculated 62% in current situation, IRR 37% was found by 10% decrease of return and 39% by 10% increase of cost. The problems like leaf rot disease, high price of boroj materials, low price of betel leaf, high price of oilcake, etc. were facing by the betel leaf farmers.

Keywords: Betel leaf, BCR, IRR, NPV, Constraints.

Introduction

Betel leaf (*Piper betle* L.), locally known as *Paan*, is a masticatory having important socio-cultural and ceremonial uses in South and Southeast Asia, significant medicinal properties and nutritional values. The vine is native to Southeast Asia including Bangladesh which is thought to be one of the cradles of earliest agriculture. The betel leaf plant is an evergreen and perennial creeper, with glossy heart-shaped leaves and white catkin. It is a native of central and eastern Malaysia, which spread at a very early date throughout tropical Asia and later to Madagascar and East Africa (www.efymag.com/ admin/issuepdf/ Betel%20Leaf_April-12.pdf).

Betel leaf a kind of pepper used in wrapping the pellets of betel nut and lime, is commonly chewed in the orient. Betel leaf is an important cash crop in our

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country and is considered to be one of the ingredients for social entertainment. It has also a sharp taste and good smell, improves taste and appetite, tonic to the brain heart, liver, strengthens the teeth and clears the throat.

Table 1: Area and production of betel leaf in Bangladesh

Year	Area (ha)	Production (tons)	Yield (t/ha)
1995-96	13943	71910	5.16
1996-97	14595	77035	5.28
1997-98	14832	79080	5.33
1998-99	13820	73525	5.32
1999-00	15063	78780	5.23
2000-01	15346	82260	5.36
2001-02	14696	80540	5.48
2002-03	15472	83830	5.42
2003-04	16480	93425	5.67
2004-05	16771	93820	5.59
2005-06	16275	97415	5.99
2006-07	16536	101240	6.12
2007-08	17346	97947	5.65
2008-09	17643	105448	5.98
2009-10	17871	91681	5.13
2010-11	18247	105953	5.81
Mean	15934	88368	5.53
CV (%)	8.84	12.81	5.63
Growth rate (%)	1.80	2.50	0.70

Source: BBS, 2011

In 2010-11, the total betel leaf area was 18,247 ha (31% higher than the area in 1995-96) with a production of 1,05,953 tons (47% higher than the production in 1995-96) in Bangladesh. The area of this crop has been increasing at an increasing rate (1.8%) over the years (Table 1). Betel leaf has become a promising commodity with an increasing trend of export every year (Anonymous, 1984).

The country may earn a huge amount of foreign currency every year by exporting betel leaf in different countries. However, data and information regarding betel leaf production and the status of local and international marketing system are scarce in the country. A very few studies were conducted (Ahmed, 1985; Islam and Elias 1991 and Moniruzzaman, *et. al* 2008) regarding the profitability and constraints to higher production as well as export potentiality of betel leaf production in Bangladesh. Earlier studies were conducted very limited areas and back dated. Thus, the present study has been designed to investigate the economics of betel leaf cultivation considering intensive cultivated areas. This study provides useful information to the policy makers to make policy guidelines for enhancing its production as well as its overall development in the near future. Therefore, the present study was undertaken with the following specific objectives:

1. To know the agronomic practices of betel leaf at growers level.
2. To determine the cost and return of betel leaf cultivation.
3. To estimate physical productivity and returns to investment in betel leaf cultivation, and
4. To find out the constraints of betel leaf cultivation at farm level.

Methodology

Study area and sampling technique: Multi-stage sampling technique was followed in this study. Four betel leaf growing districts namely Barisal, Chittagong, Rajshahi and Kustia were purposively selected. Again from each district, two upazilas were selected considering the concentration of betel leaf growers and easy access. Also from each upazila, two blocks were selected with the consultation of Upazila Agriculture Officer. A list of betel leaf growers from the selected blocks was prepared with the help of DAE personnel. Thus a total of 4×2×2×16 = 256 samples were randomly selected for the interview.

Data collection and period of study: Experienced field investigators with the direct supervision of the researchers collected data and information using a pre-tested interview schedule. Data were collected during the period of November to April, 2013-14.

Analytical technique: (a) Tabular method of analysis using descriptive statistics like average, percentage, ratio etc. was followed in presenting the results of the study. Data were categorized according to the age of betel leaf boroj. The age of the boroj were classified like 1st year, 2nd year, 3rd year, 4th year, 5th year, (6-10)th year, (11-15) th year and (16 and above) th year. Because both cost of production and yield were vary year to year. Collected data were edited, summarized, tabulated and analyzed to fulfill the objectives of the study. (b) To measure the return to investment of betel leaf cultivating project appraisal technique. For measuring capital productivity, costs and returns were discounted at 12 %, 15% and 20% rate of interest. The Benefit cost ratio (BCR), Net present value(NPV) and Internal rate of return(IRR) in betel leaf cultivation were calculated with the help of following formula.

$$\text{Net present Value} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

$$\text{Benefit cost ratio} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+t)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

$$\text{Internal Rate of Return (IRR)} = \text{Lower discount rate} + \text{Difference between the discount rates} \times \frac{\text{Present worth of incremental net benefit stream (cash flow) at the lower discount rate}}{\text{Sum of the present worth of the incremental net benefit streams (cash flows) at the two discount rates, signs ignored}}$$

Where, B_t = Total benefit (Tk/ha) in t^{th} year

C_t = Total cost (Tk/ha) in t^{th} year

t = Number of year

i = interest (discount) rate.

Results and Discussion

1. Agronomic practices of betel leaf cultivation

Respondent farmers did not plough their land for betel leaf cultivation. They prepared their land by spading. The most appropriate planting time of the betel leaf is at the end of the rainy season mostly from July to October by the farmers. The respondent farmers used betel leaf vine as seed which was mostly local variety. Within local varieties, farmers mainly cultivated Mohanali, Chailtagota and Cherifuli in Barisal, Mithapaan, Dholshi in Chittagong, Banglapaan, Mithapaan in Rajshahi and Mistipaan, Khilipaan in Kustia district. Modern varieties of betel leaf are not available in the study areas. The average number of betel leaf seed (vine) was found to be 123845 to 172841 numbers per hectare. The average plant to plant distance was found 15.24-20.32cm and line to line spacing of betel leaf vine were found to be 45.72-55.88 cm in Barisal and Chittagong. But in Rajshahi and Kustia the line to line spacing were found 81.28-91.44 cm. The average number of earthing up, application of oilcake, weeding, spraying and irrigation were 1.96, 4.23, 1.86, 5.82 and 6.02 respectively (Table 2). In Table-1, the average number of irrigation was 6.02. But in

Rajshahi, it was more than 19 times. Naturally, Rajshahi is a dry area. Moreover the farmers of that area irrigated their betel leaf plot manually carrying water with different pots. For this reason more number of irrigation was needed.

Table 2. Agronomic practices of betel leaf production followed in the study areas.

Agronomic practices	Locations				
	Barisal	Chittagong	Rajshahi	Kustia	All area
Month of plantation: (%)					
July	50	75	25	-	37
August	-	-	-	20	5
September	33	-	-	-	11
October	17	25	75	80	47
Earthing of soil (No./year)	3.4	2.0	1.5	1.0	2.0
Oilcake application (No./year)	5.0	5.4	2.8	3.8	4.2
Weeding (No./year)	1.9	2.1	2.0	1.6	1.9
Insecticides use (No./year)	4.0	8.4	5.8	2.7	5.9
Irrigation (No./year)	1.9	0.8	19.2	2.2	6.0
Number of vine per ha	165820	172841	123845	134652	149290
Plant distance (cm)	15.24	14.25	20.32	19.82	17.38

2. Input use

Human labour was required for seed(vine) planting, application of manures, fertilizing, spraying, weeding, irrigation and harvesting. On an average, 1665 mandays/ha was required for betel leaf cultivation (Table 3). The number of human labour varied from one year to another year due to change in the number of weeding, spraying insecticides, irrigation, and harvesting. Use of human labour was highest in third year old boroj. It might be due to more use of cowdung, TSP and irrigation. Respondent farmers used cowdung 2.55 t/ha. The highest 9.85 t/ha was used during the second year while the lowest 0.32 t/ha was used in 11-15 years boroj. It was observed that farmers having 16-22 old boroj did not use cowdung at all may be due to the low response in production. On an average, farmers used 2.5 t/ha oilcake in betel leaf cultivation. The highest amount of oilcake 3.2 t/ha was used in the boroj which were 16-22 years of age while the lowest in 3 years old boroj. The betel leaf farmers applied chemical fertilizers like urea 202 kg/ha, TSP 296 kg/ha, MoP 33 kg/ha and gypsum 35 kg/ha. The application of urea and TSP was observed to be higher in the case of 16-22 years old boroj.

Table 3. Per hectare input used for betel leaf cultivation in the study areas.

Parameters	Period of cultivation (Year)								
	1st	2nd	3rd	4th	5th	6-10	11-15	16 -22	All
Observations	*n=19*	*n=23*	*n=48*	*n=44*	*n=37*	*n=55*	*n=30*	*n=11*	*n=256*
Human labour (mandays)	1385	1509	1694	1619	1693	1598	1522	1491	1665
Own	662	655	790	666	718	667	605	679	718
Higher	723	854	904	953	975	931	917	812	947
Seed(Vine)	123748								
Cowdung(ton)	5.5	9.9	3.7	2.2	4.9	3.2	3.8	-	2.5
Oilcake(ton)	2.4	2.5	2.3	2.3	2.3	2.6	2.5	3.2	2.5
Fertilizer (kg):									
Urea	117	207	165	202	213	211	190	248	202
TSP	386	321	343	276	237	208	239	452	296
MP	21	56	37	24	22	20	63	15	33
Gypsum	33	87	53	110	36	35	9	45	55
Others*	26	20	5	17	12	12	-	2	12

* Others indicate DAP, Zn, Boron, etc.

3. Cost of production

The cost of production included human labour, boroj making materials, seed (vine), manures, fertilizers, pesticides, irrigation, insecticides, etc. Rental value of land was treated as fixed cost and was included in the total costs. Seed (vine) cost was needed only for the first year. The highest cost (Tk 1088333/ha) was incurred in the first year due to initial investment on seed (vine) and boroj making materials. The lowest cost (Tk 885035/ha) was observed for the boroj aged ranged from 11-15 years (Table 4). Among the cost items of betel leaf cultivation human labour incurred the highest cost (50%) followed by boroj materials cost (26%).

4. Return

For estimating the yield of betel leaf, data were collected from the survey plot on the basis of local unit like bira, Sali, gadi, kuri, pon etc. After that yield data were converted into ton per hectare on the basis of average weight of betel leaf. On an average, the weight of 265 number of betel leaf is one kilogram (Moniruzzaman, 2008). On review of Table 3, it is observed that the yield started increasing during 2nd to 5th year and declined form thereafter. Among the betel leaf boroj,

Table 4. Per hectare cost (Taka/ha) of betel leaf cultivation in the study areas.

Parameters	Period of cultivation (Year)								
	1st	2nd	3rd	4th	5th	6-10	11-15	16-22	All
Observations	*N=19*	*n=23*	*n=48*	*n=44*	*n=37*	*n=55*	*n=19*	*n=11*	*n=256*
Human labour	415374	452671	508224	485694	507962	479331	456592	447296	499393(50)
Seed(Vine)	123748	-	-	-	-	-	-	-	-
Boroj materials	331792	276617	218067	233131	265255	231792	207407	281504	254973(26)
Manures:									
Cowdung	6435	11985	4516	2790	556	414	570	-	3117(.03)
Oilcake	92918	97730	85714	88049	86248	91669	99903	118497	95841(1)
Fertilizers :									
Urea	2307	3992	3191	3920	4178	4013	3464	4570	3870(.04)
TSP	9794	7842	8949	7163	5730	5092	5933	11070	7434(.08)
MP	323	886	595	400	361	328	1013	240	535(.005)
Gypsum	260	709	471	865	278	246	93	359	440(.004)
Others	985	545	716	2089	1453	1168	-	337	1091(.01)
Insecticide	16342	15886	18926	14184	17623	19194	21973	23169	18868(2)
Irrigation	19701	17428	21624	16749	18973	16759	12549	6699	18062(2)
Interest on opt. cap.	32982	32208	32330	32611	33625	32491	32300	33294	34065(3)
Rental value of land	43807	43807	43807	43807	43807	43807	43807	43807	45689(5)
Total cost	1088333	950321	942616	928663	985494	925891	885035	970843	989297(100)

Note: Figures in the parentheses are percent of total cost.

Table 5. Profitability of betel leaf cultivation in the study areas.

Item	Period of cultivation (Year)								All
	1st	2nd	3rd	4th	5th	6-10	11-15	16-22	
Observations	*n=19*	*n=23*	*n=48*	*n=44*	*n=37*	*n=55*	*n=19*	*n=11*	*n=256*
Yield(t/ha)	5.80	6.03	7.05	7.80	9.50	9.31	7.84	6.96	8.23
T. variable cost (Tk/ha)	504153	492317	494193	498485	513980	496652	493732	508927	520703
Gross return (Tk/ha)	703320	901711	1057955	1293160	1538651	1450796	1319287	1158579	1298985
Gross margin(Tk/ha)	289166	409393	563763	794676	1024672	954145	825555	649652	778282
Net return(Tk/ha)	51649	384808	558874	859750	1153620	913511	530785	115289	721116
BCR on full cost basis	0.73	0.95	1.12	1.39	1.56	1.57	1.49	1.19	1.38
BCR on cash cost basis	0.93	1.13	1.30	1.54	1.62	1.63	1.56	1.25	1.10
Returns to labour (Tk/man-day)	87	268	368	525	627	629	585	426	486

Table 6. Cost benefit analysis of betel leaf production in the study areas.

Year of boroj	Cost (Tk/ha)	Discount factor (DF)			Discounted cost at			Gross return (Tk/ha)	Discounted benefit at		
		12%	15%	20%	12%	15%	20%		12%	15%	20%
1	1088333	0.89	0.87	0.83	971726	946377	906944	793320	708321	689843	661100
2	950321	0.80	0.76	0.69	757590	718579	659945	901711	718838	681823	626188
3	942616	0.71	0.66	0.58	670935	619785	545495	1057955	753032	695623	612243
4	928663	0.64	0.57	0.48	590182	530966	447851	1293160	821827	739369	623631
5	985494	0.57	0.50	0.40	559196	489965	396048	1538651	873072	764982	618350
6-10	925891	0.51	0.43	0.33	469085	400288	310079	1450796	735019	627219	485869
11-15	885035	0.29	0.21	0.13	254426	190232	119115	1319287	379263	283572	177560
16-22	970843	0.16	0.11	0.05	158371	103753	52513	115858	18899	12381	6267
Total					5925083	5204426	4287452		7542975	6505648	5200813

the highest yield (9.50 t/ha) was found in the 5 years old boroj and the lowest yield (5.80 t/ha) in one year old boroj (Table 5). On an average, 8.23 t/ha betel leaf was harvested. Which was higher than national yield of 5.81 t/ha (BBS, 2011). Gross return was calculated through multiplying yield and price of betel leaf. Betel lean price was varied area to area and season to season. This ranged from Tk. 20 to Tk. 120. Average gross return was Tk. 1298985/ha in which the highest gross return was received in 5th year (Tk. 1538651/ha) and the lowest in 1st year (Tk. 793320/ha). Average gross margin was found (Tk. 778282/ha). On an average, Tk. 721116 was found as net return. Highest net retrun Tk. 1153620 was found in 5th year. Average returns to labour was found to be Tk. 486 which was higher than their opportunity cost (Tk 300/day). It was evident that labour use in betel leaf cultivation was profitable than the opportunity cost of labour.

5. Returns to investment

Normally, the best discount rate to use is the "opportunity cost of capital"- i.e., the profitability of the last possible investment in an economy given the total available capital. In most developing countries it is assumed to be somewhere between 10-12% (Gittinger, 1977). To calculate a range of benefit-cost ratio (BCR), net present worth (NPV) and internal rate of return (IRR), the costs and returns were discounted at 12%, 15% and 20% rate of interest.

Firstly, the cost and benefit streams were discounted in order to find their present worth. Dividing the present worth of the gross benefits by the present worth of the gross cost it was found that the benefit cost ratio to be 1.27, 1.25 and 1.21 at 12%, 15% and 20% rate of interest. Net present worth is the difference between the present worth of benefits and present worth of costs. The discounted gross benefit has present worth at 12%, 15% and 20% rate of interest were Tk. 7542975/ha, Tk. 6505648/ha Tk. 5200813/ha and the discounted gross cost has present worth of Tk 5925083/ha, Tk 5204426/ha, Tk 4287452/ha (Table 6). The difference between the two net present worth at 12%, 15% and 20% discount rate is Tk 1617892/ha, Tk 1301222/ha, Tk 913361/ha. It signifies that betel leaf cultivation in the study areas is profitable.

Table 7. Rates of returns on investment in betel leaf production in the study areas.

Item	Discount factor (DF)		
	@12%	*@15%*	*@20%*
BCR	1.27	1.25	1.21
NPV (Tk)	1617892	1301222	913361
IRR (%)		62%	

The IRR for the investment is that discount rate which nullifies the present worth of cash flows and outflows. It represents the average earning power of the money used in the project over the project life. In betel leaf project, IRR is 62%. It is acceptable, because it is much higher than the opportunity cost of capital (Table 8).

Sensitivity Analysis

To make a valid generalization it was necessary to conduct sensitivity analysis. This table has been reworked separately to see what happens on the profitability of betel leaf under varying conditions. The cost of betel leaf cultivation was considered constant, while benefit decreases at the rate of 10% or if benefit of the betel leaf cultivation remains the same but all costs increase at the rate of 10% then what would be the outcome.

Table 8. Result of sensitivity analysis of betel leaf cultivation in the study areas.

Situation	Discount measures		
	BCR at 12%	NPV at 12%	IRR (%)
Base parameter	1.27	Tk. 1617892	62
Decrease of return:			
10%	1.04	Tk. 271086	37
Increase of gross cost:			
10%	1.16	Tk. 102583	39

The results of sensitivity analysis considering the above mentioned situation are presented in Table 8. It was revealed from the table 7 that BCR of betel leaf is greater than one, NPV is positive at 12% discount rate and IRR is also higher than the opportunity cost of capital. This implies that if the returns decrease at 10% the cost of betel leaf remains unchanged investment in betel leaf is profitable from the point of view of the owner. Again, BCR of the betel leaf is greater than one. NPV is positive and IRR is higher than the opportunity cost of capital, if gross cost increases at 10% the returns remain same. This means that the owner of betel leaf boroj can also make profit if all costs slightly increase in near future. The result of the study indicates that the owners of betel leaf boroj can earn profits under changing situation.

Constraints

Every farmer opined one or more than one problems (Table 9). Leaf rot disease was a common problem in the study areas. About 79% farmers opined that it is a serious problem for betel leaf cultivation. High price of boroj materials was another problem reported by the farmers. Many farmers reported that vine died at the end of the vine and sometimes 2-3 ft upper was a common problem which hampered the betel leaf production. About 45% farmers faced the problem of capital shortage during betel leaf cultivation. Cumbersome procedure of institutional credit was also a common problem in the study area. Price of betel leaf is very low during rainy season i.e. during the months of June to August. Regarding seed (vine), respondents had mentioned the problem of non-availability of quality seed. They did not know about the modern varieties of betel leaf. Though BARI released two betel leaf varieties but these were not reached to the farmer's field. Farmers used much quantity of oilcake in their boroj. Some of the responded opined that price of oilcake was very high. For this reason some of the farmers were unable to apply oilcake according to their desired level. Huge number of labour is required for betel leaf cultivation. About 17% farmers faced the problem of non-availability of labour. Non-availability of irrigation water was also a problem opined by 13% respondent. It is essential to irrigate the betel leaf boroj during dry period. High price of insecticides was also mentioned by 7% farmers. Besides, some farmers mentioned that insect infestation, excess cold, lack of transportation facilities were also the constraints of betel leaf cultivation.

Table 9. Constraints faced by the respondent betel leaf growers in the study areas.

Constraints	% of responses (*n=256)*
1. Infection of leaf rot disease	79
2. High price of boroj materials	56
3. Seed (vine) died	52
4. Lack of capital	45
5. Low price of betel leaf	41
6. Non-availability of modern varieties	32
7. High price of oilcake	21
8. Non-availability of labour	17
9. Non-availability of irrigation water	13
10. High price of insecticides	7
11. Others*	27

* Others indicate insect infestation, excess cold, lack of transport facilities etc.

Conclusion and Recommendation

The study has estimated the agronomic practices, profitability, returns to investment of betel leaf cultivation and constraints to its cultivation at farm level. The benefit cost ratio, net present worth and internal rate of return indicate that betel leaf cultivation is profitable. Sensitivity analysis also indicates that the owners of betel leaf boroj can earn profit under changing situation. Although betel leaf cultivation is profitable, but farmers faced various problems such as infection of leaf rot disease, high price of boroj materials, vine died, lack of capital, low price of betel leaf, high price of oilcake, non-availability of modern variety, labour scarcity, and lack of irrigation water.

For controlling leaf rot disease of betel leaf, pathologist may conduct research on this aspect. It is also imperative to carry out more research on developing high yielding varieties of betel leaf and develop appropriate production technologies for maximizing the yield as well as income and minimizing the cost. Extension works with publicity need to be strengthened to popularize the modern varieties of betel leaf in order to expand its cultivation area.

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GENETIC DIVERGENCE IN *Brassica rapa* L.

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Abstract

Different multivariate analysis techniques were used to classify 33 *Brassica rapa* L. genotypes. The genotypes were grouped into five clusters. Cluster I contained the maximum number of genotypes. Cluster III earned the highest cluster mean value for number of primary branches/plant, number of secondary branches/plant, number of siliquae/plant and seed yield/plant. Therefore, more emphasis can be given on cluster III for selecting genotypes as parents for the hybridization program. The highest intra-cluster distance (3.822) was found in cluster I and the lowest (0.000) in cluster V. The highest inter-cluster distance (15.705) was observed between clusters III and V showing wide diversity among the groups. Principal component analysis (PCA) showed that the first three principal components accounted for 99.38 % of the total variation observed. Analysis of the factor loading of the component character indicated that the characters number of siliquae/plant, plant height and days to maturity were found responsible for genetic divergence. The role of number of siliquae/plant in both the vectors was important components for genetic divergence in these materials. Among the possible 528 combinations, the highest inter-genotypic distance (1.5975) was observed between G-27 (BARI sarisha-9 x BARI sarisha-6 S-62) and G-31 (BARI sarisha-15). Considering group and inter-genotypic distance, cluster mean, contribution of different characters towards the total divergence and other agronomic performance the genotypes G-19 (BARI sarisha-6 x TORI-7 S-48), G-20 (F_6 x BARI sarisha-9 S-52), G-27 and G-30 (BARI sarisha-6 x TORI-7 S-37) from cluster III; G-26 (F_6 x BARI sarisha-9 S-15) and G-31 from cluster IV and G-33 (BARI sarisha-6) from cluster V would be considered as better parents for future hybridization program.

Keywords: Genetic diversity, principal component analysis, principal coordinate analysis, cluster analysis, *Brassica rapa* L.

Introduction

Brassica rapa L. commonly known as field mustard or turnip mustard belonging to the family Brassicaceae. The seeds of *Brassica rapa* L. contain 42% oil and 25% protein (Khaleque, 1985). It also serves as important source of raw material

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for industrial use such as in making soaps, paints, hair oils, lubricants, textile auxiliaries, pharmaceuticals and so on. It is the third most important oil crop in the world accounting for over 16% of the world's edible oil supply (Anonymous, 2005). It also plays an important role to the total edible oil production in Bangladesh. Among the oil crops grown in Bangladesh *Brassica rapa* L. occupies the first position in respect of area and production. During 2010-11, about 0.252 million hectare of land was under *Brassica rapa* L. and mustard cultivation where produced about 0.246 million tons of seed, and national average yield was 0.977 ton/ha in this country. Total annual edible oil production was about 0.833 million tons which is very low against the requirement of Bangladesh. Bangladesh imported 89.97 thousand tons of edible oil of rapeseed in the year of 2010-11 to meet up the annul requirement, which costs Tk.3718.457 million (BBS, 2011). The main reasons behind these are the use of low yielding local indigenous cultivars, low management practices and reduction of cultivation area. The area for rapeseed and mustard was reduced from 0.3177 million hectare in 2000-01 to 0.2340 million hectare in 2008-09. There was 26.32% reduction in area for this crop (Bhuiyan, 2012). For increasing the production of *Brassica rapa* L., expansion of cultivated area and unit area production are needed. There is a limited scope for horizontal expansion of its cultivation. Thus, to increase the production of *Brassica rapa* L., production per unit area must be increased. Moreover the crop should fit in the cropping pattern. Therefore, high yielding and short duration *Brassica rapa* L. varieties should be developed to fit into the existing cropping pattern (T-amon-mustard-Boro).

Genetic diversity refers to sum total of genetic variations found in a species or population. Existence of genetic diversity is very essential to meet the present and future crop breeding challenges. It is a prerequisite for the development of improved cultivars with wider adaptability and broad genetic base. It can be estimated through biometrical procedures such as Mahalanobis's D^2-statistic and is possible to choose genetically diverse parents. Diversity analysis greatly helps the breeder in identification and proper choice of parents for specific breeding objectives. The selection of potential varieties in a breeding program is based on the knowledge of genetic diversity amongst them. To realize heterosis, genetically divergent parents are generally considered to be useful. In such crosses more variability could be expected in the resulting segregating progenies (Joseph *et al.,* 1999). Precise information about the extent of genetic divergence on characters used for discrimination among the population is crucial in any crop improvement program, because selection of plants based on genetic divergence has become successful in several crops (Ananda and Rawat 1984; De *et al.,* 1988). Therefore the present study was undertaken to collect information on genetic divergence in the genotypes and selection of suitable diverse parents for the utilization in future hybridization program.

Materials and Method

The experiment was conducted at the field of Sher-e-Bangla Agricultural University farm, Dhaka, during rabi, 2011-12. Thirty-three genotypes were used in this experiment where three of them were used as checks. Among the genotypes, thirty were selected from F_9 segregating generation on the basis of their variation in different traits. The experiment was laid out in a Randomized Complete Block Design with three replications. Each plot was 3m long with two rows. The distance of 10 cm between plants, 30cm between rows and 1m between blocks were maintained. Seeds were sown in lines in the experimental plots on 29th October 2011. Recommended doses of fertilizers and standard cultural practices were applied for raising healthy crops. Data were recorded on randomly ten selected plants from each plot and plants were selected from middle to avoid border effect of the plot. Data were recorded on days to maturity, plant height (cm), number of primary branches/plant, number of secondary/branches plant, number of siliquae/plant, siliqua length (cm), number of seeds/siliqua, 1000 seed weight (g) and seed yield/plant (g). All the collected data of the study were subjected to statistical analysis. Multivariate analysis viz., Principal Component Analysis (PCA), Principal Coordinate Analysis (PCO), Canonical Variate Analysis (CVA) and Cluster Analysis were done by using GENSTAT 5 Release 4.1 (PC/Windos NT) software program (Copyright, 1997, Lawes Agricultural Trust, Rothamasted Experimental Station, UK).

Using standardized data, numerical measures of likeness/similarity were computed and distance matrix was constructed using Euclidean Distance Coefficients. Clustering by UPGMA (Unweighted Pair Group of Arithmetic Mean) method was executed (Siopongco *et al.*, 1999). Dendogram was constructed by using the SPSS.16 software. PCO is equivalent to PCA but it is used in calculating inter genotypic distance and intra cluster distance for all possible combination. When the clusters were formed, the average intra-cluster distances for each cluster was calculated by taking possible D^2 values within the member of a cluster obtained from the PCO. CVA was performed to get the inter cluster distances. Principal Components were computed from the correlation matrix (variance-covariance coefficient) and genotype scores were obtained from the first components. Two dimensional scatter diagram was prepared by using principal component score I in X-axis and II in Y-axis. Scree plot is a useful visual aid to determine an appropriate number of principal components and it was constructed according to Johnson and Wichern, (2008). The factor loadings of characters were used from PCA for identifying the major characters responsible for maximum variability. Contribution of the different morphological characters towards divergence was discussed from the latent vectors of the first two principal components.

