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ASSOCIATION OF YIELD AND YIELD RELATED TRAITS IN AROMATIC RICE (*Oryza sativa* L.)

A. H. AKHI¹, M. A. K. MIAH², N. A. IVY³
A. ISLAM⁴ AND M. Z. ISLAM⁵

Abstract

Sixty cross combinations of SakhorkhoraR and IR58025A were studied in the experimental field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur during July 2010 to November 2010, to assess the character association & contribution of characters towards grain yield in restorer lines. The correlation study revealed that days to first flowering showed significant positive relationship with seed yield per plant at genotypic levels. Days to maturity showed significant positive relationship with number of tillers per plant at both genotypic and phenotypic level and effective panicles per plant at genotypic level. Plant height showed highly significant positive relationship with effective panicles per plant at both genotypic and phenotypic level. Path analysis study revealed that effective panicles per plant (0.2153) had the highest positive direct effect followed by days to first flowering (0.1492), plant height (0.0646), spikelet fertility status (%) (0.0242) and number of seeds per panicle (0.0241). Days to maturity, spikelet sterility status, effective panicles per plant, plant height, number of tillers per plant, number of seeds per panicle and spikelet fertility status had positive indirect effects on grain yield. So, based on the study days to first flowering, plant height, spikelet fertility status, effective panicles per plant were identified as the important characters to be considered in the selection for improvement of aromatic rice genotypes.

Keywords: aromatic rice, character association, path analysis.

Introduction

Rice is tolerant to hot, humid, flooded and dry conditions, and grows in saline, alkaline and acidic soils. Asian cultivated rice has evolved into three eco-geographic races - *indica*, *japonica* and *javanica* (Jason *et al.*, 2006). Rice is the staple food for at least 63% of our planet inhabitants and contributes on an average 20% of apparent calorie intake of the world population and 30% of population in Asia (Calpe and Prakash, 2007). Among the 150 different crops grown in Bangladesh, rice alone occupies about 77% of the total cultivated area, of which aromatic rice is cultivated only on the 10% of the rice growing area (Anon., 2008). In Bangladesh, more than four thousand landraces of rice are

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adopted in different parts of this country (Sajib *et al.*, 2012). Some of these are unique for quality traits including fineness, aroma, taste and fine contents. A group of such rice is known as aromatic rice. Among the rice varieties, aromatic rice is popular in Asia and gained wider acceptance in Europe and the United States because of their aroma, flavor and texture. Aromatic rice is known for its characteristic fragrance after being cooked. This constitutes a small but special group of rice, which is considered best in quality. The natural chemical compound that is 2-acetyl-1-pyrroline gives aromatic rice the characteristic aroma and flavor but in the aromatic varieties it is present in much higher concentrations (Faridah *et al.*, 2011). The demand for aroma rice is increasing day by day. Unfortunately, the aromatic rice often has undesirable agronomic characters, such as low yield, susceptibility to pests and diseases, and strong shedding (Faruq *et al.*, 2011).

Breeding strategies should emphasise on aromatic rice production. Yield is a quantitative trait, greatly influenced by environmental fluctuations. Study on yield contributing characters assumes greater importance of fixing up characters that influence yield (Faruq *et al.*, 2011). For the development of a high yielding genotype through breeding rice requires a thorough knowledge of the association of the yield components. Correlation analysis provides a good measure of the association between characters and helps to identify the most important character(s) to be considered for effective selection for increasing yield. However, simple correlation does not provide adequate information about contribution of each factor towards yield (Nandan *et al.*, 2010). Therefore the technique of path coefficient analysis is utilized to have an idea of direct and indirect contribution of a trait towards yield, the end product. The present study was undertaken to gather some useful information on character association and path coefficient analysis in a set of 60 F₁ families of aromatic rice genotypes.

Materials and Method

The experiment was conducted at the experimental farm of BSMRAU during July 2010 to November 2010. Sixty F₁ (IR58025A x Sakkorkhora R) families of aromatic rice genotypes were planted in randomized complete block design with three replication at the rate of one seedling per hill. Each entry was planted in one rows of 5 m long plot with a spacing of 20 cm x 20 cm from plant to plant and row to row respectively. Adequate soil fertility was ensured by applying urea, TSP, MoP and Gypsum @ 180-100-70-60 kg/ha, respectively. Total TSP, MoP and Gypsum were applied in final land preparation. And total urea was applied in three installments, at 15 days after transplanting (DAT), 30 DAT and 50 DAT recommended by Anon. (1999). After transplanting various intercultural operations and irrigation were applied for better growth and development of the seedlings. Data were recorded on the parameters from 5 randomly selected plants from the middle rows of each plot on days to first flowering, days to maturity,

plant height (cm), number of tillers per plant, number of effective panicles per plant, spikelet fertility status (%), spikelet sterility status (%), number of seeds per panicle, seed yield per plant (g). For calculating the genotypic and phenotypic correlation co-efficient for all possible combinations the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1956) were adopted. Path coefficient analysis was done according to Dewey and Lu (1955).

Results and Discussion

Association study revealed that the genotypic and the phenotypic correlation coefficients showed similar trend but genotypic correlation coefficients were of higher in magnitude than the corresponding phenotypic correlation coefficients (Table 1). It may be due to the masking or modifying effect of environment on character association at the genetic level (Singh, 1980; Sarawgi *et al.*, 1997).

Days to first flowering showed significant positive relationship with seed yield per plant at genotypic levels. It was found to display highly significant positive relationships with days to maturity at both genotypic and phenotypic level but showed insignificant positive correlation with number of tillers per plant, effective panicles per plant and spikelet sterility status at both genotypic and phenotypic level. Similar findings were reported by Satyanarayan *et al.* (2005) for panicle length, number of grains per panicle and number of effective tillers per plant. Days to maturity, plant height (cm), number of tillers per plant, number of effective panicles per plant, spikelet fertility status (%) showed insignificant positive correlation with seed yield per plant and spikelet sterility status (%), number of seeds per panicle showed insignificant negative correlation with seed yield per plant (g) (Table 1). Suprio *et al.* (2010) found yield per plant showed significant positive correlation with plant height, panicle length, effective grains per panicle and harvest index.

Days to maturity showed significant positive relationship with number of tillers per plant at both genotypic and phenotypic level and effective panicles per plant at genotypic level (Table 1). And the genotypic value (0.303) is higher than the phenotypic value (0.256) which indicate that there is a strong association between these two characters genetically but the phenotypic value is lessened by the significant interaction of environment. Qamar *et al.* (2005) exhibited positive and non-significant correlation with productive tillers per plant at both levels.

Plant height showed highly significant positive relationship with effective panicle per plant at both genotypic and phenotypic level. Suprio *et al.* (2010) found effective grains per panicle revealed significant positive relationship with plant height. It indicated that increasing plant height caused to increase effective panicles per plant. The character also showed insignificant positive relationship with spikelet sterility status, number of seeds per panicle and seed yield per plant both at genotypic and phenotypic level (Table 1). Similar findings were reported by Sarkar *et al.* (2001).

Table 1. Genotypic and phenotypic correlation among yield and other traits of 60 F₁s of aromatic rice genotypes

Character	Correlation	Days to first flowering	Days to maturity	Plant Height (cm)	No. of tillers per plant	Effective panicle per plant	Spikelet fertility status (%)	Spikelet sterility status (%)	No. of seeds per panicle
Days to Maturity	G	0.999**	-						
	P	0.426**	-						
Plant Height (cm)	G	-0.038	0.120	-					
	P	0.025	0.044	-					
No. of tillers per plant	G	0.076	0.303*	-0.191	-				
	P	0.022	0.256*	-0.131	-				
Effective panicle per plant	G	0.072	0.318*	0.870**	0.988**	-			
	P	0.046	0.234	0.998**	0.915**	-			
Spikelet fertility status (%)	G	-0.219	-0.009	-0.315*	0.273*	0.254*	-		
	P	-0.077	0.038	-0.226	0.242	0.241	-		
Spikelet sterility status (%)	G	0.186	-0.016	0.307	-0.259*	0.017	0.987**	-	
	P	0.092	-0.031	0.228	-0.250*	0.019	-0.933**	-	
No. of seeds per panicle	G	-0.057	0.010	0.016	0.071	0.057	-0.379**	0.384**	-
	P	-0.021	0.004	0.016	0.068	0.053	-0.358**	0.370**	-
Seed yield per plant (g)	G	0.263*	0.087	0.031	0.038	0.067	0.055	-0.049	-0.008
	P	0.142	0.061	0.024	0.037	0.065	0.051	-0.047	-0.008

* Indicates significant at 5% level of significance, ** Indicates significant at 1% level of significance, G= Genotypic, P= Phenotypic.

Table 2. Partitioning of genotypic correlation with grain yield into direct (bold) and indirect effect of 60 F₁s of aromatic rice genotypes

Characteristics	Days to first flowering	Days to maturity	Plant height (cm)	No. of tillers per plant	Effective panicles per plant	Spikelet fertility status (%)	Spikelet sterility status (%)	No. of seeds per panicle	Genotypic correlation with yield
Days to first flowering	0.1492	-0.0081	0.0018	-0.0036	0.0096	-0.0018	-0.0049	-0.0005	0.1414
Days to maturity	0.0638	-0.0189	0.0029	-0.0399	0.0499	0.0009	0.0018	0.0001	0.0607
Plant height (cm)	0.0042	-0.0009	0.0646	0.0229	-0.0498	-0.0054	-0.0126	0.0003	0.0235
No. of tillers per plant	0.0031	-0.0044	-0.0086	-0.1721	0.1971	0.0058	0.01396	0.0016	0.0365
Effective panicles per plant	0.0065	-0.0044	-0.0149	-0.1575	0.2153	0.0058	0.0128	0.0013	0.0648
Spikelet fertility status (%)	-0.0111	-0.0008	-0.0144	-0.0415	0.0514	0.0242	0.0519	-0.0086	0.0512
Spikelet sterility status (%)	0.0134	0.0006	0.0146	0.0429	-0.0497	-0.0226	-0.0556	0.0088	-0.0475
No. of seeds per panicle	-0.0032	-0.0001	0.0010	-0.0116	0.0114	-0.0087	-0.0205	0.0241	-0.0076

R = 0.4953

Number of tillers per plant showed highly significant positive correlation with effective panicle per plant at both genotypic and phenotypic level and showed significant positive correlation with spikelet fertility status at genotypic level. The results are supported by Mulugeta *et al.* (2012). Highly significant positive correlation between two traits indicated the traits are governed by same gene and simultaneous improvement would be effective. It also showed significant negative relationship with spikelet sterility status at both genotypic and phenotypic level. Effective panicle per plant showed significant positive relationship with spikelet fertility status at genotypic level. Kole *et al.* (2008) obtained significant negative correlation with panicle number and spikelet fertility status (%). Spikelet fertility status showed highly significant negative relationship with number of seeds per panicle at both genotypic and phenotypic level. The results are in agreement with Kole *et al.* (2008) for grain number and spikelet fertility status (%). Spikelet sterility status (%) showed highly significant positive relationship with number of seeds per panicle (Table 1).

Significant negative correlations were also noted for spikelet fertility status (%) with plant height at genotypic level (Kole *et al.* 2008). The observed significant negative correlation in spikelet sterility status (%) with number of tillers per plant at both genotypic and phenotypic level which was supported by earlier workers, Ekka *et al.* (2011). They showed negative correlation in spikelet sterility status (%) with number of effective tillers per plant at both genotypic and phenotypic level. The phenotypic correlation between spikelet sterility status (%) vs. spikelet fertility status(%) were negative and significant at 1 % level. The results are in agreement with Karim *et al.* (2014) for 1000 grain weight and spikelet sterility status(%). Pleiotropy and/or linkage may also be genetic the reason for this type of negative association. According to NeWall and Eberhart (1961), when two characters show negative phenotypic and genotypic correlation it would be difficult to exercise simultaneous selection for these characters in the development of a variety. Hence, under such situations, judicious selection programme might be formulated for simultaneous improvement of such important developmental and component characters (Table 1).

Path analysis

Considering grain yield as effect and eight characters as causes, genotypic correlation coefficient were partitioned by using method of path analysis to find out the direct and indirect effects of yield contributing characters towards grain yield. The results of path analysis presented in Table-2 revealed that the effective panicles per plant (0.2153) had the highest positive direct effect on yield followed by days to first flowering (0.1492), plant height (0.0646), spikelet fertility status(%) (0.0242) and number of seeds per panicle (0.0241) indicating that these are the main contributors to yield. The findings were supported by

Mulugeta *et al.* (2012) for grains per panicle (2.226) followed by days to 50% flowering (1.465), panicle length (0.641), total spikelet fertility (0.269) and plant height (0.087).

Effective panicles per plant showed the highest positive direct effect (0.2153) on yield (Table 2). This findings is in agreement with Kole *et al.* (2008). This character also showed the highest positive indirect effect through spikelet sterility status (0.0128) followed by days to first flowering (0.0065), spikelet fertility status (0.0058) and number of seeds per panicle (0.0013). The character produced the negative indirect effect on number of tillers per plant (-0.1575) followed by plant height (-0.0149) and days to maturity (-0.0044) (Table 2). Mulugeta *et al.* (2012) reported similar finding for tillers per plant. Since the direct effect and correlation coefficient between effective panicles per plant and grain yield are positive, so it is an indication of true relationship among these traits. It suggests that the direct selection for effective panicles per plant would likely to be effective in improving the grain yield. Qamar *et al.* (2005) reported positive contribution of total spikelets towards grain yield, which supports the present finding.

Days to first flowering showed the positive direct effect (0.1492) on yield (Table 2). Similar findings were reported by Kishore *et al.* (2007). The character also showed the maximum positive indirect effect through effective panicles per plant (0.0096) followed by plant height (0.0018). The character also produced the negative indirect effect on yield via days to maturity (-0.0081), spikelet sterility status (0.0049), number of tillers per plant (-0.0036), spikelet fertility status (-0.0018) and number of seeds per panicle (0.0005).

Plant height showed the positive direct effect (0.0646) on yield (Table 2). Similar findings were reported by Kole *et al.* (2008). The character also showed the maximum positive indirect effect through number of tillers per plant (0.0229), followed by days to first flowering (0.0042) and number of seeds per panicle (0.0003). The character also produced the negative indirect effect on effective panicles per plant (-0.0498), spikelet sterility status (-0.0126), spikelet fertility status (0.0058) and days to maturity (-0.0009).

Spikelet fertility status showed the positive direct effect (0.0242) on yield (Table 2). This character also showed the highest positive indirect effect through spikelet sterility status (0.0519) followed by effective panicles per plant (0.0514). The character produced the negative indirect effect on number of tillers per plant (-0.0415), plant height (-0.0144), days to first flowering (-0.0111), number of seeds per panicle (-0.0086) and days to maturity (-0.0008).

Number of seeds per panicle showed the positive direct effect (0.0241) on yield (Table 2). Similar findings were reported by Mustafa and Elsheikh (2007) and Akinwale *et al.* (2011). This character also showed the highest positive indirect

effect through effective panicles per plant (0.0114), followed by plant height (0.0010). The character produced the negative indirect effect on spikelet sterility status (-0.0205), followed by spikelet fertility status (-0.0087), number of tillers per plant (-0.0116), days to first flowering (-0.0032), days to maturity (-0.0001).

Days to maturity, number of tillers per plant, spikelet sterility status (%) had very low negative direct effect on grain yield. Moreover the contribution of these three characters in the path way of other characters was negligible.

The residual effect was 0.4953 indicated that the contribution of component characters on grain yield was 50.47% by the eight characters studied in path analysis, the rest 49.53% was the contribution of other factors, not included in this study.

Conclusion

It is obvious from the results that the traits effective panicles per plant had the highest positive direct effect on yield and positive genotypic association as well with grain yield. And other traits such as days to first flowering, plant height, spikelet fertility status (%) do have high positive direct effect and positive genotypic association as well with grain yield. So these parameters may be given prime importance for the direct improvement of grain yield in this group. Number of seeds per panicle showed the high positive direct effect but this parameter has negative genetic association.

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EFFECT OF PLANTING SYSTEM OF POTATO AND PLANT DENSITY OF MAIZE ON PRODUCTIVITY OF POTATO- HYBRID MAIZE INTERCROPPING SYSTEM

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Abstract

The experiment was conducted at Agronomy Research Field, Bangladesh Agricultural Research Institute, Gazipur during 2010-11 to find out the appropriate planting system of potato and plant density of maize in potato-hybrid maize intercropping system for maximum yield and economic return. Ten treatments were evaluated viz., T₁= Potato whole tuber single row (75 cm × 20 cm) + 125% hybrid maize (75 cm × 20 cm), T₂=Potato whole tuber single row (75 cm × 20 cm) + 100% hybrid maize (75cm × 25 cm), T₃= Potato whole tuber single row (75 cm × 20 cm) + 83% hybrid maize (75 cm × 30 cm), T₄= Potato half tuber paired row (20 cm/ 55 cm × 20 cm) + 125% hybrid maize (75 cm × 20 cm), T₅= Potato half tuber paired row (20 cm/ 55 cm × 20 cm) +100% hybrid maize (75 cm × 25 cm), T₆= Potato half tuber paired row (20 cm/ 55 cm × 20 cm) + 83% hybrid maize (75 cm × 30 cm), T₇= Sole potato whole tuber single row planting system (60 cm × 25 cm), T₈ = Sole potato half tuber paired row (20 cm/ 55 cm × 20 cm), T₉= Sole hybrid maize in normal spacing 75 cm × 25 cm (sole HM1) and T₁₀= Sole hybrid maize (75 cm × 25 cm) sown 30 days after potato planting (sole HM2). The results revealed that sole planting of both potato and maize produced the maximum yields. In case of sole potato, potato half tuber paired row planting system was better than potato whole tuber single row planting system. On the other hand, the performance of sole HM1 was better than sole HM2 in relation to growth, yield and economic performance. Over all T₁ treatment (potato whole tuber single row planting system with 125 % hybrid maize population) was the best intercropping system for getting higher yield and economic return as well as less relative crowding coefficient with better crop performance ratio.

Keywords: Planting system, Plant density, PAR interception, Dry matter, RCC, CPR, Relative yield, Equivalent yield, Potato, Maize.

Introduction

Intercropping system is one of the important approaches of cropping systems by which production can be increased. Intercropping system becomes productive and economical only when it is done properly by selecting compatible crops

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(Santalla *et al.*, 2001), shifting the period of peak demand for growth resources through changing the time of sowing of the component crops (Santalla *et al.*, 1999) and when their component crops differ in photosynthetic pathway, growth habit, growth duration, alteration of planting arrangement and demand for growth resources (Fukai and Trenbath, 1993).

