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TRIPLE CEREAL SYSTEM WITH FERTILIZER AND PLANTING MANAGEMENT FOR IMPROVING PRODUCTIVITY IN COASTAL SALINE SOILS OF BANGLADESH

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Abstract

A field experiment was conducted on a saline environment of Shatkhira to assess the feasibility of an intensive wheat-maize-rice cropping system with crop residue used as mulch, bed planting and fertilizer management to improve productivity. Three levels of fertilizers (Recommended dose of NPKS fertilizers, recommended fertilizers plus 50% additional K and S and recommended fertilizers with 2 t/ha ash) were assigned in main plots and four combinations of soil management and mulching (Conventional flat, Conventional with straw mulching @ 3 t/ha, Bed planting, and Bed with straw mulching @ 3 t/ha) were kept in subplots with three replications. Rice straw mulch was used after wheat sowing, wheat straw mulch was applied after maize sowing. Rice was puddle transplanted without mulch. Crop varieties like BARI GOM 25, BARI Hybrid Maize 7, and BRRI Dhan 39 were used for wheat, maize and rice, respectively. Chemical analysis of soils after two years of experimentation and the response of component crops for the two cropping cycles indicated that straw mulching either on bed or flat soil was equally effective in preventing rapid development of soil salinity in the dryer periods and thereby resulted in better stand establishment contributing to higher spikes/m^2 of wheat and ears/m^2 of maize. Available nutrient contents in soil, especially P (Olsen), B and K were improved when straw much was applied in bed or flat plantings. Application of ash with recommended fertilizer was effective in improving grain yields of component crops as compared to other fertilizer treatments without ash. The highest grain yield of wheat and maize was achieved when recommended dose of fertilizers plus ash with straw mulching were applied either in bed or flat soil condition for both the years. Treatment effect was not noted on rice yield in the first year, however the residual effect of treatments and its combinations became significant in the second year. Like wheat and maize, rice yield positively increased by fertilizer+ ash and mulching. Straw mulch and ash application contributed to soil salinity mitigation, favoured crop establishment and improved the yields of component crops.

Keywords: Straw Mulch, Bed planting, Soil Salinity, Cropping System, Ash application, Soil fertility.

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1. Introduction

Salinity is one of the major constraints affecting crop production in the coastal regions of Bangladesh. The coastal region constitutes 20% of the total area of Bangladesh, of which about 53% is affected by different degrees of salinity (Asib, 2011). Crop productivity and cropping intensity in these regions are very low, at about half of the national average (Rahman and Ahsan, 2001). The low productivity and reduced cropping intensity are associated with tidal flooding and direct inundation of saline water during the wet season (June-October) and upward or lateral movement of saline ground water during dry season (November-May). Soil salinity can cause an accumulation of sodium (Na) on the soil surface**. S**odium-induced salinity reduces infiltration and hydraulic conductivity and can accelerate surface crusting. Increased amounts of calcium (Ca) and potassium (K) can reduce Na-induced dispersion by improving the balance of Ca, magnesium (Mg) and Na in soil (Khan *et al.*, 2010). Thus application of gypsum and K fertilizer may improve crop production by reducing the harmful effects of Na. Keeping the lands fallow favors the build-up high soil salinity due to capillary rise and evaporation from the bare soil, even on the higher lands. The coastal lands where flooding depth ranges from 0.3 -0.6 m are suitable for at least two crops and sometimes three crops per year, including wheat or other suitable crops in winter, but the lack of quality irrigation water is a major constraint for winter crop production (Haque, 2006). Rice and maize cultivation are expanding in Bangladesh either in double or triple-crop systems to meet food demand of increasing population and the maize demand of livestock and poultry (Timsina *et al*., 2010). Introduction of wheat-maize-rice cropping with appropriate management strategies could contribute to increased system productivity and also to year-round crop coverage, which may help to reduce soil salinity. Application of crop residues as mulch reduces soil evaporation (Rahman *et al.,* 2005), and thereby reducing the capillary rise of saline ground water. Tillage breaks and reorganizes soil capillaries, while the creation of raised beds increases the distance between the water table and the soil surface. Thus freshly prepared beds might be effective in reducing the rate of salinization of the topsoil. Furthermore, surface application of rice hull ash may also suppress soil evaporation and surface soil salinization. Considering all these factors the present experiment was undertaken to address the issue of soil salinity integrating fertilizers and locally available resources viz. ash from rice husking mill and residues of previous crop.

2. Materials and Method

2.1 Site**:** A field experiment was conducted at the Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI) at Benarpota, Shatkhira (22^{0}43´N 89^{0}06´E) to evaluate the performance of wheat-maize-rice cropping system as affected by soil and nutrient management and mulching with crop residues or rice hull ash. The experimental field is categorized as medium high land where flooding depth ranges from 0.2-0.5 m during the peak wet season, and soil salinization develops during the dry season. The topsoil (0-15 cm) is slightly alkaline silty clay with low organic matter and total nitrogen (N) content (Table 1). The topsoil is deficient in some micronutrients, especially zinc (Zn), boron (B) and copper (Cu), but rich in phosphorus (P), sulfur (S) and potassium (K). Generally, available K content decreases in saline soil with increasing Na content, but at the experimental site, exchangeable Ca and K contents were much higher than of Na and Mg, which is favorable for plant nutrition.

Table 1. Initial chemical properties of the topsoil (0-15 cm) of the experimental field, sampled on 26th November, 2011 (after rice harvest) with critical limit

	pH	OC	Total N	Available nutrients (μg g^{-1})							Cation exchange capacity (meq 100 g^{-1})			
		(%)	(%)	P	S	B	Zn	Cu	Fe	Mn	K	Ca	Mg	Na
Initial	8.2	1.21	0.65	11.7	114	0.28	2.0	0.6	108	16	0.48	9.3	3.1	0.6
Critical limit	-	-	-	7	14	0.2	2.0	1.0	10.0	5.0	0.2	2.0	0.8	-

2.2 Experimental design: The experiment comprised three fertilizer treatments, and four combinations of planting method and mulching, in a split plot design with three replicates.

Main plots: Fertilizer treatment

RF : Recommended fertilizer

RF+KS : RF+ 50% additional potassium and sulfur fertilizer

RF+Ash : RF+ Rice husk ash on the soil surface at 2 t/ha (applied to wheat and maize).

Sub-plots (5 m x 2.4 m): Combinations of planting method and mulching

Flat : Conventional method of flat planting

Flat +Mulch : Flat + straw mulching at 3 t/ha (rice straw in wheat, wheat straw in maize)

Bed : Conventional tillage followed by formation of raised beds prior to wheat sowing

Bed +Mulch : Bed +straw mulch as for Flat + Mulch.

The beds were formed manually with 30 cm wide ridges and 60 cm wide from central point of one furrow to another. Beds were formed once a year prior to wheat sowing and two rows of wheat were sown on the beds with 20 cm row spacing. Upon wheat harvest beds were reshaped and one row of maize was sown on the beds manually. After maize harvest, beds were destroyed by puddling for transplanted rice. Ash and straw mulch were applied after sowing to wheat and maize only.

2.3 Crop management: Wheat was the first component crop and was sown on 26 November, 2011, followed by maize sown on 19 March, 2012 and then rice was transplanted into the puddled soil on 20 July, 2012 to complete the first cropping cycle. Similarly, the second cropping cycle was completed in 2012-13, starting with wheat sowing on 3 December, 2012 and ending with rice harvest on 30 November, 2013. The wheat was sown with a row spacing of 20 cm at 120 kg/ha seed rate. The maize was sown between the wheat rows by opening the soil with a hand driven furrow opener for placement of seeds and fertilizers, after which the beds were reshaped. Maize row spacing was thus 60 cm, and with 20 cm plant spacing within the rows giving 8.3 plants/m^2. BARI Gom 25, BARI Hybrid Maize 7, and BRRI Dhan39 varieties were used for wheat, maize and rice, respectively. Fertilizers (urea, triple super phosphate, muriate of potash, gypsum) were applied at the recommended rates to all crops in treatment as RF. The entire dose of all fertilizers was broadcasted during final land preparation (basal application) except for urea, which was applied at two splits (basal, top-dress). For wheat, the elemental rates were 120 kg N, 30 kg P, 50 kg K and 20 kg S ha^{-1}, respectively, with two thirds of the urea applied basally, and the rest was broadcasted at crown root initiation (CRI) stage at 21 DAS (days after sowing). The recommended fertilizer rates used for maize were 200 kg N, 50 kg P, 100 kg K and 40 kg S ha^{-1}, and for rice 80 kg N, 25 kg P, 50 kg K and 20 kg S ha^{-1}. For maize and rice, one-third of urea was applied at the time of land preparation, and the rest was top dressed in two equal splits at 4 and 8 weeks after transplanting of rice and at 6-7 leaf stage and flowering stage of maize. The wheat crop was irrigated at the CRI, booting and grain filling stages. To ensure good germination and stand establishment, three irrigations were given at 3 leaf, 8 leaf and flowering stages of maize in 2012, whereas only one irrigation at 7 leaf stage other than post sowing irrigation was given for maize in 2013 due to early onset of the monsoon rains. The rice crop was entirely rain-fed.

2.4 Soil monitoring: The topsoil (0-15 cm) was sampled prior to the start of the experiment, and samples were collected from each plot after each crop cycle (three crops). The samples were analyzed for available nutrient contents following standard procedures at the Soil Science Laboratory of BARI. Soil electrical conductivity (EC) in each plot was measured at a regular interval of about 10 days starting from the date of wheat sowing in the second year (3 December, 2012) to June 20, 2013. Soil EC was measured by inserting the electrode of a digital portable EC meter (Hanna Model: HI 993310) into 10 cm depth at three randomly selected spots in each plot.

2.5 Crop monitoring: During maturity 10 wheat plants were sampled to measure plant height, grains/spike and thousand grain weight (TGW). Similarly rice plants were sampled to determine grains/panicle and TGW. Spikes/m^2 of wheat, panicles/m^{2}of rice and cobs/m^2 of maize were counted randomly selected 1.0 m x 1.0 m area with four replications in each plot. In case of maize, 5 ears from randomly selected 5 plants were collected to estimate ear length, grains/ear and TGW. At maturity, the crops were harvested duly and threshed on a whole plot basis to determine grain yield. After threshing, the grain was dried and moisture content of grain was determined for conversion of grain yields to t ha^{-1} at 12% moisture content for wheat and maize, and 14% moisture for rice.

2.6 Data analysis: All data were statistically analyzed using MSTAT-C software and the mean values were compared by the least significant difference (LSD) test at 5% level of significance.

3. Results and discussion

3.1 Yield and yield components of wheat: Grain yield and yield components of wheat responded differently to the main effect of fertilizer levels and planting methods with mulch and also by its combinations (Table 2). Plant height and thousand grain weight (TGW) were statistically similar under different fertilizer and planting methods but varied due to its interactions. Due to interactions, all the four combinations planting methods and mulch treatments resulted in similar plant height and TGW under RF+ KS and RF+ Ash. But under RF, plant height and TGW were improved in response to straw mulch application. Fertilizer levels of RF+ Ash produced the maximum spikes/m^2 that was closely followed by RF+ KS but significantly higher than RF. Germination and stand establishment of wheat was better under RF+ Ash that resulted in higher spikes/m^2. This advantage of higher spikes/m^2 in response to ash application contributed to higher wheat yield under RF+ Ash. However, the treatments of RF+ Ash and RF+ KS produced statistically similar grain yield in both the years. The combination of mulch and bed planting assigned in sub-plots indicated that straw mulch application on flat soil resulted in higher spikes/m^2 and grains/spike as compared to flat only. Similarly Bed+ Mulch performed better result in spikes/m^2 and grains/spike than Bed only. Bed+Mulch and Flat+Mulch were statistically similar with respect to yield, which were better than respective non-mulch bed or flat planting in both the years. The result indicated that application of rice straw as mulch either in bed or in flat planting was equally effective in improving wheat yield mainly by influencing spikes/m^2 and grains/spike of wheat. Only bed planting failed to produce better wheat yield but the bed was comparable to flat when straw mulch was not applied. Rahman *et al.* (2005) reported that mulching reduced the evaporative loss and ensured soil moisture conditions favorable for germination and stand establishment of wheat and thus contributed to productive spikes/m^2. Due to interactions, the highest yield was obtained from the treatment combination of RF+ Ash in the main plots and Bed+Mulch or Flat+ Mulch in the sub plots. Under any fertilizer level, Bed+ Much and Flat+ Mulch resulted in statistically identical yield of wheat in both the years.

3.2 Yield and yield components of maize: Maize grain yield and yield components viz. ears/m^2, ear length and grains/ear were significantly influenced by fertilizer levels and planting methods with mulch and also by its interactions (Table 3). Fertilizer levels of RF+ KS and RF+ Ash resulted in statistically similar ears/m^2, ear length and grains/ear of maize those were higher than RF. Thousand grain weight was statistically similar for different fertilizer levels but the grain yield was the maximum in RF+ Ash followed by RF+ KS but higher than RF in both the years. Thus application of ash or higher dose of potassium and sulfur fertilizer was effective in improving maize yield in this experimental environment. Due to the main effect of planting method with mulch, Flat+Mulch and Bed+Mulch produced similarly higher yield which were significantly higher than other couples of treatments receiving no mulch. Also Flat+ Mulch and Bed+ Mulch resulted in statistically similar ears/m^2 and grains/ear of maize. The result indicated that mulch application either in bed or flat were equally effective in improving yield of maize by increasing number of productive ears per unit areas with higher numbers of grains per ear. The length of maize ear was significantly higher under the aforementioned couple of treatments receiving straw mulch. The treatment of crop residue retention favored stand establishment of maize by influencing the hydraulic properties of soil resulting higher number of plants per unit area (Rahman *et al.*, 2013), thus cobs/m^2 was improved under Bed+ Mulch and Flat+ Mulch treatments. Another fact of mulching effect in controlling the rapid development in soil salinity during the dryer period at an early growth stage of maize (Fig. 2) might also be responsible for good stand establishment that ultimately might have contributed to higher cobs/m^2. Due to interactions, the maximum grain yield was recorded in response to treatment combination of RF+ Ash × Bed+ Mulch followed by RF+ KS × Flat+ Mulch in 2013. In general, yield was relatively low in 2012 compared to 2013 for all treatments and treatment combinations. However, with few exceptions the crop response to treatments was very similar for both the year. The yield advantage of maize under the interaction effect was attributed to cobs/m^2 and grains/cob as other yield components was not affected by the interaction effects.

3.3 ***Yield and yield components of rice:*** Different fertilizer levels and planting methods with mulch and its interactions resulted in similar rice yield in the first year. However, the residual effect of treatment on grain yield and yield component viz. panicles/m^2 and grains/panicle became significant in the second year (Table 3). In 2013, number of panicle/m^2, grains/panicle and grain yield was the maximum under the fertilizer level of RF+ Ash followed by RF and RF+ KS. Application of additional K and S fertilizers in rice crop including the residual effect of those fertilizers in previous component crops under the treatment RF+ KS caused luxurious vegetative growth of rice that influenced lodging after heading (Data not presented). Thus the number of filled-grains was decreased with higher number of un-filled grains/panicle caused less grain yield under RF+ KS. Different combination of straw mulch and bed planting produced similar yield statistically in both the years. Also the treatments gave similar panicles/m^2, grains/panicle and grain yield under the fertilizer levels of RF+ KS when considering their factor interactions. On the contrary, under RF+ Ash, Flat+ Mulch and Bed+ Mulch produced more panicles/m^2 and higher grain yield than Flat and Bed in 2013. The mulching effect was also highest yielding under RF. The result indicated that application of ash from rice husking mill had positive effect on improving rice yield and the crop residue mulching in previous crops also played a vital positive role in improving rice yield under the experimental soil conditions.

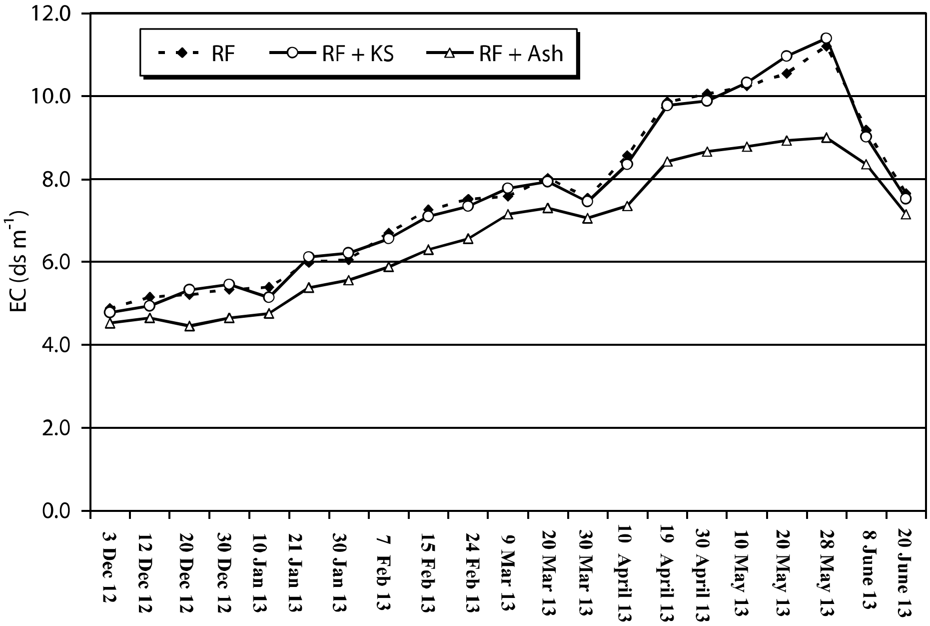

Fig. 1. Changes in soil EC with time under different fertilizer levels at Shatkhira during 2012-13.

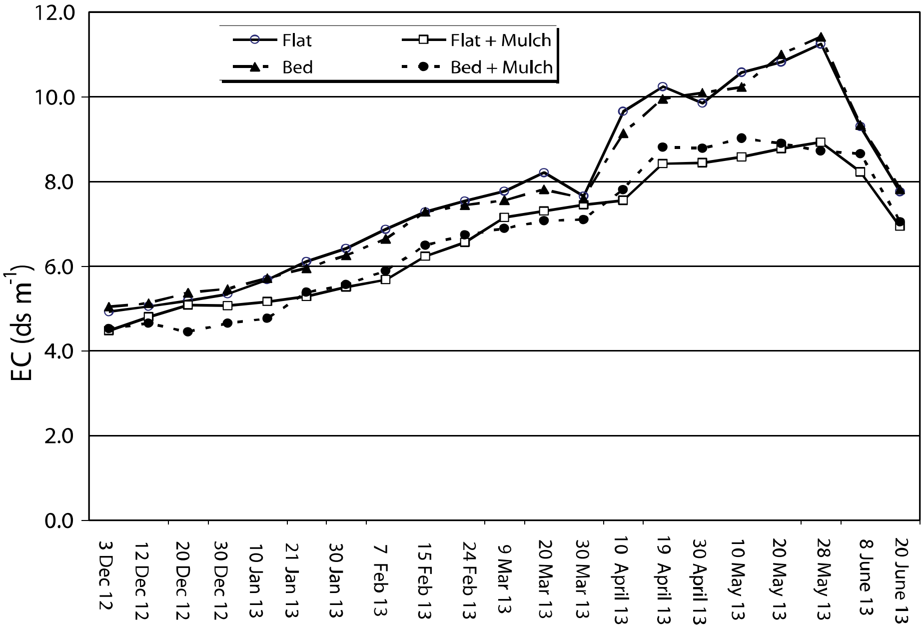

Fig. 2. Soil EC in time under planting method with mulch treatments at Shatkhira during 2012-13.

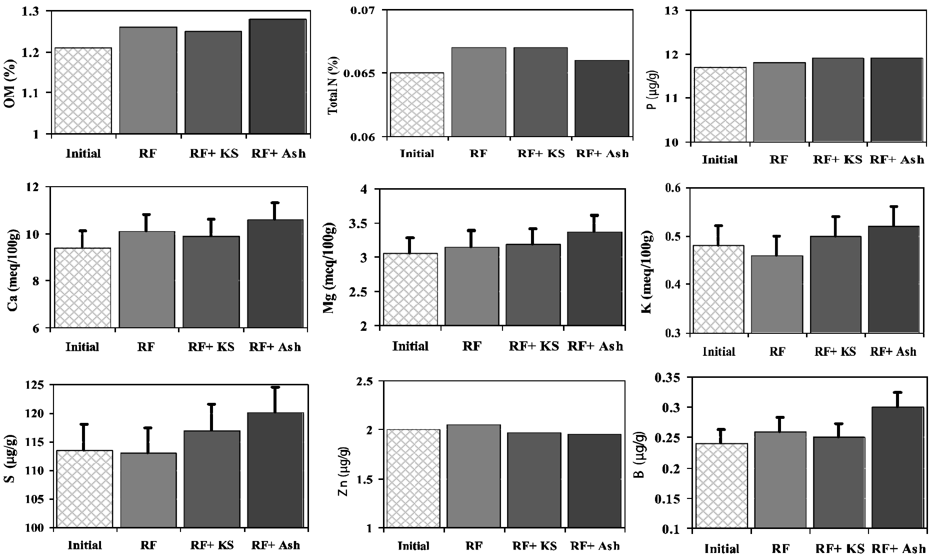

Fig. 3. Available nutrient contents in soil as affected by different fertilizer levels in relation to initial soil after two cycle of wheat-maize-rice cropping at Shatkhira (Error bar indicates LSD at 5% level of significance).

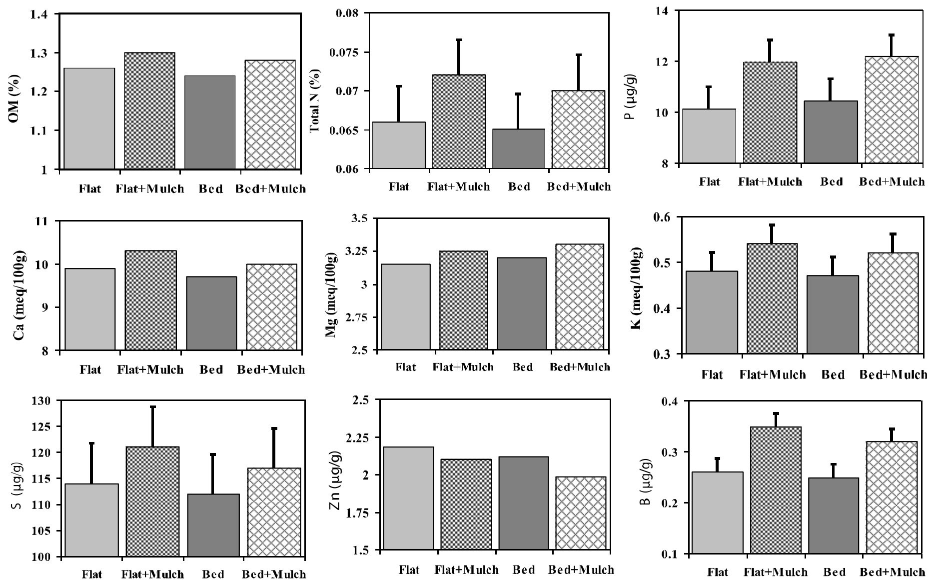

Fig. 4. Available nutrient contents in soil as affected by planting method with mulch treatments after two cycle of wheat-maize-rice cropping at Shatkhira (Error bar indicates LSD at 5% level of significance).

3.4 Soil salinity: Initially soil EC of the experimental field was around 6.7 ds/m during sowing first wheat crop on 26 November, 2011 but in the second year soil EC values came down to less than 5.0 ds/m for all the plots during sowing 2 wheat crop on 3 December, 2012. EC values were similar for different fertilizer levels and conservation treatments until the end of December (Fig. 1 & 2). Thereafter soil salinity varied in response to treatments; the soils of main plots receiving RF+ Ash showed relatively lower EC values as compared to other fertilizer levels (Fig. 1). The variation in EC in response to treatments was wider during the dryer periods of February to May with an exception in 30 March. On 30 March, EC values dropped down for all the plots and treatment variation became narrower (Fig. 1 and 2). At that period maize seed was sown and the plots were irrigated thus EC values became closer in wet soil condition. Thereafter a rapid increasing trend was found through April and May and the treatment differences were wider. Then gradually soil EC started decreasing from early June with the on-set of monsoon rain that might have washed out the surface soils salinity. Thus the differences in EC among the plots became closer after early June, 2013. Wider variations in soil EC was observed during the peak dry periods in response to fertilizer levels and ash application was effective in preventing the rapid development of soil salinity. During drier period soil EC values largely varied in response to conservation practices (Fig. 2) and EC values were lower in plots receiving Flat+ Mulch or Bed+ Mulch treatments. Though there was no remarkable difference in EC between Bed and Flat, a declining trend was

Table 2. Yield components and grain yield of wheat as influenced by fertilizer levels and planting methods with mulch at Benarpota, Satkhira during 2012 and 2013

Treatment	Yield Components (2012-13)				Grain yield (t ha^{-1})	
	Plant ht. cm	Spikes m^{-2}	Grains $spike^{-1}$	TGW (g)	2013	2012
A. Fertilizer levels						
RF	81.4	271.3	43.7	47.2	3.33	3.20
RF+ KS	85.2	317.8	44.8	49.0	3.62	3.47
RF+ Ash	88.1	331.6	45.4	49.4	3.82	3.65
LSD $_{(0.05)}$	NS	28.6	NS	NS	0.35	0.31
B. Planting method with mulch						
Flat soil	83.1	276.3	40.1	47.4	3.23	3.03
Flat+ Mulch	86.3	320.4	47.6	49.7	3.65	3.57
Bed	82.2	303.2	43.5	47.8	3.47	3.32
Bed+ Mulch	87.7	328.2	46.8	49.2	3.93	3.58
LSD $_{(0.05)}$	NS	31.3	3.9	NS	0.39	0.32
C. Interactions						
RF ×						
Flat	77.6	225.5	38.8	44.8	2.93	2.85
Flat+ Mulch	82.8	288.8	45.7	49.1	3.56	3.32
Bed	75.4	268.7	46.2	45.4	3.13	3.05
Bed+ Mulch	84.7	302.3	45.7	49.4	3.72	3.68
RF+ KS×						
Flat soil	82.8	298.5	41.3	48.8	3.25	3.05
Flat+ Mulch	87.5	328.7	47.9	49.7	3.66	3.66
Bed	84.8	308.5	42.3	48.9	3.65	3.32
Bed+ Mulch	88.2	336.3	47.5	48.5	3.92	3.85
RF+ Ash ×						
Flat soil	88.8	306.0	42.1	48.7	3.60	3.22
Flat+ Mulch	88.5	343.5	48.3	50.2	3.79	3.74
Bed	86.5	329.7	43.7	49	3.64	3.58
Bed+ Mulch	90.7	346.3	47.0	49.6	4.31	4.02
LSD $_{(0.05)}$	8.1	29.8	4.1	3.9	0.34	0. 33
CV (%)	9.2	7.8	8.1	7.8	8.6	9.4

Table 3. Grain yield and yield components of maize as influenced by fertilizer levels and planting methods with mulch at Benarpota, Satkhira during 2012 and 2013

Treatment	Yield Components (2012-13)				Grain yield (t ha^{-1})	
	Cobs m^{-2}	Cob length (cm)	Grains Cob^{-1}	TGW (g)	2012	2013
A. Fertilizer levels						
RF	7.07	17.4	282.0	232.2	4.84	4.81
RF+ KS	8.28	19.4	320.6	234.4	6.22	5.54
RF+ Ash	8.50	18.8	316.2	235.7	6.40	5.62
LSD $_{(0.05)}$	0.74	1.6	30.4	Ns	0.46	0.39
B. Planting method with mulch						
Flat soil	7.38	17.7	288.9	236.1	5.27	4.90
Flat+ Mulch	9.02	19.1	313.8	240.0	7.31	5.70
Bed	7.02	18.1	290.2	230.8	5.25	4.87
Bed+ Mulch	8.37	19.2	331.5	232.3	7.44	5.67
LSD $_{(0.05)}$	0.78	1.2	31.4	Ns	0.51	0.47
C. Interactions						
RF ×						
Flat	6.76	16.8	265.5	234.5	4.21	4.45
Flat+ Mulch	8.33	17.5	298.8	234.2	5.83	5.36
Bed	6.05	17.0	258.8	226.5	4.05	4.13
Bed+ Mulch	7.12	18.4	304.5	233.8	5.22	5.28
RF+ KS×						
Flat soil	7.70	18.4	298.8	234.0	5.38	5.21
Flat+ Mulch	9.40	20.2	324.8	241.2	7.26	5.83
Bed	7.33	19.2	308.0	233.4	5.25	5.52
Bed+ Mulch	8.67	19.8	349.7	228.8	6.96	5.86
RF+ Ash ×						
Flat soil	7.67	17.8	302.4	232.1	5.25	5.04
Flat+ Mulch	9.34	19.5	317.8	244.5	7.26	5.87
Bed	7.67	18.0	303.8	224.2	5.24	4.96
Bed+ Mulch	9.33	19.5	340.2	240.2	7.71	5.98
LSD $_{(0.05)}$	0.81	1.4	33.8	NS	0.45	0.34
CV (%)	10.3	7.8	10.5	11.4	9.1	10.2

Table 4. Grain yield and yield components of rice as influenced by fertilizer levels and planting methods with mulch at Benarpota, Satkhira during 2012 and 2013

Treatment	Yield Components (2013)				Grain yield (t ha^{-1})	
	Panicles m^{-2}	Grains $panicle^{-1}$	Un-fill grains $panicle^{-1}$	TGW (g)	2013	2012
A. Fertilizer levels						
RF	365.0	115.9	6.4	21.8	4.94	4.46
RF+ KS	354.6	107.6	10.3	21.6	4.36	4.32
RF+ Ash	384.8	123.9	5.1	22.1	5.44	4.73
LSD $_{(0.05)}$	35	14.2	1.2	NS	0.48	NS
B. Planting methods with mulch						
Flat soil	365.2	118.8	7.9	21.8	4.76	4.54
Flat+ Mulch	373.6	113.9	7.6	21.7	5.15	4.51
Bed	359.6	114.1	7.3	21.9	4.72	4.45
Bed+ Mulch	374.0	116.4	8.1	22.0	5.14	4.50
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS
C. Interactions						
RF×						
Flat	352.6	119.4	6.2	21.3	4.68	4.45
Flat+ Mulch	386.2	115.9	6.5	21.7	5.12	4.58
Bed	344.3	110.4	6.0	22.1	4.72	4.48
Bed+ Mulch	377.1	118.0	6.7	22.3	5.22	4.71
RF+ KS ×						
Flat soil	347.8	107.4	10.5	22.1	4.25	4.30
Flat+ Mulch	355.1	107.0	11.0	21.3	4.47	4.42
Bed	350.3	104.9	8.9	21.7	4.34	4.12
Bed+ Mulch	364.1	111.2	10.8	21.4	4.52	4.23
RF+ Ash ×						
Flat soil	394.6	129.7	5.4	22.1	5.26	4.72
Flat+ Mulch	379.5	118.7	5.1	22.2	5.85	4.56
Bed	384.1	127.0	5.5	22.0	5.17	4.54
Bed+ Mulch	380.8	120.1	4.6	22.3	5.68	4.63
LSD $_{(0.05)}$	34.5	14.2	1.1	NS	0.43	NS
CV (%)	10.2	7.5	7.7	6.5	9.4	8.5

observed in Bed with few exceptions. In few cases the EC value in Bed was higher than the Flat. Generally, salinity developed unevenly in the field and very often it was patchy in nature. Thus, EC in bed was higher than flat in some cases. Mulch applications either in bed or flat were equally effective in preventing rapid development of soil salinity compared to non-mulched treatments. Bed planting alone was unable to prevent soil salinity by breaking and reorganizing soil capillaries as expected during planning the experiment. Also the application of 50% higher K and S fertilizer was ineffective in contributing salinity management. Whereas the combination of ash application in the main plots and straw mulch application in the sub plots was effective in preventing rapid development of soil salinity. Rengasamy (2006) described soil salinization as a complex process involving the movement of salts and water in soils varying with seasonal cycles, interacting with groundwater and rainfall. Yang *et. al* (2006) reported that mulching was effective in conserving soil water decreasing surface soil salinity and thereby improved wheat yield. Present experiment also demonstrated the seasonal variation of salinity in coastal surface soil (0-15 cm depth) and straw mulching was effective in reducing salinity during the dryer seasons. The use of crop straw as mulch in field crops is rare in Bangladesh condition. The farmers use crop straw mostly as fodder for their livestock and as fuel. Under such a competitive need for crop residues, 3.0 t/ha straw mulch application seems to be unaffordable to the marginal farmers. However, considering the direct and residual effect of mulch in salinity management and crop productivity the farmers could prefer straw mulching whenever have the alternate source of fuel and fodder.

3.4 Soil nutrient contents: The initial soil was poor in organic matter and total N content, but the soil was rich in P, K and S contents and the soil was deficient in some of the micro-nutrients especially Zn and B (Table 1). Generally, available K content decreases in saline soil with an increase in Na content which was not found in the experimental field. The changes in nutrient availability in such a soil after two cycles of cropping indicated that available nutrient contents in soil did not decline due to intensive wheat-maize-rice cropping. Rather in some cases, availability of nutrient was improved in response to fertilizer levels and planting methods with mulch treatments (Fig. 3 & 4). Recommended fertilizers with ash application@ 2 t/ha before wheat and maize have the positive effect on Ca, Mg and S contents in soil (Fig. 3). OM, P and Zn contents remained unchanged but B content was slightly declined under RF+ Ash. Planting methods with mulch treatments had the variable effect on the availability of various plant nutrients in soil (Fig. 4). Available P content in surface soil was higher in Flat+Mulch and Bed+Mulch. Similarly total N, S and B contents were relatively higher when straw mulch was applied either in flat or bed. A total of 12 t/ha straw mulch was applied in Flat+ Mulch and Bed+ Mulch treatments and during rice, those mulches were incorporated into the soil that could contribute to N, P and K contents in surface soil. Also helped in reducing soil pH from 8.2 (during initial) to 7.9 (during second rice harvest), which might have also contributed to higher P availability in soil. The causes of higher B contents in response to straw much treatment was unclear. Usually the mobility of B is very high in soil-water system; coverage of soil surface with crop straw mulch may act as a barrier of loses that might have resulted in higher value of B compared to respective non-mulch treatments.

4. Conclusions and recommendations

The response of component crops in the system for two years cycles plus changes in soil EC in time indicated that straw mulch application is effective in improving wheat and maize yield under saline conditions on silty-clay soils. Ash from the rice husking mill also have similar positive role in improving yield of all the component crops in wheat-maize-rice system. The best result was achieved when ash was used with mulch. Bed planting alone is ineffective in contributing higher yield or controlling soil salinity. Soil nutrient contents remained either unchanged or even improved (for some elements) under the intensive triple cereal system with recommended fertilizer and straw mulches and or ash application for two year. Ash is locally available from rice husking mill, the rural household also produce some ash during cooking. Very often this ash remains unproductive and dumped on road-side with other refuses causing environmental pollution. This ash material and crop residue could be used as mulch material to improve soil health thereby improving crop productivity under saline soil condition.

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PRODUCTIVITY AND PARTIAL BUDGET ANALYSIS IN WHEAT-RICE SEQUENCES AS INFLUENCED BY INTEGRATED PLANT NUTRITION SYSTEM AND LEGUME CROPS INCLUSION

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Abstract

The experiments were carried out at the Regional Wheat Research Centre, Rajshahi of Bangladesh Agricultural Research Institute (BARI) for two consecutive years, 2009-10 and 2010-11 to evaluate the agro-economic productivity of Wheat-Rice cropping sequence as influenced by integrated plant nutrition system (IPNS) and inclusion of legume crops. The experiment comprised of four cropping sequences viz. Wheat-Mungbean- T. *Aman* rice, Wheat-Blackgram- T. *Aman* rice, Wheat-Sesbania- T. *Aman* rice and Wheat-Fallow- T. *Aman* rice; and six nutrient treatments viz. 100% recommended nutrient rates, IPNS with 3 t ha^{-1} poultry manure (PM), IPNS with 6 t ha^{-1} PM, IPNS with 5 t ha^{-1} cowdung (CD), IPNS with 10 t ha^{-1} CD and farmers' practice (FP). It was carried out in a split-plot design assigning cropping sequences in the main plots and nutrient treatments in the sub-plots with three replications. For the IPNS, the 100% nutrient rates were adjusted with manure and fertilizers. Inclusion of mungbean in the Wheat-Rice cropping sequence showed higher production cost but it gave higher system productivity, gross return, gross margin, benefit-cost ratio and production efficiency. This cropping sequence gave on an average 57% higher wheat equivalent yield (WEY) compared to the existing Wheat-Rice sequence followed by blackgram included cropping sequence. The IPNS based fertilizer and manure application had better yield performance, WEY, gross margin, gross return, benefit-cost ratio, production efficiency and land use efficiency as compared to 100% chemical fertilizers or FP. It is concluded that the Wheat-Mungbean-Rice cropping sequence with IPNS approach is a productive and profitable technology for crop cultivation.

Keywords: Wheat-Rice sequence, crop productivity, production efficiency, land use efficiency and partial budget analysis.

Introduction

Wheat and rice are major cereals contributing to food security and income in South Asia. The rice-wheat systems occupy about 0.4 million ha in Bangladesh (Timsina *et al*., 2010). Rice and wheat contribute 97% of total food grain production (BBS, 2012) and 94% of the national calorie intake in Bangladesh (Timsina and Connor,

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2001). Bangladesh produced about 1.0 million ton of wheat with a productivity 2.6 t ha^{-1} and 12.80 million tons of Transplant *Aman* rice with a productivity of 2.3 t ha^{-1} in 2010-11 (BBS, 2012) but productivity is below the potential yield of 4-5 t ha^{-1} in wheat (BARI, 2011) and 5–6 t ha^{-1} in Transplant *Aman* rice (BRRI, 2010). The continuous use of chemical fertilizers without nutrient recycling has led to an immense loss of soil fertility and productivity (Nand Ram, 2000). It has also been established that cereal-cereal sequences are more exhaustive and put a heavy demand on soil resources as compared to cereal-legume sequences (Singh *et al*., 2011). Studies by Bhandari *et al.* (2002) attributed the reduced productivity of the rice-wheat system to declining soil organic matter, decreased soil fertility, occurrence of nutrient imbalances and inappropriate fertilizer practices.

Soil organic matter (SOM) is the key factor for sustainable soil fertility and crop productivity. Organic materials, such as crop residues, green manure (GM) and animal manure, and their continuous use have a strong influence on soil productivity (Timsina and Connor, 2001; Schmidt and Merbach, 2004; Yadvinder-Singh *et al*., 2008). The wheat-rice production system generates a large amount of crop residues annually. Traditionally, wheat and rice straw have removed from the fields for use as cattle feed and for several other purposes such as livestock bedding, thatching material for house and fuel (Samra *et al.*, 2003). Inclusion of legume crops as green manure or grain legume in the system has been found more beneficial than wheat-rice sequence (Singh *et al*., 2011). Legume crops fix atmospheric N, enrich soil fertility and could help to sustain the long-term productivity of cereal-based cropping systems. It has been well documented that the rice-wheat cropping system can be diversified using grain legume or *Sesbania* for green manure as a substitute crop (Bohra *et al*., 2007). Livestock manure provides N, P, K, S and many trace minerals as well as serving as a soil conditioner by increasing organic matter and improving soil porosity and water holding capacity (Eghball *et al.*, 2002). Application of cowdung is common in Bangladesh, but availability of cowdung has been declining because of animal power is being replaced by power-tiller (small mechanization) resulting in reduced livestock as well as cowdung and farmyard manure (FYM) production. In Bangladesh, poultry industry has remarkably grown which has facilitated a use of poultry manure (PM) because it contains a high concentration of nutrients, addition of even a small quantity, in an integrated manner or alone, could meet the shortage of cowdung or FYM to some extent.

Sustainable production of a crop can not be maintained by using the chemical fertilizer alone and similarly it is not possible to obtain high yield by using only organic manure (Bair, 1990). Kumar and Goh (2000) reported that no single manure management practice is superior under all conditions. The system productivity may become sustainable through integrated use of organic and inorganic sources of nutrients (Singh and Yadav, 1992). In this respect, Integrated

Plant Nutrition System (IPNS) can be a good approach to combat nutrient depletion and promote sustainable crop production. Therefore, the present study was undertaken to evaluate the diversification of Wheat-Rice cropping sequence in respect to IPNS based nutrient management on sustaining productivity, production efficiency, land use efficiency and cost and return analysis.

Materials and Method

A two-year wheat-rice cropping sequence experiment was established in high land with medium permeability at Regional Wheat Research Centre, Rajshahi of Bangladesh Agricultural Research Institute (latitude $28^{0}22^{/}$ N; longitude $88^{0}39^{/}$ E; 20 m elevation) during November, 2009 to October 2011. The experimental site belonged to the agro-ecological zone of High Ganges River Floodplain (AEZ-11). The soil was silty clay loam with alkaline in nature (8.4 pH) having very low organic matter (0.81%). The total N and available Zn were also very low while the available P, available S and exchangeable K status were medium. The available B content was low. The chemical characteristics of the initial soils are presented in Table 1a.

The treatments were composed of four cropping sequences viz. 1) W-M-R: Wheat (*Triticum aestivum* L.)-Mungbean (*Vigna radiata* L.)- Rice (*Oryza sativa* L.), 2) W-B-R: Wheat –Blackgram (*Phaseolus mungo* L.) - Rice, 3) W-S-R: Wheat – Sesbania *(Sesbania aculeata* L.*)* - Rice, and 4) W-F-R: Wheat -Fallow -Rice; and six nutrient treatments: 1) STB: 100% recommended fertilizer dose (soil test and high yield goal basis), 2) IPNS(PM_3): Integrated plant nutrition system (IPNS) with 3.0 t ha^{-1} poultry manure (PM), 3) IPNS(PM_6): IPNS with 6.0 t ha^{-1} PM, 4) IPNS(CD_5): IPNS with 5.0 t ha^{-1} cowdung (CD), 5) IPNS(CD_{10}): IPNS with 10.0 t ha^{-1} CD, and 6) FP: Farmers' Practice. The experiment was conducted in split-plot design where cropping sequence assigned in main plot and nutrient treatment in sub-plot. In the W-M-R and W-B-R sequences mungbean and black gram were used as grain legumes. After picking of pod the remaining plant parts were chopped and incorporated in the experimental plot *in-situ*. In W-S-R sequence, sesbania was ploughed down *in-situ* before flowering at 60 days after sowing at green stage as green manure. For STB treatment only chemical fertilizer was applied. The amount of mineralizable nutrients in PM and CD were deducted from STB based nutrient rates and adjusted accordingly as per different IPNS treatments (BARC, 2005). Thus the amount of N, P an K was virtually same for treatments STB, IPNS(PM_3), IPNS(PM_6), IPNS(CD_5) and IPNS(CD_{10}). In IPNS approach, 3 t ha^{-1} PM or 5 t ha^{-1} CD was economic for crop production (OFRD, 2009). The FP treatment was determined on the interactions with representative local farmers prior to start of the experiment. Crop cycle was started with wheat as the first crop in late November 2009. Cowdung and poultry manure were applied to the wheat crop only. Fertilizer doses of mungbean and blackgram were calculated and rationalized

Table 1a. Initial soil analytical results and fertility class of experimental site

pH	OM (%)	Total N (%)	Available P (µg g^{-1})	Exchangeable K (meq100 g^{-1})	Available S (µg g^{-1})	Available Zn (µg g^{-1})	Available B (µg g^{-1})
8.40	0.81	0.04	16.60	0.22	22.30	0.28	0.27
SA	VL	VL	M	M	M	VL	L

Where, OM- Organic Matter, SA- Slightly Alkaline, M-Medium, L- Low and VL- Very Low

Table 1b. Nutrient status of soil after completion of two years crop cycle for wheat-rice cropping sequences

Treatments	pH	OM (%)	Total N (%)	Available P (µg g^{-1})	Exchangeable K (meq100 g^{-1})	Available S (µg g^{-1})	Available Zn (µg g^{-1})
Wheat-Mungbean-Rice							
STB	8.30	0.81	0.041	20.00	0.16	14.20	0.29
IPNS (PM_3)	8.30	0.83	0.044	22.10	0.16	15.80	0.33
IPNS (PM_6)	8.30	0.93	0.048	27.50	0.18	17.10	0.39
IPNS (CD_5)	8.40	0.81	0.044	20.70	0.16	14.60	0.30
IPNS (CD_{10})	8.40	0.92	0.047	22.40	0.17	15.90	0.39
FP	8.30	0.75	0.038	16.10	0.15	23.70	0.26
Wheat-Blackgram-Rice							
STB	8.40	0.82	0.043	17.60	0.16	14.40	0.29
IPNS (PM_3)	8.30	0.93	0.046	21.30	0.17	15.60	0.41
IPNS (PM_6)	8.40	0.98	0.051	22.50	0.18	20.30	0.42
IPNS (CD_5)	8.30	0.83	0.044	19.10	0.16	15.40	0.38
IPNS (CD_{10})	8.30	0.96	0.049	22.30	0.18	18.80	0.42
FP	8.30	0.76	0.040	17.20	0.16	17.10	0.24

Table 1b. Cont'd.

Treatments	pH	OM (%)	Total N (%)	Available P ($\mu g\ g^{-1}$)	Exchangeable K (meq100 g^{-1})	Available S ($\mu g\ g^{-1}$)	Available Zn ($\mu g\ g^{-1}$)
			Wheat-Sesbania-Rice				
STB	8.40	0.84	0.045	18.20	0.16	12.20	0.30
IPNS (PM_3)	8.40	1.02	0.049	20.20	0.17	18.30	0.41
IPNS (PM_6)	8.40	1.11	0.055	23.40	0.18	24.00	0.42
IPNS (CD_5)	8.40	0.98	0.048	18.60	0.17	13.80	0.34
IPNS (CD_{10})	8.40	1.07	0.052	22.70	0.18	14.10	0.40
FP	8.40	0.78	0.041	17.20	0.16	20.30	0.20
			Wheat-Fallow-Rice				
STB	8.40	0.74	0.040	17.20	0.15	14.40	0.28
IPNS (PM_3)	8.40	0.82	0.042	21.20	0.17	15.00	0.38
IPNS (PM_6)	8.40	0.88	0.046	25.90	0.17	18.90	0.39
IPNS (CD_5)	8.40	0.79	0.039	19.50	0.17	14.50	0.32
IPNS (CD_{10})	8.40	0.86	0.041	24.00	0.17	15.80	0.34
FP	8.40	0.72	0.037	15.70	0.14	18.30	0.21

considering residual effect of nutrient (except N) applied to previous crop (wheat) (BARC, 2005). Sesbania was grown without any fertilizer. Fertilizer doses of rice were calculated and rationalized on the basis of total cropping pattern. For rice, the reduction of P and K from the calculated dose was due to the residual effect and N reduction due to addition of legume residues incorporation. The fertilizer dose for FP was not rationalized. Organic manures (PM and CD) were applied on a dry weight basis. Nutrient management treatments for different cropping sequences are presented in Table 2. After final land preparation all the plots and sub-plots were separated by earthen banks line with plastic polythene to a height of about 30 cm to avoid nutrient transfer between adjacent plots by lateral seepage.

The crop cultivars were grown on a permanent layout. Rice was transplanted into well-puddled soil, and all other crops were sown by hand. Wheat (cv. BARI Gom24), mungbean (cv. BARI Mung6), blackgram (cv. BARI Mash3), Sesbania *(*cv. local *Dhaincha)* and rice (cv. BRRI dhan49) were seeded/planted with 20-cm row spacing for wheat; plant spacings were 30 × 10 cm for mungbean/ blackgram, broadcasting for Sesbania @ 60 kg ha^{-1}, and 25 × 15 cm for rice. Wheat was sown in late November, mungbean/blackgram in early April, Sesbania in early May and rice was transplanted in early to mid July in each year. For rice, all fertilizers except N was broadcast and incorporated at the time of final land preparation. Nitrogen was broadcast in three equal splits at 15, 30 and 45 days after transplanting. For wheat, full dose of all fertilizers and two-thirds of N including organic manure were applied at sowing. The remaining N was top-dressed at crown-root initiation (CRI) stage. For the other crops, all fertilizers were applied at sowing. Crop residues from legume crops (mungbean, blackgram and sesbania) were chopped and incorporated into the soil 8-10 days prior to rice transplanting. At each year wheat received three irrigations of approximately 75 mm each at CRI, maximum tillering (MT), and grain filling (GF) stages. For rice, a total 792.2 mm of precipitation was occurred in first year 2009-2010. So more irrigation was applied each time (150 mm) by flood method but no irrigation was done during the growing period of rice except puddling period in 2010-2011. Before sowing of legume crops, light irrigation (about 50 mm) was given to the field for providing necessary soil moisture in both the years. Crop management, including weeding and pesticide was given to support the normal growth of crops.

Yield of main and by-product of each crop under various cropping sequences were measured in each plot (6 m^2) at physiological maturity. The economic part of individual crops was separated manually after harvesting. Grain yield for wheat and grain legume was adjusted at 12% moisture while for rice at 14% moisture from the harvested area.