Results and Discussion

Cluster Analysis

Thirty three genotypes of *Brassica rapa* L. were grouped into 5 different clusters by applying non-hierarchical cluster using covariance matrix (Table 1). The results were more or less confirmatory with the cluster pattern of the genotypes obtained through Dendogram (Figure 1). Nath *et al.*, (2003) reported 5 clusters which support this result. Rameeh (2013) reported 4 clusters. Two dimensional scatter diagram was prepared by using principal component score I in X-axis and II in Y-axis. The scatter diagram also revealed that there were five apparent clusters. The genotypes were distantly located from each other (Figure 2). Cluster I contained the maximum number of nineteen genotypes followed by cluster II, cluster III and cluster IV having seven, four and two genotypes, respectively and cluster V having only one genotype (Table 1 and Figure 1). Mahmud *et al.*, (2008) and Dhillon *et al.*, (1999) recorded variable number of genotypes in different clusters. In the present study cluster I contained the genotypes G-1 (BARI sarisha-9 x BARI sarisha-6 S-73), G-3 (BARI sarisha-9 x BARI sarisha-6 S-51), G-4 (BARI sarisha-6 x TORI-7 S-19), G-6 (BARI sarisha-6 x TORI-7 S-62), G-7 (BARI sarisha- 9 x BARI sarisha-6 S-42), G-8 (F_6 x BARI sarisha-9 S-25), G-9 (BARI sarisha-6 x TORI-7 S-45), G-11 (BARI sarisha-9 x BARI sarisha-6 S-50), G-12 (BARI sarisha-6 x TORI-7 S-49), G-15 (BARI sarisha-6 x TORI-7 S-11), G-16 (BARI sarisha-9 x BARI sarisha-6 S-35), G-17 (F_6 x BARI sarisha-9 S-19), G-18 (BARI sarisha-6 x TORI-7 S-5), G-23 (BARI sarisha-6 x TORI-7 S-32), G-24 (F_6 x BARI sarisha-9 S-23), G-25 (F_6 x BARI sarisha-9 S-29), G-28 (BARI sarisha-9 x BARI sarisha-6 S-81), G-29 (BARI sarisha-9 x BARI sarisha-6 S-69) and G-32 (TORI-7). Cluster II was composed of the genotypes G-2 (F_6 x BARI sarisha-9 S-89), G-5 (BARI sarisha-9 x BARI sarisha-6 S-87), G-10 (BARI sarisha-6 x TORI-7 S-29), G-13 (F_6 x BARI sarisha-9 S-75), G-14 (F_6 x BARI sarisha-9 S-31), G-21 (F_6 x BARI sarisha-9 S-59) and G-22 (BARI sarisha-9 x BARI sarisha-6 S-92). Cluster III was constituted with G-19 (BARI sarisha-6 x TORI-7 S-48), G-20 (F6 x BARI sarisha-9 S-52), G-27 (BARI sarisha-9 x BARI sarisha-6 S-62) and G-30 (BARI sarisha-6 x TORI-7 S-37). On the other hand, cluster IV represented 2 genotypes namely G-26 (F6 x BARI sarisha-9 S-15) andG-31 (BARI sarisha-15) and cluster V comprised only one genotype G-33 (BARI sarisha-6).

The genotypes from cluster III earned the highest cluster mean values for number of primary branches/plant (6.75), number of secondary branches/plant (5.00), number of siliquae/plant (172.58) and seed yield/plant (5.56 g) but the lowest cluster mean for siliqua length (5.08 cm), number of seeds/siliqua (16.58) and 1000-seed weight (2.87 g). On the other hand, Cluster V produced the highest mean values for plant height (113.33 cm), number of seeds/siliqua (26.67), days to maturity (99 days) and 1000-seed weight (3.40 g) but the lowest mean values for number of primary branches/plant (4.33), indicating late maturing and coarse seeded genotypes constituted this cluster. If parents from cluster III and V are involved in hybridization program then the highest heterosis in respect of yield, earliness, tallness, higher number of branches, seeds and siliquae/plant might be obtained. Srivastav and Singh (2000) reported that cluster III had the highest number of primary and secondary branches and the highest mean value for seed yield/plant and cultivars in cluster V with 1000-grain weight supported this result. Cluster II showed better performance in case of early maturity (82.42 days) and siliqua length (5.44 cm), On the other hand the genotypes included in cluster IV showed the lowest cluster mean for number of secondary branches/plant (1.50), the lowest siliqua length (5.03 cm) and also the lowest seed yield/plant (3.68 g) (Table 2).

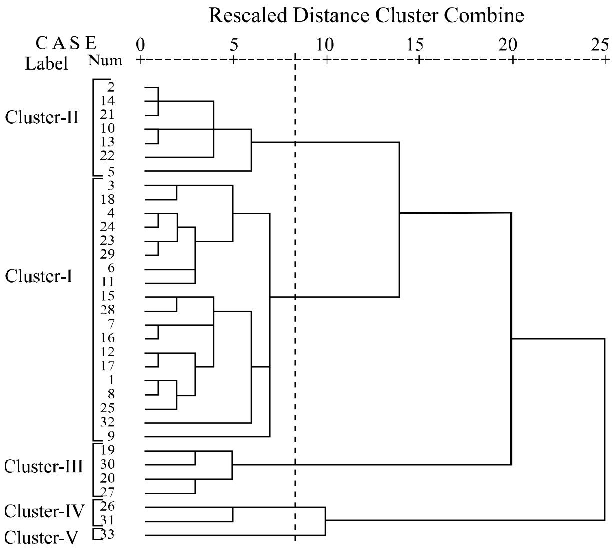

Figure 1. Dendogram of 33 genotypes of *Brassica rapa* L. by using morphological data and executed by UPGMA (Unweighted Pair Group of Arithmetic Mean)

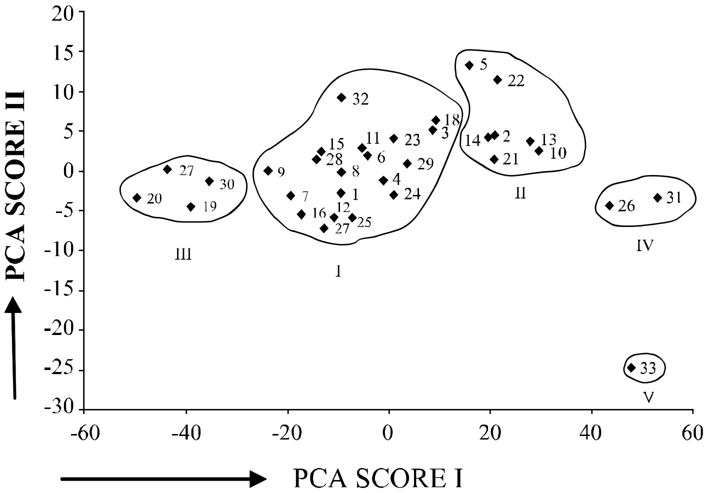

Figure 2. Scatter distribution of 33 genotypes of *Brassica rapa* L. based on their principal component scores superimposed with clustering

Table 1. Distribution of 33 genotypes of *Brassica rapa* L. in five clusters as per dendogram

Cluster	Number of genotypes	Name of Genotypes with code
I	19	G-1 (BARI sarisha-9 x BARI sarisha-6 S-73); G-3 (BARI sarisha-9 x BARI sarisha-6 S-51); G-4 (BARI sarisha-6 x TORI-7 S-19); G-6 (BARI sarisha-6 x TORI-7 S-62); G-7 (BARI sarisha- 9 x BARI sarisha-6 S-42); G-8 (F_6 x BARI sarisha-9 S-25); G-9 (BARI sarisha-6 x TORI-7 S-45); G-11 (BARI sarisha-9 x BARI sarisha-6 S-50); G-12 (BARI sarisha-6 x TORI-7 S-49); G-15 (BARI sarisha-6 x TORI-7 S-11); G-16 (BARI sarisha-9 x BARI sarisha-6 S-35); G-17 (F_6 x BARI sarisha-9 S-19); G-18 (BARI sarisha-6 x TORI-7 S-5); G-23 (BARI sarisha-6 x TORI-7 S-32); G-24 (F_6 x BARI sarisha-9 S-23); G-25 (F_6 x BARI sarisha-9 S-29); G-28 (BARI sarisha-9 x BARI sarisha-6 S-81); G-29 (BARI sarisha-9 x BARI sarisha-6 S-69) and G-32 (TORI-7)
II	7	G-2 (F_6 x BARI sarisha-9 S-89); G-5 (BARI sarisha-9 x BARI sarisha-6 S-87); G-10 (BARI sarisha-6 x TORI-7 S-29); G-13 (F_6 x BARI sarisha-9 S-75); G-14 (F_6 x BARI sarisha-9 S-31); G-21 (F_6 x BARI sarisha-9 S-59) and G-22 (BARI sarisha-9 x BARI sarisha-6 S-92)
III	4	G-19 (BARI sarisha-6 x TORI-7 S-48); G-20 (F_6 x BARI sarisha-9 S-52); G-27 (BARI sarisha-9x BARI sarisha-6 S-62) and G-30 (BARI sarisha-6 x TORI-7 S-37)
IV	2	G-26 (F_6 x BARI sarisha-9 S-15) and G-31 (BARI sarisha-15)
V	1	G-33 (BARI sarisha-6)

Table 2. Non-hierarchical cluster mean values for 9 characters of 33 genotypes of *Brassica rapa* L.

Character	Cluster				
	I	II	III	IV	V
Days to maturity	83.26	82.42	84.00	88.50	99.00
Plant height	93.83	88.35	95.06	96.28	113.33
Number of primary branches/plant	6.08	5.29	6.75	5.00	4.33
Number of secondary branches/plant	3.00	2.57	5.00	1.50	2.00
Number of siliquae/plant	137.75	108.38	172.58	82.84	84.00
siliqua length	5.30	5.44	5.08	5.03	5.21
Number of seeds/siliqua	17.35	16.95	16.58	20.66	26.67
1000 seed weight	2.89	3.08	2.87	2.93	3.40
Seed yield/plant	4.88	4.32	5.56	3.68	4.59

In many cases, the same cluster included genotypes from different eco-geographic region indicating the geographic distribution and genetic divergence did not follow the similar trend. This finding was in agreement with the findings of other researcher, Rawhat and Anad (1981), Gupta *et al.,* (1991) and Mitra and Saini (1998) reported the non-correspondence of genetic and geographic diversity.

Principal Coordinates Analysis (PCO)

Inter genotypic distance (D^2) were obtained from PCO for all possible combinations between pair of genotypes. Among the possible 528 combinations, the highest inter-genotypic distance (1.5975) was observed between G-27 (BARI sarisha-9 x BARI sarisha-6 S-62) and G-31 (BARI sarisha-15) followed by G-26 (F6 x BARI sarisha-9 S-15) and G-27 (BARI sarisha-9 x BARI sarisha-6 S-62) (1.5038); and G-27 (BARI sarisha-9 x BARI sarisha-6 S-62) and G-33 (BARI sarisha-6) (1.4781), while the lowest distance (0.1534) was observed between genotypes G-23 (BARI sarisha-6 x TORI 7 S-32) and G-29 (BARI sarisha-9 x BARI sarisha-6 S-69) (Table 3). The difference between the highest and the lowest inter genotypic distance indicated the presence of variability among the 33 genotypes of *Brassica rapa* L. studied.

The intra-cluster distance was computed by using the values of inter genotypic distance from distance matrix as per Singh and Chaudhary (1985). Cluster I showed highest intra-cluster distance (3.822) followed by cluster II (1.343), cluster III (0.747) and cluster IV (0.207). The cluster V showed zero intra-cluster distance due to containing only one genotype (Table 4).

Table 3. Ten of each higher and lower inter-genotypic distance (D^2) between pair of *Brassica rapa* L. genotypes

Genotypic Combination	Ten maximum (D^2) values	Genotypic Combination	Ten minimum (D^2)values
G-27 – G-31	1.5975	G-23 – G-29	0.1534
G-26 – G-27	1.5038	G-23 – G-24	0.1571
G-27 – G-33	1.4781	G-11 – G-12	0.1643
G-5 – G-27	1.407	G-8 – G-11	0.1757
G-15 – G-27	1.3257	G-9 – G-12	0.1779
G-30 – G-31	1.2914	G-7 – G-8	0.1864
G-20 – G-31	1.2842	G-17 – G-24	0.1912
G-3 – G-27	1.2362	G-10 – G-13	0.1916
G-20 – G-33	1.2134	G-12 – G-25	0.1952
G-18 – G-27	1.2127	G-4 – G-28	0.2123

Table 4. Average inter cluster distance and intra cluster distance (bold) for 33 genotypes of *Brassica rapa* L.

Cluster	I	II	III	IV	V
I	**3.822**	4.837	5.008	8.142	12.205
II		**1.343**	9.610	5.356	10.870
III			**0.747**	12.728	15.705
IV				**0.207**	6.674
V					**0.000**

Canonical Variate Analysis (CVA)

CVA was done to compute the inter-cluster distances. The values of inter-cluster distance (D2) are presented in Table 4. In this experiment, the inter-cluster distances were higher than the intra-cluster distances which indicated considerable range of genetic diversity among the genotypes of different groups. Mahmud *et al.,* (2011) and Zahan *et al.,* (2008) also reported similar result in *Brassica*. The highest inter-cluster distance was observed between cluster III and V (15.705), followed by those of between cluster III and IV (12.728), cluster I and V (12.205), cluster II and V (10.870), cluster II and III (9.610) and cluster I and IV (8.142). The maximum values of inter-cluster distance indicated that the genotypes belonging to cluster III were far away from those of cluster V. In contrast, the lowest inter-cluster distance was observed between cluster I and II (4.837) followed by those of cluster I and III (5.008), cluster II and IV (5.356) (Table 4). However, genotypes from clusters III and V if involved in hybridization may produce a wide spectrum of segregating population. Choudhary and Joshi (2001) reported that the derivatives selected from cross of diverse parents revealed greater diversity. Khan (2000), Dhillon *et al.,* (1999) and Harch *et al.,* (1999) also mentioned that maximum inter-cluster distance of parents gave desirable segregants for the development of high yielding varieties with quality. The genotypes of cluster I and II were genetically closed.

Principal Component Analysis (PCA)

PCA is a statistical method which attempts to describe the total variation in multivariate sample using fewer variables than in the original data set (Bartolome *et al.*, 1999). In the end, the analysis results in the identification of the major attributes that are responsible for the observed variation within a given collection.

Principal component analysis was carried out with 33 genotypes of *Brassica rapa* L. The computed eigenvalues for the 9 variables subjected to principal component analysis, together with the corresponding proportion and cumulative explained variances are given in Table 5. The first principal component accounted for 91.36 % of the total variation while principal components two and three accounted for 6.39 % and 1.63 %, respectively (Table 5). Zaman *et al.*, (2010) reported that first three axes accounted for 94.00% of the total variation whereas the first principal components accounted for 81.94%. However, Khan (2010) reported that first three principal components accounted for 70.27% of the total variation where the first principal components accounted for 28.65%.

Table 5. Eigenvalues and percentage of variation in respect of 9 principal components in 33 genotypes of *Brassica rapa* L.

Principal component axis	Eigenvalues	% of total variation accounted for	Cumulative of % Variation
1	20112	91.36	91.36
2	1406	6.39	97.75
3	358	1.63	99.38
4	72	0.32	99.7
5	32	0.15	99.85
6	24	0.11	99.96
7	7	0.03	99.99
8	3	0.01	<100
9	1	0.00	100

Scree plot is a useful visual aid to determine an appropriate number of principal components. The magnitude of an eigenvalues versus its number with the eigenvalues ordered from largest to smallest. To determine the appropriate number of components, we look for an elbow (bend) in the scree plot. The number of components is taken to be the point at which the remaining eigenvalues are relatively small and all about the same size (Johnson and Wichern, 2008). In this case, it appears without any other evidence, that three sample principal components effectively summarized the total sample variance (Figure-3). The first three principal axes accounted for 99.38% of the total variation among the characters describing 33 genotypes of *Brassica rapa* L.

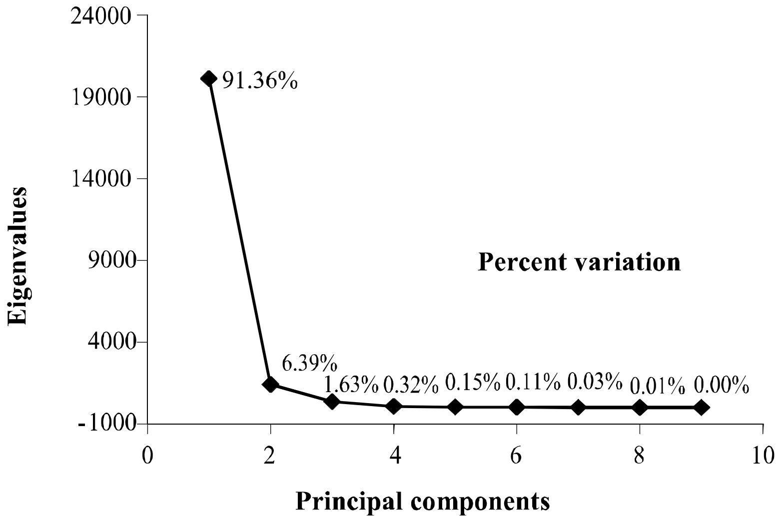

Figure 3. Scree plot constructed from eigenvalues vs number of principal components accounted for percent variations

Contribution of characters towards divergence of the genotypes

The factor loadings of characters from PCA retained three components identified the major characters responsible for maximum variability (Table 6). The first principal component (PC1) can be consider as the component of number of siliquae/plant (-0.99711). Principal component II (PC2) on the other hand indicated the importance of days to maturity (-0.50863), plant height (-0.83615) and number of seeds/siliqua (-0.20085). The characters associated with the principal component III (PC3) were siliqua length (-0.02179) and seed yield/plant (-0.01399) for high loadings. High loadings were also observed for days to maturity (-0.84123) and plant height (0.53200) but they were also important in PC2.

Table 6. Factors loadings for component character traits in principal component 1-3.

Characters	PC 1	PC 2	PC 3
Days to maturity	0.04343	-0.50863	-0.84123
Plant height	-0.00393	-0.83615	0.53200
Number of primary branches/plant	-0.01955	0.01539	-0.00478
Number of secondary branches/plant	-0.03383	0.00146	0.00042
Number of siliquae/plant	-0.99711	-0.02779	-0.04257
siliqua length	0.00089	0.00429	-0.02179
Number of seeds/siliqua	0.04479	-0.20085	-0.08176
1000 seed weight	0.00278	-0.01137	0.01079
Seed yield/plant	-0.01819	-0.02559	-0.01399

The latent vectors (Z_1 and Z_2) were also obtained from PCA (Table 7). The important characters responsible for genetic divergence in the axis of differentiation in vector I (Z_1) were plant height (0.1595), number of siliquae/plant (0.0652), number of seeds/siliqua (0.4366), days to maturity (0.3029) and 1000 seed weight (0.1287). In vector II (Z_2), number of siliquae/plant (0.1235) was important. The role of number of siliquae/plant in both the vectors was important components for genetic divergence in these materials. Afrin (2012) and Verma and Sachan (2000) reported that number of siliquae/plant in both the vectors were important components for genetic divergence. On the other hand, the role of primary branches number/plant, number of secondary branches/plant, siliqua length and yield/plant had a minor role in the genetic divergence. Dhillon *et al.*, (1997) reported that number of branches/plant showed minimum contribution to total divergence.

Table 7. Latent vectors for 9 morphological characters of 33 genotypes of *Brassica rapa* L.

Characters	Vectors 1	Vectors 2
Days to maturity	0.3029	-0.4296
Plant height	0.1595	-0.5943
Number of primary branches/plant	-0.3663	-0.1103
Number of secondary branches/plant	-0.3996	-0.2003
Number of siliquae/plant	**0.0652**	**0.1235**
siliqua length	-0.4881	-0.1761
Number of seeds/siliqua	0.4366	-0.2464
1000 seed weight	0.1287	-0.3393
Seed yield/plant	-0.3731	-0.4335

Selection of genotypes as parent for hybridization program

Selection of genetically diverge parents is the prime task for any plant breeding activities. Considering magnitude of genetic distance, contribution of different characters towards the total divergence, magnitude of cluster means for different characters and field performance the genotypes G-19 (BARI sarisha-6 x TORI-7 S-48), G-20 (F_6 x BARI sarisha-9 S-52), G-27 (BARI sarisha-9 x BARI sarisha-6 S-62) and G-30 (BARI sarisha-6 x TORI-7 S-37) from cluster III; G-26 (F_6 x BARI sarisha-9 S-15) and G-31 (BARI sarisha-15) from cluster IV and G-33 (BARI sarisha-6) from cluster V would be considered as better parents for future hybridization program. Singh and Gupta (1984) reported that out of 31 genotypes six genotypes were found to be suitable for use in one of their breeding program.

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VARIABILITY AND HERITABILITY ANALYSIS IN SPRING WHEAT (*Triricum aestivum* L.) GENOTYPES

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Abstract

The experiment was carried out with 50 wheat lines to study their inter-genotypic variability, heritability, GCV, PCV, genetic advance, and CV percent considering 14 morphological characters at the experimental field of Regional Wheat Research Centre RWRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during November 2010 to March 2010. Significant variation was observed among the genotypes for all characters studied. High GCV and PCV values were observed for grain filling duration, grain filling rate, and seed yield. High heritability along with higher genetic advance was observed for DTH, DTA, DPM, GFD, GFR, PHT, $CHL_{A,}$ spikelets/spk., and yield kg/ha. The remaining traits showed lower heritability coupled with low genetic advance in percent of mean. Considering variability among the genotypes, heritability, genetic advance, percent co-efficient of variation, and field performances, the genotypes G 3, G 10, G 11, G 12, G13, G 21, G 29, G 35, G 38, G 40, G 46 and G 48 were found suitable for future breeding programme.

Keywords: Wheat, Genotypes, Variability, Heritability .

Introduction

Wheat is the most widely grown and consumed food crop in the world (Vasil and Anderson, 1997). Intensive breeding in modern times has led to the adaption of wheat to a wide range of ecological conditions (temperate, subtropical, and tropical). Even in Asia, where rice has historically been the dominant crop, wheat is fast becoming a major crop. For example, in 1994, Asia produced 217 million tons of wheat compared with a combined harvest of 209 million tons in USA, Canada, Europe and Mexico (Vasil and Anderson, 1997). In addition to wheat being grown in countries not traditionally associated with wheat growing, over the past 40 years the introduction of new cultivars and improved husbandry has led to major increase in global wheat yield (2% increase annually from 1961-1994) (Braun *et al.*, 1998).Wheat Research Centre (WRC) of Bangladesh Agricultural Research Institute (BARI) now has a wide range of spring wheat germplasm collection from different sources. Most of these have been collected

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from International Maize and Wheat Improvement Centre (CIMMYT), Mexico and few from Nepal, India, Pakistan, and Australia.

Now, there is a need for improved varieties in respect of heat, drought and disease tolerance and germplasm is the important natural resource that should be used by the breeders to develop new cultivars. Genetic variability is a prerequisite for a successful breeding programme of any crop species and a critical survey of genetic variability is essential before initiating an improvement programme aiming to develop high yielding varieties (Falconer, 1989).The variability analysis and partitioning of the total variation into heritable and non-heritable components with suitable genetic parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), percent heritability, percent genetic advance etc. is therefore, a necessity (Barma *et al*., 1990). The genetic variability in a population along with heritability gives an idea of genetic advance to be expected from selection for a given character (Burton, 1952; Johanson *et al*., 1955). The present, attempts have been made to characterize a set of wheat germplasm for various morphological characters and estimate the variabilities available in the collections, which can be utilized as donors in hybridization programme.

Materials and Method

Fifty wheat genotypes were grown in a randomized complete block design with three replications at the experimental field of Bangladesh Agricultural Research Institute, Gazipur during first week of December 2010 to first week of April 2011. The experimental site was at 23.46 ^{0} N latitude and 90.23^{0} E longitude with an elevation of 8 meter from sea level. The experimental field was prepared thoroughly by ploughing with tractor followed by harrowing and removing the stubble. The crop was fertilized with NPKS and B @ 100, 28, 40, 20 and 2.5 kg ha^{-1}, respectively to ensure proper growth and development of wheat plant. The elements N, P, K, S and B were applied in the form of Urea, Triple Super Phosphate, Muriat of Potash, Gypsum and Boric acid, respectively. Two-third of urea and the entire quantity of other fertilizers were applied at final land preparation along with Furadon 3G @ 8 kg ha^{-1} . The rest one-third urea was top-dressed at crown root initiation stage (17-21 days after sowing) following first irrigation. Data were collected on days to heading (DTH), days to anthesis (DTA), days to maturity (DTM), grain filling duration (GFD)[days], grain filling rate (GFR) [g m^{-2} d^{-1}], plant height (PHT) in cm, chlorophyll content at anthesis (CHL_A) in SPAD unit, canopy temperature (^{0}C) at vegetative ($CT_{veg.}$), anthesis ($CT_{anth.}$) and grain filling ($CT_{gf.}$) stage, spikelets $spike^{-1}$ (no.), grains $spike^{-1}$ (no.), thousand grain weight (TGW) [g], and grain yield m^{-2} (g). Grain yield m^{-2} of each genotype was converted into grain yield (Kg/ha). The data were analyzed for phenotypic and genotypic variances (Johnson *et al.,* 1955). The Genotypic and phenotypic coefficients of variations were estimated according to the formula suggested by Burton (1952). Heritability in broad sense (h^2b), genetic advance (GA), and genetic advance in percent of mean (GA%) were estimated for different characters by the formula suggested by Johnson *et al.*, (1955) and Hanson *et al.*, (1956), Allard (1960) and Comstock and Robinson (1952), respectively.

Results and discussion

The mean, range, and CV of seed yield and yield contributing characters of 50 genotypes of spring wheat (*Triticum aestivum* L.) are presented in Table 1. Variations were observed among the lines for all the characters studied. The average days to heading (DTH) across genotypes was 72.77 days and ranged from 61 to 79. The minimum DTH was observed in genotype G 21 (61.67 days) and the maximum (79 days) in genotype G 27 (Table 2). Days to anthesis (DTA) ranged from 65 to 84. The shortest vegetative period was observed in the genotype G 21 (65.33) and the longest (84.33) in the genotype G 27 (Table 2). Days to physiological maturity (DPM) ranged from 98 to 111. The lowest days to physiological maturity was observed in the genotype G 21 (98.33) and the highest (111.33) in the genotype G 27 (Table 2). Grain filling duration (GFD) ranged from 23 to 34. The shortest GFD was recorded in genotype G 29 (23.33 days) and the longest one (34.00 days) in genotype G 44 (Table 2). The average Grain filling rate (GFR) across genotypes was 14.43 $g^{-2}d^{-1}$ m^{-2} and ranged from 10.07 to 18.98. Minimum GFR was observed in genotype G 3 (10.07 $g^{-2}d^{-1}$ m^{-2}) and the maximum (18.98 $g^{-2}d^{-1}$ m^{-2}) in genotype G 40 (Table 2). Plant height (PHT) ranged from 80 to 98 cm. The minimum plant height was observed in the genotypes G 3 (80.33cm) and the maximum (97.67cm) in the genotype G 4 and G16 (Table 2). The average Chlorophyll content at anthesis stage (CHL_A) across genotypes was 49.51 SPAD unit for all genotypes and ranged from 43.50 to 54.53. Highest chlorophyll content (54.50 SPAD unit) was recorded in genotype G 45 while the lowest chlorophyll content (43.50 SPAD unit) was recorded in G 2 (Table 2). The canopy temperature measured by infrared thermometer has been used to evaluate genotypes for their ability to keep their canopy cool with less impaired assimilation processes as suggested by Reynolds *et al.*, (1994). Canopy temperature at vegetative stage ($CT_{veg.}$) ranged from 19.90 to 22.50^0 C. Minimum average canopy temperature at vegetative stage was recorded in the genotype G 46 (19.90 ^{0}C) and the maximum (22.50 ^{0}C) was in the genotype G 7 (Table 2). Canopy temperature at anthesis stage ($CT_{anth.)}$) ranged from 21.10 to 23.50^0 C. Minimum average canopy temperature was recorded in the genotype G 39 (21.10 ^{0}C) and the maximum (23.50 ^{0}C) was in the genotype G 15 (Table 2). Canopy temperature at grain filling stage ($CT_{gf.}$) ranged from 21.50 to 24.90^{0}C.

The minimum average canopy temperature was recorded in the genotype G 44 (21.50 ^{0}C) and the maximum (24.90 ^{0}C) was in the genotype G 15 (Table 2). Spikelets spike^{-1} (Splet/spk.) ranged from 13.90 to 18.40. The minimum spikelets spike^{-1} was produced by the genotype G 3 (13.90) and the maximum (18.40) by genotype G 38 (Table 2). The average Grain spike^{-1} across genotypes was 50.74 and ranged from 40.70 to 57.90. Genotype G 49 produced minimum grains spike^{-1} (40.70) while G 35 produced the maximum (57.90) grains spike^{-1} (Table 2). Thousand grain weight (TGW) ranged from 30.50 g to 45.90 g. The lowest 1000-grain weight was recorded in the genotype G 4 (30.50g) and the highest (45.90g) was in genotype G 13 (Table 2). The average Grain yield was 3810.14 kg ha^{-1}for all genotypes and ranged from 2552 to 4998. G 41 was the lowest yielder (2552.00 kg ha^{-1}) while G 40 was the highest yielder (4998.00 kg ha^{-1}) among the genotypes studied (Table 2). The hieghest co-efficient of variation (CV%) was recorded in the character grain filling rate (8.7) followed by grain yield (8.54), grains spike^{-1} (7.60), and TGW (7.07).

Minimum variation was observed in the character days to anthsis (1) [Table 1]. The coefficient of variation (CV %) was not so high and ranged from 1 to 8.7, which indicated that the reliability level of results for these traits was high. Considering plant height, days to heading, days to maturity, grain filling duration, grain spike^{-1}, spikelets spike^{-1}, thousand grain weight, seed yield and other yield contributing characters, the genotypes G 3, G 13, G 21, G 29, G 35, G 38, G40, and G 46 were selected for future breeding programme.