Maize is a unique crop for its versatile use and low cost unit⁻¹ production. Its cultivation and uses are spreading very fast due to development of both poultry industry and increase in human consumption. So, there is ample scope for farther expansion of maize in Bangladesh (Islam, 2007). However, there is problem in increasing the cropping area of maize in the country as it has to compete with a number of crops particularly in the dry season. The production of maize can be increased if it can be included as an intercrop in the cropping system. Maize is a widely spaced crop and there is ample scope to grow short duration intercrops in the interspaces and maize is the most compatible crop with potato for their contrasting phenology, highest maize equivalent yield (179q ha⁻¹) and 163% yield advantage (Jha *et al.*, 2000). Potato (*Solanum tuberosum* L.) is leading vegetable crop in the world and it is the third largest food crop in Bangladesh. The production of potato has been increased to almost 10 million tons in Bangladesh.

Row arrangement or planting system of component crops is an important agronomic approach in intercropping systems. The intercrop productivity may be increased through minimizing of interspecific competition and maximizing complementary use of growth resources (Midmore, 1993). In potato- maize intercropping, maize being tall statured C₄ crop has higher competitive ability for light than underneath C₃ potato crop. Competition for light may be minimized by changing planting pattern of maize without affecting its yield (Waghmare *et al.*, 1982). Density of component crops plays a vital role in increasing productivity and profitability of intercropping systems. Competitive ability of a component crop in intercropping system is largely influenced by population density. For maximum productivity it is also important to determine maximum population density of the companion crops to be accommodated in the system. The experiment was, therefore, undertaken to find out planting arrangement/system of potato and plant density/spacing of maize in potato maize intercropping system for getting higher yield and economic return.

Materials and Method

The experiment was conducted at the Agronomy research field of BARI, Joydebpur during the *rabi* season of 2010-11. Ten treatments were evaluated in the experiment viz., T₁= Potato whole tuber single row (75 cm × 20 cm) + 125% hybrid maize (75 cm × 20 cm), T₂=Potato whole tuber single row (75 cm × 20 cm) + 100% hybrid maize (75cm × 25 cm), T₃= Potato whole tuber single row (75 cm × 20 cm) + 83% hybrid maize (75 cm × 30 cm), T₄= Potato half tuber paired row (20 cm/ 55 cm × 20 cm) + 125% hybrid maize (75 cm × 20 cm), T₅=

Potato half tuber paired row (20 cm/ 55 cm × 20 cm) +100% hybrid maize (75 cm × 25 cm), T₆= Potato half tuber paired row (20 cm/ 55 cm × 20 cm) + 83% hybrid maize (75 cm × 30 cm), T₇= Sole potato whole tuber single row planting system (60 cm × 25 cm), T₈ = Sole potato half tuber paired row (20 cm/ 55 cm × 20 cm), T₉= Sole hybrid maize in normal spacing 75 cm × 25 cm (sole HM1) and T₁₀= Sole hybrid maize (75 cm × 25 cm) sown 30 days after potato planting (sole HM2). The experiment was laid out in randomized complete block design with three replications. The unit plot size was 6.0 m × 5.0 m. The potato var. BARI Alu 8 (Cardinal) and maize var. BARI Hybrid maize 7 were used in the experiment. Sole potato, intercropped potato and sole HM1 (T₉) were planted on 22 November, 2010. Sole HM2 (T₁₀) and intercropped maize were planted on 22 December, 2010. Fertilizers were applied @ N₁₈₀P₄₀K₁₈₀S₂₀Zn₆B_{1.2} kg/ha and N₂₆₀P₇₂K₁₄₈S₄₈Zn₄B₂ kg/ha for sole potato and sole hybrid maize, respectively (FRG, 2005). For intercrop fertilizers were applied @ N₃₂₀P₇₃K₁₇₀S₅₀Zn₆B₂ kg/ha. The source of N, P, K, S, Zn and B was urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid, respectively. In case of sole potato, half amount of urea and MoP and the whole amount of TSP, gypsum, zinc sulphate and boric acid were applied at the time of final land preparation. Remaining half amount of urea and MoP were applied at 30 days after planting (DAP). For sole maize, one-third of urea and whole amount of other fertilizers were applied at the time of final land preparation. Remaining amount of urea was applied in two equal splits as side dressing at 30 and 55 days after sowing (DAS). In case of intercrop, 1/3 urea as basal, 1/3 at 30 DAP & 1/3 after potato harvest followed by irrigation and all other fertilizers were applied as basal. Irrigation and other intercultural operations were done as and when required. Fungicide (Dithane M 45) was sprayed at every 10-day intervals beginning from 25 DAP to 70 DAP for preventing potato disease. Photosynthetically active radiation (PAR) was measured by PAR Ceptometer (Model – LP-80, Accu PAR, Decagon, USA). PAR ($\mu\text{mole s}^{-1} \text{m}^{-2}$) was measured at 10-day intervals from 30 to 90 day after emergence (DAE) of potato at around 11:30 am to 13:00 pm. Potato was harvested at 95 DAP on 24 February, 2011 and hybrid maize were harvested on 6 May, 2011 (135 DAS) except sole HM1 (T₉) which was harvested on 15 April, 2011 (144 DAS). Collected data of both the crops were analyzed statistically and the means were adjudged using DMRT at 5% level of probability. Economic analysis was also done considering local market price of harvested crops.

Results and Discussion

Photosynthetically active radiation

The photosynthetically active radiation (PAR) was measured at 60, 68, 76, 84 and 92 DAP of potato or 30, 38, 46, 54 and 62 DAS of maize. PAR interception was significantly influenced at all time intervals by intercropping system. PAR interception was the highest in all the treatments at 60 DAP (Fig. 1). The

efficiency of PAR interception depends on the leaf area and the plant population as well as leaf shape and inclination into the canopy. Over the growing period, the higher PAR interception was observed in intercrop situation than sole crop. Higher PAR was observed in all the treatments at 60 DAP, and then declined up to potato harvest (92 DAP) except sole maize. It might be due to leaf area of potato reached its maximum growth at 60 DAP and then leaf senescence occurred sharply up to harvest. On the other hand, PAR interception was less in maize due to its incomplete canopy coverage at its early growth stage and then increased up to its maximum growth stage (after potato harvest). The results revealed that over the growing period, PAR interception was higher in intercrop than sole crop at all the time intervals. Similar result was observed by Islam (2007) who reported that PAR interception was higher in intercrop situation than sole crop in potato + maize intercropping system. Treatment comprises, potato half tuber double row planting system, attained its full canopy coverage with more vigorous within 30 DAP than that of whole tuber single row planting system. Moreover, it was found that the growth of half tuber was faster than that of whole tuber. So, emergence of intercropped hybrid maize was affected with heavy shading by potato canopy of half tuber paired row planting system. As a result, maize population decreased drastically in potato half tuber double row planting system. Though there was no significant difference in PAR interception with different maize population.

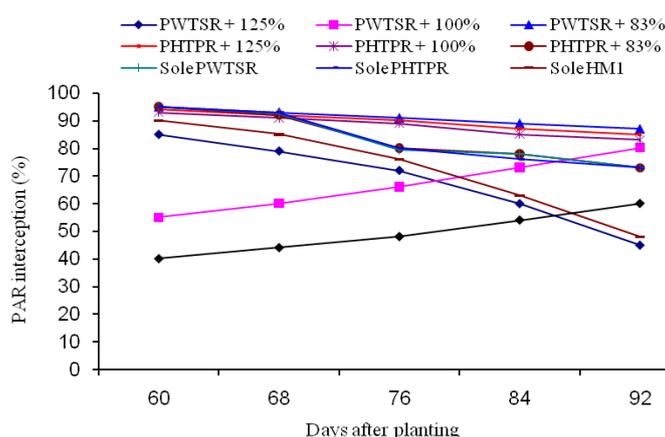


Fig. 1. PAR (%) intercepted in potato-hybrid maize intercropping system.

Note: PWTSR= Potato whole tuber single row, PHTPR = potato half tuber paired row, HM1= hybrid maize sown at the time of potato planting and HM2= hybrid maize sown 30 days after potato planting.

Total dry matter of potato and maize

Planting system and population density caused significant variation in dry matter accumulation of potato and hybrid maize (Fig. 2). Total dry matter (TDM) of

potato and hybrid maize increased with the advancement of plant age irrespective of different treatments. The differences in TDM production were slow at the initial stage of crop development and with the advancement of time. Sole potato (half tuber double row) and respective intercrops produced higher TDM than sole potato (whole tuber single row) and respective intercrops due to higher population density. On the other hand, both sole of hybrid maize gave higher TDM than that of intercropping maize. It might be due to no intercrop competition for light, nutrients, moisture and space in sole crop. This corroborates with the findings of Islam (2007) and Alom (2007).

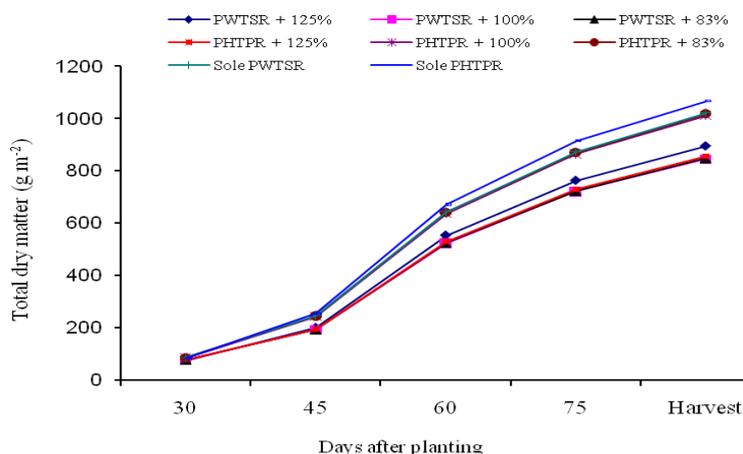


Fig. 2. Total dry matter of potato in potato-hybrid maize intercropping.

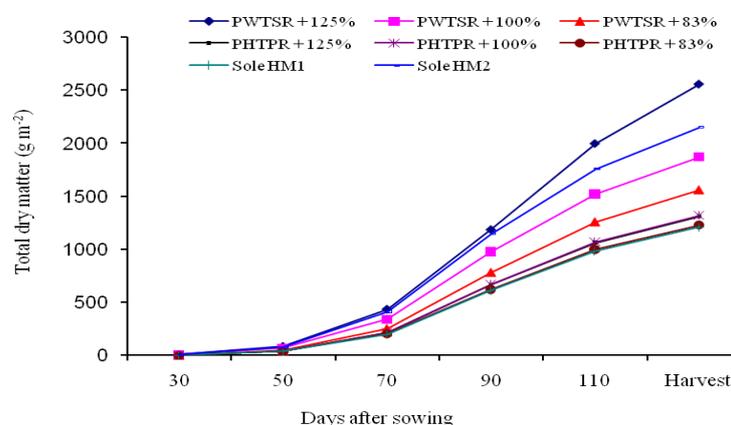


Fig. 3. Total dry matter of hybrid maize in potato-hybrid maize intercropping system.

Note: PWTSR= Potato whole tuber single row, PHTPR = potato half tuber paired row, HM1= hybrid maize sown at the time of potato planting and HM2= hybrid maize sown 30 days after potato planting

Early sown sole hybrid maize produced more TDM than delayed sown sole maize. It might be due to shortening of growth period of maize with the increased of temperature at later stage. Similar result was observed by Islam (2002). The results also revealed that TDM of hybrid maize in potato single row based intercropping were higher than that of potato double row based intercropping.

Assessment of competition in intercropping system

Crop competition quantified by relative crowding coefficient (Hall, 1974), crop performance ratio (Ali *et al.*, 1990) and relative yield and relative yield total (Jokinen, 1991). Relative crowding coefficient (RCC) provides a measure of aggressiveness of each species grown in association. In this study, RCC of potato was higher than that of hybrid maize in all intercropping systems. The results indicated that potato was more competitive than maize (Table 1). The RCC of each potato and maize (when intercropped with potato whole tuber single row system) was greater than unity indicated better utilization of growth resources in intercropping. The highest K value (20.45) was observed in potato whole tuber single row in association with 125% hybrid maize population indicating the higher compatibility in intercropping.

The crop performance ratio (CPR) is used to assess the performance of individual crop as well as total intercropping. Partial CPR of potato was greater than unity (1.83-1.91) in all intercrop combinations, which showed 83 to 91% yield advantage over its sole crop and maize also contributed 4-40 % yield advantage in different intercropping systems (Table 1). This yield improvement of component crops might be the resultant of complementary use of growth resources. Islam (2002) also reported that maize in maize + bush bean intercropping system produced 27- 99% yield advantage over sole crop. But CPR of maize was less than unity (0.67- 0.71) when maize was intercropped with potato half tuber double row system and it was found that maize had heavy shading by large potato canopy at early growth stage of maize in intercropping system. However, CPR values in different intercropping systems varied from 1.51 to 1.72 indicating 51 to 72% yield advantage over monoculture (Table 1). The highest CPR (1.72) was found in T₁ and the lowest CPR (1.51) in T₄.

The relative yields of intercropped potato varied from 0.92 to 0.96 depending upon the planting systems and population density of potato and maize (Table 1). The results indicated that intercropped potato showed poor competitiveness in accordance to different planting systems and population densities. Similarly, relative yields of intercropped maize varied from 0.34 to 0.70 in response to different planting systems and population density of component crops. The results revealed that potato had more competitive ability than maize in intercropping systems. Relative yield totals (RYT) in all intercrop combinations were greater than unity indicated yield advantage of intercropping systems over

mono cropping (Table 1). The highest RYT (1.64) was found when 125% maize population grown in potato whole tuber single row planting system.

Table 1. Relative crowding coefficient (RCC), crop performance ratio (CPR) and relative yield total of potato and hybrid maize intercropping under different planting arrangement and plant density

Treatment	RCC		Product (K)	Partial CPR		CPR	Relative Yield		Relative yield total
	Potato	Maize		Potato	Maize		Potato	Maize	
T ₁	18.58	1.87	20.45	1.87	1.40	1.72	0.94	0.70	1.64
T ₂	14.86	1.56	16.42	1.87	1.22	1.66	0.94	0.61	1.55
T ₃	18.26	1.31	19.57	1.91	1.04	1.62	0.96	0.52	1.48
T ₄	13.58	0.44	14.02	1.83	0.71	1.51	0.92	0.35	1.27
T ₅	14.86	0.59	15.45	1.87	0.70	1.54	0.94	0.35	1.29
T ₆	13.84	0.61	14.45	1.89	0.67	1.54	0.94	0.34	1.28
T ₇	1.00	-	1.00	1.00	-	1.00	1.00	-	1.00
T ₈	1.00	-	1.00	1.00	-	1.00	1.00	-	1.00
T ₉	-	1.00	1.00	-	1.00	1.00	-	1.00	1.00
T ₁₀	-	1.00	1.00	-	1.00	1.00	-	1.00	1.00

Note: T₁= Potato whole tuber single row (75 cm × 20 cm) +125% hybrid maize (75 cm × 20 cm), T₂= Potato whole tuber single row (75 cm × 20 cm) +100% hybrid maize (75 cm × 25 cm), T₃ = Potato whole tuber single row (75 cm × 20 cm) +83% hybrid maize (75 cm × 30 cm), T₄= Potato half tuber paired row (20/55 cm × 20 cm) + 125% hybrid maize (75 cm × 20 cm), T₅ = Potato half tuber paired row (20/55 cm × 20 cm) + 100% hybrid maize (75 cm × 25 cm) and T₆= Potato half tuber paired row (20/55 cm × 20 cm) +83% hybrid maize (75 cm × 30 cm), T₇= Sole potato whole tuber single row (75 cm × 20 cm) and T₈= Sole potato half tuber paired row (20/55 cm × 20 cm), T₉= Sole HM1 and T₁₀= Sole HM2.

Tuber yield & yield components of potato

Tuber yield and yield components like number of stems m⁻², number of tubers hill⁻¹ and tuber weight hill⁻¹ varied significantly by planting systems of potato and maize (Table 2). Results revealed that potato half tuber paired row planting system and respective intercropping treatments showed significantly better performance in all parameters than those of potato whole tuber single row planting system and respective intercropping treatments. The maximum number of stems m⁻² (49.33), tubers hill⁻¹ (12.0) and tuber weight hill⁻¹ (600.00 g) were observed in T₈ which was statistically similar with respective intercropping treatments while lower number of stems m⁻² (30.00), tubers hill⁻¹ (7.70) and tuber weight hill⁻¹ (495.30 g) were observed in T₁ which were statistically similar with respective intercrop treatments. The germination percentage was higher in half tuber paired row system due to fungicide treatment. As a result population as well as number of stems m⁻² became higher in paired row planting system than

that of whole tuber single row system. But there was no significantly different in the number of stems m^{-2} between the sole potato and respective intercropping due to different population of maize. The results also revealed that in both planting systems, higher number of tubers $hill^{-1}$ was obtained in monoculture compared to respective intercropping treatments. It might be due to the plants having more growth resources resulting the plants had luxurious growth which produced higher number of tubers $hill^{-1}$ than other respective intercropping treatments. The results are agreement with Islam (2007) in hybrid maize + potato intercropping system. Among the treatments, both the sole crop gave the higher tuber weight $hill^{-1}$ than respective intercropping treatments. It might be due to the plants having more space, light and nutrients resulting the plants grew luxuriously and able to produce higher tuber weight $hill^{-1}$ in monoculture than respective intercropping treatments. The results are in agreement with Islam (2007) in hybrid maize + potato intercropping. The highest tuber yield ($26.33 t ha^{-1}$) was observed in T_8 followed by respective intercropping treatments and the lowest yield ($21.55 t ha^{-1}$) was found in T_1 which was statistically similar with T_2 , T_3 & T_7 . Higher yield of potato was observed in monoculture compared to respective intercropping might be due to no intercrop competition for growth resources like light, nutrients, moisture and space in sole cropping. This corroborates with the findings of Karim *et al.* (1989) and Islam (2007).

Table 2. Yield and yield components of potato in potato- hybrid maize intercropping as affected by planting arrangement and plant density

Treatment	Stems m^{-2} (no.)	Tubers $hill^{-1}$ (no.)	Tuber wt. $hill^{-1}$ (g)	Tuber yield ($t ha^{-1}$)
T_1	30.00b	7.70d	495.30b	21.55d
T_2	30.00b	7.70d	495.30b	21.55d
T_3	31.33b	7.72d	500.70b	22.00cd
T_4	46.67a	10.80b	540.70ab	24.11abc
T_5	46.67a	11.00ab	545.00ab	24.67ab
T_6	47.33a	11.20ab	550.70ab	24.84ab
T_7	34.67b	9.00c	540.70ab	23.00bcd
T_8	49.33a	12.0a	600.00a	26.33a
CV (%)	6.00	5.10	5.44	4.06

In a column figures having common letter (s) do not differ significantly whereas the figures with dissimilar letter differ significantly as per DMRT at 5% probability level.