Table 2. Nutrient management treatments for different wheat-rice cropping sequences

Treatments	Nutrient management treatments of different crops (kg ha^{-1})														
	Wheat							Legume			Rice				
	PM/CD (t ha^{-1})	N	P	K	S	Zn	B	N	P	K	N	P	K	S	Zn
						Wheat-Mungbean-Rice									
STB	0	142.0	18.0	47.0	5.0	3.0	1.0	21.0	13.0	17.0	97.0	4.0	17.0	6.0	2.0
IPNS (PM_3)	3 PM	108.0	1.5	26.0	5.0	3.0	1.0	21.0	13.0	17.0	97.0	4.0	17.0	6.0	2.0
IPNS (PM_6)	6 PM	74.0	0	5.0	5.0	3.0	1.0	21.0	13.0	17.0	97.0	4.0	17.0	6.0	2.0
IPNS (CD_5)	5 CD	120.0	10.5	22.0	5.0	3.0	1.0	21.0	13.0	17.0	97.0	4.0	17.0	6.0	2.0
IPNS (CD_{10})	10 CD	98.0	3.0	0	5.0	3.0	1.0	21.0	13.0	17.0	97.0	4.0	17.0	6.0	2.0
FP	0	88.0	15.0	22.0	17.0	0	0	0	0	0	76.0	20.0	26.0	10.0	0
						Wheat-Blackgram-Rice									
STB	0	142.0	18.0	47.0	5.0	3.0	1.0	21.0	6.0	8.0	91.0	4.0	17.0	6.0	2.0
IPNS (PM_3)	3 PM	108.0	1.5	26.0	5.0	3.0	1.0	21.0	6.0	8.0	91.0	4.0	17.0	6.0	2.0
IPNS (PM_6)	6 PM	74.0	0	5.0	5.0	3.0	1.0	21.0	6.0	8.0	91.0	4.0	17.0	6.0	2.0
IPNS (CD_5)	5 CD	120.0	10.5	22.0	5.0	3.0	1.0	21.0	6.0	8.0	91.0	4.0	17.0	6.0	2.0
IPNS (CD_{10})	10 CD	98.0	3.0	0	5.0	3.0	1.0	21.0	6.0	8.0	91.0	4.0	17.0	6.0	2.0
FP	0	88.0	15.0	22.0	17.0	0	0	0	0	0	76.0	20.0	26.0	10.0	0
						Wheat-Sesbania-Rice									
STB	0	142.0	18.0	47.0	5.0	3.0	1.0	0	0	0	89.0	4.0	17.0	6.0	2.0
IPNS (PM_3)	3 PM	108.0	1.5	26.0	5.0	3.0	1.0	0	0	0	89.0	4.0	17.0	6.0	2.0
IPNS (PM_6)	6 PM	74.0	0	5.0	5.0	3.0	1.0	0	0	0	89.0	4.0	17.0	6.0	2.0
IPNS (CD_5)	5 CD	120.0	10.5	22.0	5.0	3.0	1.0	0	0	0	89.0	4.0	17.0	6.0	2.0
IPNS (CD_{10})	10 CD	98.0	3.0	0	5.0	3.0	1.0	0	0	0	89.0	4.0	17.0	6.0	2.0
FP	0	88.0	15.0	22.0	17.0	0	0	0	0	0	76.0	20.0	26.0	10.0	0

Table 2. Cont'd.

Treatments	Nutrient management treatments of different crops (kg ha^{-1})														
	Wheat							Legume			Rice				
	PM/CD (t ha^{-1})	N	P	K	S	Zn	B	N	P	K	N	P	K	S	Zn
Wheat-Fallow-Rice															
STB	0	142.0	18.0	47.0	5.0	3.0	1.0	-	-	-	107.0	4.0	17.0	6.0	2.0
IPNS (PM_3)	3 PM	108.0	1.5	26.0	5.0	3.0	1.0	-	-	-	107.0	4.0	17.0	6.0	2.0
IPNS (PM_6)	6 PM	74.0	0	5.0	5.0	3.0	1.0	-	-	-	107.0	4.0	17.0	6.0	2.0
IPNS (CD_5)	5 CD	120.0	10.5	22.0	5.0	3.0	1.0	-	-	-	107.0	4.0	17.0	6.0	2.0
IPNS (CD_{10})	10 CD	98.0	3.0	0	5.0	3.0	1.0	-	-	-	107.0	4.0	17.0	6.0	2.0
FP	0	88.0	15.0	22.0	17.0	0	0	-	-	-	76.0	20.0	26.0	10.0	0

NB. Boron (B) and zinc (Zn) application is not a common practice among farmers

Table 3. Productivity of crops under different cropping sequences

Cropping sequences	Economic yield of wheat (t ha^{-1})		WEY* of grain legume (t ha^{-1})		Economic yield of rice (t ha^{-1})		WEY (t ha^{-1})	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
W-M-R	3.96	4.09	4.77 a	3.59 a	5.08 ab	5.26 ab	12.55 a	11.63 a
W-B-R	4.02	4.23	3.60 b	2.62 b	5.13 a	5.37 a	11.47 b	10.87 b
W-S-R	4.02	4.36	-	-	5.29 a	5.47 a	7.99 c	8.46 c
W-F-R	3.98	4.04	-	-	4.90 b	5.04 b	7.66 c	7.82 d
CV (%)	7.09	9.20	5.42	7.24	5.07	6.48	4.33	4.97

Means having same or without letter(s) did not differ significantly at 5% level of probability

The productivity of different cropping sequences was compared by calculating their economic wheat equivalent yield (WEY) using formula given by Ahlawat and Sharma (1993), where

$$\text{WEY} = \frac{\text{Yield of each crop (t ha}^{-1}\text{) x Economic value of respective crop (Tk t}^{-1}\text{)}}{\text{Price of wheat grain (Tk t}^{-1}\text{)}}$$

Land use efficiency (LUE) was estimated total duration of crops in the sequence by 365 days and expressed in % (Jamwal, 2001).

$$\text{LUE} = \frac{\sum \text{Dc}}{365} \times 100$$

Where, Dc= Duration of crops in the sequence.

Production efficiency (PE) was calculated by taking total economic yield of the sequence on wheat equivalent basis divided duration of crops (Jamwal, 2001).

$$\text{PE} = \frac{\text{WEY}}{\sum \text{Dc}}$$

Where,

WEY= Wheat equivalent yield in a sequence

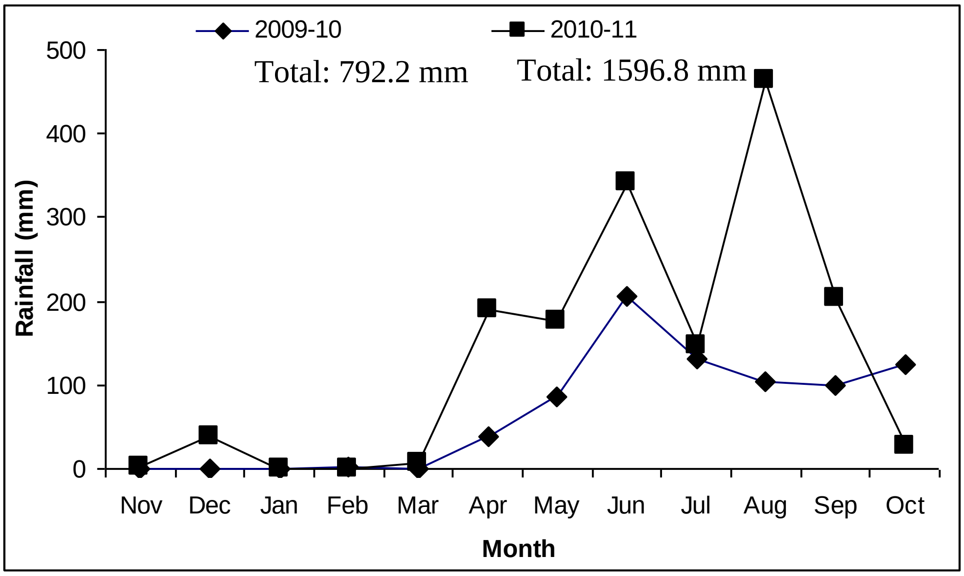
Dc= Duration of crops in that sequence.

The partial budget analysis was done for gross return, gross margin and benefit cost ratio following the method suggested by Perrin *et al.* (1979). Data on crop measured parameters of different crops for each year were subjected to statistical analysis through MSTAT-C software and the mean comparisons were made by DMRT at 5% level (Gomez and Gomez, 1984).

Results and Discussion

Monthly maximum and minimum air temperature and rainfall data are presented for each of the two years (2009-2011) in Fig. 1. There was a large difference in annual rainfall from where in 2009-2010, total rainfall was 792.2 mm but it was 1596.8 mm in 2010-2011. In both years, most rainfall occurred during April to October which ranged from 40 to 465 mm. Yearly variation of rainfall affected on crop productivity specially yield of grain legume. Maximum and minimum air temperatures also varied from year-to-year where in 2010-2011, a relatively cold period commenced in March and persisted, compared with 2009-2010, until September. This low temperature was due to cloudy and wet (monsoon) season in second year.

There was incidence of jute hairy caterpillar (*Spilosoma obliqua*), especially in blackgarm plots in the second year. Substantial rain, together with winds in that year caused lodging in some plots of rice. The heavy rainfall (1596 mm) in the second year might have resulted loss of nutrients but losses could not be studied.



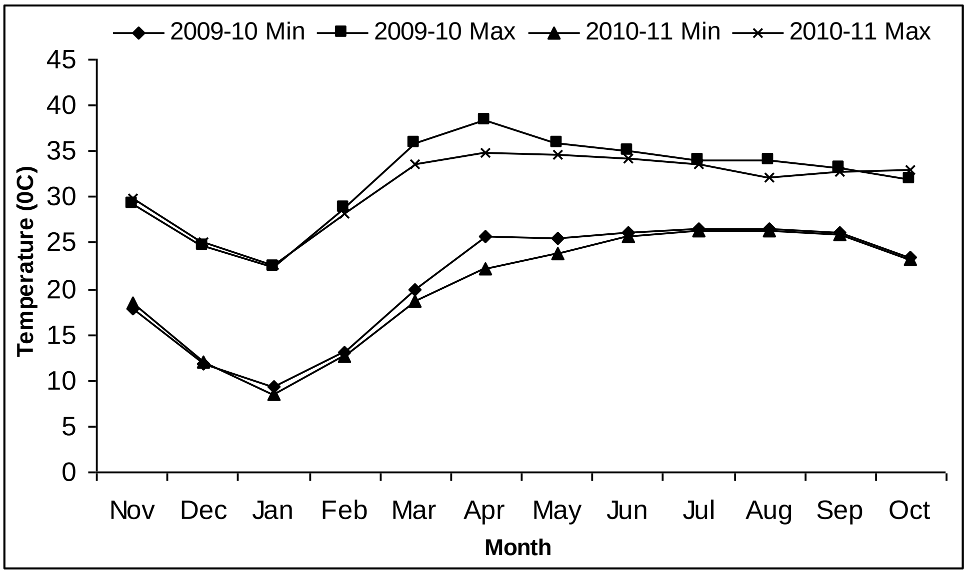


Fig. 1. Rainfall and temperature (maximum and minimum) of the study area during 2009-2010 and 2010-2011 seasons.

Soil fertility

After two years cycle, there was a very small decrease in soil pH in W-M-R and W-B-R cropping sequences compared to the initial value (Table 1b). This reduction in pH occurred possibly due to the production of organic acids from the decomposition of biomass of herbaceous legumes (mungbean and blackgram) (Chadha *et al*., 2009). Soil pH remained the same in W-S-R and W-F-R sequences. Generally, soil organic matter (SOM) in soil increased in crop sequences in which legumes had been included. This was more evident in the W-S-R sequence, in which sesbania was included. SOM in the W-F-R sequence decreased slightly, presumably due to the lack of legumes. SOM improved considerably in OM-amended plots over the initial value, the increase being more pronounced when a higher level of OM was applied. On the other hand, SOM decreased in STB and FP. The inclusion of legumes in W-S-R, W-B-R and W-M-R sequences improved soil N but declined slightly in W-F-R compared to the initial value, indicating that the use of a legume in these three crop sequences increased the total N content. Similar to SOM, the application of OM enhanced total N in manure-treated (CD, PM) plots more than STB or FP. However, the cumulative effect of OM and legume residue resulted in more positive gains in total N. Total N in FP soil decreased in the W-F-R and W-M-R sequences, but increased in W-S-R. Compared with the initial value, the available P content of soil increased in all sequences and was almost similar. All nutrient treatments except FP showed a significant increase in available P. The highest available P was recorded in IPNS (PM_6) plot. The W-F-R sequence, when using FP, showed a significant decreased in P. In contrast to P, exchangeable K was markedly depleted in all crop sequences, after two crop cycles, relative to initial soil. Among these, the largest depletion was noticed when FP was used in the W-F-R sequence. These results indicate that there was a higher uptake of K than the amount added, which may lead to a serious depletion of K in the long term. Similar to K, the available S decreased in all cropping sequences and nutrient treatments after two crop cycles with the greatest depletion taking place in the W-F-R sequence. Available Zn content showed an increasing trend after the two crop cycles in response to different cropping sequences and nutrient management. But it became depleted when FP was applied to all sequences.

Crop productivity

The effect of cropping sequence on the yields of grain legume, rice and system productivity showed significant (Table 3). Yields of both mungbean and blackgram were converted to wheat equivalent yield (WEY). Between the grain legumes mungbean gave higher WEY in comparison with blackgram in both years. The increase in WEY in mungbean over blackgram was 33 and 37% during 2009-10 and 2010-11, respectively. This variation is due to higher yield potentiality and grain price of mungbean than blackgram. However, grain yield of legume crop varied significantly from year to year where in second year, periods of heavy rainfall that severely reduced the grain yields of mungbean and blackgram. These results are in agreement with findings reported by Rahman (1991) and Quayyum *et al.* (2002). The highest grain yield of rice was observed in W-S-R (5.29 t ha^{-1}) followed by W-B-R (5.13 t ha^{-1}) and W-M-R (5.08 t ha^{-1}) and the lowest in W-F-R (4.90 t ha^{-1}) in 2009-10. Similar trend was observed for economic yield of rice in 2010-11. Grain yield increased in W-S-R, W-B-R and W-M-R by 8, 5 and 4%, respectively, over W-F-R in 2009-10. Contrary, grain yields increased in W-S-R, W-B-R and W-M-R by 9, 7 and 4%, respectively over W-F-R in 2010-2011. Overall preceded legume inclusion sequences produced higher grain yield while the lowest yield was obtained in the seasonal fallow sequence in both years. It was observed that the yield components (number of effective tillers $hill^{-1}$ (9 to 12) and grains $panicle^{-1}$ (124 to 132)) were improved due to legume residue recycling which ultimately increased grain yield compared to the seasonal fallow sequence (number of effective tillers $hill^{-1}$ (8 to 10) and grains $panicle^{-1}$ (115 to 117)). Nitrogen and other nutrients contributed through legume residue recycling might be the reason for increase of grain yield. Prasad *et al.* (1999) and Sharma and Prasad (1999) reported that yield benefits from legume crops ranging from 16 to 115% to the immediate rice crop. Legume residue could meet N needs of high yielding rice cultivars, and could show synergetic effects in increasing rice growth and yield (Yadvinder-Singh *et al.*, 2004). The W-M-R sequence recorded significantly the highest system WEY (12.55 t ha^{-1} in 2009-10 and 11.63 t ha^{-1} in 2010-11) than rest of the sequences during both years. Higher grain yield of mungbean after wheat was attributed for attaining highest system WEY by this sequence. The mungbean in wheat-mungbean-rice sequence markedly contributed to the system enhancing the productivity of succeeding crops and consequently resulted in significantly higher WEY than that of the wheat-rice system alone or with green manuring (Singh *et al.,* 2011). The W-S-R (7.99 t ha^{-1}) and W-F-R (7.66 t ha^{-1}) systems were found to be equally effective during 2009-10. During 2010-11, they differed significantly with the higher in W-S-R (8.46 t ha^{-1}). Sesbania, after harvesting of wheat, contributed to sequence besides benefiting the succeeding rice and consequently resulted in significantly higher WEY than W-F-R sequence. Sequence W-F-R (7.82 t ha^{-1}) gave the lowest WEY among the sequences in 2010-11. Total productivity increased by 64, 50 and 4% in 2009-10 and 49, 39 and 8% in 2010-11 in W-M-R, W-B-R and W-S-R, respectively over W-F-R.

The effect of nutrient treatment on economic yields of wheat showed significant in both years (Table 4). Wheat yield tended to be higher in the packages involving organic manure. In 2009-10, all the treatments had a yield in a range of 3.03 to 4.55 t ha^{-1}. Among all the different packages, IPNS (PM_6) produced maximum grain yield (4.55 t ha^{-1}) followed by IPNS (CD_{10}) (4.38 t ha^{-1}) but FP showed the lowest yield (3.03 t ha^{-1}). The IPNS treatments combine of PM_6, CD_{10}, PM_3, CD_5 and STB treatment gave 50, 45, 40, 30 and 26% higher economic yield, respectively over FP. In 2010-11, the treatments IPNS of PM_6, CD_{10} and PM_3

showed the maximum and similar yields which were 4.63, 4.40 and 4.38 t ha^{-1}, respectively. The other treatments showed similar trend as was also observed in 2009-10 (Table 4). In this year, the treatments IPNS of PM_6, CD_{10}, PM_3, CD_5 and STB yielded 36, 29, 28, 24 and 17%, respectively higher over FP. Higher grain yield of wheat in organic manure containing packages were mainly contributed by higher number of spikes $plant^{-1}$ (1.5 to 2.0), grains $spike^{-1}$ (40 to 45) and 1000-grain weight (53 to 55 g). Yield of wheat was higher with the IPNS treatments where integrated use of chemical fertilizer and organic manure might enhance growth and yield contributing characters due to slow and uninterrupted releasing of plant nutrient resulted to higher yield. Evidently, the recommended chemical fertilizer (STB) and farmers' dose (FP) was inadequate or unbalanced, as it lacked other essential nutrients including micronutrients (Behera, 2009). However, the better response to PM amended treatment than to cowdung (CD) may be ascribed to the higher nutrient content and lower C:N ratio (11) leading to increased nutrient availability in soil (Shepherd and Withers, 1999). Shepherd and Withers (1999) also reported that PM is quite rich in N content. Poultry manure contained nearly 40% of total N in a relatively easily available form and resulted to higher yield. The effect of nutrient treatment on WEY of grain legume also showed significant in both years (Table 4). In 2009-10, the maximum WEY of grain legume was obtained from nutrient treatment IPNS (PM_6) (4.60 t ha^{-1}) which was statistically identical to IPNS (CD_{10}) (4.45 t ha^{-1}) and IPNS (PM_3) (4.32 t ha^{-1}). The treatments STB (3.83 t ha^{-1}) and FP (3.75 t ha^{-1}) yielded statistically similar WEY and the WEY of both grain legumes (mungbean and blackgram) was also higher in organic amended nutrient treatments. Tagoe *et al.* (2008) also found higher seed yield of soybean and cowpea with carbonized chicken manure. The effect nutrient treatment on rice yield was significant in both years (Table 4). The economic yield of rice was found maximum in IPNS (PM_6) followed by IPNS (CD_{10}), IPNS (PM_3) and IPNS (CD_5). The STB treatment gave lower rice yield with the lowest in FP in both years. Grain yield increased by 12, 8, 7, 4 and 2% in IPNS (PM_6), IPNS (CD_{10}), IPNS (PM_3), IPNS (CD_5) and STB, respectively over FP in 2009-2010. The corresponding yields increased over FP in 2010-2011 were 14, 13, 12, 11 and 7%, respectively. Yield of rice was greater in IPNS with organic manures treatments due to positively responsive of number of effective tillers $hill^{-1}$ (9 to 12) and grains $panicle^{-1}$ (127 to 139). It showed that organics applied to preceding crop left significant quantity of nutrient for the succeeding crop. The residual effect of PM and CD on grain yield of rice during rainy season was almost comparable and significantly higher than inorganic indicating slow release of plant nutrient from manure. Hedge (1998) reported that organic source of nutrients applied to preceding crop can benefit the succeeding crop to a great extent. The results of the present study also showed that the rice responded more to PM than CD. This was because of the fact that approximately 74% of total P and 40% of

Table 4. Productivity of crops under various nutrient treatments

Nutrient Treatment	Economic yield of wheat (t ha^{-1})		WEY of grain legume (t ha^{-1})		Economic yield of rice (t ha^{-1})		WEY (t ha^{-1})	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
STB	3.83 c	4.00 c	3.82 c	2.97 c	4.95 cd	5.16 b	9.45 d	9.35 c
IPNS (PM_3)	4.24 b	4.38 ab	4.32 ab	3.25 abc	5.16 bc	5.39 ab	10.28 b	10.05 b
IPNS (PM_6)	4.55 a	4.63 a	4.60 a	3.47a	5.39 a	5.53 a	10.90 a	10.51 a
IPNS (CD_5)	3.95 c	4.24 bc	4.19 b	3.16 bc	5.04 bcd	5.35 ab	9.82 c	9.83 b
IPNS (CD_{10})	4.38 ab	4.40 ab	4.45 ab	3.32 ab	5.24 ab	5.45 ab	10.54 b	10.15 ab
FP	3.03 d	3.41 d	3.74 c	2.47 d	4.83 d	4.83 c	8.52 e	8.26 d
CV (%)	7.09	9.20	5.42	7.24	5.07	6.48	4.33	4.97

Means having same or without letter(s) did not differ significantly at 5% level of probability by DMRT.

Table 5. Land use efficiency (LUE) and production efficiency (PE) influenced by cropping sequence

Cropping sequences	LUE (%)		PE ($kg^{-1}ha^{-1}day^{-1}$)	
	2009-10	2010-11	2009-10	2010-11
W-M-R	86.09 b	86.75 b	39.96 a	36.71 a
W-B-R	88.99 a	90.27 a	35.30 b	33.03 b
W-S-R	83.04 c	85.03 b	26.36 d	27.24 c
W-F-R	64.66 d	66.07 c	32.43 c	32.42 b
CV (%)	1.63	2.17	4.97	5.84

Means having same or without letter(s) did not differ significantly at 5% level of probability by DMRT.

Table 6. Land use efficiency (LUE) and production efficiency (PE) influenced by nutrient treatment

Cropping sequences	LUE (%)		PE ($kg^{-1}ha^{-1}day^{-1}$)	
	2009-10	2010-11	2009-10	2010-11
STB	80.28 bc	81.58 ab	32.15 c	31.46 c
IPNS (PM_3)	80.67 abc	81.85 ab	34.79 b	33.60 ab
IPNS (PM_6)	81.71 a	83.01 a	36.37 a	34.65 a
IPNS (CD_5)	80.48 bc	81.85ab	33.27 c	32.92 bc
IPNS (CD_{10})	81.30 ab	83.01 a	35.34 ab	33.50 ab
FP	79.73 c	80.89 b	29.14 d	27.98 d
CV (%)	1.63	2.17	4.97	5.87

Means having same or without letter(s) did not differ significantly at 5% level of probability by DMRT.

* Wheat equivalent yield

W-M-R: Wheat - Mungbean-T. *Aman* rice
W-B-R: Wheat - Blackgram - T. *Aman* rice
W-S-R: Wheat - Sesbania - T. *Aman* rice
W-F-R: Wheat - Fallow - T. *Aman* rice

STB: 100% fertilizer dose (soil test basis)
IPNS(PM_3): Integrated plant nutrition system (IPNS) with 3.0 t ha^{-1} poultry manure (PM)
IPNS(PM_6): IPNS with 6.0 t ha^{-1} PM
IPNS(CD_5): IPNS with 5.0 t ha^{-1} cowdung (CD)
IPNS(CD_{10}): IPNS with 10.0 t ha^{-1} CD, FP: Farmers' Practice

Table 7. Cost and return analysis under different wheat-rice cropping sequences

Cropping sequences	Cost of cultivation ($Tk.\ ha^{-1}$)		Gross return ($Tk.\ ha^{-1}$)		Gross margin ($Tk.\ ha^{-1}$)		Benefit cost ratio (BCR)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
W-M-R	134159 a	129259 a	271371 a	253802 a	137212 a	124543 a	2.02 a	1.96 a
W-B-R	138075 a	133175 a	249622 b	239089 b	111546 b	105913 b	1.81 b	1.79 bc
W-S-R	114344 b	108944 b	180519 c	191343 c	66175 c	82399 c	1.58 d	1.76 c
W-F-R	99995 c	94595 c	172523 c	176568 d	72528 c	81973 c	1.72 c	1.87 b
CV (%)	2.58	2.66	3.92	4.54	8.84	9.90	3.97	4.55

Means having same or without letter(s) did not differ significantly at 5% level of probability by DMRT.

total N in PM were in available form (Shepherd and Withers, 1999). The system WEY by nutrient treatment varied significantly in both the years (Table 4). In 2009-10, the WEY in IPNS (PM_6) (10.90 t ha^{-1}) recorded the greatest among all other treatments. The WEY in IPNS (CD_{10}) and IPNS (PM_3) were 10.54 and 10.28 t ha^{-1} which were statistically similar. The WEY in IPNS (CD_5) and STB were 9.82 and 9.45 t ha^{-1} which were significantly different. The lowest WEY was obtained from FP (8.52 t ha^{-1}). During 2010-11, the trend of WEY was something different to previous year. In this year, nutrient treatments IPNS (PM_6) (10.51 t ha^{-1}) and IPNS (CD_{10}) (10.15 t ha^{-1}) gave higher and statistically similar WEY with the maximum in IPNS (PM_6). Again, the treatments IPNS (PM_3) (10.05 t ha^{-1}) and IPNS (CD_5) (9.83 t ha^{-1}) also showed similar WEY each other but lower than that of IPNS (CD_{10}). The WEY in STB (9.35 t ha^{-1}) and FP (8.26 t ha^{-1}) varied significantly and the lowest one was obtained from FP. System productivity was observed higher with conjunctive use of fertilizer and organic manure (PM and CD). The results in the present study are in agreement with the findings of other researchers who also attained maximum crop productivity by combined application of chemical fertilizers and manures (Yang *et al*., 2004; Rafique *et al*., 2012). As organic manure not only provides macro and micro nutrients (Kabeerathumma *et al*., 1993) but also improves soil physical properties (Bhattacharyya *et al*., 2004) and soil microbial activities (Tiwari *et al.,* 1998). However, PM produced higher WEY than that of CD. Evidently, the effect of organic amendments depends on how readily organic N is available. Poultry manure could increase grain yield significantly due to the ready availability of N. These results are in agreement with the findings of Behera (2009) who illustrated that yield of wheat was linearly increased with the total N inputs through PM being raised from 2.5 to 10 t ha^{-1}. These results suggest that productivity of wheat-rice cropping system cannot only be improved but sustained in the long-run with balanced fertilization and also through combine use of inorganic and nutrient-rich organic manures such as PM. Evidently, the current recommended STB and FP doses were not adequate for the wheat-rice sequence.

Land use efficiency (LUE) and production efficiency (PE)

The effect of cropping sequence on LUE and PE was significant in both years (Table 5). In general, sequences intensified by legume crops recorded higher LUE than the sequence without legume. The highest LUE (88.99% in 2009-10 and 90.27% in 2010-11) was recorded in W-B-R. The lowest LUE was recorded in W-F-R (64.66% in 2009-10 and 66.07% in 2010-11). Cropping sequence intensified with blackgram as a grain legume occupied the maximum duration of land resulted in greatest LUE of W-B-R sequence. The sequence having grain legumes generated higher PE value with W-M-R (39.96 kg^{-1} ha^{-1} day^{-1} in 2009-10 and 36.71 kg^{-1} ha^{-1} day^{-1} in 2010-11). The W-F-R was statistically different from all other treatments in 2009-10, but it remained at par with W-B-R in 2010-11. However, the sequence W-S-R (having green manuring crop) gave the lowest PE (26.36 kg^{-1} ha^{-1} day^{-1} in 2009-10 and 27.24 kg^{-1} ha^{-1} day^{-1} in 2010-11) among the cropping sequences. The maximum production efficiency was obtained in the wheat-mungbean-rice sequence. Mian (2008) observed the highest production efficiency in maize-mungbean-rice among the maize oriented cropping sequences.

The nutrient treatment had significant impact on LUE and PE in both the years 2009-10 and 2010-11 (Table 6). The treatments included by organic manure showed higher LUE than the treatments having chemical fertilizer only in both the years. However, the treatments having organic manures showed more or less similar LUE among themselves. The organic amended treatments ranking in terms of LUE were in the order of IPNS (PM_6) > IPNS (CD_{10}) > IPNS (PM_3) > IPNS (CD_5). The other two treatments STB and FP that did not include manure showed statistically identical LUE, where the FP had the lowest LUE in both the years. The nutrient treatments with organic manures recorded higher land use efficiency due to longer duration of component crop in the cropping sequence. During 2009-10, the nutrient management IPNS (PM_6) (36.37 kg^{-1} ha^{-1} day^{-1}) gave the maximum PE, which was statistically identical with that of IPNS (CD_{10}) (35.34 kg^{-1} ha^{-1} day^{-1}) due to higher WEY. The PE in IPNS (PM_3) was 34.79 kg^{-1} ha^{-1} day^{-1}, which was identical to IPNS (CD_{10}). The PE values in IPNS (CD_5) and STB were 33.27 and 32.15 kg^{-1} ha^{-1} day^{-1}, which were also statistically identical. The lowest PE was recorded in FP (29.14 kg^{-1} ha^{-1} day^{-1}). Almost similar trend was observed in 2010-11 as was found in 2009-10.

Partial budget analysis

Cropping sequence attributed a significant impact on cost of cultivation, gross return, gross margin and benefit cost ratio (BCR) in both the years (Table 7). Both the production costs and annual gross returns were considered for choosing suitable cropping sequence, because these varied widely in different cropping sequences. In general, inclusion of the third crop in the summer season either as grain legume or sesbania for green manuring, markedly enhanced the cost of production. Among the different sequences, W-B-R (Tk. 138075 ha^{-1} in 2009-10 and Tk. 133175 ha^{-1} in 2010-11) and W-M-R (Tk. 134159 ha^{-1} in 2009-10 and Tk. 129259 ha^{-1} in 2010-11) had higher cost of cultivation being the maximum in W-B-R due to extra pesticide and labour cost for blackgram cultivation. The other triple cropping sequence W-S-R (Tk. 114344 ha^{-1} in 2009-10 and Tk. 108944 ha^{-1} in 2010-11) recorded intermediate cost of cultivation, whereas the double cropping sequence W-F-R (Tk. 99995 ha^{-1} in 2009-10 and Tk. 94595 ha^{-1} in 2010-11) had the lowest annual cost of cultivation. Annual cost of cultivation increased with increasing cropping intensity, with the triple-cropping system incurring considerable higher costs than the double-cropping system primarily due to cost of fertilizer, labour and plant protection (Biswas *et al*., 2006; Singh *et al*., 2011).

However, cost of cultivation was higher in first year due to higher irrigation cost of rice because of minimum rainfall during the cropping season. The W-M-R had a maximum gross return (Tk. 271371 ha^{-1} in 2009-10 and Tk. 253802 ha^{-1} in 2010-11), which also recorded highest gross margin (Tk. 137212 ha^{-1} in 2009-10 and Tk. 124543 ha^{-1} in 2010-11) and BCR (2.02 in 2009-10 and 1.96 in 2010-11) than all other cropping sequences. This was mainly due to the production potential accompanied with good monetary returns of mungbean (Singh *et al*., 1993). Gross margin under sesbania included sequence W-S-R and double cropping sequence W-F-R were statistically identical and lower in both the cropping years. Gross margin under W-S-R and W-F-R sequences were Tk. 66175 and 72528 ha^{-1} in 2009-10 and Tk. 82399 and 81973 ha^{-1} in 2010-11, respectively. Inclusion of sesbania in the sequence W-S-R could not improve the BCR (1.58 in 2009-10 and 1.76 in 2010-11) as a result lower BCR than the W-F-R (1.72 in 2009-10 and 1.87 in 2010-11) sequence. The lowest gross margin and BCR in wheat-sesbania-rice sequence was mainly due to comparatively higher production cost.

The nutrient treatment showed significant effect on different economic parameters in both the years (Table 8). Cost of cultivation in organic manure amended different treatments and soil test based chemical fertilizer were statistically identical, but they were significantly higher than that of farmers' practice in both the years. However, the IPNS treatments with cowdung had numerically higher cost of cultivation due to higher amount of manure. Nonetheless, among the fertilizer treatments ranking in terms of cost of cultivation were in the order of IPNS (CD_{10}) > STB > IPNS (CD_5) > IPNS (PM_6) > IPNS (PM_3) and their corresponding values were Tk. 122668, 122637, 122608, 122446 and 121717 ha^{-1}, respectively in 2009-10. Similarly, the corresponding values of the treatments in 2010-11 were Tk. 117518, 117487, 117458, 117296 and 116567 ha^{-1}, respectively. The highest gross return (Tk. 239287 and 233155 ha^{-1} in 2009-10 and 2010-11, respectively) was recorded in IPNS (PM_6) and the lowest (Tk. 188700 and 184340 ha^{-1} in 2009-10 and 2010-11, respectively) was in FP. Similar trends were also observed in case of gross margin and BCR in both the years. The fertilizer management treatment IPNS (PM_6) showed the highest gross margin (Tk. 116840 and 115858 ha^{-1} in 2009-10 and 2010-11, respectively) and BCR (Tk. 1.94 and 1.99 ha^{-1} in 2009-10 and 2010-11, respectively) among all other treatments. The other manure amended treatments gave the better economic performance compared to STB or FP. Cost of cultivation was the lowest in farmers' fertilizer treatment because of lower fertilizer inputs. Gross return, gross margin and BCR were the highest in IPNS with 6 t ha^{-1} PM. This was primarily due to higher crop productivity under 6 t ha^{-1} PM amended nutrient treatment. However, other organic manure amended treatment also gave the better gross return, gross margin and BCR because of better performance of the component crop in the sequences. The farmers, fertilizer practice showed the lowest performance in respect of aforesaid economic parameters caused by poorest crop productivity.

Table 8. Cost and return analysis influenced by various nutrient treatments

Nutrient Treatments	Cost of cultivation (Tk. ha^{-1})		Gross return (Tk. ha^{-1})		Gross margin (Tk. ha^{-1})		Benefit cost ratio (BCR)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
STB	122637 a	117487 a	208795 d	207506 c	86157 d	90018 c	1.69 d	1.77 c
IPNS (PM_3)	121717 a	116567 a	225980 b	222694 b	104262 b	106127 b	1.84 b	1.91 b
IPNS (PM_6)	122446 a	117296 a	239287 a	233155 a	116840 a	115858 a	1.94 a	1.99 a
IPNS (CD_5)	122608 a	117458 a	216509 c	218278 b	93901 c	100820 b	1.75 c	1.86 b
IPNS (CD_{10})	122668 a	117518 a	231783 b	225229 ab	109114 b	107711 b	1.88 b	1.92 b
FP	117783 b	112633 b	188700 e	184340 d	70916 e	71706 d	1.59 e	1.64 d
CV (%)	2.58	2.66	3.92	4.54	8.84	9.90	3.97	4.55

Means having same or without letter(s) did not differ significantly at 5% level of probability

W-M-R: Wheat - Mungbean-T. *Aman* rice
W-B-R: Wheat - Blackgram - T. *Aman* rice
W-S-R: Wheat - Sesbania - T. *Aman* rice
W-F-R: Wheat - Fallow - T. *Aman* rice

STB: 100% fertilizer dose (soil test basis)
IPNS(PM_3): Integrated plant nutrition system (IPNS) with 3.0 t ha^{-1} poultry manure (PM)
IPNS(PM_6): IPNS with 6.0 t ha^{-1} PM
IPNS(CD_5): IPNS with 5.0 t ha^{-1} cowdung (CD)
IPNS(CD_{10}): IPNS with 10.0 t ha^{-1} CD, FP: Farmers' Practice

Input: Urea: 20 Tk kg^{-1}, TSP: 22 Tk kg^{-1}, MoP: 25 Tk kg^{-1}, gypsum: 6 Tk kg^{-1}, zinc sulphate: 90 Tk kg^{-1}, boric acid: 120 Tk kg^{-1}, furadan: 125 Tk kg^{-1}, wheat seed : 35 Tk kg^{-1}, mungbean seed: 100 Tk kg^{-1}, blackgram seed: 100 Tk kg^{-1}, *Dhaincha* seed: 60 Tk kg^{-1}, rice seed: 35 Tk kg^{-1}, Cowdung: 500 Tk ton^{-1}, poultry manure: 1000 Tk ton^{-1}, powertiller (1 pass):1500 Tk ha^{-1}, irrigation (1 time): 900 Tk ha^{-1} and Labour: 200 Tk day^{-1}(8 hours)

Output: Wheat grain: 20 Tk kg^{-1}, rice grain: 15 Tk kg^{-1}, mungbean seed: 60 Tk kg^{-1}, blackgram seed: 50 Tk kg^{-1}, wheat straw: 1 Tk kg^{-1}, rice straw: 2 Tk kg^{-1}

The interaction effect of the cropping sequence and nutrient treatment did not show significant effect on crop productivity, LUE, PE and economic parameters in both the years.

Conclusion

Inclusion of grain legume in wheat-rice sequence resulted in higher cost, but produced greater annual productivity, gross return, gross margin and benefit cost ratio. Residue recycling of legume crops could partially replace N fertilizer for rice and had a considerable positive effect, although not significant, on the following wheat crop. Organic manure (particularly PM) played a significant role in increasing the productivity of wheat as well as other component crops in the cropping sequences. So, Wheat-Mungbean-Transplant *Aman* rice under IPNS with organic manures (CD or PM) can be practiced at farmers' level for greater productivity and profitability and improvement of soil health. Nutrient management packages involving higher rate of organic manure ($N_{74}P_0K_5S_5Zn_3B_1$ kg ha^{-1} + PM 6 t ha^{-1} or $N_{98}P_3K_0S_5Zn_3B_1$ kg ha^{-1} + CD 10 t ha^{-1} for wheat; $N_{21}P_{13}K_{17}$ kg ha^{-1} for mungbean and $N_{97}P_4K_{17}S_6Zn_2$ kg ha^{-1} for T. *Aman* rice) can be the suitable practice. Poultry manure was found more effective than cowdung.

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BIOLOGY AND MANAGEMENT OF FRUIT BORER, *Virachola isocrates* (Fab.) INFESTING GUAVA

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Abstract

Two experiments were conducted to study the biology of guava fruit borer, *Virachola isocrates* (Fab.) and to evaluate the effectiveness of management practices for managing fruit borer, *Virachola isocrates* (Fab.) in Sharupkathi variety of guava. The biology including morphometrics of guava fruit borer were studied in the laboratory of the Department of Entomology, PSTU, Dumki, Patuakhali during May to October, 2012. Results revealed that incubation period, larval period, pupal period of this borer ranged from 8-10, 17-46, 7-33 days, respectively and total life cycle was completed within 30 to 60 days. Adult longevity ranged from 4-7 days. The average length of full grown larva was 17.45 mm, and breadth across thorax and abdomen were 3.36 and 2.80 mm, respectively. The average length of pupa was 15.90 mm, and breadth across thorax and abdomen were 3.68 and 2.89 mm, respectively. The average length of adult body was 16.90 mm, and breadth across thorax and abdomen were 3.91 and 2.94 mm, respectively. The average length of antennae was 10.35 mm. The mean length of pro-, meso and metathoracic legs was 7.55mm, 8.10mm and 10.45 mm, respectively. The metathoracic leg was longer as compared to pro and mesothorarcic legs. The length of fore wing across the upper and lower margin ranged from 16.00 mm to 18.00 mm and 11.50 mm to 12.00 mm, respectively. The length of hind wing across the upper and lower margin ranged from 10.00 mm to 11.00 mm and 8.00 mm to 9.00 mm, respectively. The breadth of fore wing across the middle ranged from 10.50-11.00 with mean breadth of 10.78 mm. Likewise, the breadth of hind wing across the middle ranged from 11.00-14.00 with mean breadth of 12.55 mm. The results on the percent infestation reduction over control revealed that package with field sanitation + collection of infested fruits + application of Superior (Chlorpyrifos + Cypermethrin) 505 EC @ 1 ml/ l water, and package consisting of field sanitation + collection of infested fruits + bagging of fruits with polythene bag gave 100 % control of the pest. These two packages may be used for the large scale cultivation of 'Sharupkathi' variety in Bangladesh.

Keywords: Biology, fruit borer, *virachola isocrates* (Fab.), guava, management.

Introduction

Guava (*Psidium guajava* L.) is one of the most popular and widely cultivated important fruit crops in Bangladesh. It is cultivated in 16,862 ha of land with an annual production of 80,525 metric tons in Bangladesh (Anon., 2004). It is very rich in vitamin C. Some varieties of guava such as 'Kazipiara', Kanchannagar, 'Mukundapuri' and 'Swarupkathi' grow everywhere in the country in the

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homestead gardens but commercially cultivated in Barisal, Sylhet, Gazipur and Chittagong regions. Alam *et al*. (1964) listed five different species of insect pests attacking guava in Bangladesh, but there was no report of *Virachola isocrates* (Fab.) as a pest of guava. Guava plants are attacked by a number of insect pests viz., fruit flies, bark eating caterpillars, whiteflies, semilooper, fruit borers, stem borers etc (Butani, 1979). Among them fruit borer, *V. isocrates* has been found to be a major limiting factor hindering safe cultivation of guava in Barisal region in recent years. This pest is also known as pomegranate butterfly and is, in fact, a polyphagous pest attacking a wide range of host plants, including guava, pomegranate, anola, apple, ber, citrus, litchi, peach, pear, sapota and tamarind (Atwal, 1976).

This borer damages the pomegranate by boring inside the developing fruit and feeding on pulp and seeds (Atwal, 1976; Butani, 1979). The infested fruits are also attacked by bacteria and fungi which cause the fruits to rot. The affected fruits ultimately fall off and give an offensive smell (Atwal, 1976). The extent of damage in fruit was 40-70 % and 50-90 % in India as reported by Bose (1985) and Ramkrishna Ayyar (1984), respectively. The infestation by fruit borer began at the marble stage of guava and the peak infestation was recorded in mid August to September in varieties ‘Kazipiara’, ‘Kanchannagar’, ‘Mukundapuri’ and ‘Swarupkathi’ (Biswas *et al*., 1995). Bagging of fruits was very effective means for controlling fruit borer infestation (Atwal, 1976; Nayar and Ananthakrishnan, 1976; Ramkrishna Ayyar, 1984; Biswas *et al*., 1996). Shukla and Prasad (1983) reported that the most effective treatments were bagging fruits with polythene or muslin bag. Maniruzzaman (1981) suggested control of this pest by spraying Diazinon or Malathion when the fruits were young. Kakar *et al.* (1987) suggested the use of Cypermethrin (@ 150 g a i/ha) and Deltamethrin (@ 7.5 g a i/ha) for effective and profitable control of fruit borer. Khan (2010) reported that bagging fruits with transparent perforated polythene bag and the similar bag impregnated with Decis 2.5 EC @ 1 ml/l of water were found effective against guava fruit borer infesting ‘Kazipiara’ variety in small scale cultivation. He also suggested that three sprays of Decis @ 0.25 ml/l of water at 7 days interval could be good treatment in controlling this pest in large scale cultivation. Biswas *et al.* (1996) reported that the infestation of fruit borer was reduced 39.06 % to 48.53 % over control by the application of Ripcord, Diazinon and Malathion. In Bangladesh, there are no suggested and recommended control measures for the management of this fruit borer. Therefore, the present research work was undertaken to study the detailed biology of fruit borer and to evaluate the effectiveness of different IPM packages for controlling fruit borer in guava.

Materials and Method

Biology of fruit borer infesting guava

The study on the biology of fruit borer was conducted in the laboratory of the Department of Entomology, Patuakhali Science and Technology University, Dumki, Patuakhali from April to August, 2012. Infested fruits of guava were collected from farmers' orchard and PSTU campus. The collected specimens were suitably processed and labeled for further studies. The collected fruits were kept in plastic pot for insect rearing. Ten plastic pots and each pot containing five fruits were maintained. To study the larval and pupal development, observation was made on larval instars and pupation. The infested guava of different aged were cut and opened to observe larval instars and pupal stages of this borer. The duration of larval, pupal and adult stages were recorded at each date of observation. The length and breadth of different stages of this borer was also measured and recorded. The mean temperature and relative humidity during the period of study were also recorded.

Effectiveness of different IPM packages in suppressing fruit borer

Field trial was carried out to evaluate the effectiveness of different IPM packages against fruit borer at PSTU campus and farmer's orchard during May to October, 2012. Swarupkathi variety of guava was used for the study. IPM packages were: P_1 = field sanitation + collection of infested fruits + application of Chita (Chlorpyrifos) 48 EC @ 1 ml/l water, P_2 = field sanitation + collection of infested fruits + application of Fighter (Cypermethrin) 10 EC @ 1 ml/ l water, P_3 = field sanitation + collection of infested fruits + application of Superior (Chlorpyrifos + Cypermethrin) 505 EC @ 1 ml/ l water, P_4 = field sanitation + collection of infested fruits + bagging of fruits with polythene bag and an untreated control. The experiment was laid out in RCBD with 4 replications. A total of 20 branches were randomly selected for the study. The spraying was done as a full cover (covering leaves, fruits, branches and the trunk of a tree) at the time of application.

Data collection

Fruits of all treatments were harvested, bagged and labeled carefully for each plant and transported to the laboratory where the fruits were checked thoroughly for detecting the sign of the fruit borer infestation. The visible damage symptom in an infested fruit was the presence of excreta of the larva which coming out of the entry hole. Even single entry hole on the fruit was considered as an infested fruit. Data on the number of fruit examined, the number and weight of healthy and infested fruits were recorded for each treatment and for each plant. The percent of fruit infestation (by number and weight) in each treatment was calculated from the number and weight of the infested fruits. The percent infestation reduction over untreated control was also calculated.

The statistical analysis was performed by using MSTAT-C program. The analysis of variance (ANOVA) of the results on various insect pests was done after square root transformation. Test of significance was performed by F-test. Means were separated by Least Significant Difference (LSD) test.

Results and Discussion

Biology of guava fruit borer

Appearance

Adult male butterfly is violet-blue and the female is violet brown, female with V shaped patch on forewing. Hind wing bears spots (Fig. 1-3). Larvae of different instars were dark brown (Fig. 4-6). The full-grown larvae are dark brown with short hair and white patches all over the body (Fig. 7).

Developmental period and adult longevity of guava fruit borer

Eggs are laid singly on tender leaves, stalks and flower buds. Incubation period lasts for 8-10 days with average period of 8.8 days. Larval period lasts for 17-46 days with mean duration of 31.4 days. Pupation occurs either inside the damaged fruits or on the stalk holding it (Fig. 8). Pupal period lasts for 7-33 days with mean duration of 16 days. Total life cycle is completed within 30 to 60 days with average duration of 46.5 days. Adult longevity ranged from 4-7 days with average 5.7 days (Table 1). No published research report regarding this is available to compare the findings of the present study.

Fig. 1. Adult emergence from pupa

Fig. 2. Adult butterfly (dorsal view)

Fig. 3. Adult butterfly (ventral view)

Fig. 4. First instar larva

Fig. 5. Second instar larva

Fig. 6. Third instar larva

Fig. 7. Fourth instar larva

Fig. 8. Pupa (enlarged form)

Table 1. Developmental period and adult longevity of guava fruit borer, *Virachola isocrates* (Fab.) grown on Sharupkathi variety

Developmental stages	Duration (Days)	
	Range	Mean ± SE
Incubation period	8-10	8.80 ± 0.24
Larval period	17-46	31.40 ± 3.09
Pupal period	7-33	16.00 ± 2.71
Total life cycle	30-60	46.50 ± 2.91
Adult longevity	4-7	5.70 ± 0.35

Values are averages of 10 observations. SE= Standard Error.

Nature of damage

The larvae bored into the guava fruits soon after hatching. Once inside the fruit, larvae (approx 2cm length) feed on the flesh and seeds. The bored hole was plugged by the last abdominal segment of the larva (Plate 9 A-C). When fully grown, the larva came out of boring through the hard shell and spined a web, which tied the fruit or stalked of the main branch.

A B C

Fig. 9 (A-C). Damaged and bored guava fruit with larvae and excreta.

Damage symptoms

Offensive smell emitted and excreta of caterpillars came toward the entry holes and it stucks around the holes. The infested fruits rotted and dropped off. The holes ultimately exposed and act predisposing factor to diseases, and typically rotten on the tree (Fig. 10-12).