Variability among the genotypes

Out of 50 wheat genotypes the lowest days to heading was taken by genotype G21 (61.77 days) followed by genotype G8 (62.33 days), G44(62.67 days), and G1 (66.33 days). The highest days to heading was taken by genotype G 27 (79.00), which was close to genotype G32 (77.33 days) [Table 2]. The low and close GCV (5.09) and PCV (5.20) indicated narrow range of genotypic variability along with less influence of environment for the expression of this trait. Barma *et al.*, (1990) and Rahman (2009) reported a narrow range of variation among genotypes for this trait (Table 3).

The highest days to anthesis was observed in genotype G27 (84.33 days) followed by G 25 (82.67 days) and G29 (81.67 days), whereas the lowest days to anthesis was observed in genotype G21 (65.33 days) [Table 2]. The phenotypic coefficient of variation (5.40) and genotypic coefficient of variation (5.30) were low and close to each other. This is indicating less influence of environment for the expression of this trait and at the same time narrow range of genetic variation among genotypes for DTA (Table 3).

Table 1. Mean, Range, and CV (%) of seed yield and yield contributing characters of fifty spring wheat genotypes.

Component	MSp	MS_G	MS_E	Mean	Range	CV%	F-Value
DTH	41.693	41.088	0.605	72.77	61-79	1.07	**
DTA	50.398	49.804	0.594	76.83	65-84	1	**
DPM	22.278	21.684	1.372	103.35	98-111	1.13	**
GFD	18.348	17.754	1.739	26.55	23-34	4.97	**
GFR	12.091	10.52	15.76	14.3	10.07-18.98	8.7	**
PHT	41.854	40.115	4.765	91.83	80-98	2.38	**
CHL_A	19.984	18.75	1.234	49.51	43.5-54.5	2.24	**
CT_{vg} (°C)	0.585	0.312	0.273	21.03	19.9-22.5	2.48	**
CT_{anth} (°C)	0.514	0.236	0.278	22.08	21.1-23.5	2.39	**
$CT_{g\,f}$(°C)	0.786	0.463	0.323	23.75	21.5-24.9	2.39	**
Splet/spk.	3.946	3.458	0.488	16.02	13.9-18.4	4.36	**
Gr./spk.	46.76	31.88	14.872	50.74	40.7-57.9	7.6	**
TGW	32.652	25.727	6.925	37.21	30.5-45.9	7.07	**
Grain yield (kg/ha)	815481	709547	105934	3810.14	2552-4998	8.54	**

** Significant at 1% level of probability.

DTH= Days to heading, DTA= Days to anthesis, DPM=Days to physiological maturity (days); GFD= Grain filling duration, GFR= Grain filling rate, PHT= Plant height (cm), CHL_A=Chlorophyll content at anthesisstage (SPAD unit), CT_{vg}=Canopy temperature at vegetative stage (°C); CT_{anth}= Canopy temperature at anthesis stage (°C); CT_{gf}=Canopy temperature at grain filling stage (°C); Splet/spk.= Spikelets per spike, Gr./spk.= Grains per spike, TGW= Thousand grain weight, MS_P= Mean sum of squares due to phenotype, MS_G= Mean sum of squares due to genotype; MSE= Mean sum of squares due to error.

Among 50 genotypes, the highest days to physiological maturity was observed in genotype G 27 (111.33 days), whereas the lowest was in genotype G21 (98.33 days) followed by G40 (99.67 days) and G 8 (99.67 days) [Table 2]. The phenotypic coefficient of variation (2.79) and genotypic coefficient of variation (2.60) were low and close to each other indicating narrow range of genetic variation and at the same time very small environmental influence for the expression of this trait (Table 3).

The highest grain filling duration was observed in genotype G44 (34.00 days) followed by G8 (33.67 days) and G21 (33.00 days), whereas the lowest was observed in genotype G29 (23.33 days), which was close to genotype G50 (23.67), G49 (23.67 days), and G41(23.67 days) [Table 2]. The phenotypic coefficient of variation (10.16) was close to genotypic coefficient of variation (9.16) (Table 1). So, environment had a minor influence for the expression of this trait (Table 3).

The highest grain filling rate was observed in genotype G40 (18.98 1 $g^{-2}d^{-1}$ m^{-2}) followed by G48 (18.15 1 $g^{-2}d^{-1}$ m^{-2}) and G11 (17.65 1 $g^{-2}d^{-1}$ m^{-2}), whereas the lowest was observed in genotype G3 (10.07$g^{-2}d^{-1}$ m^{-2}) followed by genotype G41 (10.78 1 $g^{-2}d^{-1}$ m^{-2}) and G5 (10.99 1 $g^{-2}d^{-1}$ m^{-2}) [Table 2]. The phenotypic coefficient of variation (15.63) and genotypic coefficient of variation (12.98) was moderate. Little difference in phenotypic and genotypic coefficient of variation indicated less influence of environment for the character (Table 3).

The highest plant height was observed in genotype G4 (97.67 cm), G16 (97.67 cm), and G30 (97.67 cm), whereas the lowest plant height was observed in genotype G3 (80.33cm) followed by the genotypes G41 (81.33 cm) and G 21 (83 cm) [Table 2]. Lower estimate of phenotypic coefficient of variation (4.51) was little higher than genotypic coefficient of variation (3.98) indicating narrow range of genetic variation as well as some degree of environmental influence for the expression of this trait (Table 3).

The highest chlorophyll content at anthesis stage was observed in genotype G45 (54.53 SPAD unit) followed by genotype G 12 (53.67 SPAD unit) and G9 (53.63 SPAD unit), whereas the lowest was observed in genotype G2 (43.47 SPAD unit) [Table 2]. Lower estimate of phenotypic coefficient of variation (5.53) was slightly higher to genotypic coefficient of variation (5.05) indicating narrow range of genetic variation as well as some degree of environmental influence for the expression of this trait (Table 2).

The highest canopy temperature at vegetative stage was found in genotype G7 (22.47) and the lowest was in genotype G46 (19.93) [Table 2]. The PCV (2.92) was higher to GCV (1.53), indicating that the environment itself had played major role for the expression of this trait (Table 3).

The highest canopy temperature at anthesis stage was found in genotype G15 (23.47) and the lowest was found in genotype G39 (21.17) [Table 2]. The PCV (2.70) was higher to GCV (1.27), indicating that the environment itself had played major role for the expression of this trait (Table 3).

The highest canopy temperature at grain filling stage was found in the genotype G15 (24.97) and the lowest was in genotype G44 (21.50) [Table 2]. The phenotypic coefficient of variation (2.91) was higher to genotypic coefficient of variation (1.65), indicating the presence of environmental influence for the expression of this trait (Table 3).

The highest number of spikelets spike^{-1} was produced by the genotype G38 (18.37) which was followed by the genotypes G42 (18.10) and G 5(17.60) [Table 2]. The phenotypic coefficient of variation (7.99) was little higher to genotypic coefficient of variation (6.70) [Table 3]. So, it could be realized that range of genetic variation for the expression of this trait was narrow and environment might have very minor influence.

The highest number of grains spike^{-1} was found from the genotype G35 (57.93) followed by the genotypes G25 (56.90) and G30 (56.77), whereas the lowest grains spike^{-1} was produced by the genotype G49 (40.73) [Table 2]. The phenotypic coefficient of variation (9.95) was higher to genotypic coefficient of variation (6.42) indicating a considerable level of environmental influence for the expression of this trait (Table 3).

The highest thousand grain weight (TGW) was observed in genotype G13 (45.90 g.) followed by that of the genotypes G40 (42.40g.) and G 17 (42.20 g.), whereas the lowest was observed in genotype G4 (30.50 g.) [Table 2]. The phenotypic coefficient of variation (10.58) was higher to genotypic coefficient of variation (7.87) indicating a considerable level of environmental influence for the expression of this trait (Table 3). Chaturvedi and Gupta (1995) found phenotypic variation being higher than the genotypic variation.

In this experiment, the highest variation was found for grain yield. The highest grain yield was produced by the genotype G40 (4998 kg/ha.) followed by the genotypes G11 (4905 kg/ha.) and G12 (4899 kg/ha.), whereas the lowest grain yield was produced by the genotype G41 (2552 kg/ha.) [Table 2]. The phenotypic coefficient of variation (15.36) was higher to genotypic coefficient of variation (12.76) indicating a considerable level of environmental influence for the expression of this trait (Table 3).

The analysis of variance showed significance differences among the genotypes for all the characters. The ranges were high for most of the traits also. In order to obtain a clear understanding of the pattern of variations, the phenotypic variances were portioned into genotypic and environmental variances. The highest genotypic, environmental, and phenotypic variances were found in grain yield. The lowest variances were found in canopy temperature at anthesis stage. The phenotypic co-efficient of variations (PCV) were higher than the genotypic co-efficient of variations (GCV) for all the characters studied indicating the presence of environmental influence in the phenotypic expression of the characters. The difference between PCV and GCV was remarkably low for days to anthesis. The difference between PCV and GCV was high for grains spike^{-1}.

Heritability and genetic advance

The knowledge of heritability of a character helps the breeder in predicting the behavior of the succeeding generation and making desirable selections. Days to heading exhibited higher estimate of broad sense heritability (95.8%) along with low genetic advance in percent of mean (8.76%) suggests that improvement through phenotypic selection for this trait is feasible but it may not be rewarding (Table 3).

Days to anthesis showed higher estimate of broad sense heritability (96.5%) and low genetic advance in percent of mean (9.17) [Table 3]. Rahman (2009) observed similar results in spring wheat. Direct phenotypic selection may lead to some limited improvement in this trait but it may not be rewarding.

Days to physiological maturity (DPM) showed very high estimate of broad sense heritability (83.6%) and the genetic advance in percent of mean (4.11) was low (Table 3). All these indicated that the trait might be governed by non-additive gene action; hence there is few to zero probability of getting positive response through selection.

Grain filling duration exhibited higher estimate of broad sense heritability (76.10) along with moderate genetic advance in percent of mean (13.60) assuming that phenotypic selection may provide some improvement for this trait as there might be presence of additive gene action (Table 3).

Grain filling rate exhibited higher estimate of broad sense heritability (87.00) coupled with higher genetic advance in percent of mean (23.93) [Table 3]. Direct phenotypic selection will result in good positive improvement of this trait as there might be presence of additive gene action which had the late heat stress tolerance mechanism. Barma (2005) reported high heritability coupled with moderate genetic advance for this trait.

Plant height showed higher estimate of broad sense heritability (72.2) and lower genetic advance in percent of mean (5.73) [Table 3]. Under such indications selection for this character will not be effective. Ali *et al.,* (2008) and Rahman (2009) reported moderate heritability along with low genetic advance in spring wheat for plant height

Chlorophyll content at anthesis stage showed higher estimate of broad sense heritability (83.5%) along with lower genetic advance in percent of mean (8.12), which indicated that both additive and non-additive gene action was present there (Table 3). Direct phenotypic selection has limited chance for the improvement of this trait. Barma (2005) reported moderately high broad sense heritability coupled with moderate genetic advance in percent of mean for chlorophyll content.

Canopy temperature at vegetative stage exhibited lower estimate of broad sense heritability (27.6%) along with lower genetic advance in percent of mean (1.42) again reveals preponderance of non-additive gene action (Table 3). Raynolds *et al,* (1997) reported sensitivity of canopy temperature to environmental fluxes along with moderate heritability. Selection for this character will not be effective.

Canopy temperature at anthesis stage exhibited lower estimate of broad sense heritability (22.1%) along with lower genetic advance in percent of mean (1.05) again reveals preponderance of non-additive gene action (Table 3). Reynolds *et al.,* (1997) reported that canopy temperature is quite sensitive to environmental fluxes and moderate heritability values were found for this trait. Selection for this character will not be effective.

Canopy temperature at grain filling stage showed moderate estimate of broad sense heritability (32.3%) along with lower genetic advance in percent of mean (1.66) suggests that there were predominance of non-additive gene action (Table 3). Rahman (2009) observed lower genetic advance along with moderate heritability for canopy temperature in spring wheat. Selection for these traits will not be effective.

Spikelets spike^{-1} exhibited higher estimate of broad sense heritability (70.3) but lower genetic advance in percent of mean (9.88) [Table 3]. Phenotypic selection may provide some improvement for this trait as there might be presence of non-additive gene action. Ali *et al.,* (2008) estimated high heritability coupled with high genetic advance for spikelets spike^{-1}.

Grains spike^{-1} exhibited moderate estimate of broad sense heritability (41.7%) along with lower genetic advance (7.30) in percent of mean suggests that there were predominance of non-additive gene action (Table 3). Direct phenotypic selection has limited chance for the improvement of this trait. Sharma *et al.,* (1995) reported high genotypic coefficient of variation, high heritability and high genetic advance in grains spike^{-1}, suggesting the operation of additive gene effect for these traits

Table 2. Mean performance of the 50 genotypes for phenological, physiological, and yield contributing traits.

ENT	DTH	DTA	DPM	GFD	GFR	PHT	CHL_A	CT_{vg} (°C)	CT_{anth} (°C)	$CT_{g f}$ (°C)	Splet/spk.	Gr./spk.	TGW	Yield kg/ha
1	66.33	69.30	100.67	31.3	13.90	90.00	45.90	21.70	22.20	23.60	16.30	46.80	40.40	4365
2	75.00	79.70	106.00	26.3	14.90	89.00	43.50	21.60	22.10	24.10	16.50	51.30	32.30	3911
3	71.00	75.70	104.67	29.0	10.10	80.33	44.50	21.40	22.20	23.90	13.90	45.00	31.90	2918
4	73.00	77.30	104.00	26.7	15.80	97.67	47.00	20.80	21.90	23.70	14.20	53.60	30.50	4229
5	74.00	78.70	106.67	28.0	10.90	96.00	45.30	20.80	21.90	23.80	17.60	53.80	34.70	3049
6	74.67	79.70	105.67	26.0	14.30	93.67	51.20	22.00	22.80	24.40	15.00	41.20	41.20	3723
7	67.67	71.00	101.00	30.7	11.20	94.00	49.80	22.50	22.80	24.30	15.20	52.10	33.90	3418
8	62.33	66.00	99.67	33.7	11.20	92.33	46.40	21.90	22.90	24.40	17.00	51.30	38.40	3766
9	70.33	73.70	100.67	27.0	16.20	96.00	53.60	21.40	22.00	23.70	15.80	51.90	34.90	4367
10	69.67	73.00	100.67	27.7	16.00	94.67	51.60	21.50	21.90	23.90	14.90	47.00	32.80	4424
11	69.67	73.30	101.33	28.0	17.60	91.33	52.50	21.30	22.00	23.80	16.60	54.30	35.70	4905
12	70.00	73.70	102.67	29.0	16.90	95.67	53.70	21.30	22.00	23.70	14.50	50.30	40.50	4899
13	72.33	76.00	100.67	24.7	14.90	91.33	50.70	21.10	22.10	23.70	16.30	50.70	45.90	3678
14	74.33	78.30	105.67	27.3	13.80	92.33	50.40	21.00	21.90	23.90	17.30	52.70	41.70	3762
15	74.00	77.70	102.33	24.7	14.30	92.00	50.50	21.00	23.50	24.90	15.70	47.90	35.40	3516
16	72.00	76.00	101.33	25.3	13.70	97.67	52.40	21.10	22.20	23.70	16.50	51.40	36.90	3458
17	71.00	74.70	100.00	25.3	15.80	94.33	51.30	20.80	21.80	23.80	17.30	50.90	42.20	4000
18	73.33	77.00	102.00	25.0	11.90	95.00	48.60	20.90	21.70	23.80	16.10	45.30	38.00	2983
19	72.33	76.00	102.33	26.3	15.20	89.67	48.00	21.20	21.80	23.90	15.00	49.00	35.60	3987
20	72.33	76.30	101.33	25.0	14.40	92.00	47.20	21.40	21.90	23.10	16.80	50.70	38.00	3600
21	61.67	65.30	98.33	33.0	12.70	83.00	48.50	21.50	22.30	23.80	16.40	54.70	32.80	4199

Table 2. Continued.

ENT	DTH	DTA	DPM	GFD	GFR	PHT	CHL_A	CT_{vg} (°C)	CT_{anth} (°C)	CT_{gf} (°C)	Splet/spk.	Gr./spk.	TGW	Yield kg/ha
22	74.33	78.00	103.00	25.0	15.10	93.67	51.10	20.70	21.80	23.70	16.20	51.20	38.30	3781
23	73.00	77.00	104.33	27.3	14.70	90.67	49.80	20.50	21.90	23.80	14.30	52.10	36.80	4012
24	75.33	79.30	105.00	25.7	12.80	91.00	46.40	21.10	22.00	24.20	14.00	46.70	35.00	3282
25	76.67	82.70	108.00	25.3	11.70	88.00	49.80	21.00	22.00	22.50	15.70	56.90	39.90	2966
26	76.00	80.70	105.00	24.3	13.80	88.00	50.70	20.80	22.10	24.30	16.40	43.10	32.30	3355
27	79.00	84.30	111.33	27.0	13.00	89.33	46.50	20.70	22.20	23.90	16.30	52.20	37.10	3502
28	72.00	75.70	101.33	25.7	14.20	92.33	50.20	20.80	22.40	24.20	14.40	51.00	38.40	3636
29	77.00	81.70	105.00	23.3	14.20	94.33	48.20	21.30	22.00	24.10	17.30	52.30	36.60	3333
30	75.00	79.70	107.33	27.7	13.20	96.67	51.40	20.80	21.70	23.60	17.40	56.80	37.90	3654
31	75.33	79.70	107.00	27.3	13.70	95.67	53.30	20.80	22.10	23.70	16.20	52.60	39.10	3746
32	77.33	81.70	107.00	25.3	16.30	91.00	47.40	20.90	21.80	23.70	17.20	48.80	33.10	4132
33	76.33	80.70	105.00	24.3	15.80	91.67	46.90	21.00	21.70	23.50	16.80	51.00	38.10	3799
34	71.67	75.30	100.00	24.7	16.20	92.33	52.00	20.80	21.60	23.50	14.90	56.00	36.60	3994
35	71.00	74.70	100.67	26.0	17.30	87.67	52.30	20.80	22.00	23.70	14.70	57.90	36.40	4495
36	73.00	76.70	102.00	25.3	15.60	88.67	52.60	20.80	22.00	23.90	15.10	55.60	30.90	3953
37	74.33	78.70	106.00	27.3	12.80	94.00	48.60	20.90	21.80	23.50	16.50	55.10	36.40	3504
38	75.33	79.30	105.67	27.0	15.60	93.33	47.70	20.40	21.30	23.10	18.40	46.30	41.80	4212
39	74.67	79.00	106.33	27.3	14.70	93.67	48.90	20.40	21.10	23.30	17.40	56.40	39.60	4048
40	69.00	73.30	99.67	26.3	19.00	96.33	46.50	20.80	21.90	23.80	14.90	50.00	42.40	4998
41	76.00	80.70	104.33	23.7	10.80	81.33	50.30	21.00	22.60	24.20	17.10	55.50	37.00	2552
42	74.33	78.30	103.33	25.0	16.70	96.33	45.90	20.80	22.60	24.10	18.10	47.90	38.10	4148
43	75.00	78.70	103.67	25.0	14.70	90.67	48.20	20.60	22.70	24.40	15.90	49.40	38.40	3671

Table 2. Continued.

ENT	DTH	DTA	DPM	GFD	GFR	PHT	CHL_A	CT_{vg} (°C)	CT_{anth} (°C)	CT_{gf} (°C)	Splet/spk.	Gr./spk.	TGW	Yield kg/ha
44	62.67	66.00	100.00	34.0	11.70	91.33	51.20	21.10	21.80	21.50	16.60	48.40	37.10	3991
45	73.33	77.00	101.33	24.3	12.80	91.33	54.50	21.20	22.70	23.90	16.70	55.00	34.60	3107
46	74.33	78.30	105.00	26.7	14.60	88.67	51.50	19.90	22.10	23.30	17.40	51.60	42.00	3890
47	76.33	80.30	104.67	24.3	14.70	91.67	48.80	20.50	22.10	23.40	14.30	48.60	36.50	3577
48	71.33	75.00	100.00	25.0	18.20	92.00	50.30	20.80	22.50	23.70	14.60	48.10	36.10	4546
49	76.00	80.00	103.67	23.7	17.20	94.00	50.30	20.40	21.90	23.50	15.60	40.70	40.40	4053
50	76.00	80.70	104.33	23.7	14.40	88.00	51.50	21.00	21.80	23.50	15.70	47.90	39.30	3410

DTH= Days to heading, DTA= Days to anthesis, DPM=Days to physiological maturity (days); GFD= Grain filling duration, GFR= Grain filling rate, PHT= Plant height (cm), CHL_A=Chlorophyll content at anthesisstage (SPAD unit), CT_{vg}=Canopy temperature at vegetative stage (°C); CT_{anth}= Canopy temperature at anthesis stage (°C); CT_{gf}=Canopy temperature at grain filling stage (°C), Splet/spk.= Spikelet per spike, Gr./spk.= Grain per spike, TGW= Thousand grain weight.

Thousand grain weight exhibited higher estimate of broad sense heritability (55.3%) along with lower genetic advance in percent of mean (10.30) [Table 3]. Phenotypic selection may provide some improvement for this trait as there might be presence of non-additive gene action. Chaturvedi and Gupta (1995) found higher estimates of heritability for 1000-grain weight. Many other authors reported high heritability along with high genetic advance for 1000-grain weight (Sharma *et al*., 1995; Shoran, 1995; Vilhelmsen *et al*., 2001 and Ali *et al*., 2008).

Grain yield showed high estimate of broad sense heritability (69.10%) along with moderate genetic advance in percent of mean (18.67) indicating the presence of additive and non-additive gene action for the expression of this trait [Table 3]. There is a scope of phenotypic selection for the improvement of this trait. Many authors found high heritability along with high to moderate genetic advance for grain yield in wheat (Barma, 2005; Singh *et al*., 2006; Ali *et al*., 2008; Rahman, 2009).

Genotypic co-efficient of variation together with high heritability and genetic advance are considered as good estimates of genetic gain to be expected in making selection of superior genotypes on the basis of phenotypic performance. Johnson *et al.,* (1955) mentioned that high heritability along with high genetic gain are more successful than the heritability alone to select desirable genotypes with higher yield.Panse (1957) stated that high value of heritability with low genetic advance indicated that the heritability was probably due to the effect of non-additive gene action. The characters with high values of GCV, PCV, and heritability accompanied by high genetic advance in percent of mean might be transmitted to their progenies and therefore, phenotypic selection based on these characters would be effective.

Estimated phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) revealed higher to moderate range of genetic variations for most of the phenological and physiological traits. Grain filling period, grain filling rate, grain yield, exhibited more than 10% GCV. DTH, DTA, $CHL_{A,}$ spikelets $spike^{-1}$, grains $spike^{-1}$, TGW also had moderate range of PCV% and GCV%. DPM, PHT, CT_{vg} (^{o}C), CT_{g} (^{o}C), CT_{anth} (^{o}C), had lower GCV estimate (<10%) indicating narrow range of genetic variation. The PCV and corresponding GCV estimates were close to each other for CHL_{A}, DTA, DPM, DTH indicating less influence of environment for the expression of these traits. On the other hand the PCV estimate for GFD, GFR, PHT, CT_{vg} (^{o}C), CT_{anth} (^{o}C), CT_{g} (^{o}C), spikelets $spike^{-1}$, grains $spike^{-1}$, TGW , and yield (kg/ha), were moderately higher to much higher than corresponding GCV indicating that the environment had moderate to major influence for the expression of these traits.

Table 3. Estimation of some genetic parameters in fifty spring wheat genotypes.

Component	GCV	PCV	δ^2g	δ^2p	H^2_b	H^2_b%	$GA_{(10\%)}$	GA % of mean
DTH	5.09	5.2	13.7	14.3	0.96	95.8	6.37	8.76
DTA	5.3	5.4	16.6	17.2	0.97	96.5	7.05	9.17
DPM	2.6	2.79	6.97	8.34	0.84	83.6	4.25	4.11
GFD	9.16	10.16	5.54	7.28	0.76	76.1	3.61	11.6
GFR	12.98	15.63	3.51	5.08	0.87	87	3.45	23.93
PHT	3.98	4.51	12.36	17.13	0.72	72.2	5.26	5.73
CHL_A	5.05	5.53	6.25	7.48	0.84	83.5	4.02	8.12
CT_{vg} (^oC)	1.53	2.92	0.1	0.38	0.28	27.6	0.3	1.42
CT_{anth} (^oC)	1.27	2.7	0.08	0.36	0.22	22.1	0.23	1.05
$CT_{g f}$(^oC)	1.65	2.91	0.15	0.48	0.32	32.3	0.39	1.66
Splet/spk.	6.7	7.99	1.15	1.64	0.7	70.3	1.58	9.88
Gr./spk.	6.42	9.95	10.63	25.5	0.42	41.7	3.7	7.3
TGW (g)	7.87	10.58	8.58	15.5	0.55	55.3	3.83	1030
Yield (kg/ha)	12.76	15.36	236516	342450	0.69	69.1	711.33	18.67

DTH= Days to heading, DTA= Days to anthesis, DPM=Days to physiological maturity (days); GFD= Grain filling duration, GFR= Grain filling rate, PHT= Plant height (cm), CHL_A=Chlorophyll content at anthesis stage (SPAD unit), CT_{vg}=Canopy temperature at vegetative stage (^oC), CT_{anth}= Canopy temperature at anthesis stage (^oC), CT_{gf}=Canopy temperature at grain filling stage (^oC), Splet/spk.= Spikelet per spike, Gr./spk.= Grain per spike, TGW= Thousand grain weight, GCV=Genotypic coefficient of variation, PCV=Phenotypic coefficient of variation, δ^2g=Genotypic variance; δ^2p=Phenotypic variance, H^2b=Heritability in broad sense, H^2b% = Heritability in broad sense in percentage, GA=Genetic advance

High heritability along with higher genetic advance was observed for DTH, DTA, DPM, GFD, GFR, PHT, $CHL_{A,}$ spikelets spike^{-1}, and yield (kg/ha) indicated that direct phenotypic selection has good chances to bring some good improvement in these traits. The remaining traits showed lower heritability coupled with low genetic advance in percent of mean indicating that selection has little to no chance for improvement. Considering variability among the genotypes, heritability, genetic advance, percent co-efficient of variance, and field performances, the genotypes G 3, G 10, G 11, G 12, G13, G 21, G 29, G 35, G 38, G 40, and G 48 were found suitable for future breeding programme.

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LARVICIDAL EFFICACY OF SOME INDIGENOUS PLANT EXTRACTS AGAINST EPILACHNA BEETLE, *EPILACHNA VIGINTIOCTOPUNCTATA* (FAB.) (COLEOPTERA: COCCINELLIDAE)

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Abstract

The study was carried out to assess the larvicidal efficacies of some indigenous plant seed extracts against epilachna beetle, *Epilachna vigintioctopunctata* in the laboratory of the Department of Entomology, HSTU, Dinajpur, Bangladesh. Petroleum ether and methanol solvent extracts of ata (*Annona squamosa*), neem (*Azadirachta indica*), dhutura (*Datura metel*) and castor (*Ricinus communis*) seeds were evaluated for their larvicidal properties against the larval stage of *E. vigintioctopunctata*. The result revealed that all the tested plant extracts had more or less insecticidal effect against the larvae and their progeny. Among the plant extracts, ata seed extract in methanol solvent performed the highest toxicity (LD_{50} value 0.031 mg/insect) in larval stage after 72 hours exposure time. The effects of the extracts on fecundity, fertility and F_1 adult emergence of the epilachna beetle at doses 4.0, 2.0 and 1.0 ml/l of water including untreated control were also evaluated. The result indicated that, among the extracts, ata seed extract at maximum dose (4.0 ml/l water) showed the highest efficacy with the inhibition of total eggs (74.1%), viable eggs (80.4%) and number of emergent adult progeny (87.3%). The result also revealed that the number of eggs, number of viable eggs and F_1 progeny production decreased with the increase of doses. All the treated doses effectively reduced the epilachna beetle as compared to untreated control.

Keywords: Plant extracts, petroleum ether, methanol solvent, larval mortality, *Epilachna vigintioctopunctata*.

Introduction

Two species of epilachna beetle viz. *Epilachna vigintioctopunctata* (Fab.) and *Epilachna dodecastigma* (Wied.) are serious pests of vegetables in Bangladesh (Khan *et al*., 2000). Epilachna beetles are locally known as hadda beetles and common throughout the country and cause a considerable damage to a number of solanaceous, cucurbitaceous and leguminous crops (Anam *et al*., 2006; Rahaman *et al*., 2008; Islam, *et al*., 2011). Both adults and grubs feed voraciously by scrapping the chlorophyll of the leaves, causing characteristics skeletonization of the lamina. Affected leaves gradually dry and drop down (Srivastava and Butani, 1998).