T_1 = Potato whole tuber single row (75 cm \times 20 cm) +125% HM (75 cm \times 20 cm), T_2 = Potato whole tuber single row (75 cm \times 20 cm) +100% HM (75cm \times 25 cm), T_3 = Potato whole tuber single row (75 cm \times 20 cm) +83% HM (75 cm \times 30 cm), T_4 = Potato half tuber paired row (20/55 cm \times 20 cm) + 125% HM (75 cm \times 20 cm), T_5 = Potato half

tuber paired row (20/55 cm × 20 cm) + 100% HM (75 cm × 25 cm), T₆= Potato half tuber paired row (20/55 cm × 20 cm) +83% HM (75 cm × 30 cm), T₇= Sole potato whole tuber single row (75 cm × 20 cm) and T₈= Sole potato half tuber paired row (20/55 cm × 20 cm).

Grain yield & yield component of maize

Grain yield and yield component of hybrid maize was significantly affected by planting system and population density (Table 4). Number of cobs m⁻² was observed higher in intercropping treatments involving potato whole tuber planting. Lower number of cobs m⁻² was observed in intercropping treatments based on potato half tuber paired row planting system. At early growth stage, vigorous potato canopy under potato half tuber paired row planting system affected germination of maize. As a result, lower plant stand and number of cobs m⁻² in maize under potato half tuber paired row planting system. However, the highest number of cobs m⁻² was obtained in potato whole tuber single row + 125% hybrid maize treatment due to higher maize population while lowest number of cobs m⁻² from potato half tuber paired row + 83% maize population due to lower maize population. Similar result was found by Dehdashti and Riahinia (2008) and Ahmed *et al.* (2010). They reported that higher plant population increased number of cobs per unit area. Both sole maize gave significantly higher number of grains cob⁻¹ than their intercrop treatments and there was no significant difference among the intercrop treatments. Highest number of grains cob⁻¹ was observed in sole maize presumably due to plants having more space, light and nutrients where plants grew luxuriously. The findings are in accordance to those of Quayyum *et al.* (1985) and Nag *et al.* (1996). Sole maize (both) and potato whole tuber single row based intercropping treatments gave higher 1000-grain weight. It might be due to more availability of growth resources in sole maize than in intercropping treatments. On the other hand, maize in intercropping treatments (potato half tuber paired row planting system) gave lower grain weight probably due to the fact that maize had poor growth caused by heavy shading at early growth stage. Grain yield of maize followed almost similar pattern to its yield contributing characters at the different intercropping systems (Table 3). However, sole maize (both) gave the higher grain yield which might be due to low competition occurrence for growth resources. The result also revealed that sole HM2 gave lower yield than sole HM1. It might be due to shortening of growth period of maize under late sown condition due to rise of temperature, especially at the later growth stage. On the other hand, potato half tuber paired row based intercropping treatments showed lower yield due to lower number of cobs m⁻². Besides this, other yield contributing characters were also lower in potato half tuber paired row based intercropping treatments.

Table 3. Yield and yield components of hybrid maize in potato- hybrid maize intercropping as affected by planting arrangement and plant density

Treatment	Cobs m ⁻² (no.)	Grains cob ⁻¹ (no.)	1000-grain wt. (g)	Grain yield (t ha ⁻¹)
T ₁	6.67a	459.3bc	320.18b	8.05c
T ₂	5.34b	459.4bc	327.20ab	7.00d
T ₃	4.45c	460.2bc	330.50ab	6.00d
T ₄	3.50d	445.0c	300.20b	3.67e
T ₅	3.50d	445.1c	310.80b	3.64e
T ₆	3.20d	445.0c	320.20b	3.50e
T ₉	5.50b	510.1a	375.90a	11.50a
T ₁₀	5.40b	500.0ab	349.00ab	10.40b
CV (%)	5.88	5.17	6.74	6.23

In a column figures having common letter (s) do not differ significantly whereas the figures with dissimilar letter differ significantly as per DMRT at 5% probability level.

T₁= Potato whole tuber single row (75 cm × 20 cm) +125% HM (75 cm × 20 cm), T₂= Potato whole tuber single row (75 cm × 20 cm) +100% HM (75cm × 25 cm), T₃ = Potato whole tuber single row (75 cm × 20 cm) +83% HM (75 cm × 30 cm), T₄= Potato half tuber paired row (20/55 cm × 20 cm) + 125% HM (75 cm × 20 cm), T₅ = Potato half tuber paired row (20/55 cm × 20 cm) + 100% HM (75 cm × 25 cm), T₆= Potato half tuber paired row (20/55 cm × 20 cm) +83% HM (75 cm × 30 cm), T₉= Sole HM1 and T₁₀= Sole HM2.

Intercrop efficiency

Potato-hybrid maize intercrop productivity was evaluated on the basis of equivalent yield (Bandyopadhyay, 1984). The result showed that all the intercropping systems gave higher potato and maize equivalent yield than that of corresponding sole crop yield (Table 4). The highest potato equivalent yield was recorded in the treatment of potato whole tuber single row + 125% maize population which showed yield advantages of 32% whereas maize equivalent yield advantages of 169% over the respective sole crops. Jha *et al.* (2000) reported the highest maize equivalent yield (179 q ha⁻¹) and yield advantage (163 %) in potato + hybrid maize intercropping. Land equivalent ratio (LER) values in the intercrops ranged from 1.27 to 1.64 which indicated 27 to 64% yield advantage due to intercropping (Table 4). The highest LER value (1.64) was obtained from the treatment of potato whole tuber single row + 125% maize population, which might be due to maximum complementary use of different growth resources in potato this treatment.

Economic performance

Economic analysis is an important tool to evaluate the economic feasibility of intercropping systems and monetary advantage was evaluated according to Shah *et al.* (1991). Data pertaining to monetary return of intercropping system indicated that higher gross return and gross margin was observed in all intercropped treatments than in monoculture of potato or maize (Table 4). Potato whole tuber single row + 125% hybrid maize gave the highest gross return (Tk. 363240 ha⁻¹) 32% and 155% more than sole cropping of potato and hybrid maize, respectively. The data showed that potato whole tuber single row + 125% hybrid maize gave the highest BCR of 2.66 (Table 4). Islam (2007) reported that BCR and gross margin was higher in intercropped situation than sole crop. The findings are also in agreement with those of Jha *et al.* (2002) and Sharma *et al.* (2000) and they reported that highest productivity and profitability in terms of equivalent yield and monetary return from intercropping system.

Table 4. Equivalent yield and economic performance of potato- hybrid maize intercropping under different planting arrangement and plant density

Treatment	PEY (t ha ⁻¹)	MEY (t ha ⁻¹)	LER	Gross return (Tk. ha ⁻¹)	Total cost of cultivation (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)	BCR
T ₁	30.27	27.94	1.64	363240	136467	226773	2.66
T ₂	29.13	26.89	1.55	349560	135867	213693	2.57
T ₃	28.50	26.31	1.48	342000	135467	206533	2.52
T ₄	28.09	25.93	1.27	337080	137917	199163	2.44
T ₅	28.61	26.41	1.29	343320	137317	206003	2.50
T ₆	28.63	26.43	1.28	343560	136917	206643	2.51
T ₇	23.00	21.23	1.00	276000	119086	156914	2.32
T ₈	26.33	24.30	1.00	315960	120536	195424	2.62
T ₉	12.46	11.50	1.00	142500	83065	59435	1.80
T ₁₀	11.27	10.40	1.00	135200	83065	52135	1.63

Market price: Potato Tk. 12 kg⁻¹; Maize Tk. 13 kg⁻¹.

PEY= Potato equivalent yield, MEY=Maize equivalent yield, LER= Land equivalent ratio.

T₁= Potato whole tuber single row (75 cm × 20 cm) +125% HM (75 cm × 20 cm), T₂= Potato whole tuber single row (75 cm × 20 cm) +100% HM (75cm × 25 cm), T₃ = Potato whole tuber single row (75 cm × 20 cm) +83% HM (75 cm × 30 cm), T₄= Potato half tuber paired row (20/55 cm × 20 cm) + 125% HM (75 cm × 20 cm), T₅ = Potato half tuber paired row (20/55 cm × 20 cm) + 100% HM (75 cm × 25 cm), T₆= Potato half tuber paired row (20/55 cm × 20 cm) +83% HM (75 cm × 30 cm), T₉= Sole HM1 and T₁₀= Sole HM2.

Conclusion

The result revealed that the intercropping system of potato whole tuber single row planting system (75cm × 20cm) + 125% hybrid maize (75cm × 20cm) was the most productive and profitable combination than all other intercropping systems as well as than sole cropping of potato and maize.

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EFFECTIVENESS OF SOIL AND FOLIAR APPLICATIONS OF ZINC AND BORON ON THE YIELD OF TOMATO

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Abstract

Field experiment was carried out for two consecutive years to study the effectiveness of soil and foliar application of micronutrients on the yield of tomato (*Lycopersicon esculentum* Mill.) at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The micronutrients zinc (Zn) in the form of zinc sulphate ($ZnSO_4 \cdot 7H_2O$) at the rate of 0.05 % and boron (B) in the form of boric acid (H_3BO_3) at the rate of 0.03% were applied as foliar spray at three different stages of plant growth i.e (i) before flower initiation; (ii) after fruit set when it becomes approximately marble sized; and (iii) at 20 days interval of second spray. The tomato yield and its contributing yield traits were significantly affected by foliar fertilizer treatments as against soil application of B and Zn fertilizers. Among various treatments, foliar application of Zn (0.05 %) + B (0.03%) produced maximum fruit yield (85.5 and 81.7 t ha⁻¹ in 2013 and 2014, respectively) while the control no application of Zn (0.0) and B (0.0) produced 66.8 and 60.7 t ha⁻¹ in 2013 and 2014, respectively and it was statistically identical with soil application of B and Zn @ 2 and 6 kg ha⁻¹ (T₅), respectively. The increment of yield was 19.2 to 31.1% and 7.57 to 18.3%, respectively, over control and soil application. The integrated use of foliar application of micronutrients and soil application of macronutrients are recommended to enhance tomato yield.

Keywords: Foliar applications, zinc, boron, tomato and yield.

Introduction

Micronutrient deficiencies are not only hampering crop productivity but also are deteriorating quality. The low micronutrient feed and food stuffs are causing health hazards in human beings and animals. Micronutrient acts as catalyst in the uptake and use of certain macronutrients (Phillips, 2004). Fruit size and quality as well as quality of some crops, are improved with micronutrient (Zn and B) use.

Tomato (*Lycopersicon esculentum* Mill.) is an important vegetable crop, which belongs to the family Solanaceae and also used in daily diet due to its good taste. The yield of tomato has declined due to micronutrient deficiency (Ejaz *et al.*, 2011). Excess use of phosphate fertilizers in soils with micronutrients

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deficiencies is causing imposed deficiency of micronutrients in the plants (Salimpour *et al.*, 2010; Khorgamy and Farnis, 2009; Hopkins and Ellsworth, 2003). With increasing utilization of chemical fertilizer environmental pollution has increased remarkably.

In spite of adequate application of NPK fertilizer, normal growth of high yielding varieties could not be obtained due to little or no application of micronutrients. High fertilizer responsive varieties express their full yield potential when trace elements are applied along with NPK fertilizers (Nataraja *et al.*, 2006). Chaudry *et al.* (2007) stated that micronutrients especially zinc (Zn) and boron (B) significantly increased the crop yield over control when applied single or in combination with each other, while Mandal *et al.* (2007) observed significant positive interaction between fertilizer treatments and physiological stages of crop growth. Considering the aforementioned facts, it is felt necessary to study the factors responsible for fertilizer efficiency improvement.

Keeping in view the key role played by Zn and B nutrition in plant growth, this study is designed to find out the suitable dose and method of Zn and B application for tomato production. The objectives of this research, therefore, were (i) to identify a suitable combination of Zn and B fertilization for tomato production; and (ii) to compare the effects of the methods of micronutrient application foliar vs. soil fertilization on yield of tomato.

Materials and Method

Field research was conducted at micronutrient experimental field of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, located at 23°59'26" N and 90°24'52" E. The experiment was laid out in a RCB design with three replications. The unit plot was 3 m × 3 m. Two adjacent unit plots were separated by 75 cm and 1m space was given between the blocks. Land was separated into two parts viz., a. Foliar application and b. Soil application. Part (a) consisted of 12 unit plots and (b) part consisted of 3 unit plots. During final land preparation on November 2013 and 2014, fertilizers were applied to the soil at the rate of N₁₄₀, P₄₅, K₉₀ and S₁₈ kg ha⁻¹ as urea, triple super phosphate, muriate of potash and gypsum, respectively, in both (a) and (b) applications plot. For soil fertilization, at the same time B and Zn were applied at the rates of 2 and 6 kg ha⁻¹ in soil application part (b). BARI Tomato 15 was used in this experiment. Healthy and uniform sized 30 days old seedlings were transplanted at 60 cm × 50 cm spacing and total plant per plot was 30. Inter cultural operations were done as and when needed.

Foliar application

To study the effect of Zn and B as foliar spray on growth and yield of tomato, two micronutrients Zn and B at a single rate alone and at different combinations

in the form of zinc sulphate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) containing 23 % Zn at the rate of 0.05 % and boric acid (H_3BO_3) having 18 % boron at the rate of 0.03 % were applied as foliar spray at three different stages of plant growth (i) before flower initiation; (ii) after fruit set when it becomes approximately marble sized; and (iii) at 20 days interval of second spray. The treatment combinations of foliar spray of Zn and B were T_1 : Zn (0.0 %) + B (0.0%) as control; T_2 : Zn (0.05 %) + B (0.0%); T_3 : Zn (0.0 %) + B (0.03%); and T_4 : Zn (0.05 %) + B (0.03%). Soil fertilization treated as T_5 : Zn (6) and B (2) kg ha^{-1} was applied basal as stated above.

The solution of all treatments were prepared and contained urea at the rate of 0.08 % to activate mineral absorption and surf (detergent) used as wetting agent at the rate of 0.01 % for reducing contact angle between the liquid and leaf surface (Sajid *et al.*, 2010). The volume of water 1.0 liter plant^{-1} was estimated (3 split at three different stages of plant growth viz., 300 ml + 300 ml + 400 ml of solution, approximate) to wet completely the tomato plant. The spray solution was prepared separately on the basis of 2.17 mg and 1.67 mg of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ and H_3BO_3 in 1.0 liter of water, respectively. Urea at the rate of 1.74 mg and surf 0.1 mg liter^{-1} as a wetting agent were applied along with each treatment. The foliar spray contained Zn (0.05%) and B (0.03%), amended with surfactant to curtail water desertion during the spray process, to ensure the nutrients adhered to the leaf surface, and to maximize uptake by foliage. Data were collected on fruit diameter, fruit height, individual fruit weight and fruit yield of tomato and recorded data were analyzed statistically and means were compared by Tukey's multiple comparisons test using Excel Statistics version 4.0 (Esumi Co. Ltd., Tokyo, Japan).

To compare different treatments combination with control/soil application treatment the following equation was applied (Rhaman *et al.*, 2011).

$$\begin{aligned} \text{MBCR (Over control)} &= \frac{\text{Gross return (T}_1\text{)} - \text{Gross return (T}_0\text{)}}{\text{VC (T}_1\text{)} - \text{VC (T}_0\text{)}} \\ &= \frac{\text{Added benefit (over control)}}{\text{Added cost (over control)}} \end{aligned}$$

Where, $T_1 = T_1, T_2, T_4, T_5$ treatments; $T_0 =$ Control treatment; VC = Variable cost; and Gross return = Yield \times price.

Methods of chemical analysis of soil

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). Soil pH was measured by a combined glass calomel electrode. Organic carbon was determined by the wet oxidation method. Total N was determined by a modified Kjeldahl method. Calcium (Ca), magnesium (Mg) and K were

determined by NH_4OAc extractable method, copper (Cu), iron (Fe) and zinc (Zn) were determined by DTPA extraction followed by AAS reading. Boron (B) was determined by CaCl_2 extraction method. Available P was determined by the Bray and Kurtz method while S was determined using the turbidimetric method with BaCl_2 .

Results and discussion

Experimental field soil was neutral in reaction pH (7.08), low in organic matter (1.09%), total nitrogen content (0.06%) and exchangeable potassium (0.08 meq 100g), however quite high in available phosphorus ($15.1 \mu\text{g g}^{-1}$). The status of B ($0.13 \mu\text{g g}^{-1}$) was below the critical level and Zn ($2.60 \mu\text{g g}^{-1}$) was higher than the critical level (Table 1). In general terrace soil (Chiata Series) of Joydebpur is acidic in nature. But the soil of experimental field does not belong to terrace soil. Soil development in this experimental field has been made with river-bed soil from the nearby areas.

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	pH	OM %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			meq 100g ⁻¹				$\mu\text{g g}^{-1}$					
Result [§]	7.08	1.09	6.88	2.26	0.08	0.06	15.1	3.33	0.13	2.01	11.2	2.60
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.2	0.2	4.0	0.6

The tomato yield and its contributing yield traits were significantly affected by foliar fertilizer treatments as against soil application of B and Zn fertilizers, as depicted by the significance of F-values from the analysis of variance (Tables 2 and 3). A significant variation was observed for tomato yield when the plants treated with foliar application of Zn and B alone or either in combinations. Maximum yield (85.5 and 81.7 t ha⁻¹ in 2013 and 2014, respectively) was produced, when plants were treated with 0.05% of Zn in combination with 0.03% of B, followed by plants sprayed with 0.05% of Zn alone (84.3.1 and 76.8 t ha⁻¹ in 2013 and 2014, respectively). Minimum fruit yield (66.8 and 60.7 t ha⁻¹ in 2013 and 2014, respectively) was produced by untreated plants - control. Comparatively lower yield was recorded in plants which sprayed with 0.03% of B alone than that of plants sprayed with 0.05% Zn. Soil of this experiment is neutral and content of Zn was $2.6 \mu\text{g g}^{-1}$, which was higher than the critical limit. But due to neutrality Zn is unavailable to uptake by plant. For that reason, only B application did not help maximize the yield of tomato. Mousavi (2011) reported that soils with high pH, in this type of soils solubility of micronutrients except B is less and cause decline uptake of these elements by plant. On the other hand, higher yield in treatment sprayed with 0.05% Zn alone, perhaps these increases in fruit yields were due to the significant increase in leaf Zn concentration which in turn induced more

flowering and minimized the fruit drop in tomato plant (Garcia *et al.* 1984). Higher yield in foliar application of Zn without B application might be due to foliar application of zinc increased B uptake by plants in the soils with sufficient stores (Rengel *et al.*, 1998). The supply of B needed for reproductive growth in many crops is more needed than that needed for vegetative growth (Mengel and Kirkby, 1982; Marschner, 1986; Hanson, 1991).