Fig. 10. Infested fruits of different size

Fig. 11. Small size infested and rotten fruits

Fig. 12. Guava tree bearing bored and rot fruits

Table 2. Morphometrics of life stages and appendages of guava fruit borer, *Virachola isocrates*

Life stages and appendages	Range (mm)	Mean ± SE (mm)
Full grown larva		
Length	16.00-20.00	17.45 ± 0.39
Breadth		
-Across thorax	3.00-3.80	3.36 ± 0.08
-Across abdomen	2.70-2.90	2.80 ± 0.02
Pupa		
Length	15.00-17.00	15.90 ± 0.23
Breadth		
-Across thorax	3.50-4.00	3.68 ± 0.06
-Across abdomen	2.80-3.00	2.89 ± 0.03
Adult		
Body		
Length	16.50-17.50	16.90 ± 0.12
Breadth		
-Across thorax	3.80-4.00	3.91 ± 0.03
-Across abdomen	2.80-3.00	2.94 ± 0.03
Antenna		
Length	9.00-11.00	10.35 ± 0.21
Leg length		
Prothoracic	7.00-8.00	7.55 ± 0.13
Mesothoracic	7.50-9.00	8.10 ± 0.17
Metathoracic	9.50-11.50	10.45 ± 0.21
Wing length		
Fore wing		
- Across upper margin	16.00-18.00	17.05 ± 0.22
- Across lower margin	11.50-12.00	11.85 ± 0.07
Hind wing		
- Across upper margin	10.00-11.00	10.55 ± 0.13
- Across lower margin	8.00-9.00	8.58 ± 0.11
Wing Breadth		
Fore wing -Across middle	10.50-11.00	10.78 ± 0.06
Hind wing-Across middle	11.00-14.00	12.55 ± 0.34

Values are averages of 10 observations. SE= Standard Error.

Morphometrics of larva, pupa, adult and appendages

The results on the morphometrical aspect of guava fruit borer, *Virachola isocrates* are presented in Table 2 and Fig. 13-16. The full-grown larvae were dark brown with short hair and white patches all over the body. The length of full grown larva ranged from 16.00 mm to 20.00 mm. The average length of full grown larva was 17.45 mm and breadth across thorax and abdomen were 3.36 and 2.80 mm, respectively (Table 2). The larva pupates either inside the damaged fruits or on the stalk holding it. The average length of pupa was 15.90 mm and breadth across thorax and abdomen were 3.68 and 2.89 mm, respectively (Table 2). Adult *Virachola isocrates* was bluish brown and the average length of body was 16.90 mm, and breadth across thorax and abdomen were 3.91 and 2.94 mm, respectively. Antennae were very long and the average length of antennae was 10.35 mm (Table 2). The mean length of pro, meso and metathoracic legs was 7.55mm, 8.10mm and 10.45 mm, respectively. The metathoracic leg was longer as compared to pro and mesothorarcic legs. The length of fore wing across the upper and lower margin ranged from 16.00 mm to 18.00 mm and 11.50 mm to 12.00 mm, respectively with average length 17.05 mm and 11.85 mm, respectively. Similarly, the length of hind wing across the upper and lower margin ranged from 10.00 mm to 11.00 mm and 8.00 mm to 9.00 mm, respectively with average length 10.55 mm and 8.58 mm, respectively. The breadth of fore wing across the middle ranged from 10.50-11.00 with mean breadth of 10.78 mm. Likewise, the breadth of fore wing across the middle ranged from 11.00-14.00 with mean breadth of 12.55 mm (Table 2). No published research report regarding this is available to compare the findings of the present study.

Fig. 13. Antenna

Fig. 14. Leg

Fig. 15. Fore wing

Fig. 16. Hind wing

Management of guava fruit borer

The effectiveness of different IPM packages on the infestation of guava fruit borer is presented in Table 3. The number of infested fruits ranged from 4.13 (P_1) to 9.69 (Untreated control). The infestation was not observed in the packages P_3 and P_4. Significantly the highest number (9.69) of infested fruits was observed in untreated control and lowest (4.13) in P_1 which was statistically similar to that of P_2. The weight of infested fruits varied from 102.76 g (P_1) to 203.24 g for (Untreated control). Statistically significant difference was observed among different packages with respect to the percentage of fruit infestation (by number and weight) due to the damage caused by the guava fruit borer. The highest percentage of infested fruits (by number) was in untreated control (24.22%). Likewise, the same trend was also found on the percentage of infested fruits by weight. Percentage of infestation was nil in the treatments P_3 and P_4 and the highest percentage of infestation (by weight) was also observed in the untreated control (41.03%).

Table 3. Effectiveness of different IPM packages on the infestation of fruit borer, *Virachola isocrates* (Fab.) in guava

Treatment	Total no. of fruits studied	No. of infested fruits	Weight of healthy fruits (g)	Weight of infested fruits (g)	% infested fruits (by number)	% infested fruits (by weight)	% infestation reduction over control (by number)
P_1	40	4.13b	486.00	102.76b	10.33b (3.29)	21.14b (4.65)	48.48
P_2	40	5.11b	486.12	107.00b	12.78b (3.64)	22.01b (4.74)	46.36
P_3	40	0.00c	412.76	0.00c	0.00c (0.71)	0.00c (0.71)	100.00
P_4	40	0.00c	413.04	0.00c	0.00c (0.71)	0.00c (0.71)	100.00
Untreated control	40	9.69a	495.28	203.24a	24.22a (4.97)	41.03a (6.44)	-
F-value		7.46		8.43	16.39	13.75	
CV (%)		8.53		9.54	11.23	10.39	
LSD (0.01)		1.36		0.75	0.80	0.45	

Figures within parentheses are the transformed values based on square root ($\sqrt{x}+0.5$) transformation.

Values are averages of 4 replications.

IPM packages were: P_1 = field sanitation + collection of infested fruits + application of Chita (Chlorpyrifos) 48 EC @ 1 ml/l water, P_2 = field sanitation + collection of infested fruits + application of Fighter (Cypermethrin) 10 EC @ 1 ml/ l water, P_3 = field sanitation + collection of infested fruits application of Superior (Chlorpyrifos + Cypermethrin) 505 EC @ 1 ml/ l water, P_4 = field sanitation + collection of infested fruits + bagging of fruits with polythene bag and an untreated control.

The results on the per cent infestation reduction over control revealed that field sanitation + collection of infested fruits + application of Superior (Chlorpyrifos + Cypermethrin) 505 EC @ 1 ml/ l water (P_3), and field sanitation + collection of infested fruits + bagging of fruits with polythene bag (P_4) gave 100 % control of the pest followed by field sanitation + collection of infested fruits + application of Chita (Chlorpyrifos) 48 EC @ 1 ml/l water (P_1) and field sanitation + collection of infested fruits + application of Fighter (Cypermethrin) 10 EC @ 1 ml/ l water (P_2) resulting in 48.48 % and 46.36 % reduction, respectively of infestation over control (Table 3). These findings were in agreement with the observations of Biswas *et al*. (1996) who found that the infestation of fruit borer was reduced 39.06% to 48.53% over control by the application of Ripcord, Diazinon and Malathion, and Khan (2010) found that three spraying of Decis @ 0.25 ml/l of water was effective against fruit borer of ‘Kazipiara’ variety of guava in large scale cultivation in Bangladesh. Atwal (1976) and Nayar and Ananthakrishnan (1976) reported that bagging an effective means of controlling fruit borer infestation. Shukla and Prasad (1983) reported that the most effective treatments were bagging fruits with polyethene or muslin. Similar observations were made by Ramkrishna Ayyar (1984).

The study had provided information on biology of guava fruit borer and effectiveness of IPM packages for their suppression. From the above mentioned results it may be concluded that field sanitation + collection of infested fruits + bagging of fruits with polythene bag could be an effective and profitable IPM package for the production of Sharupkathi variety of guava in small scale cultivation. But the IPM package consisting of field sanitation + collection of infested fruits + application of Superior (Chlorpyrifos + Cypermethrin) 505 EC @ 1 ml/ l water may be practiced for large scale cultivation of Sharupkathi guava variety in Bangladesh.

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PRODUCTIVITY OF GARLIC UNDER DIFFERENT TILLAGE METHODS AND MULCHES IN ORGANIC CONDITION

M. A. KABIR[1], M. A. RAHIM[2] AND D. A. N. MAJUMDER[3]

Abstract

An experiment was conducted at the field of USDA-Alliums project, Bangladesh Agricultural University, Mymensingh to study the effect of tillage and mulches on the growth and yield of garlic. The experiment consisted of three tillage conditions (conventional, puddling and zero tillage) and four mulches (control, rice straw, water hyacinth and *Curcuma amada* leaf). The results revealed that different mulches had remarkable contributions on the growth and yield of garlic. The highest values of growth parameters as well as bulb yield were obtained from rice straw mulch identical with that of water hyacinth mulch. Different tillage also had significant influence on yield and yield contributing traits of garlic. Garlic cultivated under zero tillage showed remarkable variation in terms of percent emergence. Puddling and zero tillage practices resulted in higher yield compared to the conventional tillage. It was also noticed that both the tillage conditions as well as mulches showed profound effects on the yield and yield contributing parameters. Moreover, the highest net return (196647Tk. /ha) and the highest BCR of 2.90 was obtained from zero tillage with rice straw.

Keywords: Tillage, mulches, growth, productivity, garlic.

Introduction

Garlic (*Allium sativum* L) is an aromatic herbaceous plant and the second most widely used *Allium* after onion (Bose and Som, 1990). This crop is extensively cultivated in many countries of the world including Bangladesh as a popular spice crop. Garlic is a rich source of carbohydrate and phosphorus (Rahman *et al*., 2007). The average yield of garlic in this country is only 5.21 t/ha (BBS, 2012). The poor yield of garlic may be due to the lack of inadequate soil and water management practices with reference to soil water shortage in the soil profile. Successful garlic cultivation largely depends on the optimum cultural management practices. These include judicious manuring, efficient use of residual soil moisture and mulching.

However, a considerable amount of fallow land in Mymensingh area can be brought under garlic cultivation through utilization of residual soil moisture as well as application of reduced supplemental irrigation. But the common practice of garlic production in the dry lands of this area is to make a good tilth of soil and maintain soil moisture near field capacity. So, it is vital to compare farmers'

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practice of growing garlic under dry land conditions with that of the wet land conditions in the lowland area. However, little work has been done to test the feasibility of garlic production by conserving soil moisture through the management of tillage and mulch practice. So, the present investigation was carried out to observe the effect of tillage and mulches on the yield and yield contributing characters of garlic.

Materials and Method

The experiment was conducted at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh under the Agro-ecological zone of Old Brahmaputra floodplain. The experiment consisted of three tillage conditions (conventional, puddling and zero tillage) and three mulches (rice straw, water hyacinth and sotty leaf mulch). It was laid out in a split plot design assigning tillage treatments in the main plot and mulches in the sub plot with three replications. In the conventional tillage, a good tilth of soil was made by four ploughings followed by laddering and puddling was made by two ploughings followed by irrigation. On the other hand, in the zero tillage conditions the plot was arranged without any tillage practices. The chemical compositions of the soils were analyzed at the Laboratory of Soil Resources Development Institute, Dhaka (soil pH of the lands were 6.15, 6.34 and 6.83, and organic matter contents were 2.86, 2.98 and 3.52%, respectively in conventional, puddling and zero tillage). The initial soil moistures of the lands were 27.69, 36.13.and 72.10%, respectively. Only organic manure was used in the experiment and @ 20 t/ha cow dung was applied as a basal dose (Kabir, 2011a; Kabir, 2011b). In case of conventional tillage and puddling conditions, cow dung was applied in the plot and mixed well with the soil by spading. But under zero tillage conditions, it was applied on the soil. BAU garlic-1 was used as the test materials and the cloves of garlic were planted on 27 November, 2008. Immediately after planting, 10cm thick rice straw, water hyacinth and sotty leaf mulch (*Curcuma amada*) were used in respective plots as per experimental specification. The emergence of plants was recorded by counting total number of emerged plants per plot. The crop was always kept under careful observation. Irrigation was applied according to the moisture status of the soil. Ten plants were selected at random from each plot and plant heights (cm), no. of leaves per plant, leaf area (cm^2) were recorded. Length and breadth of the leaf was measured and leaf area was calculated (leaf length × leaf breadth × 0.72) according to the method developed by (Djordje *et al*., 2011 and Hunt, 1978). Growth parameters were recorded at 20 days interval from 30 to 110 days after planting. Moreover, after fifteen days of planting and before harvesting of the crop the soil moisture status of the lands were estimated due to the variations of mulches (Table 1). The crop was harvested on the 30 march, 2009. Yield of bulb per plot was measured and it was converted into yield per hectare in metric ton. The data were recorded on percent dry matter of leaves, bulbs and roots, bulbs diameter (cm), no. of cloves per bulb, yield of bulb per plot (kg) and yield of bulb per hectare (t/ha). The collected data were statistically analyzed and the mean differences were tested by the Least Significant Difference test (LSD) (Gomez and Gomez, 1984).

Table1. Average soil moisture content monitored in different mulches and tillage conditions at growth stage and before harvesting of plants

Different tillage	Mulches	Moisture (%)	
		Growth stage	Before harvesting
Normal or conventional tillage (N_t)	Control	16.57	10.60
	Water Hyacinth	21.30	14.34
	Straw	23.08	17.78
	Sotty leaf	20.26	12.28
Puddling(P_d)	Control	22.48	14.39
	Water Hyacinth	31.13	16.33
	Straw	30.96	18.86
	Sotty leaf	28.35	13.95
Zero tillage (Z_t)	Control	41.91	25.62
	Water Hyacinth	50.30	40.42
	Straw	48.13	38.23
	Sotty leaf	49.64	30.55

Results and Discussion

Effect of different mulches on garlic

The results presented in Table 2 showed that the effect of mulches were significant in respect of emergence of plant per plot. The highest (95.17 %) number of emergence was obtained from the rice straw mulch. No significant differences were observed between rice straw mulch (95.17 %) and water hyacinth mulch (93.64 %). The plants were grown with sotty (*Curcuma amada*) leaf mulch gave the lowest emergence (87.72 %) per plot. From the table 1, it was clear that soil moisture was low in case of sotty leaf mulch which may be the reason for low emergence of plant. The plant height increased gradually with the advancement of time and continued up to 90 days after planting (DAP((Table 2). At 90 DAP the tallest plant (72.38 cm) was obtained with rice straw mulch followed by the water hyacinth mulch (70.82 cm) and the lowest (61.89 cm) was recorded from the control. The lowest height at all the dates of observation was found when the plants were grown without mulches or sotty leaf mulch. Garlic is a shallow rooted plant and it needs continuations moisture supply to the soil. But moisture content was not available at the root zone of the plant which may be the reason for lower height of the plant. The increase in plant heights due to various mulches in onion had been reported by Suh *et al.* (1991). Result revealed that at 90 days after planting rice straw mulch produced relatively higher number of leaves per plant (8.07) followed by water hyacinth mulch (7.93) (Table 2). Leaf area was recorded at 30, 50, 70, 90 and 110 days after planting (DAP) and differed significantly due to the application of different natural mulch materials (Table 3). The highest leaf area (39.13 cm^2) was found from rice straw mulch at 90 DAP followed by water hyacinth (37.34 cm^2) and control (29.47 cm^2). The lowest (29.10 cm^2) was observed from sotty leaf mulch. Again, at 30, 50, 70 and 110 days after planting rice straw mulch produced the highest leaf areas (11.65, 22.66, 36.01 and 35.97 cm^2, respectively) (Table 3).

On the other hand, the maximum fresh weight of leaves (17.80 g), fresh weight of bulb (18.96 g) and roots (0.73 g) per plant were obtained when the plants were grown with rice straw mulch (Table 4). The increased bulb weight produced in the rice straw was possibly for efficient use of available soil moisture, inhibition of weed growth, protection of surface soil erosion, reduction in nutrient loss from soil etc., which might conducive for yield contributing characters of plant resulting in the production of big sized bulb (Azam, 2005). On the other hand, the maximum dry weight of leaves (2.62 g), bulb (3.55 g) and roots per plants (0.22g) were found in rice straw mulch. The diameter of bulb per plant was the highest (3.40 cm) when the plants were grown with rice straw mulch, which was statically identical with water hyacinth significantly different from sotty leaf mulch (2.95 cm) and control (2.77 cm). The highest number of cloves per bulb (19.71) was recorded from water hyacinth mulch and the lowest (14.76) was found from control (Table 4). A highly significant variation in respect of yield per plot as well as yield per hectare was observed from the rice straw mulch. The highest yields per plot (2.21kg) and hectare (11.06 t) were obtained from the treatment rice straw mulch and the lowest (1.63 kg kg/plot and 8.15 ton/ha) was in the control (Table 4).

Rice straw mulch showed better performance than the control or sotty (*Curcuma amada*) leaf. The reason for higher yield in the rice straw mulch might be due to decreased soil temperature (Azam, 2005) and more efficient conservation of water, which favoured growth of the crop. High soil temperature suppressed the rate of root elongation and decreased root density in the surface layer of unmulched bare soil (Sans *et al.*, 1974). The increased root density enhanced better uptake of water and nutrients and ultimately increased plant height and yield of garlic. Furthermore, rice straw mulch prevented the weeds and thus plants grew without any competition. These results are in agreement with the experiences of Halim (2000) and Aliuddin (1986).

Effect of tillage conditions on garlic

The variations due to different tillage method under the study were highly significant in respect of percent emerged plant per plot. The highest emerged (93.67 %) plants were recorded from the zero tillage, which was statistically identical with puddling. On the contrary, the lowest (90.67 %) was recorded from the good tilth plot under dry land condition (Table 5). Plant height increased up to 90 days after planting and thereafter it declined due to senescence. The tallest plant (72.75 cm) was observed from zero tillage at 90 days after planting but a non significant difference was observed between zero tillage and puddling (Table 5). Again, the highest (8.05) number of leaves per plant was found from puddling condition at 90 DAP followed by zero tillage (7.35). The minimum number of leaves (6.93) was obtained from the well tilth plot (Table 5). The highest leaf area (36.59 cm^2) was recorded from the puddling at 90 DAP, which was statistically identical with that of the zero tillage (36.24 cm^2). On the contrary, the highest areas (11.37 and 23.26 cm^2) were recoded from zero tillage at 30 and 50 days after planting. From the table 6, it was also clear that at 30, 50, 70, 90 and 110 days after planting the lowest areas (7.59, 14.39, 24.65, 28.45 and 24.87 cm^2, respectively) were recorded from the conventional tillage. The highest fresh weight of leaves (17.40 g) and bulb (17.72 g) were observed from puddling condition. The lowest fresh weight of leaves (14.82 g) and bulb (15.45 g) was observed from conventional tillage (Table 7). But the maximum fresh weight of roots was observed from zero tillage (0.67 g) followed by puddling (0.66 g). The highest dry weight of leaves (2.57 g), bulb (3.22 g), and roots (0.20 g) were observed from puddling. The maximum diameter of bulb (3.22 cm) and the highest number of cloves per bulb (18.55) was recorded from zero tillage. A significant difference was observed on yield per plot as well as yield per hectare in respect of different tillage methods (Table 7). The maximum yields per plot (2.08 kg) and per hectare (10.38 ton) were recorded from puddling condition, which was statistically identical with zero tillage (2.00 kg and 9.97 ton). The minimum yield (1.78 kg/plot) and (8.89 t/ha) were recorded from the conventional tillage.

From the results it revealed that puddling and zero tillage produced higher yield compared to normal or conventional tillage method. Soil organic matter was higher in zero tillage and puddling than the conventional production method. Moreover, garlic is a shallow rooted plant and it needs continuous moisture supply to the soil. Zero tillage favoured greater and deeper water accumulation in the soil profile and profuse root growth (Mondal *et al*., 2007). Hence, moisture availability at root zone of the plant enhanced vegetative growth and ultimately higher yield. However, growth of the plant was restricted in conventional tillage due to lower initial moisture level in the soil. Reduced plant height might have caused lower nutrient uptake which is responsible for the poor yield of the crop (Mondal *et al*., 2007).

Table 2. Main effect of mulch on the growth of garlic at different days after planting

Treatment	Emergence (%)	Plant height (cm) at different DAP					Number of leaves/ plant at different DAP				
		30	50	70	90	110	30	50	70	90	110
M_0	93.46	29.56	40.89	54.51	61.89	59.73	4.22	5.02	6.53	6.84	6.51
M_1	95.17	37.69	47.11	62.87	72.38	68.47	5.11	5.42	7.82	8.07	7.67
M_2	93.64	36.93	46.22	62.71	70.82	66.60	4.91	5.58	7.53	7.93	7.58
M_3	87.72	33.78	41.96	55.56	62.20	58.80	4.29	5.02	6.64	6.93	6.69
LSD (0.05)	2.07	1.67	2.50	5.25	2.95	3.09	0.27	0.29	0.58	0.57	0.68
LSD (0.01)	2.82	2.27	3.39	7.14	4.00	4.20	0.37	0.40	0.79	0.78	0.92
Level of significance	**	**	**	**	**	**	**	**	**	**	**

** Significant at 1% level; DAP = days after planting.

M_0 = No mulch M_1 = Rice straw
M_2 = Water hyacinth and M_3 = Sotty leaf mulch

Table 3. Main effect of mulch on leaf area of garlic at different days after planting

Treatment	Leaf area (cm^2) at different DAP				
	30	50	70	90	110
M_0	6.92	15.94	25.32	29.47	26.60
M_1	11.65	22.66	36.01	39.13	35.97
M_2	10.88	22.02	34.59	37.34	33.54
M_3	8.92	16.48	27.11	29.10	25.60
LSD (0.05)	1.02	1.48	3.53	4.14	3.92
LSD (0.01)	1.39	2.03	4.83	5.67	5.37
Level of significance	**	**	**	**	**

** Significant at 1% level; DAP = days after planting.

M_0 = No mulch M_1 = Rice straw

M_2 = Water hyacinth and M_3 = Sotty leaf mulch

Table 4. Main effect of different mulch materials on the yield and yield contributing characters of garlic

Treatment	Fresh weight(g) of			Dry weight(g) of			Bulb diameter (cm)	Cloves/bulb (no.)	Yield (kg/plot)	Yield (t/ha)
	Leaves per plant	Bulb	Roots per plant	Leaves per plant	Bulb	Roots per plant				
M_0	14.18	13.84	0.53	2.09	2.46	0.16	2.77	14.76	1.63	8.15
M_1	17.80	18.96	0.73	2.62	3.55	0.22	3.40	19.56	2.21	11.06
M_2	17.07	18.20	0.68	2.52	3.30	0.22	3.29	19.71	2.19	10.92
M_3	15.51	15.91	0.58	2.28	2.88	0.18	2.95	16.16	1.77	8.86
LSD (0.05)	1.77	1.67	0.05	0.22	0.28	0.02	0.17	1.44	0.19	0.96
LSD (0.01)	2.41	2.27	0.07	0.29	0.38	0.03	0.23	1.96	0.26	1.31
Level of significance	**	**	**	**	**	**	**	**	**	**

** Significant at 1% level

P_d = Puddling N_t = Normal or conventional tillage and Z_t = Zero tillage

Table 5. Main effect of tillage on the growth of garlic at different days after planting

Treatment	Emergence (%)	Plant height (cm) at different DAP					Number of leaves/plant at different DAP				
		30	50	70	90	110	30	50	70	90	110
P_d	93.16	34.43	44.97	64.97	72.75	69.20	4.83	5.08	7.82	8.05	7.42
N_t	90.67	30.47	35.85	47.57	57.65	54.10	4.38	4.85	6.58	6.93	6.68
Z_t	93.67	38.57	51.32	64.20	70.07	66.90	4.68	5.85	7.00	7.35	7.23
LSD (0.05)	1.79	1.44	2.16	4.55	2.55	2.68	0.24	0.25	0.50	0.49	0.59
LSD (0.01)	2.44	1.96	2.93	6.18	3.47	3.64	0.32	0.35	0.69	0.67	0.80
Level of significance		**	**	**	**	**	**	**	**	**	**

** Significant at 1% level; DAP = days after planting.

P_d = Puddling, N_t = Normal or conventional tillage and Z_t = Zero tillage

Table 6. Main effect of tillage on leaf area of garlic at different days after planting

Treatment	Leaf area (cm^2) at different DAP				
	30	50	70	90	110
P_d	9.82	20.18	34.32	36.59	33.78
N_t	7.59	14.39	24.65	28.45	24.87
Z_t	11.37	23.26	33.31	36.24	32.63
LSD (0.05)	0.99	3.08	3.44	5.87	4.79
LSD (0.01)	1.64	5.11	5.70	9.74	7.94
Level of significance	**	**	**	*	*

** Significant at 1% level, * Significant at 5% level; DAP = days after planting.
P_d = Puddling, N_t = Normal or conventional tillage and Z_t = Zero tillage

Table 7. Main effect of tillage on the yield and yield contributing characters of garlic.

Treatment	Fresh weight(g) of			Dry weight(g) of			Bulb diameter (cm)	Cloves/bulb (no.)	Yield (kg/plot)	Yield (t/ha)
	Leaves per plant	Bulb	Roots per plant	Leaves per plant	Bulb	Roots per plant				
P_d	17.40	17.72	0.66	2.57	3.22	0.20	3.10	17.70	2.08	10.38
N_t	14.82	15.45	0.56	2.18	2.79	0.18	2.99	16.38	1.78	8.89
Z_t	16.20	17.02	0.67	2.39	3.14	0.20	3.22	18.55	2.00	9.97
LSD (0.05)	1.53	1.44	0.05	0.19	0.24	0.02	0.15	1.25	0.17	0.84
LSD (0.01)	2.08	1.96	0.06	0.25	0.33	0.03	0.20	1.70	0.23	1.14
Level of significance	**	**	**	**	**	**	**	**	**	**

P_d = Puddling N_t = Normal or conventional tillage and Z_t = Zero tillage
** Significant at 1% level,

Combined effect of tillage methods and mulches

Significant interaction and combined effects were found due to the combination of different mulches and tillage in respect of percent emergence. The results presented in the fig. 1 showed that the maximum emergence (97.63%) was obtained from the rice straw mulch with zero tillage followed by water hyacinth mulch with zero tillage (96.37 %), control with puddling (96.10 %) and rice straw mulch with puddling (95.07 %). It was observed that at 90 days after planting the tallest plant (78.07 cm) and the maximum number of leaves (8.60) was found from rice straw mulch with puddling. On the other hand, the lowest plant height (51.40 cm) and minimum number (6.0) of leaves per plant were obtained in conventional tillage with sotty leaf mulch and zero tillage with no mulch, respectively (Fig. 2 & 3). The treatment combination of rice straw mulch with zero tillage (M_1Z_t) gave the highest leaf area (43.47 cm^2) at 90 DAP followed by puddling with rice straw (42.37 cm^2) and puddling with water hyacinth mulch (40.30 cm^2). Again, at 30, 50 , 70 and 110 days after planting the maximum leaf areas (13.67, 28.37, 41.70 and 40.47 cm^2, respectively) were also recorded from the combination of zero tillage with rice straw mulch (Table 8). On the other hand, the lowest area (5.87 cm^2) was noted from the conventional tillage with no mulch at 30 days after planting, whereas it was lowest in conventional tillage with sotty leaf mulch at 50, 70, 90 and 110 days after planting (Table 8). Treatment combinations of mulches and tillage also exhibited highly significant variation in respect of fresh weight of leaves. When the plants were grown under zero tillage with rice straw mulch, it produced the maximum (19.20 g) fresh weight of leaves, bulb (20.93g) and roots (0.83g). However, the minimum fresh weight of leaves (11.67 g), bulb (10.73 g) and roots (0.47 g) were recorded from the combination of zero tillage with no mulch (Table 9).

The highest dry weight of leaves per plant (2.83 g), dry weight of bulb (4.15 g) and the maximum (0.25g) dry weight of roots were observed from rice straw mulch with zero tillage and the lowest dry weight of leaves (1.72g), bulb (1.78 g) and roots (0.09g) were recorded from the treatment combination of no mulch with zero tillage (Table 9). Significant interaction and combined effect of different thickness of mulch and tillage were recorded on diameter of bulb that ranged from 2.39 cm to 3.77 cm. The highest number of cloves per bulb (22.20) was recorded in the treatment combination of zero tillage with rice straw mulch whereas, the lowest number of cloves per bulb (11.27) was found in the treatment combination of zero tillage with no mulch. The maximum and the minimum ((2.40 and 1.22 kg, respectively) yield of bulb were obtained from the treatment combinations of zero tillage with rice straw and zero tillage with no mulch. No significant differences were observed among the combinations of zero tillage with rice straw (2.40 kg), zero tillage with water hyacinth mulch (2.38 kg) and puddling with rice straw mulch (2.37 kg). The treatment combination of zero tillage with rice straw mulch produced the highest yield (12.00 t/ha) while the lowest yield (6.12 t/ha) was obtained from the combination of zero tillage with no mulch (Table 9).

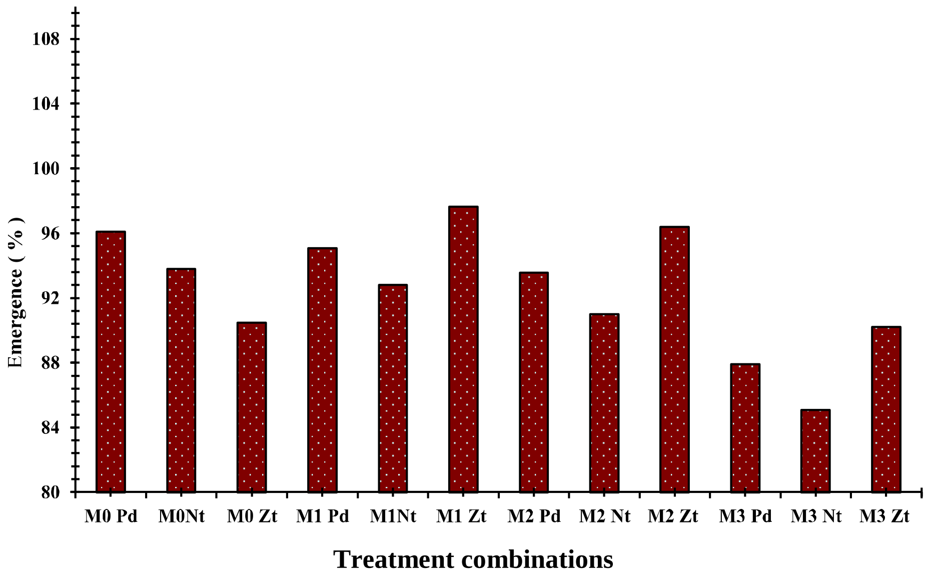

Fig. 1. Combined effect of mulch and tillage on the emergence of garlic.

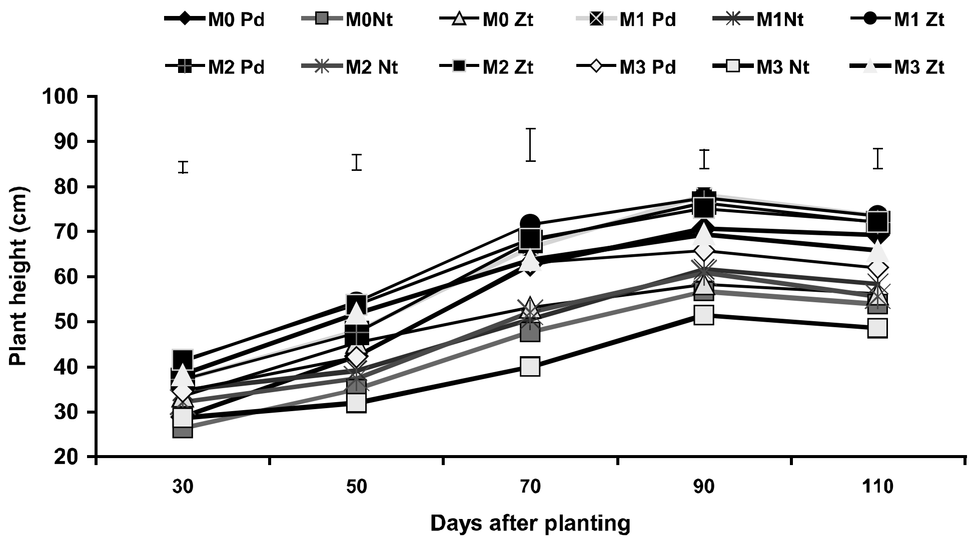

Fig. 2. Combined effect of mulch and tillage on the plant height of garlic at different days after planting. Vertical bars represent LSD at 0.05 level of significance.

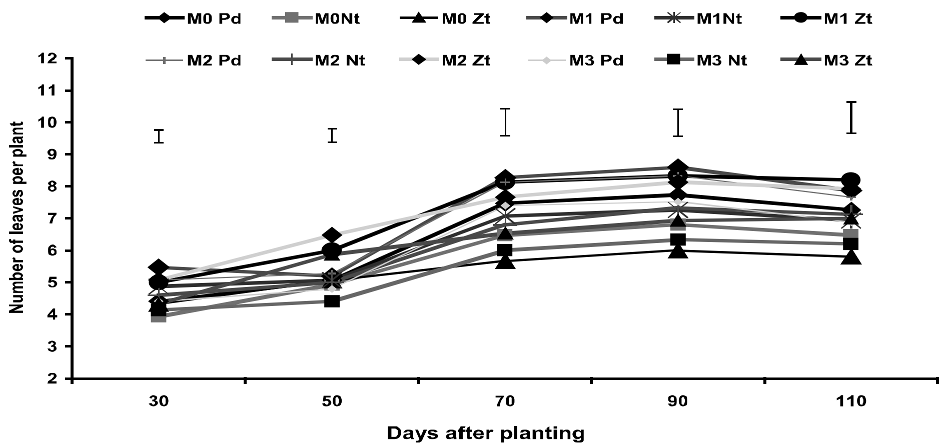

Fig. 3. Combined effect of tillage and mulch on the number of leaves per plant of garlic at different days after planting. Vertical bars represent LSD at 0.05 level of significance.

Table 8. Combined effects of mulch and tillage on leaf area of garlic at different days after planting

Treatment combinations	Leaf area (cm^2) at different DAP				
	30	50	70	90	110
M_0 P_d	7.74	17.63	31.90	33.80	31.63
M_0N_t	5.87	13.43	23.90	28.43	25.30
M_0 Z_t	7.13	16.77	20.17	26.17	22.87
M_1 P_d	11.63	23.17	38.47	42.37	39.33
M_1N_t	9.65	16.43	27.87	31.57	28.10
M_1 Z_t	13.67	28.37	41.70	43.47	40.47
M_2 P_d	10.48	22.67	37.60	40.30	37.57
M_2 N_t	8.65	16.53	27.70	31.60	26.60
M_2 Z_t	13.50	26.87	38.47	40.13	36.47
M_3 P_d	9.413	17.23	29.30	29.90	26.60
M_3 N_t	6.177	11.17	19.13	22.20	19.47
M_3 Z_t	11.167	21.03	32.90	35.20	30.73
LSD (0.05)	1.76	2.57	6.11	7.17	6.78
LSD (0.01)	2.41	3.52	8.37	9.83	9.29
Level of significance	**	**	**	**	**

DAP = days after planting, ** Significant at 1% level, PD= paddling, M_o= No mulch, M_1= Rice strand, M_2= water hyacynth, M_3= soft leaf mulch, N_t= normal or convention and Z_t= Zero tillage.

Table 9. Combined effects of different mulch materials and tillage on the yield and yield contributing characters of garlic

Treatment	Fresh weight(g) of			Dry weight (g) of			Bulb diameter (cm)	Cloves/bulb (no.)	Yield (kg/plot)	Yield (t/ha)
	Leaves per plant	Bulb	Roots per plant	Leaves per plant	Bulb	Roots per plant				
M_0 P_d	16.20	15.73	0.61	2.39	2.87	0.19	2.97	16.67	1.89	9.47
M_0N_t	14.67	15.07	0.53	2.16	2.73	0.16	2.96	16.33	1.77	8.87
M_0 Z_t	11.67	10.73	0.47	1.72	1.78	0.09	2.39	11.27	1.22	6.12
M_1P_d	19.00	19.87	0.75	2.80	3.60	0.23	3.37	18.60	2.37	11.87
M_1 N_t	15.20	16.07	0.61	2.23	2.91	0.19	3.07	17.87	1.86	9.32
M_1 Z_t	19.20	20.93	0.83	2.83	4.15	0.25	3.77	22.20	2.40	12.00
M_2 P_d	17.80	19.07	0.69	2.63	3.46	0.22	3.09	19.73	2.24	11.17
M_2 N_t	16.33	16.27	0.58	2.40	2.90	0.19	3.15	17.93	1.94	9.68
M_2 Z_t	17.07	19.27	0.77	2.51	3.53	0.25	3.63	21.47	2.38	11.90
M_3 P_d	16.60	16.20	0.59	2.45	2.95	0.18	2.97	15.80	1.81	9.03
M_3 N_t	13.07	14.40	0.54	1.91	2.61	0.17	2.79	13.40	1.54	7.68
M_3 Z_t	16.87	17.13	0.61	2.48	3.09	0.18	3.09	19.27	1.98	9.87
LSD (0.05)	3.07	2.89	0.09	0.37	0.49	0.04	0.29	2.50	0.33	1.67
LSD (0.01)	4.17	3.93	0.13	0.51	0.66	0.05	0.40	3.40	0.45	2.27
Level of significance	**	**	**	**	**	**	**	**	**	**

** Significant at 1% level

M_0 = No mulch
M_1 = Rice straw
M_2 = Water hyacinth and
M_3 = Sotty leaf mulch

P_d = Puddling
N_t = Normal or conventional tillage and
Z_t = Zero tillage

Economic analysis

It is evident from the Table 10 that the total cost of production was the highest (135768Tk. /ha) in conventional tillage with sotty leaf and the lowest expenditure of production (98469Tk./ha) was recorded from zero tillage with no mulch. But, the highest value of gross return (300000Tk. /ha) was obtained from the zero tillage with rice straw mulch. The lowest value of gross return (153000Tk. /ha) and net return (54531Tk. /ha) was obtained from the zero tillage with no mulch. Moreover, the highest net return (196647Tk. /ha) and the highest BCR of 2.90 was obtained from zero tillage with rice straw. Garlic production under zero tillage with water hyacinth mulch gave the next highest net return of Tk.193703 and gave second highest BCR of 2.87. So, garlic cultivation under zero tillage covering either by rice straw or water hyacinth mulch was a very advantageous production system.

Table 10. Cost and return analysis of garlic due to different tillage and mulch materials

Treatment	Yield (t/ha)	Gross return (Tk. /ha	Total cost of production (Tk.)	Net return (Tk.)	BCR
M_0 P_d	9.47	236750	125445	111305	1.89
M_0N_t	8.87	221750	128109	93641	1.73
M_0 Z_t	6.12	153000	98469	54531	1.55
M_1 P_d	11.87	295750	130329	165421	2.27
M_1 N_t	9.32	233000	132993	100007	1.75
M_1 Z_t	12.00	300000	103353	196647	2.90
M_2 P_d	11.17	279250	132327	146923	2.11
M_2 N_t	9.68	242000	134991	107009	1.79
M_2 Z_t	11.90	297500	103797	193703	2.87
M_3 P_d	9.03	225750	133104	92646	1.69
M_3 N_t	7.68	192000	135768	56232	1.41
M_3 Z_t	9.87	246750	104574	142176	2.36

Rate of fresh garlic @25Tk./kg.

** Significant at 1% level
M_0 = No mulch
M_1 = Rice straw
M_2 = Water hyacinth and
M_3 = Sotty leaf mulch

P_d = Puddling
N_t = Normal or conventional tillage and
Z_t = Zero tillage

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IN VITRO CONSERVATION OF TARO *(Colocasia esculenta* var. *globulifera)* AS INFLUENCED BY MANNITOL

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Abstract

In vitro conservation of germplasm plays a vital role in maintenance breeding and also has many advantages over the conventional system. The experimental results for conservation of *Colocasia* sp. also proved this. In relation to explants and osmoticum, meristem and axillary bud could be conserved for 24 months while meristem-base died after 6 months. Mannitol as osmoticum @ 4% performed nicely to conserve *Colocasia* upto 24 months. Only meristem and axillary bud could be conserved for 24 months with the use of 4 % mannitol. But other level of mannitol remained culture alive for varying periods (6 to 12 months). After 24 months, the plant height was 6.5 cm for the meristem and 6.4 for axillary bud.

Keywords: *Colocasia*, mannitol, meristem and axillary bud.

Introduction

Generatively reproduced plants are simply kept for long periods in the form of seed in closed containers or air-tight packets and are stored at low temperature (- 18^0c or lower) and low humidity. Problems occur only when the seeds are viable for short period or in vegetatively propagated plants, the other methods (*in vitro*) can be adopted in this situation successfully (Pierik, 1987)

Taro is a vegetatively propagated crop; it has traditionally been conserved in field collections. Significant genetic erosion may occur because most of the taro clones are contaminated with endogenous pathogens and under field conditions, reinfections may also occur (Matthews, 2002). The taro corms and cormels have short storage life under natural storage condition (Akhond *et al*., 1997). Losses may also occur due to natural hazards (drought, flood etc.) and unconscious cultural practices (varietal admixtures). Therefore, it is essential to establish a repository where disease free planting materials can be stored for longer periods.

In vitro system is extremely suitable for storage of plant materials (Hadiuzzaman *et al*., 1997), since, in principle, it can be stored disease free on a small scale under limited growth conditions (Kartha, 1985). Recently, carnation, strawberry, potato, pea, fruit trees, carrot, ground nut, Prunus, Ipomoea, anthurium, gerbera etc. are stored *in vitro* of meristems or shoot tip cultures (Pierik, 1987).

Arditti and Strauss (1979) opined that *in vitro* storage of taro with the minimum growth condition is feasible. Addition of osmotic agents such as sucrose, mannitol

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or sorbitol to the culture medium efficiently reduced growth and extended storage life of many vegetatively propagated crop (Karhu, 1997; Shibli, 1990; Shibli *et al.*, 1992). Many researchers around the world worked on conservation of taro but very scarce. Storage under growth retarding conditions is most suitable for conservation of active collections (Withers, 1980). Slow growth can be achieved by using mannitol (Jarret and Gawel, 1991; Mourai and Maria, 1993).

Though, many of the research on the conservation of taro have been reported but works were mostly done in abroad with exotic varieties. Therefore, to conserve our taro variety for long-term without sub culture, the present study has been undertaken.

Materials and Method

For conservation of taro an experiment was conducted at tissue culture laboratory of the Tuber Crops Research Centre (TCRC), BARI, Joydebpur, Gazipur. Well sprouted cormels of mukhikachu var. 'Bilashi' (*Colocasia esculenta* var. *globulifera*) was used. The axillary bud (*ca*. 0.2 - 0.4 mm) and meristem (*ca*. 0.5 mm) were excised from sterilized sprout of cormel and used as explant. After excising the meristem remaining meristem base was also used as explant.

The *in vitro* growing medium contained mineral salts and vitamins (Murashige and Skoog, 1962) plus mannitol according to the treatment. Three types of explants (axillary bud (Ab), meristem (M) and meristem base (Mb) and four levels of mannitol (0, 2, 4 and 6 %) were used in this experiment. Cultures were maintained under light (16 h photoperiod). Complete Randomized Design (CRD) was followed having five replications each having 5 tubes. The cultured tubes were stored for 24 months. The total number of plants survived at different intervals after *in vitro* multiplication was recorded. The percent plant survival at 2, 4, 6, 8, 12 and 24 months after *in vitro* multiplication was calculated by the formula as follows:

$$\%\ \text{plant survival} = \frac{\text{Total number of tubes with survived plant}}{\text{Total number of tubes cultured}} \times 100$$

Plant height at different intervals was measured by destroying the test tube. Data were analyzed statistically and mean separation was done at 1% level of probability by DMRT.

Results and Discussion

The results of explants on long term conservation are presented in Fig.1. The survival of explants with time was recorded upto 24 months. After two months about 70.0 % plant of meristem, 52.5% of axillary bud and 75.0 % of meristem base were survived. These figures were gradually reduced with time. After eight months, no plants derived from meristem-base survived and after 24 months, only

20.0 % and 15.0 % plant derived from meristem and axillary bud, respectively found alive. After 8 months all plants derived from meristem-base died because the concentration of the osmoticum used in this experiment might have failed to produce any significant effect. Further investigation may be needed to find out the reasons.

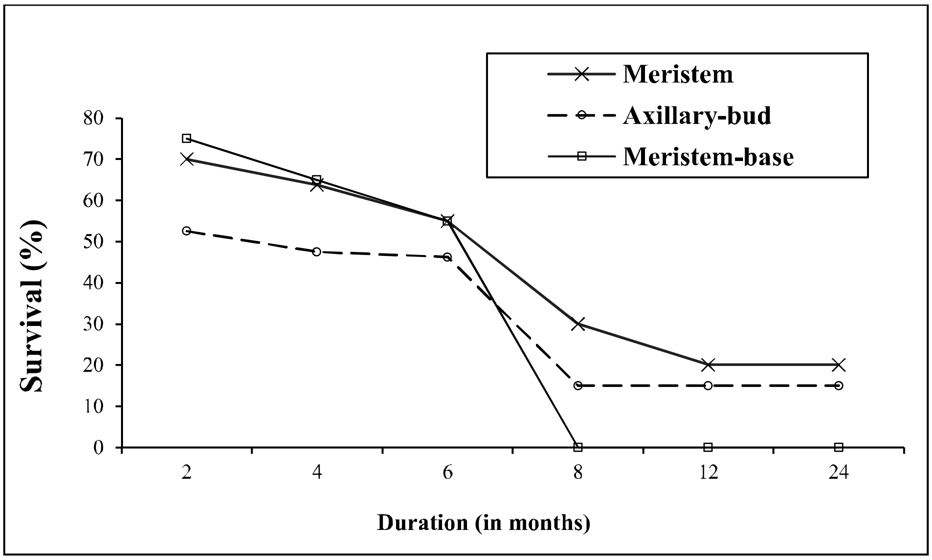

Fig1. Showing effect of explants on survival (%) of *in vitro* conserved plants.

Table 1. Main effect of explants on plant height

Explant	Plant height after different months of conservation (cm)					
	2	4	6	8	12	24
Meristem (M)	2.6 b	4.4 b	6.8 b	4.3 b	1.5 a	1.6 a
Axillary bud (Ab)	2.3 c	4.5 b	6.8 b	5.4 a	1.3 b	1.6 a
Meristem base (Mb)	4.5 a	7.5 a	12.9 a	0.0 c	0.0 c	0.0 b

In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT.

At the same time plant height was measured (Table 1). It was found that plants grew slowly and continued up to 24 months when meristem and axillary bud were used as explants. Whereas plants grew up to 6 months and gained a height up to 12.93 cm when derived from meristem-base. With advancing of time, the larger leaves became senescence and died; in case of meristem base after 6 months not a single plant remained alive. But In case of meristem and axillary bud, only the central leaves remained alive up to the end of the experiment. The height of which was about 1.60 cm after 24 month. After eight months the gradual declining of plant height was may be due to shortage of osmoticum (Jarret and Gawel, 1991). This finding was in agreement with Mourai and Maria (1993).

Mannitol as a suitable osmoticum keeps plant alive for long with very slow shoot growth. After 2 months, the survival rate was the maximum of 71.7 % at 0 or 2.0 % mannitol, which reduced gradually with increasing mannitol level. Culture survival rate started reduced from four months. After 8 months, all cultures of 0.0 or 6.0 % mannitol died, which also happened for 2.0 % mannitol after 12 month but about 46.7 % plants with 4.0% mannitol remained quite alive after 24 months (Fig. 2), which is in accordance with previous by Mourai and Maria (1993).

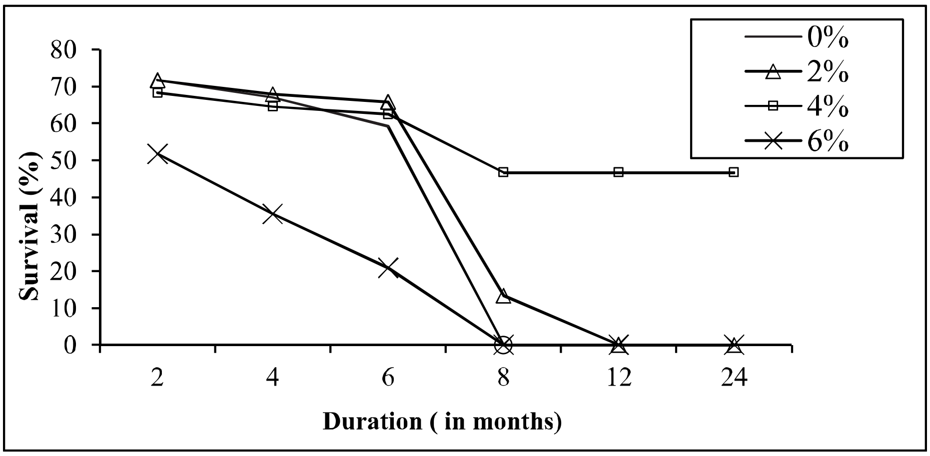

Fig.2. Showing effect of mannitol on survival (%) of *in vitro* conserved plants.

Table 2. Main effect of Mannitol on plant height

Mannitol (%)	Plant height after different months of conservation (cm)					
	2	4	6	8	12	24
0	4.5 a	7.6 a	12.9 a	0.0 c	0.0 b	0.0 b
2	3.1 b	6.3 b	10.6 b	8.3a	0.0 b	0.0 b
4	3.1 b	5.0 c	7.2 c	3.4 b	3.8 a	4.3 a
6	1.7 c	2.9 d	4.6 d	0.0 c	0.0 b	0.0 b

In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT.

In all the mannitol levels, the plants attained the maximum height after 6 months ranging from 4.6 cm with 6.0 % mannitol to 12.9 cm with control. After 8 months all plants derived from 0 and 6.0 % mannitol died. After 12 months all plants died except 4.0 % mannitol. After 24 months, the plants with 4.0 % mannitol had 4.3 cm in height (Table 2). In the lowest and the highest level of mannitol, plants could not perform well may be due to different osmotic concentration of mannitol.