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Due to infestation of epilachna beetle about 80% of plants are damaged depending on place and season for prevailing environmental conditions (Rajagopal and Trivedi, 1989). The presence of this pest is one of the limiting factors in the vegetable production causing qualitative as well as quantitative losses. Synthetic chemical insecticides have been widely preferred to combat this pest problem because of their quick knock-down effect. But due to some ill-effects of the chemical insecticides, there have been numerous problems, such as acute and chronic poisoning of applicators, farm workers, consumers, fishes, birds and other wild life animals etc. (National Research Council, 2000; Rohani *et al*., 2001). Substitutes are being strongly conceived whereby researchers are now paying much emphasis on the biologically active indigenous plant products as they are environmentally safe, biodegradable and cost effective. Plant extracts contain botanical insecticides or phytochemicals that could be used to repel, deter feeding, or limit reproduction and survival of various insect pest species including coccinellid beetles (Rajagopal and Trivedi, 1989; Swaminathan *et al*., 2010).

Using various plant extracts, attempts have been made to save such crops as potato (Rajagopal and Trivedi, 1989), brinjal (Sreedevi *et al*., 1993; Ghatak and Mondal, 2008), oilseed (Ahmed, 2007; Ahmed *et al*., 2010), cucumber (Mondal and Ghatak, 2009) and bitter gourd (Rahaman *et al.,* 2008) against the attacks of the beetle. Ahmed (2007) reported that aqueous extract sprays of the castor oil plant *Ricinus communis* L. (F. Euphorbiaceae) reduced *Epilachna* attack on foliage. Subsequently, methanol extracts of *R. communis* were found to have larvicidal properties against the mosquitoes *Aedes aegypti* (Zahir *et al.*, 2009). Anam *et al.,* (2006) reported that neem oil significantly prolonged larval and pupal periods and some of the treated larvae never reached to the pupae. Pupal recovery and adult emergence were greatly reduced in treated larvae. The aqueous extract of *Calotropis procera* showed strong repellent activity against the *Henosepilachna elaterii* (Ahmed *et al.,* 2006). The uses of plant products against vegetable pests are scanty in Bangladesh. Therefore, an attempt was made to find out the larvicidal efficacy of the seed extracts of neem, ata, dhutura and castor against the larvae of epilachna beetle.

Materials and Method

Collection and preparation of test plant seed powder: The study was conducted in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh during August 2012 to November 2012. Test plant materials, such as neem (*Azadirachta indica* A. Juss.), ata (*Annona squamosa* L.), dhutura (*Datura metel* L.) and castor (*R. communis* L.) seeds were collected from the villages of the Dinajpur district. All seeds were collected at the ripening stage. Collected seeds were washed in the running tap water and then dried under shade in the laboratory as breakdown of various compounds may occur in sunlight. The dried seeds were then powdered in a hand grinding machine separately. Before grinding the seeds were well-dried in an oven at 40°C for six hours. A sieve of 60-mesh diameter was used to obtain the fine powder. Later each powder was stored in plastic containers under laboratory condition for experimental use.

Preparation of seed extract: Hundred grams of different seed powders were dissolved in 300 ml of pure methanol (polar) and petroleum ether (non-polar) solvent separately and stirred for 30 minutes in a magnetic stirrer. The mixture was then allowed to stand for 72 hours and shaking several intervals. Then, the mixture was filtered through a filter paper (Whatman no. 42) and allowed to evaporate the solvents in water bath at 70^0C. Finally, the oily crude extracts were obtained. The oily extracts were preserved in tightly corked vials and stored in a refrigerator for experimental use.

Rearing and mass culture of the test insect (*E. vigintioctopunctata*): In order to obtain a huge number of beetles continuously for experimental use a mass culture was maintained in cages with potted plant of bitter gourd. The adults of *E. vigintioctopunctata* were collected from the infested bitter gourd plant cultivated in the field of Entomology Department, HSTU campus. They were sexed and one pair of beetle was released in each plant in the fine mesh nylon cages (45 cm x 35 cm x 60 cm) under laboratory conditions at 28±2°C and 81±2% RH for oviposition. After oviposition adult beetles were transferred in different cages and the egg masses were left undisturbed for hatching. After hatching the larvae and pupae were reared up to adult emergence. For continuous supply of the potted plants as food, bitter gourd seeds were sown in earthen pots every alternate day. When the plants were fed by larvae in cages, the fresh plant pot was placed attached to the adjacent pot, thus all the larvae moved to the fresh one. The number of instars was determined by their shed skin. This procedure was used to obtain a large number of larvae of the same instar (4th) at the same time for experiments.

Experimental protocol

Effect of plant extract on the larval mortality (direct toxicity): Direct toxicity tests on the larvae of epilachna beetle were conducted under laboratory conditions at 28±2°C and 81±2% RH following Completely Randomized Design (CRD). Different concentrations of crude extracts were prepared by diluting with the respective solvents. The concentrations were 100, 50, 25, 12.5 and 6.25 mg/ml of each plant in each solvent. Before applying extracts, the larvae were chilled for a period of 10 minutes in refrigerator. The immobilized larvae were individually picked up and 10 micro-liter solutions of different concentrations

(100, 50, 25, 12.5 and 6.25 mg/ml) were applied to the dorsal surface of the thorax of each individual with the help of a micro syringe (Hamilton, USA). Ten larvae were treated in one replication. Three replications were used in each dose. The insects of control treatment were treated with the respective solvent only. The insects were then transferred into 9.0 cm diameter Petri dishes containing leaf disc of bitter gourd as food. Insect mortality was recorded at 24, 48 and 72 hours after treatment. The data were corrected by Abbott's (1987) formula. The probit analyses were done to estimate LD_{50} values with 95% fiducial limits. Heterogeneity was tested by a chi-square test.

Effect of plant extracts on the fecundity, egg hatchability, and adult population of F_1 progeny (residual effect)

The seeds of neem, ata, dhutura and castor were extracted in two solvents (petroleum spirit and methanol) for their residual effect on the fecundity, egg hatchability, and adult population of F_1 progeny. Each type of crude extract was diluted with distilled water containing 0.01% nonidet to prepare different concentrations of spray solution. The doses were 4.0, 2.0, and 1.0 ml/l of water for each treatment. The total numbers of treatments were 25 and replication was thrice for each dose. The test extracts were compared with untreated control.

The entire experiment was conducted with the potted bitter gourd plant. Bitter gourd seeds were collected from regional BRAC seed centre, Dinajpur and planted in earthen pot. To prevent the pest infestation, plants were covered with mosquito net. Sprayings with different solutions were done at 40 days after sowing (DAS) by a hand sprayer. After spraying each plant was marked with marking card. To induce population build up one pair of 10-15 days old fresh healthy adult beetles were released in each plant and kept for oviposition. The total numbers of eggs in masses were counted and recorded after seven days with the help of magnifying glass and then the parent beetles were removed. Observations on total number of larvae, pupae and adult emergence (F_1 progeny) were also counted and recorded up to adult emergence.

Statistical analysis: The experiments were conducted using CRD. The data obtained from the experiments were statistically analyzed by MSTAT-C computer program. The means of the treatments were tested by DMRT. The observed mortality data were corrected by Abbott's (1987) formula and then subjected to probit analysis.

Results and Discussion

Effect of plant seed extracts on larval mortality: The results of the larval mortality for the estimation of LD_{50} values, 95% confidence limits, regression equations and χ^2 values were calculated and presented in Table 1. The calculated LD_{50} values were 0.136, 0.693, 0.176, 0.230 mg/insect at 24 hours after treatment(HAT); 0.071, 0.434, 0.074, 0.115 mg/insect after 48 HAT and 0.045, 0.163, 0.037, 0.055 mg/insect after 72 HAT in ata, neem, dhutura, castor seed extract respectively in petroleum spirit. Comparing the LD_{50} values, the order of toxicity was found as ata > dhutura > castor > neem at 24 and 48 HAT whereas after 72 HAT the toxicity was dhutura > ata > castor > neem (Table 1).

In methanol solvent extract, the LD_{50} values were found as 0.094, 0.348, 0.250, 0.175 mg/insect at 24 HAT; 0.039, 0.114, 0.144, 0.088 mg/insect at 48 HAT and 0.031, 0.046, 0.073, 0.050 mg/insect at 72 HAT in ata, neem, dhutura and castor seed extract, respectively. The toxicity rank of the seed extracts was found as ata > castor > dhutura > neem at 24 HAT whereas it was found as ata > castor > neem > dhutura at 48 and ata > neem > castor > dhutura at 72 HAT (Table 1) depending on the LD_{50} values.

The probit regression lines of *E. vigintioctopunctata* larvae treated with ata, neem, dhutura and castor seed extract in two solvent at different exposure hours are presented in Fig. 1. The insect mortality rates showed positive correlation with doses in all cases. From the non-significant χ^2 values it indicated that larval mortality did not show heterogeneity with the doses of extracts. Karunaratne and Arukwatta (2009) evaluated the methanol extracts of *A. indica* (Neem), *A. reticulata,* (Custard apple) and *A. squamosa* (Sugar apple) for their potential as antifeedants and insecticides for the control of *E. vigintioctopunctata.* They found that all three plants eliciting a highly significant reduction in food consumption at all concentrations. *A. squamosa* at the highest concentration (20.0 g/L) showed very strong antifeedant and contact toxic effect on the epilachna larvae whereas *A. indica* extract elicited a much more delayed toxic action. Swaminathan *et al.,* (2010) investigated that Neem oil showed 60 per cent mortality at 5 per cent concentration. The leaf extract and seed kernel extract of *A. indica* had less antifeedant activity as compared to the oil formulations of *A. indica.* In the present study neem seed extract showed less toxic effect than other botanicals.

Effect of plant extracts on fecundity, hatchability, and adult population of F_1 progeny (**residual effect):** The results of the effect of plant extracts on the fecundity, fertility and F_1 progeny production of *E. vigintioctopunctata* are presented in Table 2. Statistical analysis indicated that the individual effect of two solvents did not differ significantly. Probably this may happen that the solvents were not used as in spray material, these solvent were only used as in extract preparation.

Table 1. Relative toxicity of different indigenous plant seed extracts of two solvents treated against *Epilachna vigintioctopunctata* (Fab.)

Solvent used	Plant seed	Duration of Treatment	No. of larvae used	LD_{50} (mg/insect)	95% confidence limit		Regression equation	χ^2 value (df = 3)
					Lower	Upper		
Petroleum spirit	Ata	24 HAT	150	0.136409	0.060226	0.308959	Y = 4.349508+ 0.5732004 X	0.0582404
		48 HAT	150	0.070588	0.030432	0.163728	Y = 4.455248+ 0.6418457 X	0.1351719
		72 HAT	150	0.044658	0.017003	0.117293	Y = 4.545282+ 0.6996722 X	0.4227400
	Castor	24 HAT	150	0.230393	0.085189	0.736046	Y = 4.263516+ 0.5265698 X	0.0182552
		48 HAT	150	0.115483	0.046141	0.289032	Y = 4.458756 + 0.509398 X	0.1651783
		72 HAT	150	0.055376	0.019371	0.158300	Y = 4.572763 + 0.574769 X	0.1289406
	Dhutura	24 HAT	150	0.176029	0.077441	0.400126	Y = 4.252675+ 0.5999796 X	0.0089731
		48 HAT	150	0.073807	0.035377	0.153982	Y = 4.374619+ 0.7204061 X	0.2571945
		72 HAT	150	0.037054	0.012258	0.112005	Y = 4.618414+ 0.6708236 X	0.3140278
	Neem	24 HAT	150	0.693245	0.234595	2.048586	Y = 3.340462+ 0.9014887 X	0.3007021
		48 HAT	150	0.434204	0.148463	1.269902	Y = 3.849556+ 0.7024786 X	0.1576462
		72 HAT	150	0.163368	0.080371	0.332076	Y = 4.171383+ 0.6830195 X	0.1061063
Methanol	Ata	24 HAT	150	0.093866	0.042869	0.205525	Y = 4.39381+ 0.6233270 X	0.0992475
		48 HAT	150	0.038696	0.010375	0.144321	Y = 4.67689+ 0.5498185 X	0.0756526
		72 HAT	150	0.031386	0.010829	0.090959	Y = 4.621701+ 0.761578 X	0.2303925
	Castor	24 HAT	150	0.174867	0.081747	0.374060	Y = 4.193177 + 0.649246 X	0.1053519
		48 HAT	150	0.088185	0.045211	0.172006	Y = 4.294052 + 0.746722 X	0.1739197
		72 HAT	150	0.050367	0.021342	0.118868	Y = 4.48158 + 0.7383339 X	0.1600962
	Dhutura	24 HAT	150	0.250407	0.851897	0.736046	Y = 4.263516+ 0.5265698 X	0.0182552
		48 HAT	150	0.144136	0.060331	0.344351	Y = 4.374189+ 0.540064 X	0.2390728
		72 HAT	150	0.072803	0.029430	0.180097	Y = 4.492859+ 0.588230 X	0.3903656
	Neem	24 HAT	150	0.347731	0.107107	1.128934	Y = 4.121894+ 0.569739 X	0.1259551
		48 HAT	150	0.114038	0.054175	0.240051	Y = 4.331665+ 0.632264 X	0.0293164
		72 HAT	150	0.046336	0.016386	0.131025	Y = 4.576223 + 0.636384 X	0.2607088

HAT = Hour after treatment, Values were based on five concentrations, three replications of 10 larvae each.
χ^2 = Goodness of fit, The tabulated value of χ^2 is 5.99 (d. f = 2 at 5% level).

Table 2. Mean of eggs laid, viable eggs, adult population of *E. vigintioctopunctata* reared in bitter gourd plant treated by different plant seed extract in various doses.

Solvent/ Plant seed extract/ Doses	No. of eggs /insect	inhibition rate (%)	No. of egg hatched	inhibition rate (%)	No. of larvae	inhibition rate (%)	No. of pupae	inhibition rate (%)	No. of adult emerged	inhibition rate (%)
Petroleum spirit	60.3	-	45.7	-	29.3	-	17.5	-	15.1	-
Methanol	58.3	-	44.1	-	28.6	-	16.9	-	14.7	-
LSD (0.05)	NS	-	NS	-	NS	-	NS	-	NS	-
Ata seed extract (ASE)	50.9 c	45.4	38.6 c	51.1	25.5 c	58.0	15.4 c	59.5	13.6 c	58.8
Castor seed extract (CSE)	52.5 c	43.7	39.9 c	49.5	26.4 c	56.5	15.9 c	58.2	14.0 c	57.6
Dhutura seed extract (DSE)	67.7 b	27.4	51.3 b	35.1	32.1 b	47.1	18.8 b	50.5	16.3 b	50.6
Neem seed extract (NSE)	66.2 b	29.0	49.7 b	37.1	31.7 b	47.8	18.8 b	50.5	15.7 b	52.4
Control	93.3 a	0	79.0 a	0	60.7 a	0	38.0 a	0	33.0 a	0
LSD (0.05)	4.2	-	3.2	-	1.8	-	1.0	-	0.7	-
Dose-1 (4.0 ml/litre)	32.3 d	65.4	20.6 d	73.9	10.8 d	82.2	6.1 d	83.9	5.3 d	83.9
Dose-2 (2.0 ml/litre)	45.4 c	51.3	30.8 c	61.0	16.7 c	72.5	9.1 c	76.1	7.9 c	76.1
Dose-3 (1.0 ml/litre)	66.3 b	28.9	49.1 b	37.8	27.7 b	54.4	15.7 b	58.7	13.5 b	59.1
Control	93.3 a	0	79.0 a	0	60.7 a	0	38.0 a	0	33.0 a	0
LSD (0.05)	4.2	-	3.2	-	1.8	-	1.0	-	0.7	-

Table 2. Continued.

Solvent/ Plant seed extract/ Doses	No. of eggs /insect	inhibi-tion rate (%)	No. of egg hatched	inhibi-tion rate (%)	No. of larvae	inhibi-tion rate (%)	No. of pupae	inhibi-tion rate (%)	No. of adult emerged	inhibi-tion rate (%)
ASE Dose-1 (4.0 ml/litre)	24.2 h	74.1	15.5 g	80.4	8.0 f	86.8	4.7 g	87.6	4.2 h	87.3
ASE Dose-2 (2.0 ml/litre)	34.5 fg	63.0	23.2 ef	70.6	12.2 de	79.9	7.0 e	81.6	6.2 g	81.2
ASE Dose-3 (1.0 ml/litre)	51.7 d	44.6	36.7 d	53.5	21.3 c	64.9	11.8 d	68.9	10.5 e	68.2
CSE Dose-1 (4.0 ml/litre)	26.5 gh	71.6	16.8 fg	78.7	8.7 ef	85.7	5.0 fg	86.8	4.5 h	86.4
CSE Dose-2 (2.0 ml/litre)	34.2 fg	63.3	22.8 ef	71.1	12.5 d	79.4	6.8 ef	82.1	6.5 g	80.3
CSE Dose-3 (1.0 ml/litre)	56.2 d	39.8	40.8 d	48.4	23.8 c	60.8	13.8 c	63.7	12.2 d	63.0
DSE Dose-1 (4.0 ml/litre)	35.7 ef	61.7	23.3 e	70.5	12.0 de	80.2	6.8 ef	82.1	6.0 g	81.8
DSE Dose-2 (2.0 ml/litre)	57.5 d	38.4	39.7 d	49.7	21.3 c	64.9	11.5 d	69.7	9.8 ef	70.3
DSE Dose-3 (1.0 ml/litre)	84.2 b	9.8	63.3 b	19.9	34.5 b	43.2	19.0 b	50.0	16.3 b	50.6
NSE Dose-1 (4.0 ml/litre)	43.0 e	53.9	26.8 e	66.1	14.5 d	76.1	7.8 e	79.5	6.3 g	80.9
NSE Dose-2 (2.0 ml/litre)	55.3 d	40.7	37.5 d	52.5	20.7 c	65.9	11.2 d	70.5	9.0 f	72.7
NSE Dose-3 (1.0 ml/litre)	73.0 c	21.8	55.5 c	29.7	31.0 b	48.9	18.0 b	52.6	14.8 c	55.2
Control	93.3 a	0	79.0 a	0	60.7 a	0	38.0 a	0	33.0 a	0

* Within column values followed by same letter(s) are not significantly different by DMRT at 5 % level of probability.

ASE- Ata seed extract, CSE- Castor seed extract, DSE- Dhutura seed extract and NSE-Neem seed extract.

The individual effects of plant extracts on the fecundity, fertility and F_1 progeny production of *E. vigintioctopunctata* were significantly different among the plant extracts. Among the extracts, ata seed extracts showed maximum efficacy to produce the lowest number of eggs (50.9), viable eggs (38.6) and population production (13.6) followed by castor seed extract. On the other hand, dhutura seed extracts showed the highest number of eggs (67.7), viable eggs (51.3) and population production (16.3). The inhibition rate of the plant extracts ranged from 27.4 to 45.4 % for the number of eggs per insect and 35.1 to 51.1% for the number of egg hatched. The per cent larval and pupal inhibition was found 47.1 to 58.0 and 50.5 to 59.5 in all tested plant extract while no larval and pupal inhibition was found in control treatment. Similarly, adult emergence inhibition was found 50.6 to 58.8 % among the all the tested plant extracts whereas no per cent inhibition of adult emergence was observed in control treatment. On the basis of fecundity, hatchability, and adult population of F_1 progeny the order of toxicity was found as ata > castor > neem > dhutura.

The lowest average numbers of eggs laid, eggs hatched and population production were observed in the highest dose of all plant extracts (4.0 ml/l) and the highest numbers of eggs laid, eggs hatched and population production were found in control (Table 2). The present result indicates that the fecundity, fertility and population production decreased with the increased doses. Statistical analysis showed that all the doses of the plant extracts differed significantly over control and also among the plant extracts (Table 2). The per cent of the highest egg laying inhibition rate was observed in highest dose (4.0 ml/l) and lowest was in lowest dose (1.0 ml/l), whereas no egg laying inhibition rate was observed in the control treatment. Similar results were found in per cent inhibition of egg hatch, larval population, pupal population and adult emergence. (Table 2).

The ata seed extract showed the highest efficacy in producing the lowest number of eggs per insect, viable eggs and F_1 progeny productions in the highest dose (4.0 ml/l). Similarly, ata showed the highest inhibition (%) rate in egg hatch, larval population, pupal population and adult emergence (Table 2).

Reddy *et al.*, (1990) reported that petroleum spirit (1%) extracts of *A. indica* and *A. squamosa* reduced the number of *H. vigintioctopunctata* larvae infesting brinjal by 88.0 and 92.99%; 85.98 and 91.02% at 24 and 72 hours after spraying, respectively. Similarly, Rao *et al.*, (1990) observed that extracts of *A. squamosa, Argemone mexicana, Calotropis gigantea, D. stramonium, Eucalyptus globulus, Pongamia glabra* and *R. communis* (0.5%) produced cent per cent protection against second instar larvae of *H. vigintioctopunctata*. Mondal and Ghatak (2009) found that seed extract of *A. squamosa* in methanol solvent achieved the highest extent of 76.37% population reduction at 3ml/l of water followed by 64% in Neem Azal at 5ml/l of water and 57% in petroleum spirit extracts of rhizome of *Acorus calamus* at 2ml/l of water against *H. vigintioctopunctata*. The overall result of the present study achieved the bioefficacy of all the tested plant seed extracts against *E. vigintioctopunctata* but among these, ata seed extract showed the highest effect in reducing fecundity, hatchability and adult emergence of the pest.

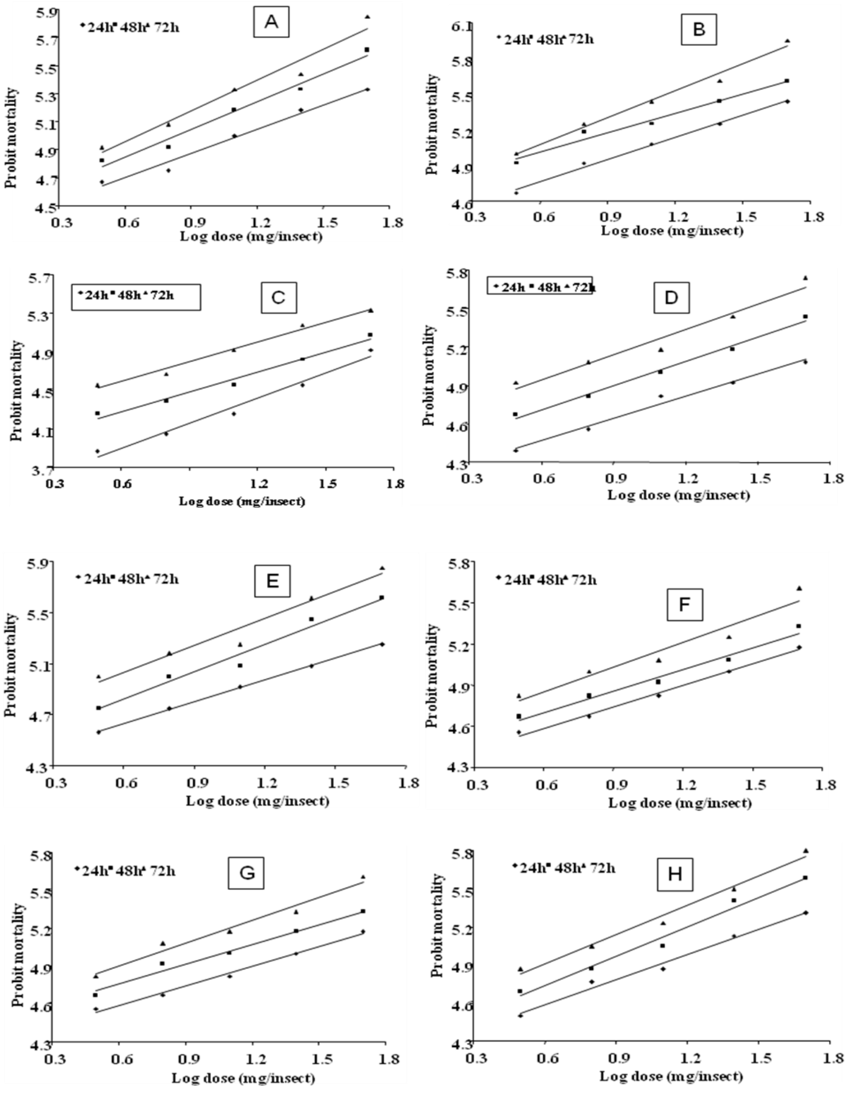

Fig. 1. Relation between log doses and probit mortality for different plant extracts against larvae of *E. vigintioctopunctata* [A= Petroleun spirit of ata, B= methanol extract of ata, C= Petroleun spirit of neem, D= methanol extract of neem, E= Petroleun spirit of dhutura, F= methanol extract of dhutura, G= Petroleun spirit of castor H= methanol extract of castor].

Babu *et al.*, (1998) reported that the seeds of *A. squamosa* were found to have insecticidal properties. The larval mortality is probably due to the presence of bioactive chemical components in plant products. The biological activity of ata seed extracts might be attributed to its several alkaloids contents, such as Anonaine, Squamocins B to N, Annotemoyin-1, Annotemoyin-2, Squamocin, Cholesterol and Glucopyranoside etc. (Pandey and Brave, 2011) which might cause mortality to insects.

Conclusion

The present result indicates the larvicidal efficacy of methanol and petroleum spirit seed extracts of ata, neem, dhutura and castor against *E. vigintioctopunctata* with some promising information on the direct toxicity on the larval mortality and residual toxicity against the fecundity, fertility and F_1 progeny production. The mortality increased with increasing doses and exposure time. The dhutura seed extract in petroleum spirit showed the highest toxicity in larval stages whereas in methanol solvent, ata and castor seed extract achieved the highest toxicity at 72 hours exposure time. The results revealed that among the extracts, ata seed extract at maximum dose (4.0 ml/l water) showed the highest efficacy with the inhibition of total eggs laid, viable eggs and the number of emergence of F_1 adult progeny. All the treated doses effectively reduced the epilachna beetle as compared to untreated control.

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EFFECT OF PLANTING DATES ON THE YIELD OF BROCCOLI GENOTYPES

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Abstract

This experiment was conducted during September, 2011 to March, 2012 in the experimental field of Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur to find out the effect of planting date on the yield of broccoli genotypes. There were five genotypes viz. Early green, Forest green, Green calabrese, Premium crop and Green king and four planting dates viz. 2 October, 27 October, 21 November and 16 December. The treatment effects were statistically analyzed and found significant in most of the characters studied. Genotype Green calabrese was the highest in average plant height (53.70 cm). Green king produced the maximum spread diameter (69.23 cm), stem diameter (30.35 mm) and early initiation of floral head. Genotype Early green performed the best regarding head weight (343.87 g), yield per plant (477.4 g) and yield (19.10 t/ha). Broccoli planted on 21 November initiated early flower head, maximum head diameter (16.99 cm), head weight (314.49 g), yield per plant (453.64 g) and total yield (18.15 t/ha). The genotype Early green planted on 21 November showed the best performance in yield per plant (580.17 g) and yield hectare (23.21 t/ha).

Keywords: Broccoli genotype(s), planting date, yield.

Introduction

Broccoli (*Brassica oleracea var. italica* L.), is an important member of "Cole" crops, belongs to the family Brassicaceae. Broccoli originated from west Europe (Prasad and Kumer, 1999). The word "Cole" means a group of highly differentiated plants originated from a single wild *Brassica oleracea var. oleracea* (*Sylvestris* L.) commonly known as wild cabbage (Bose and Som, 1986). Cole crops are the most widely grown vegetables in the temperate zones. After the Second World War these have spread rapidly to both tropical and sub-tropical areas and cabbage has increased in Africa by 31.5% and in Asia by 8.9% compared to the total increase in the world by 5.8% from 1970 to 1980. In Bangladesh, broccoli was introduced about two decades ago.

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Broccoli is grown in winter season in Bangladesh as an annual crop. It is environmentally better adapted and can withstand comparatively high temperature than cauliflower (Rashid *et al.*, 1976). Its wider environmental adaptability, higher nutritive value, good taste and less risk to crop failure due to various biotic and abiotic factors indicate that there is enough scope for its promotional efforts. Its popularity to the consumers of urban area is increasing day by day in our country. But its cultivation has not spread much beyond the farms of different agricultural organizations. This is mainly due to the lack of awareness among the people about its importance and lack of available information production technology about it. Cultivation of broccoli in our country are confined into a very limited area with a minimum production and its average yield is only about 10.5 metric tons per hectare (Anon., 2004) which is very low compared to other broccoli growing countries like 24 t/ha in Italy, 20 t/ha in Japan and 18 t/ha in Turkey (Ahmed *et al.*, 2004).

The planting dates have significant effect on yield and other yield contributing characters of broccoli. The yield decreased with delay planting. Head yield is higher when crops are planted earlier and show a linear decreasing trend with delay in planting dates (Bianco *et al.*, 1996). Early planted crops resulted in longer duration and produced taller plants with more number of leaves, higher plant spread and more leaf size index as well as the lowest percentage of abnormal curds than late planted crops and finally attributed to higher curd yield (Gautam *et al.*, 1998). So there is enough scope to identify the optimum planting date to maximize the broccoli yield.

Broccoli genotypes have also significant effect on yield of broccoli. Cultivar “Captain” produced the highest total yield as well as top and lateral head yields, the largest top head weight and marked earliness which was followed by cultivars Lucky, General, Griffen, Liberty and Milady (Toth *et al.*, 2007). Several broccoli genotypes are cultivated in our country those differ in yield. So it is essential to identify high yielding genotypes to maximize broccoli yield. Therefore, the present experiment was undertaken to find out optimum planting date and appropriate genotype for maximum yield of Broccoli.