Table 2. Agronomic traits of tomato as affected by foliar and soil application of Zn and B during 2013

Treatment	Agronomic traits			Fruit yield	
	Fruit diameter (cm)	Fruit height (cm)	Individual fruit wt. (g)	Yield (kg plot ⁻¹)*	Yield (t ha ⁻¹)
1. Zn (0.0) + B (0.0) – control	4.18±0.26c	5.07±0.32c	55.8±10.2c	60.1±8.72c	66.8±9.68c
2. Zn (0.05 %) + B (0.0%) foliar application	4.59±0.19ab	5.32±0.26b	65.6±5.09ab	75.9±10.7a	84.3±11.9a
3. Zn (0.0 %) + B (0.03%) foliar application	4.44±0.45ab	5.29±0.28bc	60.9±8.62bc	72.1±10.1ab	80.1±11.3ab
4. Zn (0.05 %) + B (0.03%) foliar application	4.68±0.19a	5.41±0.18a	68.5±6.26a	77.0±11.5a	85.5±12.8a
5. Zn (6) + B (2) soil application (kg ha ⁻¹)	4.37±0.22b	5.18±0.61bc	59.3±6.03bc	67.4±7.07bc	74.9±7.9bc
CV (%)	4.96	7.06	12.1	14.7	-

Mean values in the same column followed by the same letters are not significantly different ($P < 0.05$). * Plot size: 9 m².

Plants sprayed with Zn in combination with B or alone Zn showed maximum response in fruit diameter, fruit height and individual fruit weight compared with control and soil application of both elements. Gitte *et al.* (2005) observed that the combined application of Zn and B exhibited yield increases over unfertilized controls. The data given in Table 2 indicated that micronutrient and their foliar doses had significant effect on fruit yield of tomato. Among various treatments, foliar application of Zn (0.05 %) + B (0.03%) (T₄) produced maximum grain yield (81.3 t ha⁻¹) while the control (T₁) no use of Zn (0.0) and B (0.0) produced 63.6 t ha⁻¹. And T₄ was statistically differed with soil application of B and Zn @ 2 and 6 kg ha⁻¹ (T₅), respectively. The foliar application of Zn in combination with B and Zn alone was more effective than the soil application of both fertilizers. When compared the fruit yield from control or soil application plot with foliar applications the increment of yield were 19.2 to 31.1% and 7.57 to 18.3%, respectively, over

control and soil application (Table 4). The maximum marginal benefit-cost ratio (MBCR) of 211 was obtained by application of Zn in combination with B followed by Zn alone (181) which are almost on par at each other compared to control which recorded minimum gross returns of Tk. 957000 ha⁻¹.

Table 3. Agronomic traits of tomato as affected by foliar and soil application of Zn and B during 2014

Treatment	Agronomic traits			Fruit yield	
	Fruit diameter (cm)	Fruit height (cm)	Individual fruit wt. (g)	Yield* (kg plot ⁻¹)	Yield (t ha ⁻¹)
1. Zn (0.0) + B (0.0) – control	3.72±0.14b	4.26±0.32b	49.3±3.46b	54.6 ±2.12b	60.7±2.35b
2. Zn (0.05 %) + B (0.0%) foliar application	4.55±0.54a	5.09±0.41a	63.1±5.99a	69.1±6.64ab	76.8±7.38ab
3. Zn (0.0 %) + B (0.03%) foliar application	4.37±0.24ab	4.91±0.27ab	54.9±5.14b	64.7±2.52ab	71.9±2.80ab
4. Zn (0.05 %) + B (0.03%) foliar application	4.63±0.31a	5.17±0.34a	67.2±4.44a	73.5±8.68a	81.7±9.65a
5. Zn (6) + B (2) soil application (kg ha ⁻¹)	4.25±0.41ab	4.79±0.49ab	51.0±6.10b	59.8±4.89ab	66.4±5.44ab
CV (%)	6.64	5.90	5.86	9.42	-

Mean values in the column followed by the same letters are not significantly different ($P < 0.05$). * Plot size: 9 m²

Table 4. Yield comparison between foliar and soil application of Zn and B and their economics of two years average

Treatment	Fruit yield (t ha ⁻¹)	Yield increased (%)		Variable cost [§] (Tk ha ⁻¹)	Gross return (Tk ha ⁻¹)	MBCR	
		Over control	Over soil application			over control	over soil application
1. Zn (0.0) + B (0.0) – control	63.8	-	-10.8	14595	957000	-	(16.0)
2. Zn (0.05 %) + B (0.0%) foliar application	80.6	26.4	14.0	15988	1209000	181	-29.2
3. Zn (0.0 %) + B (0.03%) foliar application	76.0	19.2	7.57	15991	1140000	131	-15.7
4. Zn (0.05 %) + B (0.03%) foliar application	83.6	31.1	18.3	16004	1254000	211	-38.2
5. Zn (6) + B (2) soil application (kg ha ⁻¹)	70.7	10.8	-	21070	1060500	(16.0)	-

[§] Variable cost considering only fertilizer and wage rate

Input prices (Tk kg⁻¹): Urea: 16; TSP: 25; MoP: 15; Gypsum: 15; Zincsulphate: 140; Boric acid: 240.

Wage rate: 230 Tk

Out put price (Tk kg⁻¹): Tomato: 15

Conclusion

Foliar applications of micronutrients are more suitable than the soil application, due to the rapid overcoming on deficient, easy to use, reducing the toxicity caused by accumulation and preventing of elements stabilization in the soil. The integrated use of foliar application of micronutrients and soil application of macronutrients is recommended to enhance tomato yield. This paper also suggests that foliar application of micronutrients; particularly of Zn and B is an effective technology for increasing the yield of tomato.

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EFFECT OF DIFFERENT STAKING METHODS AND STEM PRUNING ON YIELD AND QUALITY OF SUMMER TOMATO

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Abstract

The study was carried out during summer of 2012 with BARI hybrid tomato 4, planted in the Olericulture farm of Bangladesh Agriculture Research Institute, Joydebpur, Gazipur, Bangladesh to find out the response of plants to some staking and pruning treatments on yield, fruit quality and cost of production. A two factor experiment consisting of three staking methods and four level of pruning, laid out in complete block design with three repetitions. Plants were staked on inverted 'V' shaped staking, high platform and string. The plants were pruned to two stem, three stem, four stem and no pruning as control. Results showed that significantly the highest total number of fruits per plant (37.1), marketable fruits per plant (33.7), yield per plant (1.68 kg) and total yield (44.6 t/ha) were produced by the plants having the treatment string staking with four stem. The highest fruit set (43.50%) was found in the plants staking with string having three stems. Plants grown on string staking allowing two stem gave the maximum length (4.71 cm), diameter (4.83 cm) and weight (53.4g) of single fruit as well as maximum fruit firmness (3.43 kg-f cm⁻²). From the economic point of view, it was apparent that summer tomato produced by string staking with four stem pruning exhibited better performance compared to other treatment combinations in relation to net return and BCR (2.10).

Keywords: Different staking, Stem pruning, Yield, Quality, Summer Tomato.

Introduction

Yields of summer tomato do not always reach the full production potential. This is probably because of inadequate management. Improved management such as, staking and pruning could improve the yield of tomatoes. Staking refers to support of plants with sturdy material to keep the fruits and foliage off the ground. Staking increases fruit yield, reduces the proportion of unmarketable fruit, enhances the production of high quality fruits, prevents disease and fruit rot, allows better aeration and better exposure of the foliage to sunlight and photosynthetic activities (Anon., 2007). Akoroda *et al.* (1990) and Amina *et al.* (2012) recommended staking of crops for higher yield, quality fruits, easy harvesting and exposure of leaves for effective light reception. In Bangladesh inverted 'V' shaped staking is most common. Now-a-days farmers are using high

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platform system in some areas. In many countries tomato plants are staked by jute or nylon string hanging from the top of the tunnel which is less costly.

Pruning is the selective removal of side shoots or stem to limit plant growth and to divert nutrients to flower clusters on the remaining shoot or stem. Pruning in tomatoes has been reported to increase yields and quality of fruits (Hadfield, 1989; Preece, 1995; Srinivasan *et al.*, 2001). In order to maximize the efficiency of photosynthesis and minimize the risk of diseases pruning is necessary when the growth is extremely dense. Franco *et al.* (2009) stated that choosing a proper pruning system was important to keep a balance in the relationship's source/sink and the carbon/nitrogen (C/N) ratio. Cockshull *et al.* (2001) found a tendency for side shoots to reduce the yield of marketable fruit produced on each cluster in greenhouse production. Guan and Janes (1991) also reported that pruning tomato plants regulate N:CHO ratio within the plant, and enhance fruiting. Literature indicates that productivity per area increases when pruning tomato plants to two stems. Aung (1999) reported that greater marketable yield/area was obtained by pruning indeterminate tomato plants to two stems rather than one stem. Rughoo and Govinden (1999) reported that yield of pruned and staked tomato plants was significantly lower than unpruned and unstaked plants, in a determinate variety, but significantly higher in indeterminate and semi-indeterminate varieties. So, the requirements of stem pruning and staking system are variable for different variety and growing conditions. In this context, selection of proper staking method and stem pruning for the BARI hybrid tomato 4 especially in hot humid climates of summer season in Bangladesh is important to ensure higher yield and economic return. Therefore, the study was undertaken to assess the influence of various staking methods and level of pruning on the yield and fruit quality of tomato.

Materials and Method

The experiment was carried out in summer of 2012 on BARI hybrid tomato 4, planted in the Olericulture farm of Bangladesh Agriculture Research Institute located at Joydebpur, Gazipur, Bangladesh to study the response of plants to staking and pruning on yield and fruit quality. The treatments consisted of a factorial combination of three staking methods and four levels of pruning, laid out in complete block design with three replications. Plants were staked on inverted 'V' shaped staking (S₁), high platform (S₂) and string (S₃), hanging from the top of the poly tunnel. Plants were pruned to two stem (B₂), three stem (B₃) and four stem (B₄) with no pruning (B₁) as control. Seeds were sown on May 1, 2012, in seed bed having mixture of soil and cowdung (1:1 ratio). After germination, at two true leaves stage the seedlings were shifted to second seed bed at a spacing of 5x5 cm to ensure better seedling growth. Twenty nine days old seedlings were transplanted in the main field under poly tunnel on May 29,

2012. Poly tunnels and beds were prepared prior to transplanting. Every single tunnel was 20 m long and 2.3 m wide with a height of 1.40 m along the sides and 2.0 m along the middle covering 0.10 mm thick transparent polyethylene sheet. Each tunnel had two beds of 1 m width separated by a 30 cm drain. Plants were spaced at 60x40 cm distance from each other thus a single tunnel accommodated 200 plants. Plants were staked 10-15 days after transplanting when plants reach a height of 25-30 cm. Bamboo sticks (1.5 m long and 2.5 cm diameter) were used for making inverted “V” shaped staking. High platform were made by bamboo over the bed. Platform was 40 cm of height, 1m width and as long as necessary. Plants were allowed to grow freely over the platform. Jute rope (5 mm thickness) was used as string staking hanging one end from the top of the tunnel and the other end was tied with the stem of the plant. Plants were twisted with the string gradually with the increasing of plant height. Different string was used for every single branch. Tomato plants were pruned to retain two stems, three stems and four stems. Pruning was done at weekly interval from 20 to 30 days after transplanting. While pruning, weak branches were removed retaining the strong branches. All the shoots appearing at the base of the plants were removed as they are not productive. Pruning was done by hand or using sharp knife in the morning. Data were recorded on the plant height at last harvest, days to flowering, days to first harvest, days to last harvest, fruit set, number of marketable fruits per plant, number of non marketable fruits per plant, fruit size (length and diameter), fruit firmness, total soluble solid, individual fruit weight and fruit yield. The digital fruit firmness tester “PENFEEL” (Model- DFT 14, Agro-Technologie, France) with flat head stainless-steel cylindrical probe of diameter 2 mm was used for the measurement of tomato fruit firmness. Collected data were analyzed statistically by using MSTAT-C to find out the variation among different treatments. Treatment means were separated using Least Significant Difference (LSD) test at 5 % level of significance (Gomez and Gomez, 1984).

Results and Discussions

Plant height: Types of staking had not much influence on plant height but plant height varied significantly for stem pruning (Table 1). The two stems plants were the tallest (147 cm) while no pruning was the shortest (123 cm). Treatment combinations had a great effect on plant height. Significantly the tallest (152 cm) plants were produced by inverted ‘V’ shaped staking with two stem whereas the shortest (121 cm) plants were produced by inverted ‘V’ shaped staking with no pruning. Results revealed that two stems plants significantly increased plant height followed by pruning treatment of three stems per plant and four stems per plant, while the non-pruned plants were the poorest. These results are in harmony with the findings of Malash and Gawish (1989) on tomato. The increase in plant height of tomato might be due to removal of branches that leads to supply

nutrients in the remaining branches. Similar observations were noticed by Mangal *et al.* (1981) and Srinivasan *et al.* (2001) in tomato. Saen and Pathom (1998) recorded increased plant height with three pruning methods on pepper.

Table 1. Effects of staking type and stem pruning on plant height at last harvest, days to flowering, fruit set, days to first harvest and days to last harvest of summer tomato

Staking type	Plant height (cm)	Days to flowering	Fruit set (%)	Days to first harvest	Days to last harvest
S ₁	135	46	37.15	86	122
S ₂	133	47	35.10	87	121
S ₃	133	46	38.29	83	119
LSD (5 %)	ns	ns	2.542	3.298	ns
Stem pruning					
B ₁	123	47	31.97	86	122
B ₂	147	46	38.64	83	116
B ₃	135	45	41.47	85	123
B ₄	129	46	35.31	86	122
LSD (5 %)	4.332	ns	2.935	ns	ns
Combined effect					
S ₁ B ₁	121	46	36.20	86	125
S ₁ B ₂	152	46	38.00	84	114
S ₁ B ₃	136	45	39.60	86	125
S ₁ B ₄	132	47	34.82	88	124
S ₂ B ₁	122	45	28.12	88	121
S ₂ B ₂	144	46	37.56	85	118
S ₂ B ₃	137	48	41.32	87	124
S ₂ B ₄	127	47	33.40	87	120
S ₃ B ₁	125	47	31.60	84	119
S ₃ B ₂	145	45	40.35	81	115
S ₃ B ₃	132	46	43.50	83	120
S ₃ B ₄	129	45	37.70	83	122
LSD (5 %)	5.521	ns	5.084	ns	ns
CV(%)	2.44	3.87	5.99	4.57	5.28

Note: S₁= Inverted 'V' shaped staking; S₂= High platform; S₃= Staking with string; B₁= No pruning; B₂= Allow two branches; B₃= Allow three branches; B₄= Allow four branches.

Days to flowering: Data on days to 50% flowering, presented in Table 1. Type of staking, stem pruning and their combinations had no significant effect on the parameter. The plants took 45 to 48 days to 50% flowering for different treatments and treatment combinations.

Fruit set: Data presented in Table 1 clearly demonstrated the effect of the different treatments and their combined effects on fruit set of tomato. Percent

fruit set differed significantly by staking type. The highest fruit-set (38.29%) was obtained from the plants staked with string and the lowest (35.10%) from the plants staked with high platform. Stem pruning influenced significantly on percent fruit-set. The maximum fruit set (41.47%) was counted in plants with three stems followed by plants with two stem (38.64%) which were statistically at par. The minimum (31.97%) fruit set was counted in no pruning treatment. Combination of treatments differed significantly in respect fruit set. The highest fruit set (43.50%) was found in the plants staking with string having three stems. The lowest fruit set (28.12%) was recorded in the plants staking on high platform with no pruning. Light becomes a limiting factor in crowded branches where pruning with string staking improves light access. Adjustments must be made in the height, row width, and hedging angle to maximize sunlight penetration through the canopy. Staking with string and stem pruning provide enough space among the branches to enter sunlight and good aeration which might be a good reason to increase fruit set. Sunlight not only influences the flowering and fruit set but also enhances fruit quality and colour development of fruit (Ahmed *et al.*, 2006). Similarly high fruit set percentage were recorded by Mangal *et al.* (1981); Sharfuddin and Ahmed (1986) in pruning treatments. Lim and Chen (1988) studied the effect of training on tomato and found double stems had increased proportion of fruit setting, size and quality than single stem.

Days to first harvest: A significant variation was observed in respect of days to first harvest among different types of staking. Fruits harvested the earliest from plants those staked with string (83 days) and the most delayed (87 days) from the plants sprawl over high platform. Effect of stem pruning was not significant on the parameter. The treatment combinations also showed no significant differences on days to first harvest but the earlier harvest was done in string staking with two stems (81 days) and delayed in high platform staking with no pruning (88 days). Mangal *et al.* (1981) stated that pruned tomato plant cropped earlier which is closely similar to the findings of present study.

Days to last harvest: Days to last harvest was not affected significantly by staking types, stem pruning and their combinations (Table 1). It ranges 119 to 122 days for different type of staking and 116 to 123 days for stem pruning. Among the treatment combinations, days to last harvest ranges from 114 to 125 days. This might be due to higher number of active leaves that continue photosynthetic activity which regulate the plant to retain fruit for longer period.

Number of marketable fruits per plant: Number of marketable fruits per plant varied remarkably with staking type (Table 2). The maximum marketable fruits per plant (29.5) were obtained from the treatment string staking and the minimum were recorded from inverted “V” shaped staking (26.2). Results in respect of marketable fruits per plant were found to be statistically significant as influenced by stem pruning. The plants pruned with four stem produced the highest marketable fruits per plant (32.6) and the lowest from the plants pruned with two stem (22.5). Combined effects of staking type and stem pruning showed

wide variation in this parameter. It was maximum in the plants managed by string staking having four stems (33.7) and minimum in inverted “V” shaped staking having two stems (21.2). String staking facilitates exposure of branches and leaves for aeration and effective light reception as a result number of marketable fruits increased. Akoroda *et al.* (1990) and Amina *et al.* (2012) recommended staking of crops for higher yield of quality fruits. Staking increases fruit yield, reduces the proportion of unmarketable fruit, enhances the production of high quality fruits (Anon. 2007). Ramirez *et al.* (1977) reported that punning to two or three stems produced the best quality fruits. Salinas *et al.* (1997) subjected tomato plants, that were pruned produced significantly higher per cent of good quality fruits than unpruned ones. Singh (1994) recorded, lower unmarketable yield, higher marketable fruits and higher net return from rainy season tomato crop with raised bed and staking at Ranchi, Bihar, India. These results are in agreement with the presents findings.