At the lowest level there was no osmoticum but at the highest level the concentration of osmoticum was lethal for plant growth or phytotoxic (Bessembinder *et al.*, 1993).

Explants with mannitol levels showed that survival rate was the highest after two months, which became reduced onwards and after 8 months living plants were only obtained for meristem with 2.0 % and 4.0 % mannitol and axillary bud with 4.0 % mannitol. After 24 months, survival plants only found with 4.0 % level of mannitol with meristem and axillary bud (Table 3).

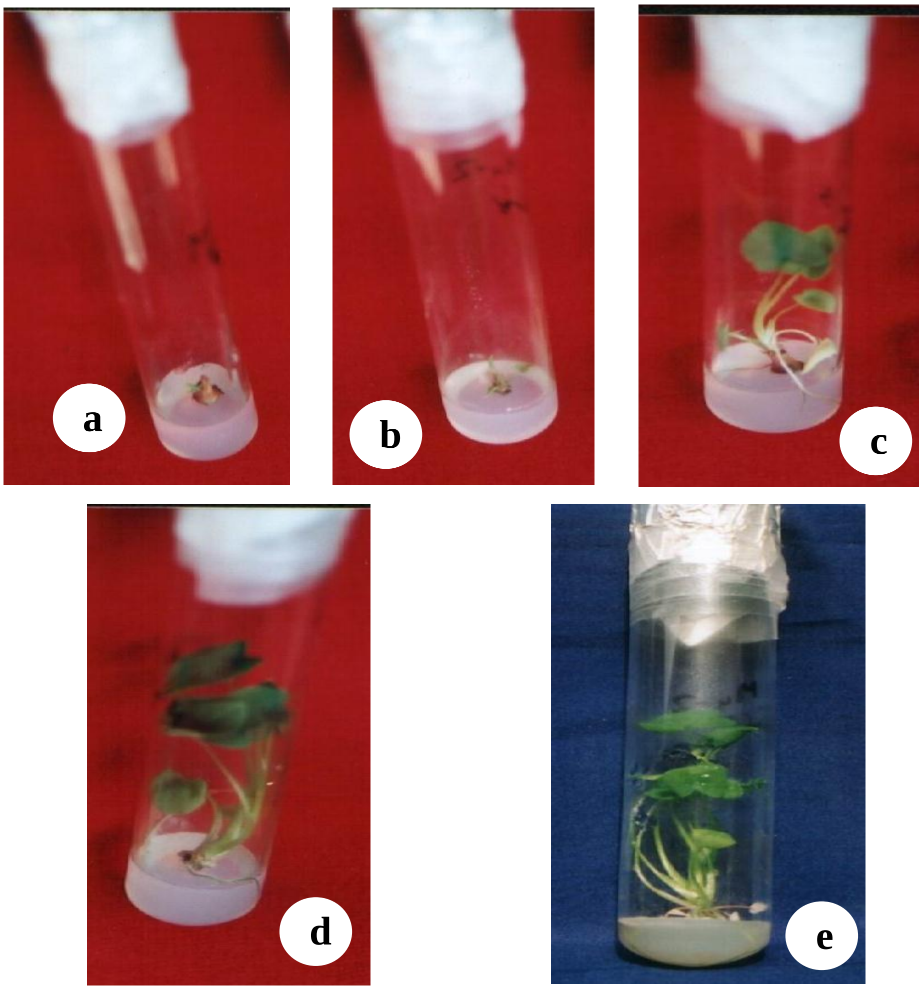

Fig. 3 (a-e). Conserved plants of *Colocasia esculenta* in 4% mannitol at different months after culture (a. 2 months after culture, b. 4 months after culture, c. 8 months after culture, d. 12 months after cultue and e. 24 months after culture).

Table 3. Combined effect of explant and mannitol on survival (%) of conserved plants

Treatment		Plant survival(%) after different months of conservation					
Explant	Mannitol (%)	2	4	6	8	12	24
Meristem	0	75.0 (8.7) a	73.7 (8.6) a	57.5 (7.6) bc	0.0 d	0.0 c	0.0 c
	2	75.0 (8.7) a	73.7 (8.6) a	73.7 (8.6) a	40.0 (6.3) c	0.0 c	0.0 c
	4	85.0 (9.4) a	83.7 (9.2) a	83.7 (9.2) a	80.0 (9.0) a	80.0 (9.0) a	80.0 (9.0) a
	6	55.0 (7.4)c	33.7 (5.8) d	7.5 (2.7) d	0.0 d	0.0 c	0.0 c
Axillary bud	0	65.0 (8.1) b	62.5 (7.9) b	62.5 (7.9) b	0.0 d	0.0 c	0.0 c
	2	65.0 (8.1) b	65.0 (8.1) b	65.0 (8.1) b	0.0 d	0.0 c	0.0 c
	4	55.0 (7.4) c	55.0 (7.4) c	55.0 (7.4) c	50.0 (7.1) b	50.0 (7.1) b	50.0 (7.1) b
	6	25.0 (5.0) d	7.5 (2.8) e	0.0 d	0.0 d	0.0 c	0.0 c
Meristem-base	0	75.0 (8.7) a	65.0 (8.1) b	55.0 (7.4) c	0.0 d	0.0 c	0.0 c
	2	75.0 (8.7) a	65.0 (8.1) b	55.0 (7.4) c	0.0 d	0.0 c	0.0 c
	4	75.0 (8.7) a	65.0 (8.1) b	55.0 (7.4) c	0.0 d	0.0 c	0.0 c
	6	75.0 (8.7) a	65.00 (8.1) b	55.0 (7.4) c	0.0 d	0.0 c	0.0 c

Figures in parenthesis indicate square root transformed data

In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT

The plants attained the maximum height after 6 months (13.0 cm). At this period, all plants of axillary buds died with 6.0 % mannitol. After 8 months all plants from meristem-base and mannitol at 0.0 and 6.0 % died. This might be due to the fact that mannitol failed to work on meristem-base. Mannitol at 0.0 % might be insufficient to act, whereas 6.0 % mannitol might be phytotoxic (Bessembinder *et al.*, 1993). In some cases, the slow growth of plants was observed with 4.0 % mannitol up to 24 months (Table 4), which is an advantage for *in vitro* conservation of any crop. The result of this experiment was in agreement with the findings of Siddiqui *et al.* (1996)

Table 4. Combined effect of explant and mannitol on plant height

Treatment		Plant height after different months of conservation (cm)					
Explant	Mannitol (%)	2	4	6	8	12	24
Meristem	0	4.8 a	7.5 a	13.0 a	0.0 e	0.0 c	0.0 c
	2	2.5 d	5.5 c	8.8 c	12.0 b	0.0c	0.0 c
	4	2.5 d	3.8 d	4.5 d	5.2 c	5.8 a	6.5 a
	6	0.6 f	0.8 e	1.0 e	0.0 e	0.0 c	0.0 c
Axillary bud	0	4.2 c	7.6 a	12.8 a	0.0 e	0.0 c	0.0 c
	2	2.2 e	5.8 b	10.0 b	12.9 a	0.0 c	0.0 c
	4	2.2 e	3.7 d	4.4 d	5.0 d	5.6 b	6.4 b
	6	0.6 f	0.7 e	0.0 f	0.0 e	0.0 c	0.0 c
Meristem-base	0	4.7 ab	7.6 a	13.0 a	0.0e	0.0 c	0.0 c
	2	4.5 ab	7.5 a	13.0 a	0.0 e	0.0 c	0.0 c
	4	4.4 b	7.5 a	12.8 a	0.0 e	0.0 c	0.0 c
	6	4.0 c	7.4 a	12.9 a	0.0 e	0.0 c	0.0 c

In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT.

who found that 0.0-3.0 % mannitol had no significant effect on survival percentage of cultures. Bessembinder *et al.* (1993) found that mannitol concentration of 4.5 to 6.0 % appeared to be lethal which is also in agreement with the findings of the present study.

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EFFECT OF WEED EXTRACTS AGAINST PULSE BEETLE, *Callosobruchus chinensis* L. (*COLEOPTERA: BRUCHIDAE*) OF MUNG BEAN

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Abstract

The n-hexane extracts of the weeds 'bhatpata' *Clerodendrum viscosum*, 'kashiature' *Cassia tora*, 'dhakishak' *Dryoptris filix-max*, 'bonmorich' *Croton bonpalandianum* and 'ghagra' *Xanthium strumarium* were used to evaluate their effectiveness for suppressing pulse beetle, *Callosobruchus chinensis* reared on mung bean *Vigna radiata* grains. The investigations were done with 1, 2 and 4% n-hexane extracts of the weeds and an untreated control. The weed extracts exhibited considerable effectiveness which varied with weed species, concentrations and exposure durations. The higher concentrations showed the higher rate of insect mortality, fecundity, adult emergence inhibition, and grain protection. The LC_{50} values of the extracts ranged from 5.3 to 7.8, 4.7 to 6.5 and 4.1 to 6.0 g/100 ml at 24, 48 and 72 hours after treatment, respectively. The fecundity inhibition varied from 31.7 to 78.7%, adult emergence inhibition from 33.8 to 81.1%, and grain damage inhibition from 10.3 to 60.1% when 'bhatpata' with concentration of 1 g/100 ml and 'ghagra' with concentration of 4g/100 ml were applied, respectively. Among the tested weeds, ghagra (4g/100 ml) showed better efficacy against *C. chinensis* compared to other tested extracts and may be suggested to control pulse beetle and protection of mung bean grains.

Keywords: Adult emergence, bruchids, fecundity, grain damage, toxicity, weed extracts.

Introduction

The pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) is a serious pest of mung bean and many other pulse grains in the tropics (Roy *et al.*, 2012a). The larvae of this pest penetrate into the pulse grains and feed endosperms, thus lead to damage grains as well as deteriorate nutritional value and germination capacity (Roy *et al.*, 2014). Different microorganisms, especially fungi develop in the infested grains and eventually make it unfit for human consumption and propagation (Deeba *et al.*, 2006).

Protection of pulse grains in the storage from the attack of *C. chinensis* mostly relied on synthetic insecticides like fumigation with methyl bromide and

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phosphine. These chemicals undoubtedly protect the grains but their excessive and inadvertent use created serious health hazards, environment pollution, cause ozone depletion and resistance to insects (Kim *et al.,* 2003). These problems demand the need for restriction of such chemicals to ensure pesticide free foodstuffs (Daglish, 2008). Therefore, environmentally safe and convenient methods such as the use of plant extracts, oils, leaf powders and pressurized carbon dioxide and temperature management techniques are the growing interest to replace synthetic pesticides (Yuya *et al.,* 2009).

Insecticidal activities of the plants have been intensively investigated and demonstrated promising for control of field and stored grain pests. Plant derived chemicals are hazard free and possess bitter substances which may show toxic, repellent, antifeedant, and growth and progeny inhibition activity against insect pests (Roy *et al.*, 2005; Roy *et al.*, 2014). Many plant-derived materials have been proved as toxic and growth regulators against stored products insects (Cosimi *et al.,* 2009). Plant lectins are biodegradable insecticidal agents that possessed deleterious effects on the survival, growth, oviposition and reproduction of stored grain insect pests (Oliveira *et al.*, 2011). The leaf extracts of ghagra *Xanthium strumerium* revealed insecticidal effectiveness against *C. chinensis* reared on black gram grains.

Plant powders, extracts and oils are a rich source of bioactive chemicals which reveal toxic effect and produce odors that repel adult beetles. The weed plants are excellent store of medicine and possess toxic chemicals, but little investigations have been done on their use in insect pest management. This study was designed with n-hexane extracts of five indigenous weed species to evaluate their effectiveness on mortality, fecundity and adult emergence inhibition of *C. chinensis* reared on mung bean grains. In addition, an assessment of the grain damage inhibition with the extracts was also determined.

Materials and Method

Insect culture

Mass culture of the insect was done on mung bean (*Vigna radiata;* Leguminosae) grains at an ambient temperature of 27 ± 2 °C and 80 ± 5 % RH in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. Ten pairs of adult beetles (1-3 day old) along with the food were placed in 1l glass jar. The mouth of the jar was fastened with muslin cloth with rubber band and kept 7 days in the laboratory for mating and oviposition of the insects. The beetles were removed from the jar and the eggs laid on the pulses were allowed to hatch. To study bioassay, insect rearing was repeated until 3^{rd} generations with a view to ensuring enough population without affecting original culture.

Collection and preparation of weed sample

The weed species ‘bhatpata’, *Clerodendrum viscosum* Vent. (Verbenaceae), ‘kashiature’, *Cassia tora* L. (Leguminosae), ‘dhakishak’, *Dryoptris filix-max* L. (Polypodiaceae), ‘bonmorich’, *Croton bonplandianum* Baill. (Euphorbiacae) and ‘ghagra’, *Xanthium strumarium* L. (Asteraceae) were collected from the road side of HSTU, collected in plastic bags and transported to the Entomology Laboratory. The weeds were washed with tap water and air dried for 7 days in the shade. Furthermore, the weeds were dried in an oven at 50 - 60˚C for 24h to obtain constant weight. The weeds were powdered mechanically by using an electric blender (Braun Multiquick Immersion Hand Blender, B White Mixer MR 5550 CA, Germany), passed through 40 mesh screen and stored at 28 ºC in tightly-closed dark glass bottles.

Preparation of n-hexane extracts from the weeds

Dried powder of each weed species was separately extracted in n-hexane. For each preparation, 10g powder was macerated in a 2.5 l capacity glass bottle using 1l n-hexane (96% analytical pure) for 7 days. To be sure for complete extraction, the sample was shaken for 72h using an electric shaker. The extract was filtered and the filtrate was considered as 1% concentration (1 g/100 ml). Similarly, 2 and 4% extracts were prepared and stored in a refrigerator at 4 ºC until bioassay.

Contact toxicity test

Three day-old adult beetles were chilled for a period of 10 minutes in a refrigerator at 5 ºC, and then 1µl of an extract was applied to the dorsal thorax of the beetles with a micro pipette. Fifty insects were used for each treatment and untreated control treatment was applied with n-hexane only. The insects were then transferred into 9 cm diameter Petri dishes (10 insects / Petri dish) that contained 100 g mung bean grains. Number of insect mortality in each Petri dish was recorded at 24, 48 and 72h after treatment and % mortality was calculated. Data of toxicity studies were corrected for untreated control mortality according to Schneider-Orelli's (1947) formula as mortalities in the control treatment ranged between 5 and 20%.

$$\text{Corrected mortality (\%)} = \frac{\%\ \text{Mortality in treatments} - \%\ \text{Mortality in control}}{100 - \%\ \text{Mortality in control}} \times 100$$

Toxicity ratios (TR) were calculated using the formula: TR = LC_{50} and /or LC_{95} of the extract with less toxicity / LC_{50} and /or LC95 of the other extract, individually (Gusmao *et al.,* 2013).

Fecundity inhibition test

In each glass container 100 g grains were put and the predetermined extract concentrations were distinctly added to the containers with pipette, and subjected to manual agitation for 2 min. Thereafter, the grains were placed in Petri dishes and five pairs of newly emerged beetles were released in each Petri dish. After 7 days, the numbers of eggs laid by the females on mung bean grains in the Petri dishes were counted by using hand lens. There were three replications for each extract concentration and a control treatment was made with untreated grains. The fecundity inhibition (%FI) of each extract concentration was calculated using the following formula:

$$\% \text{ F1} = \frac{\text{Eggs laid in control grains - Eggs laid in treated grains}}{\text{Eggs laid in control grains}} \times 100$$

Observation on adult insect emergence and grain damage inhibition

The weed extracts were poured distinctly into the glass containers which had mung bean grains. The extracts were mixed with the grains and then air dried. The grains were placed in different Petri dishes and five pairs of newly emerged beetles were released in each Petri dish. After 7 days the beetles were removed from the Petri dishes and the Petri dishes along with pulse grains were kept in the laboratory. Daily observation was made after one month of egg laid because bruchids adult usually emerge after 30 days of egg-laid. Observation was continued up to 15 days and removed the newly emerged beetles. A control treatment consisting of untreated grains was taken into account and each treatment replicated thrice. The adult emergence inhibition rate (%IR) was calculated by using the following formula:

$$\% \text{ IR} = \frac{\text{No. of insects in control grains - No. of insects in treated grains}}{\text{No. of insects in control grains}} \times 100$$

Number of damaged grains in each Petri dish was counted and percent grain damage inhibition (%DI) was calculated by the following formula:

$$\% \text{ DI} = \frac{\text{No. of damaged grains in control - No. of damaged grains in treatments}}{\text{No. of damaged grains in control}} \times 100$$

Statistical analysis

Probit analysis was employed in analyzing the dose-mortality response. LC_{50} and LC_{95} values and their fiducial limits were estimated. Data of the fecundity, adult emergence and grain damage inhibition were expressed as mean ± SD (Standard Deviation). Significance of mean differences among the treatments were statistically compared using GLM at 5% probability level. The individual pair wise comparisons were made using Tukey's HSD posthoc analysis through SPSS (IBM SPSS statistics 21).

Results and Discussion

The extracts of the weeds at 24h after treatment showed toxicity effect on adult *C. chinensis* (Table 1). Contact toxicity data revealed LC_{50} and LC_{95} values from 5.3 (4.2-9.3) to 7.8 (5.3-23.4) and 10.2 (7.3-20.2) to 16.9 (10.6-57.7) g /100 ml, respectively. Results demonstrated that the $\chi 2$ values of the data differed significantly ($p < 0.05$) and 'ghagra' extract was found to be the most effective. Its concentration response curve showed the steepest slope which indicated that small variations in the concentrations induced greater responses in mortality. The order of mortality activity of the weed extracts at 24h post treatment showed 'ghagra' > 'bonmorich' > 'dhakishak' > 'kashiature' > 'bhatpata'.

Table 1. Toxicity effect of five weed extracts on adult *Callosobruchus chinensis* exposed to24 h post treatment

Weed plant	Slope (± S.E)	LC^a50 (95% fl)	TR_{50}	$LC95^a$(95%fl)	TR_{95}	χ^2 (df)
Bhatpata	0.20 ± 0.05	7.8 (5.3 - 23.4)	-	16.9 (10.6 -57.7)	-	28.8 (13)
Kashiature	0.22 ±0.05	6.5 (4.4- 41.2)	1.20	15.3 (9.1-118.4)	1.10	36.8 (13)
Dhakishak	0.28 ± 0.05	5.9 (4.4 - 11.6)	1.32	12.2 (8.4-27.4)	1.39	28.8 (13)
Bonmorich	0.31 ± 0.05	5.3 (4.2 - 9.7)	1.47	11.0 (7.7-23.0)	1.54	34.0 (13)
Ghagra	0.33 ± 0.05	5.3 (4.2 - 9.3)	1.47	10.2 (7.3-20.2)	1.67	36.6 (13)

Each datum represents the mean of five replicates, each set up with 10 adults (n = 50). Concentrations are expressed as g/ ml. fl stands for fiducial limits. [a]Different concentrations (1, 2 and 4g/100 ml). SE= Standards Error.

Table 2. Toxicity effect of five weed extracts on adult *Callosobruchus chinensis* exposed to 48 h post treatment

Weed plant	Slope (± S.E)	LC^a50 (95% fl)	TR_{50}	$LC95^a$(95%fl)	TR_{95}	χ^2 (df)
Bhatpata	0.13 ± 0.04	6.5 (4.7 - 13.9)	-	18.7 (12.3 -46.2)	-	12.9 (13)
Kashiature	0.19 ± 0.04	6.1 (4.4- 16.5)	1.07	14.9 (9.5-47.7)	1.26	25.4 (13)
Dhakishak	0.26 ± 0.05	5.6 (4.6- 7.6)	1.16	11.9 (9.3-17.6)	1.57	13.9 (13)
Bonmorich	0.29 ± 0.05	4.9 (3.9 - 8.5)	1.33	10.8 (7.7-21.9)	1.73	31.5 (13)
Ghagra	0.33 ± 0.05	4.7 (4.1- 5.7)	1.38	9.6(7.9-12.5)	1.95	17.3 (13)

Each datum represents the mean of five replicates, each set up with 10 adults (n = 50). Concentrations are expressed as g/ ml. fl stands for fiducial limits. [a]Different concentrations (1, 2 and 4g/100 ml). SE= Standards Error.

The toxicity of the weed extracts against pulse beetle at 48h post treatment showed LC_{50} and LC_{95} values from 4.7 (4.1-5.7) to 6.5 (4.7-13.9) and 9.6 (7.9-12.5) to 18.7 (12.3-46.2) g/100 ml, respectively (Table 2). The results indicated that the χ^2 values of the data were significantly different ($p < 0.05$). The 'ghagra' extract revealed the lowest LC_{50} and LC_{95} values and the concentration response curve of this plant also showed the steepest slope. The order of toxicity of the weeds at 48h post treatment was 'ghagra' > 'bonmorich' > 'dhakishak' > 'kashiature' > 'bhatpata'.

When the n-hexane extracts of the weeds were examined for toxicity against *C. chinensis* at 72h post treatment, significant differences ($p < 0.05$) were observed (Table 3). The insecticidal activities of the weeds showed that their LC_{50} and LC_{95} ranged from 4.1 (3.4-5.7) to 6.0 (4.4-12.7) and 9.0 (6.9-14.3) to 18.6 (12.2-46.5) g/100 ml, respectively. Among the treatments, ghagra revealed the most toxic effect as it showed the lowest LC_{50} and LC_{95} values as well as steepest slope of the concentration curve. The order of toxicity of the weeds was 'ghagra' > 'bonmorich' > 'dhakishak' > 'kashiature' > 'bhatpata'.

Table 3. Toxicity effect of five weed extracts on adult *Callosobruchus chinensis* exposed to 72 h post treatment

Weed plant	Slope (± S.E)	$LC^{a}50$ (95% fl)	TR_{50}	$LC95^{a}$ (95%fl)	TR_{95}	χ^2 (df)
Bhatpata	0.14 ± 0.04	6.0 (4.4 - 12.7)	-	18.6 (12.2 -46.5)	-	13.5(13)
Kashiature	0.25 ± 0.04	4.6 (3.6- 8.3)	1.30	11.3 (7.8-24.5)	1.65	31.2 (13)
Dhakishak	0.28 ± 0.04	4.6 (3.7- 7.2)	1.30	11.1 (8.1-19.8)	1.68	22.2 (13)
Bonmorich	0.31 ± 0.04	4.2 (3.4-7.1)	1.43	10.0 (7.1-20.7)	1.86	38.1 (13)
Ghagra	0.36 ± 0.05	4.1 (3.4 - 5.7)	1.46	9.0 (6.9-14.3)	2.07	28.9 (13)

Each datum represents the mean of five replicates, each set up with 10 adults (n = 50). Concentrations are expressed as g/ ml. fl stands for fiducial limits. [a]Different concentrations (1, 2 and 4g/100 ml). SE= Standards Error.

The toxicity of the extracts clearly showed that insect mortality varied with weed species, extract concentrations and exposure periods. The weed species acted as a valuable source of insecticide. The ingredients of these weeds may have the ability to inject into the body of the beetles and dysfunction their nutritional balance, thus caused mortality. Adedire and Akinneye (2004) reported the mortality effect of *Tithonia diversifolia* flower extracts on *C. maculatus*. Botanical insecticides offer broad spectrum toxic substances that interrupt insect's normal physiology and behavior, and influence on their feeding, mating, oviposition and mortality (Fouad *et al.*, 2014).

The fecundity inhibition effects of the weed extracts on *C. chinensis* are presented in Table 4. The weed species ($F_{4,30}$ = 8.9, $p < 0.001$), extract concentrations ($F_{2,30}$ = 91.3, $p < 0.001$) and interaction of weed species and extract concentrations ($F_{8,30}$ = 2.6, $p < 0.05$) had significant effects on the fecundity. The extracts showed 31.7 ± 8.3 to 78.7 ± 1.2% fecundity inhibition and the most promising result was obtained by 4% 'ghagra'. It may be that the weeds have compounds with broad spectrum action affecting the life stages of the insect and inhibit their oviposition. Ambrósio *et al.* (2008) reported that the plant Mexican tournesol *Tithonia diversifolia* possessed sesquiterpene lactones which inhibited the oviposition of herbivore insects. The fecundity inhibition effects of the stem and flower extracts of kair *Capparis decidua* on caper *C. chinensis* have been reported by Upadhyay *et al.* (2006).

Table 4. Effect of five weed extracts on the fecundity inhibition (%mean ± SD) of *Callosobruchus chinensis*

Weed plant	% Fecundity inhibition at different extract concentration.		
	1g/100 ml	2g/100 ml	4g/100 ml
Bhatpata	31.7±8.3bB	60.6±2.8aAB	66.6±7.1aA
Kashiature	48.1±5.7cA	57.6±6.9abB	68.1±1.3aA
Dhakishak	49.1±6.3bA	60.9±2.0abAB	66.2±6.8aA
Bonmorich	49.3±1.5bA	65.3±2.0aAB	68.3±6.1aA
Ghagra	52.7±3.2cA	67.5±1.5bA	78.7±1.2aA

Values followed by the same small letter(s) on the same row or by the same capital letter(s) in the same column are not significantly different, as assessed by Tukey HSD Posthoc ($p \leq 0.05$). SE= Standard Error.

Table 5. Effect of five weed extracts on the adult emergence inhibition (%mean ± SD) of *Callosobruchus chinensis*

Weed plant	% Adult beetle emergence inhibition at different extract concentration.		
	1g/100 ml	2g/100 ml	4g/100 ml
Bhatpata	33.8 ± 4.4cD	48.2 ± 3.5abC	63.5 ± 2.5aC
Kashiture	35.8 ± 4.9cCD	54.6 ± 2.0abC	73.8 ± 1.5aB
Dhakishak	48.9 ± 4.8bBC	64.5 ± 5.4aB	66.5 ± 3.4aC
Bonmorich	53.0 ± 5.8bB	72.5 ± 3.4aAB	78.2 ± 2.4aAB
Ghagra	76.9 ± 5.1cA	78.2 ± 2.4bA	81.1 ± 1.4aA

Values followed by the same small letter(s) on the same row or by the same capital letter(s) in the same column are not significantly different, as assessed by Tukey HSD Posthoc ($p \leq 0.05$). SE= Standard Error.

The weed species ($F_{4,30} = 86.7$, $p < 0.001$), extract concentrations ($F_{2,30} = 139.2$, $p < 0.001$) and interaction of weed species and extract concentrations ($F_{8,30} = 9.7$, $p < 0.001$) showed significant effect on the adult beetle emergence (Table 5). Adult beetle emergence inhibition in different treatments varied from 33.8 ± 4.4 to 81.1 ± 1.4%. Among the treatments, 4% ghagra and 1% bhatpata revealed the highest and lowest level of inhibition, respectively.

Nennah (2011) reared *T. castaneum* and *R. dominica* on ground wheat grains mixed with methanolic extracts of harmel *Peganum harmala* seed and found abnormal larvae and pupae, as well as dose dependent adult emergence inhibition of the insects. In the present study, the weed extracts showed remarkable effect on the adult emergence of *C. chinensis*. The extracts revealed 33.8 to 81.1% adult emergence inhibition and the inhibitory activity of the extracts increased with increased concentration. Roy *et al.* (2012b) observed 37.0% adult emergence inhibition of *C. chinensis* with 4% aqueous extract of common cocklebur, *X. strumarium*.

Table 6 showed that the extracts possessed grain damage inhibition against *C. chinensis*. The effects of weed species ($F_{4,30} = 22.8$, $p < 0.001$), extract concentrations ($F_{2,30} = 92.6$, $p < 0.001$) and interaction of weed species and extract concentrations ($F_{8,30} = 3.9$, $p < 0.01$) differed significantly. Grain damage inhibition among the treatments varied from 10.3 ± 7.2 to 60.1 ± 3.8%, and the highest and lowest inhibition levels were attained by 4% ghagra and 1% bhatpata, respectively. The present findings indicated that the weed extracts had potential effect to control stored grain pest. The toxicity of the extracts might hamper food ingestion and feeding activity of the pests. Tavares *et al.* (2011) observed that the extracts of tournesol *T. diversifolia* reduced egg hatching of *Spodoptera frugiperda* and inhibited grain damage of *Triticum aestivum* both in the field and storage conditions.

Table 6. Effect of five weed extract on the grain damage inhibition (%mean ± SD) of mung bean from the attack of *Callosobruchus chinensis*

Weed plant	% Grain damage inhibition at different extract concentration.		
	1g/100 ml	2g/100 ml	4g/100 ml
Bhatpata	10.3 ± 7.2cB	26.8 ± 2.7bBC	50.2 ± 3.1aA
Kashiture	18.9 ± 7.3bAB	38.7 ± 5.7aB	39.6 ± 3.6aB
Dhakishak	20.6 ± 6.8cAB	24.4 ± 6.5abC	38.6 ± 5.5aB
Bonmorich	23.3 ± 6.3bAB	52.2 ± 5.5aA	59.8 ± 3.9aA
Ghagra	28.6 ± 2.8bA	57.0 ± 1.3aA	60.1 ± 3.8aA

Values followed by the same small letter(s) on the same row or by the same capital letter(s) in the same column are not significantly different, as assessed by Tukey HSD Posthoc ($p \leq 0.05$). SE= Standard Error.

Grain protection from the attack of insect pests without hampering environment is the main objective of the application of botanical pesticides. Plant materials possessed antifeedant substances and deterred insects from feeding and damaging grains (Amin *et al.,* 2000; Shahjahan and Amin, 2000; Roy *et al.,* 2010). The studied weed extracts protected mung bean grains from the attack of *C. chinensis* to a significant level (10.3 to 60.1%). This finding indicated that the weed extracts inhibited feeding behavior of the pest and protected the grains. Other authors have obtained similar results with different plant and insect species. Rahman and Talukder (2006) reported that 3% acetone extract of lagundi *Vitex negundo* revealed good protection for black gram seeds against *C. chinensis* infestation.

Plant materials are easy to manufacture and application and the studied weed species are very common in the rural areas of Bangladesh. The mixtures of weed materials with rapid and slow action insecticide might be useful in the protection of stored grains. In the present study, 4% ‘ghagra’ extract demonstrated the highest mortality and inhibited fecundity, adult emergence, as well as protected grains from infestation. So, the findings suggested that the ‘ghagra’ leaf extract as an alternative means of chemical insecticides may be used to save mung bean grains from the attack of *C. chinensis.* Further studies are needed to identify the toxic compounds, cost of treatment, effect of the odor and flavor on processed grains, toxicity of extract on non-target species including human and development of formulation for effective application.

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RESPONSES OF GARLIC TO ZINC, COPPER, BORON AND MOLYBDENUM APPLICATION IN GREY TERRACE SOIL OF AMNURA SOIL SERIES

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Abstract

A field experiment was conducted at the Spices Research Centre, Shibgonj, Bogra, Bangladesh during *rabi* (winter) seasons of 2008-09 and 2009-10 to determine the requirement of Zn, Cu, B and Mo of garlic (BARI Garlic 2) along with a blanket dose of cowdung 5 t, 100 kg N, 40 kg P, 100 kg K and 30 kg S/ha for achieving satisfactory bulb yield of this crop. Different levels of zinc (0, 1.0, 1.5, 3.0 and 4.5 kg/ha), copper (0, 0.5, 1.0 and 1.5 kg/ha), boron (0, 1.0, 2.0 and 3.0 kg/ha) and molybdenum (0, 0.5 and 1.0 kg/ha) were distributed in the plot. The experiment was tested in randomized complete block design with three replications. The positive impact of application of those nutrients plant height, number of leaves per plant, cloves per bulb, diameter and weight of bulb and yield of garlic up to a moderate level of $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha. The highest bulb yield (4.87 t/ha in 2008-09 and 6.6 t/ha in 2009-10) was obtained from $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha and yield was declined with higher dose of these elements except Mo. The fertilizer treatment $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha was observed to be the best suitable dose for garlic production on Grey Terrace Soil of Amnura Soil Series under AEZ-25 (Level Barind Tract) of Bangladesh.

Keywords: Garlic, growth, bulb yield, Zinc, Copper, Boron and Molybdenum.

Introduction

Garlic (*Allium sativum* L.) is the second most widely used spices crop of the cultivated *Allium* group, next to onion in the world (Purseglove, 1987). It has a characteristic pungent, spicy flavor that mellows and sweetens considerably with cooking (Katzer, 2005). The cloves are used as seed, for consumption (raw or cooked), and for medicinal purposes. It has higher nutritive value than other bulb crops as it is rich in proteins, P, K, Ca, Mg and carbohydrates and hence also finds medicinal usages especially in treating intestinal diseases, heart disease including atherosclerosis, high cholesterol, high blood pressure, and cancer (Balch, 2000; Durak *et al*., 2004). Most of the researches on nutrition of garlic limit the recommendation for major nutrients like N, P and K but micronutrients also play a vital role in deciding the growth and development of plants. Significant effects were noticed on yield and yield attributes of garlic when micronutrients were used (Chanchan *et al.*, 2013). Gupta and Ganeshe (2000)

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revealed that zinc sulfate (25kg/ha) + borax (10kg/ha) promoted yield marginally by 45.8kg/ha in garlic over the control (recommended dose of N, P and K. Application of boron at 0.1% + sodiummolybdate at 0.05% (w/v) recorded the highest healthy bulb yield and reduced premature field-sprouting of Cloves(Selvaraj *et al*., 2002). Srivastava *et al.* (2005) reported that boric acid at 0.1% and zinc sulfate at 0.4% resulted in maximum bulb yield and total soluble solids. Jermsiri *et al*. (1995) reported that applying borax to garlic increased the yield by 24-40%. The lack of experimental evidence on the response of garlic to the micronutrients necessitated the assessment of the efficacy of Zn, Cu, B and Mo in order to achieve its productivity potential. The present experiment was, therefore undertaken to assess the response of Zn, Cu, B and Mo on growth and yield of garlic in presence of N, P, K and S in Grey Terrace Soil of Amnura Soil Series under AEZ-25 (Level Barind Tract) of Bangladesh.

Materials and Method

The experiment was carried out at the Spices Research Centre, Shibgonj, Bogra, Bangladesh on Grey Terrace Soil of Amnura Soil Series under AEZ-25 (Level Barind Tract) during rabi (winter) season of two consecutive years i.e., 2008-2009 and 2009-2010. A description of some physical and chemical properties of experimental soil collected from a depth of 0-15 cm prior to application of fertilizers is presented in Table 1. The experiment was set up in Randomized Complete Block (RCB) design with 14 treatment combinations having three replications. The treatments included 5 levels of zinc (0, 1.0, 1.5, 3.0 and 4.5 kg/ha as zinc oxide), 4 levels of copper (0, 0.5, 1.0 and 1.5 kg/ha as copper sulfate), 4 levels of boron (0, 1.0, 2.0 and 3.0 t/ha as boric acid) and 3 levels of molybdenum (0, 0.5 and 1.0 kg/ha as sodium molybdate). A blanket dose of cowdung 5 t/ha, 100 kg N/ha as Urea, 40 kg P/ha from TSP, 100 kg K/ha as MOP and 30 kg S/ha as Gypsum were applied to each treatment. The whole amount of cowdung, TSP, MOP, Gypsum, Zinc oxide, Boric acid, Copper sulfate, Sodium molybdate applied as basal dose and 1/3rd urea was applied in two equal installments at 3rd and 6th week after transplanting. The cloves of garlic cv. BARI Garlic-2 were planted on 30 October of both years in 3 m x 3 m plot at 15 cm x 10 cm spacing. The first irrigation was given immediately after planting. The intercultural operations (four irrigations, three weeding and Rovral + Ridomil Gold/Antracol + Gain spray every 10 days interval for controlling diseases and insects pest) were done in the cropping period. The observations on growth parameters like plant height and number of leaves were recorded at 100 days after planting (DAP). The bulb of garlic was harvested on 27 March, 2009 and 30 March, 2010 at it was fully matured. Ten bulbs were selected randomly from each treatment for counting number of cloves and recorded bulb size and single bulb weight. The total weight of bulb per plot was recorded to obtain the yield per hectare. The data were subjected to statistical analysis by using

MSTAT-C software to find out the significance of variation resulting from the experimental treatments. The difference between the treatment means were judged by Duncan's Multiple Range Test (DMRT) at 5% level of probability according to Gomez and Gomez (1984).

Table 1. Soil properties of the experimental site during 2008-09 and 2009-10

Texture	pH	OM %	Ca	Mg	K	Total N	P	S	B	Zn	Cu	Mn	Mo
			(meq/100g soil)			%	(µg/g soil)						
2008-09													
Sandy loam	5.4	1.00	1.6	0.71	0.30	0.053	14	15.1	0.12	0.91	0.08	2.0	0.05
2009-10													
Clay loam	5.7	0.89	1.9	0.77	0.56	0.043	13	15.5	0.09	0.96	0.06	2.0	0.05
Critical level	-	-	2.0	0.5	0.12	-	07	10	0.2	0.6	0.2	1.0	0.1

Results and Discussion

Plant height recorded at 100 days after planting (DAP) reveled that no significant variations were observed in the year 2008-09 and significant variations in the year 2009-10 among different treatments (Table 2). The tallest plant (25.6 cm and 60.43 cm) was recorded in treatment $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha in both the years (2008-09 and 2009-10, respectively), while smallest plant was recorded in control. Number of leaves per plant differed significantly due to application of micronutrients (Table 2) revealed that maximum number of leaves per plant (8.47 and 8.9) were found with the application of $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha in both the years (2008-09 and 2009-10, respectively). Chanchan *et al.* (2013) also obtained similar results. This was probably due to the availability of more nutriment elements to plant at which could produce more leaves resulting more photosynthetic production. The bulb size i.e., bulb length and bulb diameter was significantly influenced by different levels of micronutrients (Table 2). The Longest bulb (4.53 cm and 7.77 cm) were found with the application of $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha, while the smallest bulb in control in the year 2008-09 and 2009-10, respectively. The maximum bulb diameter (4.9 cm) was noticed with the application of $Zn_{3.0}Cu_{1.0}B_{2.0}Mo_{0.5}$ kg/ha in the year 2008-09 and the maximum bulb diameter (7.2 cm) was found with the application of $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha and $Zn_{3.0}Cu_{1.0}B_{2.0}Mo_{0.5}$ kg/ha in the year 2009-10, while the minimum bulb diameter were found in control both the years. Bulb size seems to be the most important component closely related with yield per hectare. The favorable effects of micronutrients might be attributed due to its involvement in cell division and cell expansion, improve physiological activities like photosynthesis during food manufactured by the plant and translocate in the bulb.

Table 2. Influence of micronutrients on vegetative growth of garlic

Treatment	Plant height (cm)		No. of leaves per plant		Bulb size			
					Bulb length (cm)		Bulb diameter (cm)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
$Zn_0Cu_{1.0}B_{2.0}Mo_{1.0}$	23.33	49.50b	7.8ab	7.83d	3.03f	5.03de	4.10bc	5.30cd
$Zn_{1.0}Cu_{1.0}B_{2.0}Mo_{1.0}$	25.13	55.83a	7.73b	8.33bc	3.47def	5.87b-e	4.40ab	5.67a-d
$Zn_{1.5}Cu_{1.0}B_{2.0}Mo_{1.0}$	23.67	58.77a	7.87ab	8.30bcd	3.63c-f	5.87b-e	4.40ab	6.13abc
$Zn_{3.0}Cu_{1.0}B_{2.0}Mo_{1.0}$	23.53	59.27a	7.90ab	8.50abc	4.33ab	6.97abc	4.73ab	7.03ab
$Zn_{4.5}Cu_{1.0}B_{2.0}Mo_{1.0}$	23.20	59.20a	7.07c	8.47abc	4.10a-d	6.77abc	4.40ab	7.00abc
$Zn_{3.0}Cu_0B_{2.0}Mo_{1.0}$	25.00	58.13a	8.07ab	8.07cd	3.63c-f	6.13a-d	3.40d	6.40abc
$Zn_{3.0}Cu_{0.5}B_{2.0}Mo_{1.0}$	24.67	58.13a	7.93ab	8.40bc	4.20abc	6.30a-d	4.723ab	6.63abc
$Zn_{3.0}Cu_{1.5}B_{2.0}Mo_{1.0}$	24.30	60.27a	8.13ab	8.60ab	4.47a	7.60a	4.87a	6.47abc
$Zn_{3.0}Cu_{1.0}B_0Mo_{1.0}$	22.60	56.10a	8.07ab	8.23bcd	3.13ef	5.63cde	3.20d	5.67a-d
$Zn_{3.0}Cu_{1.0}B_{1.0}Mo_{1.0}$	23.00	60.43a	8.07ab	8.60ab	4.00a-d	6.87abc	4.80ab	6.47abc
$Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$	25.60	61.30a	8.47a	8.90a	4.53a	7.77a	4.80ab	7.20a
$Zn_{3.0}Cu_{1.0}B_{2.0}Mo_0$	22.73	58.03a	7.87ab	8.20bcd	3.17ef	6.27a-d	3.57ed	5.40bcd
$Zn_{3.0}Cu_{1.0}B_{2.0}Mo_{0.5}$	23.27	59.97a	8.17ab	8.20bcd	3.73b-e	7.37ab	4.90a	7.20a
$Zn_0Cu_0B_0Mo_0$	22.47	34.87c	7.73b	7.13e	1.80g	4.43e	2.37e	4.23d
CV (%)	**6.36**	**6.12**	**4.63**	**2.98**	**9.67**	**13.25**	**8.72**	**13.85**

Treatment means having common letter(s) are not significantly different from each other at 5% level of probability by DMRT.

Data presented in Table 3, indicated that different levels of micronutrients had significant variations on number of cloves per bulb. Maximum number of cloves per bulb (40.37) was observed with the application of $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha and $Zn_{3.0}Cu_{1.0}B_{2.0}Mo_{0.5}$ kg/ha in the year 2008-09 and in year 2009-10 the maximum number of cloves per bulb (45.37) was recorded with $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha. The minimum number of cloves per bulb (20.07 and 21.13) was noticed with control in both years. These parameters could be used as indicators of improving yield potential in garlic. These results are in accordance with the research findings of (Selvaraj *et al*., 2002 and Srivastava *et al*., 2005). The effect of different levels of applied micronutrient on single bulb weight of garlic was statistically significant (Table 3). The maximum weight of single bulb (28.93 g in 2008-09 and 41.70 g in 2009-10) was recorded from $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha treatment, while minimum value (18.33 g in 2008-09 and 23.83 g in 2009-10) noticed in control. Bulb yield is more important than total biological yield which results from different combinations of many physiological processes based on the environment under which the crop was grown. The maximum bulb yield (4.87 t/ha in 2008-09 and 6.6 t/ha in 2009-10) were recorded in $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha treatment, while minimum bulb yield (2.3 t/ha in 2008-09 and 2.9 t/ha in 2009-10) were in control (Table 3).

Table 3. Effect of micronutrients yield and yield attributes of garlic

Treatment	No. of Cloves per bulb		Weight of single bulb (g)		Yield of bulb (t/ha)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
$Zn_0Cu_{1.0}B_{2.0}Mo_{1.0}$	30.23d	24.70fg	22.27de	26.87ef	3.30d	3.3fg
$Zn_{1.0}Cu_{1.0}B_{2.0}Mo_{1.0}$	33.80bcd	33.93cde	22.83cde	26.60ef	3.57d	3.9ef
$Zn_{1.5}Cu_{1.0}B_{2.0}Mo_{1.0}$	35.53abc	33.93cde	24.47b-e	27.23ef	4.17bc	4.2de
$Zn_{3.0}Cu_{1.0}B_{2.0}Mo_{1.0}$	39.47a	42.60ab	26.50abc	38.27ab	4.43abc	6.4a
$Zn_{4.5}Cu_{1.0}B_{2.0}Mo_{1.0}$	37.37ab	37.97a-d	24.93bcd	31.00cde	4.27bc	5.4bc
$Zn_{3.0}Cu_0B_{2.0}Mo_{1.0}$	34.27bcd	37.20b-e	22.27de	32.27b-e	3.40d	3.7efg
$Zn_{3.0}Cu_{0.5}B_{2.0}Mo_{1.0}$	39.77a	38.63a-d	25.27a-d	29.23def	4.10c	4.8cd
$Zn_{3.0}Cu_{1.5}B_{2.0}Mo_{1.0}$	36.50a	40.00a-d	25.67a-d	33.30b-e	4.67ab	5.3c
$Zn_{3.0}Cu_{1.0}B_0Mo_{1.0}$	36.87abc	29.40ef	20.80ef	28.27ef	3.40d	4.1def
$Zn_{3.0}Cu_{1.0}B_{1.0}Mo_{1.0}$	39.57a	43.37ab	24.87bcd	35.03bcd	4.47ab	5.5bc
$Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$	40.37a	45.37a	28.93a	41.70a	4.87a	6.6a
$Zn_{3.0}Cu_{1.0}B_{2.0}Mo_0$	32.57cd	33.07de	23.50cde	29.30def	3.30d	3.7efg
$Zn_{3.0}Cu_{1.0}B_{2.0}Mo_{0.5}$	40.37a	41.50abc	27.90ab	36.53abc	4.57abc	6.2ab
$Zn_0Cu_0B_0Mo_0$	20.07e	21.13g	18.33f	23.83f	2.30e	2.9g
CV (%)	**6.99**	**11.86**	**8.17**	**10.75**	**6.99**	**9.71**

Treatment means having common letter(s) are not significantly different from each other at 5% level of probability by DMRT.

The improvement on growth and yield of garlic might be due to the enhanced enzymatic and photosynthetic activity and greater translocation rate due to the influence of micronutrients. The entire favorable effect was also attributed to the fact that the micronutrients were essential in better absorption of water, macronutrients uptake and metabolism. The higher bulb yield of garlic may be attributed to improved growth parameters and yield components which ultimately resulted in higher bulb yield and also due to the supply of micronutrients and indirectly the physical condition of soil viz., aggregation, aeration, permeability, water holding capacity and biological condition of soil, which resulted in significantly higher bulb yield of garlic.

Conclusion

Zinc, copper, boron and molybdenum played an important role in increasing growth and bulb yield of garlic. The fertilizer treatment $Zn_{3.0}Cu_{1.0}B_{3.0}Mo_{1.0}$ kg/ha was found to be the best suitable dose for garlic cultivation in Grey Terrace Soil of Amnura Soil Series under AEZ-25 (Level Barind Tract) of Bangladesh.

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RESPONSE OF N, P AND K ON THE GROWTH AND FLOWERING OF HIPPEASTRUM (*Hippeastrum hybridum* Hort.)

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Abstract

An experiment was conducted at the Horticultural Research Field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur during September 2008 to May 2009 to determine the response of hippeastrum (cu. 'Apple Blassom) to different combinations of nitrogen, phosphorus and potassium levels. There were 14 treatment combinations comprising four levels of nitrogen viz. 0, 100, 200, and 300 kgha^{-1}; five levels of phosphorus viz. 0, 200,300, 400 and 500 kgha^{-1} and five levels of potassium viz. 0, 100, 200, 300 and 400 kgha^{-1} with an exclusively Cowdung treatment at the rate of 10 tha^{-1} . The experiment was laid out in a Randomized Complete Block Design with three replications. The growth and flowering parameter of hippeastrum were significantly influenced by combined application of N, P & K.The highest values in respect of leaves per plant (8.6), leaf breadth (5.4 cm), number of plants per bulb (3.07), flower scape per plant (2.07), flowers per scape (4.2), length and diameter of flower (14 cm x 13.83 cm), flower scape (43.33 cm x 29.37 cm) and flowering duration (10.7 days) were observed with $N_{200}P_{400}K_{300}$. The same treatment showed earliness in days to flower scape emergence (172.3 days), days to flower bud appearance (185.3 days) and days to first flower open (189.3 days). The biggest flower (14.00 cm x 13.83 cm), longest flower scape (43.33 cm), maximum number of flowers per scape (4.20), and maximum flowering duration (11.5 days) were also exhibited by the treatment $N_{200}P_{400}K_{300}$ .The control treatment ($N_0P_0K_0$) recorded the lowest values except days to first leaf emergence, days to flower scape emergence, days to flower bud appearance and days to first flower open.

Keywords: Hippeastrum, Nitrogen, Phosphorus, Potassium, flower yield.

Introduction

Hippeastrum (*Hippeastrum hybridum* Hort.) is a newly introduced flower in Bangladesh. It is an ornamental bulbous flowering plant belonging to the family Amaryllidaceae having large and showy flowers with many bright colours (Zandbergen, 1980) which is commonly known as Royal Dutch Amaryllis (Jana, 1995). They are suitable for planting in the bed, pot, rockery, shrubbery, greenhouse

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garden and also in landscaping. This flower is cultivated to a small scale in the peri-urban areas primarily for the supply to some city markets. Being a new crop, its fertilizer management is not known. As most of the soils of Bangladesh are deficient in major nutrients particularly N, P & K, so judicial application of those nutrients can play a good role in successful production of hippeastrum.

Response of every crop in Bangladesh to nitrogen application is well documented since this element is deficient all over the country. Nitrogen is absorbed as NH_4^+ form by young plants whereas NO_3^- is the principal form utilized during the late growth stages. However, plants vary in their proportion of ammonium versus nitrate utilization (Bennett, 1993).