Materials and Method

The experiment was conducted at the Horticultural Research Farm, BSMRAU, Gazipur during September, 2011 to March, 2012. The location of the experimental site was at the centre of Madhupur Tract (24.09^{0}N latitude and 90.26^{0}E longitudes) at 8.5m above the sea level (Anon., 1995). The soil of the experimental field was silty clay of shallow Red Brown Terrace type under Salna

Series of Madhupur Tract in agroecological zone (AEZ) 28 (Brammer,1971 and Saheed,1984). The soil contained pH of 6.4 (Anon., 1998 and Haider *et al*., 1991). There were four planting dates viz. 2 October, 27 October, 21 November and 16 December and five genotypes viz. Early green, Forest green, Green calabrase, Premium crop and Green king. The field experiment was laid out in a factorial Randomized Complete Block Design with three replications. The unit plot size was 4m x 1.5m. The genotypes of broccoli were collected from the market of Siddique bazaar of Dhaka. The land was manured and fertilized with N, P, K and Molybdenum as Cowdung, Urea, TSP, MoP and Molybdenum @ 1500, 210, 120, 100 and 1kg/ha, respectively. The entire amount of Cow dung, TSP, MoP and Molybdenum were applied at the time of final land preparation and the entire urea was applied as top dressing in two equal split at 15 and 30 days after transplanting. Healthy and uniform 30 days old seedlings were transplanted in the main field at each date of planting maintaining a spacing of 50 cm x 50 cm. Weeding, irrigation and other cultural practices were done as and when necessary. Data were recorded from randomly selected plants for individual plant performance and from total plot for per hectare yield. Collected data were statistically analyzed by MSTATC.

Results and Discussion

Plant height

Significant variation in plant height was observed due to different planting dates (Table 1). The highest plant height was obtained from 2 October planting at 15, 25 and 35 DAT (30.10, 40.75 and 54.83 cm, respectively) while it was the minimum with delayed planting i.e. 16 December). This result was in agreement with the result obtained by Ahmed and Abdullah (1986) who found taller plant of broccoli from earlier planting than late planting.

Plant height varied significantly at 15, 25 and 35 DAT among the genotypes (Table 1). The highest plant height (31.42 and 39.20cm) was recorded from the genotype Premium at 15 and 25 DAT, respectively. At 35 DAT, Green calabrese produced the tallest plant (53.70cm), which was statistically identical to Premium (51.66 cm). At 15 DAT, the lowest plant height (26.81 cm) was obtained from Green calabrese, which was statistically similar to Green king (27.70 cm) and Forest green (27.11 cm). But at 25 and 35 DAT, Forest green produced the lowest plant height as 34.05 and 46.07 cm, respectively. Variation in plant height may be due to the difference in genetic make-up of broccoli genotypes.

The interaction effect between genotypes and planting dates varied significantly at 15 DAT, but it did not vary significantly at 25 and 35 DAT (Table 2). The highest plant height (34.50 cm) was recorded from the genotype Premium planted on 27 October which was similar to G_4P_3 (32.50 cm) and the lowest

Table 1. Effect of genotypes and planting dates on plant height, spread diameter and diameter of stem of broccoli plant at different DATs.

Treatments	Plant height (cm)			Spread diameter (cm)			Diameter of stem (mm)		
	15 DAT	25 DAT	35 DAT	15 DAT	25 DAT	35 DAT	15 DAT	25 DAT	35 DAT
Genotypes									
Early green (G_1)	29.31 b	37.30 b	48.27 b	32.89 cd	52.14 cd	63.89 b	10.43 b	17.63 c	27.54 c
Forest green (G_2)	27.11 c	34.05 c	46.07 b	36.05 a	55.58 a	68.55 a	11.28 a	18.80 b	28.23 bc
Green calabrese (G_3)	26.81 c	36.80 b	53.70 a	31.98 d	51.73 d	68.32 a	8.40 c	13.93 d	22.36 d
Premium (G_4)	31.42 a	39.20 a	51.66 a	33.88 bc	53.41 bc	64.65 b	10.54 b	19.21 b	28.98 b
Green king (G_5)	27.70 c	37.07 b	46.44 b	35.12 ab	54.56 ab	69.23 a	11.73 a	21.06 a	30.35 a
Planting time									
2 October (P_1)	30.10 a	40.75 a	54.83 a	41.40 a	60.99 a	77.03 a	10.54 b	19.01 a	28.34 a
27 October (P_2)	29.41 a	38.96 b	49.02 b	38.72 b	51.81 b	69.09 b	11.17 a	19.85 a	27.99 ab
21 November (P_3)	27.23 b	36.79 c	46.60 c	37.59 b	50.23 c	61.46 c	10.79 ab	17.33 b	26.47 c
16 December (P_4)	27.13 b	31.03 d	46.46 c	18.23 c	50.91 bc	60.12 d	9.40 c	16.32 c	27.16 bc
CV (%)	6.13	5.89	5.18	6.15	3.37	2.60	5.71	6.62	5.42

Means bearing same letter(s) in a column do not differ significantly at 1% level of probability.

Table 2. Interaction effect of genotypes and planting dates on plant height, spread diameter and diameter of stem of broccoli plant at different DATs.

Interection	Plant height (cm)			Spread diameter (cm)			Diameter of stem (mm)		
(G×P)	15 DAT	25 DAT	35 DAT	15 DAT	25 DAT	35 DAT	15 DAT	25 DAT	35 DAT
$G_1×P_1$	29.20 c-f	36.87	45.40	19.77 g	51.30 c-f	57.57 k	12.00 ab	17.53 ef	26.53 d-f
$G_1×P_2$	31.03 bc	39.93	48.50	37.60 d-f	51.40 c-f	59.47 i-k	11.20 a-c	20.20 bc	30.40 ab
$G_1×P_3$	29.13 c-f	41.37	53.20	38.27 c-f	57.87 b	70.80 c	9.70 de	17.03 ef	26.30 d-f
$G_1×P_4$	27.87 c-g	31.03	45.97	35.93 d-f	48.00 fg	67.73 de	8.83 e	15.77 fg	26.93 c-f
$G_2×P_1$	26.70 e-h	32.63	42.40	44.47 a	64.60 a	61.03 g-j	11.40 a-c	19.80 b-d	25.33 e-g
$G_2×P_2$	27.30 e-h	34.73	44.47	38.30 c-f	52.40 c-e	63.83 f-h	12.33 a	18.93 c-e	26.33 d-f
$G_2×P_3$	28.20 c-f	39.80	54.33	18.50 g	50.80 d-g	77.87 b	11.60 a-c	18.63 c-e	31.00 a
$G_2×P_4$	26.23 e-h	29.03	43.07	42.93 ab	54.53 c	71.47 c	9.77 de	17.83 d-f	30.23 ab
$G_3×P_1$	24.60 gh	37.17	52.23	16.53 g	49.53 e-g	80.93 a	7.17 f	14.60 gh	21.20 hi
$G_3×P_2$	29.20 c-f	39.80	54.67	35.33 f	51.40 c-f	61.57 g-i	9.80 de	16.33 fg	23.30 gh
$G_3×P_3$	27.57 d-g	40.13	59.87	39.73 b-e	58.47 b	60.83 h-j	9.10 e	13.13 hi	24.30 fg
$G_3×P_4$	25.87 f-h	30.10	48.03	36.33 d-f	47.53 g	69.93 cd	7.53 f	11.67 i	20.63 i
$G_4×P_1$	30.97 b-d	40.30	49.43	18.00 g	50.17 e-g	58.40 i-k	10.90 bc	20.60 a-c	28.07 b-e
$G_4×P_2$	34.50 a	42.47	52.67	39.93 b-d	52.47 c-e	58.30 jk	10.69 cd	21.33 ab	29.40 a-c
$G_4×P_3$	32.50 ab	42.17	54.27	41.67 a-c	60.47 b	76.57 b	11.20 a-c	17.30 ef	29.83 ab
$G_4×P_4$	27.70 c-g	31.87	50.27	35.93 ef	50.53 d-g	65.33 ef	9.37 e	17.60 d-f	28.63 a-d
$G_5×P_1$	28.50 c-f	37.00	42.83	42.87 ab	63.57 a	62.77 f-h	11.23 a-c	22.50 a	31.23 a
$G_5×P_2$	28.47 c-f	37.87	44.80	42.47 ab	51.40 c-f	64.13 fg	11.83 a-c	22.47 a	30.53 ab
$G_5×P_3$	29.63 b-e	40.27	52.47	18.33 g	49.33 e-g	79.00 ab	12.33 a	20.52 a-c	30.27 ab
$G_5×P_4$	24.20 h	33.13	45.67	36.80 d-f	53.93 cd	71.00 c	11.50 a-c	18.73 c-e	29.37 a-c
CV (%)	6.13	5.89	5.18	6.15	3.37	2.60	5.71	6.62	5.42

Means bearing same letter(s) or without letter in a column do not differ significantly at 5% level of probability.

G_1 = Early green, G_2 = Forest green, G_3 = Green calabrese, G_4 = Premium, G_5 = Green king and P_1= 2 October, P_2 = 27 October, P_3= 21 November, P_4= 16 December.

plant height (24.20 cm) was obtained from treatment G_5P_4 (Green king planted on 16 December) at 15 DAT. Plant height varied from 42.40 cm to 59.87 cm at 35 DAT.

Spread diameter

Spread diameter of broccoli varied significantly with planting dates (Table 1). Spread diameter increased with the increase of days after transplanting in the all sampling dates. At 35 DAT, broccoli planted on 2 October showed maximum spread diameter (77.03 cm) followed by 27 October planting (69.09 cm) while spread diameter was minimum (60.12 cm) in most delayed planting (16 December).

There were significant differences among the genotypes in respect of spread diameter (Table 1). Spread diameter increased with the advancement of days after transplanting. At 35 DAT, genotype Green king spreaded maximum (69.23cm), which was similar to Forest green (68.55 cm) and Green calabrese (68.32 cm) while it was minimum (63.89 cm) in Early green.

The combined effect of genotypes and planting dates was found significant in respect of spread diameter (Table 2). The maximum spread diameter was obtained in Forest green planted on 2 October (44.47 and 64.60 cm) at 15 and 25 DAT, respectively followed by $G_5 \times P_1$ (42.87 and 63.57cm). At 35DAT, the plants of $G_3 \times P_1$ produced the maximum spread diameter (80.93 cm), which was statistically identical with $G_5 \times P_3$ (79.00cm) closely followed by $G_2 \times P_3$ (77.87 cm) and $G_4 \times P_3$ (76.57 cm) while it was minimum (57.57 cm) in $G_1 \times P_1$.

Diameter of stem

Significant variation in stem diameter was observed due to the influence of planting dates (Table 1). Broccoli planted on 27 October produced the maximum (11.17 and 19.85 mm) stem diameter at 15 and 25 DAT and it was the highest (28.34 mm) in the plants planted on 2 October at 35 DAT.

Diameter of stem varied significantly among the genotypes (Table 1). Green king produced the maximum (11.73, 21.06 and 30.35 mm) diameter of stem at 15, 25 and 35 DAT, respectively. Green calabrese gave minimum (8.40, 13.93 and 22.36 mm) in stem diameter at 15, 25 and 35 DAT, respectively.

There were significant differences in stem diameter due to interaction of genotypes and planting dates (Table 2). Stem diameter increased with the increase of days after planting in all treatment combinations. At 35 DAT, Green king planted on 2 October produced the maximum stem diameter (31.23 mm), which was similar to $G_2 \times P_3$ (31.00 mm), $G_5 \times P_2$ (30.53 mm), $G_1 \times P_2$ (30.40 mm), $G_5 \times P_3$ (30.27 mm), $G_2 \times P_4$ (30.23 mm),$G_4 \times P_3$ (29.83 mm), $G_4 \times P_2$ (29.40 mm),

$G_5 \times P_4$ (29.37 mm) and $G_4 \times P_4$ (28.63 mm) while it was minimum (20.63 mm) in $G_3 \times P_4$.

Head initiation

Variation in days to head initiation due to planting date was observed (Fig. 1). It was revealed that maximum number of days (75.3) for first head initiation was required in 2 October planting which showed a decreasing trend with the later planting. Similar trend were also observed in 50% head initiation and total head initiation. In both cases maximum number of days 84.7 and 89.3 were required for 50% and 100% head initiation, respectively in 2 October planting, which decreased to 70.3 and 75.3 days in most delayed planting i.e. 16 December planting. Head formation in broccoli was quite similar to the curd formation of cauliflower which was primarily influenced by temperature. When broccoli sown late exhibited premature head initiation i.e., head initiation started before completion of vegetative growth. Similar results were obtained in cauliflower by Salter and Ward (1972) who reported that cauliflower plants grown in late planting at low temperature passed from vegetative phase to reproductive phase rapidly.

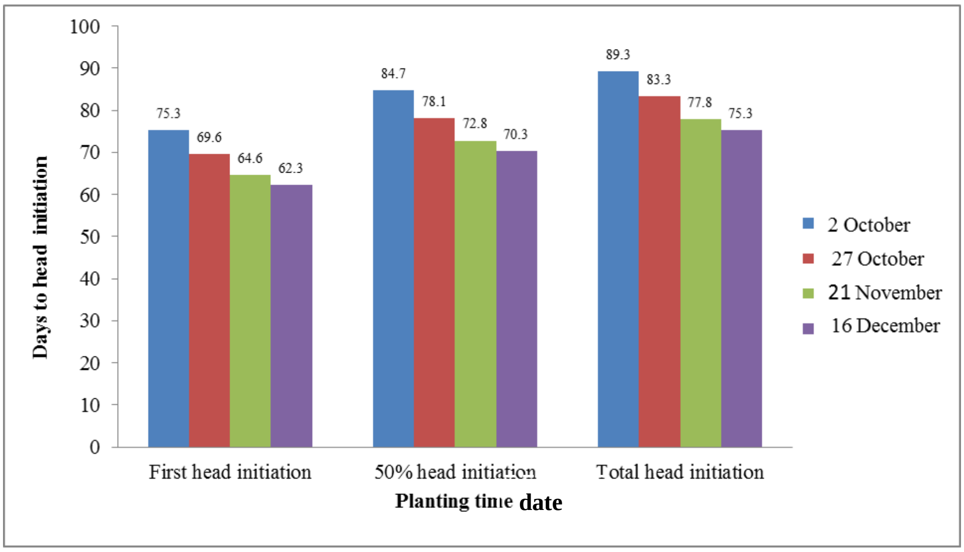

Fig. 1. Effect of planting dates on days to head initiation.

Genotypic differences were observed on days to head initiation (Figure 2). Green king required minimum number of days 67.33, 71.5 and 76.66, respectively for first head initiation, 50% head initiation and total head initiation while these were maximum in Green calabrese, which were 86.33, 93.5 and 103.66 days for first head, 50% and 100% head initiation, respectively.

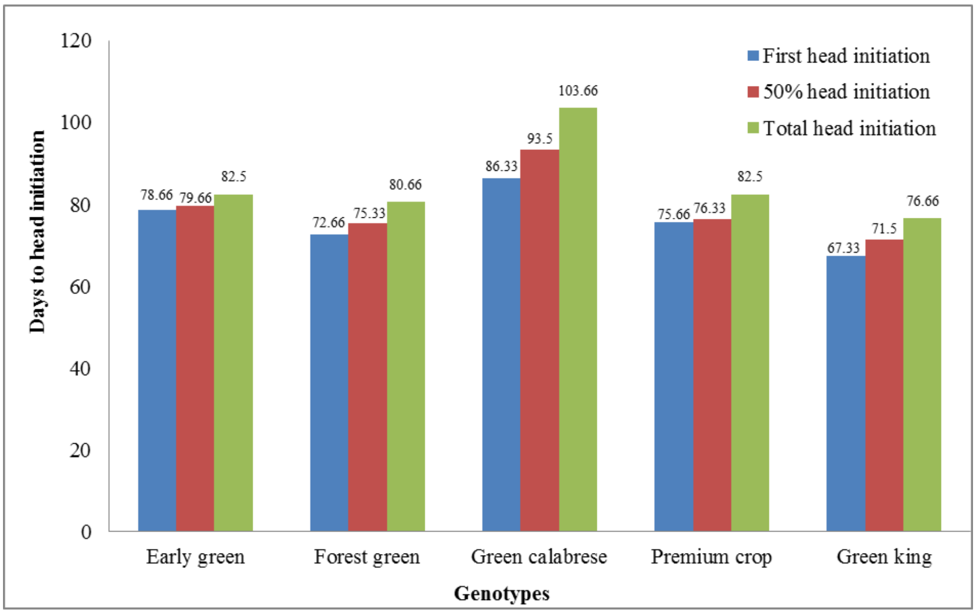

Fig. 2. Genotypic differences on days to head initiation in broccoli.

Head diameter

Broccoli planted on 21 November produced the highest diameter of head (16.99 cm) and it was the lowest (13.64 cm) in 2 October planting (Table 3). The result was in agreement with the findings of Anon. (1980) who reported that transplanting of broccoli in November produced the largest sized main head.

Diameter of head significantly varied due to genotypes, planting dates and the interaction between them (Table 3).The largest head diameter obtained from in the genotype Premium (17.34 cm), which was statistically identical with Early green (16.89 cm) and Forest green (16.36 cm) while the smallest head diameter (12.92cm) was found in genotype Green calabrese (Table 3).

The treatment combination $G_4{\times}P_3$ produced the highest head diameter (18.62cm), which was statistically identical to $G_1{\times}P_2$ (18.32 cm), $G_2{\times}P_4$ (17.76 cm), $G_4{\times}P_2$ (17.64 cm), $G_2{\times}P_3$ (17.63 cm), $G_1{\times}P_3$ (17.59 cm), $G_2{\times}P_2$ (17.47 cm) and $G_4{\times}P_4$ (17.27 cm) while it was minimum (10.31 cm) in $G_3{\times}P_1$ (Table 4).

Head weight

Head weight varied due to planting dates (Table 3). The maximum head weight (314.44 g) was found from 21 November planting, which was statistically identical with 16 December planting and the minimum head weight (154.12 g)

Table 3. Effect of genotypes and planting date on yield and yield contributing characters of broccoli.

Treatments	Head diameter (cm)	Head weight (g)	No. of secondary head/plant	Secondary head weight (g)	Yield /plant (g)	Yield (t/ha)
Genotypes						
Early green (G_1)	16.89 a	343.87 a	3.83 a	133.54 a	477.41 a	19.10 a
Forest green (G_2)	16.36 ab	236.22 b	3.08 b	108.26 b	344.48 b	13.78 b
Green calabrese (G_3)	12.92 c	147.39 c	1.92 c	66.53 c	213.92 c	8.56 c
Premium (G_4)	17.34 a	264.07 b	3.08 b	108.28 b	372.35 b	14.89 b
Green king (G_5)	15.58 b	239.11 b	3.17 b	111.01 b	350.13 b	14.00 b
Planting time						
2 October (P_1)	13.64 c	154.12 c	2.73 bc	88.35 c	242.46 d	9.70 d
27 October (P_2)	16.63 b	221.12 b	3.20 b	112.94 b	334.07 c	13.36 c
21 November (P_3)	16.99 a	314.49 a	3.73 a	139.16 a	453.64 a	18.15 a
16 December (P_4)	16.02 b	294.80 a	2.40 c	81.65 c	376.46 b	15.06 b
CV (%)	6.01	10.34	10.26	10.31	8.38	8.38

Means bearing same letter(s) or without letter in a column do not differ significantly at 1% level of probability.

Table 4. Interaction effect of genotypes and planting dates on yield and yield contributing characters of broccoli.

Interaction (G×P)	Head diameter (cm)	Head weight (g)	No. of secondary head/plant	Secondary head weight (g)	Yield /plant (g)	Yield (t/ha)
$G_1 \times P_1$	15.60 de	239.83 ef	3.67 a-c	118.25 b-d	358.08 fg	14.32 f
$G_1 \times P_2$	18.32 a	437.42 a	4.00 ab	140.91 a-c	432.47 de	17.30 d
$G_1 \times P_3$	17.59 a-c	406.69 ab	4.67 a	173.48 a	580.17 a	23.21 a
$G_1 \times P_4$	16.04 b-e	291.56 c-e	3.00 b-e	101.52 c-e	538.94 ab	21.56 ab
$G_2 \times P_1$	12.59 g	120.85 ij	2.67 b-e	86.59 d-f	207.44 jk	8.30 jk
$G_2 \times P_2$	17.47 a-c	253.52 d-f	3.33 b-d	117.65 b-d	371.17 e-g	14.85 ef
$G_2 \times P_3$	17.63 a-c	303.49 cd	4.00 ab	149.04 ab	452.53 cd	18.10 cd
$G_2 \times P_4$	17.76 ab	267.01 d-f	2.33 c-e	79.77 d-f	346.77 fg	13.87 fg
$G_3 \times P_1$	10.31 h	175.52 g-i	1.67 e	56.65 ef	129.17 l	5.17 l
$G_3 \times P_2$	13.82 fg	120.13 ij	2.00 de	69.98 ef	192.11 kl	7.68 k
$G_3 \times P_3$	14.62 ef	215.11 f-h	2.33 c-e	87.11 d-f	302.23 gi	12.09 gh
$G_3 \times P_4$	12.95 fg	76.79 j	1.67 e	52.38 f	232.17 jk	9.29 i-k
$G_4 \times P_1$	15.85 c-e	163.25 hi	2.67 b-e	86.73 d-f	249.98 i-k	10.00 ij
$G_4 \times P_2$	17.64 a-c	211.04 f-h	3.33 b-d	118.00 b-d	329.04 gh	13.16 fg
$G_4 \times P_3$	18.62 a	352.12 bc	4.00 ab	148.82 ab	500.93 bc	20.04 bc
$G_4 \times P_4$	17.27 a-d	329.88 c	2.33 c-e	79.56 d-f	409.44 d-f	16.38 de
$G_5 \times P_1$	13.83 fg	169.87 gi	3.00b-e	97.78 c-f	267.65 h-j	10.71 hi
$G_5 \times P_2$	15.90 c-e	227.37 fg	3.33 b-d	118.17 b-d	345.54 fg	13.82 fg
$G_5 \times P_3$	16.49 b-d	295.01 c-e	3.67 a-c	137.34 a-c	432.35 c-e	17.29 d
$G_5 \times P_4$	16.09 b-e	264.20 d-f	2.67 b-e	90.77 d-f	354.96 fg	14.20 fg
CV (%)	6.01	10.34	10.26	10.31	8.38	8.38

Means bearing same letter(s) in a column do not differ significantly at 5% level of Probability.

G_1 = Early green, G_2 = Forest green, G_3 = Green calabrese, G_4 = Premium crop, G_5 = Green king and P_1= 2 October, P_2 = 27 October, P_3= 21 November, P_4= 16 December.

was found from 2 October planting. This result was in agreement with the findings of Anon. (1977) who reported that planting of broccoli on 28 November gave the maximum weight of head.

Central head weight was significantly influenced by the genotypes, planting dates and their interaction effects (Table 3). The maximum weight was recorded from genotype Early green (343.87 g) followed by Premium (264.07 g) which was statistically identical with Green king (239.11 g) and Forest green (236.22 g) while it was minimum (147.39 g) in Green calabrese (Table 3).Genotype Early green produced the highest head weight might be due to producing higher number of leaves and head diameter. Srivastava (1960) reported that good head depends on the number of leaves, their size (length and breadth) and ability to store carbohydrates and other nutrients within a particular temperature range.

Due to combined effect of genotype and planting dates head weight differed significantly ranging from 76.79 to 437.42 g (Table 4). The maximum head weight (437.42 g) was recorded from $G_1 \times P_2$ (Early green planted on 27 October) that was statistically identical with $G_1 \times P_3$ (406.69 g). The minimum head weight (76.79 g) was obtained from $G_3 \times P_4$ (Green calabrese planted on 16 December). The plants of G_1P_2 and G_1P_3 performed better might be due to prevailing suitable temperature for vigorous vegetative growth resulting in higher head weight. Similar results were obtained by Bianco *et al.*, (1996) who reported that central head yield was higher when crop planted earlier.

Number of secondary heads per plant

Number of secondary heads per plant also varied significantly due to different planting dates (Table 3). Number of secondary head of broccoli per plant varied from 2.40 to 3.73. The maximum number of secondary head per plant (3.73) was observed on 21 November planting and minimum (2.40) on 16 December planting.

The secondary head was those, which develop after harvest of main head. The results revealed that there was a variation in number of secondary heads among the genotypes (Table 3). Maximum number of secondary heads per plant (3.83) was recorded in genotype Early green. The minimum number of secondary heads per plant (1.92) was found in Green calabrese.

A significant variation in number of secondary heads per plant was observed due to interaction of genotypes and planting dates (Table 4). The maximum number of secondary heads per plant (4.67) was obtained from $G_1 \times P_3$ (Early green planted on 21 November) which was statistically identical to $G_1 \times P_2$ (4.00), $G_2 \times P_3$ (4.00), $G_4 \times P_3$ (4.00), $G_1 \times P_1$ (3.67) and $G_5 \times P_3$ (3.67).The minimum number of secondary heads per plant (1.67) was observed in treatment $G_3 \times P_1$ and $G_3 \times P_4$.

Secondary head weight

Secondary head weight differed significantly among planting dates ranging from 139.16 g to 81.65 g (Table 3). The maximum weight of secondary head (139.16 g) was obtained from 21 November planting which was statistically different to others, while the minimum (81.65 g) was found from 16 December planting.

There was significant variation on weight of secondary head per plant among the genotypes (Table 3). The highest weight (133.54 g) of secondary head per plant was found in Early green and the minimum was in Green calabrese (66.53 g) while rest of the genotypes produced statistically identical weight of secondary heads per plant.

The combined effect of genotypes and planting dates was found significant on secondary head weight (Table 4). The secondary head weight varied from 173.48 to 52.38 g. The maximum head weight (173.48 g) was obtained from treatment combination $G_1 \times P_3$ (Early green planted on 21 November) which was statistically identical to $G_2 \times P_3$ (149.04 g), $G_4 \times P_3$ (148.82 g), $G_1 \times P_2$ (140.91 g) and $G_5 \times P_3$ (137.34 g) while it was the minimum (52.38g) in $G_3 \times P_4$ (Green calabrese planted at 16 December).

Yield per plant

Yield per plant varied significantly with planting dates (Table 3). The maximum yield per plant (453.64 g) was found in 21 November planting followed by 16 December (376.46 g) and 27 October planting (334.07 g) whereas it was the minimum (242.46 g) in 2 October planting.

Genotypes of broccoli differed significantly regarding yield per plant (Table 3). The genotype Early green produced the maximum yield per plant (477.41 g) followed by Premium (372.35 g), which was statistically similar to Green king (350.13 g) and Forest green (344.48 g). The minimum yield per plant (213.92 g) was found in Green calabrese.

Significant variation was observed in yield per plant due to the interaction of genotypes and planting dates (Table 4). The highest yield per plant (580.17 g) was obtained from $G_1 \times P_{3,}$ which was statistically identical to $G_1 \times P_4$ (538.94 g) followed by $G_4 \times P_3$ (500.93 g) and $G_2 \times P_3$ (452.53 g) while it was minimum (129.17 g) in G_3P_1. The treatment combination G_1P_3 performed the best might be due to the production of higher number of leaves, head diameter, head weight and secondary head weight by the genotype Early green in presence of good environmental condition on 21 November planting.

Total yield

Planting dates also had significant influence on the yield of broccoli (Table 3). Broccoli of 21 November planting produced the highest yield (18.15 t/ha) followed by the 16 December planting (15.06 t/ha). It might be due to favorable low temperature for the head setting and development. On the other hand, minimum yield (9.70 t/ha) was obtained from 2 October planting. It might be due to comparatively higher temperature than the optimum at that time.

The total yield of broccoli consisted of the main head and the secondary head those develop after the removal of the main one. Although the core of stem is also edible, it is usually not included as part of the yield. Significant variation in yield (t/ha) was observed among the genotypes (Table 3).The maximum yield (19.10 t/ha) was obtained from genotype Early green. This might be due to best performance of this genotype in head diameter, head weight and secondary head weight. The lowest yield (8.56 t/ha) was recorded from Green calabrese.

Interaction effect of genotypes and planting dates on yield per hectare was found significant (Table 4). The plants of $G_1 \times P_3$ produced the maximum yield (23.21 t/ha) which was statistically identical to $G_1 \times P_4$ (21.56 t/ha) followed by $G_4 \times P_3$ (20.04 t/ha) while the lowest yield was obtained from $G_3 \times P_1$ (5.17 t/ha).

Conclusion

Considering yield contributing characters and yield potential of Broccoli, genotype Early green was found the best among the studied genotypes. 21 November was found to be the optimum date of planting for Broccoli. So the genotypes Early green should be planted on 21 November for maximum yield of Broccoli.

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VARIABILITY, CORRELATION AND PATH ANALYSIS IN PUMPKIN (*Cucurbita moschata* L .)