Number of non marketable fruits per plant: Staking type had significant effect on the number of non marketable fruits per plant. Plants staked with inverted “V” shaped staking (4.6) produced the maximum non marketable fruits per plant closely followed by plants sprawl over high platform (4.3). The minimum non marketable fruits per plant were found in string staking (3.5). Stem pruning also varied significantly for this parameter. The highest and the lowest number of non marketable fruits per plant were obtained from the treatments no pruning (5.9) and with two stem pruning (3.1) respectively. Combined effect of staking type and stem pruning had significant effect on number of non marketable fruits per plant. It was the maximum in the plants managed by inverted “V” shaped staking with no pruning (7.5) and the minimum in string staking with two stem (2.6). The plants managed by inverted “V” shaped staking with no pruning was crowded with branches where light becomes a limiting factor with less aeration which enhance disease and fruit rot resulted higher non marketable fruits. Cordt (1999a) reported that non marketable fruits were the maximum in unpruned plants while staking increases fruit yield, reduces the proportion of unmarketable fruit, enhances the production of high quality fruits (Anon. 2007). Amina *et al.* (2012) and Akoroda *et al.* (1990) observed the similar findings. Hanson (1998) suggested staking the tomato plants increases the fruit yield, reduces the proportion of cull fruit.

Individual fruit weight: Individual fruit weight was significantly the largest with string staking (50.2 g) and the *lowest* with high platform (44.7 g). Stem pruning had the much influence on individual fruit weight. Significantly the highest weight of fruit was obtained from the plant with two stems (50.1 g) and the lowest from no pruning treatment (45.0 g). Treatment combination differed significantly for the trait. Plants grown on string staking with two stems (53.4 g) gave the maximum weight of single fruit while plants grown on high platform staking with no pruning gave the minimum (42.6 g) fruit weight

(Table 2). Photosynthetic activities may be enhanced due to better exposure of the foliage to sunlight as a result, fruits accumulate higher assimilates which might be responsible for higher fruit weight in the plants staked with string staking. The results are in agreement with Kumar *et al.* (2001) who found increased mean fruit weight of tomato by staking. Ara *et al.* (2007) noticed that removal lateral branches resulted in increasing fruit weight of tomato plants. The competition for assimilates among the fruits lead to reduced fruit size. Plants pruned to two stems resulted in significantly higher number and mass of large fruits compared to plants pruned to three stems, four stems and no pruning. The results of increased average fruit weight by pruning side shoots was in conformity with the findings of Cebula (1995) who also reported that the fewer shoots per plant produced heavier fruits in peeper. Cordt (1999b) reported that maintenance of additional one stem per plant in an area of one square meter resulted in increased production of 12 fruits per square meter. However, there was a reduction of average fruit weight (1.5g).

Fruit firmness: The firmness of tomato fruits varied significantly as influenced by staking type, stem pruning and their combinations (Table 2). Significantly the highest firmness was measured from string staking ($3.07 \text{ kg-f cm}^{-2}$) and the lowest from high platform staking ($2.88 \text{ kg-f cm}^{-2}$). It was also found that firmness of tomato was the highest in the plants with two stems ($3.31 \text{ kg-f cm}^{-2}$) and the lowest in the plants received no pruning ($2.52 \text{ kg-f cm}^{-2}$). Among the treatment combinations, the maximum ($3.43 \text{ kg-f cm}^{-2}$) fruit firmness was found in the combination of string staking with two stems and the minimum ($2.42 \text{ kg-f cm}^{-2}$) in high platform staking with no pruning. Results of the experiment showed that string staking produced the larger fruit due to accumulation of photo-assimilates which might be a possible reason to produce more firmness of fruit. It was observed that two stem pruning resulted in a significant increase in fruit firmness while three stem, four stem and no pruning treatment decreased in fruit firmness. These results agreed with Bennewitz *et al.* (2011) who found that removal of lateral branches resulted in increasing fruit firmness of sweet cherries.

TSS: Total soluble solid (%) was not affected significantly by staking types (Table 2). TSS ranges from 4.32% to 4.35% for different staking methods. Stem pruning significantly influenced the TSS. The maximum (4.44%) and the minimum (4.24%) total soluble solid were obtained in the fruits harvested from plants with two stems and no pruning, respectively. Among the treatment combinations no significant variation was observed. Fruits from the plants with inverted 'V' shaped staking having two stems gave the highest (4.46%) total soluble solid and fruits from the plants staked with high platform having no pruning gave the lowest (4.23%) total soluble solid. Fruits harvested from the plants with lower number of stems gave higher TSS. The results agreed with those obtained by Malash and Gawish (1989) and Hesamil *et al.* (2012), who noticed that removal of lateral branches resulted in increasing fruit TSS of tomato.

Table 2. Effects of staking type and stem pruning on marketable and non marketable fruits per plant, individual fruit weight, fruit firmness and TSS of summer tomato

Staking type	Marketable fruits per plant	Non marketable fruits per plant	Individual fruit weight (g)	Fruit firmness (kg-f cm ⁻²)	TSS (%)
S ₁	26.2	4.6	47.8	2.90	4.35
S ₂	26.6	4.3	44.7	2.88	4.32
S ₃	29.5	3.5	50.2	3.07	4.35
LSD (5 %)	1.615	0.4019	1.112	0.1261	ns
Stem pruning					
B ₁	28.7	5.9	45.0	2.52	4.24
B ₂	22.5	3.1	50.1	3.31	4.44
B ₃	25.9	3.4	48.0	3.20	4.37
B ₄	32.6	4.0	47.1	2.78	4.30
LSD (5 %)	1.865	0.4641	1.283	0.1456	0.096
Combined effect					
S ₁ B ₁	28.3	7.5	45.4	2.48	4.23
S ₁ B ₂	21.2	3.2	49.6	3.26	4.46
S ₁ B ₃	22.6	3.4	48.1	3.28	4.38
S ₁ B ₄	32.7	4.1	48.3	2.58	4.32
S ₂ B ₁	26.9	5.3	42.6	2.42	4.23
S ₂ B ₂	21.8	3.4	47.4	3.24	4.43
S ₂ B ₃	26.4	3.8	44.5	3.10	4.36
S ₂ B ₄	31.3	4.5	44.2	2.78	4.26
S ₃ B ₁	31.0	4.9	47.1	2.65	4.27
S ₃ B ₂	24.6	2.6	53.4	3.43	4.43
S ₃ B ₃	28.7	3.1	51.5	3.22	4.38
S ₃ B ₄	33.7	3.4	48.8	2.97	4.33
LSD (5 %)	2.377	0.8.39	1.636	0.1855	ns
CV(%)	5.12	8.53	2.03	3.77	1.96

Note: S₁= Inverted 'V' shaped staking; S₂= High platform; S₃= Staking with string; B₁= No pruning; B₂= Allow two branches; B₃= Allow three branches; B₄= Allow four branches.

Fruit length: Fruit length was significantly influenced by staking types, stem pruning and their combinations (Table 3). The highest fruit length was measured from string staking (4.47 cm) and the lowest from high platform (4.25 cm). Fruit length differed significantly for stem pruning. The maximum fruit length was found in plants with two stems (4.47 cm) where no pruning treatment (4.21 cm) gave the minimum. Among treatment combinations, significantly the highest fruit length (4.71 cm) was obtained from string staking with two stems. The lowest (4.15 cm) fruit length was measured from high platform staking with no pruning treatment followed by inverted "V" shaped staking with no pruning (4.20

cm) and string staking with no pruning (4.25 cm). Staking with string allows plant for better aeration and better exposure of the foliage to sunlight that enhance photosynthetic activities which might be responsible for larger fruit size. However, the competition for assimilates among the fruit lead to reduced fruit size. Plants pruned to two stems had lower number of fruits resulted less competition for assimilates leads significantly higher length of fruits compared to plants pruned to three stems, four stems and no pruning. The results agreed with those obtained by Hesamil *et al.* (2012), who noticed that removal of lateral branches resulted in increasing fruit size of tomato plants. Saen and Pathom (1998) also found increased fruit length when studied the effect of three pruning methods (no pruning, two branch pruning and four branch pruning) on peeper. Ledo *et al.* (1998) reported that tomato with the maximum shoots removed, produced larger sized fruits (52 mm) than control.

Fruit diameter: Fruit diameter was also influenced by staking types, stem pruning and their combinations (Table 3.). The highest fruit diameter was found in string staking (4.55 cm) and the lowest in high platform staking (4.36 cm) which were statistically significant. The variation was observed for stem pruning treatment also significant. Two stem gave the highest (4.59 cm) diameter and no pruning treatment gave the lowest (4.32 cm) fruit diameter. Treatment combinations were significantly differed for this parameter. The maximum (4.83 cm) diameter was obtained from string staking with two stems and the minimum (4.26 cm) from high platform staking with no pruning treatment. Kumar *et al.* (2001) noticed higher fruit diameter of tomato obtained by staking. Results revealed that plant pruned to fewer stem resulted in a significant increase in fruit diameter. The results supported with those obtained by Hesamil *et al.* (2012). The competition for assimilates among the fruits might be the cause of reduced fruit size. Hernanden *et al.* (1992) also found increased fruit diameter of tomato when plants were pruned.

Yield per plant: Highly significant variations were recorded for fruit yield per plant among staking methods (Table 3). The highest yield per plant was obtained from plants staking with string (1.52 kg) and the lowest from high platform (1.25 kg). Stem pruning had a pronounced effect on yield per plant. The plants allowed to grow with four stems gave the highest yield (1.54 kg) and the lowest yield (1.19 kg) from the plants with two stems. Among the treatment combinations, significantly the maximum yield (1.68 kg) per plant was obtained in the plants staking with string having four stems and the minimum (1.05 kg) in the plants staking with high platform having two stem. The findings of the present investigation are in agreement with Kumar *et al.* (2001) who found increased mean fruit weight of tomato by staking. In South-West Nigeria, Adelaine (1976) reported that staking increases fruit yield by 18 to 25% and Quinn (1973) showed at Samaru, Nigeria that under wet conditions marketable yields were significantly increased by staking the tomato crop. The increased yield per plant induced by pruning may be due to the increased average fruit weight and number of fruit per plant. The result agreed with those obtained by Ara *et al.* (2007) and Huat *et al.*

(2013). This increased yield per plant is due to presence of more stem, increased number of clusters per plant, high fruit set percentage and large number of leaves which intern increases the photosynthetic activity and ultimately leads to higher yield per plant. Similar results were reported by Mangal *et al.* (1981); Sharfuddin and Ahmed (1986). Joshi *et al.* (1992) studied effect of training on six winter grown indeterminate tomato cultivars and observed training the plants to three main stems gave the best yield.

Table 3. Effects of staking type and stem pruning on fruit size and yield of summer tomato

Staking type	Fruit length (cm)	Fruit diameter (cm)	Yield per plant (kg)	Yield (t/ha)
S ₁	4.36	4.50	1.37	38.1
S ₂	4.25	4.36	1.25	34.3
S ₃	4.47	4.55	1.52	40.9
LSD (5 %)	0.1856	0.1409	0.0514	1.398
Stem pruning				
B ₁	4.21	4.32	1.33	36.3
B ₂	4.47	4.59	1.19	31.7
B ₃	4.37	4.46	1.46	40.5
B ₄	4.40	4.50	1.54	42.5
LSD (5 %)	0.2143	0.1627	0.0594	1.614
Combined effect				
S ₁ B ₁	4.20	4.32	1.38	37.4
S ₁ B ₂	4.54	4.67	1.15	32.3
S ₁ B ₃	4.32	4.46	1.44	40.2
S ₁ B ₄	4.40	4.53	1.51	42.6
S ₂ B ₁	4.15	4.26	1.16	30.4
S ₂ B ₂	4.29	4.28	1.05	28.5
S ₂ B ₃	4.25	4.36	1.36	38.7
S ₂ B ₄	4.31	4.41	1.42	39.4
S ₃ B ₁	4.25	4.37	1.45	41.2
S ₃ B ₂	4.71	4.83	1.38	34.3
S ₃ B ₃	4.53	4.57	1.57	42.3
S ₃ B ₄	4.50	4.55	1.68	44.6
LSD (5 %)	0.273	0.2819	0.0757	2.795
CV(%)	3.69	2.76	3.43	3.22

Note: S₁= Inverted 'V' shaped staking; S₂= High platform; S₃= Staking with string; B₁= No pruning; B₂= Allow two branches; B₃= Allow three branches; B₄= Allow four branches.

Yield (t/ha): Remarkable variation was observed among the staking types in respect of yield (t/ha). Significantly the highest yield (40.9 t/ha) was measured from the treatment string staking, while the lowest yield (34.3 t/ha) from high platform staking. Yield (t/ha) differed significantly for stem pruning. The highest total yield (42.5 t/ha) was obtained from the treatment four stem pruning and the lowest (31.7 t/ha) with two stem. Combined effect was also significant for this

trait. The combination string staking with four stems produced the highest yield (44.6 t/ha) and the high platform with two stems produced the lowest (28.5 t/ha). Staking of tomatoes gives higher yield, and good quality fruits with higher market value (Amina *et al.* 2012; Anon., 2007). Hui *et al.* (2003) reported that staked tomato plants yielded roughly a total of 20% over unstaked plants. In their experiment, they observed that the highest total yield was obtained by the 'Castelleto' system in which the plants were staked individually which is closely similar to string staking. Adelaine (1976) reported that staking increases fruit yield by 18 to 25%. The increased total yield observed in four stem pruning was due to higher yield per plant in the same treatment. Sharfuddin and Ahmed (1986) investigated the response of cv. Marglobe to four levels of pruning. The highest yield of 123.26 tons per ha was obtained in plants pruned to three stems. Mangal *et al.* (1981) reported that pruned plants gave higher total yield than unpruned and un-staked ones. Ayas *et al.* (1981) observed that field grown tomato cv. Chonta Liceto when pruned to leaving six branches per plant produced 65.99 tons fruits per ha. Whereas, plants pruned to level of two branches produced 55.90 tons fruits per ha. Joshi *et al.* (1992) studied effect of training on six winter grown indeterminate tomato cultivars and observed training as marked effect on yield of tomato, training enhances yield by 9.13 to 114.33 percent depending on the cultivars. Training the plants to three main stems gave the best yield. In a greenhouse trial of tomato, training (no pruning, training at 5 and 6 stems) five stems per plant resulted in higher net fruit yield with least wastage, while, training to six stems per plant resulted in equivalent total yield, but with more waste production (Cordt, 1999a).

Table 4. Cost and return analysis of summer tomato as influenced by staking methods and stem pruning

Treatment	Marketable yield (t/ha)	Gross return (Tk./ha)	Total cost of production (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio (BCR)
S ₁ B ₁	37.4	1683000	1043192	639808	1.61
S ₁ B ₂	32.3	1453500	1041030	412470	1.40
S ₁ B ₃	40.2	1809000	1044380	764620	1.73
S ₁ B ₄	42.6	1917000	1045397	871603	1.83
S ₂ B ₁	30.4	1368000	1019560	348440	1.34
S ₂ B ₂	28.5	1282500	1018754	263746	1.26
S ₂ B ₃	38.7	1741500	1023079	718421	1.70
S ₂ B ₄	39.4	1773000	1023376	749624	1.73
S ₃ B ₁	41.2	1854000	1008742	845258	1.84
S ₃ B ₂	34.3	1543500	954301	589199	1.62
S ₃ B ₃	42.3	1912500	954302	958198	1.99
S ₃ B ₄	44.6	2052000	954303	1097697	2.10

Note: S₁= Inverted 'V' shaped staking; S₂= High platform; S₃= Staking with string; B₁= No pruning; B₂= Allow two branches; B₃= Allow three branches; B₄= Allow four branches. Tomato sale @ Tk 45/kg (Farm gate price)

Cost and return analysis

Partial cost-benefit analysis was done in this experiment. Variation on cost and return analysis was found for tomato produced with different staking methods and stem pruning. Inverted “V” shaped staking with four stems pruning incurred the highest cost of production TK. 1045397/ha, whereas staking with string with two stems incurred the lowest (TK. 954301/ha) cost of production. The gross return was proportionate to marketable yields. It was the maximum (Tk. 2052000/ha) in tomato produced by string staking with four stems and the minimum was obtained from tomato grown by high platform with two stems (Tk. 1282500/ha). In case net return and benefit cost ratio (BCR), it was observed that crop produced by string staking with four stem pruning gave the highest (Tk. 1097697/ha) net return as well as the maximum BCR (2.10). The minimum net return (TK. 263746/ha) and BCR (1.26) was found in tomato grown on high platform with two stem. From the economic point of view, it was apparent that summer tomato produced by string staking with the plant having four stems exhibited better performance compared to other treatment combinations in relation to net return and BCR.

Conclusion

The study demonstrated that yield, quality and profitability of tomato can be effectively manipulated by staking methods and stem pruning. Plants managed by string staking having four stem produced significantly the highest number of fruits per plant and yielded the highest. From the economic point of view, the above treatment combination exhibited better economic performance compared to farmers’ practices. The results need to be confirmed with other cultivars.

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GENETIC DIVERGENCE IN EGGPLANT (*Solanum melongena* L.) GENOTYPES

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Abstract

Multivariate analysis of twenty six genotypes of eggplant were done to estimate the genetic diversity and to select the potential parents for a successful hybridization program. As per PCA, D² and cluster analysis, the genotypes were grouped into five clusters. The highest inter-cluster distance was between Cluster II and Cluster III (37.82) and the lowest between Cluster I and Cluster III (4.39). Cluster III showed the maximum intra-cluster distance (1.58), whereas Cluster II showed the lowest intra-cluster distance (0.48). Considering the magnitude of genetic distance and agronomic performance, the genotypes SM 208 and SM 209 from Cluster II and SM 201, SM 218 and SM 227 from Cluster III might be suitable for efficient hybridization program. On the other hand the genotypes of Cluster I (SM 206, SM 210, SM 211, SM 212, SM 213, SM 215, SM 216, SM 217, SM 221, SM 224, SM 225 and SM 226) possess all the superior characters in respect of yield and yield related component. Thus the genotypes SM 206, SM 216, SM 217, SM 224 and SM 225 from this Cluster could be selected to develop high yielding eggplant varieties.

Keywords: Eggplant, D², Genetic diversity, Hybridization, Multivariate analysis, PCA.

Introduction

Eggplant (*Solanum melongena* L.) is one of the most important commercial vegetable crops in the world, especially in the tropics and subtropics. Eggplant belongs to the family Solanaceae and is mainly self-pollinated crop (Bose *et al.*, 2003).

Various forms, colors and shapes of eggplant are found throughout Southeast Asia, suggesting that this area is an important center of variation and possibly of origin. Vavilov (1928) suggested that its center of origin was in the Indo-Burma region. It originated in India but has a secondary center of variation in China. In China, eggplant has been known for the last 1,500 years. It is extensively grown in Bangladesh, India, Pakistan, Nepal, China, Japan and the Philippines. Batugal (2013) stated genetic diversity as a major factor that determines yield security in future.