Proper management of nitrogen fertilization for hippeastrum bulb production is critical. Several studies showed that when bulbous plants are cultivated on the field, multiple applications of smaller amounts of nitrogen are the most efficient in reducing nitrate losses through leaching. Usually it is recommended that one third of the nitrogen is applied early in the growing season (1-8 weeks after planting) and the remaining two thirds of nitrogen will be applied in the late part of the growing season. This approach ensures nitrogen availability during the vegetative and reproductive phase of most bulbous plants (Slangen *et al.*, 1989; Batal *et al.*, 1994; Diaz-perez *et al.*, 2003).

Phosphorus deficiency is considered as one of the major constraints to successful crop production. The ion absorption is determined by the pH of the soil. There is a notable effect of nitrogen on phosphorus uptake by plants.

Potassium is important in cell growth primary by through its effect on cell extension. With adequate potassium, cell walls are thicker and provide more tissue stability. This effect on cell growth normally improves resistance to lodging, pests and diseases. Potassium is required for production of high energy phosphate and is involved in starch as well as protein synthesis (Bennett, 1993).

Attention should therefore, be paid to the proportionate application of nitrogen, phosphorus and potassium. An excess amount of one nutrient element causes a relative or absolute deficiency of the other nutrients. The opposite is also true if there is a deficiency of some nutrient. In both cases the result is an "unbalanced diet" for the plants (Bergmann, 1992). In such a situation, balanced application of N, P & K which are deficient in most of our soils is imperative. Keeping this point in mind, the present study was undertaken to determine the response of hippeastrum to the application of different combinations of nitrogen, phosphorus and potassium levels.

Materials and Method

The experiment was carried out at the Horticultural Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur during September 2008 to May 2009.The experimental site was located in the centre of the Madhupur Tract at about 24.09^0 North latitude and 90.26^0 East longitude having a mean elevation of 8.5 m on the sea level. The soil of the experimental field belongs to Salna series of Shallow Red Brown Terrace Soils. The soil is silty clay loam in texture and acidic in nature being characterized by poor fertility status and impeded internal drainage. Chemical characteristics of soil were pH 6.2, organic matter content 0.95%, total N 0.05%, available P 26.0 mg kg^{-1}, copper 5.0 mg kg^{-1}, iron 53.0 mg kg^{-1}, manganese 46 mg kg^{-1}, exchangeable K 0.3 meq100^{-1}g soil, available S 13.6 mg kg^{-1}, and available Zn 1.86 mg kg^{-1} (Golder, 2000).

The experiment was laid out in a Randomized Complete Block Design with three replications. The total number of unit plots were 42 (14 x 3), each measuring 1.0 m x 1.0 m with 30 cm ridge around each plot and the blocks and plots were separated by 1.0m and 0.75m, respectively. There were 14 treatment combinations comprising four levels of nitrogen viz. 0, 100, 200, and 300 kgha^{-1}; five levels of phosphorus viz. 0, 200, 300, 400 and 500 kgha^{-1} and five levels of potassium viz. 0, 100, 200, 300 and 400 kgha^{-1} with cowdung treatment at the rate of 10 tha^{-1}. The treatment combinations are shown in Table 1 under Result and Discussion section.

Nitrogen, phosphorus and potassium were applied in the form of urea, triple super phosphate (TSP) and muriate of potash (MOP), respectively. The entire quantity of cowdung and TSP and one-third each of urea and MOP were applied during plot preparation. The rest of urea and MOP were applied in two equal installments, 30 and 60 days after emergence. The variety of Hippeastrum used was Apple Blossom. Intercultural operations like irrigation, weeding, pest and disease control measures were taken as and when required. Data on different growth and flowering characteristics were collected from randomly selected 10 plants of each individual plots. The flower scape was cut when the buds were fully elongated. Harvesting was done early in the morning and the stalks were placed in water. The recorded data for different characters were analyzed statistically using MSTAT- C to find out the variation among the treatments. Treatment means were compared by Duncan's Multiple Range Test (DMRT) for interpretation of results (Gomez and Gomez, 1984).

Results and Discussion

The effect of different levels of nitrogen, phosphorus and potassium application on the growth and flowering of Hippeastrum cv. Apple Blossom are shown in different tables and figures.

Days to first leaf emergence

Days required for the first leaf emergence of hippeastrum varied significantly with different levels of N, P & K application (Table 1). It appears that the earliest leaf emergence (15.3 days) commenced with the treatment T_4 ($N_{300}P_{400}K_{300}$) and T_{13} (cowdung 10 tha^{-1}) and are statistically similar with T_3 ($N_{200}P_{400}K_{300}$) while 36.0 days were required for treatment T_9 ($N_{200}P_{400}K_0$). Thus, higher dose of N, P & K combination and cowdung alone were most suitable for the first leaf emergence of hippeastrum bulb, but in absence of K and other combination of N and P it took longer time for the first leaf emergence.

Leaves per plant

Active leaf number was counted and highly significant variation was found due to different levels of N, P & K treatment (Table 1). Leaf number varied from 5.40 to 8.60 per plant. The highest number of leaves (8.60) was recorded with the treatment T_3 ($N_{200}P_{400}K_{300}$) which was statistically similar with T_{11} ($N_{200}P_{400}K_{200}$), T_{12} ($N_{200}P_{400}K_{400}$), T_5 ($N_{200}P_0K_{300}$) and T_{10} ($N_{200}P_{400}K_{100}$). The lowest number of leaves per plant was noted with the control T_{14} ($N_0P_0K_0$). Similar results were also reported by Dash *et al.* (2003) and Jaggi (2005) in onion. Shah *et al.* (1984) observed that higher doses of N, P & K encouraged producing higher number of leaves per plant in gladiolus.

Plant height

Plant height of hippeastrum was measured after flowering. It was observed that plant height was influenced significantly by different levels of N, P & K application (Table 1). The tallest plant (63.8 cm) was recorded in T_4 ($N_{300}P_{400}K_{300}$) and the shortest plant (48.1 cm) was found in control (T_{14}). The maximum vegetative growth was recorded with the application of higher levels of nitrogen. Shah *et al.* (1984) also found in gladiolus that increasing N rates influenced the plant growth. Maximum vegetative growth in tuberose with the highest dose of 300 kg Nha^{-1} was recorded by Yadav *et al.* (1985).

Leaf breadth

Leaf breadth of hippeastrum varied from 4.13cm to 5.40 cm over the treatments (Table 1). The broadest leaf (5.40cm) was recorded with T_3 ($N_{200}P_{400}K_{300}$) which was followed by and statistically similar with T_{10} ($N_{200}P_{400}K_{100}$), T_{11} ($N_{200}P_{400}K_{200}$), T_7 ($N_{200}P_{300}K_{300}$), T_{13} (cowdung @ 10 tha^{-1}), T_2 ($N_{100}P_{400}K_{300}$) and T_6 ($N_{200}P_{200}K_{300}$). The narrowest leaf (4.13cm) was produced from the control treatment ($N_0P_0K_0$) produced. This result is in agreement with that of Prodhan *et al.* (2004) reporting that combined application of N at 400 $kgha^{-1}$ and K at 300 $kgha^{-1}$ showed the highest values for leaf area. Low levels of nitrogen and phosphorus reduced the growth and affected flowering in tulip, as reported by Cheal and Winsor (1986).

Plantlets bulb^{-1}

Plantlets per bulb of hippeastrum were counted at the time of bulb lifting from the plot. Highly significant variation occurred in plantlets per bulb due to different N, P & K treatments (Table 1). The maximum plantlets per bulb (3.07) was obtained from the treatment T_3 ($N_{200}P_{400}K_{300}$) followed by T_{12} ($N_{200}P_{400}K_{400}$), T_{13} (cowdung @ 10 tha^{-1}) and T_{10} ($N_{200}P_{400}K_{100}$). The T_{14} (control) treatment produced the minimum (1.60) plantlets per bulb; it was statistically similar to T_1 ($N_0P_{400}K_{300}$), T_2 ($N_{100}P_{400}K_{300}$) and T_{11} ($N_{200}P_{400}K_{200}$). Similar result was also reported by Jana and Bose (1980) in hippeastrum where they obtained the maximum yield of bulbs, bulb-lets and flowers with a combined application of 200 kg N, 400 kg P and 200 kg K per hectare.

Table 1. Growth characteristics of hippeastrum under different levels of N, P & K application

Treat-ment	Treatment combination (kg ha^{-1})			Days to first leaf emergence	Leaves plant^{-1} (no.)	Plant height (cm)	Leaf breadth (cm)	Plantlets bulb^{-1} (no.)
	N	P	K					
T_1	0	400	300	27.0 cd	6.00 bc	51.5 def	4.67 bc	1.67 c
T_2	100	400	300	23.7 de	6.40 bc	50.3 ef	4.93 ab	1.73 c
T_3	200	400	300	16.0 gh	8.60 a	55.5 bcd	5.40 a	3.07 a
T_4	300	400	300	15.3 h	6.80 bc	63.8 a	4.67 bc	2.00 bc
T_5	200	0	300	29.0 bc	7.40 ab	55.9 bcd	4.80 ab	2.13 bc
T_6	200	200	300	31.7 b	6.47 bc	54.8 b-e	4.93 ab	1.80 bc
T_7	200	300	300	23.3 e	5.87 bc	53.7 cde	5.00 ab	2.2 bc
T_8	200	500	300	19.3 fg	6.40 bc	57.2 bc	4.53 bc	2.07 bc
T_9	200	400	0	36.0 a	6.93 abc	53.4 cde	4.60 bc	2.20 bc
T_{10}	200	400	100	30.3 bc	7.00 abc	51.6 def	5.07 ab	2.33abc
T_{11}	200	400	200	22.3 ef	7.67 ab	55.3 b-e	5.00 ab	1.80 c
T_{12}	200	400	400	20.3 ef	7.47 ab	59.5 ab	4.67 bc	2.60 ab
T_{13}	Only cowdung 10 t/ha.			15.3 h	6.53 bc	51.6 def	5.00 ab	2.40 abc
T_{14}	control			29.0 bc	5.40 c	48.1 f	4.13 c	1.60 c
Level of significance				**	**	**	*	**
CV(%)				5.71	9.58	3.28	6.81	13.54

Means having same letter(s) and without letter(s) in a column are not significant by DMRT. ** indicates significant at 1% level, * indicates significant at 5% level.

Days to flower scape emergence

Days taken to flower scape emergence of hippeastrum was significantly affected by different levels of NPK fertilizers and cowdung alone (Table 2). The earliest flower scape emerged at 172.3 days after planting (DAP) in T_3 ($N_{200}P_{400}K_{300}$) and was statistically at par with T_6, T_{11}, T_{12}, T_{13}, T_4, T_5, T_3 and T_2 while late flower scape emergence at 194.3 DAP was found with control i.e. ($N_0P_0K_0$) which was statistically similar with treatment T_7 ($N_{200}P_{300}K_{300}$), T_8 ($N_{200}P_{500}K_{300}$) and T_9 ($N_{200}P_{400}K_0$). Jana (1995) from microscopical studies on hippeastrum reported that the application of fertilizer needs to be completed by the onset of flower initiation which happened to be 120 days after planting of bulbs.

Days to flower bud appearance

Time required to flower bud appearance of hippeastrum varied significantly with different N, P & K treatments (Table 2). Early flower bud (185.3 DAP) was found in T_3 ($N_{200}P_{400}K_{300}$) followed by T_{12} ($N_{200}P_{400}K4_{00}$) and T_6 ($N_{200}P_{200}K_{300}$). The plant in control treatment ($N_0P_0K_0$) took the maximum time (207.3 DAP) to produce flower bud in the experiment. This result is an agreement with the findings of Bhattacharjee (1981) who found that application of 200 kg of N per hectare induced early flowering in gladiolus cv. 'Friendship' over lower doses whereas in the cultivar 'Vink's Glory' an addition of 500 kg Nha^{-1} resulted in delayed flowering (Shah *et al.*, 1984).

Days to first flower open

Non-significant difference was observed in case of first flower open of hippeastrum by different levels of N,P & K fertilizers (Table 2). However, it can be revealed that days to the first flower open was the earliest (189.3 DAP) in T_3 ($N_{200}P_{400}K_{300}$) which was closely followed by T_{12} ($N_{200}P_{400}K_{400}$) and T_6 ($N_{200}P_{200}K_{300}$). The control ($N_0P_0K_0$) plant took the longest time (212.0 DAP) for the first flower open. The results are in agreement with the findings of Singh and Akhilesh (2003) who explained earlier flowering with K at the rate of 90 and 120 $kgha^{-1}$.

Flower scape per plant

Flower scape per plant of hippeastrum was counted at the time of flower harvested. Significant variation was observed in the number of flower scape per plant due to different levels of N,P & K fertilizers and cowdung alone (Table 2). The highest number of flower scape per plant (2.07) was observed in T_3 ($N_{200}P_{400}K_{300}$) which was closely followed by T_{13} (cowdung @ 10 tha^{-1}) and the lowest (1.00) was in the control ($N_0P_0K_0$). In a sand culture experiment, Bose *et al.* (1980) reported that treatment with high level of nitrogen caused maximum plant growth and number of flower stalks and flowers. Treatment with phosphorus at the rate of 400 kg per hectare significantly increased the number of flower stalks and flowers as reported by Jana and Bose (1980).

Table 2. Flowering characteristics of hippeastrum under different levels of nitrogen, phosphorus and potassium application

Treatment	Treatment combinations ($kgha^{-1}$)			Days to flower scape emergence	Days to flower bud appearance	Days to first flower open	Flower scapeplant^{-1} (no.)
	N	P	K				
T_1	0	400	300	184.0 a-d	198.0 a-d	204.0	1.07 e
T_2	100	400	300	182.3 a-d	196.0 a-d	200.0	1.27 cde
T_3	200	400	300	172.3 d	185.3 d	189.3	2.07 a
T_4	300	400	300	180.7 a-d	193.7 a-d	198.7	1.93 abc
T_5	200	0	300	181.3 a-d	192.3 a-d	196.7	1.07 e
T_6	200	200	300	176.7 cd	189.3 bcd	193.7	1.33 b-e
T_7	200	300	300	192.7 ab	207.0 a	211.7	1.40 a-e
T_8	200	500	300	190.7 abc	205.0 ab	208.7	1.60 a-e
T_9	200	400	0	190.7 abc	203.3 abc	207.3	1.13 de
T_{10}	200	400	100	188.7 abc	201.0 a-d	207.3	1.60 a-e
T_{11}	200	400	200	179.7 a-d	192.7 a-d	198.0	1.20 de
T_{12}	200	400	400	176.7 bcd	187.7 cd	192.7	1.80 a-d
T_{13}	Only cowdung 10 t/ha.			180.0 a-d	194.3 a-d	196.0	2.00 ab
T_{14}	control			194.3 a	207.3 a	212.0	1.00 e
Level of significance				*	*	ns	**
CV (%)				4.34	4.17	4.39	17.34

Means having same letter(s) and without letter(s) in a column are not significant by DMRT. ** indicates significant at 1% level, * indicates significant at 5% level and 'ns' indicates non-significant.

Flowers per scape

Highly significant difference was observed in number of flowers per scape of hippeastrum due to different levels of N, P & K fertilizers (Table 3). The maximum flowers per scape (4.20) was produced by the plant in T_3 ($N_{200}P_{400}K_{300}$) which was statistically similar with T_{13} (cowdung @ 10 tha^{-1}), T_8 ($N_{200}P_{500}K_{300}$) and T_{11} ($N_{200}P_{400}K_{200}$) whereas, the minimum (2.00) flowers per scape was noted with no N, P & K application ($N_0P_0K_0$). The result is in agreement with the findings of Bhattacharjee *et al.* (1982) who stated that the number of flowers per plant increased with the application of NPK.

Flower length

A noticeable variation in the length of flower was recorded due to application of different levels of N, P & K and cowdung application alone (Table 3). The longest flower (14.0 cm) was measured with T_3 ($N_{200}P_{400}K_{300}$) which was statistically similar with that of T_{13} (cowdung @10 tha^{-1}), T_{12} ($N_{200}P_{400}K_{400}$) and T_{10} ($N_{200}P_{400}K_{100}$). The shortest flower (10.67 cm) was produced with control ($N_0P_0K_0$). Similar result was also reported by Jana and Bose (1980) who observed that the number of flowers and their size (diameter and length) were improved under high levels of nitrogen and phosphorus.

Flower diameter

Flower diameter was significantly influenced by different levels of N, P & K supplement (Table 3). The biggest flower diameter of 13.83 cm was found in plants grown under T_3 ($N_{200}P_{400}K_{300}$) which was statistically similar with T_{13} (cowdung @ 10 tha^{-1}) and T_{12} ($N_{200}P_{400}K_{400}$). The smallest flower diameter of 10.00 cm was recorded with the control treatment. This might be due to higher dose of nitrogen in combination with optimum dose of potassium and phosphorus leading to the better growth and development of plants resulted in high flower diameter in T_3 treatment. This result is in agreement with the findings of Singh *et al.* (1965) and Bhattacharjee *et al.* (1982).

Flower scape length

Flower scape length of hippeastrum was measured at the time of harvesting. Flower scape length was influenced significantly by different levels of N P K fertilizers and cowdung alone (Table 3).The longest flower scape (43.3 cm) was recorded in T_3 ($N_{200}P_{400}K_{300}$) and the shortest flower scape (26.0cm) was produced by control ($N_0P_0K_0$) treatment. This might be due to fact that increasing N rates delayed flowering but influenced plant growth in terms the number of $leavesplant^{-1}$, spike length and number of $floretsspike^{-1}$. The results are in close agreement with the findings of Bhattacharjee (1981) who reported that 200 kg Nha^{-1} increased flower spike length of tuberose. Similar results were also reported by Bankar and Mukhopadhyay (1980) in tuberose and Gowda *et al.* (1988) in gladiolus.

Flower scape diameter

Different levels of N, P & K fertilizers exhibited significant variation on flower scape diameter of hippeastrum (Table 3). The maximum value for flower scape diameter (29.4cm) was obtained with T_3 ($N_{200}P_{400}K_{300}$) and the minimum (20.00 cm) was recorded with plants that grown without application of N, P & K fertilizers. Jana and Bose (1980) observed that bulbs grown under $N_{200}P_{400}$ produced the widest flower stalks, whereas the narrowest flower stalk appeared in plants under N_0P_0 which is comparable with the present study.

Table 3. Effect of N, P & K on flower and flower scape characteristics of hippeastrum

Treat-ment	Treatment combinations ($kgha^{-1}$)			Flowers $Scape^{-1}$ (no.)	Flower length (cm)	Flower diameter (cm)	Flower scape length (cm)	Flower scape diameter (mm)
	N	P	K					
T_1	0	400	300	2.13 d	11.00 gh	10.17 hi	32.00 b	23.57 b
T_2	100	400	300	2.73 bcd	11.17 fgh	11.50 d-g	26.00 b	23.85 b
T_3	200	400	300	4.20 a	14.00 a	13.83 a	43.33 a	29.37 a
T_4	300	400	300	3.67 ab	12.67 bcd	12.17 c-f	26.00 b	22.29 bc
T_5	200	0	300	2.67 bcd	11.50 e-h	10.83 ghi	29.67 b	23.04 b
T_6	200	200	300	3.53 ab	12.00 c-g	11.33 e-h	27.33 b	21.82 bc
T_7	200	300	300	3.20 abc	12.17 b-f	12.17 c-f	31.00 b	23.81 b
T_8	200	500	300	4.00 a	12.50 b-e	11.83 c-g	31.00 b	23.83 b
T_9	200	400	0	2.40 cd	11.67 d-h	11.17 f-i	33.00 b	24.00 b
T_{10}	200	400	100	3.60 ab	13.00 abc	12.67 a-d	33.00 b	24.26 b
T_{11}	200	400	200	3.87 a	12.50 b-e	12.50 b-e	30.83 b	24.12 b
T_{12}	200	400	400	3.67 ab	13.17 ab	12.83 abc	29.17 b	23.18 b
T_{13}	Only cowdung @10 t/ha.			4.07 a	13.83 a	13.50 ab	31.50 b	23.60 b
T_{14}	control			2.00 d	10.67 h	10.00 i	26.67 b	20.00 c
Level of significance				**	**	**	**	**
CV (%)				11.38	3.11	3.84	8.11	4.24

Means having same letter(s) in a column are not significant by DMRT. ** indicates significant at 1% level.

Flowering duration

Highly significant variation was observed in freshness of flowers produced under different levels of N, P & K application and cowdung alone (Fig. 1). It was found that flowers produced in T_3 ($N_{200}P_{400}K_{300}$) remained fresh for longer period (10.7 days) which was statistically varied with other treatments except the treatments T_7 ($N_{200}P_{300}K_{300}$) and T_{13} (Cowdung @ $10tha^{-1}$). The shelf life of flowers was the lowest (4.7 days) in control. The increased flowering duration could be attributed to the increased phosphorus levels in the experiment. Similar findings were also observed by Bhattacharjee *et al.* (1982) in hippeastrum where higher duration from full bloom to flower deterioration was observed in plants grown in increased dose (400 $kgha^{-1}$) of phosphorus.

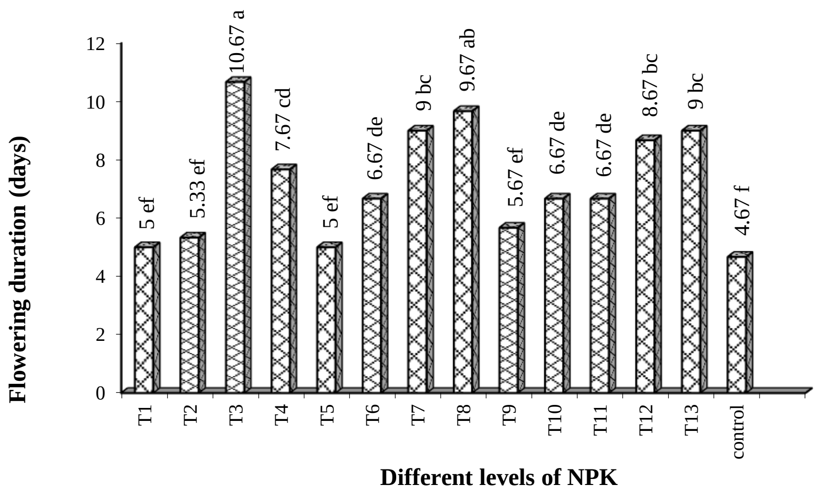

Fig. 1. Effect of different levels of NPK on flowering duration (days) of hippeastrum.

$T_1 = N_0P_{400}K_{300}$, $T_2 = N_{100}P_{400}K_{300}$, $T_3 = N_{200}P_{400}K_{300}$, $T_4 = N_{300}P_{400}K_{300}$, $T_5 = N_{200}P_0K_{300}$, $T_6 = N_{200}P_{200}K_{300}$, $T_7 = N_{200}P_{300}K_{300}$, $T_8 = N_{200}P_{500}K_{300}$, $T_9 = N_{200}P_{400}K_0$, $T_{10} = N_{200}P_{400}K_{100}$, $T_{11} = N_{200}P_{400}K_{200}$, $T_{12} = N_{200}P_{400}K_{400}$, T_{13} = Cowdung @ 10t/ha. and T_{14} = Control.

Conclusion

Combined application of N, P & K significantly influenced the growth and flowering of hippeastrum. Application at the rate of 200 kg N, 400 kg P and 300 kg K per hectare performed the best in terms of growth and flower production of hippeastrum. Thus this rate can be recommended for the healthy growth and high quality flower production of hippeastrum in Salna Series of Shallow Red Brown Terrace Soils of Madhupur Tract.

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FIELD PERFORMANCE OF BARI UREA SUPER GRANULE APPLICATOR

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Abstract

Field performance of BARI Urea Super Granule (USG) applicator was evaluated on BARI research stations (Gazipur, Pabna, and Barisal) and farmer's field (Pabna, Barisal, Magura,Narshingdi,Jhenadah, Sirajgang, Rajbari and Jhalkathi) during the *boro* season of 2012-13. The applicator was tested with four treatments- application of USG by hand (165 kg/ha), application of USG by BARI USG applicator (165 kg/ha), application of prilled urea at USG rate (165 kg/ha) and application of prilled urea at farmers practice. In the farmer's field, USG applicators were evaluated with the traditional broadcasting of granular urea. Similar yield of rice was obtained from machine and hand application of USG in all locations. Higher yield of rice was obtained from USG than granular urea. During field test, average field capacity and efficiency of the applicator were 0.138 ha/h and 81%, respectively. Considering custom hiring, the net income per year was Tk. 71750 and the payback period was 3 days. The price of the applicator is Tk. 3500.

Keywords: USG applicator, Field capacity, Field efficiency, Payback period.

Introduction

Urea has emerged as an important nitrogen fertilizer for rice. Statistics indicates that about 80% of urea is used for rice production. But only 15 to 35% of the total applied nitrogen is used by the rice plant (Prasad and Datta, 1979). The low level of nitrogen recovery by rice plant is generally caused by huge losses of the soil-water-plant complex. Nitrogen loss processes are due to ammonia volatilization, de-nitrification, runoff, seepage, and leaching. Thus there is a great need to improve nitrogen use efficiency for rice production. Due to excessive loss of nitrogen, farmers in Bangladesh have not been able to make more effective use of fertilizer to boost their rice yields. In the present (granular/prilled urea) method of application, only 40% of the applied urea is used by the plant and the remaining 60% is lost by air, water or leaching under the ground (Iqbal, 2009). Another statistics showed that two out of three bags of urea go un-used in wet land rice production (Amit, 2011).With deep placement methods, fertilizers are placed in the soil irrespective of the position of seed, seedling or growing plants before sowing or after sowing the crops (Datta and Fillery, 1983). Deep placement of

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nitrogenous fertilizer (N) is an alternative for increasing the N use efficiency of wetland rice besides minimizing the adverse effects of fertilizers on the environment (Bautista *et al.* 2001). On the contrary, deep placement of urea is environment friendly having minimal loss (Ahamed, 2012). Bangladesh has substantially increased its rice production through increased use of inorganic fertilizer. The nature and degree of loss depends upon soil, climatic conditions, nitrogen fertilizer and water management practices. Much effort has been made to improve fertilizer use efficiencies in lowland rice production. Deep placement of nitrogen fertilizer into the anaerobic soil zone is an effective method to reduce volatilization loss. At present, Urea Super Granule (USG) has been started to be used in puddled rice field and found to be economic and effective method of urea fertilizer application in rice field. Hand placement of USG of 1.8-2.7 g sizes into soil of flood water has been resulted less loss of nitrogen, greater nitrogen recovery and higher yield than conventional nitrogen application method (Diamond, 1985). Instead of normal dose of 247 kg of granular urea, only 165 kg/ha of USG is required (35% less) and it increases rice yield up to 20% (Hoque, 2008). Depending on agroclimate and nitrogen use, deep-placed USG can save urea fertilizer up to 65% with an average of 33% and increase grain yields up to 50% with an average of 15% to 20% over the same amount of split-applied nitrogen as prilled urea, especially in the lower range of nitrogen rates (Savant and Stangel, 1990). But, deep placement of USG by hand requires more labour and cost. Labor shortage in rice production is one of the major constraints which cause due to migration of people to town and need mechanization for rice production (Mohammada *et al*., 2011).The hand placement of USG is labor intensive and very slow i.e. 0.07 to 0.12 ha/workday (Savant *et al.*, 1992). Also hand placement of USG is tedious work and caused back pain.

Unfortunately, farmers have not been able to be benefited from these findings, primarily because they have no suitable fertilizer placement equipment. Cost of fertilizer is increasing day by day. Efforts should be made to develop a low cost, efficient fertilizer application machine for placing the fertilizer at required depths for different crops. Thus fertilizer use efficiency will be high, resulting in higher yield and lower production cost. To minimize nitrogen loss, USG application may be a good technology to increase rice yield as well as the reduction of production cost. Minimum effort has been made in the county to develop a fertilizer applicator machine for improving fertilizer use efficiency. To solve the problem of USG placement by hand, a manually operated push type fertilizer applicator for puddled rice field has been developed in Farm Machinery and Postharvest Process (FMP) Engineering Division of Bangladesh Agricultural Research Institute (BARI) (Wohab *et al.*, 2009). DAE and IFDC in collaboration with BARI have been demonstrating this technology in 68 Upazilas (The daily Star, 27 June, 2011). This study was therefore, undertaken to evaluate the field performance of BARI USG the applicator.

Materials and Method

Operation of the USG applicator

The skids of the applicator were placed between rows of rice plants keeping two rows of rice plants between the skids. Half of the fertilizer hoppers were filled with Urea Super Granule (USG). The applicator was then pushed forward manually. This made the cage wheel and the metering devices rotated. During rotation of the metering devices, it carries USG into the pockets and delivers them to the furrow openers. During forward movement of the applicator, the skids helped float the machine. The applicator dropped the USG at 20 cm row spacing, at about 38 cm spacing along the row and at 5-6 cm depth. Furrow closers closed the furrows providing anaerobic condition for the USG. The total width of application was adjustable (70 cm-100 cm). The field operation of the machine is shown in Fig. 1.

Field performance test

The field performance test of the applicator was done in the experimental field of FMP Engineering division, Gazipur; Agricultural Research Station (ARS), Pabna and Regional Agricultural Research Station, Rahmatpur, Barisal during *boro* season of 2012-13. The USG applicator was operated at 8 days after transplanting rice seedlings. The applicator was used in 2-5 cm of standing water. The machine was operated at an average speed of 1.50 km/h. One operator could comfortably run the machine. The experiment was laid out in RCB design with the following treatments and three replications.

T_1= Application of USG (urea super granule) by hand (165 kg/ha)

T_2= Application of USG (urea super granule) by the machine (165 kg/ha)

T_3= Application of prilled urea at USG rate (165 kg/ha)

T_4= Application of prilled urea at farmers’ practice (287 kg/ha)

Each plot size was 5.5 × 5 m in Gazipur; 10 × 8 m in Pabna and 17.5 m × 12.5 m in Barisal. The soil type was clay loam, loam, and sandy loam in Gazipur, Pabna, Barisal and Magura, respectively. The rice variety was BRRI dhan 28. The ages of seedlings were 35, 30 and 36 days in Gazipur, Pabna, and Barisal, respectively. The date of planting of seedlings in Gazipur was 10 March 2013, in Pabna was 14 February 2012 and in Barisal was 19 April, 2013. Row to row and hill to hill distance was 20 cm. For counting missing percentage of USG for the applicator, required numbers of USG was calculated for each plot and after application numbers of remain USG in the hopper was counted. TSP 51 kg/ha, MOP 70 kg/ha, Zinc 50 kg/ha and Boron 5 kg/ha were applied as basal dose before final land preparation. Full dose of USG was applied at 8 DAS (days after transplanting). One third prilled urea was applied at 8 days after transplanting and second one third urea was applied 40 DAS. The rest one third urea was applied at 55-60 DAS. Weeding was done manually at 35 DAS. Irrigation was applied when the soil moisture content became below the saturation condition. The insecticides were applied as and when necessary.

To compare field performance of the USG applicator with manual broadcasted prilled urea application, total 22 crop cuts were taken from different locations of the country. Farmers were selected who has cultivated BRRI dhan 28 and applied both USG by BARI applicator and broadcasted prilled urea. Each set of data was collected from Babugang and Gouranadi upzilla of Barisal, Shibpur upzilla of Narshingdi district, Baliakandi and Pangsa upzilla of Rajbari district, Sailokopaupzilla of Jhinaidah district. Two sets of data were collected from each upzilla of Sujanagar and Sathia of Pabna, Shahajadpur and Ullapara of Sirajgang, Jhalkathisadar and Rajapur of Jhalkathi, Salikha and Sreepur of Magura. Mean values were analyzed statistically and mean separation was done at 5% level by DMRT. Incase of USG applicator and Broadcast method mean values were analysed using test. A list of farmers selected are shown in Appendix 1 and Appendix 2.

Fig. 1 BARI USG Applicator **Fig.2 Operation of USG Applicator in field**

Results and Discussion

Performance of USG applicator at different locations is shown in Table 1. Average operating time, field capacity and operator efficiency of USG applicator were 7.22 h/ha, 0.138 ha/h, 81%, respectively. Urea saved over farmers' practice of prilled urea was 122 kg/ha. In case of hand application of USG, operating time per hector was 35.97 h. USG applicator can save 80 % operation time and 78 % cost of operation than hand application of USG. During field operation missing of USG dropping was very low as 1.0%.

Table 1. Performance of BARI Urea Super Granule (USG) applicator at different locations

Parameter	Gazipur	Pabna	Barisal	Mean
USG Applicator:				
Operating time, h/ha	7.02	7.43	7.20	7.22
Field capacity, ha/h	0.143	0.135	0.138	0.138
Operator efficiency, %	83	80	81	81.33
USG used, kg/ha	165	165	165	165
Urea saved over prilled urea, kg/ha	122	122	122	122
Missing of USG dropping, %	0.98	1.2	1.0	1.06
Cost, Tk/ha	350	250	325	308.33
Hand Application:				
Operating time, h/ha	33.33	39.16	35.42	35.97
Cost, Tk/ha	1458	1224	1439	1373.66
Comparison:				
Time saved over hand application, %	80			
Cost saved over hand application, %	78			

The yield and yield contributing factors of different urea application method in *boro* rice in Gazipur is shown in Table 2. There was no significant difference in yield of treatment T_1 and T_2. The highest yield of rice was obtained from treatment T_2 followed by T_1 and T_4 and the lowest yield was found from treatment T_3. This may be due to significantly higher number of tillers per hill and number of fill grain per panicle in treatment T_2 than other treatments.

Table 2. Yield and yield contributing factors for different urea application method in *boro* rice in Gazipur

Treatment	No of hill/m^2	No. of tillers/hill	Plant height (cm)	Length of panicle (cm)	No. of fill grain / panicle	No. of unfilled grain / panicle	1000 grain (g)	Grain yield (t/ha)
T_1	19.33	16.83 a	72.40 ab	20.19 a	71.40 a	14.33 b	24.60 a	5.35 ab
T_2	19.00	16.65 a	78.40 a	20.70 a	73.15 a	15.93 b	24.86 a	5.57 a
T_3	19.00	13.23 ab	70.20 ab	17.77 b	50.40 b	31.20 a	22.16 c	4.83 c
T_4	18.66	12.13 b	68.96 b	17.38 b	62.46 ab	22.80 ab	23.06 b	5.07 bc

Similar letter(s) in same column does not differ significantly each other at 5% level by DMRT.

Yield and yield contributing factor for different urea application method in *boro* rice in Pabna is given in Table 3. It is observed from the table that there were no significant differences of number of hill per meter square, plant height, length of panicle, and numbers of unfilled grain per panicle of rice among the treatments. Number of tillers per hill, number of fill grain per panicle and 1000 grain weight were significantly lower in treatment T_3 than other treatments. It is also observed from the table that significantly highest yield was found for USG application than that of prilled urea. There was no significant difference of grain yield between machine and hand application of USG.

Table 3 Yield and yield contributing factors for different urea application methods in boro rice in Pabna

Treatment	No of hill/m^2	No. of tillers/hill	Plant height (cm)	Length of panicle (cm)	No. of fill grain / panicle	No. of unfilled grain / panicle	1000 grain (g)	Grain yield (t/ha)
T_1	25.33	11.36 a	92.46	23.64	126.60 a	13.00	27.00 a	5.21 a
T_2	15.33	11.76 a	94.33	23.430	125.43 a	14.43	26.66 a	5.10 a
T_3	26.66	9.90 b	94.41	22.90	112.56 b	14.50	23.00 b	4.45 b
T_4	123.66	11.43 ab	89.99	23.00	121.13 ab	12.23	24.67 ab	5.08 a

Similar letter(s) in same column does not differ significantly each other at 5% level by DMRT.

Table 4. Yield and yield contributing factors for different urea application method in rice in Barisal

Treatment	No of hill/m^2	No. of tillers/ hill	Plant height (cm)	Length of panicle (cm)	No. of fill grain / panicle	No. of unfilled grain / panicle	1000 grain (g)	Grain yield (t/ha)
T_1	18.66	16.65	37.66 ab	20.33	132.33 a	4.66 b	32.00 a	6.16 a
T_2	19.33	16.83	40.06 a	20.16	129.33 a	4.00 b	31.20 a	6.04 a
T_3	18.66	12.80	35.83 b	19.66	114.00 b	6.33 b	29.80 b	5.59 b
T_4	19.33	13.56	39.13 ab	20.00	109.66 a	9.66 a	30.80 b	5.70 b

Similar letter(s) in same column does not differ significantly each other at 5% level by DMRT.

Table 4 show the yield and yield contributing factors for different area application method in *boro* rice in Barisal. Significantly the highest plant height was observed for treatment T_2 than other treatments. But the plant heights of treatment T_1 and T_2 were statistically alike. Treatment T_3 and T_4 were also statistically alike. There were no significant differences of number of hills per square meter, number of tillers per hill, and length of panicle among the treatments. The highest yield of rice was obtained from treatment T_1 followed by

T_2 and T_4 and lowest yield was found from treatment T_3. But there was no significant difference between treatment T_1 and T_2. Grain yields of treatment T_3 and T_4 were also statistically alike. These results indicated that there was non-significant effect of machine and hand application of USG, but machine application method saved time about 80% and cost of application about 77.84%.

Comparative performance of yield and yield contributing characters of *boro* rice urea applied by BARI USG applicator and broadcasted is shown in Table 5. The detailed data obtained at farmer's field are presented in Appendix 1 and Appendix 2. There was no significant difference of number of hill per meter square, plant height and number of unfilled grain per panicle between the fields where urea were applied by USG applicator and broadcasted. Significantly higher yield was observed due to higher number of tiller per hill, number of effective tillers per meter square, length of panicle, number of fill grain per panicle and 1000 grain weight. Thus application of USG by BARI applicator contributed to increase the rice production.

Table 5. Comparative performance of yield and yield contributing character of *boro* rice urea applied by BARI Urea Super Granule (USG) applicator and broadcasted

Treatment	No of hill/m^2	No. of tillers/hill	Plant height (cm)	Effective tillers/m^2	Length of panicle (cm)	No. of fill grain / panicle	No. of unfilled grain / panicle	1000 grain (g)	Grain yield (t/ha)
USG applicator	29.22	422.27	93.06	409.18	25.05	146.21	17.33	21.61	7.10
Broadcast	28.95	373.27	92.70	356.27	23.65	129.08	19.79	20.56	6.15
t-test	Ns	*	ns	*	*	*	ns	*	*

Table 6. Economic performance of the Urea Super Granule (USG) applicator

Parameters	Cost
Price of the USG applicator, Tk	3500
Operating area per year, ha	
Aus	05
Aman	15
Boro	20
Total Operating time per year, day	40
Custom hire rate, Tk/ha	1875
Gross income per year, Tk	75000
Repair and maintenance cost, Tk/year	250
Net income per year, Tk	71750
Payback period, day (Rounded)	3

Economic performance and payback period of the USG applicator is given in Table 6. If one person engaged him in custom hiring of USG applicator, then the net income per year will be Tk. 71750. Considering capacity of the operator of the applicator was 1 ha/day and labour wage was 500 Tk/day, the payback period of the USG applicator in custom hiring was 3 days.

Conclusion

The field performance test of the applicator was satisfactory. Use of the applicator ensured similar yield to hand application of USG in all locations. USG applicator was easy to operate as its weight is 6 kg. It saved about 80% of USG application time and saved application cost about 78% than hand application. USG provided higher yield over the granular urea application system. Payback period was 3 days.

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Appendix 1. Data of different field where urea was applied as USG by BARI Urea Super Granule (USG) applicator

Name of the farmers and Address	District	Hill/m^2	No of Tillers/m^2	Plant height (cm)	No. of effective tillers	Panicle Length (cm)	No. of filled grains/ panicle	No. of unfilled grains/ panicle	1000 grain weight	Yield (t/ha)
Md. AlomTalukder, Sadar	Jhalkathi	32	448	94.45	445	23.00	113.90	12.40	23.00	8.40
Md. Khokon Sharif, Sadar	Jhalkathi	27	382	106.25	372	25.40	124.30	18.20	22.50	8.00
Abul Bashar, Rajapur	Jhalkathi	22	353	118.80	348	25.95	134.70	11.50	20.40	6.80
Abu SobhanSikder, Rajapur	Jhalkathi	26	394	113.20	382	26.90	133.60	19.40	22.60	8.00
Md. Rabiul Islam, Rajbari	Rajbari	25	355	104.46	347	26.63	116.00	30.44	21.20	7.20
Md. Hanif, Rajbari	Rajbari	25	363	111.65	358	27.04	162.66	56.77	22.80	7.40
Abdul Aziz, Sujanagor	Pabna	30	580	87.11	562	27.17	168.44	15.55	20.00	5.76
Abdul GafurPramanik, Sujanagor	Pabna	26	390	90.47	373	27.33	151.33	15.11	22.20	6.00
ShahadatHossain, Ullapara	Sirajgang	25	355	83.30	335	24.03	133.00	17.70	22.60	6.36
Abu Syed, Shahjadpur	Sirajgang	25	375	9.55	366	25.14	163.70	12.70	21.00	6.40
Md. Najmul Bari, Shahjadpur	Sirajgang	25	425	86.90	408	25.79	132.70	14.50	22.30	6.60
Md. JasimUddin, Santhia	Pabna	23	378	83.32	362	24.72	134.70	14.20	21.60	5.28
Md. IsmaylHossain, Santhia	Pabna	24	456	87.57	437	25.03	155.60	16.60	22.80	7.00
Md. Abdul Matin, Ullapara	Sirajgang	25	455	98.25	432	24.38	140.00	16.10	20.70	5.77
Anwar Hossain, Narsindhi	Narshindhi	29	370	92.20	359	23.17	104.20	28.10	22.76	8.00
FaridMolla, Gouranadi	Barisal	36	410	103.00	364	27.00	140.71	8.86	22.00	8.40
KhalilurRahman, Babugang	Barisal	36	599	103.20	560	21.30	107.80	11.66	21.20	8.40

Appendix 1. Cont'd.

Name of the farmers and Address	District	Hill/m^2	No of Tillers/m^2	Plant height (cm)	No. of effective tillers	Panicle Length (cm)	No. of filled grains/ panicle	No. of unfilled grains/ panicle	1000 grain weight	Yield (t/ha)
NikonjonKumer, Sreepur	Magura	39	461	99.97	460	24.13	123.40	7.00	21.10	7.60
SailenKumerMondol, Magura	Magura	48	497	90.59	495	23.95	139.10	10.40	22.20	6.80
GolamFaruk, Sodohati, Sailkopa	Jinaidah	28	434	103.14	430	24.51	126.80	26.40	21.16	5.20
AbulKashemMonshi, Shalikha	Jinaidah	37	510	67.73	507	24.28	248.00	7.40	17.07	8.40
IqbalMonshi, Satnaforia, Shalikha,	Magura	30	300	112.17	300	24.31	262.00	10.20	22.30	8.40

Appendix 2. Data of different fields where urea was applied by broadcasting.

Name of the farmers and Address	District	$Hill/m^2$	No of $Tillers/m^2$	Plant height (cm)	No. of effective tillers	Panicle Length (cm)	No. of filled grains/ panicle	No. of unfilled grains/ panicle	1000 grain weight	Yield (t/ha)
Md. AlomTalukder, Sadar	Jhalkathi	35	420	88.05	418	22.00	92.60	18.70	21.70	5.60
Md. Khokon Sharif, Sadar	Jhalkathi	25	260	95.75	251	22.30	88.70	19.10	21.10	5.20
Abul Bashar, Rajapur	Jhalkathi	22	332	107.50	325	24.00	120.50	14.90	21.50	6.00
Abu SobhanSikder, Rajapur	Jhalkathi	24	340	108.30	332	23.10	108.50	24.50	21.60	6.40
Md. Rabiul Islam, Rajbari	Rajbari	25	327	98.05	315	29.73	107.77	33.11	21.80	6.80
Md. Hanif, Rajbari	Rajbari	25	335	100.12	322	27.40	136.33	38.22	20.90	6.88
Abdul Aziz, Sujanagor	Pabna	25	400	78.34	381	24.52	172.22	16.44	20.30	5.40
Abdul GafurPramanik, Sujanagor	Pabna	25	375	95.14	354	27.71	141.77	16.00	21.20	5.68
ShahadatHossain, Ullapara	Sirajgang	24	339	110.40	322	23.80	133.90	15.80	22.28	5.68
Abu Syed, Shahjadpur	Sirajgang	23	365	91.75	353	24.23	118.80	17.90	21.90	5.80
Md. Najmul Bari, Shahjadpur	Sirajgang	25	400	84.26	385	24.47	129.90	14.50	19.20	5.80
Md. JasimUddin, Santhia	Pabna	20	364	86.40	344	23.54	135.70	15.40	21.80	4.80
Md. IsmaylHossain, Santhia	Pabna	22	396	91.05	375	23.87	144.50	15.10	20.70	6.24
Md. Abdul Matin, Ullapara	Sirajgang	22	389	97.07	377	23.49	137.30	12.40	20.70	5.24
Anwar Hossain, Narsindhi	Narshindhi	28	298	94.10	284	22.74	76.50	46.30	20.86	6.91
FaridMolla, Gouranadi	Barisal	32	409	93.25	350	22.91	96.66	19.50	19.50	7.60
KhalilurRahman, Babugang	Barisal	33	480	95.30	452	21.53	103.50	5.80	19.20	7.60
NikonjonKumer, Sreepur	Magura	48	393	76.32	390	20.24	85.80	16.20	19.70	6.20
SailenKumerMondol, Magura	Magura	53	421	83.88	417	21.84	124.60	11.50	19.80	6.00
GolamFaruk, Sodohati, Sailkopa	Jinaidah	35	497	92.69	491	22.35	108.10	33.30	19.90	4.92
AbulKashemMonshi, Shalikha	Jinaidah	33	396	63.28	390	20.17	228.00	17.50	16.07	7.00
IqbalMonshi, Satnaforia, Shalikha	Magura	33	276	108.51	276	24.26	248.30	13.10	20.80	7.60

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ASSESSMENT OF MICROBIAL QUALITY OF WATER IN POPULAR RESTAURANTS IN SYLHET CITY OF BANGLADESH

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Abstract

Microbial contaminations of drinking water constitute a major burden on human health. Interventions to improve the quality of drinking-water provide significant benefits to health. An assessment of microbial quality of water in the samples obtained from different popular restaurants of Sylhet City Corporation, Bangladesh were analyzed in the laboratory. Our aims were to find out the microbial properties of water, to analyze the potable water qualities of the restaurants and also to compare it with different standards to assess the health risk of people. The microbial tests viz. MPN, TVC and total coliform test were studied. Results revealed that all the water samples were fecal contaminated and had a great chance of contamination by other pathogenic bacteria. Results indicated that most of the samples were significantly positive to MPN test and TVC bacteria were highly significant. The risk score for coliform bacteria also remarked high risk for human health according to WHO standards and were not suitable as potable water. Our recommendations are therefore, water supply authority including restaurant owners should take necessary steps for the maintenance of microbial quality of water and microbial assessments should be done very often to leading a hygienic water distribution environment of the city.

Keywords: Microbial properties, water quality, fecal coliform, MPN index, human health.

Introduction

The quality of drinking water is closely associated with human health, and providing of drinking water is one of the important public health priorities. The impact of water on health derives principally from the consumption of water, containing pathogenic organisms or toxic chemicals. In the developing countries, consumption of contaminated water is responsible for 80% of all diseases and hence, causes one third of deaths (UNCED, 1992). Bangladesh is not an exception in this regard and the drinking water quality is at high risk and problems are even more acute in the urban areas. Sylhet is a north-eastern

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divisional city of Bangladesh, rich in natural resources that attract tourists and business entrepreneurs. According to Sylhet City Corporation, the city has 331 registered/licensed restaurants. However, many unregistered restaurants also exist. Only 15% of the restaurants maintain sanitary facilities and the rest 85% remains in unhygienic conditions that are unsafe for public health (Ahmed and Rahman, 2000). Alam *et al.* (2006) reported that the drinking water of each surveyed restaurant in the supply water of Sylhet City Corporation was contaminated with fecal coliforms and from which 25% restaurants had unsafe levels of iron. Health risk score for coliform bacteria was at high risk and about half of the population (55%) comes under very high risk zone in the city. According to WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (2000), approximately 20-40% of urban water systems in the developing countries do not disinfect their water supplies. Contaminated water, poor sanitation and improper hygiene practice leads to water borne diseases. As a consequence, 34 million deaths a year occur throughout the world, which are mostly children (UNICEF, 2008).

According to a systematic review on microbial drinking water quality, even the improved sources including piped water were observed to be contaminated with E. coli or TTC (Bain *et al.*, 2014b). Thus, microbial contamination is widespread and affects all water sources (Bain *et al.*, 2014a). Piped water supply is available to about 60% of the Dhaka city population, but the city dwellers often find that the water is contaminated and needs boiling at home for drinking because of leaks in pipeline, imperfect water taps and misuse (Nazz, 2008). Hence, 89% samples were not up to the standard level as drinking water and there was the presence of total viable bacteria, total coliform, total faecal coliform etc. in the piped water in Dhaka city (Zakia *et al*., 2001). Also, in some locations in Chittagong, pathogenic organisms present in water exceed the permissible limit (Zuthi *et al.*, 2009). Similarly, Nasrin *et al.* (2005) reported that drinking water quality in the distribution network in Khulna City Corporation at some locations did not meet the potable water quality standard. In Bangladesh, about 80% of all diseases are linked with contaminated water and 28% of children’s death is attributed to waterborne diseases caused by pathogenic microorganisms (Aziz *et al*., 1990).