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Abstract

Twenty one genotypes of pumpkin (*Cucurbita moschata* L.) were evaluated to measure the variability among the genotypes for several characters, estimate genetic parameters, association among the characters and their contribution to yield. There was a great deal of significant variation for all the characters among the genotypes. High variability was observed in number of female flowers/plant, number of male flowers/plant, single fruit weight and fruit yield/plant. All the characters except days to first male flowering and days to first female flowering showed high heritability along with high genetic advance in percent of mean. The positive and strong association of number of female flowers/plant (r_g=0.918, r_p=0.839), number of male flowers/plant (r_g=0.687, r_p=0.638), fruit length (r_g=0.691, r_p= 0.520), fruit breadth (r_g=0.518, r_p=0.420) and single fruit weight (r_g=0.492, r_p= 0.431) with fruit yield/plant revealed the importance of these characters in determining fruit yield/plant. On the other hand, days to first male flowering (r_g = -0.623, r_p = -0.550) and days to first female flowering (r_g= -0.689, r_p= -0.543) correlated significantly and negatively with fruit yield/plant. The path co-efficient analysis revealed that the highest positive direct effect was recorded in number of female flowers (0.887) to fruit yield and high direct effect was found in case of days to first female flowering (0.798). Fruit breadth was observed to have the highest positive indirect effect (0.899). In case of fruit length (0.381) and single fruit weight (0.398), the significant positive correlation with fruit yield/plant was observed because of the combination of the direct and indirect effects of fruit length and single fruit weight to fruit yield/plant. Overall, the results indicated that days to first female flowering, number of female flowers, fruit length, fruit breadth and single fruit weight can be used as useful selection criteria to increase fruit yield/plant in pumpkin.

Keywords: Pumpkin, variability, Correlation, Path co-efficient analysis.

Introduction

Pumpkin (*Cucurbita spp.*) is one of the cucurbitaceous fruit vegetables of Bangladesh. It is an important source of minerals, fibres, vitamins, antioxidants and phytonutrients (Aruah *et al*, 2010) and these make the fruit a whole-some and healthy item for human consumption. Some authors have reported that

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pumpkin fruits possess high medicinal values (Abd El-Aziz and Abd El- Kakek, 2011). Pumpkin seed is an excellent source of protein and has pharmacological values such as anti-diabetic (Li *et al,* 2003), antibacterial and antiinflammation activities (Fu *et al*, 2006) and antioxidant effects (Nkosi *et al.*, 2006). Despite its health and dietary benefits, the production of pumpkin in Bangladesh is mostly done on a small scale with low yield. The total production of pumpkin was 0.218 million tons in 2011 in this country (BBS, 2011). However, cultivation of this crop is highly desirable to overcome the problems of under-nourishment and food poverty in Bangladesh. A large number of pumpkin genotypes are cultivated in Bangladesh but no serious attempts have been made to improve its productivity and acceptability.

The success of any crop improvement program depends, to a large extent, on the amount of genetic variability present in the population. Intensive research efforts are needed in several areas particularly in selection of superior pumpkin genotypes. There is a wide genetic variability among the existing genotypes (Aliu *et al*, 2011) and thus, the utilization of such variability in the breeding programs of this crop is possible. In a crop selection program, knowledge of the interrelationships among yield and yield contributing characters are necessary. Path analysis would help in partitioning the correlation coefficient into direct and indirect effects of various traits on the genetic variability, character association and the direct and indirect contributions of some yield characters towards fruit yield. Thus, the present investigation was undertaken with the view to estimate variability and character association in pumpkin.

Materials and Method

The investigation was carried out at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to August 2010 to study the variability and character association in 21 pumpkin genotypes. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. These genotypes were assigned at random into pits of each replication. Pits of 55 cm x 55 cm x 50 cm were prepared in each block at a spacing of 3 m x 3 m. Standard production package was followed for raising a healthy crop. For studying different genetic parameters and inter-relationships, thirteen characters were taken into consideration namely, leaf length, leaf breadth, internodes distance, days to first male flowering, days to first female flowering, pedicel length of male flower, pedicel length of female flower, number of male and female flowers/plant, fruit length, fruit breadth, single fruit weight and fruit yield plant^{-1}. Analysis of variance (ANOVA), mean and range were calculated by using MSTATC software program. Phenotypic and genotypic variances were estimated by the formula given by Johnson *et al*, (1955). Genotypic and phenotypic co-efficients of variations were calculated using the formula of Burton (1952) and the values were categorized as low (0-10%), moderate(10-20%) and high (20% and above) as suggested by Shivasubramanian and Menon (1973). Heritability was measured using the formula given by Singh and Chaudhary, (1985) and the percentage was categorized as low (0-30%), moderate (30-60%) and high (60% and above) as given by Robinson *et al*, (1949). Genetic advance in percentage of mean was calculated by the formula given by Johnson *et al*, (1955), and the values were categorized as low (0-10%), moderate (10-20%) and high (20% and above) as given by him. Genotypic and phenotypic correlation coefficients were obtained using the formula suggested by Miller *et a*,. (1958), and path co-efficient analysis was done following the method outlined by Dewey and Lu (1959).

Results and Discussion

Genetic Variability: Variance components, genotypic and phenotypic coefficients of variations, heritability, genetic advance and genetic advance in percent of mean (GAPM) are presented in Table 1. The phenotypic variance and phenotypic coefficient of variation were higher than the corresponding genotypic variance and genotypic coefficient of variation for all the characters under study suggesting the presence of environmental influence to some extent in the expressions of these characters. The highest genotypic variance (57.87) as well as phenotypic variance (85.62) was found in fruit length followed by days to first male flowering and days to first female flowering. Saha *et al*, (1992) also found high genotypic variance (30.34) and phenotypic variance (31.76) in fruit length.

The difference between genotypic variance and phenotypic variance was the minimum in single fruit weight indicating that less influence of environment on this character. The highest genotypic (45.76) and phenotypic co-efficients of variation (69.78) were found in number of female flowers/plant, which indicated that the genotypes were highly variable for this trait. High variability was also observed in internode distance, pedicel length of male flower, pedicel length of female flower, number of male flowers/plant, single fruit weight and fruit yield/plant. All the characters except days to first male flowering and days to first female flowering showed high heritability along with high genetic advance in percent of mean. High heritability estimates for the characters like pedicel length of male flower (96.49), pedicel length of female flower (95.94), single fruit weight (81.20) and fruit yield/plant. On the other hand, genetic advance for these characters were 71.39, 82.02, 65.55 and 106.73, respectively. Chowdhury and Sharma (2002) found high values of heritability, PCV, GCV and genetic advance for yield/ha and single fruit weight. High heritability with high genetic advance in percent of mean indicated that the character is mostly governed by additive genes, and selection based on this character would be effective for future breeding program.

Table 1. Estimation of some genetic parameters in 21 genotypes of pumpkin.

Parameters	σ^2 p	σ^2g	PCV	GCV	Heritability (%)	Genetic advance	Genetic advance (% mean)
Leaf length without petiole (cm)	8.71	7.90	17.16	16.34	90.70	5.51	32.03
Leaf breadth at the maximum width (cm)	13.58	12.37	15.76	15.04	91.12	6.92	29.59
Internodes distance	12.61	8.25	25.06	20.27	65.43	4.79	33.80
Days to first male flowering	62.30	44.07	11.21	9.43	70.74	11.50	16.34
Days to first female flowering	55.90	39.96	9.95	8.41	71.50	11.01	14.65
Pedicel length of male flower (cm)	35.86	34.60	35.91	35.28	96.49	11.90	71.39
Pedicel length of female flower (cm)	3.41	3.27	41.42	40.57	95.94	3.65	82.02
Number of male flowers/plant	17.31	11.82	61.38	50.72	68.28	5.85	86.41
Number of female flowers/plant	6.10	2.62	69.78	45.76	43.00	2.19	62.04
Fruit length (cm)	85.62	57.87	17.35	14.26	67.59	12.88	24.15
Fruit breadth (cm)	26.90	19.23	18.79	15.89	71.47	7.64	27.69
Single fruit weight (kg)	0.67	0.55	39.26	35.38	81.20	1.37	65.55
Fruit yield/plant (kg)	8.73	6.14	73.53	61.64	70.27	4.28	106.73

σ^2 p = Phenotypic variance, σ^2g = Genotypic variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation.

High heritability and moderate genetic advance in percent of mean found in days to first male flowering (70.74, 16.34) and days to first female flowering (71.50, 14.65) indicated the non-additive gene effect. Therefore, high heritability does not necessarily mean that the character will show high genetic advance. Selection based upon phenotypic expression of these characters would not be effective for the improvement of this crop. Singh and Lal (2005) reported similar results.

Correlation co-efficient: Correlation studies have been done both at phenotypic and genotypic level and showed that genotypic correlation was higheer than the respective phenotypic correlation in most of the cases suggesting strong inherent association between the characters under study (Table 2). Similar result was found by Pankaj *et al*, (2002). Lower phenotypic correlation coefficients than genotypic correlation coefficients indicate that both environmental and genotypic correlations in those cases act in same direction, and finally maximize their expression at phenotypic level.

In present investigation, number of female flowers/plant gave the highest significant positive association with fruit yield/plant (r_g=0.918, r_p=0.839). In addition, fruit yield/plant was also correlated positively and significantly with number of male flowers (r_g=0.687, r_p= 0.638). This means that increase in the number of male and female flowers would result in higher pollen production and therefore, enhance fertilization and ultimately fruit yield/plant. Shah and Kale (2002) reported close association and dependency of yield with number of female flowers.

A significant positive correlation was also obtained between number of male flowers and number of female flowers (r_g = 0.852, r_p = 0.769). This suggests that the number of male and female flowers increases or decreases simultaneously, and these could be linked to enhance pollination efficiency in the plant. Positive genetic correlation was reported between the number of male and female flowers in pumpkin (Aruah *et al*., 2012)

On the other hand, the number of male flowers was correlated significantly and negatively with days to first male flowering (r_g = -0.597, r_p = -0.410) and days to first female flowering (r_g = -0.443, r_p = -0.329). Similar result was found in case of number of female flowers. These results indicated that early flowering increased the number of male and female flowers and increased number of male and female flowers which increased yield/plant. This result was in agreement with Mohanty (2001) who reported that early flowering at lower nodes and higher number of flowers/plant, particularly the female flower, increase fruit yield. Badade *et al*, (2001) found negative association of yield/ vine with days to first male flower opening.

Table 2. Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of pumpkin.

Characters		LB	ID	DFMF	DFFF	PLMF	PLFF	NMF	NFF	FL	FB	FW	FYP
LLWP	r_g	0.713**	0.324**	-0.779**	-0.575**	0.121	0.125	0.338**	0.540**	0.346**	0.335**	0.252	0.316*
	r_p	0.652**	0.240	-0.633**	-0.484**	0.007	0.112	0.248	0.326**	0.244	0.272*	0.212	0.245
LB	r_g		0.485**	-0.594**	-0.405**	-0.093	0.044	0.065	0.334**	0.419**	0.259	0.307*	0.133
	r_p		0.367**	-0.493**	-0.329**	-0.101	0.042	0.065	0.062	0.312*	0.168	0.220	0.103
ID	r_g			-0.266	-0.270*	-0.107	-0.102	-0.011	0.451**	0.090	-0.131	0.075	0.270*
	r_p			-0.230	-0.258	-0.086	-0.086	-0.004	0.276*	0.126	-0.103	0.028	0.171
DFMF	r_g				0.914**	-0.515**	-0.335**	-0.597**	-0.881**	-0.559**	-0.498**	-0.386**	-0.623**
	r_p				0.878**	-0.442**	-0.295*	-0.410**	-0.537**	-0.383**	-0.307*	-0.269*	-0.550**
DFFF	r_g					-0.590**	-0.286*	-0.443**	-0.775**	-0.461**	-0.245	-0.183	-0.689**
	r_p					-0.508**	-0.243	-0.329*	-0.529**	-0.327**	-0.167	-0.159	-0.543**
PLMF	r_g						0.244	0.373**	0.416**	0.341**	0.251	0.170	0.566**
	r_p						0.240	0.296*	0.268	0.276*	0.214	0.163	0.459**
PLFF	r_g							0.028	0.034	0.376**	0.487**	0.449**	0.167
	r_p							0.001	0.011	0.297*	0.416**	0.390**	0.130
NMFP	r_g								0.852**	0.435**	0.572**	0.316*	0.687**
	r_p								0.769**	0.307*	0.409**	0.269*	0.638**
NFFP	r_g									0.576**	0.407**	0.317	0.918**
	r_p									0.369**	0.260	0.224	0.839**
FL	r_g										0.793**	0.861**	0.691**
	r_p										0.682**	0.734**	0.520**
FB	r_g											0.968**	0.518**
	r_p											0.827**	0.420**
SFW	r_g												0.492**
	r_p												0.431**

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

LLP = Leaf length without petiole (cm), LB = Leaf breadth at the maximum width (cm), ID = Internodes distance (cm), DFMF = Days to first male flowering, DFFF = Days to first female flowering, PLMF = Pedicel length of male flower (cm), PLFF = Pedicel length of female flower (cm), NMFP = Number of male flowers/plant, NFFP = Number of female flowers/plant , FL = Fruit length (cm), FB = Fruit breadth (cm), SFW = Single fruit weight (Kg) and FYP = Fruit yield/plant (kg).

The positive and strong associations of fruit length (r_g = 0.691, r_p = 0.520), fruit breadth (r_g = 0.518, r_p = 0.420) and single fruit weight (r_g = 0.492, r_p = 0.431) with fruit yield/plant revealed the importance of the characters in determining fruit yield/plant, and showed that selection for these traits would result in superior fruit yield. However, pedicel length of female flower had non significant correlations with most of the agronomic traits evaluated which indicated that it had minimal and non-significant contributions to the crops fruit yield and development.

This picture becomes more clear when correlation co-efficient was partitioned into direct and indirect effects by path analysis both at genotypic and phenotypic levels.

Path co-efficient analysis: The path co-efficient analysis revealed that the highest positive direct effect was recorded in number of female flowers (0.887). The positive and significant correlation (r_g = 0.918 **) obtained between number of female flowers and fruit yield/plant was because of the contribution of this direct effects to fruit yield/plant. Aruah *et al* (2012) reported high positive direct effect of number of female flowers on weight of fruit/plant. Similarly, days to first female flowering showed highly significant but negative correlation with fruit yield/plant due to high direct effect (0.798) to fruit yield/plant. Thus, a dependable trait for the improvement of pumpkin. Although the direct selection of fruit length (0.381) and single fruit weight (0.318) had a high contribution to fruit yield/plant, the indirect selections of fruit length via days to first male flowering (0.814), number of female flowers (0.511), single fruit weight (0.273) and the indirect selection of single fruit weight via days to first male flowering (0.562), number of female flowers (0.281), fruit length (0.328) could also be adopted for improving the fruit yield. Fruit breadth was observed to have the highest positive indirect effect (0.899), but high negative direct effect which ultimately show highly significant positive correlation (0.518**) (Table 3). In such a situation indirect factors are to be considered simultaneously for selection. The path diagrams are presented in Fig.1.

Leaf breadth (-0.224) and pedicel length of female flower (-0.157) were observed to have high negative direct effects on fruit yield/plant. However, the high indirect effects of these characters on fruit yield/plant. However the high indirect effects of these characters on fruit yield/plant did not produce significant correlations between the fruit yield/plant and above traits due to the masking effect and suppressing action of their direct effect.

Through path analysis the residual effect (0.38) was observed which indicated that the characters under study contributed 62% of the fruit yield plant^{-1} (Table 3). It is suggested that there were some other factors those contributed 38% to the fruit yield plant^{-1} not included in the present study.

Table 3. Path coefficient analysis showing direct and indirect effect of different characters on yield of pumpkin

Characters	Direct effect	Indirect effects												Total Indirect effect	correlation
		LLWP	LB	ID	DFMF	DFFF	PLMF	PLFF	NMF	NFF	FL	FB	FW		
LLWP	-0.314	-	-0.409	-0.016	1.134	-0.459	0.004	-0.020	-0.168	0.479	0.132	-0.128	0.080	0.629	0.316*
LB	-0.573	-0.224	-	-0.023	0.865	-0.323	-0.003	-0.007	-0.032	0.296	0.160	-0.099	0.098	0.706	0.133
ID	-0.048	-0.102	-0.278	-	0.387	-0.215	-0.004	0.016	0.006	0.400	0.034	0.050	0.024	0.318	0.270*
DFMF	-1.456	0.345	0.341	0.013	-	0.729	-0.017	0.053	0.297	-0.782	-0.213	0.190	-0.123	0.833	-0.623**
DFFF	0.798	0.181	0.232	0.013	-1.331	-	-0.020	0.045	0.220	-0.688	-0.176	0.094	-0.058	-1.487	-0.689**
PLMF	0.033	-0.038	0.053	0.005	0.750	-0.471	-	-0.038	-0.185	0.369	0.130	-0.096	0.054	0.533	0.566**
PLFF	-0.157	-0.039	-0.025	0.005	0.488	-0.228	0.008	-	-0.014	0.030	0.143	-0.186	0.143	0.324	0.167
NMFP	-0.497	-0.106	-0.037	0.001	0.869	-0.354	0.012	-0.004	-	0.756	0.166	-0.219	0.100	1.184	0.687**
NFFP	0.887	-0.170	-0.192	-0.022	1.283	-0.618	0.014	-0.005	-0.424	-	0.219	-0.156	0.101	0.031	0.918**
FL	0.381	-0.109	-0.240	-0.004	0.814	-0.368	0.011	-0.059	-0.216	0.511	-	-0.303	0.273	0.310	0.691**
FB	-0.382	-0.105	-0.149	0.006	0.725	-0.196	0.008	-0.076	-0.284	0.361	0.302	-	0.307	0.899	0.518**
SFW	0.318	-0.079	-0.176	-0.004	0.562	-0.146	0.006	-0.070	-0.157	0.281	0.328	-0.370	-	0.174	0.492**

Residual effect: 0.391, ** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

LLP = Leaf length without petiole (cm), LB = Leaf breadth at the maximum width (cm), ID = Internodes distance (cm), DFMF = Days to first male flowering, DFFF = Days to first female flowering, PLMF = Pedicel length of male flower (cm), PLFF = Pedicel length of female flower (cm), NMFP = Number of male flowers/plant, NFFP = Number of female flowers/plant , FL = Fruit length (cm), FB = Fruit breadth (cm), SFW = Single fruit weight (Kg) and FYP = Fruit yield/ plant (kg)

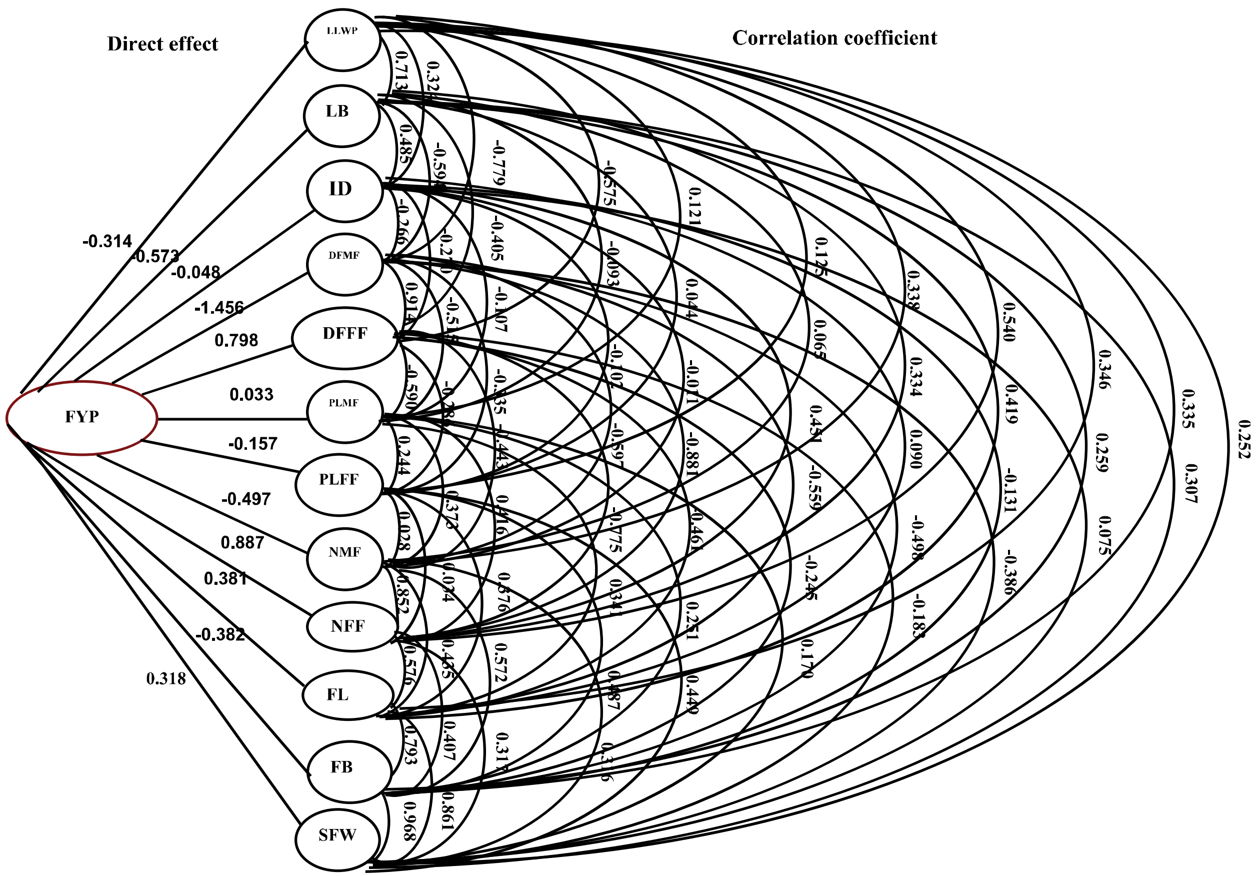

Fig.1. Diagrammatic representation of direct effect and correlation coefficients of variables on dependent variable in pumpkin genotypes

Wide genetic variability was found among the genotypes. After analyzing the data obtained from genotypic co-efficient of variation, phenotypic co-efficient of variation, heritability, genetic advance in percent of mean, correlation coefficient and path co-efficient analysis, it can be concluded that days to first female flowering, number of female flowers, fruit length, fruit breadth and single fruit weight can be used as selection criteria to increase fruit yield/plant in pumpkin.

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EFFECT OF SOWING DATE AND PLANT SPACING ON SEED PRODUCTION OF CAULIFLOWER

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Abstract

The experiment was conducted at Regional Agricultural Research Station, Ishurdi, Pabna during rabi season of 2011-2012 and 2012-2013 to find out the appropriate sowing date and optimum plant spacing for seed production of cauliflower (var. BARI Phulcopi-1). Four sowing dates viz. 20 September, 1 October, 10 October and 20 October and three plant spacing viz. 60 cm × 50 cm, 60 cm × 60 cm and 60 cm × 70 cm were used as treatment variables. Significant variation in seed yield and yield contributing characters of cauliflower were observed due to execution of different sowing dates and plant spacing. Number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1} showed the highest in 1 October sowing as a result the highest seed yield (361.69 kgha^{-1}) was obtained from same date of sowing. Sowing on 10 October and 20 October reduced seed yield drastically compared to that obtained from 1 October sowing. The lowest seed yield (188.54 kgha^{-1}) was obtained from 20 October sowing. On the contrary, closer spacing (60 cm × 50 cm) produced the highest seed yield (315.88 kgha^{-1}) and the wider spacing (60 cm × 70 cm) produced the lowest seed yield (254.07 kgha^{-1}). However, combination of 1 October sowing with 60 cm × 50 cm plant spacing produced the highest seed yield (414.81 kgha^{-1}) due to higher number of seeds pod^{-1}. The seed yield decreased after 10 October sowing irrespective of plant spacing. So, early sowing (1 October) with closer spacing (60 cm× 50 cm) would be economically profitable for cauliflower seed production in North-Western part of Bangladesh.

Keywords: Cauliflower, sowing, spacing, yield and seed.

Introduction

Cauliflower (*Brassica oleracea var. botrytis* L.) is a biannual and herbaceous vegetable crop belonging to the family Cruciferae. It is one of the popular winter vegetables in Bangladesh. Cauliflower thrives best in a cool moist climate and it does not withstand very low temperature or too much heat (Din *et al.*, 2007). The temperature in the country remains higher up to mid October after which gradually comes down in mid-December and extends up to mid-February. The

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temperature increases sharply thereafter. Optimum plant spacing is important for crop production through efficient utilization of light, nutrients and water by the plants. In some cases higher plant population adversely affect yield per unit area hampering vegetative and reproductive growth of plant specially head size and delay in seed maturity. So, it is essential to maintain optimum plant spacing for maximum seed yield of cauliflower. Baloch (1994) recommended that relatively wide spacing (60 cm × 60 cm) promotes earliness and larger heads, but yield and number of curds usually increased by close spacing (45 cm × 45 cm). Increase the plant density limits the availability of space for lateral growth, resulting in increase in plant height (*Pandita et al.,* 2005). Seeds of cauliflower are produced in the country in a small scale but the maximum amount of seeds of cauliflower is imported from other countries. The meteorological data for the last 10 years indicated that the crop suffer from cold injury during the month of January (Anon, 2007) which resulted low yield of crop. The optimum temperature for cauliflower withstands is 10 to 15^0C (Din *et al.*, 2007) but in the north-western part of the country, the night temperature falls even below 5-6^0C which affects crop yield loss. Early sowing recorded maximum vegetative growth and higher yield than late planting (Alam *et al*., 2010). Lavanya *et al*., (2014) recommended that early sowing (1^{st} October) with closer spacing is suitable treatment combination for higher seed yield of radish. So, it is needed to optimize sowing date for quality seed production of cauliflower. Keeping in view, the present experiment was conducted to find out the suitable sowing date and determine the optimum plant spacing for seed production of cauliflower.

Materials and Method

The experiment was carried out at Regional Agricultural Research Station, Ishurdi, Pabna during rabi season of 2011-12 and 2012-13. The initial soil samples were collected from the experimental field for a depth of 0-15 cmprior to application of fertilizers. The nutrient status of soil of the experimental plot was determined at the Soil Science Lab of Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. Results of soil analysis are presented in Table 1. Four sowing dates viz. 20 September, 1 October, 10 October and 20 October and three plant spacing viz. 60 cm × 50 cm, 60 cm × 60 cm and 60 cm × 70 cm were used as treatment variables. The treatments were factorial combination of the two factors and the experiment was conducted using a randomized complete block design with three replications. The unit plot size was 10 m ×1.2 m. Seeds of variety BARI Phulcopi-1 were sown in the nursery beds at an interval of 10 days started from 20 September. Beds were immediately irrigated with the help of watering cane. After germination, when the seedlings were attained at a height of 3 cm then the seedlings were transplanted in the other nursery beds 10 cm apart for proper growth and development of the seedlings. Thirty days old seedlings were transplanted in the evening time in the experimental plot according to the treatment. Healthy seedlings of uniform size were selected for planting. Before transplantation, the nursery beds were irrigated so that the seedlings could be easily uprooted from the beds without any damage of the root. After one week of transplantation, dead seedlings were replaced by planting fresh seedlings to obtain a uniform stand. The land was fertilized with well decomposed cowdung @ 15 tha^{-1} and 120, 55, 100, 15 1.5, 2 and 1 kgha^{-1} N P K S B Zn and Mo, respectively as a source of Urea, TSP, MoP, Gypsum, Boric acid, Zinc sulphate and Sodium molybdate, respectively. Curds with hollow stem disorder is a major problem in cauliflower production and is associated with Mo deficiency. So, Mo application is a crucial factor for yield and quality as well as to control curds with hollow stem disorder. Total amount of cow dung, TSP, gypsum, zinc sulphate, boric acid and sodium molybdate were applied in the plot during final land preparation. Urea and MoP were applied in four equal installments at 20, 40, 60 and 90 days after planting. After transplantation, the experimental plot was irrigated by watering cane and second irrigation (flood irrigation) was done 3 days after transplantation. After this, irrigations were done after fertilizer application and as and when required. Three weeding were done for weed control at 20, 40 and 60 DAT. In the early stage of transplantation damping off disease was occurred in early sowing but serious in late sowing and it was controlled by spraying Bavistin @ 2 g liter^{-1} water. In the seed maturation stage, the plant was attacked by Cercospora leaf spot disease and controlled by spraying Rovral @ 2 g liter^{-1} water. Scooping (removing centre portion of curd) was done when it is fully formed to help the easy emergence of the flower stalks. The flower stalks were supported with bamboo stakes to avoid lodging. Ten plants were selected randomly for data collection. Harvesting was done on 16 to 30 March in 2012 and 14 to 30 March in 2013 when the pods were brown in colour. The collected data were analyzed statistically and the means were separated by Duncan Multiple Range Test (DMRT). The crop received 273 mm and 351 mm total rainfall during crop period of 2011-12 and 2012-13, respectively. A little bit more rainfall occurred in 2012-13. The mean monthly maximum air temperature was 30.66 ^{0}C &30.96 ^{0}C and minimum was 18.36 ^{0}C and 16.92 ^{0}C during crop period of 2011-12 and 2012-13, respectively. The lowest mean (10 days) maximum (21^{0}C) and minimum (13^{0}C) air temperature was occurred in 20 to 31 December (Fig. 1).