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A new variety can be developed from an assembled diverse genetic stock of any crop. The quantification of genetic divergence through biometrical procedures has made it possible to choose genetically diverse parents for a successful hybridization program (Uddin *et al.*, 2014). Moreover, evaluation of genetic diversity is important to know the source of genes for a particular trait within the available germplasm (Amin *et al.*, 2014).

Multivariate analysis is a useful tool to quantify the degree of divergence between the biological population at genotypic level and to assess the relative contribution of different components to the total divergence both inter and intra cluster levels (Ivy *et al.*, 2007; Quamruzzaman *et al.*, 2009; Amin *et al.*, 2014 and Nalla *et al.*, 2014).

Considering the above facts, the present study was under taken to estimate the genetic diversity of selected eggplant genotypes and to select effective parents for future hybridization program.

Materials and Method

The research work was conducted at the Olericulture division of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during the period from 14 August 2012 to the last week of February 2013. A total of 26 eggplant genotypes were collected by Olericulture division of Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur, during 2010-2011 which were used in this study. Among 26 genotypes, 22 were collected from abroad (SM 201 from Brazil; SM 202 from Israel; SM 206-210, SM 215-216, SM 220-222, SM 225 and SM 226 from India; SM 211-212, SM 219, SM 223-224 and SM 227 from Thailand; SM 213 from Italy and SM 218 from Netherlands) and 4 (SM 203-204, SM 217 and BARI released Hybrid Tarapuri variety) from local source.

The experiment was laid out in Randomized Complete Block Design with three replications. Each replication contained 26 genotypes and the genotypes were randomly distributed to unit plot within each block. Multivariate analysis was done by computer using GENSTAT 5 (Fifth Edition Beta) and Microsoft Excel Professional Plus 2010 software through four techniques viz., Principal Component Analysis (PCA), Principal Coordinate Analysis (PCO), Cluster Analysis (CLA) and Canonical Variate Analysis (CVA).

Results and Discussion

Principal component analysis (PCA)

Principal components were computed from the correlation matrix and genotype scores obtained from first components and succeeding components with latent roots

greater than the unity. Contributions of the different morphological characters towards divergence were discussed from the latent vectors of the first two principal components. The principal component analysis yielded eigen values of each principal component axes with the first axes totally accounting for the variation among the genotypes for days to 50% plant flowering is 48.22, while two of these with eigen values above unity accounted for 63.15% (Table 1). The first three principal axes accounted for 76.59% of the total variation among the 10 characters describing 26 eggplant genotypes. Alam *et al.* (2011) found 78.13% total variation for the first three eigen values for three principal coordination axes from the principal component analysis of 22 lentil genotypes. The minimum acceptable value of cumulative eigen value of the principal component for coconut is 75% (Emanuel, 2002).

Table 1. Eigen values and percent of variation in respect of 10 characters in 26 eggplant genotypes

Principal component Axis	Principal component characters	Eigen values	Percentage of total variation accounted for	Cumulative (%)
I	Days to 50% plant flowering	4.823	48.22	48.22
II	Flower per inflorescence	1.493	14.93	63.15
III	Fruit length (cm)	1.344	13.44	76.59
IV	Fruit breadth (cm)	0.772	7.72	84.31
V	Fruits per infructescence	0.545	5.45	89.76
VI	Fruits per plant	0.544	5.44	95.20
VII	Fruit weight (g)	0.315	3.15	98.35
VIII	Fruit yield (t/ha)	0.114	1.14	99.49
IX	Seeds per fruit	0.050	0.50	99.99
X	100 seeds weight (g)	0.0005	0.01	100.00

Construction of scatter diagram

Depending on the values of principal component scores 2 and 1 obtained from the principal component analysis, a two dimensional scatter diagram ($Z_1 - Z_2$) using component score 1 as X-axis and component score 2 as Y-axis was constructed. The position of the genotypes in the scatter diagram was apparently distributed into five groups, which indicated that there existed considerable diversity among the genotypes (Figure 1).

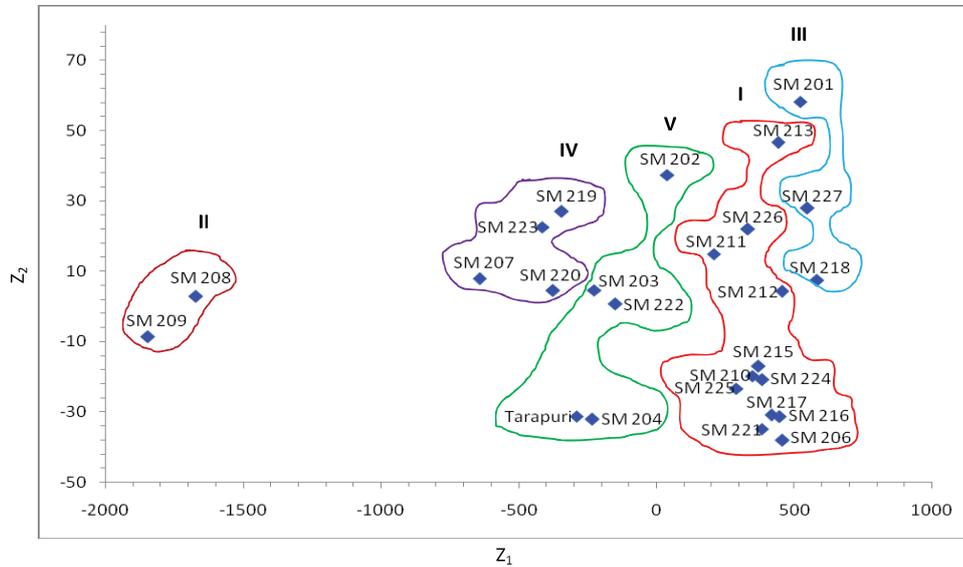


Figure 1. Scatter distribution of 26 eggplant genotypes based on their principal component scores superimposed with clustering.

Cluster analysis (CLA)

Cluster analysis is used to arrange the genotypes into more or less homogeneous groups and it confirmed the clustering pattern of principle component analysis. By using covariance matrix with the application of non- hierarchical clustering, the 26 eggplant genotypes were grouped into 5 (five) clusters. Singh *et al.* (2012) also found five different clusters from the cluster analysis of 36 pecan genotypes on the basis of their genetic distinctness. Compositions of different clusters with their corresponding genotype(s) in each cluster were presented in Table 2.

Table 2. Distribution of 26 eggplant genotypes in five different clusters with their place of collection

Cluster No.	Genotypes	Genotypes including sources of collection
I	12	SM 206, SM 210, SM 211, SM 212, SM 213, SM 215, SM 216, SM 217, SM 221, SM 224, SM 225 and SM 226
II	2	SM 208 and SM 209
III	3	SM 201, SM 218 and SM 227
IV	4	SM 207, SM 219, SM 220 and SM 223
V	5	SM 202, SM 203, SM 204, SM 222 and Tarapuri

Principal coordinate analysis (PCO)

Principal coordinate analysis was performed on auxiliary of principal component analysis. Inter genotypic distances obtained from Principal Coordinate Analysis

showed that the highest distance (3.931) was observed between the genotypes SM 209 and SM 218 followed by SM 208 and SM 218 (3.930), SM 209 and SM 227 (3.511), SM 208 and SM 227 (3.450) and the lowest distance was observed between the genotypes SM 206 and SM 216 (0.298) followed by SM 217 and SM 221 (0.399), SM 211 and SM 226 (0.454) and SM 215 and SM 224 (0.456) (Table 3). From the principal coordinate analysis of 22 Lentil genotypes Alam *et al.* (2011) observed that the highest distance between two genotypes was 0.9365 where as the lowest distance was 0.0595 which indicate the presence of moderate variability among the genotypes. By using these distances from distance matrix intra and inter-cluster distances were calculated (Table 4).

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

10 higher D^2 values	Genotypes combination	10 lower D^2 values	Genotypes combination
3.931	SM 209 and SM 218	0.298	SM 206 and SM 216
3.930	SM 208 and SM 218	0.399	SM 217 and SM 221
3.511	SM 209 and SM 227	0.454	SM 211 and SM 226
3.450	SM 208 and SM 227	0.456	SM 215 and SM 224
3.317	SM 207 and SM 218	0.482	SM 208 and SM 209
3.257	SM 201 and SM 209	0.546	SM 206 and SM 221
3.137	SM 218 and SM 223	0.570	SM 206 and SM 217
3.120	SM 218 and SM 219	0.584	SM 210 and SM 215
3.112	SM 201 and SM 208	0.590	SM 216 and SM 221
3.065	SM 206 and SM 208	0.593	SM 216 and SM 217

Canonical variate analysis (CVA)

Canonical variate analysis was used to compute the inter-cluster Mahalanobis' D^2 values. The Table 4 indicates the intra and inter-cluster distance (D^2) values. The inter-cluster distances were higher than the intra-cluster distances suggesting wider genetic diversity among the genotypes of different groups (Table 4). Results indicated that the highest inter-cluster distance was observed between Cluster II and Cluster III (37.82) followed by between Cluster I and Cluster II (34.20), Cluster II and Cluster V (26.40) and finally Cluster II and Cluster IV (21.22) (Table 4). The lowest inter-cluster distance was observed between the Cluster I and Cluster III (4.39), followed by Cluster IV and Cluster V (5.51), Cluster I and Cluster V (8.35) and finally Cluster III and Cluster V (11.46) (Table 4). So, genotypes from the Cluster II and Cluster III if involved in hybridization might produce a wide spectrum of segregating population, as genetic variation was very distinct among these groups. According to Singh *et al.* (2012) these

genotypes can also be utilized for transfer of useful traits in the commercial cultivars.

Table 4. Average intra (Bold) and inter cluster distances (D^2) for 26 genotypes of eggplant

Cluster	I	II	III	IV	V
I	1.08	34.20	4.39	12.99	8.35
II		0.48	37.82	21.22	26.40
III			1.58	16.65	11.46
IV				0.83	5.51
V					1.21

Contribution of characters towards divergence of the genotypes is presented in Table 5. The vector-I (Z_1) obtained from PCA, the important characters responsible for genetic divergence in the axis of the differentiation were 100 seeds weight (g) (3.6482), fruits per infructescence (1.5199), fruit yield (t/ha) (0.1935) and flower per inflorescence (0.1398). In vector-II (Z_2), 100 seeds weight (g) (5.8597), fruits per infructescence (1.8438), fruit yield (t/ha) (0.4458) and days to 50% plant flowering (0.0271) were the important characters responsible for genetic divergence. The role of fruits per infructescence, fruit yield (t/ha) and 100 seeds weight (g) in both the vectors were important components for genetic divergence in these materials. From the canonical variate analysis of 22 Lentil genotypes Alam *et al.* (2011) also noticed three characters such as days to maturity, plant height and pods per plant have positive values in both the vectors which indicate the highest contribution of these characters towards the divergence.

Table 5. Latent vectors for ten characters of 26 eggplant genotypes

Characters	Vector 1	Vector 2
Days to 50% plant flowering	-0.0180	0.0271
Flower per inflorescence	0.1398	-0.5484
Fruit length (cm)	0.0297	-0.0927
Fruit breadth (cm)	-0.1151	-1.0795
Fruits per inflorescence	1.5199	1.8438
Fruits per plant	-0.0054	-0.6222
Fruit weight (g)	-0.1600	-0.1553
Fruit yield (t/ha)	0.1935	0.4458
Seeds per fruit	0.0169	0.0016
100 seeds weight (g)	3.6482	5.8597

Conclusion

Considering the magnitude of genetic distance and agronomic performance, the genotypes SM 208 and SM 209 from Cluster II and SM 201, SM 218 and SM 227 from Cluster III would be suitable for efficient hybridization program.

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SCREENING OF SOYBEAN (*Glycine max* L.) GENOTYPES UNDER WATER STRESS CONDITION

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Abstract

Fifty soybean genotypes were screened for their water stress tolerance in a vinylhouse of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during January to May, 2011. The objective of this study was to screen for drought tolerant soybean genotype(s) for improving yield of soybean under rainfed condition in Bangladesh. Water stress was imposed throughout the growing period by withholding irrigation until appearance of wilting symptom. Water stress caused an overall reduction in seed yield of soybean. However, reduction in seed yield due to water stress varied among the soybean genotypes. Variations were measured by tolerance indices, ranking and cluster analysis. Considering stress tolerance indices, ranking and cluster analysis, the genotypes BARI Soybean 5, BARI Soybean 6, Shohag and BD2331 were found as tolerant to water stress.

Introduction

The yield and quality of soybean are affected by water stress. Water stress is a worldwide problem and one of the major obstacles for crop production in the tropics and subtropics (Kumar *et al.*, 2005). Water stress reduces soybean yield by about 40% (Pathan *et al.*, 2007). Insufficient water, especially during emergence, flowering and pod-filling stages lower the yield of soybean as reported by Soheil *et al.* (2011) and John (2001). The extent of drought damage depends on cultivars, growth stage, duration and intensity of stress (Mark and Antony. 2005; Araus *et al.*, 2002).

Among different abiotic approaches, screening available germplasm of a crop for water stress tolerance is the most important one (Kramer, 1980). Soybean is mainly cultivated during late *rabi* season in Noakhali and Laxipur district of Bangladesh. In these areas rainfall (75%) is concentrated mainly during summer monsoon season (June to September), and there is scanty rain during October to May. Thus, the crop grown during this period faces terminal water stress. Maleki

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et. al. (2013) was reported that water stress is the major yield limiting factor for soybean yield enhancement under dry climate and water stress conditions. Despite the availability of a large number of soybean genotypes in Bangladesh (Khan, 2013), but their tolerance in water stress has not yet been evaluated in a systematic study. Selection of genotypes under water stress conditions is one of the main tasks for developing genetic variations to improve the water stress tolerant cultivar of soybean. Therefore, the present study was undertaken to identify suitable tolerant genotype(s) for improving yield of soybean under water stress condition in Bangladesh.

Materials and Method

Pot experiment was conducted at the Environmental Stress Research Site of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during January to May, 2011. The experiment consisted of fifty soybean genotypes, which have high yield potential and relatively more tolerant against salinity stress. The genotypes were selected based on the research findings done by Khan *et al.* (2013). The pot was filled with 12 kg air-dried soil including cowdung at a ratio of 4:1 which was equivalent to 9 kg oven dry soil and holds about 28% moisture at field capacity (FC). The soil of the pot was fertilized uniformly with 0.15, 0.18, 0.36 and 0.1 g urea, triple super phosphate, muriate of potash and gypsum corresponding to 24-30-60-15 kg NPKS per hectare, respectively. Six healthy seeds per pot were sown on 16 January, 2011. Most of the seedlings emerged within 6-7 days after sowing. Seedlings were thinned out after two weeks of emergence keeping three healthy seedlings of uniform growth in each pot. Optimum soil moisture conditions were maintained for the seedling growth. Two treatments were imposed such as non-stress and water stress when 50 genotypes were evaluated. The experiment was designed in a completely randomized design (Factorial) with four replications. In water stress treatment, before starting treatment imposition, all pots were equally irrigated. Water stress was induced by withholding water completely from 21 days after emergence. The treatment was continued until symptom of wilting persisted throughout the night. After that they were re-watered to 50% field capacity. During the treatment period, wilting symptom was visually observed every day. In non-stress treatment, water was applied when it was needed. The experiment was designed as a completely randomized design under factorial arrangement with four replications. Admire @ 0.5 ml litre⁻¹ of water was sprayed to protect the crop from insect attack. The pots were kept weed free throughout the growing season.

At harvest data were recorded on yield and different drought tolerance and susceptibility indices including relative performance (RP), tolerance (TOL)

and drought susceptibility index (DSI) was calculated based on grain yield under water deficit and control conditions. The tolerance indices were calculated by the following formulae:

$$\text{Relative performance (RP)} = \frac{\text{Value of a plant character under water stress condition}}{\text{Value of that character under non stress condition}}$$

(Asana and Williams, 1965)

$$\text{Tolérance (TOL)} = (Y_c - Y_s), \text{ (Hossain } et al., 1990)$$

$$\text{Drought susceptibility index (DSI)} = (1 - Y_s/Y_c)/(1 - \bar{Y}_s/\bar{Y}_c), \text{ (Fischer and Maurer, 1978)}$$

Where,

Y_c = the yield of a given genotype in control condition

Y_s = the yield of a given genotype in stress condition

\bar{Y}_s = mean yields of all genotypes under control condition

\bar{Y}_c = mean yields of all genotypes under stress condition

Ranking was done based on yield reduction due to water stress. Cluster analysis was also done to classify the 50 soybean genotypes subjected to water stress. It was carried out using non-hierarchical clustering by using SPSS 11.5.

Results and Discussion

Yield and tolerance indices

Pods plant^{-1} , seeds pod^{-1} and 100 seed weight of soybean genotypes in stress environment was significantly less than that in non stress environment (Table 1). Due to water stress the lowest reduction of pods plant^{-1} was occurred in BARI Soybean 6 (38.00%). But in case of seeds pod^{-1} the lowest reduction was in Shohag (4.58). The lowest reduction percent of 100 seed weight was 9.98% which was found in both BARI Soybean 6 and Shohag. Seed yield of all the 50 soybean genotypes grown in water stress environment was significantly lower than that in non-stress environment (Table 2). The highest (79.97%) reduction in seed yield due to water stress was observed in G00085 and the lowest (42.90%) in BARI Soybean 6. Considering tolerance, lower TOL values were recorded in genotypes BD2336 (3.26) followed by MTD459 (3.28), BD2339 (3.38), PK416 (3.6), G00389 (3.72), BD2331 (3.76), Shohag (3.77), G00056 (3.79), BD2335 (3.81), BD2327 (3.87), G00032 (3.87), G00035 (3.92) and BARI Soybean 6 (3.95). The lower the TOL value, the lower was the reduction in grain yield under stress conditions and consequently indicates lower stress sensitivity. But genotypes BD2336, MTD459, BD2339, PK416, G00389, G00056, BD2335, BD2327, G00032, and G00035 exhibited the lower RP but higher DSI.