Apart from Bangladesh, several researchers in different countries around the world also observed that various disease-causing agents or pathogens viz. faecal coliform bacteria or toxic chemicals result in water contamination. As a consequence, consumption of water leads to several health problems once the water travels through a distribution system (Lahlou, 2002; Howard, 2002; Obiri-Danso *et al.*, 2003; Dodoo *et al.*, 2006). Guidelines for Drinking-Water Quality recommend that faecal indicator bacteria (FIB), preferably E. coli or alternatively thermotolerant coliform (TTC), should not be detectable in any 100 ml drinking water sample (WHO, 2011). The 2010 global burden of disease estimates (Lim *et al.,* 2012) assumed that improved sources present no risk to consumer. Unclean and unsafe water, poor sanitary and hygienic facilities in restaurants of the city possess a potential source of diseases and risk to human health. Nevertheless, very few studies were observed in these regards in Sylhet City Corporation. In view of this, the present investigation aimed at studying water quality of selected restaurants of Sylhet City with the objectives to find out the microbiological properties of water, to analyze the potable water qualities of popular restaurants and also to compare it with different standards to assess the health risk of people.

Materials and Method

Study area and experimental design

The study was carried out at the Department of Food Engineering and Tea technology laboratory, Shahjalal University of Science and Technology and Microbiology and Hygiene Laboratory, Sylhet Agricultural University, Sylhet, Bangladesh during the year 2011. Water samples were collected from various popular restaurants situated in different parts of Sylhet City Corporation (SCC), Bangladesh. It was observed that most of the restaurants used water for drinking and cooking purpose supplied by SCC. Completely randomized design was followed with three replications.

Media used and working steps

Growth media viz. Lactose Broth (LB), Plate Count Agar (PCA) or Nutrient Agar (NA) and Eosine Methylene Blue (EMB) Agar were used for microbial study. The whole experiment was conducted in the following four steps. Step-I: collection of supply water samples from different restaurants of Sylhet City Corporation (SCC), step-II: tests of the samples for microbial properties in the laboratories, step-III: comparison with different standard guidelines for drinking water and step-IV: assessment of water quality of the restaurant in SCC.

Collection of sample and their preservation

The water samples were collected from 20 (twenty) various popular restaurants in different wards of SCC which are shown in Table 1. Two liters of sample were collected from each restaurant in plastic containers. The containers were cleaned with cleaning solution prior to sample collection. Before taking the samples from the tap, it was allowed to flow for a while and the containers were rinsed at least three times by filling it to one fourth of its capacity with water to be sampled, properly shaked and then emptied. The containers were air tighten with stopper and wrapped by tape to restrict contact of air with water samples. All possible efforts were made to minimize the time lag between collection and analysis so as to avoid significant change in water quality. All the samples were then transported to the laboratory in an isolated foam box with ice to maintain temperatures ranging from 4-6^{o}C. After that samples were stored in the laboratory in 4^{o}C temperature.

Table 1. List of the sampling restaurants

Code No.	Selected restaurants	Address
S1001	Gram Bangla Restaurants	JollarPar, Sylhet
S1002	Pritiraj Restaurant	Zindabazar, Sylhet
S1003	Alpine Restaurants	Chowhatta, Sylhet
S1004	Ashiana Restaurants	Chowhatta, Sylhet
S1005	Panchkhana Restaurants	Amberkhana, Sylhet
S1006	Safran Restaurants	Shibgonj, Sylhet
S1007	Rongdhonu Restaurants	Amberkhana, Sylhet
S1008	Akash Restaurants	Modina Market, Sylhet
S1009	Fatema Restaurants	Lamabazar, Sylhet
S1010	Istikutum Restaurants	Amberkhana , Sylhet
S1011	Rosuighar Restaurants	Pathantula, Sylhet
S1012	Nobanno Restaurants	Taltola, Sylhet
S1013	Fakrudddin Restaurants & Biriany House	Barutkhana, Sylhet
S1014	Satkania Restaurants	Dorgha Gate, Sylhet
S1015	Choruivati Restaurants	SUST gate, Sylhet
S1016	City Restaurants	Amberkhana, Sylhet
S1017	Panchbhai Restaurants	JollarPar, Sylhet
S1018	Dhansiri Restaurants	Subidbazar, Sylhet
S1019	Habib Restaurants	Amberkhana, Sylhet
S1020	Al-Kawsar Restaurants	Zindabazar, Sylhet

Microbial properties tests

Tests for indicator bacteria were done for the assessment of microbial properties of water samples. Indirect evidence of presence of pathogens was also confirmed by coliform test. Most probable number (MPN), confirmed test for coliform and total viable count or standard plate count were studied for microbial properties analysis.

Most Probable Number (MPN) or Presumptive test for Coliform

MPN provides an estimate of the number of living organisms in a sample which are capable of multiplying in the sample. The test is used when the number of microorganisms is very few (<1 ml^{-1}) in the sample. This method can be conducted by different techniques and the three tubes techniques were used here for determining MPN of the sample (Methods adapted from Alam *et. al.* 2006)**.** However, multiple samples of water being tested were added to a lactose broth in sterile tubes and inoculated at 35ºC temperature for 24 hours. Nine tubes were used for each sample. Three tubes of single strength lactose broth were inoculated with 0.1 ml sample per tube and another three tubes of single strength lactose broth were inoculated with 1ml sample per tube. Ten ml of samples were also inoculated in three tubes of double strength lactose broth. As coliform bacteria were grown, they produced acid and gas, changing the broth colour and producing bubbles, which were captured in a small inverted tube. The number of tubes showing a positive result were counted and compared with standard tables. Statistical estimates of the MPN of bacteria were then made with the results reported as MPN per 100ml.

Confirm test for Coliform

This test was meant for differentiating the coliforms with that of non-coliforms as well as Gram-negative with Gram-positive bacteria. The Eosine Methyline Blue (EMB) agar plates were inoculated from previous tubes producing gas and incubated at 30±1ºC for 12 hours. *E. coli* colonies grown on this medium were observed as small with metallic sheen, whereas *E. aerogenes* colonies were usually large and lack the sheen.

Total Viable Count (TVC) or Standard Plate Count (SPC)

Total Viable Count gives a quantitative idea about the presence of micro organisms such as bacteria, yeast and mould in a sample. TVC was determined by multiplying colony numbers with reciprocal dilution factor and reported as the number of colony forming units per gram ($cfug^{-1}$) or ml^{-1} and the results per dilution counted were recorded. It was done to enumerate total viable population (eg. bacterial population) and not to detect either coliform or other pathogenic forms present therein. After inoculation and incubation for 24 hours the colonies were counted. Repeated trials with more dilution were also conducted to avoid swarming bacteria that may cover the plate. However, TVC can be expressed in numbers ml^{-1}.

$TVC = m \times 10^n$;

Here, m is the number of colonies and n is the dilution factor.

Statistical analysis

Mean and standard deviation were followed for statistical analysis. T-test was done and compared with tabulated values for the interpretation of the results.

Results and Discussion

Most Probable Number (MPN)

Most Probable Number (MPN) is a presumptive test in which tube showing gas production are counted. By counting the number of tubes showing a positive result and comparing with standard table, a statistical estimate of the MPN of bacteria were made. Results revealed that samples produced gas bubble to show the positive results of MPN and were significantly varied in their MPN (Table 2). However, the sample 19 secured low MPN index value (Table 4). Average MPN index value for these collected samples was 3.05 ml^{-1} which indicated that the water samples were not potable at all. According to Dubey and Maheshwari (2005), water sample containing gas producing lactose fermenters would not be considered as potable water. The findings of the assessment are in agreement with Alam *et al.* (2006) who reported that the mean value of Total Coliform Bacteria (TCB) varied between 24.6 $MPN100ml^{-1}$ (dry season) and 22.5 $MPN100ml^{-1}$ (monsoon season) in Sylhet City restaurants. These levels are clearly unsafe as far as drinking water is concerned. Thus it might be prudent to monitor the bacteriological quality of drinking water/supply water at the source in addition to resistance profiles of the isolates.

Coliform test (CF)

In presumptive test, sometimes gas is also produced by non coliform group of bacteria. So, this test is meant for differentiating the coliforms with that of non-coliforms as well as Gram-negative with Gram positive bacteria. In this study, dark centered or nucleated colonies with metallic sheen were noticed which indicate that all the samples were coliform positive (Table 4). The findings of the present study are in agreement with Alam *et al.* (2005) who reported that the drinking water of each restaurant was contaminated with coliforms in Sylhet city. Health risk score for coliform bacteria was 1,474.77, indicating high risk. Mukhopadhyay *et al.* (2012) isolated fecal indicator organisms, including *Escherichia coli* and *Enterococcus* spp. from 22 (27.5%) samples, and reported that the majority (92.5%) of the water sources were contaminated with coliforms in their studies. Gwimbi (2011) remarked that protected sources of water had significantly less number of colony forming units (cfu) per 100 ml of water sample compared to unprotected sources (56% versus 95%, $p < 0.05$). These findings suggest that source water protection and good hygiene practices can improve the quality of drinking water where disinfection is not available.

Table 2. Mean and standard deviation of Most Probable Number (MPN) values of the samples

Treatment /Sample Code	MPN ml^{-1} (Xi)	$(Xi-\bar{X})$	$(Xi-\bar{X})^2$
S1001	0.43	-2.62	6.86
S1002	0.75	-2.30	5.29
S1003	0.43	-2.62	6.86
S1004	1.50	-1.55	2.40
S1005	24.00	20.95	438.90
S1006	11.00	7.95	63.20
S1007	0.43	-2.62	6.86
S1008	0.39	-2.66	7.08
S1009	11.00	7.95	63.20
S1010	0.93	-2.12	4.49
S1011	0.39	-2.66	7.08
S1012	0.43	-2.62	6.86
S1013	1.20	-1.85	3.42
S1014	0.93	-2.12	4.49
S1015	0.34	-2.71	7.34
S1016	0.43	-2.62	6.86
S1017	4.60	1.55	2.40
S1018	0.93	-2.12	4.49
S1019	0.15	-2.90	8.41
S1020	0.75	-2.30	5.25
Total	61.01		661.74
Mean	3.05		
t-test (0.05)		2.26**	

Total Viable Count (TVC) or Standard Plate Count (SPC)

Total Viable Count (TVC) or Standard Plate Count (SPC) was done to enumerate total viable bacteria present in the sample. After inoculation and incubation for 24 hours, the colonies were counted. Results showed that TVC was significantly varied (Table 3). Naturally, the pathogenic bacteria are very much lower in number than the non-pathogenic bacteria. But when there is high concentration of viable bacteria, there is chance of contamination of non-fecal pathogenic bacteria. According to guideline of WHO (1996), TVC value should be 1×10^3 cfuml^{-1}. The US Environmental Protection Agency (EPA) also recommended that the TVC value should be 500 cfuml^{-1}. But, we found much higher TVC value than those values (Table 4). The quality of water used in the popular restaurants of Sylhet City Corporation are at high risk that might be deteriorated during its flow through the water distribution system and also due to probability of non protection of water sources in some cases**.**

Table 3. Mean and standard deviation from the Total Viable Count (TVC) values of the samples

Treatment /Sample Code	Total TVC (cfu.g^{-1}) (Xi)	(Xi- $\overline{X}$)	(Xi- $\overline{X}$)^2
S1001	11.46×10^6	-7.44×10^6	5.54×10^{13}
S1002	21.94×10^6	3.04×10^6	9.42×10^{12}
S1003	12.16×10^6	-6.74×10^6	4.54×10^{13}
S1004	18.80×10^6	-1×10^5	1×10^{10}
S1005	26.80×10^6	7.9×10^6	6.24×10^{13}
S1006	24.20×10^6	5.3×10^6	2.809×10^{13}
S1007	16.40×10^6	-2.5×10^6	6.25×10^{12}
S1008	19.40×10^6	5×10^5	2.5×10^{11}
S1009	24.40×10^6	5.5×10^6	3.025×10^{13}
S1010	19.20×10^6	3×10^5	9×10^{10}
S1011	18.40×10^6	-5×10^5	2.5×10^{11}
S1012	18.80×10^6	-1×10^5	1×10^{10}
S1013	19.60×10^6	7×10^5	4.9×10^{11}
S1014	24.40×10^6	5.5×10^6	3.025×10^{13}
S1015	16.20×10^6	-2.7×10^6	7.29×10^{12}
S1016	13.80×10^6	-5.1×10^6	2.6×10^{13}
S1017	24.00×10^6	5.1×10^6	2.6×10^{13}
S1018	16.40×10^6	-2.5×10^6	6.25×10^{12}
S1019	13.40×10^6	-5.5×10^6	3.02×10^{13}
S1020	17.80×10^6	-1.1×10^6	1.21×10^{12}
Total	3.78×10^8		3.65×10^{14}
t-test (0.05)		19.30**	

Table 4. Microbial properties of the water samples along with WHO, ISI and US EPA standards

Treatment	Most Probable No. (MPN) ml^{-1} (Xi)	Total Viable Count (TVC) (cfu ml^{-1})	Coloform (#/100ml)
S1001	0.43	11.46×10^6	+ve
S1002	0.75	21.94×10^6	+ve
S1003	0.43	12.16×10^6	+ve
S1004	1.50	18.80×10^6	+ve
S1005	24.00	26.80×10^6	+ve
S1006	11.00	24.20×10^6	+ve
S1007	0.43	16.40×10^6	+ve
S1008	0.39	19.40×10^6	+ve
S1009	11.00	24.40×10^6	+ve
S1010	0.93	19.20×10^6	+ve
S1011	0.39	18.40×10^6	+ve
S1012	0.43	18.80×10^6	+ve
S1013	1.20	19.60×10^6	+ve
S1014	0.93	24.40×10^6	+ve
S1015	0.34	16.20×10^6	+ve
S1016	0.43	13.80×10^6	+ve
S1017	4.60	24.00×10^6	+ve
S1018	0.93	16.40×10^6	+ve
S1019	0.15	13.40×10^6	+ve
S1020	0.75	17.80×10^6	+ve
WHO[1]	MPN positive water sample in not potable water (Dubey and Maheshwari, 2005)	1×10^3	-ve
ISI[2]			-ve
BD[3]			-ve
EPA[4]		500 cfu/ml	-ve

WHO[1]= World Health Organization, ISI[2]= Indian standard Institute, BD[3]= Bangladesh standards and EPA[4]= Environmental Protection Agency

Conclusion

The present investigation on the microbial quality of water used in popular restaurants of Sylhet City Corporation showed that it was highly unsafe for human consumption. Results remarked that these water samples were fecal contaminated and had also great chance of contamination by other pathogenic bacteria. Most of the samples were significantly positive to MPN test and TVC values were significantly high. This indicates that other microbes such as fungi, protozoa etc. may be present at alarming concentration in the samples. The risk score for coliform bacteria also indicate high risk as per WHO, ISI and US EPA standards. Thus, it is imperative that the effluent discharge from industries, various domestic and household sources (which enhance levels of heavy metals and pesticides in the city's water supply, especially during the dry season) must be controlled through vigorous efforts. Furthermore, to elucidate the reasons behind the contamination of water, a thorough study of the source water as well as water in the distribution channels must be monitored periodically and treated accordingly. The findings of the study might help the water supply authority as well as the restaurant owners to take necessary steps for the maintenance of microbial quality to prevent waterborne infectious disease both in the urban and rural areas in Bangladesh. However, further studies in depth are urgently needed for time interval.

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EFFECT OF SOWING TIME AND VARIETY ON SEED GERMINATION AND VIGOUR INDEX OF WHEAT

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Abstract

Experiments were carried out in research field and laboratory of Seed Technology Division, Bangladesh Agricultural Research Institute, Gazipur during *rabi* season of 2008-09 and 2009-10 to find out the effect of sowing time and variety on seed germination and vigour index of wheat after harvest of the crop. There were two sets of treatments, comprising a) three dates of sowing viz. 20 November, 5 December and 20 December; and b) three varieties viz. 'Bijoy', 'Sufi' and 'Prodip'. Split plot design and complete block design were followed in field and laboratory experiments, respectively. Results revealed that the highest seed germination 93.33% was recorded in 'Prodip' sown on 20 December, 2008 and 'Bijoy' sown on 5 December, 2009. However, all the varieties showed more than 83% seed germination at all dates of sowing of wheat. The highest vigour indices, 1.53 and 1.41 were found in the seeds of 'Sufi' sown on 20 November in both the years of 2008 and 2009, respectively.

Keywords: wheat, sowing time, variety, seed germination, vigour index.

Introduction

Wheat is the second most important food grains in Bangladesh. Rice and wheat altogether occupied over 80% of the total cropped area. In 2010-11, the total area and productions of wheat in the country were 3.74 lac hectares and 9.72 lac. MT (BBS, 2011). Quality seed is considered as the basic critical input which directly affects yield and could increase crop production by 10-15% (Mondal, 2005), while BADC (2012) reported that quality seed alone can contribute to the increase of yield by 15-20%. In order to maintain purity and quality of seeds several steps should be undertaken. Sowing in optimum time, application of balanced fertilizer and irrigation in proper time, rouging and weeding are essential for successful seed production. Greven *et al.* (2004) reported that timing of harvest is an important factor since both seed immaturity and weathering reduce seed quality. Kumar *et al*. (2002) reported that seed yield and quality largely depend on the stage of maturity of crops. Shaheb *et al.* (2011 and 2012) reported higher seed yield of wheat from November sowing and seed yield was decreased with the delaying of sowing time. Dharmalingam and Basu (1990) reported that seed development and maturation are important because the seeds are harvested to ensure good yield associated with viability, vigour and field performance. Harvesting with high moisture content increases the chances of

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mycofloral infection on seed, while harvesting at low moisture content increases mechanical damage to seed (Yadav *et al*., 2005). The seed reaches its maximum dry weight at physiological maturity and should be harvested at proper time to ensure better germinability and vigour. Late sowing, higher plant population, desiccation and earlier harvesting reduces seed size of dwarf French beans, and seed germination of all treatments is ≥ 91% though significant differences are found in seed vigour (Greven *et. at*., 2004).

The seed quality in general does not change significantly between physiological maturity (PM) and harvest maturity (HM), but in some cases the proportion of viable seeds increases between PM and HM, especially when ambient temperatures are relatively low (Muasya *et al*., 2008). Thus harvesting of seed crop at optimum stage of seed maturation is essential to obtain better seed quality. The major three aspects of seed quality are a) genetic and physical maturity, b) high germination percentage and vigour, and c) freedom from seed-borne disease and insects (Seshu and Dadlani, 1989). There is hardly any literature available on seed quality studies on popular varieties of wheat sown at different times in Bangladesh. Hence, the experiment was undertaken to see the effect of sowing time and variety on the seed germination and vigour index after the harvest of wheat.

Materials and Method

Experiments were conducted in research field and laboratory of Seed Technology Division, Bangladesh Agricultural Research Institute, Gazipur during *rabi* season of November 2008 to April 2010. There were two sets of treatments comprising a) three dates of sowing viz. S_1: 20 November, S_2: 5 December and S_3: 20 December; and b) three varieties viz. V_1: 'Bijoy', V_2: 'Sufi' and V_3: 'Prodip'. The field experiment was laid out in a split plot design with three replications assigning sowing time in main plot and variety in sub plot for field and completely randomized design was followed for laboratory studies. The unit plot size was 3m x 5m. The land was fertilized with 92, 32, 23 and 20 kg ha^{-1} of N, P, K and S, respectively. One-third of N and all other fertilizers were applied at final land preparation. Seeds were sown in furrows at the rate of 120 kg ha^{-1} in 20 cm apart rows. The two years weather data are given in Fig.1 and 2.

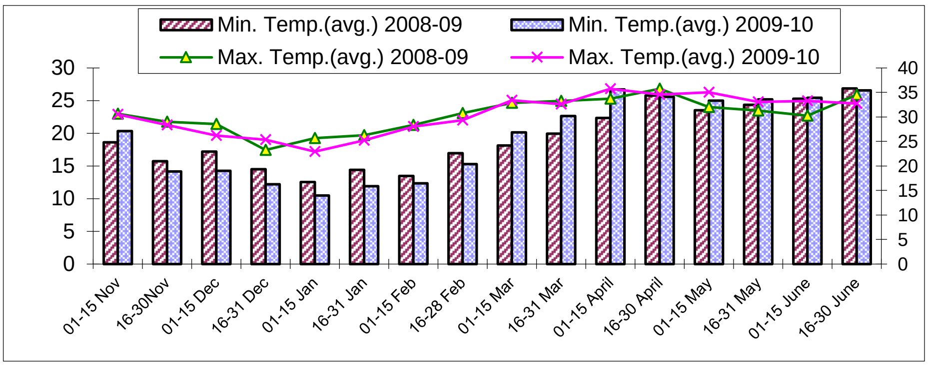

Fig. 1. Mean maximum and minimum temperature (^{0}C) data at Joydebpur, Gazipur from November to June (2008-10).

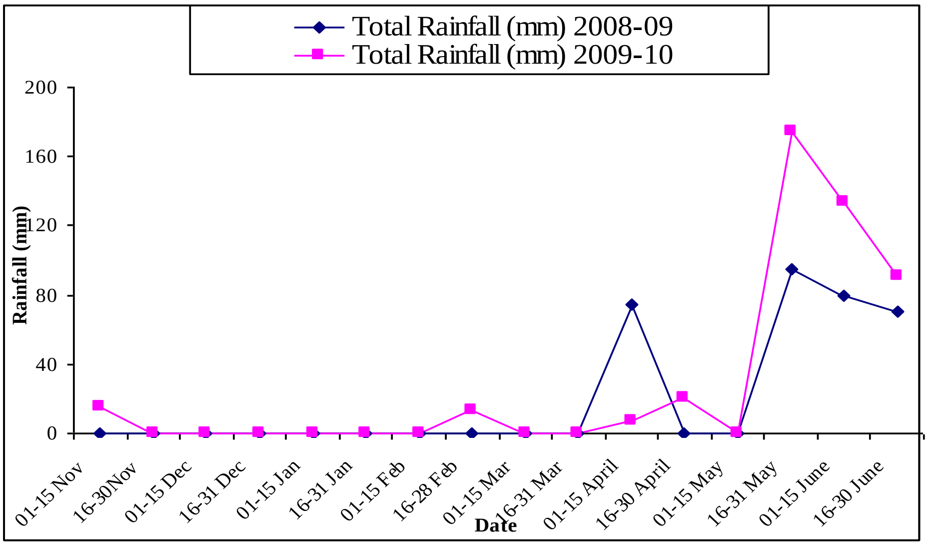

Fig. 2. Total rainfall (mm) data at Joydebpur, Gazipur from November to June (2008-10).

From the figures, it was observed that the average maximum temperatures (around 34^{0}C) were in the month April in both the years while the lowest minimum temperature was recorded in the middle of January (above 9^{o}C). There was almost no rainfall recorded during the growing period (November to February) of wheat in both the years except in the last week of February, when only 5 mm of precipitation was recorded. However, total rainfall ranged from 5 mm to well above 160 mm.

All intercultural operations viz. weeding, thinning, irrigation and drainage were carried out as and when necessary. The wheat varieties sown on 20 November, 05 December and 20 December were harvested on 11 March, 23 March and 05 April, respectively. After threshing, seeds of each plot were sun dried and then cleaned properly. Seed quality parameters including seed vigour data of wheat varieties were recorded as per following methods:

Determination of moisture content

The moisture content (MC) of seed sample as per treatment was determined after harvest according to ISTA (1999). Ground seed samples of each treatment were taken into moisture cup and put into a pre heated oven at temperature of 103 ± 2^{0}C for one hour according to Morshed *et al.* (2003). After cooling, the weight of the container with its cover and contents were taken. The seed samples were cooled in desiccators and weighed to work out the percent moisture content of the grains. However, the MC of all varieties harvested at different dates were brought and adjusted at 11.50%. The seed moisture content was determined by dry weight basis and was calculated by the following formula:

$$\text{Seed moisture content } (\%) = \frac{M_2 - M_3}{M_2 - M_1} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Where,

M_1 is the weight in grams of the container and its cover,

M_2 is the weight in grams of the container, its cover and its contents before drying

M_3 is the weight in grams of the container, its cover and contents after drying.

Determination of germination percentage

The data on seed germination (%) was taken out after harvest by the following formula (ISTA, 1999). For each treatment, 100 seeds were put into large petri dishes with four replications. The Petri-dishes were then put at room temperature (25 ± 2^0C). After eight days, sprouted normal, abnormal and diseased seeds were counted by the following formula:

$$\text{Seed Germination } (\%) = \frac{\text{No. of seed germinated}}{\text{Total seed}} \times 100 \ldots\ldots\ldots\ldots\ldots (ii)$$

Measurement of root and shoot length

From the eight days of seedlings, 10 plants were randomly selected. Seedlings were then cut and root and shoot parts were separated and their lengths were measured.

Determination of fresh and dry weight of seedling

After measurement of root and shoot length, fresh weight and dry weight of seedlings were recorded. Then the root and seedlings were put into paper packet and placed into the preheated oven (70^0C± 2^0C) for 48 hours. After cooling in desiccators, the dry weights were taken.

Determination of vigour index

Seed vigour index was calculated and determined by multiplying germination (%) and seedling dry weight according to Abdul-Baki and Anderson (1973) and Reddy and Khan (2001).

$$\text{Vigour index (VI)} = \text{PG} \times \text{SDW} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

Where,
VI = Vigour index;
PG =Percent germination of seed, and
SDW = Seedling dry weight (Average)

The collected data were analyzed statistically following the ANOVA technique with the help of MSTAT-C software. The mean differences among the treatment means were done by Least Significant Difference (LSD) test (Gomez and Gomez, 1984).

Results and Discussion

Results obtained from the two consecutive years of 2008-09 and 2009-10 were presented in Tables 1-3.

Effect of sowing time on the seed quality of wheat

Significant variations were observed due to different sowing time on the seed quality of wheat viz. shoot length and vigour index for both 2008-09 and 2009-10 and only in root length of seedling in 2008-09, though the others were not significant (Table 1). It revealed that the highest shoot lengths (11.88 and 12.95 cm) were found from 20 December sowing during the year 2008-09 and 2009-10, respectively while the lowest shoot lengths (11.11 and 11.70 cm) were recorded from 20 November sowing. The highest seed vigour indices, 1.38 and 1.30, were recorded in 20 November and 05 December sowing from the year 2008-09 and 2009-2010, respectively and the lowest seed vigour indices, 1.15 and 1.02, were observed from 20 December sowing in 2008-09 and 2009-10, respectively.

Effect of variety on the seed quality of wheat

Wheat varieties showed significant differences on the seed quality of wheat viz. seedling root and shoot length in 2008-09 and 2009-10 and seed germination and vigour index only for the year 2008-09 and the other characters were not significant (Table 2). In 2008-09, the highest seed germination (92.44%) was found from the variety ‘Sufi’ and the lowest (87.78%) was found in the variety ‘Bijoy’. The highest seedling root lengths (11.99 and 12.13 cm) were observed in variety ‘Prodip’ and ‘Sufi’ in 2008-09 and 2009-2010, respectively while the lowest seedling root lengths (10.71 and 10.48 cm) were found in the variety ‘Bijoy’ both from the years, respectively. The highest shoot lengths (11.79 and 13.16cm) were observed in the variety ‘Prodip’ and ‘Bijoy’, respectively and the lowest shoot lengths (10.94 and 11.64 cm) were found in variety ‘Bijoy’ and ‘Sufi’ in the year 2008-09 and 2009-2010, respectively. However, in 2008-09, the highest vigour index (1.44) was found in the variety ‘Sufi’ and the lowest vigour index (1.19) was obtained in variety Prodip, respectively (Table 2).

Combined effect of sowing time and variety on the seed quality of wheat

It was observed that seed germination, root and shoot lengths, root-shoot ratio and vigour index of wheat were significantly affected by sowing time and variety though the other parameters were not significant (Table 3). The highest seed germination (93.33%) and shoot length (12.23 cm) were recorded in the treatment

Table 1. Effect of sowing time on seed germination, seedling root and shoot length, seedling dry weight and vigour index of wheat

Sowing time	Seed germination (%)		Root length (cm)		Shoot length (cm)		Root-shoot ratio		Seedling dry weight (g)		Vigour index	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
S_1	90.00	89.78	11.26	11.04	11.11	11.70	1.01	0.95	0.013	0.012	1.17	1.08
S_2	89.56	91.11	11.59	11.61	11.33	12.34	1.03	0.94	0.015	0.014	1.34	1.28
S_3	95.44	91.11	11.79	11.76	11.88	12.95	0.99	0.93	0.015	0.012	1.43	1.09
LSD(0.05)	NS	NS	0.159	NS	0.399	0.841	NS	NS	NS	NS	0.19	0.14
CV (%)	3.26	5.72	3.77	7.24	2.66	5.91	4.12	8.30	9.25	12.56	10.02	11.28

NS= Not significant.

S_1: 20 November, S_2: 07 December and S_3: 20 December.

Table 2. Effect of variety on seed germination, seedling root and shoot length, seedling dry weight and vigour index of wheat.

Variety	Seed germination (%)		Root length (cm)		Shoot length (cm)		Root-shoot ratio		Seedling dry weight (g)		Vigour index	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
V_1	87.78	89.78	10.71	10.48	10.94	13.16	0.98	0.80	0.014	0.013	1.23	1.17
V_2	92.44	91.56	11.94	12.13	11.59	11.64	1.03	1.04	0.016	0.012	1.48	1.10
V_3	91.78	90.67	11.99	11.80	11.79	12.19	1.02	0.97	0.013	0.013	1.19	1.18
LSD(0.05)	3.04	NS	0.14	0.85	0.31	0.75	0.05	0.08	NS	NS	0.15	NS
CV (%)	3.26	5.72	3.77	7.24	2.66	5.91	4.12	8.30	9.25	12.56	10.02	11.28

NS= Not significant.

V_1: 'Bijoy', V_2: 'Sufi' and V_3: 'Prodip'.

Table 3. Combined effect of sowing time and variety on seed germination, seedling root and shoot length, seedling dry weight and vigour index of wheat

Sowing time × variety	Seed germination (%)		Root length (cm)		Shoot length (cm)		Root-shoot ratio		Ave. seedling dry weight (g)		Vigour index	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
$S_1 \times V_1$	84.00	85.33	11.24	10.85	11.11	12.15	1.01	0.89	0.014	0.012	1.18	1.02
$S_1 \times V_2$	92.67	92.00	11.28	11.15	11.13	10.90	1.01	01.03	0.015	0.012	1.39	1.10
$S_1 \times V_3$	93.33	92.00	11.27	11.12	11.08	12.05	1.01	0.92	0.010	0.011	0.93	1.01
$S_2 \times V_1$	88.00	93.33	10.45	10.50	10.40	12.98	1.01	0.81	0.015	0.015	1.32	1.40
$S_2 \times V_2$	91.33	91.33	12.20	12.22	11.42	12.53	1.07	0.81	0.016	0.013	1.46	1.19
$S_2 \times V_3$	89.33	88.67	12.13	12.12	12.18	11.51	1.00	0.97	0.014	0.015	1.25	1.33
$S_3 \times V_1$	91.33	90.67	10.43	10.09	11.31	14.53	0.92	1.05	0.014	0.010	1.28	0.91
$S_3 \times V_2$	93.33	91.33	12.35	13.01	12.23	11.49	1.01	0.70	0.016	0.012	1.49	1.10
$S_3 \times V_3$	92.67	91.33	12.58	12.17	12.10	13.02	1.04	1.13	0.015	0.013	1.39	1.19
LSD(0.05)	5.26	NS	0.25	1.48	0.54	1.29	0.08	NS	NS	NS	0.47	NS
CV (%)	3.26	5.72	3.77	7.24	2.66	5.91	4.12	0.137	9.25	12.56	10.02	11.28

NS= Not significant.

S_1: 20 November, S_2: 07 December and S_3: 20 December and V_1: 'Bijoy', V_2: 'Sufi' and V_3: 'Prodip'.

combination $S_3 \times V_2$ and the lowest was found from the treatment combination $S_1 \times V_1$ and $S_1 \times V_3$, respectively in 2008-09 while in 2009-10, these values were recorded higher (93.33% and 14.53 cm) in the treatment combination of $S_2 \times V_1$ and $S_3 \times V_1$, respectively. The lowest values of seed germination (85.33%) and shoot length (10.90 cm) were obtained in the treatment combination $S_1 \times V_2$. The highest seedling root lengths (12.58 and 13.01 cm) were observed in $S_3 \times V_3$ and $S_3 \times V_2$ in the year 2008-09 and 2009-10, respectively and the lowest values (10.43 and 10.09 cm) were recorded in $S_3 \times V_1$ treatment combination, respectively in both the years. In case of vigour index, the variety 'Sufi' sown on 20 November showed the highest vigour indices (1.53 and 1.41) in the year 2008-09 and 2009-10, respectively. The lowest values of vigour indices (0.96 and 0.95) were recorded from the treatment combinations $S_1 \times V_3$ (the variety 'Prodip' sown on 20 November) and $S_3 \times V_1$ (the variety 'Prodip' sown on 20 December) during the year 2008-09 and 2009-10, respectively. The seed lot showing higher seed vigour index is considered to be more vigorous (Abdul-Baki and Anderson, 1973). The results are in agreement with the findings of Ayyub *et al.* (2007) who reported that physiologically mature seeds displayed better viability and seed quality. The results are also in line with the findings of Seshu and Dadlani (1989) who asserted that high germination percentage and vigour are significant aspects of seed quality. Quality seed with higher germination percentage and vigour index might be contributed to get optimum plant population, growth and development. This was also supported by Parera and Cantliffe (1994) who reported that rapid and uniform field emergence is essential to achieve better growth and high yield. Findings of previous works also showed that variation in seed germination and vigour were observed due to variation in sowing date (Tekrony *et al*., 1997 and Rahman *et al*., 2005). Adam *et al*. (1989) reported that early sowing of seed was associated with more yield and higher seed quality than late sowing in Ohio, USA. Similar findings were also reported in soybean by Rahman *et al*. (2013) who observed that germination percentage and vigour index of seed decreased with delayed sowing.

Conclusion

The present investigation revealed that most of the seed quality parameters were significantly influenced by date of sowing and variety. The highest seed germination 93.33% was recorded in the seeds of 'Prodip' variety sown on 20 December 2008, and 'Bijoy' variety sown on 5 December 2009, respectively. However, all the varieties showed more than 83% seed germination at all the dates of sowing. The highest vigour indices (1.53 and 1.41) were found in the seeds of 'Sufi' variety sown on 20 November in both the years of 2008-09 and 2009-10, respectively. Although seed germination and vigour index of wheat varieties were influenced by sowing times, all the tested varieties exhibited better seed quality immediately after harvest.

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TREND AND OUTPUT GROWTH ANALYSIS OF MAJOR FRUITS IN CHITTAGONG REGION OF BANGLADESH

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Abstract

The study analyzed the trends, growth rates of area, production and yield of major fruits in Chittagong region and identified factors contributing to output growth during 1993/94-2009/10 using secondary data. The fruits under study were mango, jackfruit, litchi, guava, banana, papaya, ber, pomelo, pineapple, watermelon, lime and lemon. The study revealed that the area of all fruits increased over the period except banana, ber, pomelo and water melon. The highest increase in area was estimated for guava (131.6%) and the lowest for jackfruit (6.4%). Similarly, the production of all fruits over the period was increased except banana and pineapple. The average annual growth rates of area, production and yield for all fruits were found to be positive in all periods (i.e, period I: 1993/94-1997/98; Period II: 1998/99-2003/04, and Period III: 2004/05-2009/10). But the magnitude of the growth rates of area for all fruits varied significantly. The growth rates of area for mango, jackfruit, litchi and pineapple were increased impressively and significantly. This might be due to the adoption of improved variety and management practices by the farmers. The growth rate of area, production and yield of banana decreased drastically over the period due to absence of modern variety of banana and lack of improved management practices in the region. The growth rates of production for mango were found to be highest in the period III (2004/05-2009/10). But the growth rate of yield of mango was found to be decreased significantly over the periods due to improper management against the pest and diseases by the farmers. The highest percentage of output changed was observed in Banana (149%) followed by pineapple (106%) and jackfruit (83%) between the periods. The lowest percentage of output changed was found in guava (11.7%). The contribution of area was the highest in changing output for mango, jackfruit, litchi, guava, ber, pomelo, watermelon, lime and lemon. The contribution of yield was the highest for banana (135.57%), papaya (76.92%) and pineapple (158.62%) for changing output indicated that the increased area was more responsible for changing in output growth of selected fruits. To increase the growth rate of fruits, improved variety and management practices should be disseminated through undertaking special programme and strengthening research-extension linkage in the Chittagong region.

Keywords: Trends, fruits, area, production, yield, output growth, Chittagong region.

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Introduction

Bangladesh is blessed with many horticultural crops. More than 90 vegetables, 60 fruits and 25 spices are being grown in the country. Fruits in Bangladesh cover an area of 242.8 thousand hectares with a total production of 10.91 lakh metric tons (BBS, 2012). Fruits play a unique role both in economic and social sphere for improving income and nutritional status, particularly rural masses. Fruits are highly valued in human diet mainly for vitamins and minerals. Along with these, orchards of fruits help in maintaining ecological balance. Fruit contributes 10% income of the national economy and 1-2% land covered of the total cultivable land in Bangladeh (Mondal *et al.*, 2011).

Per capita per day fruit intake is 44.7 gram at national level and that of 42.6 gram for rural areas (HIES, 2010) as compared to the minimum requirement of 100 g/capita (FAO/WHO, 2003; BAN-HRDB, 2007).

Due to tropical and subtropical climate, a variety of fruits and vegetables are grown in our country. Particularly, the distinctive climatic conditions in the Chittagong region provide a great diversity and variety for fruit production. The major fruits grown in the Chittagong region (Chittagong and Cox's Bazar districts) include mango, jackfruit, litchi, guava, banana, papaya, ber, pomelo, pineapple, watermelon, lime & lemon. The area, total production and yield of major fruits grown in the region are shown in the Table1.

Table1. Area and production of major fruits in the Chittagong region, 2009-10

Sl. No.	Fruits	Area (ha)	Production (mt)	Yield (t/ha)
1	Mango	2262	16366	8.82
2	Jackfruit	1312	50635	38.59
3	Litchi	304	1932	6.36
4	Guava	1126	30763	2733
5	Banana	1417	16011	11.30
6	Papaya	413	3737	9.05
7	Ber	94	3763	39.89
8	Pomelo	302	3556	11.79
9	Pineapple	1091	12712	11.66
10	Watermelon	1351	22159	1641
11	Lime & lemon	416	6286	1512

Source: (BBS, 2012).

Currently, export of fruits is considered to be a big source of foreign earning exchange. The region produces a million tons of fruits annually. That is why, this region is rightly considered to be a fruit basket of Bangladesh. An analysis of fluctuations of fruit production, productivity apart from growth, is of importance for understanding the status of fruit development in the region. The magnitude of fluctuations depends on fruit production technology, its sensitivity to weather, economic environment, availability of inputs and many other associated factors.

The growth rate of area, production and yield of fruits could help to facilitate, the forecasting on the future development of fruits in the region. Therefore, the findings of the study are of great importance for horticulturist, researcher, extension workers, and policy makers for improving fruit production in the region.

The specific objectives of the study were:

i) to analyze the trends in average area, production and productivity of major fruits grown in the Chittagong region during 1993/94 - 2009/10;

ii) to estimate the annual growth rates of area, production, and yield of major fruits in the Chittagong region during 1993/94 - 2009/10;

iii) to identify the contribution of area, yield and interaction of yield and area in output growth of the selected fruits; and

iv) to derive policy implications from the above.

Methodology

This study was carried out based on secondary data sources i.e. different issues of BBS and other published scientific articles and journals. The data period was 1993/94 to 2009/10 (16 years). The selected fruits were mango, jackfruit, litchi, guava, banana, papaya, ber, pomelo, pineapple, watermelon, lime and lemon. The BBS authority collected time series data on mango and jackfruit for the period of 06 years (2004-05 to 2009-10) in a different way. So, for getting unbiased and meaningful results of the growth rates, the data was analysed on disaggregated manner i.e. {Period I (1993/94-1997/98); Period II (1998/99-2003/04, and Period III (2004/05-2009/10)}. The descriptive analyses were done for estimating the trend of area, production and yield of the selected fruits.

In the study compound growth rate (CGR) analysis was used. It is usually estimated by fitting a semi-log trend equation (repeated) of the following form CGRs of area, production and yield of the selected fruits (Gujarati, 1988:

$Y= a.e^{bti}$…………………(i)

Or In Y = Ina+bti

Or InY = A+ bti (here A=Ina)

Where,

A = Intercept

Y = Quantity of major fruits production, area and yield

b = Growth rate in ratio scale and when multiplied by 100, it express % age growth i.e, annual growth rate

ti = Time, i= 1,2, 3,…………, 16 years

In = Natural log of the variable

The slop coefficient ‘b’ measures the instantaneous rate of growth. The compound growth rate ‘r’ may be calculated as follow:

CGR (r) = (antilog of b -1) x 100

The above mentioned equation was estimated by applying OLS method. The standard error was applied to test the significance of ‘b’. This equation is generally used on the consideration that changes in agricultural area or output or yield in a given year would depend upon the area or output or yield in the preceding year (Deosthali and chandrathekhar, 2014).

For estimating the contributing factors on fruit output, the decomposition analyses were used:

Decomposition analysis: To decompose the components of change in major fruits production and their contributions, the following algebric equation is estimated (Kamruzzaman *et al.,* 1998):

Change in total production	$P_t - P_0 =$
Contribution of area change (Absolute change in area)	Y_0 [A_t (1 + $C_0 - C_t$) – A_0] +
Contribution of yield change	[A_t { 1 + ($C_0 - C_t$) ($Y_t - Y_0$)}]

Where, P_0 = production of the respective fruit in 1993/94

P_t = production of the respective fruit in 2009/10

A_0 = area under the fruit in 1993/94

A_t= area under the fruit in 2009/10

Y_0= the yield of respective fruit in 1993/94

Y_t = the yield of respective fruit in 2009/10

C_0 = the proportion of area under the fruit to gross fruit production area under all fruits in 1993/94

C_t = the proportion of area under the fruit to gross fruit production area under all fruits in 2009/10.

Results and Discussion

Trends in average area, production and yield of major fruits

During the period, the area of all fruits increased except banana, ber, pomelo and water melon and these were decreased negatively. The highest increase in area was recorded for guava (131.67%), while the lowest for jackfruit (6.4%). Ber fruit recorded the highest decrease in area, while the lowest decrease was in pomelo (0.67%) (Table 2). The average production of all fruits increased except banana and pineapple. They were negatively decreased in production over the period. The highest increase in production was recorded for guava (754.53%) while the lowest for jackfruit (20.29%) (Table 2). The average yield of all fruits increased except banana and pineapple over the base year (1993/94). Yield of all fruits was lower than national average except pineapple and water melon.

Table 2. Percentage change in area, production and yield of major fruits in Chittagong region over the period of 1993/94 to 2009/10

Sl. No.	Fruits	Average area (ha) over 1993/94 to 2009/10	Percentage change in area over 1993/94 to 2009/10	Average production (tons) over 1993/94 to 2009/10	Percentage change in production over 1993/94 to 2009/10	Average yield (ton/ha) over 1993/94 to 2009/10	Percentage change in yield over 1993/94 to 2009/10
1	Mango	2181	7.15	13284	106.41	6.04	92.64
2	Jackfruit	1253	6.40	11848	20.39	9.46	13.15
3	Litchi	280	12.78	1346	100.21	4.75	77.72
4	Guava	1184	131.67	14784	754.53	13.47	268.86
5	Banana	1672	-14.75	20217	-37.12	12.21	-26.24
6	Papaya	313	68.60	2261	119.18	7.19	30.00
7	Ber	323	-57.64	2733	263.57	12.05	758.22
8	Pomelo	369	-0.67	2202	397.37	6.23	400.68
9	Pineapple	838	48.43	12665	-6.43	15.54	-36.96
10	Watermelon	1454	-10.08	17550	55.83	12.21	73.03
11	Lime & lemon	265	65.65	2323	461.25	11.12	238.83

Source: BBS (2001 to 2010).

Growth rate of area of major fruits

The average annual growth rates of area for all fruits were found to be positive in all periods. But the magnitudes of the growth rates varied significantly among the fruits as well as over the period. The growth rates of area for mango and litchi was found to be highest in period III (2004/05-2009/10) as compared to other two periods. This might be due to adopt improved varieties of mango is and litchis as a profitable fruits. But the growth rates of area for jackfruit and pineapple was the highest in the period I (1993/94-1997/98) as compared to next two periods. The growth rates of area for others fruits were found to be lower over the three periods (Table 2, Table 5 and Table 8 and Figure 4). Reasons for increased growth rates of area of fruits might be accelerated to create awareness and profitability of those fruits.

Growth rates of production of major fruits

The average annual growth rates of production for all fruits were found to be positive in all periods. But the magnitudes of the growth rates of production for all fruits were varied insignificantly. The growth rates of production for mango were found to be highest in the period III (2004/05-2009/10) compared to other two periods. But the growth rates of production for jackfruit and pineapple were the highest in period I (1993/94-1997/98) compared to next two periods. The growth rate of production of litchi was found to be increased significantly over the periods. This might be due to adopt improved varieties of litchi as a profitable fruit. But the growth rate of production of banana fluctuated over the periods. The growth rate of production of banana decreased drastically in the period III. This may be due to decrease the area of banana and might be most of the farmers were highly motivated to be planted mango and litchi as an economic fruit. The growth rates of production for others fruits were found to be fluctuated over the three periods (Table 2, Table 3, Table 6 and Table 9). Reasons for increased and decreased growth rates might be accelerated to create awareness and profitability of those fruits.

Growth rates of yield of major fruits

The average annual growth rates of yield for all fruits were found to be positive in all periods. But the magnitudes of the growth rates of yield for all fruits were varied significantly. The highest growth rate of yield for mango was obtained in the period I (2004/05-2009/10) as compared to other two periods. But the growth rate of yield for mango was found to be decreased gradually over the periods. This might be happened due to improper management against the pest and diseases by the farmers. Similarly, the growth rate of yield of jackfruit was found to be decreased gradually over the periods might be the same reasons. On the other hand, the growth rate of yield of litchi was recorded to be increased over the period. This might be happened due to introduce improved variety of litchi at farmers level. Notably, the growth rate of yield of guava was found to be decreased drastically over the periods. The growth rate of yield of banana was found to be fluctuated over the period but drastically decreased in the current period i.e 2004/05 -2009/10. This might be happened due to absence of modern varieties of bananas and lack of improved management practices. The growth rates of yield for other fruits were found to be fluctuated over the three periods (Table 4, Table 7 and Table 10). Reasons for increased and decreased growth rates of yield might be accelerated to adopt modern varieties and improved management practices. The growth rate of yield of watermelon was found to be highest in the period I (i.e. 1993/94 -1997/98). But the growth rate of yield of watermelon was decreased drastically in the next two periods. This might be due to severe disease and improper management by the farmers.

Table 3. Average annual growth rates of area of major fruits in Chittagong region, Period I (1993/94-1997/1998

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	8.55	65.26	4.59**	0.04	0.91
2	Jackfruit	8.02	96.65	1.65^{ns}	0.24	0.57
3	Litchi	6.49	48.04	0.15^{ns}	0.89	0.11
4	Guava	7.09	4.41	3.03*	0.09	0.82
5	Banana	8.31	21.7	0.92^{ns}	0.45	0.30
6	Papaya	6.41	1.10	1.61^{ns}	0.24	0.56
7	Ber	6.30	0.73	17.57***	0.00	0.99
8	Pomelo	6.62	12.22	2.65^{ns}	011	0.77
9	Pineapple	7.50	47.53	0.58^{ns}	0.61	0.14
10	Watermelon	8.21	14.31	7.71**	0.01	0.96
11	Lime & lemon	6.42	17.05	2.13^{ns}	0.16	0.69

Note: ***=Significant at 1% level; **= Significant at 5% level; * Significant at 10% level; and ns= Not significant.

Table 4. Average annual growth rates of production of major fruits in Chittagong region, Period I (1993/94-1997/1998.

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	9.17	13.6	1.29^{ns}	0.32	0.45
2	Jackfruit	9.32	42.5	0.32^{ns}	0.77	0.49
3	Litchi	6.87	6.19	0.33^{ns}	0.76	0.15
4	Guava	8.18	3.74	2.39^{ns}	0.13	0.74
5	Banana	10.14	12.33	1.59^{ns}	0.25	0.56
6	Papaya	7.44	1.31	1.72^{ns}	0.21	0.62
7	Ber	11.02	1.18	9.34**	0.01	0.97
8	Pomelo	6.57	3.89	3.33*	0.07	0.84
9	Pineapple	9.51	20.17	2.35^{ns}	0.14	0.73
10	Watermelon	9.56	15.65	5.71**	0.02	0.94
11	Lime & lemon	7.02	13.63	2.86*	0.10	0.80

Note: **=Significant at 5% level; *= Significant at 10% level; and ns= Not significant.