Table1. Chemical properties of initial soils of the experimental field.

pH	OM (%)	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Mn	Zn
		meq100^{-1} g				μgml^{-1}						
7.16	1.35	11.20	1.6	0.12	0.049	11	15	0.2	1.5	18	11	1.9
Critical level		2.0	0.8	0.2	-	14	14	0.2	1.0	10	5.0	2.0

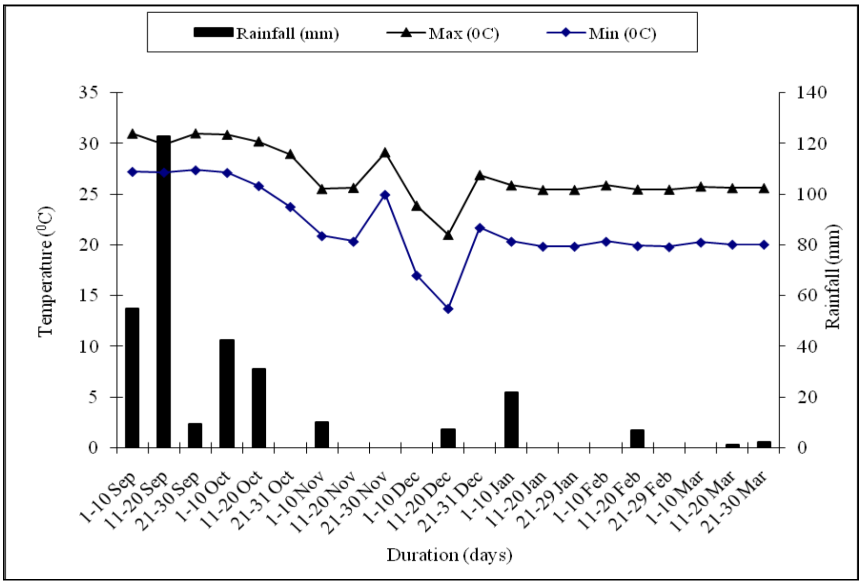

Fig. 1 Average maximum and minimum air temperature (^{0}C) and total rainfall (mm) during the growing period (pooled data of 2011-2012 and 2012-2013)

(Source: Bangladesh Sugarcane Research Institute, Ishurdi, Pabna).

Results and Discussion

Significant variation was not found in years. So, pooled analysis on seed yield and yield attributes were done and discussed accordingly.

Effect of sowing date on plant character and seed yield of cauliflower

Plant height was significantly affected by sowing dates. The maximum plant height (94 cm) was measured from 20 September sowing which was statistically similar to 1 October sowing (92 cm) and the minimum plant height (84 cm) from 20 October sowing (Table 1). This might be due to favourable conditions prevailing during the growing period when planted earlier *i.e.*, 1 October and also due to longer growth experienced by plants resulted from the seeds sown earlier. Similar results were obtained under different climatic conditions as influenced sowing time by Jaiswal *et al.*, (1996). Number of plants m^{-2} was same (2.83) in all the sowing dates as no plants were dead in the later stage and in very early stage of planting dead plants were replaced with the same aged seedlings. Early flowering was enhanced by different sowing dates. The earliest 50% flowering (105 days) occurred on 20 October sowing whereas, delayed flowering (120 days) on 20 September sowing. Sowing on 20 October took shorter cool period for vegetative growth and it turned quickly for reproductive phase. These results coincide with the findings of Castillo *et al.,* (1992) who reported that the short growing cycle in winter enhanced flowering. Similar trend was observed in case of seed harvest. Early sowing (20 September) required the maximum days (176) whereas, the last sowing (20 October) required the minimum days (161) for pod harvest. Early sowing received long cool period for growth of the plant resulted delayed flowering as well as harvesting. The maximum number of branches plant^{-1} (11.84) was obtained from 1 October sowing followed by 20 September sowing (10.86) and the minimum number of branches plant^{-1} (9.10) from 10 October sowing. Being a thermo sensitive plant, the early planted plant received comparatively low temperature during vegetative growth which produced bigger sized head which ultimately produced branches (Kanwar, 1996). Number of pods plant^{-1} is an important yield contributing factor for cauliflower seed production, which is significantly influenced by the prevailing growing conditions of a crop. The maximum number of pods plant^{-1} was produced from 1 October sowing (1263) which was statistically similar to 20 September sowing (1238) and the lowest was produced from 20 October sowing (863). These results are in agreement with the findings of Incalcaterr *et al.,* (2000). The maximum number of seeds pod^{-1} (16.22) was recorded from 1 October sowing and while the minimum number of seeds pod^{-1} (14.47) was recorded from 20 September sowing which was statistically similar to 10 October sowing. This might be due to plants sowing on 1 October took the optimum growing period which produced the optimum size of pod as well as the maximum number of seeds pod^{-1}. Patil *et al.,* (1995) reported that plants grown in early winter produced large sized pod and increased number of seeds pod^{-1} because of proper growth and development of the cauliflower plants. There was no significantly difference among the sowing dates in respect of 1000-seed weight. However, 1000-seed weight was decreased with the advancement of date from 1 October sowing. The highest seed yield (361.69 kgha^{-1}) was obtained from 1 October sowing possibly due to higher number of branches as well as pods plant^{-1}. Moreover, by sowing the crop on 1 October, the phonological phase of plant influenced to thermal regimes conceded with optimum temperature (Fig.1). These results are almost similar to Gurusamy (1999) who reported that early sowing increased head size and produced the highest seed yield. Significantly the lower seed yield (188.54 kgha^{-1}) was obtained from 20 October sowing. Shorter growing period experienced by the crop sown on 20 October caused reduction in seed yield. Castillo *et al.,* (1992) also observed that the short growing cycle in winter cultivars both stages (curd and seed yield) were decreased at later sowing dates.

Table 2. Effect of sowing date on plant characters and seed yield of cauliflower (pooled data of 2011-2012 and 2012-2013).

Date of sowing	Plant height (cm)	Plants m^{-2} (no)	Days to 50% flowering	Days to harvest	Number of branches $plant^{-1}$	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	1000-seed weight (g)	Seed yield ($kgha^{-1}$)
20 September	94 a	2.83	120 a	176 a	10.86 a	1238 a	14.47 b	2.38	304.20 b
1 October	92 a	2.83	112 b	171 b	11.84 a	1263 a	16.22 a	2.50	361.69 a
10 October	88 b	2.83	113 b	167 c	9.10 b	1059 b	14.64 b	2.37	280.83 b
20 October	84 b	2.83	105 c	161 d	9.15 b	863 c	15.43 ab	2.08	188.54 c
CV (%)	4.32	1.20	1.21	1.02	10.73	14.09	4.25	7.66	3.14

Means bearing same or without letter in a column do not differ significantly at 5% level of probability.

Table 3. Effect of plant spacing on plant characters and seed yield of cauliflower (pooled data of 2011-2012 and 2012-2013).

Plant spacing	Plant height (cm)	Plants m^{-2} (no)	Days to 50% flowering	Days to harvest	Number of branches $plant^{-1}$	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	1000-seed weight (g)	Seed yield ($kgha^{-1}$)
60cm×50cm	92	3.33a	113	169	9.41 b	1096 b	15.97 a	2.36	315.88 a
60cm×60cm	89	2.83b	112	169	9.80 b	1108 b	15.27 ab	2.39	281.51 b
60cm×70cm	88	2.33c	112	168	11.51 a	1140 a	14.34 b	2.25	254.07 c
CV (%)	4.32	1.20	1.21	1.02	10.73	14.09	4.25	7.66	3.14

Means bearing same or without letter in a column do not differ significantly at 5% level of probability.

Effect of plant spacing on plant characters and seed yield of cauliflower

Number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1} and seed yield ha^{-1} were significantly affected by plant spacing. Number of plants m^{-2} was maximum (3.33) in 60cm × 70cm followed by 60cm × 60cm (2.83) and minimum in 60cm × 70cm (2.33) according to the treatments. Variation of plant population did not show significant effect in respect of days to 50% flowering, days to harvest, plant height and 1000-seed weight (Table3). The highest number of branches plant^{-1} (11.51) was recorded from 60cm × 70cm spacing and the minimum number of branches plant^{-1} (9.41) from 60cm × 50cm spacing. This may be due to the wider spacing where plant received more nutrients, space, aeration and sunlight for better curd growth and development which increased curd diameter and enhanced more branching. Similar results were quoted by Rahman *et al.*, (2007). The highest number of pods plant^{-1} (1140) was produced from 60cm × 70cm spacing, while closer spacing (60cm × 50cm) produced the minimum number of pods plant^{-1} (1096). The more branches plant^{-1}produce more number of pods per plant. On the contrary, the maximum number of seeds plant^{-1} (15.97) was counted from 60cm×50cm spacing which was statistically similar to 60cm×60cm spacing and the minimum number of seeds plant^{-1} (14.34) was counted from wider spacing (60cm×70cm). The plants which produced less number of pods required more nutrient and produce comparatively long pod resulted more number of seeds plant^{-1}. Plant spacing had a significant effect on seed production of cauliflower. The highest seed yield (315.88 kgha^{-1}) was obtained from 60cm×50cm plant spacing due to closer spacing accumulates more number of plants which ultimately increased seed yield. Increasing the plants number plot^{-1} decreased the head size but increased the seed yield. Sharma and Arora (1984) reported that curd yield as well as seed yield increased with increasing plant density. There was a trend to decrease seed yield with the increase in plant spacing.

Combined effect of sowing date and plant spacing on plant characters and seed yield of cauliflower

Most of the parameters were not significant except number of pods plant^{-1}and seed yield ha^{-1} of cauliflower (Table 4). The maximum number of pods plant^{-1} (1392) was counted from 1 October sowing with 60cm×70cm spacing, whereas the minimum number of pods plant^{-1} (840) from 20 October sowing with 60cm×70cm spacing. The highest yield (414.81 kgha^{-1}) was obtained from 1 October sowing with 60cm×50cm spacing due to more number of seeds pod^{-1} though branches plant^{-1}and pods plant^{-1}lower than I October sowing with wider spacing (60cm×70cm). The higher yield in above treatment is due to better plant survival owing to the favourable conditions for growth and development of plant and the closer spacing accommodates more number of plants per unit area. Similar results were reported by Azizur Rehman and Nawab Ali (2000). Seed yield was considerably decreased in late sowing (20 October).

Table 4. Combined effect of sowing dates and plant spacing on plant characters and seed yield of cauliflower (pooled data of 2011-2012 and 2012-2013).

Treatment combination	Plant height (cm)	Plants m^{-2} (no)	Days to 50% flowering	Days to harvest	Number of branches $plant^{-1}$	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	1000- seed weight (g)	Seed yield ($kgha^{-1}$)
$T_1 S_1$	95	3.33	120	176	10.17	1164 c	13.97	2.50	332.30 c
$T_1 S_2$	94	2.83	120	177	10.67	1280 b	15.00	2.40	302.47 d
$T_1 S_3$	93	2.33	119	176	11.77	1268 b	14.10	2.17	269.84 ef
$T_2 S_1$	95	3.33	113	172	10.83	1169 c	18.36	2.51	414.81 a
$T_2 S_2$	89	2.83	112	171	11.67	1228 b	15.96	2.51	352.88 b
$T_2 S_3$	90	2.33	111	170	13.03	1392 a	14.33	2.47	320.98 c
$T_3 S_1$	92	3.33	113	168	8.31	1094 cd	14.67	2.26	303.70 d
$T_3 S_2$	89	2.83	113	167	8.66	1024 e	14.70	2.31	281.89 e
$T_3 S_3$	84	2.33	112	166	10.37	1059 d	14.56	2.36	261.90 f
$T_4 S_1$	86	3.33	105	160	8.33	850 h	16.53	2.60	233.30 g
$T_4 S_2$	82	2.83	104	161	8.21	900 g	14.40	2.41	206.78 h
T_4S_3	83	2.33	105	161	10.90	840 h	14.36	2.51	182.54 i
CV (%)	4.32	1.20	1.21	1.02	10.73	14.09	4.25	7.66	3.14

Means bearing same or without letter in a column do not differ significantly at 5% level of probability.

T_1=20 Sep, T_2=1 Oct, T_3=10 Oct, and T_4=20 Oct, S_1=60 cm × 50 cm, S_2=60 cm × 60 cm and S_3=60 cm × 70 cm.

Economic performance

The economic performances of sowing date and plant spacing on seed production of cauliflower are presented in Table 5. The highest gross return (Tk. 4148100 ha^{-1}) and gross margin (Tk. 3967125 ha^{-1}) was obtained from the crop sown on 1 October with 60cm×50cm plant spacing. Maximum benefit cost ratio (23.18) was also obtained from the same treatment combination. Hence early sowing (1 October) with 60cm×50cm plant spacing would be economically profitable for cauliflower seed production.

Table 5. Benefit-cost analysis of cauliflower seed production under different sowing dates and plant spacing (pooled data of 2011-2012 and 2012-2013).

Treatments	Seed yield ($kgha^{-1}$)	Gross return ($Tkha^{-1}$)	Cost of production (Tk/ha)	Net margin (Tk/ha)	BCR
$T_1 S_1$	332.30	3323000	178975	3144025	18.57
$T_1 S_2$	302.47	3024700	178975	2845725	16.90
$T_1 S_3$	269.84	2698400	178975	2519425	15.08
$T_2 S_1$	414.81	4148100	178975	3969125	**23.18**
$T_2 S_2$	352.88	3528800	178975	3349825	19.72
$T_2 S_3$	320.98	3209800	178975	3030825	17.93
$T_3 S_1$	303.70	3037000	178975	2858025	16.97
$T_3 S_2$	281.89	2818900	178975	2639925	15.75
$T_3 S_3$	261.90	2619000	178975	2440025	14.63
$T_4 S_1$	233.30	2333000	178975	2154025	13.04
$T_4 S_2$	206.78	2067800	178975	1888825	11.55
T_4S_3	182.54	1825400	178975	1646425	10.20

T_1=20 September, T_2=1 October, T_3=10 October, T_4=20 October, S_1=60cm×50cm, S_2=60cm×60cm and S_3=60cm×70cm

Marked price: Seed = Tk. 10,000 kg^{-1} (OP variety)

Conclusion

The study revealed that the seed yield of cauliflower was significantly affected by different sowing dates. Early October sowing with 60cm×50cm plant spacing produced the highest seed yield due to higher yield attributes as well as prevail longer period of cool. So, early sowing (1October) with 60cm×50cm plant spacing would be economically profitable for enhancing growth parameters and seed production of cauliflower in North-western part of Bangladesh.

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RESPONSE OF LENTIL TO BIO AND CHEMICAL FERTILIZERS AT FARMER'S FIELD

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Abstract

Field trials were carried out at the Farming System Research & Development site, Hatgavindapur, Faridpur, On-Farm Research Division of Bangladesh Agricultural Research Institute during rabi seasons of 2006-2007 and 2007-2008 with the objectives to evaluate the response of lentil to *Rhizobium* biofertilizer and to reduce the use of N-fertilizer under farmer's field condition. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Unit plot size was 4 m x 5 m. Four fertilizer treatments viz. T_1: 24-22-42-20-5 kg N-P-K-S-Zn ha^{-1}, T_2: 50-22-42-20-5 kg N-P-K-S-Zn ha^{-1}, T_3: 0-22-42-20-5 kg N- P-K-S-Zn ha^{-1} + *Rhizobium* Inoculum and T_4: Farmer's practices were studied. Farmer's practice was 25-18-21-0-0 kg N-P-K-S-Zn ha^{-1}. BARI Masur-4 and peat based rhizobial inoculum (strain BARI RLc-102) @ 1.5 kg ha^{-1} were used. Result revealed that application of *Rhizobium* biofertilizer along with PKSZn chemical fertilizers produced the highest nodule number (11.62 $plant^{-1}$) and nodule weight (11.94 mg $plant^{-1}$), and the seed yield 1.44 t ha^{-1}. The seed yield was higher in T_3 treatments ($N_0P_{22}K_{42}S_{20}Zn_5$ + Inoculum) than T_1 ($N_{24}P_{22}K_{42}S_{20}Zn_5$) and T_2 ($N_{50}P_{22}K_{42}S_{20}Zn_5$) treatments. No variation was observed in seed yield in treatments T_1, T_2 and T_3 but significantly different from farmer's practice. Farmer's practice showed the lowest yield. Economic analysis revealed that T_3 treatment i.e. PKSZn plus *Rhizobium* inoculum gave the highest 5.36 benefit cost ratio (BCR) followed by T_1 4.68 and T_2 3.61. It is evident from the experiment that application of biofertilizer can be used as substitute of nitrogenous fertilizer for higher yield of lentil at farmer's field in Faridpur.

Keywords: Lentil, biofertilizer, chemical fertilizers, nodulation, yield, benefit cost ratio

Introduction

Lentil (*Lens culinaris* L.) occupies the top position in terms of popularity and has been placed second in respect of area and production in Bangladesh (BBS, 2012). It is cultivated during rabi season under rainfed condition. About 80% of total lentil in the country is grown in greater Faridpur, Kustia, Jessore, Rajshahi and Pabna districts of Bangladesh (BBS, 2012). The yield of lentil is very poor (928 kg ha^{-1}) (BBS, 2012). There is a great possibility to increase its production by

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exploiting better colonization of their root and rhizosphere through *Rhizobium*, which can also reduce the use of nitrogenous fertilizer as well as protect environment. But there is still lacking of sufficient, effective and resistant *Rhizobium* strains in soil. Moreover, degradation of *Rhizobium* occurs regularly. So, collection and screening of new *Rhizobium* strains and their sub-culturing and testing are necessary. For this reason, few indigenous *Rhizobium* strains were collected from different AEZs of Bangladesh and were screened, tested at research stations. Their efficiency in crop production is needed to be tested at farmers' level. Response of inoculation depends on soil type, cultivars and effectiveness of *Rhizobium* strains and its competitive ability with native *Rhizobium* (Dube, 1976; Khanam *et al*., 1993). Khanam *et al.,* (1999) found 46% higher seed yield in lentil at Meherpur, 30% higher at Faridpur and 33% higher at Jessore districts of Bangladesh due to *Rhizobium inoculum*. They also observed that inoculated plant with chemical fertilizers gave 72%, 59% and 75% higher yield over farmers' practice at Meherpur, Faridpur and Jessore districts of Bangladesh, respectively. The present study was, therefore, undertaken with the following objectives; i) the response of lentil to *Rhizobium* biofertilizer along with chemical fertilizers and ii) to evaluate the reduction of the uses of N-fertilizer for lentil cultivation under farmer's field condition.

Material and Method

Field trials were carried out at the Farming System Research & Development (FSRD) site, Hatgavindapur of On-Farm Research Division, Bangladesh Agricultural Research Institute in Faridpur district during rabi seasons of 2006-2007 and 2007-2008 in randomized complete block design having four replications with four treatments. The unit plot size was 4 m × 5 m. The variety was BARI Masur-4 and peat based rhizobial inoculum BARI RLc-102 was used for the experiment. There were four treatments viz. T_1: 24-22-42-20-5 kg N-P-K-S-Zn ha^{-1} (BARC, 2005), T_2: 50-22-42-20-5 kg N-P-K-S-Zn ha^{-1} (Recommended by Soil Science Division, BARI), T_3: 0-22-42-20-5 kg N-P-K-S-Zn ha^{-1} + *Rhizobium* Inoculum and T_4: Farmer's practice was studied. Farmer's practice was 25-18-21-0-0 kg N-P-K-S-Zn ha^{-1}. Peat based *Rhizobium* inoculum was prepared in the Soil Microbiology Laboratory of BARI. The above peat based rhizobial inoculum @ 1.5 kg ha^{-1} containing about 10^8 cells g^{-1} inoculum was used. Chemical fertilizers i.e. N, P, K, S and Zn were applied in the treatments @ 24 kg N ha^{-1} in T_1 and 50 kg N ha^{-1} in T_2 from urea, 22 kg P ha^{-1} from TSP, 42 kg K ha^{-1} from MoP, 20 kg S ha^{-1} from gypsum and 5 kg Zn ha^{-1} from zinc oxide in T_1, T_2 and T_3 treatments but in farmer's practice, 25-18-21-0-0 kg N-P-K-S-Zn ha^{-1} was used. The seeds were sown on 16 November 2006 and 27 November 2007.

Table 1. Effect of rhizobial inoculum and chemical fertilizers on nodulation, dry matter production and yield of lentil at Faridpur, Bangladesh (pooled data of 2 years).

Treatment	Nodule number $plant^{-1}$	Nodule weight (mg $plant^{-1}$)	Root weight (g $plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Plant height (cm)	Stover yield (t ha^{-1})	1000 seed weight (g)	Seed yield (t ha^{-1})	Yield increase over FP (%)
T_1: $N_{24}P_{22}K_{42}S_{20}Zn_5$	7.20b	6.70b	0.09	1.25	32.4	1.57	17.4	1.40a	41.4
T_2: $N_{50}P_{22}K_{42}S_{20}Zn_5$	6.16b	6.45b	0.11	1.41	34.1	1.59	17.2	1.34a	35.4
T_3:$N_OP_{22}K_{42}S_{20}Zn_5$+Inoc.	11.62a	11.94a	0.11	1.44	31.6	1.60	17.4	1.44a	45.5
T_4:FP ($N_{20}P_{12}K_{17}S_0Zn_0$)	6.85b	6.67b	0.09	1.29	32.4	1.53	17.0	0.99b	-
CV (%)	15.5	14.5	13.6	12.0	6.8	11.4	4.7	9.3	-

Means followed by common letter are not significantly different at 5% level by DMRT

T_1: $N_{24}P_{22}K_{42}S_{20}Zn_5$ kg ha^{-1}, T_2: $N_{50}P_{22}K_{42}S_{20}Zn_5$ kg ha^{-1}, T_3: $N_0P_{22}K_{42}S_{20}Zn_5$ kg ha^{-1} + *Rhizobium* inoculum,

T_4: FP ($N_{20}P_{12}K_{17}S_0Zn_0$ kg ha^{-1}), FP = Farmer's practice

During the experiment, growth and development of plants in the field were carefully observed. Ten plants along with roots were collected at 50% flowering stage from each unit plot. The dry weight of roots; shoots and nodules including nodule numbers were recorded. The plants were harvested on 07 March for 2007 and 02 March for 2008. Data on plant height, 1000-seed weight, stover yield and seed yield were taken. All data were analyzed statistically.

Results and Discussion

Effect of *Rhizobium* inoculation and the application of chemical fertilizers on nodule number (plant^{-1}), nodule weight (mg plant^{-1}), root weight (g plant^{-1}), shoot weight (g plant^{-1}), plant height (cm), 1000-seed weight (g), stover yield (t ha^{-1}), seed yield (t ha^{-1}) and percent yield increased over farmer's practice have been presented in Table 1.

The highest nodule number (11.62 plant^{-1}) and nodule weight (11.94 mg plant^{-1}) were recorded in PKSZn + Inoculum treated plot which was significantly higher over other treatments (Table 1). The treatments T_1, T_2 and T_4 produced identical nodule number and weight. Among the 4 treatments, T_2 treatments ($N_{24}P_{22}K_{42}S_{20}Zn_5$) produced the lowest nodule number and weight. Khanam *et al.,* (1993) reported higher nodule number (156-245%) and nodule weight (169-284%) due to *Rhizobium* inoculation in lentil. Khanam *et al.,* (1999) observed that *Rhizobium* inoculum gave 167%, 60% and 136% higher nodule mass over control at Kustia, Faridpur and Jessore, respectively while *Rhizobium* inoculum plus chemical fertilizers except N gave 342%, 106% and 264% higher nodule mass at Meherpur, Faridpur and Jessore, respectively. Bhuiyan *et al.,* (1996) also found higher nodule number (101%) at farmer's field of Faridpur, Bangladesh and 110% at farmer's field of Jessore, Bangladesh, and nodule weight 52% higher at Faridpur and 81% higher at farmer's field at Jessore due to *Rhizobim* inoculation in chickpea. Similar trends were also reported by Bhuiyan *et al.,* (2001) for chickpea at farmers' field of Meherpur and Rajshahi districts of Bangladesh. Root weight, shoot weight, plant height, stover yield and 1000-seed weight were found insignificant, though the highest values were observed in PKSZn + Inoculum treatment. Similar results were reported by Bhuiyan *et al.,* (2001) in chickpea at Rajshahi, Bangladesh. The seed yield was significantly influenced by inoculum. The highest seed yield 1.44 t ha^{-1} were recorded with the treatment $P_{22}K_{42}S_{20}Zn_5$ + Inoculum but identical with T_1 and T_2 treatments. The seed yield showed higher 1.44 t ha^{-1} due to higher pods plant^{-1}, seeds pod^{-1} and 1000-seed weight. The similar trend was also reported by Khanam *et al.,* (1993). They reported that *Rhizobium* inoculation gave 64-68% higher seed yield in lentil. In another study, Khanam *et al.,* (1999) found 46% higher seed yield in lentil at Meherpur, 30% at Faridpur and 33% at Jessore districts of Bangladesh due to *Rhizobium* inoculum. The lower seed yield was recorded in T_2 treatment than T_1 which might be due to excess plant growth and less pod setting. The lowest yield was with farmer's practice (0.99 t ha^{-1}). *Rhizobium* inoculum with inorganic fertilizer T_3, showed better performance against only with inorganic fertilizers T_1 and T_2 treatments. The yield was 100 kg higher than T_2 due to application of *Rhizobium* inoculum. So, *Rhizobium* inoculum can be used as the substitute of urea for lentil cultivation at Faridpur area. Khanam *et al.*, (1999) also observed that inoculated plant with chemical fertilizers gave 72%, 59% and 75% higher yield over farmers' practice at Meherpur, Faridpur and Jessore districts of Bangladesh, respectively. The results are also an agreement with the findings of Bhuiyan *et al.*, (1998).

Farmers' reaction

The farmer's of Faridpur district were very encouraged by observing the performance of BARI Masur-4 with rhizobial inoculum.

Economic analysis

Benefit cost ratio (BCR) analysis for lentil at Faridpur has been presented in Table 2. For BCR only cost of chemical fertilizers and *Rhizobium* inoculum were considered and other costs remain constant. Economic analysis revealed that T_3 treatment i.e. PKSZn with inoculum gave the highest BCR 5.36 at Faridpur. Khanam *et al.*, (1993) found that inoculated treatment with PKSZn fertilizers gave higher benefit cost ratio 6.44-7.68 in lentil. Bhuiyan and Khanam (1996) found BCR 8.71-9.61 by PKSZn + *Rhizobium* inoculum in chickpea.

Table 2. Benefit cost ratio analysis for lentil at Faridpur (mean of 2 years).

Treatments	Yield (t ha^{-1})	Variable cost (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	Net return over farmer's practice (Tk. ha^{-1})	Benefit cost ratio
T_1: $N_{24}P_{22}K_{42}S_{20}Zn_5$	1.40	5,948/-	1,05,000/-	99,052/-	27,848/-	4.68
T_2: $N_{50}P_{22}K_{42}S_{20}Zn_5$	1.34	6,348/-	1,00,500/-	94,152/-	22,948/-	3.61
T_3:$N_0P_{22}K_{42}S_{10}Zn_5$+Inoc.	1.44	5,728/-	1,07,625/-	1,01,897/-	30,693/-	5.36
T_4: FP($N_{25}P_{18}K_{21}S_0$Zno)	0.99	2,671/-	73,875/-	71,204/-	-	-

Urea= Tk. 7.00 kg^{-1}, TSP= Tk. 17.00 kg^{-1}, MoP= Tk. 18.00 kg^{-1}, Gypsum= Tk. 8.00 kg^{-1}, $ZnSO_4$= Tk. 95.00 kg^{-1}, *Rhizobium* inoculum = Tk. 100 kg^{-1}, Lentil= Tk. 75.00 kg^{-1}

For both the years, positive and significant correlation was found in nodule number with nodule weight (Table 3). Nodule number was strongly correlated with nodule weight. Nodule number was also correlated with root weight in 2007 and nodule weight was correlated with shoot weight and stover yield in 2008 (Table 3). Bhuiyan *et al.*, (1996 and 2001) also reported positive and significant correlation for the inoculated chickpea.

Table 3. Relationship between different parameters of lentil at Faridpur

Parameters	r values	
	2007	2008
Nodule number vs nodule weight	0.939**	0.966**
Nodule number vs root weight	0.618*	-0.207^{NS}
Nodule number vs shoot weight	0.581^{NS}	0.532^{NS}
Nodule number vs stover yield	-0.075^{NS}	0.412^{NS}
Nodule number vs seed yield	0.223^{NS}	0.386^{NS}
Nodule weight vs shoot weight	0.523^{NS}	0. 647*
Nodule weight vs stover yield	0.048^{NS}	0.459^{NS}
Nodule weight vs seed yield	0.299^{NS}	0.400^{NS}
Shoot weight vs stover yield	-0.417^{NS}	0. 670*
Shoot weight vs seed yield	-0.015^{NS}	0.091^{NS}
Stover yield vs seed yield	0.172^{NS}	0.050^{NS}

*Significant at 5% level, **significant at 1% level, NS: Non-significant

Conclusion

It is evident from the experiment that biofertilizer can be used as the substitute of nitrogenous fertilizer in lentil at farmer's field in Faridpur district of Bangladesh.