Table 1. Seed yield attributes of 50 soybean genotypes under non-stressed and water stressed conditions

Genotypes	Pod no. plant ⁻¹		Seed no. pod ⁻¹		100-seed weight		Genotypes		Pod no. plant ⁻¹		Seed no. pod ⁻¹		100-seed weight	
	NS	WS	NS	WS	NS	WS	Genotypes	NS	WS	NS	WS	NS	WS	
AGS129	43	17.1	2.2	1.75	10.55	8.66	G00015	46	21	2	1.86	12.49	10.56	
G00389	41	15	2.1	1.74	10	7.9	G00084	48	19	2.1	1.81	11	10.12	
MTD459	51	23.06	2.4	1.94	9.5	8.4	BD2336	41	20.6	2.5	2.26	7.58	6.28	
G00035	40.67	16.26	2.2	1.91	11.56	9.59	G00115	39	14	2.35	1.65	9.77	8.04	
G00382	45	14	2.1	1.68	10.22	9.4	BGM2093	44	20	2.3	1.98	7.48	6.82	
G00103	48	18.4	2.1	1.82	12.2	10.56	G00056	49	14.7	2.2	1.65	9.56	9.15	
BARI Soybean 6	52	32.24	2.2	2.08	12.63	11.37	Shohag	51	28.2	2.4	2.29	12.02	10.82	
BD2337	45	20.2	2.4	1.93	8.48	7.12	BD2331	50	26.3	2.3	2.14	11.68	9.8	
Bangladesh Soybean 4	43	21	2.1	1.68	8.76	7.18	BD2329	50	23	2.1	1.83	11.1	9.33	
G00032	45	19.3	2.3	1.93	7.2	5.76	G00127	44.67	19.2	2.2	1.91	11.1	10	
BD2338	45	18.5	2.28	1.82	12.03	10.47	G00168	48	20	1.7	1.46	9.2	8.68	
BD2355	44	17.2	2.4	2.01	11.28	9.82	BD2324	54	21.85	2.4	2.01	6.84	6	
BD2327	41	18.57	2.3	2.01	8.56	7.45	G00167	53	20.14	2.2	1.65	7.96	6.74	
BGM 2026	70	24.4	2.3	1.89	6.96	5.28	G00003	40.93	18.42	2.33	2.03	10.96	9.92	
G00083	41.67	20	2.2	1.93	12.6	10.06	G00157	53	19	2.4	1.92	7.76	7	
MTD453	52.67	20	2.5	2.16	8.43	7.72	G00119	48.5	17	2.2	1.93	10.6	9.98	
ASET95	48	14.4	2.2	1.76	7.84	6.75	G00209	50	21	2.6	2.4	8.6	7.92	

Table 1. Cont'd

Genotypes	Pod no. plant ⁻¹		Seed no. pod ⁻¹		100-seed weight		Genotypes		Pod no. plant ⁻¹		Seed no. pod ⁻¹		100-seed weight	
	NS	WS	NS	WS	NS	WS			NS	WS	NS	WS	NS	WS
AGS275	44.63	18	2.3	1.95	10.08	8.87	G00166	52	17	2.4	2.03	9.04	8.96	
BD2339	53	19	2	1.68	13.4	11.8	G00163	46	21	2.3	2.1	10.86	8.5	
BD2335	42	18	2.4	1.92	9.12	7.03	G00125	48	18	2.2	1.89	8.76	8.46	
G00006	47	18	2.3	1.82	8.45	7.39	G00136	52	20	2.3	2	11.92	10.04	
PK416	39.91	18	2.3	1.98	8.4	7.56	G00124	50	15	2.4	2.02	8.6	6.97	
BD2340	50	20.5	2.2	1.78	11.6	8.7	BD2325	51	22.44	2.3	2.1	7	6.9	
G00342	62	25	2.1	1.85	8.4	6.22	G00044	48	18	2.4	2	8.4	6.84	
BARI Soybean 5	49	25	2.4	2.19	11.16	9.82	G00085	42	14	2.5	1.75	11.62	9.1	
LSD _(0.05)	9.144	6.768	0.213	0.211	1.038	2.136	LSD _(0.05)	9.144	6.768	0.213	0.211	1.038	2.136	
CV (%)	11.7	11.29	5.83	6.89	6.58	5.38	CV (%)	11.7	11.29	5.83	6.89	6.58	5.38	

NS = Non-stressed, WS = Water-stressed.

Table 2. Seed yield and tolerance indices of 50 soybean genotypes evaluated in non-stressed and water stressed conditions

Genotypes	Seed yield (g plant ⁻¹)		TOL	RP	DSI	Genotypes	Seed yield (g plant ⁻¹)		TOL	RP	DSI
	NS	WS					NS	WS			
AGS129	6.15	1.5	4.65	0.24	1.12	G00015	6.42	2.4	4.02	0.37	0.93
G00389	5.17	1.45	3.72	0.28	1.06	G00084	7.25	2.54	4.71	0.35	0.96
MTD459	5.05	1.77	3.28	0.35	0.96	BD2336	5.52	2.26	3.26	0.409	0.87
G00035	5.60	1.68	3.92	0.3	1.10	G00115	5.49	1.26	4.23	0.23	1.13
G00382	5.86	1.41	4.45	0.24	1.12	BGM2093	5.97	2.18	3.79	0.36	0.94
G00103	7.51	2.33	5.18	0.31	1.09	G00056	5.84	1.46	4.38	0.25	1.1
BARI Soybean 6	9.27	5.32	3.95	0.574	0.63	Shohag	8.61	4.84	3.77	0.57	0.64
BD2337	6.40	1.71	4.69	0.26	1.09	BD2331	8.20	4.7	3.76	0.57	0.67
Bangladesh Soybean 4	6.64	1.73	4.91	0.26	1.09	BD2329	9.11	3.65	5.46	0.40	0.88
G00032	5.54	1.67	3.87	0.301	1.06	G00127	6.65	2.33	4.32	0.35	0.96
BD2338	7.90	1.8	6.1	0.23	1.13	G00168	7.02	2.17	4.85	0.309	1.02
BD2355	7.63	2.0	5.63	0.26	1.09	BD2324	7.60	2.28	5.32	0.30	1.03
BD2327	5.96	2.09	3.87	0.35	0.96	G00167	7.58	1.89	5.69	0.24	1.12
BGM 2026	9.23	2.74	6.49	0.29	1.05	G00003	6.57	2.3	4.27	0.35	0.96
G00083	6.60	2.39	4.21	0.36	0.94	G00157	6.84	1.84	5	0.27	1.07
MTD453	7.62	2.67	4.95	0.35	0.96	G00119	6.84	2.06	4.78	0.301	1.03
ASET95	6.47	1.56	4.91	0.24	1.12	G00209	8.05	2.82	5.23	0.35	0.96

Table 2. Cont'd

Genotypes	Seed yield (g plant ⁻¹)		TOL	RP	DSI	Genotypes	Seed yield (g plant ⁻¹)		TOL	RP	DSI
	NS	WS					NS	WS			
AGS275	6.61	1.99	4.62	0.301	1.03	G00166	7.50	2.2	5.3	0.29	1.05
BD2339	4.69	1.31	3.38	0.27	1.07	G00163	6.85	2.4	4.45	0.35	0.96
BD2335	5.09	1.28	3.81	0.251	1.10	G00125	7.26	1.9	5.36	0.26	1.09
G00006	6.41	1.47	4.94	0.23	1.13	G00136	7.99	2.3	5.69	0.28	1.07
PK416	5.54	1.94	3.6	0.35	0.96	G00124	5.62	1.41	4.21	0.25	1.10
BD2340	8.61	2.49	6.12	0.28	1.06	BD2325	7.12	2.5	4.62	0.351	0.96
G00342	6.85	2.48	4.37	0.36	0.94	G00044	5.95	1.6	4.35	0.27	1.07
BARI Soybean 5	9.18	4.67	4.39	0.51	0.72	G00085	6.99	1.4	5.59	0.20	1.18
LSD _(0.05)	1.252	1.302	-	-	-	LSD _(0.05)	1.252	1.302	-	-	-
CV(%)	11.29	3.5	-	-	-	CV(%)	11.29	3.5	-	-	-

NS = Non-stressed, WS = Water-stressed, RP = Relative performance, TOL = Tolerance in the WS in relation to the NS environment, DSI = Drought susceptibility index.

On the contrary, BARI Soybean 6, BD2331, Shohag and BARI Soybean 5 showed higher RP and DSI. The genotypic variation in drought susceptibility index ranged from 0.63-1.18. The DSI for seed yield was the minimum (0.64) in BARI Soybean 6 (0.63) followed by Shohag (0.64) and BD2331 (0.67). The highest DSI (1.18) for seed yield was found in the genotype G00085. Tera'n and Singh (2002) reported that drought resistant lines had relatively low DSI while the drought susceptible lines had high DSI values and grouping of genotypes based on susceptibility index under stress conditions has been widely used and found to be effective to select tolerant genotypes of different crops, such as french bean (Choudhury *et al.*, 2012) and soybean (Mannan *et al.*, 2012). Based on tolerance indices values recorded in this experiment, the genotypes BARI Soybean 6, Shohag, BD2331 and BARI Soybean 5 could be considered as relatively water stress tolerant compared to rest of the genotypes.

Table 3. Ranking of 50 soybean genotypes on the basis of their yield reduction under non-stress condition

Rank Order	Yield reduction (%) over control (non-stress)	Genotypes(50)
Tolerant	Less than 50.00	BARI Soybean-6, Shohag, BARI Soybean-5, and BD2331 (4)
Moderately Tolerant	50.01-60.00	BD2336, and BD2329 (2)
Moderately Susceptible	60.01-70.00	G00015, and BGM2093 (2)
Susceptible	Above 70.01	AGS129, G00389, MTD459, G00035, G00382, G00103, BD2337, Bangladesh Soybean-4, G00032, BD2338, BD2355, BD2327, BGM2026, G00083, MTD453, ASET95, AGS275, BD2339, BD2335, G00006, PK416, BD2340, G00342, G00084, G00115, G00056, G00127, G00168, BD2324, G00167, G00003, G00157, G00119, G00209, G00166, G00163, G00125, G00136, G00124, BD2325, G00044, and G00085 (42)

Ranking of genotypes

To determine the most desirable drought tolerant genotype, all soybean genotypes were ranked on the basis of their yield reduction due to water stress over non-stress (Table 3). A hypothetical scale was made to categorize the genotypes in different rank order on the basis of yield reduction. According to the yield reduction, genotypes were ranked into four groups as tolerant (less than 50% yield reduction), moderately tolerant (50.01-60.00% yield reduction), moderately susceptible (60.01-70.00% yield reduction) and susceptible (above 70.01% yield reduction). In consideration to yield reduction, four genotypes were found in tolerant group

because they were relatively more productive both under non-stress and water stress conditions, and exhibited low yield reduction due to water stress. Similarly, two genotypes were found moderately tolerant as they gave lower yield than the tolerant ones, but higher yield than the susceptible genotypes. Two genotypes were grouped as moderately susceptible due to higher yield reduction in water stress condition. The rest of forty-two genotypes were ranked in susceptible group due to their very low yielding ability and very high yield reduction.

Table 4. Distribution of fifty soybean genotypes into different clusters subjected to water stress

Cluster	No. of genotypes	Soybean genotypes
I	1	BARI soybean 6
II	3	Shohag, BD2331, BARI soybean 5
III	2	G00342, BGM2026
IV	7	G00115, G00389, G00124, ASET95, G00056, G00085, G00383
V	37	G00083, G00136, G00015, G00084, G00127, G00103, BD2338, G00003, BD2339, BD2335, G00044, G00006, BD2327, PK416, G00157, BD2355, G00119, G00035, AGS275, G00125, AGS129, G00166, MTD459, BD2329, BD2324, BD2325, BD2340, G00163, G00168, MTD453, G00209, BGM2093, G00167, BD2337, BD2336, Bangladesh Soybean-4, and G00032

Grouping of genotypes

Cluster analysis was used for grouping the genotypes for water stress tolerance. Cluster analysis showed that the genotypes, based on relative value of yield of all genotypes tended to group into five groups with 1, 3, 2, 7 and 37 genotypes (Table 4). The first cluster included only one genotype (BARI Soybean 6) which exhibited the highest relative values in its quantitative characters with very low yield reduction and low DSI value under water stress condition (Table 2). This indicated that the genotype BARI Soybean 6 was tolerant to water deficit stress with good productivity both in non-stress and water deficit stress condition. The second cluster included three genotypes namely Shohag, BD2331 and BARI Soybean 5. These genotypes had the second highest relative values in their quantitative characters with moderately low DSI value under water stress condition. This indicates that they were relatively tolerant to water stress with good productivity in water stress and non-stress condition. The third cluster included two genotypes viz. G00342 and BGM2026. These genotypes showed medium relative values in their quantitative characters with medium DSI under water deficit stress condition indicating moderate susceptibility to water stress and high productivity in optimum soil moisture condition. The fourth cluster included seven genotypes, namely G00115, G00389, G00124, ASET95, G00056,

G00085, and G00383 which had low relative values in their quantitative characters with high DSI value under water stress condition indicating high susceptibility to water stress and high productivity in non-stress condition. The fifth cluster included the rest thirty-seven genotypes which showed very low relative values.

Conclusion

Soybean genotypes exhibited a wide variation in seed yield under water stress conditions. Considering degree of different tolerance as measured by different indices the genotypes BARI Soybean 5, BARI Soybean 6, Shohag and BD2331 were found as tolerance to water stress.

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EFFECT OF OSMOPRIMING ON GERMINATION OF RICE SEED

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Abstract

The experiment was conducted at the Seed Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh during the period from September to October, 2011 to study the effect of chemical priming of seed on germination and growth of rice seedling cv. BRRI dhan 29. Seeds were soaked in 3% and 5% solutions of CaCl₂, ZnSO₄ and KCl for 24, 30, 36, 42, 48, 54, 60 hours, respectively. A control was maintained where seeds were subjected to no priming treatment. The experiment was laid out in a Completely Randomized Design with three replications. Primed seeds were tested for germination and vigour on sandy soil media (60:40) in petridish under field capacity. Seed quality tests included mean germination time, shoot length, shoot dry mass, root length and root dry mass. The results revealed that priming treatments had significant influence on germination and all the growth parameters of rice seedlings. Priming with 3% ZnSO₄ for 30 hours showed the highest germination percentage and the lowest mean germination time. Priming with 5% KCl for 54 hours showed the highest root length while 5% of the same solution for 24 hours showed the highest root dry mass. On the contrary, seeds having no priming treatment showed the lowest values for germination, vigour index, shoot length, shoot dry mass, root length and root dry mass and the highest mean germination time. The present study concludes that rice seed cv. BRRI dhan29 could be primed with 3% ZnSO₄ solution for 30 hours for improving germination and seedling growth.

Keyword: Priming, germination, seed vigour and rice seedlings.

Introduction

Rice (*Oryza sativa*) is one of the most extensively cultivated cereals of the world. It is the principal food crop of Bangladesh and constitutes 95% of food grain production in this country. At the end of the 2008 global rice reserve is estimated at 102.4 million tons, which would be fall or 1.2 million tons from already two opening level while rice production in 2007 indicated 4.0% increase over 2006 (Rahman *et al.*, 2009). About half of the world's population live on rice, so global food production needs to be doubled in order to feed the nonstop

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mounting mouth of the word. In many Asian countries, including Bangladesh rice provides food and livelihood security where it is the staple food. Bangladesh is predominately a rice based country as she earns about 21.10% of her gross domestic product (GDP) from Agriculture (Anon.,2008). Rice production depend on a lot of factors. Quality seed is one of the important factors for production of rice. A good seed with in a variety gives good stand establishment in the soil, which in turn ensures a good harvest. Seed quality is a multiple concept comprising several components (Thomson, 1979) like germination capacity, viability, vigour, moisture content and seed health. Quality seed insures quality seedling. It is an important and obligatory input to maintain optimum growth and better grain yield for mordern rice varieties (BRRI, 2006). Optimum crop stand establishment is the pre-requisite for successful production. Crops often fail to establish quickly and uniformly, leading to decreased yield, because of low plant population, constraints to good establishment of crops includes lake of soil moisture, low or high temperature, soil salinity, weed competition, low seed quality and extreme disease pressure. Seeds that germinate faster and rapidly are able to produce sufficient deep root system before the seed beds dired out and these seedlings have enough competitive ability against weed and seedling diseases. If seeds are soaked in different chemical solutions, germination happens more quickly, resulting in a healthier crop. Germination and seedling vigour are appraised on the basis of important physiological and biochemical attributes mainly related to the rapidity of germination, vigourous seedling and reserve metabolism pattern. Priming treatments have been found to enhance the amylase activity,which is positively correlated with the reserve mobilization and germination rate in rice (Lee and Kim, 2000; Basar *et al.*, 2005). Priming increases level of a-amylase activity was reported by Basar *et al.* (2005) in hardened rice seeds. Good seedling establishment is an important constraint to crop production in the semi-arid tropics (Harris *et al.*, 1999). Priming in the semi-arid tropics has been reported to increase emergence and improvement of stand, more vigourous plants, better drought tolerance, earlier maturing and higher grain yield (Harris *et al.*, 1999, 2001,2002). Osmo-hardening with KCl or CaCl₂ for 12 h improved emergence, stand establishment, tiller number, grain and straw yields and harvest index. However, seed priming techniques did not affect plant height, number of spikelets, number of grains and 1000-grain weight. Improved yield was attributed principally to better stand establishment and improved number of fertile tillers (Farooq *et al.*, 2008). Chemical priming partically ensured rapid and uniform germination and seedling growth. The above discussion indicates that chemical priming of seed is an effective tool for rapid and uniform seedling emergence. However, methods for priming of rice have not yet been developed in bangladesh. Hence, the present study was undertaken with an objective to study the effect of chemical priming of rice seed for germination and vigour.