Table 5. Average annual growth rates of yield of major fruits in Chittagong region, Period I (1993/94- 1997/1998

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	0.61	79.70	4.01**	0.05	0.88
2	Jackfruit	1.32	102.14	2.01^{ns}	0.18	0.67
3	Litchi	0.37	88.66	0.63^{ns}	0.59	0.16
4	Guava	1.09	16.60	1.45^{ns}	0.28	0.51
5	Banana	1.82	25.65	1.69^{ns}	0.23	0.58
6	Papaya	5.03	5.14	1.15^{ns}	0.36	0.40
7	Ber	0.63	29.17	1.92^{ns}	0.19	0.64
8	Pomelo	-0.04	8.12	1.92^{ns}	0.19	0.64
9	Pineapple	2.01	20.92	4.19**	0.05	0.89
10	Watermelon	1.34	152.46	2.45^{ns}	0.13	0.75
11	Lime & lemon	0.59	72.38	0.63^{ns}	0.59	0.16

Note: **=Significant at 5% level; and ns= Not significant.

Table 6. Average annual growth rates of area of major fruits in Chittagong region, Period II (1998/99 – 2003/04.

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	8.57	88.72	0.38^{ns}	0.76	0.12
2	Jackfruit	8.02	28.20	14.75***	0.00	0.99
3	Litchi	6.46	49.00	22.76**	0.02	0.99
4	Guava	7.50	5.50	1.85^{ns}	0.31	0.77
5	Banana	8.37	67.50	0.53^{ns}	0.68	0.22
6	Papaya	6.77	24.98	0.92^{ns}	0.52	0.45
7	Ber	6.70	1.42	2.19^{ns}	0.27	0.82
8	Pomelo	6.87	3.33	5.16^{ns}	0.12	0.96
9	Pineapple	7.53	17.89	1.94^{ns}	0.30	0.79
10	Watermelon	8.22	3.34	5.19^{ns}	0.12	0.96
11	Lime & lemon	6.52	2.36	2.29^{ns}	0.26	0.84

Note: ***=Significant at 1% level; **=Significant at 5% level; and ns= Not significant.

Table 7. Average annual growth rates of production of major fruits in Chittagong region, Period II (1998/99 -2003/04

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	11.43	16.98	1.63^{ns}	0.34	0.72
2	Jackfruit	9.32	26.87	5.63^{ns}	0.11	0.96
3	Litchi	6.82	8.38	0.94^{ns}	0.51	0.47
4	Guava	8.70	0.85	1.76^{ns}	0.32	0.75
5	Banana	9.89	29.17	0.80^{ns}	0.56	0.39
6	Papaya	7.73	34.76	0.04^{ns}	0.97	0.16
7	Ber	7.34	1.18	2.03^{ns}	0.28	0.81
8	Pomelo	7.02	20.38	0.33^{ns}	0.79	0.99
9	Pineapple	9.56	7.44	1.40^{ns}	0.48	0.52
10	Watermelon	9.54	7.34	3.11^{ns}	0.19	0.90
11	Lime & lemon	7.06	7.18	6.12*	0.10	0.97

Note: *=Significant at 10% level; and ns= Not significant.

Table 8. Average annual growth rates of yield of major fruits in Chittagong region, Period II (1998/99 – 2003/04.

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	0.58	8.16	1.25^{ns}	0.43	0.60
2	Jackfruit	1.58	36.48	1.36^{ns}	0.40	0.64
3	Litchi	3.51	3.73	0.41^{ns}	0.75	0.14
4	Guava	1.20	1.57	2.06^{ns}	0.28	0.81
5	Banana	1.52	47.01	1.13^{ns}	0.46	0.56
6	Papaya	0.96	14.19	3.00^{ns}	0.20	0.90
7	Ber	0.68	6.31	1.62^{ns}	0.35	0.72
8	Pomelo	0.15	11.84	1.23^{ns}	0.43	0.60
9	Pineapple	2.02	4.83	1.71^{ns}	0.33	0.74
10	Watermelon	1.31	7.83	7.88*	0.08	0.98
11	Lime & lemon	0.53	2.94	2.07^{ns}	0.28	0.81

Note: *=Significant at 10% level; and ns= Not significant.

Table 9. Average annual growth rates of area of major fruits in Chittagong region, Period III (2004/05 – 2009/10

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	8.63	94.90	1.86^{ns}	0.15	0.53
2	Jackfruit	8.03	24.33	1.90^{ns}	0.15	0.54
3	Litchi	6.61	57.58	2.37^{ns}	0.09	0.65
4	Guava	7.68	14.49	3.34^{ns}	0.04	0.78
5	Banana	8.39	2.39	2.80^{ns}	0.06	0.72
6	Papaya	6.78	7.69	0.48^{ns}	0.65	0.07
7	Ber	6.73	0.72	1.94^{ns}	0.14	0.55
8	Pomelo	6.76	3.63	3.03^{ns}	0.05	0.75
9	Pineapple	7.37	14.92	1.66^{ns}	0.19	0.48
10	Watermelon	8.14	20.45	0.54^{ns}	0.62	0.08
11	Lime & lemon	5.73	1.72	0.02**	0.98	0.06

Note: **=Significant at 5% level; and ns= Not significant.

Table 10. Average annual growth rates of production of major fruits in Chittagong region, Period III (2004/05-2009/10).

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	9.89	24.51	2.46*	0.09	0.66
2	Jackfruit	9.43	12.28	1.95^{ns}	0.14	0.56
3	Litchi	15.65	12.00	1.40^{ns}	0.25	0.39
4	Guava	9.91	3.26	3.34*	0.04	0.79
5	Banana	9.87	5.91	0.94^{ns}	0.41	0.23
6	Papaya	8.17	2.96	1.85^{ns}	0.15	0.53
7	Ber	8.70	1.34	1.43^{ns}	0.24	0.40
8	Pomelo	9.09	5.10	0.61^{ns}	0.58	0.10
9	Pineapple	9.01	3.68	3.33**	0.04	0.78
10	Watermelon	10.12	17.97	0.70^{ns}	0.53	0.14
11	Lime & lemon	7.95	0.73	7.43***	0.00	0.94

Note: ***=Significant at 1% level; **=Significant at 5% level; *=Significant at 10% level; and ns= Not significant.

Table 11. Average annual growth rates of yield of major fruits in Chittagong region, Period III (2004/05 -2009/10

Sl. No.	Fruits	Intercept	Compound Growth Rate (%)	t-ratio	P-value	R^2
1	Mango	1.25	4.75	2.47*	0.09	0.66
2	Jackfruit	1.39	24.96	1.91ns	0.15	0.54
3	Litchi	0.74	7.92	0.64ns	0.56	0.12
4	Guava	2.23	1.96	5.24***	0.01	0.90
5	Banana	1.48	4.23	1.37ns	0.26	0.38
6	Papaya	1.39	3.38	1.11ns	0.34	0.29
7	Ber	1.97	0.37	3.53**	0.03	0.81
8	Pomelo	1.33	2.78	1.56ns	0.21	0.45
9	Pineapple	1.63	6.43	1.83ns	0.16	0.52
10	Watermelon	1.97	10.87	4.02**	0.02	0.84
11	Lime & lemon	2.23	1.44	0.97ns	0.40	0.23

Note: ***=Significant at 1% level; **=Significant at 5% level; *=Significant at 10% level; and ns= Not significant.

Table 12. Summary of annual growth rate (%) of major fruits in the Chittagong region

Fruits	Period I			Period II			Period III		
	1993/94 -1997/1998			1998/99 -2003/04			2004/05-2009/10		
	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
Mango	65.3	13.6	79.7	88.7	17.0	8.2	94.9	24.5	4.8
Jackfruit	96.7	42.5	102.1	28.2	26.9	36.5	24.3	12.3	25.0
Litchi	48.0	6.2	88.7	49.0	8.4	3.7	57.6	12.0	7.9
Guava	4.4	3.7	16.6	5.5	0.9	1.6	14.5	3.3	2.0
Banana	21.7	12.3	25.7	67.5	29.2	47.0	2.4	5.9	4.2
Papaya	1.1	1.3	5.1	25.0	34.8	14.2	7.7	3.0	3.4
Ber	0.7	1.2	29.2	1.4	1.2	6.3	0.7	1.3	0.4
Pomelo	12.2	3.9	8.1	3.3	20.4	11.8	3.6	5.1	2.8
Pineapple	47.5	20.2	20.9	17.9	7.4	4.8	14.9	3.7	6.4
Watermelon	14.3	15.7	152.5	3.3	7.3	7.8	20.5	18.0	10.9
Lime & lemon	17.1	13.6	72.4	2.4	7.2	2.9	1.7	0.7	1.4

Decomposition of output growth of individual fruits

The sources of output change between two periods might be due to the change in area, yield and the multiplicative effects of the both. The relative contribution of area, yield, and their interaction to change the production of individual fruit is presented in Table 13. Results revealed that among the fruits, the highest percentage of output changed was observed in banana (149%) followed by pineapple (106%) and jackfruit (83%) between the two periods. The lowest percentage of output changed was found in guava (11.7%) between the two periods. The contribution of area was the highest in changing output between two periods for mango, jackfruit, litchi, guava, ber, pomelo, watermelon, lime and lemon. On the other hand, the contribution of yield was the highest for banana (135.57%), papaya (76.92%) and pineapple (158.62%) for changing output between the periods. It indicated that the increased area was more responsible for changing in output growth of selected fruits between the two periods.

Table 13. Sources of change in output growth of the selected fruits in between 1993/94 and 2009/10.

Sl. No.	Fruits	Changes in output between the periods (%)	Contribution of area (%) (1)	Contribution of yield (%) (2)	Interaction between yield and area (3)	Total (%) (1+2+3)
1.	Mango	48.44	93.32	51.91	-45.23	100
2.	Jackfruit	83.06	93.98	88.38	-82.36	100
3.	Litchi	49.95	88.67	56.33	-45.00	100
4.	Guava	11.70	43.17	27.11	29.72	100
5.	Banana	149.04	117.32	135.57	-152.89	100
6.	Papaya	45.62	59.31	76.92	-36.23	100
7.	Ber	27.50	236.05	11.65	-147.7	100
8.	Pomelo	20.11	100.67	19.97	-20.64	100
9.	Pineapple	106.86	67.37	158.62	-125.99	100
10.	Watermelon	64.17	111.21	57.70	-68.91	100
11.	Lime & lemon	17.82	60.37	29.91	9.72	100

Conclusions

It may be concluded that the average annual growth rates of area, production and yield was found to be positive for all the selected fruits. But the magnitude of the growth rate was varied significantly among the fruits. Increased in area rather than yield of individual fruit was mostly responsible for changing the output growth significantly between the periods. Reasons for increased the growth rates might be accelerated to create awareness and profitability of those fruits. Similarly, reasons for lower growth rates of the selected fruits might be responsible for lower adoption of improved varieties and lack of improved management practices. So, there is a scope for enhancing productivity of all major fruits grown in the Chittagong region.

Recommendations and policy implications

Based on the above findings, the following recommendations and policy implications are made accordingly:

In view of protecting the decreasing trend of land allocation to banana, ber, pomelo, watermelon, lime and lemon, Government of Bangladesh and concerned departments at first should look out the causes of decreasing trend of land allocation of those fruits. Secondly, improved fruit technology so far existing in the country should be disseminated throughout the Chittagong region by strengthening research and extension linkage. In order to increase the production of banana, improved variety (BARI Kola 3 and BARI Kola 4) and management practices could be disseminated through undertaking special programme. Concerned department i.e. Department of Agriculture Extension (DAE), Bangladesh Agriculture Development Corporation (BADC) and Bangladesh Agricultural Research Institute (BARI) can play crucial role in disseminating the technology throughout the Chittagong region.Year round pineapple production technology developed by BARI can reduce the lower growth rate. The yield of pineapple could be enhanced through applying recommended doses of fertilizer and maintained intercultural operation regularly. Training should be needed in this aspect. The lower growth rate of production for, ber, pomelo, lemon and papaya can be increased by the adoption of improved variety and management practices at farmers' level throughout the Chittagong region. The DAE, BARI, BADC, NGO can play vital role for disseminating the technologies at farm level. The lower growth rates of yield of other fruits can also be increased at the same way.

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EFFECT OF FLOODING ON GROWTH AND YIELD OF MUNGBEAN GENOTYPES

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Abstract

The field experiment was carried out with some selected mungbean genotypes viz. IPSA-13, VC-6173A, BU mug 2, BARI Mung-5 and IPSA-12 to observe the effect of 4-days flooding on their growth and yield of mungbean under field conditions at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during September to November, 2011 maintaining 3-5 cm standing water at 24 days after emergence. Days to flowering and maturity delayed in flooded plants over control depending on the genotypes. Flooding significantly reduced Total Day Matters (TDM), number of pods per plant, seed size and seed yield of the mungbean genotypes over control. Considering higher seed yield, larger seed size and less yield reduction relative to control VC-6173A, BU mug 2 and IPSA-13 were found tolerant to soil flooding condition.

Keywords: Soil flooding, growth and yield, mungbean genotypes.

Introduction

In tropical and subtropical region, heavy rainfall in the rainy season frequently induces short-term flooding in crop fields. Soil flooding occurs over a vast regions throughout the world (Kozlowski, 1984) adversely affecting approximately 10% of the global land area (FAO, 2002). Inundation of land for a long period is harmful even for wetland crops, especially if the standing water is stagnant. Soil flooding has long been identified as a major abiotic stress and the constraints it imposes on roots have marked effects on plant growth and development (Parent *et al.*, 2008). Flooding restricts aeration of the soil creating an oxygen-free environment in the root zone. Under this condition, crops cultivated are damaged to various degrees resulting in poor growth and low yield. Thus soil flooding is a significant agronomic problem for crop production (Carter *et al.*, 1990).

Mungbean is widely cultivated in the tropical and subtropical regions of the world. The crop is sometimes subjected to the detrimental effect of flooding. Mungbean cannot withstand soil flooding, particularly during the early stages of growth (Singh and Singh, 2011). Since this crop is highly susceptible to flooding damage, soil flooding is considered as one of the major factors that restrict the productivity

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of this crop. A high monsoon rain at the time of reproductive period caused enormous loss of both seed yield and seed quality of mungbean (Williams *et al.,* 1995). The extent of responses of crop plants to flooding is controlled mainly by plant genetic factors and is influenced by environmental conditions as well. The aspects concerning the agronomic responses of mungbean to soil flooding are important, as (Nawata, 1989) reported that under actual field conditions most of the crops experienced only transient or short-term soil flooding.

Some earlier experiments indicated that varietal differences in tolerance to soil flooding were existed in mungbean (Hamid *et al.,* 1991). Genotypic difference of mungbean plants to short-term soil flooding was also reported by Islam (2005). However, those experiments were conducted mostly under semi-controlled conditions. The findings of those studies may or may not reflect that of the actual field conditions. Therefore, the experiment was designed to find out the effect of soil flooding under field conditions at pre-flowering stage on the growth and yield of some selected mungbean genotypes.

Materials and Method

The experiment was conducted in the field of the Department of Agronomy of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during 8 September, 2011 to 15 November, 2011. Five mungbean genotypes viz. IPSA-13, VC-6173A, BU mug 2, BARI Mung-5 and IPSA-12 were tested under this study. The genotypes were flooded with 3-5 cm of standing water for 4 days (96 hours) at pre-flowering stage from 24-27 days after emergence (DAE).

The experiment was laid out in a split-plot design with three replications. Flooding treatments were placed in the main-plots and mungbean genotypes were in the sub-plots. The size of each main plot was 8m x 2m =16 m^2 and the size of each sub-plot was (2m x 1.5m). Drain in between two main plots was 1.5 m so that flooded water cannot soak to the neighboring experimental plots. Each sub-plot had 5 rows of mungbean genotype with a spacing of 30 cm x 10 cm. At the border of each plot respective mungbean genotype was grown to avoid border effect.

The experimental land was ploughed properly and at the time of first ploughing cowdung @ 10 t/ha was applied. A blanket dose of fertilizers 20-20-30 kg/ha of N-P-K 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 five mungbean genotypes were sorted from their stock and treated with Vitavex 200 @ 3 g per kg seed before sowing. The seeds were soaked in water for 4 hours before sowing and imbibed seeds were selected for sowing. Most seedlings emerged within 3 days of sowing. Seedlings were thinned out after one week of emergence keeping healthy seedlings of uniform growth. During growing period the average maximum and minimum temperature ranged were between 30.43ºC and 25.30ºC, respectively. The total rainfall during experimentation period was 186.60 mm. Seedlings were raised at optimal soil moisture condition (about 50% AWC). The insecticide Karate at the rate of 2.0 ml per litre water was sprayed to protect the plants from thrips and aphids. Other management practices were done adequately to maintain normal growth of seedlings.

Two treatments were imposed on the growing seedlings in separate experimental plots. Among 6 experimental plots, 3 main-plots were maintained as non-flooded (control) and the rest 3 plots were flooded. Treatments were randomly placed in the experimental units. When the seedlings were 24 days old, flooding with 3-5 cm of standing water was maintained continuously for 4 days (96 hours) during 24-27 DAE. At the same time the optimal soil moisture (about 50% AWC) was maintained as control treatment. Normal irrigation was given to the control plots for establishment of the crops. Data were collected from the beginning of the flood treatment and five plants from each plot of each genotype were pulled out for destructive sampling to determine the dry weight of different plant parts every 10 days interval. After harvesting, the seedlings of both waterlogged and control experiments were segmented into components i.e. stem, leaf, petiole, and reproductive organs. The segmented parts were then oven dried at 80^0C for 72 hours to a constant weight and dry weights were taken separately. Total dry weight (DW) was calculated by summing up the dry weights of stem, leaf, petiole, and reproductive parts of plants. Dates of flowering and maturity were recorded based on the visual observation. When about 50% plants bloomed was considered as first 50% flowering and when about 80% pods matured was considered as maturity stage. Yield and yield components were recorded from the harvested sample at maturity. All data were analysed statistically and mean separation was done using LSD at 5% level.

Results and Discussion

Days to 50% flowering and days to maturity

Irrespective of genotypes, 4-days flooding delayed days to 50% flowering by 3 days than that of non-flooded control. Across the genotypes they were however, statistically non-significant. The shortest duration to 50% flowering was required in BU mug 2 (34 days) followed by BARI Mung-5 (35 days) and VC-6173A (36 days). IPSA-13 and IPSA-12 took 37.00 and 37.83 days to 50% flowering, respectively (Table 1).

Genotype-treatment interaction on days to maturity was significant (Table 2). Soil flooding for 4 days significantly delayed days to maturity. Days to maturity in control plants ranged from 55 to 59 days and BU mug 2 and BARI Mung 5 both took 55 days to mature. IPSA-12 and VC-6173A took 57 and 58 days, respectively to mature and the longest duration was 59 days in IPSA-13. On the other hand, days to maturity in flooded plants ranged from 59 to 66 days where maturity delayed by 4 days in VC-6173A (63 days), BU mug 2 (59 days), BARI Mung-5 (59 days) and IPSA-12 (61 days).Whereas, IPSA-13 (66 days) took 7 more days to mature than that of control. Similarly Kumar *et al.* (2013) reported that both tolerant and sensitive mungbean genotypes showed the inhibition of flowering and pod setting under waterlogging.

Table 1. Effect of 4-days flooding on days to 50% flowering of 5 selected mungbean genotypes

Treatment	Days to 50% flowering	Genotype	Days to 50% flowering under flooding condition
Control	34.40	IPSA-13	37 (3)
Flooding (4 days)	37.46 (3)	VC-6173A	35 (1)
		BU mug 2	34 (0)
		BARI Mung-5	35 (1)
		IPSA-12	37 (3)
$LSD_{0.05}$	NS	$LSD_{0.05}$	0.83
CV (%)	1.88	CV (%)	1.88

Figures in parenthesis indicate delay in days to flowering over control.

Table 2. Effect of 4-days flooding on days to maturity of 5 selected mungbean genotypes

Genotypes	Days to maturity		Delay in days to maturity over the control
	Control	4-days flooding	
IPSA-13	59	66	7
VC-6173A	58	63	5
BU mug 2	55	59	4
BARI mung 5	55	59	4
IPSA-12	57	61	4
$LSD_{0.05}$	0.88		
CV (%)	0.82		

Plant height

Plant height of flooded mungbean genotypes increased progressively from vegetative stage to maturity (Fig. 1). Among the genotypes, plant height varied significantly at all the growth stages except vegetative stage (0 day after termination of flooding). During 10 days recovery period (10 days), plant height of IPSA-13 (30.49 cm) was the highest though other genotypes did not differ significantly and were almost uniform when excess soil moisture was removed.

Plant height at later stages of growth varied among the genotypes. The increment in plant height of some genotypes at later stages of growth indicated the greater recovery ability. Voesenek and Blom (1996) stated that the elongation of stems and petioles may enable plants to emerge from the water in aquatic and flooding tolerant terrestrial species. At 20 days after termination of flooding, the tallest plant was found in VC-6173A (33.93 cm) but other genotypes had statistically similar height while, BU mug 2 (29.12 cm) was the shortest. At maturity (30 DTF), the tallest plant was recorded in IPSA-12 (40.68 cm) followed by VC-6173A (38.60 cm) and BARI Mung-5 (36.87 cm). The lowest height was recorded in BU mug 2 (34.37 cm).

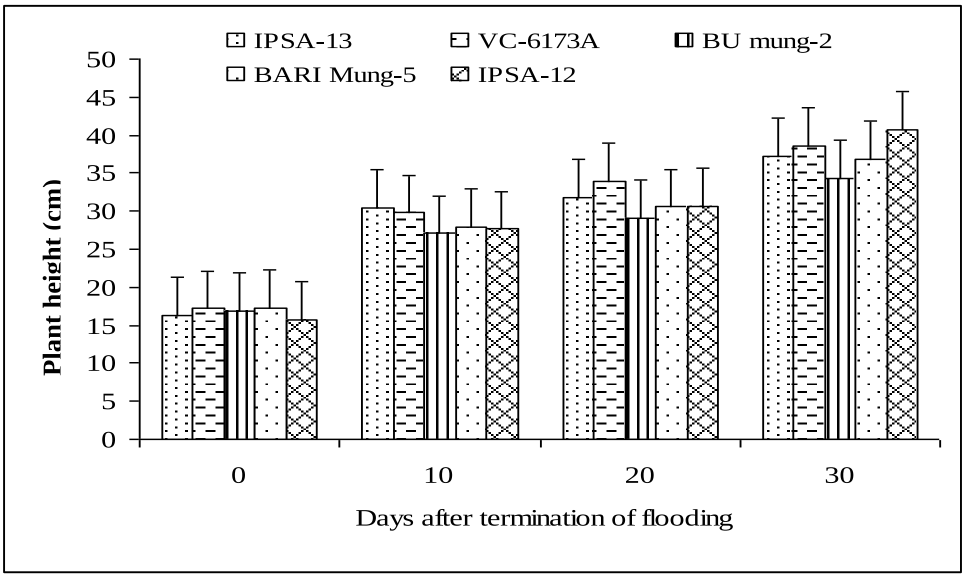

Fig.1. Effect of 4-days soil flooding on plant height of 5 mungbean genotypes.

Number of leaves plant^{-1}

Soil flooding and genotypes interacted significantly on the number of leaves plant^{-1} during 10 days recovery period (10 days after termination of flooding (DTF) but it was non-significant at 0, 20 and 30 days after termination of flooding (Table 3). Control treatment produced higher number of leaves plant^{-1} than those of 4-days flooded plants. The number of leaves plant^{-1} in control plants increased considerably and ranged from 5.00 to 5.60 in control plants and 3.80 to 4.55 in flooded plants. At later stages of growth (20 and 30 DTF), the soil flooding-genotype interaction effect on the number of leaves plant^{-1} was non-significant but small scale genotypic differences were observed. Leaf production plant^{-1} is a varietal character of mungbean as reported by Saha (2005). Nawata (1989) observed that short-term flooding did not affect the changes of the number of leaves in all the varieties of yard long bean.

Table 3. Effect of 4-day soil flooding on number of leaves plant^{-1} of 5 selected mungbean genotypes at 10 days after termination of flooding (DTF)

Genotypes	Number of leaves plant^{-1}	
	Control (Mean ± SD)	4-day flooding (Mean ± SD)
IPSA-13	5.07 ± 0.12	4.33 ± 0.31
VC-6173A	5.60 ± 0.20	4.53 ± 0.31
BU mug 2	5.40 ± 0.20	3.80 ± 0.35
BARI Mung-5	5.00 ± 0.00	4.07 ± 0.31
IPSA-12	5.13 ± 0.23	4.50 ± 0.10
LSD $_{0.05}$	0.405	
CV (%)	4.94	

SD = Standard Deviation

Leaf area plant^{-1}

The soil flooding-genotype interaction on leaf area plant^{-1} was found significant at all the growth stages of mungbean (Table 4). Control treatment produced the higher leaf area plant^{-1} than those of flooded plants after termination of flooding (0 DTF). The highest leaf area plant^{-1} was produced by IPSA-13 (307.18 cm^2 plant^{-1}) followed by VC-6173A (192.76 cm^2 plant^{-1})), BU mug 2 (179.17 cm^2 plant^{-1}) and IPSA-12 (220.07 cm^2 plant^{-1}). The lowest leaf area plant^{-1} was obtained by BARI Mug-5 (150.19 cm^2 plant^{-1}). Leaf area was reduced significantly when plants were flooded for 4 days. The reduction in leaf area relative to control was 49.4% in IPSA-12 followed by IPSA-13 (62.8%) and the lowest was in BARI Mung-5 (86.6%). Leaf area plant^{-1} of flooded plants increased to some extent during the recovery period (10 DTF). Under the non-flooded control condition VC-6173A produced the highest leaf area (365.51 cm^2 plant^{-1}) followed by IPSA-13 (300.58 cm^2 plant^{-1}), but leaf area of IPSA-12 (319.62 cm^2 plant^{-1}) and BARI Mung-5 (317.67 cm^2 plant^{-1}) did not differ significantly. The lowest leaf area (283.9 cm^2 plant^{-1}) was produced by BU mug 2. Leaf area plant^{-1} of all the flooded genotypes were reduced by 50% relative to control. Umaharan *et al.* (1997) reported that leaf area development during the vegetative phase showed significant differences between flooded and control in cowpea plants. At 20 days after termination of flooding, leaf area plant^{-1} of control plants were statistically higher than those of flooded plants except in BU mung-2 (284.10 cm^2 plant^{-1}) and IPSA-12 (315.18 cm^2 plant^{-1}). The leaf area of VC-6173A and BARI Mung-5 were 480.20 and 436.30 cm^2 plant^{-1}, respectively. At maturity (30 DTF), the leaf area plant^{-1} of both control and flooded plants were lower than those of leaf area produced during pre-flowering (0 DTF) or pod filling stage (20 DTF). This might be due to the senescence and abscission of lower leaves at maturity. Similar result was also observed by Islam (2003).

Table 4. Effect of 4-days flooding on leaf area plant^{-1} of 5 selected mungbean genotypes

Genotypes	Leaf area plant^{-1}							
	0 DTF		10 DTF		20 DTF		30 DTF	
	Control	Flooded	Control	Flooded	Control	Flooded	Control	Flooded
IPSA-13	307.18	192.84	300.58	157.74	323.4	215.4	200.30	105.30
VC-6173A	192.76	129.61	365.51	159.48	480.2	213.2	161.20	124.60
BU mug 2	179.17	112.9	283.9	129.63	284.1	237.7	140.80	102.60
BARI Mung- 5	150.19	130.02	317.67	146.81	436.3	196.7	145.20	105.10
IPSA-12	220.07	108.75	319.62	137.47	315.18	232.70	164.40	100.80
LSD $_{0.05}$	42.78		28.69		48.90		23.18	
CV (%)	15.22		9.87		9.63		9.92	

DTF=days after termination of flooding.

Total dry matter

The control treatment had the higher total dry matter (TDM) than that of 4 days flooded plants although genotypic variation existed (Table 5). After termination of flooding, IPSA-13 grown under control produced the highest TDM but other genotypes did not vary significantly. Similar trend was also observed during 10 days recovery period (10 DTF) and also at pod filling stage (20 DTF). At maturity, control treatment produced the highest TDM by BARI Mung-5 (7.45 g plant^{-1}) followed by IPSA-13 (7.23 g plant^{-1}). The lowest TDM was produced by IPSA-12 (5.61 g plant^{-1}). TDM obtained in flooded plants of mungbean genotypes did not vary significantly except VC-6173A. The rate of reduction relative to control was about 50% after termination of flooding (0 DTF), whereas TDM reduced during the recovery period (10 DTF) ranged from 42.6 to 23.9% in different genotypes. Minchin *et al.* (1978) observed severe reduction in biomass (50% of the control) when cowpea plants were flooded in a similar fashion during vegetative phase. Kumar *et al.* (2013) reported that soil flooding in mungbean reduced total dry matter production and also affected the dry matter partitioning. TDM at pod filling stage (20 DTF) increased to a considerable extent than that of TDM gained during the recovery period (10 DTF) and the value was 62.4 to 45.3% relative to control. VC-6173A and BU mug 2 had the lowest rate of reduction relative to control 62.4% and 61.2%, respectively. At maturity (30 DTF), TDM of flooded plants reduced to a great extent ranged from 42.3% to 26.6%. This might be due to the reduction of leaf dry weight as caused by senescence and abscission of lower leaves at maturity. At maturity, the rate of reduction in TDM ranged from 42.3% to 26.6%, VC-6173A being the lowest and BARI Mung-5 the highest which was statistically similar to those of IPSA-13 (29.6%), BU mug 2 (37.3%) and IPSA-12 (39.8%).

Table 5. Effect of 4-days flooding on total dry matter of 5 selected mungbean genotypes

Genotypes	Total dry matter (g plant^{-1})							
	0 DTF		10 DTF		20 DTF		30 DTF	
	Control	Flood	Control	Flood	Control	Flood	Control	Flood
IPSA-13	2.00	0.49	3.12	1.33	6.00	2.46	7.23	2.14
VC-6173A	1.50	0.63	3.43	1.35	5.16	3.11	7.02	2.97
BU mug 2	1.43	0.55	3.68	0.88	4.38	2.42	6.07	2.25
BARI Mung- 5	1.43	0.51	3.41	1.04	4.88	2.01	7.45	1.98
IPSA-12	1.39	0.53	3.38	0.77	4.83	2.35	5.61	2.23
LSD $_{0.05}$	1.44		0.25		0.28		0.363	
CV (%)	8.14		6.43		4.25		4.66	

DTF=days after termination of flooding

Yield and yield components

Yield and yield characters of mungbean genotypes varied significantly due to the influence of 4-days soil flooding. Soil flooding-genotype interacted significantly on pod plant^{-1}, 1000-seeds weight and seed yield (g plant^{-1}) but non-significant on other yield contributing characters (Table 6). Under control condition, the highest number of pods plant^{-1} was produced by IPSA-12 (11.50) which was statistically similar to IPSA-13 (11.30). BARI Mung-5 (9.80) and BU mug 2 (9.40) while VC-6173A produced the least (9.00). Soil flooding for 4 days significantly reduced the number of pods plant^{-1} irrespective of genotypes. Similar result was also observed in legumes by Suleiman *et al.*, (2007), Pociecha *et al.* (2008) and Celik and Turhan (2011) under flooding condition. The higher rate of reduction in pods plant^{-1} over the control was in the genotypes IPSA-13 (54.9%) and IPSA-12 (55.7%). The rate of reduction in BARI Mung-5, BU mug 2 and VC-6173A was 63.6%, 73.4% and 76.7%, respectively.

Table 6. Effect of 4-days flooding on pod plant^{-1} of mungbean genotypes

Genotypes	Pod plant^{-1}		% of reduction rate over control
	Control	4-days soil flooding	
IPSA-13	11.30	6.20	54.9
VC-6173A	9.00	6.90	76.7
BU mug 2	9.40	6.90	73.4
BARI Mung-5	9.80	6.23	63.6
IPSA-12	11.50	6.40	55.7
LSD$_{0.05}$	0.70		
CV (%)	4.88		

DTF=days after termination of flooding

The interaction effect of mungbean genotypes and 4-days soil flooding on 1000-seed weight was statistically significant (Table 7). Plants grown under non-flooded control treatment had the larger seed size than those of 4-days soil flooded plants. One thousand seed weight of IPSA-13 was the highest (57.47 g) while the lowest was in IPSA-12 (37.50 g). Other genotypes viz. VC-6173A (46.25 g), BU mug 2 (46.70 g) and BARI Mung-5 (44.75 g) were statistically similar in 1000-seed weight. Across the genotypes, seed size in flooded plants ranged from 55.4 to 34.2g. 1000-seed weight in flooded plants reduced to different extent over the control where in the genotype IPSA-13 (96.4%) was less affected followed by IPSA-12 (91.2%) and VC-6173A (92%). Seed size of BARI Mung-5 and BU mug 2 reduced by 88.6% and 85.9%, respectively relative to control.

Table 7. Effect of 4-days flooding on 1000-seeds weight of mungbean genotypes

Genotypes	1000-seed weight (g)		
	Control (Mean ± SD)	4-days soil flooding (Mean ± SD)	% of reduction rate over control
IPSA-13	57.47 ± 0.87	55.40 ± 1.35	96.4
VC-6173A	46.25 ± 2.55	42.55 ± 1.95	92.0
BU mug 2	46.70 ± 0.70	40.10 ± 1.18	85.9
BARI Mung-5	44.75 ± 0.55	39.63 ± 0.21	88.6
IPSA-12	37.50 ± 0.96	34.20 ± 0.92	91.2
$LSD_{0.05}$	2.135		
CV (%)	2.78		

SD = Standard Deviation.

Table 8. Effect of 4-days flooding on the seed yield of mungbean genotypes

Genotypes	Seed yield (g plant^{-1})		% of reduction rate over control
	Control (Mean ± SD)	4-days soil floodings	
IPSA-13	4.81 ± 0.11	2.40 ± 0.29	50.0
VC-6173A	4.04 ± 0.72	2. 99 ± 0.40	75.0
BU mug 2	3.79 ± 0.57	2.46 ± 0.34	65.0
BARI Mung-5	3.95 ± 0.34	1.96 ± 0.40	50.0
IPSA-12	3.79 ± 0.48	2.16 ± 0.52	57.0
$LSD_{0.05}$	0.375		
CV (%)	6.73		

SD = Standard Deviation.

Seed yield of mungbean genotypes ranged from 3.79 to 4.81 g plant^{-1} in non-flooded control plot (Table 8). IPSA-13 produced the highest seed yield (4.81g plant^{-1}) but seed yield of other genotypes did not vary significantly viz. VC-6173A (4.04 g plant^{-1}), BARI Mung-5 (3.95 g plant^{-1}), BU mug 2 and IPSA-12 both 3.79 g plant^{-1} in control treatment. Seed yield in flooded plants ranged from 1.96 g to 2.99 g plant^{-1} and reduced at different degrees depending on the genotypes. From the Table 8, it was observed that 50% reduction in seed yield relative to control was both in IPSA-13 and BARI Mung-5. Seed yield was reduced by 57% in IPSA-12, 65% in BU mug 2 and the lowest was in VC-6173A (75%). This indicated that VC-6173A was least affected by 4-days flooding in respect of seed yield. Total dry matter production and seed yield of flooded plants showed linear association and seed yield increased with the increment of TDM (Fig. 2).

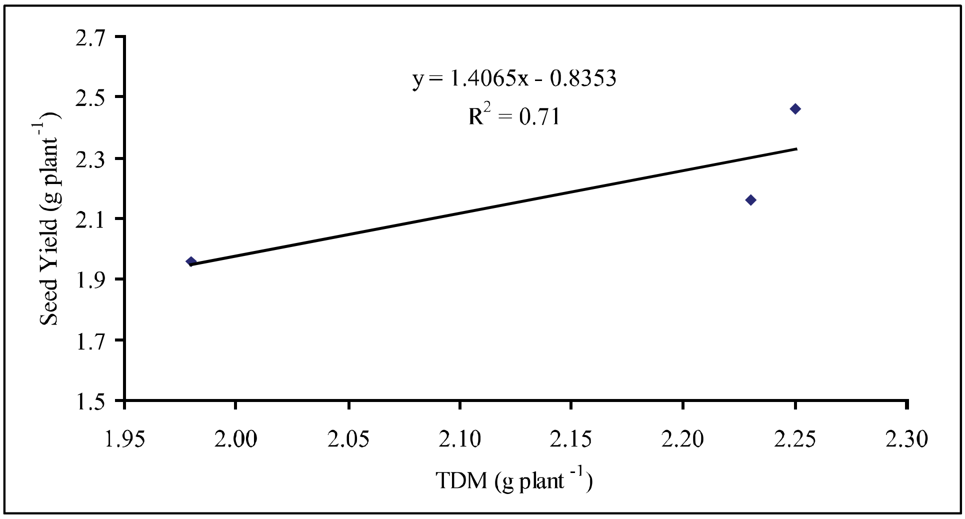

Fig. 2. Functional relationship between TDM and seed yield of mungbean genotypes.

Conclusion

Soil flooding during pre-flowering stage delayed flowering and maturity of mungbean. Among the five selected mungbean genotypes tested under 4 days waterlogging in field condition and it was observed that plant height, leaves plant^{-1}, leaf area plant^{-1}, total dry matter and yield contributing characters of mungbean reduced to a significant extent when exposed to 4 days flooding. TDM and seed yield was positively correlated. Mungbean genotypes VC-6173A, BU mug 2 and IPSA-13 accumulated the highest TDM. Those genotypes were also produced highest seed yields, larger seed size and less yield reduction relative to control. Therefore, those genotypes seem to be more tolerant to soil flooding under 4 days soil flooding condition.

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NITROGEN FIXATING ABILITY OF MUNGBEAN GENOTYPES UNDER DIFFERENT LEVELS OF NITROGEN APPLICATION

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Abstract

A pot culture experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during kharif II, 2012 to evaluate the nodulation, biological nitrogen fixation and yield potential of genotypes of mungbean under varying levels of N application. There were 10 mungbean genotypes viz. IPSA 12, GK 27, IPSA 3, IPSA 5, ACC12890055, GK 63, ACC12890053, BU mug 4, BARI Mung 6 and Binamoog 5, each genotype treated with six levels of N (0, 20, 40, 60, 80 and 100 kg N ha^{-1}) . Among the genotypes, the IPSA 12 at 40 kg N ha^{-1} produced the maximum number of nodules (14.54 $plant^{-1}$) as well as the highest nitrogen fixation (2.684 μmol C_2H_4). This resulted in the highest seed yield (14.22 g $plant^{-1}$). The genotype ACC12890053 recorded the lowest nodulation (6 $plant^{-1}$), nitrogen fixation (1.134) and seed yield (7.33 g $plant^{-1}$).

Keywords: Genotypic variability, Nitrogen fixation, Yield.

Introduction

Mungbean is one of the most important pulse crops in Bangladesh. It is now well agreed that despite nitrogen fixation, N alimentation in legumes is a limiting factor in terms of either quantitative (seed) or qualitative (N) yields. Generally, young plants meet up their initial nitrogen requirements through soil mineral nitrogen. After nodules have been established, N_2 fixation succeeds to assimilation, reaches peak at pod developing stage and declines thereafter (Jensen, 1987). Later, most of the seed filling is achieved by the redistribution of N from vegetative plant organs to the developing seeds (Sagan *et al.*, 1993). However, nitrogen fixation in plants itself is an energy expensive process. To reduce one molecule of atmospheric N_2 to NH_4 about 15 ATP energies are required (Poehlman, 1991). Atmospheric nitrogen fixation depends on plant age and presence of appropriate nitrogen fixing bacteria (Sagan *et al*., 1993). Contrary, presence of high mineral nitrogen in the soil inhibits atmospheric nitrogen fixation in grain legumes (Minchin *et al*., 1989; Walsh and Corroll, 1992).

The seed yield of mungbean is low in Bangladesh compared with the yield potential (Hossain *et al*., 2009). One of the major limitations of mungbean productivity is low soil fertility with a very low to low soil N nutrients.

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High yield of mungbean in low fertile soil is not possible without a supply of substantial amount of nitrogen in the crop. One option for obtaining nitrogen, at least without relying on a soil source, is to take full advantage of those mungbean genotypes that can symbiotically fix more atmospheric N_2. In fixing more atmospheric N_2, some of the carbon fixed by the plant is used to provide the energy required for reduction of N_2 to NH_3 organic molecules. Although this process is energetically expensive, it might be very effective in low nitrogen environments where assimilated carbon is abundant relative to nitrogen (Sinclair and Vadez, 2002). The present study was therefore, undertaken to evaluate the nodulation, nitrogen fixation and yield of different genotypes of mungbean at varying levels of N application to soil.

Materials and Method

The pot culture experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during *kharif II* season of 2012. The soil was sandy loam having 6.9 pH, 0.538 % organic matter, 0.05%N, 0.16 mg kg^{-1} P, 0.85 meq % K, and 0.70 mg kg^{-1} the Rhizobium count was 4.55 x 10^8 g soil. Each pot containing 12 kg soil was fertilized 25 kg P and 32 kg K ha^{-1} in the form of triple super phosphate and muriate of potash, respectively and mixed thoroughly with soil. The experiment was laid out in completely randomized design (CRD) with ten mungbean genotypes and six nitrogen levels, each replicated four times. Ten mungbean genotypes were (IPSA 12, GK 27, IPSA 3, IPSA5, ACC12890055, GK 63, ACC12890053, BU mug 4, BARI Mung 6 and Binamoog 5). The N levels were 0, 20, 40, 60, 80 and 100 kg N ha^{-1} and applied at 15 days after sowing.

Seeds were sown on 22 August, 2012. At first trifoliate stage, the plants were thinned and maintained one plant per pot. All agronomic management and plant protection measures were kept uniform during the whole growing period of mungbean. Data on nodulation, biological nitrogen fixation, yield and yield components were recorded. The pots were weeded manually throughout the growing season. The crop was harvested at full maturity. Harvesting was done twice one on 31 October and another on 13 November, 2010. Nodulation was counted at pod developing stage. For determination of N_2 fixation, nitrogen activity was assessed by measuring acetylene reduction assay (ARA) in a gas chromotograph. Mungbean plant samples were collected and brought immediately to the laboratory. Soil was removed from the roots and nodules remained intact with the plant. Roots were separated from the shoot at the cotyledonary node. Then the roots of the plants in each pot were individually placed in conical flask and were sealed with air tight rubber septum. Ten percent of the air in the flask was replaced with acetylene gas. One ml of gas sample was collected from each flask with a disposable 1 ml syringe at 5 and 35 minutes after incubation and immediately injected in the gas chromotograph (Shimadzu, GC-8A) fitted with a flame ionization detector and a stainless steel column (3 MM DIA, 102 m length). The column was fitted with porapak-R, 100-200 mesh. The column and injector temperature was 60^0C. All gases used from cylinder were of purity grade in which the following flow rates were maintained: H_2 20 ml/min. air 45 ml/min, N_2 30 ml/min. N_2 was used as carrier gas. Ethylene and acetylene gases were separated in the column, detected in flame ionization detector and finally the peaks were recorded on the recorder (model Shimadzu, R-11).

The amount of ethylene was measured using the following formula:

$$\frac{(b - a) \text{ x vol. of conical flask x } 60}{30} = \text{mol } C_2H_4\text{/plant/hr}$$

where, b= amount of N mol C_2H_4/ml produced after 35 minutes, a = amount of N mol C_2H_4/ml produced after 5 minutes, c = amount of N mol C_2H_4/ml plant, Vol. of conical flask = Volume determined by subtracting root fresh weight from total water weight in the flask. After determination of ARA, roots were separated from the nodules and then nodule number and weight were recorded. Microsoft EXCEL and MSTAT-C software programs were used to perform statistical analysis of the data. Mean separation was done at 5% level of probability by DMRT.

Results and Discussion

Nodule number

At pod developing stage mungbean nodule number was counted because at this stage it reaches peak (Murakami *et al.,* 1990). Nodules with a red or pink region usually are active in nitrogen fixation and are said to be effective, whereas nodules which are white or greenish brown are not effective and said to be senescing. Number of nodules of mungbean genotype was lower at no nitrogen application, but application of 40 kg N ha^{-1} gave the maximum number of nodules per plant (Fig. 1). It is conceivable that the fertilizer N stimulated plant establishment and early growth and might have improved nodulation through positive effect on seedling roots (Akbari *et al.*, 2008). Rate of nitrogen fixation is trivial at beginning of growing season and bacteria do not supply any nitrogen to the seedlings. Therefore, seedlings need starter dose of nitrogen either from mineral or chemical fertilizers (Patra and Bhuttacharyya, 1997). Results revealed that application of nitrogen beyond 40 kg N ha^{-1} reduced nodule number. Nitrogen nutrition inhibits nitrogen fixation in legumes as it is energy expensive processes resulting in the substantial consumption of carbohydrates in the nodules which is detrimental to development of other parts of plants (Warenbourg and Roumet, 1989). However, the mungbean genotype IPSA 12 was found most efficient in maintaining higher nodule number throughout the growing season.

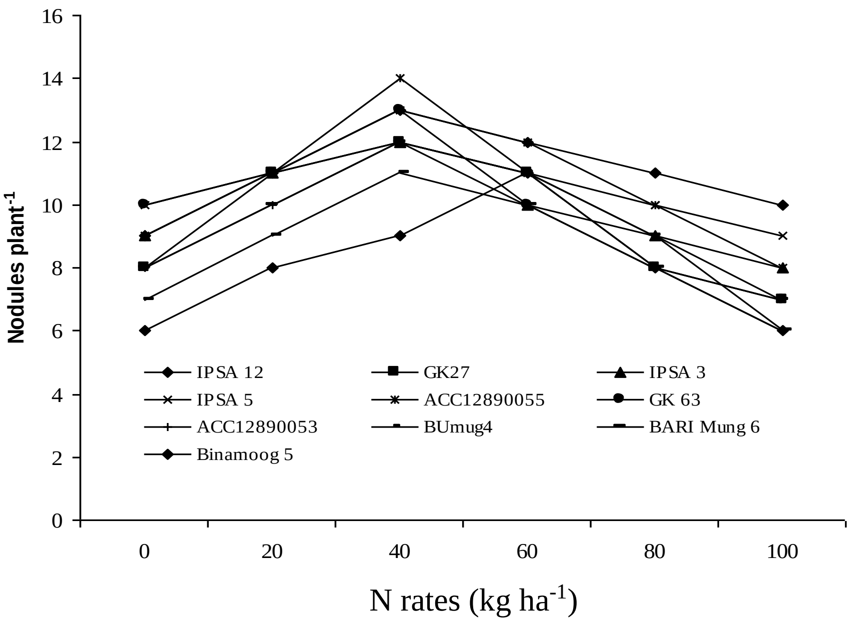

Fig.1. Nodule number of mungbean genotypes as at different levels of N application.

Nitrogen fixation

There was a wide variability among the mungbean genotypes in the rate of N_2 fixation measured by acetylene reduction assay (ARA) using gas chromatograph at pod developing stage. The genotype also differed in N_2 fixation under variable N levels where N_2 fixation in IPSA 12 increased progressively with the increase of fertilizer N rates (Fig. 2). Thus the highest ARA value (2.684 μ mol C_2H_4 plant^{-1} hour^{-1}) was recorded at 40 kg N in IPSA 12 at pod developing stage. Contrary, the genotype ACC12890053 was less responsive to N_2 fixation at control condition (no nitrogen). Higher nitrogen level inhibits nitrogen fixation of mungbean plant because nitrogen fixing bacteria consume nutrient easily from soil. These results are in accordance with other results that there exists evidence in genetic variability in N_2 fixation among common bean (Devi *et al*., 2013), soybean (Sinclair *et al.*, 2000) and peanut (Devi *et al*., 2010). Out of the five mungbean genotypes, IPSA 12 was of particular importance because of its maintaining higher ARA value (2.684 μmol C_2H_4 plant^{-1} hour^{-1}) at 40 kg N ha^{-1} and lower ARA value (1.134 μmol C_2H_4 plant^{-1} hour^{-1}) was recorded in genotype ACC12890053.

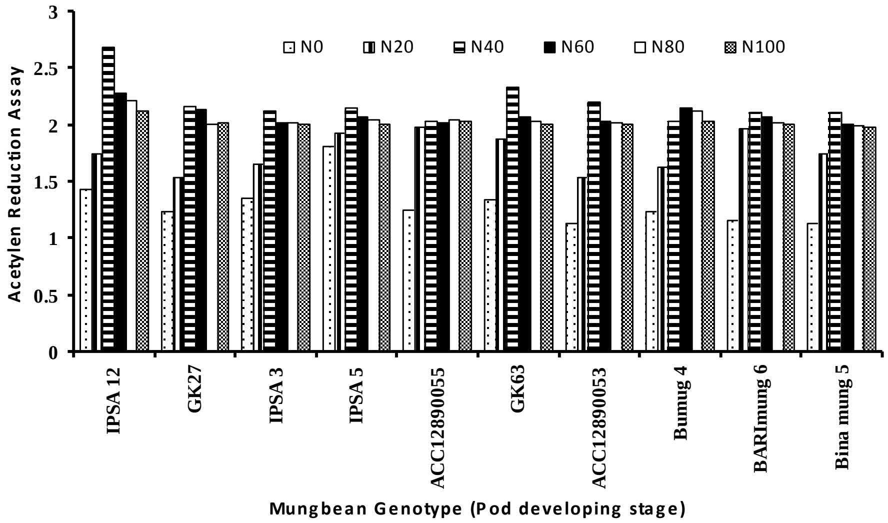

Fig. 2. Biological nitrogen fixation (Acetylene Reduction Assay micro mol/ C_2H_4/ plant/ hour) of mungbean genotypes at different levels of N application.