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INCIDENCE, DAMAGE POTENTIAL AND MANAGEMENT OF JASSIDS IN GROUNDNUT FIELD

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Keywords : Incidence, damage severity, jassid, groundnut.

The studies were made on the incidence, damage severity and management of jassid in groundnut in the experimental field during Rabi season of two consecutive years 2011-12 and 2012-13. The highest jassid population (24.25/plant) and leaf infestation (54.25%) were observed in the second week of April at the pod formation stage of the crop. Among the treatments, Imidaclorprid (Admire 200Sl @ 0.50ml/l) reduced significantly the highest jassid population (80.25%) as well as leaf infestation (54.25%) over the untreated control. The pod yield was significantly highest (1.60 t/ha) obtained from Admire treated plot and calculated high BCR (3.16) followed by Dimethoid (Tafgor 40EC @ 2ml/l) treated plot having pod yield of 1.53t/ha and BCR 2.60.

Groundnut (*Arachis hypogaea* L.) is the second important oilseed crop after rapeseed and mustard on the basis of area and annual production in Bangladesh (Biswas *et al.,* 2000). Its cultivation covered about 95,000 hectares of land and produced about 1,40,000 metric tones of seeds during 2011-2012 (Anon. 2013). It is a good source of oil (48-52%) and protein (25-30%) (Kaul and Das 1986). Jassid (*Empoasca terminalis*) the important foliage pest of groundnut and acts as limiting factors in successful cultivation of the crop in South- East Asia especially in India and Bangladesh (Ahmed *et al.,* 1989; Begum, 1995; Biswas *et al.,* 2000; Biswas *et al.,* 2009 ; Biswas and Das 2011; and Singh, 1990). Both the nymphs and adults of Jssids suck the sap from the tender leaf and under surface of the leaflet causing yellowing the leaflets, leaf curling, necrosis. V shaped yellowing appears at the tip of the leaflets resulting stunted growth and gradually die. It also acts as a vector of leaf curled, tomato spotted and other viruses (Singh, 1990). Infested leaves become spotted, pale and sickly curled (Amin and Palmer, 1985). Incidence of jassid on groundnut crop, losses, and suitable management techniques are of very important. Information on these aspects of jassid in groundnut crop field are scanty in Bangladesh. The research work was undertaken to know the incidence, extent of damage and to develop the suitable management techniques for jassid in groundnut crop.

The experiment was conducted in the field of the Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during Rabi season of two consecutive years 2011-12 and 2012-13. Seeds of groundnut variety BARI Chinabadam-9 were sown on November 27, 2011 and 2012 in 4m

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X 3m plots in Randomized Complete Block design with 3 replications. There were five treatments, namely, application of detergent (Jet powder) 3g/litre, Crude Neem seed mixture (NSM) @ 50 g/l, Spraying of Dimethoid (Tafgor 40 EC @ 2ml/l), Spraying of Imidaclorprid (Admire 200Sl) @ 0.5 ml/l of water and Untreated control with only water were used uniformly. The recommended agronomic practices like fertilizers and other intercultural operations were maintained for raising the crop (Mondal and Wahhab, 2001).

Fresh ripe and sun dried neem seeds (5 kg) were crushed and then added 10 litres of water and kept over night. Then the solution was sieved with fine mesh net and added 10 g of detergent and the solution was prepared for spray. This is known as crude neem seed and detergent mixture. The detergent, botanicals and other insecticides were applied with the help of knapsack sprayer in three frequencies on the crop in second and last week of February 2012 and 2013 at the vegetative and flowering stages of the crop at 10 days intervals. The population of jassids were recorded from the crop during February - May in both the years. The leaf infestation caused by jassids was recorded on February - May in 2012 and 2013 at the vegetative, flowering and pod forming stages of the crop. Randomly 10 plants were selected per plot for counting jassid population. Percent leaf damage by jassids was recorded by counting leaves from five (5) selected plant population in each treatment. Percent leaf infestation reduction over untreated in each treatment was calculated. The crop was harvested on last week of May in each year. Seed yield of different treatments were recorded. Weather data mainly temperature was also recorded during the study period in both the years. Data were compiled and analyzed statistically. Analysis of variance (ANOVA) was done following MSTATE C and means were separated following Duncan's multiple range test (DMRT). Benefit cost ratio (BCR) of the different treatments was also calculated.

Jassid population was observed in the groundnut crop during first week of February in 2012 at the vegetative and flowering stages of the crop and continued up to second week of May at the pod formation stage. The maximum jassid population was observed (24.25/plant) in the second week of April 2012 and then gradually decreased (Fig.1). Almost similar increasing trend of jassid population was observed during 2013. But slightly higher jassid population (25.68/plant) was observed in 2013 than in 2012 (Fig. 2). Leaf infestation by jassid showed the similar pattern in both the years. The highest leaf infestation caused by jassid was 52.54% recorded in 2012 (Fig. 1) and slightly higher leaf infestation rate by jassid (55.68/plant) in 2013 than in 2012 (Fig. 2). It was observed that jassid population and leaf infestation in groundnut crop increased in time with the increasing average temperature (From 23^0 C -$30\,^0$C) in two years (Figs 1 and 2.).

Almost similar results were reported by Campbell (1986), Santos and Sutton, (1983), Singh *et al.*, (1990) Jayanthi *et al.*, (1993) in India and Biswas *et al.*, (2000) in Bangladesh. Amin (1983) observed jassid population buildup in May and June in India. Turnjit and Campbell (1989) reported that more than 40% groundnut leaf damaged by jassids and thrips up to six weeks after sowing and causing yield loss of 5-10%. Campbell (1986) indicated that when 60% of groundnut leaves were scorched by jassids then yield loss could be detected and when all leaves were scorched by jassids then yield loss was only about 15 percent.

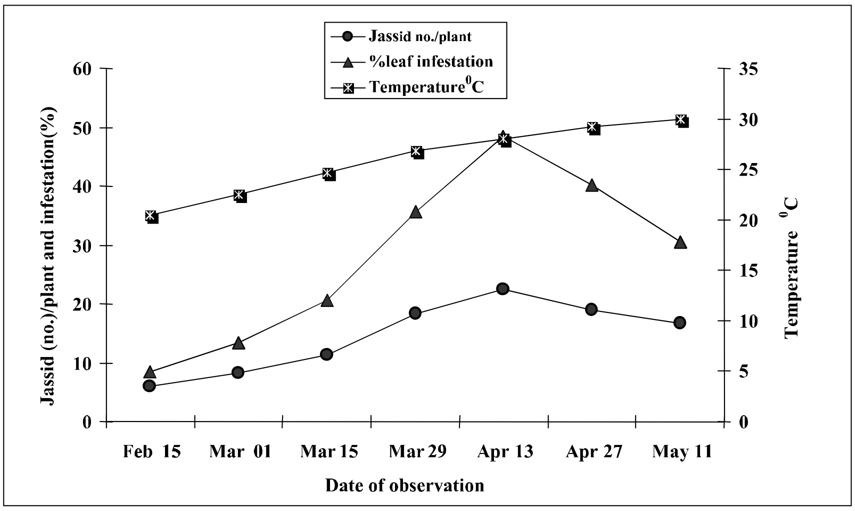

Fig 1. Number and infestation of jassids in groundnut in 2012 at BARI Gazipur.

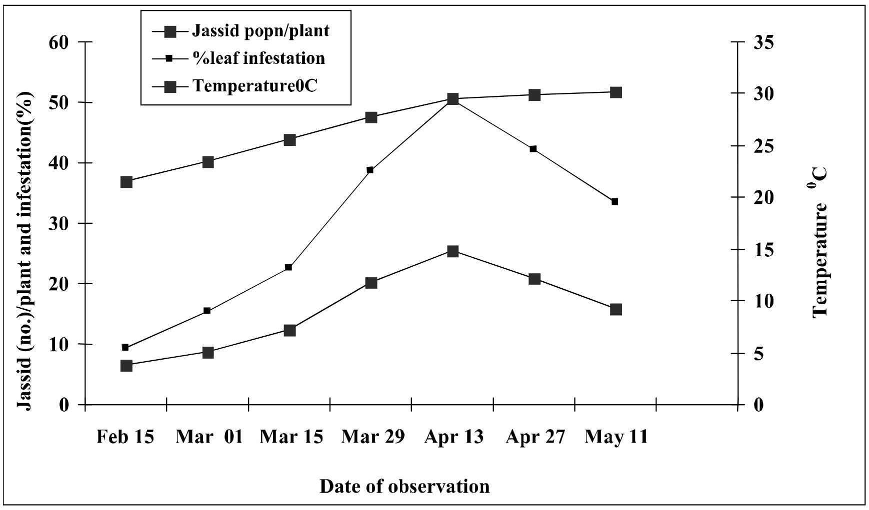

Fig 2. Number and infestation of jassids in groundnut in 2013 at BARI Gazipur.

Efficacy of jet powder, neem seed mixture and chemical insecticides in controlling jassids in groundnut crop during 2012 and 2013 is presented in Table 1. All the treatments reduced jassid population with significant variation among them. Of these Imidaclorprid (Admire 200SL @ 0.50ml/l) reduced significantly the highest jassid population (80.25%) over the untreated. Reduction of jassid occurred by 65-68% in Tafgor (Dimethoid) 40 EC @2ml/l and neem seed mixture+Jet powder treated plots and these two treatments caused similar controlling effects on jassid next to Imidaclorprid (admire, 82.72%) while Jet powder @ 3g/l reduced the lowest jassid population (49.86%) over the untreated control. The leaf infestation by jassid had the same trend as the number in all the treatments with the highest efficacy of Imidaclorprid resulted 80.72% reduction over untreated control. The lowest efficacy was recorded in jet powder treatment (Table 2). Almost similar information was recorded by Campbell (1986) in India and Biswas *et al.,* (2009 and 2011) in Bangladesh.

Table 1. Number of jassids and reduction of its population over control in different treatments in groundnut crop in two years pooled data.

Treatments	Number of jassid/plant after three times of spray				% Population reduction over untreated
	7 days after 1st spray	7 days after 2nd spray	7 days after 3rd spray	Mean	
Jet powder @ 3g/L	15.60 b	10.40 b	08.00 b	11.40 b	49.86 c
NSM + jet powder	12.00 c	08.50 c	06.50 c	8.80 c	65.07 b
Tafgor @ 2 ml/L	10.00 c	06.50 c	05.50 c	7.66 c	68.58 b
Admire @0.5 ml/L	08.50 d	05.50 d	02.00 d	5.00 d	80.72 a
Untreated	20.50 a	25.50 a	35.00 a	25.67 a	-

Means followed by the same letter in a column did not differ significantly at 5% level by DMRT. Neem Seed Mixture= NSM.

Table 2. Percent of leaf infestation in different treatments used against jassids in groundnut in the pooled data of 2012 and 2013 at Gazipur.

Treatments	Leaf infestation(%) by jassid recorded on				% infestation reduction over untreated
	7 days after 1st spray	7 days after 2nd spray	7 days after 3rd spray	Mean leaf infestation (%)	
Jet powder @ 3g/L	30.60 b	21.40 b	18.00 b	23.40 b	49.86 c
NSM + jet powder	23.00 c	15.50 c	10.50 c	16.30 c	65.07 b
Tafgor @ 2 ml/L	22.00 c	13.50 c	8.50 c	14.66 c	68.58 b
Admire @0.5 ml/L	13.50 d	8.50 d	5.00 d	9.00 d	80.72 a
Untreated	40.50 a	56.50 a	65.00 a	54.67 a	-

Means followed by the same letter in a column do not differ significantly at 5% level by DMRT. Data were recorded in average of 10 plants/plot. . Neem Seed Mixture= NSM.

Table 3. Benefit cost ratio of different treatments against jassid in groundnut from the pooled data of 2012 and 2013 at BARI, farm Gazipur

Treatments	Seed yield (t/ha)	Increased yield over untreated	Additional income (TK./ha)	Cost of insecticides & spray	Net income (TK./ha)	BCR
Jet powder @3g/L	1.43 bc	0.08	4000.00	1500.00	2500.00	1.66
NSM + jet powder	1.48 ab	0.13	6500.00	2000.00	4500.00	2.25
Tafgor @ 2ml/L	1.53 ab	0.18	9000.00	2500.00	6500.00	2.60
Admire @0.5 ml/L	1.60 a	0.25	12500.00	3000.00	9500.00	3.16
Untreated	1.35 d	-	-	-		

Means followed by the same letters in a column do not differ significantly at 5% level by DMRT.

Price of Jet powder = 250, Price of Admire = 10000 Tk./L, Price of Tafhor = 800 TK./L

Price of groundnut seed= 50 Tk./kg, Cost of neem seed = 50 Tk./Kg, Cost of labour=200 Tk./labour/day , Three labours and 0.5 litre of Tafgor 40 EC @ 2 ml/I being required for 1 hectare of crop field sprayed in one time. One machine spray volume = 10 litre required 200 sqm field spraying in one time. Other variable costs were same in all the treatments.

BCR= Net income/ Management cost

The Benefit Cost Ratio (BCR) analysis of different treatments in suppressing jassids in groundnut crop is presented in the Table 3. The result revealed that significantly the highest pod yield of groundnut was obtained from Admire 200 Sl treated plot (1.60 t/ha) and calculated the highest BCR (3.16) followed by that of Tafgor 40 EC treated plot (2.60). The groundnut pod yield was 1.53 t/ha which was not statistically significant different from that of neem seed mixture + jet powder treated plot (Table 3). Significantly the lowest pod yield was recorded from the untreated control plot (1.35t/ha) and the lowest BCR was calculated from Jet powder treated plot (1.66)(Table 3). Similar information was also reported by Amin and palmer (1985), Singh (1990) in India and Ahmed *et al.*, (1989) and Biswas *et al.*, (2009 and 2011) in Bangladesh.

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SCREENING OF MUNGBEAN GENOTYPES FOR TOLERANCE TO WATERLOGGING UNDER FIELD CONDITION

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Keywords: Mungbean genotypes, screening, waterlogging tolerance.

Mungbean [*Vigna radiata* (L.) Wilczek] is the second most important pulse crop grown in Bangladesh with an area of 27,440 hectares and production of 19,445 metric tons during 2010-2011 (BBS, 2011). Being a rich source of protein, it maintains soil fertility through biological nitrogen fixation in soil and thus plays a vital role in sustainable agriculture (Kannaiyan, 1999). Mungbean can be grown both under rainfed and irrigated conditions depending on the availability of irrigation facilities. Since it is sensitive to waterlogging, the land should have well drainage system. Mungbean is generally susceptible to excess water, although genotypic variation in the tolerance to waterlogging has also been reported (Islam *et al.*, 2007; Hamid *et al.*, 1991; Miah *et al.*, 1991). Apart from genetic factors, waterlogging stress stands prominent that attributed to low yields of mungbean. The study was therefore carried out to observe the genotypic differences of mungbean cultivars and to identify their ability to tolerate to the waterlogged stress under field condition.

Forty mungbean genotypes (Table 1) were evaluated in the field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during April to June, 2010. The experiment was set up in split plot design with three replications. The plants were subjected to 3-5 cm standing water for 7-days at 22 days after sowing above the soil surface. At the same time the optimal soil moisture was provided to the plants retained as control to observe the difference of growth and convenient for data collection. The depth of water in the experimental plots was maintained by using polythene sheet in the border of each main plot along with continuous supply of water. Drain in between two main plots was 1m so that water cannot soak to the neighboring experimental plots. The performance of the selected mungbean genotypes were compared with that of control. A blanket rate of fertilizers 40-25-35 kg ha^{-1} of N-P-K and 10 t ha^{-1} cowdung was applied and thoroughly incorporated into the soil of each plot at the time of final land preparation. Seeds of uniform size and shape of mungbean genotypes were sorted from their stock and treated with Vitavex 200 at 1g per kg seed. The seeds were soaked in water for 4 hours before sowing and imbibed seeds were selected for sowing. Seedlings were thinned out after one week of

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emergence keeping one healthy seedlings per hill. Management practices and plant protection measures were taken as and when necessary. Five plants both from control and waterlogging treatments were harvested after 28 and 38 days from their corresponding emergence dates and data were collected. Height of individual plants was measured from the base to the top of main shoot. After harvesting, the seedlings of both waterlogged and controls were segmented into components i.e. stem, leaf, petiole, and reproductive organs. The segmented parts were oven dried at 80^0C for 72 hours to a constant weight and dry weights were recorded separately. Total dry weight was calculated by summing up the dry weights of stem, leaf, petiole, and reproductive parts of plants. Leaf area was measured using automatic leaf area meter (Model AAM-8. Hayashi Denkoh Co. Ltd., Tokyo, Japan). The screening criterion of the genotypes was based on survival % after removal of the flooding stress. Their survival percentage was recorded on the 28 DAE, 38 DAE and 48 DAE after termination of flooding. Plant survival percentage of each genotype was calculated by the following formula,

$$\text{Survival (\%)} = \frac{\text{The no. of plants of each genotype survived after 7-day waterlogging}}{\text{Total plants of each genotype present at the beginning of waterlogging}} \times 100$$

The screening criterion of the genotypes was based on survival rate and recovery of plants after termination of waterlogging as suggested by Nawata (1989). After termination of waterlogging (28 DAE), a significant number of plants of each genotypes were found to survive. During 10-days recovery period (38 DAE), the number of plants of each genotype greatly reduced due to seedling mortality. Finally, a number of plants of each mungbean genotype were survived till maturity. The percentage of plant survival was calculated (Table 1). Among the total number of genotypes, only 15 genotypes namely, IPSA-13 (entry no.26), IPSA-15 (entry no.27), VC-3173 (B-10) (entry no.28), VC-6367 (44-55-2) (entry no.29), ACC-12890054 (entry no.30), ACC-12890085 (entry no.31), GK-1(entry no.32), GK-3 (entry no.33), GK-63 (entry no.34), GK-48 (entry no.35), GK-65 (entry no.36), BU mug 2 (entry no.37), CO-3 (entry no.38), VC-6173A (entry no.39), VC-3160(A-89) (entry no.40) showed 20-34% survival, and the rest 25 genotypes had survival of <20%. Lawn and Russel (1978) reported that after emergence, the stand establishment of the mungbean crop may reduce to 65-100% for eight days waterlogging at second trifoliate leaf stage.

The variability in plant characters of the mungbean genotypes at the end of waterlogging (28 DAE) and during 10 days recovery period (38 DAE) have been shown in Table 2. Some plants were taller viz. IPK-1040-94 (entry no.3), ML-613 (entry no.5), GK-46 (entry no.11), PDM-11 (entry no.23), ACC-12890054 (entry no.30), ACC-12890085 (entry no.31), GK-63 (entry no.34), GK-48 (entry no.35), CO-3 (entry no.38) and some were shorter viz. GK-29 (entry no.19), GK-

55 (entry no.20), VC-6367 (44-55-2) (entry no.29), GK-1 (entry no.32), GK-48 (entry no.35) under control condition but significant reduction in plant height of all the waterlogged treated genotypes was observed. The difference in plant height of waterlogged plants were increased to a great extent during 10 days recovery period and less reduction in plant height over the control was recorded 35.59 % in BARI mung 6, 76 % in BARI mung 5, 29.33 %, in GK-6 and 3.85 % in BU mug 2. The relative elongation rate of plant height is a morphological mechanism of waterlogged tolerance of plants as reported by Futakuchi *et al*., (2001).

Table 1. List of mungbean genotypes and percentage of plant survived at 28, 38 and 48 days after emergence of seedlings

Sl. no.	Genotypes	% of plant survival at 28 DAE	% of plant survival at 38DAE	% of plant survival at 48DAE
1	BINA-6	65.21	13.04	4.34
2	BINA-7	66.66	17.77	6.66
3	IPK-1040-94	83.33	14.28	9.52
4	IPSA -18	63.15	21.05	7.89
5	ML-613	74.41	20.93	6.97
6	GK-6	55.88	11.76	2.94
7	GK-7	57.57	12.12	3.03
8	GK-32	55.88	17.64	8.82
9	GK-36	65.90	13.63	6.81
10	GK-37	63.88	13.88	8.33
11	GK-46	62.22	13.33	6.66
12	VC-3950-88	76.74	13.95	2.32
13	BARI mung 5	69.44	22.22	19.44
14	BARI mung 6	76.31	21.05	10.52
15	IPSA-12	35.00	25.00	17.50
16	IPSA-19	57.77	22.22	13.33
17	GK-5	58.33	16.66	11.11
18	GK14	58.13	16.27	13.95
19	GK-29	60.52	21.05	19.44
20	GK-55	61.53	20.51	15.38
21	GK-56	63.15	18.42	10.52
22	ML-267	71.42	23.80	16.66
23	PDM-11	75.00	18.18	11.36

Table 1. Continued.

Sl. no.	Genotypes	% of plant survival at 28 DAE	% of plant survival at 38DAE	% of plant survival at 48DAE
24	VC-6379 (23-11)	70.21	21.27	10.63
25	VC-3173 (B-6)	80.95	19.04	11.90
26	IPSA-13	76.92	23.07	20.51
27	IPSA-15	61.90	28.57	21.42
28	VC-3173 (B-10)	68.18	36.36	29.54
29	VC-6367(44-55-2)	77.77	31.11	26.66
30	ACC-12890054	66.66	28.57	23.80
31	ACC-12890085	73.33	28.88	22.22
32	GK-1	65.78	23.68	21.05
33	GK-3	66.66	25.64	25.64
34	GK-63	60.52	26.31	21.05
35	GK-48	66.66	27.27	24.24
36	GK-65	65.00	25.00	22.50
37	BU mug 2	81.81	43.18	34.09
38	CO-3	85.71	33.33	30.95
39	VC-6173 A	81.25	46.87	31.25
40	VC-3160 (A-89)	71.42	33.33	30.95

Leaf area (cm^2 $plant^{-1}$) increased significantly in control plants over time and decreased significantly in flooded plants at the end of waterlogging (28 DAE). The reduction in leaf area over control ranged from 6% to 80% in different genotypes among which comparatively higher recovery in leaf area was recorded in (BINA-7) 27% (entry no.2), (IPSA-19) 38% (entry no.16), (GK-29) 26% (entry no.29), (GK-56) 36% (entry no.21), {VC-6379 (23-11)} 6% (entry no.24), {VC-3173 (B-10)} 1% (entry no.28), {VC-6367 (44-55-2)}29% (entry no.29), (VC3950-88) 34% (entry no.12), (ACC-12890085) 11% (entry no.31). While higher leaf area during the recovery period (28 DAE) indicated greater foliage development ability of some mungbean genotypes overcoming waterlogging stress reported by Islam (2005).

Plant components such as stem, leaf, and petiole and pod dry weight varied in between the control and waterlogged plants. A wide range of genetic variation in waterlogging induced changes in dry matter accumulation in the plant component observed by Islam *et al.*, (2007). The dry matter weight of plant parts in different mungbean genotypes reduced greatly after waterlogging and increased considerably during 10 days recovery period. Some genotypes produced pods which contributed to increase dry weight viz. GK-6 (entry no.6), GK-7 (entry no.7), GK-37 (entry no.10), BARI mung 5 (entry no.13), BARI mung 6 (entry no.14), GK-5 (entry no.17), GK-14 (entry no.18), GK-55 (entry no.20), ML-267 (entry no.22), PDM-11 (entry no.23), VC-6379(23-11) (entry no.24), VC-3173(B-6) (entry no.25).

Table 2. Dry weight (g plant^{-1}) of plant components of 40 mungbean genotypes grown under waterlogged and non-waterlogged control condition.

Changes in plant characters	Waterlogging level	At the end of waterlogging (28 DAE)	At the end of 10 days recovery period (38 DAE)
		Mean ± SD	Mean ± SD
Plant height (cm)	Control	20.69 ± 3.18	53.37 ± 8.15
	Waterlogging	11.65 ± 1.66	26.06 ± 6.73
Leaf area (cm^2 plant^{-1})	Control	404.28 ±94.76	549.64±188.52
	Waterlogging	220.86 ±79.39	283.02±130.08
Components DW (g plant^{-1})			
Stem	Control	1.14 ± 0.33	4.95 ± 1.42
	Waterlogging	0.88 ± 0.41	1.37 ± 0.41
Leaf	Control	2.06 ± 0.49	5.60 ± 1.37
	Waterlogging	1.32 ± 0.57	1.82 ± 0.57
Petiole	Control	0.53 ± 0.14	1.60 ± 0.54
	Waterlogging	0.31± 0.14	0.81 ± 0.14
Pod	Control	-	3.53 ± 1.88
	Waterlogging	-	0.64 ± 0.18
Total dry matter (g plant^{-1})	Control	3.73 ± 0.76	15.68 ± 3.59
	Waterlogging	2.51 ± 0.96	3.15 ± 0.98

Total dry matter (TDM) accumulation at the end of 7-day waterlogging and during 10 days recovery period (28-38 DAE) was markedly affected and a wide range of genotypic variation was observed (Table 2). On an average, waterlogging induced reduction in TDM by 33% at the end of waterlogging. Among the 40 mungbean genotypes, total dry matter in some genotypes were higher at the end of waterlogging and those were BINA-7 (entry no.2), BARI mug 5 (entry no.13), IPSA-19 (entry no.16), GK-65 (entry no.36), BU mug 2 (entry no.37), VC-6137A (entry no.39), VC-3160(A-89) (entry no.40) (Fig.1). During 10 days recovery period, some of the genotypes accumulated fairly higher amount of TDM over non-waterlogged control (Fig. 2). The rate of reduction in TDM in waterlogged plants over the control ranged from 43% to 84% depending on the genotypes. Lower reduction in TDM over the control was recorded in BARI mung 5 (65%), IPSA-12 (61%), IPSA-13 (61%), IPSA-15 (47%), VC-3173(B-10) (65%), VC-6367(44-55-2) (51%), ACC-12890054 (51%), ACC-128900850 (43%), VC-6173A (61%). Accumulation of higher TDM in waterlogged plants over the control was observed in some mungbean genotypes which might tolerate soil flooding to a great extent. Yadav and Saxena (1998) found decreased production of total dry matter in waterlogged mungbean.

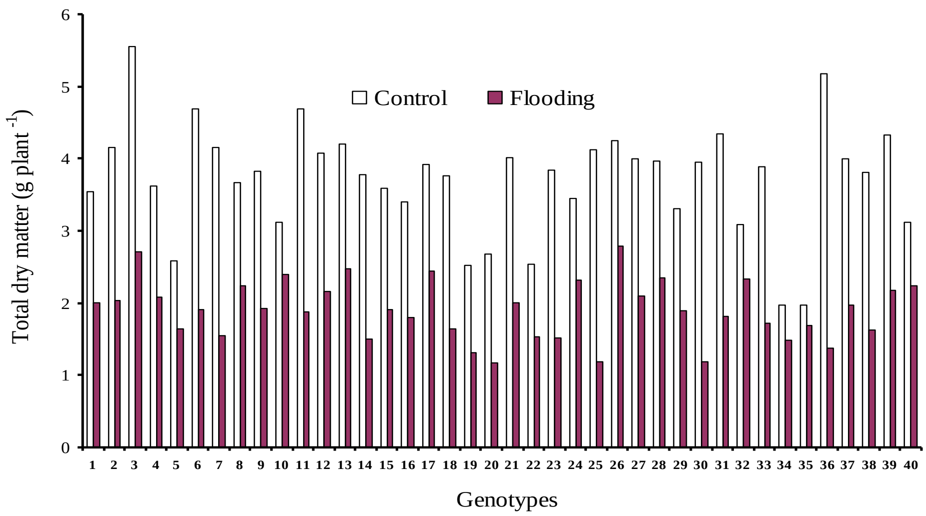

Fig.1. Total dry matter of mungbean genotypes at the end of 7-day waterlogging

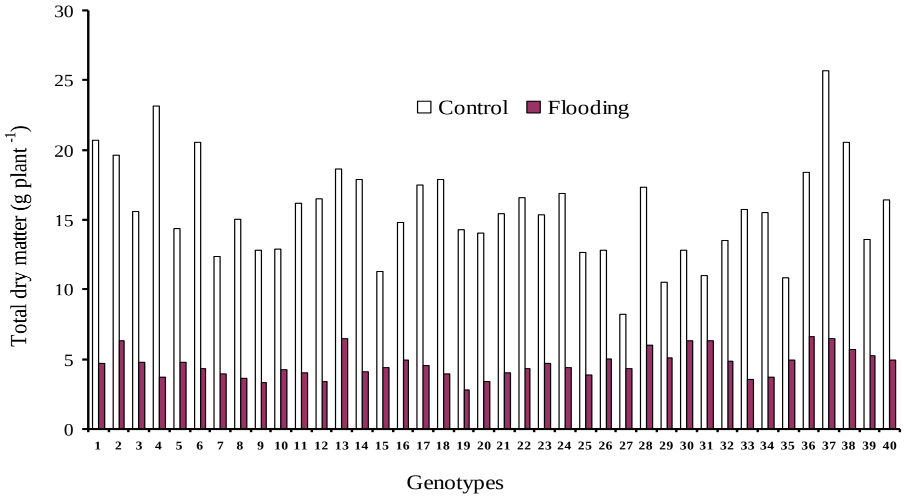

Fig. 2. Total dry matter of mungbean genotypes at the end of 10 days recovery period

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C O N T E N T S

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