Pods per plant

Number of pods per plant of mungbean genotypes was significantly influenced by N levels. Increasing nitrogen level led to an increase in pods plant^{-1} up to 40 kg N ha^{-1} and thereafter the number decreased with the increasing N rates (Table 1). This result is in line with the findings of Patra and Patel (1991) who reported that number of pods per plant of mungbean increased with application of nitrogen fertilizer and excess application reduced pod number of mungbean. There were genotypic variations in pod development where the genotype IPSA 12 produced the highest number of pods (30.2) and the lowest number of pods per plant (18.9) was recorded in genotype BARI Mung 6 in N control condition. This means that mungbean genotypes require additional N for better pod development although it is capable to fix atmospheric N through rhizobium species living in root nodules (Anjum *et al*., 2006).

Seeds per pod

Interaction effect of genotype and nitrogen was not significant but genotype had significant effects on seeds per pod of mungbean (Table 2). The highest number of seeds per pod (12.4) was obtained with IPSA 12 and the lowest seed per pod (10.3) was recorded with BARI Mung 6. These findings agree with Asaduzzaman *et al.* (2008) who reported that nitrogen level had no significant effect on seeds per pod. The number of seeds per pod is mostly genetically controlled, but its number may be regulated by canopy photosynthesis during pod developing stage. Seed number also may be limited by the activity of the source (Akther, 2005). During seed filling, the ability of the individual seed to utilize, assimilate and determine number of seeds per pod is important and limitation of assimilate reduces the seeds per pod (Jenner *et al.*, 1992).

Table 1. Number of pods per plant of mungbean genotype as affected by N rates.

Genotypes	N rates (kg ha^{-1})						
	0	20	40	60	80	100	Mean
IPSA 12	22.0cA	24.8bcA	30.2aA	27.5bA	26.7bA	22.7cA	25.6
GK 27	20.0bA	22.5abAB	23.5aC	23.6aB	22.3abB	19.7bB	21.9
IPSA 3	19.7cAB	22.7bAB	25.2aB	23.2bB	22.5bB	20.3bcB	22.2
IPSA 5	21.8bcA	25.3aA	27.5aB	26.3aA	26.0aA	23.7bA	25.0
ACC12890055	20.7cA	23.0abAB	25.0aB	23.2abB	21.7bB	20.8bcB	22.3
GK 63	18.8cB	21.3bB	23.3aC	21.6bC	22.33bB	16.7cC	20.6
ACC12890053	20.3cA	22.0bcAB	25.8aB	22.7bC	22.0bB	22.7bA	22.5
BU mug 4	19.0cAB	22.0bAB	24.2aC	25.7aAB	21.8bBC	21.0bcAB	22.2
BARI Mung 6	18.9cB	20.5bB	23.3aC	22.5abC	22.3aB	20.8bBC	21.4
Binamoog 5	16.8dC	19.8cC	24.8aC	23.3aB	21.5bB	17.7dC	20.6
Mean	19.7	22.3	25.3	23.6	22.9	20.5	

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

Table 2. Number of seeds per pod of mungbean genotype as affected by N rates.

Genotype	N rates (kg ha^{-1})						
	0	20	40	60	80	100	Mean
IPSA 12	12.40A	12.33A	12.03A	12.13A	11.66A	11.83A	12.06
GK-27	10.93A	11.11A	10.76B	10.85A	10.76B	10.66B	1084
IPSA 3	11.65A	11.20A	11.08A	11.91A	11.38A	11.05A	11.38
IPSA 5	11.46A	12.15A	11.96A	11.98A	11.60A	11.86A	11.83
ACC12890055	10.60B	11.20A	11.20A	11.16A	11.00A	11.05A	11.03
GK-63	10.83B	11.23A	11.36A	11.20A	10.83A	10.23A	10.95
ACC12890053	10.40B	11.65A	10.66B	11.25A	11.23A	10.40B	10.93
BU mug 4	10.20B	10.84A	11.15A	10.65B	11.06A	11.20A	10.85
BARI Mung 6	10.30B	10.76A	11.01A	10.75B	11.40A	11.11A	10.88
Binamoog 5	11.40A	11.28A	11.13A	10.73B	11.10A	11.54A	11.19
Mean	11.02	11.37	11.23	11.26	11.20	10.09	

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

1000 - Seed weight

Thousand seed weight was not affected significantly by N fertilizer application as it is largely governed by genetic factors. Thus 1000 -seed weight varied with the mungbean genotypes where the maximum 1000 -seed weight (50.2 g) was recorded in GK 27 at control and the lowest seed weight (34.2 g) was recorded in ACC12890053 at 20 kg Nha^{-1} (Table 3). The genotype which produced lower number of seeds pod^{-1} showed higher seed weight.

Table 3. Thousand seed weight (g) of mungbean genotypes as affected by N rates

Genotype	N rates (kg ha^{-1})						
	0	20	40	60	80	100	Mean
IPSA 12	41.5	38.8	38.7	39.2	40.7	40.3	39.9
GK-27	50.2	49.4	49.9	49.9	49.7	49.8	48.1
IPSA 3	47.1	47.7	46.5	47.8	45.5	46.1	46.8
IPSA 5	38.5	38.1	39.5	41.5	41.0	36.8	39.2
ACC12890055	43.7	46.2	45.7	43.9	45.9	42.9	44.7
GK-63	49.8	50.1	49.9	49.4	49.6	49.7	49.7
ACC12890053	34.7	34.2	35.8	34.9	37.7	34.5	35.3
BU mug 4	46.1	43.4	41.6	40.3	43.5	40.8	42.6
BARI Mung 6	49.3	48.9	48.9	50.0	49.0	48.6	49.1
Binamoog 5	39.0	40.3	37.2	37.0	40.7	41.1	39.2
Mean	44.0	43.7	43.4	43.4	44.3	43.1	

Means without letter did not differ significantly at 5% level of probability by DMRT.

Seed yield

Per plant seed yield of mungbean was significantly affected by genotypes and N fertilizer application. The yield varied from 7.33 g to 14.22 g plant^{-1} (Table 4) and it was the highest in IPSA 12 grown with 40 kg N ha^{-1} and the lowest in ACC12890053 under control condition. There was a general trend of increased seed yield with the increase of N fertilizer up to 40 kg N ha^{-1} and thereafter the yield decreased with higher N doses. This finding agrees with Biswas and Hamid (1989) and Mitra and Ghildiyal (1988) who separated that application of N fertilizer enhanced nodulation, nitrogen fixation and consequently improved yield components of mungbean genotype.

Table 4. Seed yield (g plant $^{-1}$) of mungbean genotypes as affected by N rates.

Genotype	N rates (kg ha^{-1})						
	0	20	40	60	80	100	Mean
IPSA 12	11.32Ac	11.87Ac	14.22Aa	12.87Ab	12.41Ab	10.80Ac	12.25
GK-27	10.97Ab	12.34Aa	12.61Ba	12.80Aa	11.94Ab	10.43Ab	11.85
IPSA 3	10.78Abc	11.83Ab	13.32ABa	12.82Aa	11.65Ab	10.35Ac	11.79
IPSA 5	9.60Bc	11.72Ab	13.64Aa	12.45Aa	12.36Aa	10.10Abc	11.64
ACC12890055	9.33Bc	11.90Aab	12.29Ba	11.81Bab	10.93Bb	9.87ABb	11.02
GK-63	10.06Bb	12.00Aa	13.09Ba	12.20Ba	11.99Aa	9.23ABb	11.43
ACC12890053	7.33Dcd	8.49Db	9.60Ca	9.12Cab	9.31BCab	7.95Cc	8.63
BU mug 4	8.93Bbc	10.35Bab	10.85Ba	11.14Ba	10.40Bab	9.59ABbc	10.21
BARI Mung 6	8.55Bbc	10.78Bb	12.84Aa	11.82Bab	12.40Aa	11.24Aab	11.27
Binamoog 5	7.48Dc	8.61Cb	10.23Ca	9.31BCab	9.71Cab	8.37Cbc	8.95
Mean	9.43	10.99	12.27	11.64	11.31	9.79	

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

Conclusion

Nodulation, nitrogen fixation and seed yield varied with mungbean genotypes and N rates. The IPSA 12 mungbean performed the best result at 40 kg N ha^{-1} application and the ACC12890053 did the lowest.

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GENETIC VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS IN MAIZE (*Zea mays* L.)

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Abstract

Twenty-two maize hybrids were evaluated to find out their variability, character association and path coefficient of grain yield and its component characters. Significant differences were found among the genotypes for the characters studied. Ear length and grain yield (t/ha) had moderate genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV), but the had the low environmental co-efficient of variation (ECV). The heritability for all the characters was high. The characters viz. plant height, ear height and 1000-grain weight, showed high heritability along with high genetic advance. Ear length, ear diameter and kernel per row had highly significant positive correlation with grain yield. However, the deviations between genotypic and phenotypic correlation and magnitude of environmental correlation suggested considerable influence of growing environment in expressing almost all the characters. Path coefficient analysis revealed that plant height (0.659), ear length (0.934) and kernel-rows per ear (0.715) had highly significant positive direct effect on grain yield suggesting their importance during selection. Simultaneous restricted selection should be done for number of kernel rows per ear.

Keywords: Genetic variability, heritability, character association, path analysis, *Zea mays*.

Introduction

Maize (*Zea mays* L.) plays a significant role in human and livestock nutrition world-wide. Among the cereal crops over the world, maize ranks first in total production followed by wheat and rice. In Bangladesh, maize is also becoming an emerging crop and ranks the third most important cereal after rice and wheat. Currently maize is grown on about 0.31 million hectares of land with a production of 2.18 million metric tons and average yield of 6.98 t/ha (BBS, 2014).

Bangladesh Agricultural Research Institute (BARI) has been doing research on hybrid maize since 2000. However, the yield of BARI developed hybrids is slightly lower than the imported commercial varieties (Anon., 2014). Therefore, through recycling method from top yielded commercial variety 900M, new populations are being advanced to develop new inbreds. In breeding methods, variation and

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character association are checked for fruitful selection during generation advance. Grain yield is a complex character which is highly influenced by the environment and is the result of inter-relationships of its various yield components (Grafius, 1960). Thus information on genotypic and phenotypic correlation coefficients among various plant traits help to ascertain the degree to which these are associated with economic productivity. The association between two characters can directly be observed as phenotypic correlation, while genotypic correlation expresses the extent to which two traits are genetically associated. Both genotypic and phenotypic correlations among and between pairs of agronomic traits provide scope for indirect selection in a crop breeding program (Pavan *et al*., 2011). Since yield components are inter-related and develop sequentially at different growth stages, correlations may not provide a clear picture of the importance of each component in determining grain yield. Path coefficient analysis provides more information among variables than correlation coefficients (Aycicek and Yildirim, 2006). Path coefficient analysis furnish a method of partitioning the correlation coefficient into direct and indirect effect and provides the information on actual contribution of a trait on the yield (Dewey and Lu, 1959). Therefore, correlation and path coefficient analysis are effective tools to improve the efficiency of breeding programs through the use of appropriate selection indices (Mohammadi *et al*., 2003). The present study was therefore, undertaken to derive information on variability, correlations and path coefficient among characters in newly developed S_4 lines derived from commercial hybrid 900M.

Materials and Method

The experiment was conducted with 22 genotypes including F_1s generated from crosses of selected S_4 lines and four different testers viz., L22, BIL28, BIL106 and BIL110 along with three commercial checks viz., BHM 9, 900 M and BHM 7. The crosses were produced in 2012-13 and the genotypes were evaluated at the research field of Bangladesh Agricultural Research Institute, Gazipur, during winter 2013-14. Each entry was raised in two rows maintaining space of 75 cm × 20 cm. The recommended package of production practices was followed to raise a good crop. Observations were recorded from ten randomly selected plants for each replication on days to 50% tasseling and 50% silking, plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of kernel-rows per ear (R/E), number of kernels per row (K/R), 1000-grain weight (g) and grain yield (t/ha). The phenotypic, genotypic, environmental variances and heritability were estimated as suggested by Lush (1940). The phenotypic, genotypic and environmental coefficients of variances were estimated as suggested by Burton (1952) and categorized as low (>10%), moderate (10-20%) and high (<20%) as suggested by Sivasubramanian and Madhavamenon (1973). Heritability was calculated as suggested by Lush (1940) and categorized as low (>30%), moderate (30-60%) and high (<60%) as suggested by Jonson *et al*. (1955). Genetic advance and genetic advance as percent of mean and phenotypic, genotypic and environmental correlation coefficients were worked out by following the method suggested by Jonson *et al*. (1955), and the range of genetic advance as per cent of mean is also classified as suggested by him as low (>10%), moderate (10-20%) and high (<20%). Path analysis was carried out using the genotypic correlation coefficient as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

Results and Discussion

Variability, heritability and genetic advance

Mean performance of all genotypes was presented in Table 1. It was observed that there was a significant variation for all the characters studied in the present investigation and a scope for effective selection. Genotypic, environmental and phenotypic variation and coefficient of variation, heritability, genetic advance and genetic advance as per cent of mean and percent of coefficient of variation (CV%) for yield and yield component traits were furnished in Table 2. Analysis of variance revealed highly significant differences for all quantitative traits. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for ear length and grain yield (t/ha) were moderate. The environment coefficient of variation (ECV) for the same characters was low which means the lower influence of environment on these characters. Hence, selection on the basis of phenotype can be effective for improvement of these traits. Heritability for all the characters was high, indicating the low influence of environment on the studied characters. The maximum heritability was recorded for ear length (95%) and the minimum for kernel per row (62%). Heritability estimates along with genetic advance are more helpful in predicting the gain under selection (Johnson *et al*., 1955a). In the present study, high heritability coupled with high genetic advance was recorded for plant height, ear height and 1000-grain weight indicating that the heritability is due to additive gene effects and selection may be effective for these three traits. On the other hand, days to 50% tasseling and silking and ear diameter showed high heritability but low genetic advance; reveal non-additive gene action and selection for these traits may not be effective.

Correlation coefficient analysis

Correlations (genotypic, environmental and phenotypic) of yield and yield component characters in the present investigation were presented in Table 3. In most cases, the genotypic correlation was higher than that of phenotypic correlation; reveal that association may be largely due to genetic reason (strong coupling linkage) (Sharma, 1988). Grain yield showed highly significant positive correlations with ear length, ear diameter and number of kernels per row. Similar findings were reported by Batool *et al.* (2012) and Zarei *et al.* (2012) for positive correlation of grain yield with ear length and Rafiq *et al*. (2010) for ear diameter and number of kernels per ear.

Table 1. Mean performance of 22 maize hybrid including three checks evaluated at BARI, Bangladesh during 2013-14

Sl no.	Entry	DT	DS	PH	EH	EL	ED	R/E	K/R	1000-GW	Grain yield (t/ha)
1	$9MS_4$-4 × L-22	90	95	185	81	15	16	17	30	245	8.11
2	$9MS_4$-5×L-22	90	95	200	96	16	16	14	32	335	9.24
3	$9MS_4$-6×L-22	90	95	183	94	14	14	15	28	280	6.38
4	$9MS_4$-12×L-22	94	98	192	94	17	17	16	30	320	10.48
5	$9MS_4$-14×L-22	93	98	183	90	17	16	16	33	295	9.60
6	$9MS_4$-16×L-22	90	94	183	85	17	16	16	31	285	9.51
7	$9MS_4$-18×L-22	91	95	180	84	17	14	16	31	265	8.56
8	$9MS_4$-5×BIL-28	92	96	204	95	16	14	13	33	236	7.93
9	$9MS_4$-12×BIL-28	95	99	211	102	20	16	14	39	330	11.25
10	$9MS_4$-6×BIL-106	92	98	211	106	16	15	16	27	270	8.98
11	$9MS_4$-10×BIL-106	90	99	210	105	14	18	20	27	270	10.35
12	$9MS_4$-16×BIL-110	86	93	190	87	16	16	16	30	259	9.23
13	$9MS_4$-2×BIL-110	90	94	205	110	18	15	14	36	285	10.95
14	$9MS_4$-6×BIL-110	90	94	193	97	16	16	17	32	274	10.25
15	$9MS_4$-12×BIL-110	89	94	186	82	16	16	17	30	240	11.20
16	$9MS_4$-13×BIL-110	91	96	199	95	13	16	16	30	275	8.92
17	$9MS_4$-14×BIL-110	86	90	150	62	15	15	14	31	265	9.00
18	$9MS_4$-16×BIL-110	89	91	166	70	17	15	15	34	275	10.49
19	$9MS_4$-18×BIL-110	88	94	174	70	17	15	16	34	300	9.37
20	BHM 9 (CK-1)	89	94	202	99	19	16	15	38	240	10.52
21	900 M (CK-2)	89	94	186	89	17	15	14	34	240	10.11
22	BHM 7 (CK-3)	90	95	188	87	16	16	16	34	239	9.82
	Mean	90.2	95.1	190.1	90	16.3	15.6	15.6	32	273.77	9.56
	LSD	2.17	2.32	15.09	12.11	1.59	0.96	1.50	3.15	29.09	1.17
	F-test	**	**	**	**	**	**	**	**	**	**

DT=Days to 50% tasseling, DS=Days to 50% silking, PH=Plant height, EH=Ear height, EL=Ear length, ED=Ear diameter, R/E= Kernel rows per ear, K/R= Kernel per row, 1000-GW=1000-grain weight.

Table 2. Variance, Co-variance, heritability, genetic advance, genetic advance per cent of mean and per cent of coefficient of variation for all studied traits in hybrid maize

	DT	DS	PH	EH	EL	ED	R/E	K/R	1000-GW	Grain yield (t/ha)
$б^2g$	3.84	4.15	220.87	143.02	2.03	0.77	2.08	7.58	802.11	1.13
$б^2 e$	1.77	2.46	13.58	7.49	0.98	0.31	0.35	4.65	87.76	0.47
$б^2 p$	5.61	6.61	234.45	150.50	3.00	1.07	2.43	12.23	889.87	1.60
GCV	2.17	2.14	7.82	13.29	8.72	5.62	9.24	8.61	10.34	11.14
ECV	1.48	1.65	1.94	3.04	6.05	3.55	3.80	6.74	3.42	7.18
PCV	2.63	2.71	8.06	13.63	10.62	6.65	9.99	10.93	10.90	13.25
h^2b	0.68	0.63	0.94	0.95	0.68	0.71	0.86	0.62	0.90	0.71
GA	3.34	3.32	29.72	24.02	2.41	1.52	2.74	4.47	55.39	1.84
GAP%	3.70	3.50	15.64	26.68	14.76	9.77	17.60	13.96	20.23	19.29
CV%	1.48	1.65	1.94	3.04	6.05	3.56	3.80	6.74	3.42	7.18

$б^2g$ = Genotypic variance, $б^2e$ = Environmental variance, $б^2p$ = Phenotypic variance, GCV= Genotypic coefficient of variation, ECV = Environmental coefficient of variation , PCV = Phenotypic coefficient of variation, h^2b = Heritability, GA = Genetic advance, GAP = Genetic Advance per cent of mean, DT=Days to 50% tasseling, DS=Days to 50% silking, PH=Plant height, EH=Ear height, EL=Ear length, ED=Ear diameter, R/E= Kernel rows per ear, K/R= Kernel per row, 1000-GW=1000-grain weight.

Table 3. Genotypic (G), environmental (E) and phenotypic (P) correlation coefficient for yield and yield contributing characters in hybrid maize

		DS	PH	EH	EL	ED	R/E	K/R	1000-GW	Grain yield (t/ha)
DT	G	0.980**	0.605**	0.615**	0.372*	0.064	-0.039	0.202	0.482*	0.081
	E	0.214	0.047	-0.042	-0.076	0.439*	-0.123	-0.131	0.148	0.261
	P	0.715**	0.493**	0.491**	0.228	0.175	-0.057	0.086	0.404*	0.135
DS	G		0.792**	0.783**	0.043	0.461**	0.366*	-0.166	0.365*	0.082
	E		0.466**	0.029	0.065	0.125	-0.037	-0.040	0.283*	-0.016
	P		0.678**	0.609**	0.051	0.349*	0.260	-0.119	0.328*	0.049
PH	G			0.947**	0.125	0.349*	0.108	0.049	0.115	0.212
	E			0.365*	0.522**	0.052	-0.110	0.335	0.446*	0.252
	P			0.916**	0.172	0.293	0.087	0.087	0.140	0.206
EH	G				0.146	0.256	0.064	0.049	0.186	0.166
	E				-0.048	0.296	-0.019	-0.146	-0.169	0.206
	P				0.111	0.246	0.056	0.018	0.161	0.161
EL	G					-0.074	-0.468*	0.868**	0.278*	0.631**
	E					-0.034	0.010	0.562**	0.030	0.319
	P					-0.062	-0.354*	0.759**	0.223	0.534**
ED	G						0.702**	-0.105	0.281	0.637**
	E						0.199	-0.214	-0.351*	0.019
	P						0.589**	-0.140	0.166	0.458**
R/E	G							-0.578**	-0.110	0.183
	E							-0.503**	-0.275	-0.268
	P							-0.539**	-0.129	0.087
K/R	G								0.103	0.488**
	E								0.223	0.490**
	P								0.120	0.487**
1000 -GW	G									0.173
	E									0.087
	P									0.153

* $p < 0.05$, ** $p < 0.01$.

DT=Days to 50% tasseling, DS=Days to 50% silking, PH=Plant height, EH=Ear height, EL=Ear length, ED=Ear diameter, R/E=Kernel rows per ear, K/R= Kernels per row, 1000-GW=1000- grain weight.

Table 4. Direct and indirect effect of yield contributing characters on grain yield in hybrid maize

	DT	DS	PH	EH	EL	ED	R/E	K/R	1000-GW	Yield (t/ha)
DT	**-0.3682****	-0.2214	0.3991	-0.1730	0.3471	-0.0006	-0.0290	0.0172	0.1091	0.0803
DS	-0.3608	**-0.2260**^{NS}	0.5222	-0.2205	0.0404	-0.0043	0.2619	-0.0141	0.0826	0.0815
PH	-0.2230	-0.1791	**0.6590****	-0.2666	0.1172	-0.0032	0.0775	0.0041	0.0261	0.2121
EH	-0.2263	-0.1770	0.6243	**-0.2814***	0.1368	-0.0024	0.0461	0.0042	0.0422	0.1663
EL	-0.1369	-0.0098	0.0827	-0.0412	**0.9337****	0.0007	-0.3348	0.0735	0.0631	0.6310
ED	-0.0229	-0.1042	0.2299	-0.0721	-0.0693	**-0.0093**^{NS}	0.5022	-0.0089	0.1921	0.6376
R/E	0.0149	-0.0828	0.0714	-0.0181	-0.4373	-0.0065	**0.7149***	-0.0490	-0.0248	0.1827
K/R	-0.0746	0.0376	0.0322	-0.0139	0.8106	0.0010	-0.4133	**0.0847**^{NS}	0.0234	0.4878
1000-GW	-0.1774	-0.0824	0.0759	-0.0524	0.2600	-0.0079	-0.0784	0.0087	**0.2266**^{NS}	0.1727

Residual effect (R) = 0.4008

* $p < 0.05$, ** $p < 0.01$

DT=Days to 50% tasseling, DS=Days to 50% silking, PH=Plant, height, EH=Ear height, EL=Ear length, ED=Ear diameter, R/E= Kernel rows per ear, K/R= Kernels per row, 1000-GW=1000-grain weight.

Studies on inter-character associations for yield components revealed positive and highly significant association of days to 50% tasseling with days to 50% silking, plant height and ear height. The result is supported by Nataraj *et al. (*2014). Furthermore, days to 50% silking showed highly significant positive correlation with plant and ear height, ear diameter, kernel rows per ear and 1000-grain weight. These results are in accordance with the finding of Nataraj *et al. (*2014). On the Contrary, Sadek *et al*. (2006) reported negative correlations of days to silking with 1000 kernel weight which might be due to genotypic differences. Plant height showed highly significant positive correlation with ear height. Similar result was reported by Nataraj *et al. (*2014). Significant positive correlation was observed among the two important yield components viz. ear length with number of kernel per row. These results are in harmony with that of Nataraj *et al*. (2014). Concerning ear diameter, positive correlation coefficient was found with number of rows per ear but, it was negatively correlated with number of kernel per row. Such results are in harmony with the findings of Wannows *et al.* (2010) who found significant and negative correlations with number of kernel per row. Similar results were reported by Khazaei *et al.* (2010).

Path coefficient analysis

High correlation coefficients may not be always giving the true picture or could mislead the decision because the correlation between two variables may be due to a third factor. Therefore, it is necessary to analyze the cause and effect relationship between dependent and independent variables to reveal the nature of relationship between the variables. Path coefficient analysis furnished a method of partitioning the correlation coefficient into direct and indirect effect and provides the information on actual contribution of a trait on the yield (Dewey and Lu, 1959). In the present study, direct and indirect effects of nine characters on grain yield were estimated and are presented in Table 4. The traits having high positive correlation along with high direct effects are expected to be useful as selection criteria in improvement program (Pavan *et al.*, 2011). In the present study, plant height, ear length and kernel rows per ear had highly significant positive direct effect on grain yield. The findings are in consonance with the reports of Pavan *et al.* (2011). Kernels per row and 1000-grain weight also had positive but non-significant direct effect on grain yield. Batool *et al*. (2012) also found that ear length had high positive direct effect on grain yield, which support the present result. On the other hand, days to 50% tasseling, days to 50% silking and ear height had negative direct effect on grain yield. For these characters, restricted selection should be followed. Emphasis should be given on days to 50% tasseling, plant height and ear height should be emphasized during selection as they had positive indirect effect (Table 4). Ear height, plant height and kernel rows per ear nullify the negative direct effect therefore, for these characters, simultaneous restricted selection is suggested. Although plant height and kernel rows per ear don't have significant positive correlation with grain yield but these two traits had highly direct positive effect on grain yield. On the other hand, Kernel per row had highly significant positive correlation with grain yield and its direct effect on grain yield was positive but low. However, its positive effect on improving the yield was indirect through the increment of ear length.

The residual effects permit precise explanation about the pattern of interaction of other possible components of yield. The residual effect recorded was 0.4008; it indicates the studied characters contribute 60% of variations in yield of maize.

Conclusion

From the analysis of variability, it can be concluded that phenotypic selection for ear length and grain yield will be effective. As plant height, ear height and 1000-grain weight revealed high heritability coupled with high genetic advance therefore, selection may be effective for these three traits. From correlation coefficient and path analysis, it was found that plant height, ear length and kernel rows per ear had positive correlation coefficient with grain yield and had high direct positive effect on yield. Though number of kernels per row had low positive direct effect on grain yield, it had highly significant positive correlation coefficient with grain yield. Similarly though ear diameter had low negative direct effect on yield, it had highly significant positive correlation coefficient with grain yield. Thus selection for these characters could be considered as important criteria in improving grain yield of maize.

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EFFECT OF VARIOUS CEREALS ON THE DEVELOPMENT OF *CORCYRA CEPHALONICA* (STAINTON) AND ITS EGG PARASITOID *TRICHOGRAMMA CHILONIS* (ISHII)

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Abstract

Eight types of cereals viz., wheat grain, chopped wheat, paddy grain, rice grain, maize grain, chopped maize, rice bran, mixture of rice bran and chopped rice were fed to observe the development parameters like egg, larva, pupa and adult stages of *Corcyra cephalonica* (stainton) for three consecutive generations. The parasitism efficiency of *Trichogramma chilonis* (Ishii) was also evaluated on the resultant host eggs of *C. cephalonica*. The *C. cephalonica* revealed the highest number of eggs (115.6 female^{1}), higher hatchability (92.9%), extented larval duration (45.9 days), increased larval weight (0.058 gm), survival rate (88.3%), adult emergence rate (93.5%), and male and female longevity (7.7, 7.2 days respectively) when they were reared on chopped wheat. On the other hand, the lowest number of egg was found on paddy husk (29.2 female^{-1}). The lowest hatchability (45.6%), larval duration (45.9 days), larval weight (0.029gm), and survival rate (38.2%), pupal duration (17.9 days) adult emergence (42.0%), male and female longevity (4.8 and 4.7 days respectively) were found on paddy husk. The effect of food materials also reflected on the parasitism efficiency of the egg parasitoid *T. chilonis*. The highest percent egg parasitization was done by the *T. chilonis* on the host eggs, reared on chopped wheat (94.8±0.07%) followed by wheat grain (82.5±0.08%) and chopped maize (73.8±0.09%). On the other hand, the lowest parasitism was obtained when the larvae were reared on paddy husk (42.2±0.14 %) and paddy grain (48.8±0.05 %).

Keywords: Cereals, *C. cephalonica,* development, parasitism, *T . chilonis.*

Introduction

There are many biological control agents such as predators, parasitoids and microorganisms, which are naturally controlling the insect pests (Bhandari, 2014). Among them, parasitoids have a major role in agricultural ecosystem. Of the effective bio-control agents, the egg parasitoid, *Trichogramma* is considered as the most important, particularly for augmentation. But, the number of eggs destroyed by natural *Trichogramma* is not sufficient to combat the pest from reaching the economic threshold level. So, its mass rearing and release for augmentation is vital.

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Mass rearing of *Trichogramma* requires the rearing of its host. The typically rearing of a species of moth can produce enough eggs on which the wasps may be developed. The rice meal moth, *Corcyra cephalonica* (stainton) and the Mediterranean flour moth *Ephestia kuehniella* Zeller are easily and inexpensively reared on wheat, rice or other cereals and their eggs are commonly used to rear *Trichogramma* (Morrison *et al.,* 1976). They also advocated to mass rear *Sitotroga cerealella* (Olivier) to provide eggs for *Trichogramma* rearing.

The *C. cephalonica* is popularly known as "rice moth". It is distributed worldwide and a serious pest of stored husked and unhusked rice, other cereals and leguminous grains. It also attacks gingelly, oil-cakes, dry fruits, cocoa, chocolates, biscuits, flax seeds, cream of wheat, flour etc. in many countries of the world (Perveen, 2012). The larvae damage the stored grains by feeding under silken webs (Alam, 1971). When infestation is high, the entire stock of grains may be converted into a webbed mass and ultimately a characteristic bad smell develops and the grains are rendered unfit for human consumption (Alam, 1965). Besides, many damaging properties of *C. cephalonica* and its eggs serve as an important medium for the successful breeding and rearing of *Ttichogramma* spp. which are used for biological control programme of different destructive borers in many countries of the world (Chu *et al*., 1994; Mukhukrishnan *et al*,. 1996; Cadapan, 1998). Due to the unavailability of egg masses of different borers throughout the year for mass production of *T. chilonis*, sufficient numbers of *C. cephalonica* eggs are essential. All the activities in life are dependent on the type and quality of food material of an individual. Andrewartha and Birch (1954) stated that both the longevity and reproductive potential of insects were influenced by the components of the environment, including temperature, moisture, and food. A considerable amount of information on various aspects of *Corcyra* are available. Rearing of these moths is generally done on wheat or chopped rice in the laboratory. However, the cost of rearing of rice moth on wheat or chopped rice is considerably high (Avasthy, 1962). As a result, the commercial productions of the parasitoid, *Trchogramma* spp. from their eggs also become costly. So, it is very much necessary to select some cheaper and cost effective food material(s) which can ensure proper development of *C. cephalonica* and production of its significant number of eggs for successful rearing of the egg parasitoid, *Trichogramma* spp.

Materials and Methods

This study was carried out in the IPM laboratory of the Entomology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during July 2008 and May 2009.

Stock culture of *C. cephalonica*

For constant supply of test insects and to avoid the effect of previous food, separate stock cultures of *C. cephalonica* were used. Five kg of wheat poured into boiled water and left for 2-3 minutes. Then the treated wheat was kept in steel trays (50 cm × 60 cm), each tray containing 2.5 kg wheat and 1 gm *C. cephalonica* egg and kept for 5-6 days untouched. After that requisite quantity of water was added and mixed properly with gentle stirring. After 22-25 days, *C. cephalonica* infested wheat was placed in mass rearing chamber for adult emergence. From the insect mass rearing chamber *C. cephalonica* adults were collected for two studies.

Determination of the cost effective food materials

Eight types of cereals : wheat grain, chopped wheat, paddy grain, rice grain, maize grain, chopped maize, rice bran, and mixture of rice bran and chopped rice were taken in separate plastic pots (500 gm for each) after sterilization. In each pot, 50 eggs of *C. cephalonica* were spread over on 500 gm cereals and kept in ambiant temperature of 26.0±2.0 ^{0}C in the laboratory. The mouths of the pots were covered with mosquito net. The pots were checked regularly to observe larval emergence, growth period, duration of pupa and adult. Each plastic pot containing host insect with a single cereal was considered as one treatment replication. There were three replications per treatment and the experiment was set in completely randomized design. Data on the duration of different development parameters viz., egg, larva, pupa and adult stages were measured for consecutive three generations.

Determination of economic host for egg parasitoid, *T. chilonis*

Eggs were collected from the reared moth population grown on different cereals and these were parasitized by egg parasitoid in the following means*:* Paper strips with host eggs were made to use them in the present study. For making the egg strips the material like, i) paper strip (10 cm × 1 cm) with different colours (yellow, red, blue) and labeling, ii) acacia powder of *Acacia arabica* (LAM), iii) distilled water, iv) small petri dish, and v) dropper are required. At first 10% acacia gum was prepared in a small petri dish by mixing acacia powder and distilled water. Mixing of water was done with dropper to maintain the proper dilution of the gum to hold the host eggs firmly with the paper strips. To make the host egg strips, a small amount of acacia glue was taken by finger and smeared on the front side of the labeled paper strip. Previously counted 100 eggs were placed carefully on the glued portion of the paper strip to have a single layer of eggs on the strips. After preparing the strips, it was labeled with date, host name, parasitoid name and number of eggs per strip.

The parasitism efficacy of *T. chilonis* was evaluated on the resultant host eggs of *C. cephalonica*. For the parasitization, one host egg strip, containing 100 eggs of the host and one *T. chilonis* pupae strip were placed together in individual test tube. Strips with *T. chilonis* pupae ready to emerge were taken from the already reared colony of *T. chilonis*. A strip containing 100 pupae of *Trichogramma* / strip of *C. cephalonica* eggs were placed in the test tube. The test tubes, each containing one host egg strip and one *T. chilonis* pupae strip were then placed in the parasitization chamber after proper labeling with date, number of eggs, host name and parasitoid name.

In the parasitization chamber, two third portions of the test tubes were covered by black cloths except the eggs which were placed for the parasitization to provide enough light for frequent movement of *Trichogramma*.

Data collection

Data on parasitism efficacy of *T. chilonis* attacking resultant host eggs of *C. cephalonica* deposited on different cereals were collected. Percent egg parasitism and percent emergence of *T. chilonis* were calculated.

Statistical analysis

Data were analysed by following MSTAT-C program. The mean values were separated by DMRT test ($p<0.05$).

Results and Discussion

There was significant difference in the number of eggs per female when fed on different cereals (Table 1). Considering the mean of three generations, the highest eggs were laid per female when their larvae fed on chopped wheat (115.6), chopped maize (62.2), and maize grain (52.2) (Table 1). On the other hand, the lowest eggs were laid per female when larvae reared on paddy grain (37.9) and paddy husk (29.2) (Table 1). It indicates that the paddy is the most non preferred host. This was probably due to the presence of trichome on the rice grain surface which restrains the female moths to lay their eggs. Acevedo and Aviles (1985) obtained higher number of larvae from polished grains compared to unpolished ones.

The highest incubation period was observed when larvae of *C. cephalonica* reared on paddy husk (5.8 days) and this was followed by paddy grain (4.5 days), maize grain (4.4 days), chopped maize (4.2 days) etc. However, the lowest incubation period was observed in chopped wheat (2.8 days), which was significantly different from that of rice grain (3.5 days) (Table 1). Therefore, the food quality also affects the incubation of eggs. The poorest quality food materials may prolong incubation period, while the best quality food reduces the incubation period. Mbata (1989) indicated that development of *C. cephalonica* on quality food (broken and meal maize) shortened the incubation and larval period.

Table 1. Effect of different cereals on the number of eggs laid /female, incubation period and percent hatchability of *C. cephalonica*

Cereals	No. of eggs laid/ female				Incubation periods (days)				Percent hatchability			
	Gen 1	Gen 2	Gen 3	Mean	Gen 1	Gen 2	Gen 3	Mean	Gen 1	Gen 2	Gen 3	Mean
Paddy grain	38.2	36.5	39.2	37.9 ef	4.7	4.2	4.5	4.5 b	51.3	49.4	53.5	51.4 e
Rice grain	86.5	82.5	84.5	84.5 bc	3.7	3.5	3.2	3.5 a	72.3	73.5	75.6	73.8 c
Wheat grain	97.5	98.7	99.5	98.6 b	3.2	3.2	3.2	3.2 a	83.4	81.4	83.8	82.9 b
Chopped wheat	112.2	116.5	118.2	115.6 a	2.7	3.0	2.7	2.8 a	92.7	91.5	94.5	92.9 a
Maize grain	53.7	49.5	53.5	52.2 e	4.2	4.5	4.5	4.4 b	54.6	52.5	54.6	53.9 e
Chopped maize	61.5	62.5	62.7	62.2 d	4.0	4.5	4.2	4.2 b	61.9	59.9	63.8	61.9 d
Paddy husk	31.2	29.2	27.2	29.2 f	5.2	6.0	6.2	5.8 c	43.2	45.8	47.9	45.6 f
Paddy husk + chopped rice	74.5	75.2	75.7	75.1 c	4.0	4.0	3.7	3.9 b	68.3	62.5	63.9	64.9 d

Table 2. Effect of different cereals on the larval duration, weight and survival of *C. cephalonica*

Cereals	Larval duration (days)				Larval weight (gm)				Larval survival (%)			
	Gen 1	Gen 2	Gen 3	Mean	Gen 1	Gen 2	Gen 3	Mean	Gen 1	Gen 2	Gen 3	Mean
Paddy grain	38.2	42.2	43.5	41.3 d	0.034	0.028	0.027	0.029 d	42.3	39.6	42.8	41.6 e
Rice grain	28.5	31.2	29.7	29.8 b	0.042	0.039	0.046	0.042 b	63.5	64.6	66.8	64.9 c
Wheat grain	25.7	27.2	25.2	26.1 a	0.051	0.049	0.057	0.052 a	74.4	75.2	78.9	76.2 b
Chopped wheat	23.5	24.4	22.5	23.5 a	0.054	0.058	0.062	0.058 a	85.4	88.3	91.2	88.3 a
Maize grain	39.2	41.2	42.5	40.9 d	0.032	0.028	0.030	0.030 d	45.6	41.2	43.8	43.5 e
Chopped maize	36.2	37.5	35.5	36.4 c	0.036	0.035	0.041	0.037 bc	51.5	49.3	52.4	51.1 d
Paddy husk	42.5	46.7	48.5	45.9 e	0.036	0.031	0.026	0.031 c	40.5	38.4	35.6	38.2 f
Paddy husk + chopped rice	32.2	35.5	31.2	33.5 c	0.041	0.038	0.042	0.040 b	49.4	50.6	51.2	37.1 f

The highest percent hatchability was observed among eggs on the chopped wheat (92.9) which was significantly higher than that of the others. However, the lowest percent hatchability was observed in paddy husk (45.6) and paddy grain (51.4). Hatchability might be increased by the good quality of food as indicated by Mbata (1989).

Gen = Generation

Means followed by the same letter(s) in a column did not differ significantly (DMRT test; p =0.05)

Table 2 shows that the larval duration was the highest on paddy husk (45.9 days) and paddy grain (41.3 days). On the other hand, larval duration was significantly the lowest on chopped wheat (23.5 days) followed by wheat grain (26.1 days), rice grain (29.8 days), paddy husk and chopped rice (33.5 days), chopped maize (36.4 days) and maize grain (40.9 days) (Table 2). Qualities of food also have a significant effect on the larval growth. Larval duration of *C. cephalonica* was studied by several authors and it was revealed that the larval duration in sorghum lasted for 45.56 days with a maximum of 111 days (Ayyar, 1934). Seshagiri (1954) reported larval duration of 47.57 days on cereals and 46-60 days on pulses. Alam (1965) observed the period with a range of 23-25 days on wheat, but sometime it may be extended up to 55 days.

The highest weight was gained when the larva fed on the preferred food materials, chopped wheat (0.058 gm), and this was followed by wheat grain (0.052 gm), rice grain (0.042 gm), paddy husk and chopped rice (0.040 gm), chopped maize (0.037 gm), maize grain (0.030 gm) (Table 2). On the other hand, the lowest weight was obtained when the larvae were reared on paddy grain (0.029 gm) and paddy husk (0.031 gm).

Survival of larva was also depended on the quality of food materials. Due to quality of food, larval survival rate became higher as compared to low quality of food. The highest percentage of larval survival was observed in chopped wheat (88.3%) and the lowest in paddy husk (38.2%) with significant difference (Table 2). The higher larval weight and its survival may also be influenced by the preferred food with high quality as reported by Mbata, 1989 and Ray, 1994.

Gen = Generation

Means followed by the same letter (s) in a column did not differ significantly (DMRT test; p =0.05)

The pupal duration was also significantly affected by the qualities of food materials used for rearing *C. cephalonica* (Table 3). The lowest pupal period was observed when chopped wheat was utilized as food (9.1 days) followed by wheat grain (9.5

Table 3. Effect of different cereals on the pupal durations, weight and adult emergence of *C. cephalonica*

Cereals	Pupal duration (days)				Pupal weight (gm)				Adult emergence (%)			
	Gen 1	Gen 2	Gen 3	Mean	Gen 1	Gen 2	Gen 3	Mean	Gen 1	Gen 2	Gen 3	Mean
Paddy grain	17.2	18.2	17.7	17.7 c	0.018	0.014	0.013	0.015 f	48.4	46.6	51.8	48.9 de
Rice grain	11.5	11.7	11.5	11.6 b	0.028	0.026	0.029	0.027 c	64.4	63.6	66.9	64.9 c
Wheat grain	9.7	9.7	9.2	9.5 a	0.032	0.031	0.035	0.032 b	82.5	83.2	86.5	84.1 b
Chopped wheat	9.0	9.2	9.0	9.1 a	0.035	0.039	0.041	0.038 a	92.4	93.4	94.6	93.5 a
Maize grain	16.5	16.7	17.2	16.8 c	0.019	0.017	0.021	0.019 e	51.6	49.2	52.8	51.2 d
Chopped maize	15.2	14.7	14.2	14.7 bc	0.021	0.020	0.023	0.021 d	54.7	55.8	57.9	56.1 d
Paddy husk	16.2	18.2	19.5	17.9 c	0.018	0.014	0.015	0.016 df	42.8	39.8	43.4	42.0 e
Paddy husk + chopped rice	13.5	13.2	12.7	13.1 bc	0.022	0.023	0.025	0.023 d	61.6	63.5	64.8	63.3 c

days), rice grain (11.6 days), paddy husk and chopped rice (13.1 days), chopped maize (14.7 days), maize grain (16.8 days). On the other hand, the highest duration was required for pupa to became adult when the larva was reared on paddy grain (17.7 days) and paddy husk (17.9 days). Ayyar (1934) observed pupal period of 12 days when cultured on sorghum, Nicol (1935) obtained a pupal period of 10 days when grown on wheat grains. On the other hand, Alam (1965) observed 10 days pupal period when reared on stored wheat.

The highest pupal weight was gained by the pupa when its larva was fed on the preferred food materials, chopped wheat (0.038 gm), followed by those grown on wheat grain (0.032 gm), rice grain (0.027 gm), paddy husk, chopped rice (0.023 gm), chopped maize (0.021 gm), maize grain (0.019 gm) (Table 3). On the other hand, the lowest pupal weight was obtained

when the larvae were reared on paddy grain (0.015 gm) and paddy husk (0.016 gm). Like pupal duration, pupal weight was also affected positively by the preferred food with better quality (Ayyar, 1934; Nicol, 1935).

The highest numbers of adult were emerged from the pupae when their larvae were reared on chopped wheat (93.5%) and the pupal weight recorded in this food material was also the highest. The similar trend was followed in other food materials. The lowest adult emergence was recorded from the paddy grain (48.9%) and paddy husk (42.0%).

Gen = Generation

Means followed by the same letter (s) in a column did not differ significantly (DMRT test; p =0.05)

The highest longevity of male moth was 7.7 days when their larvae grown on chopped wheat followed by 7.1 days when fed on wheat grain, 6.6 days on rice grain, 6.4 days in paddy husk and chopped rice, 6.2 days in chopped maize and 5.5 days on maize grain (Table 4). On the other hand, the lowest longevity of male moth was recorded when the larvae were reared on paddy grain (5.4 days) and paddy husk (4.8 days). Similar trend of female longevity was also recorded due to qualitative difference of various cereals used during its development. The highest longevity of female moths was found 7.2 days when larvae grown on the chopped wheat while the lowest was 4.7 days on paddy husk. (Ozpnar, 1997)

The lowest life span was evident when larvae fed on chopped wheat (43.1 days) while the highest on paddy husk (74.5 days) (Table 4). It was 45.9 days when larvae grown on wheat grain, but it was 51.4 days on rice grain, 56.5 days in paddy husk + chopped rice , 67.7 days on maize grain, 61.6 days on chopped maize and

Table 4. Effect of different cereals on the adult longevity (both male and female) of *C. cephalonica*

Cereals	Adult longevity (male) (days)				Adult longevity (female) (days)				Total life cycle (days)			
	Gen 1	Gen 2	Gen 3	Mean	Gen 1	Gen 2	Gen 3	Mean	Gen 1	Gen 2	Gen 3	Mean
Paddy grain	5.5	5.2	5.5	5.4 c	5.2	5.0	5.2	5.1 c	63.7	69.7	71.2	68.2 c
Rice grain	6.7	6.5	6.7	6.6 b	6.5	6.5	6.7	6.6 b	50.2	52.7	51.2	51.4 b
Wheat grain	7.0	7.0	7.2	7.1 a	6.5	6.3	6.7	6.5 b	45.7	47.2	44.7	45.9 a
Chopped wheat	7.5	7.5	8.0	7.7 a	7.0	7.2	7.5	7.2 a	42.7	44.2	42.2	43.1 a
Maize grain	5.7	5.2	5.5	5.5 c	5.7	5.2	4.7	5.2 c	65.7	67.7	69.7	67.7 c
Chopped maize	6.2	6.0	6.5	6.2 b	6.0	5.7	6.0	5.9 c	61.7	62.7	60.5	61.6 bc
Paddy husk	5.2	4.7	4.5	4.8 c	5.2	4.5	4.5	4.7 d	69.2	75.7	78.7	74.5 d
Paddy husk + chopped rice	6.2	6.5	6.5	6.4 b	6.0	6.2	6.7	6.3 b	56.2	59.2	54.2	56.5 b

68.2 days on paddy grain. The adult longevity of both male and female moths and the total life span were influenced by the quality of food. Better quality food increased the longevity of both male and female moths but shorten the total life span of *C. cephalonica* as reported by Devaraj and Mukherjee (1966) when they reared *C. cephalonica* on groundnut and sesame. They found groundnut was superior than sesame qualitatively. Total life span of 61.42 days in groundnut while 76.89 days in sesame was recorded by them. On the other hand, the highest longevity of female moths (7.2 days) was observed when larvae fed on the chopped wheat and the lowest (4.7 days) was on paddy husk.

Gen = Generation

Means followed by the same letter (s) in a column did not differ significantly (DMRT test; p =0.05)

The highest percent egg parasitization (94.8±0.07%) was on chopped wheat followed by those reared on wheat grain (82.5±0.08%), chopped maize (73.8±0.09%), rice grain (67.8±0.11%), paddy husk and chopped rice (66.8±0.09 %), maize grain (59.8±0.13 %). On the other hand, the lowest parasitism was obtained when the larvae were reared on paddy husk (42.2±0.14 %) and paddy grain (48.8±0.05).

Table 5. Parasitism efficacy of *T. chilonis* on *C. cephalonica* eggs reared on different cereals

Cereals	Percent egg parasitism *	Percent adult parasitoid emergence *
Paddy grain	48.8±0.05 f	37.5±0.13 d
Rice grain	67.8±0.11 d	78.6±0.09 c
Wheat grain	82.5±0.08 b	88.7±0.18 b
Chopped wheat	94.8±0.07 a	98.6±0.07 a
Maize grain	59.8±0.13 e	76.6±0.19 c
Chopped maize	73.8±0.09 c	87.9±0.11 b
Paddy husk	42.2±0.14 f	32.2±0.17 d
Paddy husk + chopped rice	66.8±0.09 d	77.8±0.10 c

± Standard Error; means followed by the same letter (s) did not differ significantly by DMRT ($p<0.05$).

* Analysis was done after square root transformation.

Like percent egg parasitism, percent adult parasitoid emergence also differed among the food items (Table 5). The variations of egg parasitism and adult parasitoids emergence from the parasitised eggs may be due to the quality of the food materials. The present study revealed that chopped wheat was the most preferred food. On the other hand, both paddy grain and paddy husk were the most non-preferred food items and these might be poor in quality for development of host eggs, which in turns invited less number of parasitoids female than the most preferred quality food like chopped wheat.

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C O N T E N T S

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