Materials and Methods

The experiment was conducted at the Seed Laboratory of the Department of Agronomy, Bangladesh Agricultural University (BAU), Mymensingh during the period from September to October, 2011. The experiment was laid out in a Completely Randomized Design with three replications. In this experiment, seeds of rice variety BRRI dhan 29 was used as the test material. Rice seeds were soaked in 3% and 5% solutions of CaCl_2 , ZnSO_4 and KCl for 24, 30, 36, 42, 48, 54 and 60 hours respectively at room temperature (27 ± 3). The seeds were then dried at room temperature and were used in the further tests. A control was maintained where seeds were not primed. Therefore, there were 43 treatment combinations as follows-

T_1 = Priming with 3% solution of CaCl_2 for 24 hrs, T_2 = Priming with 3% solution of CaCl_2 for 30 hrs, T_3 = Priming with 3% solution of CaCl_2 for 36 hrs, T_4 = Priming with 3% solution of CaCl_2 for 42 hrs, T_5 = Priming with 3% solution of CaCl_2 for 48 hrs, T_6 = Priming with 3% solution of CaCl_2 for 54 hrs, T_7 = Priming with 3% solution of CaCl_2 for 60 hrs, T_8 = Priming with 5% solution of CaCl_2 for 24 hrs, T_9 = Priming with 5% solution of CaCl_2 for 30 hrs, T_{10} = Priming with 5% solution of CaCl_2 for 36 hrs, T_{11} = Priming with 5% solution of CaCl_2 for 42 hrs, T_{12} = Priming with 5% solution of CaCl_2 for 48 hrs, T_{13} = Priming with 5% solution of CaCl_2 for 54 hrs, T_{14} = Priming with 5% solution of CaCl_2 for 60 hrs, T_{15} = Priming with 3% solution of ZnSO_4 for 24 hrs, T_{16} = Priming with 3% solution of ZnSO_4 for 30 hrs, T_{17} = Priming with 3% solution of ZnSO_4 for 36 hrs, T_{18} = Priming with 3% solution of ZnSO_4 for 42 hrs, T_{19} = Priming with 3% solution of ZnSO_4 for 48 hrs, T_{20} = Priming with 3% solution of ZnSO_4 for 54 hrs, T_{21} = Priming with 3% solution of ZnSO_4 for 60 hrs, T_{22} = Priming with 5% solution of ZnSO_4 for 24 hrs, T_{23} = Priming with 5% solution of ZnSO_4 for 30 hrs, T_{24} = Priming with 5% solution of ZnSO_4 for 36 hrs, T_{25} = Priming with 5% solution of ZnSO_4 for 42 hrs, T_{26} = Priming with 5% solution of ZnSO_4 for 48 hrs, T_{27} = Priming with 5% solution of ZnSO_4 for 54 hrs, T_{28} = Priming with 5% solution of ZnSO_4 for 60 hrs, T_{29} = Priming with 3% solution of KCl for 24 hrs, T_{30} = Priming with 3% solution of KCl for 30 hrs, T_{31} = Priming with 3% solution of KCl for 36 hrs, T_{32} = Priming with 3% solution of KCl for 42 hrs, T_{33} = Priming with 3% solution of KCl for 48 hrs, T_{34} = Priming with 3% solution of KCl for 54 hrs, T_{35} = Priming with 3% solution of KCl for 60 hrs, T_{36} = Priming with 5% solution of KCl for 24 hrs, T_{37} = Priming with 5% solution of KCl for 30 hrs, T_{38} = Priming with 5% solution of KCl for 36 hrs, T_{39} = Priming with 5% solution of KCl for 42 hrs, T_{40} = Priming with 5% solution of KCl for 48 hrs, T_{41} = Priming with 5% solution of KCl for 54 hrs, T_{42} = Priming with 5% solution of KCl for 60 hrs, T_{43} = No priming (control)

Sterilized sand was used as germination media and Petridish was used as germination media and Petridish was used as container. The moisture content of

the media was maintained at 60% of the capacity. The following seed quality parameters were measured: 1. Germination %, 2. Mean germination time, 3. Vigour index by Seedling Vigour Classification Test (Germination% x average seedling length), 4. Seedling shoot length (cm), 5. Seedling root length (cm), 6. Seedling shoot dry mass (mg) and 7. Seedling root dry mass (mg). The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique and the means were compared by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Result and Discussion

Germination

Table 1 revealed that germination of rice seedlings was significantly affected due to the priming treatment. The germination of seed for different treatments ranged between 71 and 96.67 percentages. The highest germination (95.67%) was obtained in seed primed with 3% ZnSO₄ for 30 hours whereas the lowest value of germination (60%) was found in non-primed seed. This result is similar to that of Farooq *et al.* (2006a). Osmo-hardening with KCl performed better than all other treatments including control. Priming improved the K⁺ balance that activates alpha-amylase, a basis for seed in vigouration. Osmo-hardening with KCl in another experiment (Farooq *et al.*, 2006c). The results of the present study clearly showed that more germination advantages of rice seed could be achieved by priming with different chemicals.

Mean germination time

It is found that priming treatments had significant effect on mean germination time (days) of rice seedlings for different chemical treatments (Table 1). The mean germination time of seed for different treatments ranged from 4.0109 to 7.6224 days. Under all the treatments, the highest mean germination time was found with non-primed seed. The lowest mean germination time for priming with 5% ZnSO₄ for 24 hours. The results revealed that priming enhanced rapid germination of seed compared with non-primed seed. The significant enhancement in germination might have been caused due to increased amylase activity that is positively correlated with the reserve mobilization and mean germination rate in rice (Lee and Kim, 2000). The results revealed that primed seed emerged faster and decreased the mean germination time. Similar results were also found by Harris *et al.* (2001).

Vigour index

The vigour index (VI) of rice seedlings was affected significantly by priming with different chemical treatments (Table 1). The vigour index of the seed for different treatments ranged from 10.5519 to 25.1913. At all conditions, the

highest vigour index was found with the seed primed with 5% ZnSO₄ for 24 hours. On the other hand the lowest vigour index was found with non-primed seed. The results showed that vigour index increased in primed seeds. The vigour index increase might be related to reduction of imbibition of lag time for priming treatment (Bradford, 1986). Priming also causes physiological and bio-chemical changes in seed during the seed treatments and metabolic activities increases α -amylase activity, thus indicating higher vigour index (Lee and Kim, 2003). The results showed that priming increased the vigour index of seed. This result is similar to that of Harris *et al.* (2000), lee and Kim (2000) and Basar *et al.* (2003).

Table 1. Effect of chemical priming of rice seed on germination (%), mean germination time and vigour index

No.	Seed Priming treatment	Growth parameters		
		Germination (%)	Mean germination time	vigour index
1	3% CaCl ₂ for 24 H	71 k-l	6.7863 a-f	12.419 h-j
2	3% CaCl ₂ for 30 H	84 a-j	5.0369 c-h	19.7208 a-g
3	3% CaCl ₂ for 36 H	85.33 a-j	5.3594 a-h	18.6734 a-i
4	3% CaCl ₂ for 42 H	80.67 d-l	5.5725 a-h	17.8110 b-j
5	3% CaCl ₂ for 48 H	93.33 a-c	4.9468 d-h	22.2772 a-d
6	3% CaCl ₂ for 54 H	87.33 a-i	5.2482 a-h	20.0955 a-g
7	3% CaCl ₂ for 60 H	75 i-l	7.6224 a	11.8872 i-j
8	5% CaCl ₂ for 24 H	76.67 g-l	5.8588 a-h	15.2882 e-j
9	5% CaCl ₂ for 30 H	86 a-j	5.1686 c-h	20.0171 a-g
10	5% CaCl ₂ for 36 H	78 f-l	6.0497 a-h	15.1530 e-j
11	5% CaCl ₂ for 42 H	94.67 a-b	4.5616 e-h	24.07132 a-b
12	5% CaCl ₂ for 48 H	86.33 a-j	5.9312 a-h	16.3392 d-j
13	5% CaCl ₂ for 54 H	86.33 a-j	4.9734 d-h	20.0911 d-j
14	5% CaCl ₂ for 60 H	92 a-d	5.8124 a-h	18.9476 a-j
15	3% ZnSO ₄ for 24 H	85.33 a-j	6.4199 a-g	17.8286 b-i
16	3% ZnSO ₄ for 30 H	95.67 a	4.9132 d-h	22.9472 a-d
17	3% ZnSO ₄ for 36 H	93.67 a-c	4.4887 f-h	24.1658 a-b
18	3% ZnSO ₄ for 42 H	90.678 a-e	4.1590 g-h	23.8403 a-c
19	3% ZnSO ₄ for 48 H	91.678 a-d	5.4032 a-h	20.1372 a-g
20	3% ZnSO ₄ for 54 H	78.33 e-l	7.2224 a-d	13.7988 f-j
21	3% ZnSO ₄ for 60 H	70.33 l	6.7317 a-f	12.558 h-j
22	5% ZnSO ₄ for 24 H	94. a-d	4.0109 h	25.1913 a
23	5% ZnSO ₄ for 30 H	85.33 a-j	5.63936 a-h	18.9149 a-h
24	5% ZnSO ₄ for 36 H	90.67 a-e	4.3023 g-h	24.0624 a-b

Table 1. Cont'd.

No.	Seed Priming treatment	Growth parameters		
		Germination (%)	Mean germination time	vigour index
25	5% ZnSO ₄ for 42 H	93.67 a-c	5.2094 b-h	20.5260 a-f
26	5% ZnSO ₄ for 48 H	90 a-f	5.6136 a-h	18.5260 a-f
27	5% ZnSO ₄ for 54 H	83.33 a-j	5.9603 a-h	17.3942 b-i
28	5% ZnSO ₄ for 60 H	89 a-g	5.0507 a-h	18.4316 a-i
29	3% KCl for 24 H	82.67 b-k	5.007 d-h	19.0176 a-h
30	3% KCl for 30 H	83.33 a-j	6.2408 a-h	16.8514 l-k
31	3% KCl for 36 H	81.64 c-l	6.0815 a-h	16.2277d-j
32	3% KCl for 42 H	86.67 a-g	5.1412 c-h	19.5361 a-g
33	3% KCl for 48 H	91 a-d	5.1148 c-h	21.2382 a-e
34	3% KCl ₄ for 54 H	90.33 a-f	5.3876 a-h	20.6484 a-f
35	3% KCl for 60 H	85 a-j	5.4091 a-h	18.5118 a-l
36	5% KCl for 24 H	87 a-i	5.6401 a-h	18.7931 a-h
37	5% KCl for 30 H	87.33 a-i	6.78301 a-f	14.943 e-j
38	5% KCl for 36 H	83 b-k	5.5405 a-h	17.6437 b-j
39	5% KCl for 42 H	86.67 a-j	6.2992 a-h	17.3441 b-i
40	5% KCl ₄ for 48 H	88.33 a-h	6.1029 a-h	17.0403 c-j
41	5% KCl for 54 H	75 i-l	7.4204 a-c	12.4572 h-j
42	5% KCl for 60 H	76.33 h-l	6.8847 a-e	12.3292 g-h
43	No Priming	74.33 j-l	7.5858 a-b	10.5519 j
	Level of Significant	**	**	**
	CV (%)	78.28	12.69	24.48

** = Significant at 1 % level of probability, * = Significant at 5 % level of probability, CV = Co-efficient of variation.

Shoot length

Table 2 revealed that shoot length of rice seedling was significant at significant at moist sandy condition in the priming treatments. The shoot length of rice seedlings for different treatments ranged from 10.26 cm to 12.42 cm. At all the conditions, the highest shoot length (12.43 cm) was found in seed primed with 3% ZnSO₄ for 30 hours. On the other hand, the lowest shoot length was found in 5% KCl for 48 hours. The results of the present study clearly showed that priming enhanced shoot length of rice for soil with moisture stress conditions. This result is in agreement with that of Tongma *et al.* (2001) and Farooq *et al.* (2006b).

Shoot dry mass

Seed priming treatments influenced significantly the growth of shoots dry mass of rice seedlings (Table 2). The shoot dry mass of rice seedlings for different

treatments ranged from 0.04 to .08 mg. The highest shoot dry mass of rice seedlings (0.8 mg) was obtained in seed primed with 5% CaCl₂ for 24 hours whereas the lowest shoot dry mass of rice seedlings (0.4 mg) was found in no primed seed. The lowest shoot dry mass was found in no primed seed. Seed priming increased seedling dry mass probably by enhancing K⁺ condition in both seeds and seedlings, leading to improved α-amylase activity and the concentration of reducing sugars with amylase activity (Faarooq *et al.*, 2007). The results clearly exhibited that seed priming had effect on shoot dry mass growth. The result of the present study is in agreement with that of Farooq *et al.* (2006b, 2007 and 2008) and Tongma *et al.* (2001).

Root length

The root length of rice seedling was affected significantly due to the priming treatments (Table 2). The root length of seedling for different treatments ranged from 8.147 to 10.14 cm. The highest root length (10.14 cm) was obtained in seed primed with 5% KCl for 54 hours whereas the lowest root length (8.147 cm) was found in non-primed seed. The results of the present study showed that root length of rice seedling increased by priming treatments. Similar result was reported by Ruan *et al.* (2002).

Table 2. Effect of chemical priming on shoot length (cm), shoot weight (mg), root length (cm) and root weight (mg) of rice

No.	Seed Priming treatment	Growth parameters			
		Shoot length (cm)	Shoot dry weight (mg)	Root length (cm)	Root dry weight (mg)
1	3% CaCl ₂ for 24 H	10.37 b	0.05333 c-e	9.160 a-h	0.04333 d-e
2	3% CaCl ₂ for 30 H	10.27 b	0.06667 a-d	9.393 a-f	0.06667 a-d
3	3% CaCl ₂ for 36 H	10.51 b	0.0700 a-d	9.560 a-f	0.06667 a-d
4	3% CaCl ₂ for 42 H	12.42 a	0.06333 a-d	8.8378 e-h	0.05667 b-e
5	3% CaCl ₂ for 48 H	11.07 a-b	0.06667 a-d	9.197 a-h	0.0600 a-e
6	3% CaCl ₂ for 54 H	11.40 a-b	0.0700 a-d	9.543 a-f	0.0700 a-d
7	3% CaCl ₂ for 60 H	10.45 b	0.0700 a-d	9.243 a-g	0.0600 a-e
8	5% CaCl ₂ for 24 H	10.59 b	0.080 a	8.957 b-h	0.0700 a-d
9	5% CaCl ₂ for 30 H	10.77 b	0.0700 a-d	9.87 a-e	0.05667 b-e
10	5% CaCl ₂ for 36 H	11.14 a-b	0.0600 a-e	9.787 a-f	0.0600 a-e
11	5% CaCl ₂ for 42 H	10.93 a-b	0.05667 b-c	10.02 a-d	0.0600 a-e
12	5% CaCl ₂ for 48 H	10.78 b	0.080 a	9.112 a-h	0.06667 a-d
13	5% CaCl ₂ for 54 H	11.04 a-b	0.06333 a-d	9.217 a-g	0.0600 a-e
14	5% CaCl ₂ for 60 H	11.02 a-b	0.07333 a-e	9.06 a-h	0.06667 a-d
15	3% ZnSO ₄ for 24 H	11.39 a-b	0.0700 a-d	8.722 f-h	0.0600 a-e

Table 2. Cont'd

No.	Seed Priming treatment	Growth parameters			
		Shoot length (cm)	Shoot dry weight (mg)	Root length (cm)	Root dry weight (mg)
16	3% ZnSO ₄ for 30 H	10.92 a-b	0.07667 a-b	8.093 h	0.08333 a-b
17	3% ZnSO ₄ for 36 H	11.19 a-b	0.06667 a-d	8.667 e-h	0.08333 a-b
18	3% ZnSO ₄ for 42 H	11.03 a-b	0.05667 b-e	8.833 e-h	0.06333 a-d
19	3% ZnSO ₄ for 48 H	11.58 a-b	0.06333 a-d	10.03 a-e	0.08333 a-b
20	3% ZnSO ₄ for 54 H	11.24 a-b	0.06333 a-d	9.45 a-f	0.0700 a-d
21	3% ZnSO ₄ for 60 H	11.34 a-b	0.0600 a-e	9.29 a-f	0.07333 a-c
22	5% ZnSO ₄ for 24 H	10.85 b	0.05333 c-l	10.03 a-d	0.0600 a-e
23	5% ZnSO ₄ for 30 H	10.46 b	0.05333 c-l	9.347 a-f	0.0600 a-e
24	5% ZnSO ₄ for 36 H	10.58 b	0.0500 d-e	0.263 a-g	0.056667 b-e
25	5% ZnSO ₄ for 42 H	11.04 a-b	0.0500 d-e	9.2227 a-g	0.0700 a-d
26	5% ZnSO ₄ for 48 H	11.23 a-b	0.05333 c-e	9.583 a-f	0.06667 a-d
27	5% ZnSO ₄ for 54 H	10.83 b	0.06667 a-d.	9.667 a-f	0.07333 a-c
28	5% ZnSO ₄ for 60 H	10.92 a-b	0.0500 d-e	9.673 a-f	0.05667 b-e
29	3% KCl for 24 H	11.18 b	0.0600 a-e	9.0078 a-h	0.06667 a-d
30	3% KCl for 30 H	11.07 a-b	0.06667 a-d	8.92 c-h	0.06333 a-d
31	3% KCl for 36 H	10.06 a-b	0.06333 a-d	9.389 a-f	0.0700 a-d
32	3% KCl for 42 H	11.14 a-b	0.06667 d	9.617 a-h	0.08667 a
33	3% KCl for 48 H	10.53 b	0.05667 b-e	9.00 a-h	0.05667 b-e
34	3% KCl ₄ for 54 H	11.06 a-b	0.06667 a-d	9.593 a-f	0.0700 a-d
35	3% KCl for 60 H	11.02 a-b	0.0500 d-e	9.307 a-f	0.05667 b-e
36	5% KCl for 24 H	11.06 a-b	0.06667 a-d	8.839 e-h	0.06667 a-d
37	5% KCl for 30 H	10.52 b	0.06667 a-d	8.887 d-h	0.07333 a-e
38	5% KCl for 36 H	10.70 b	0.053337 c-d	9.133 a-h	0.06667 a-d
39	5% KCl for 42 H	10.76 b	0.0600 a-e	9.320 a-g	0.0666 a-d
40	5% KCl ₄ for 48 H	10.20 b	0.05667 b-e	9.447 a-f	0.06667 a-d
41	5% KCl for 54 H	11.98 a-b	0.06333 a-d	10.14 a	0.07333 a-e
42	5% KCl for 60 H	11.19 a-b	0.0400 e	10.06 a-b	0.0500 c-e
43	No Priming	11.47 a-b	0.0400	8.1478 g-h	0.03333 e
	Level of Significant	NS	**	**	**
	CV (%)	6.81	6.03	9.39	9.42

** = Significant at 1 % level of probability, * = Significant at 5 % level of probability, CV = Co-efficient of variation, NS = Non significant.

Root dry mass

It is clear from (Table 2) that root dry mass of rice seedling was affected significantly due to priming treatments. The root dry mass of rice seedling for

different treatments ranged from 0.03333 to 0.08667 mg. The highest root dry mass of rice seedlings was found in priming with 3% KCl for 42 hrs. The lowest root dry mass of rice seedling was 0.0333 mg for non-primed seed. The results of the present study clearly showed that root dry mass of rice seedling increased by priming. From results of the present study, it may be stated that seed chemical priming treatments enhanced rapid germination and vigour index of seedling and lessen the mean germination time by different priming treatments. Therefore, the present study concludes that improvement of germination capacity and rapidity of germination of rice seed could be possible by employing priming treatment. Similar result was reported by Ruan *et al.* (2002).

Conclusion

Results showed that chemical priming treatments had significant effect on germination, mean germination time, vigour index of rice seeds and shoot length, shoot dry mass, root length and root dry mass of rice seedlings. Primed with 3% ZnSO₄ solution for 30 hours in a remarkable technique for improving seed germination and seedling growth of rice cv. BRRI dhan 29. The no priming treatment showed the lowest germination, vigour index of rice seed and shoots dry mass, root length and root dry mass of rice seedlings and the highest mean germination time.

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**DIVERSITY OF INSECT PESTS AND NATURAL ENEMIES AS
INFLUENCED BY GROWTH STAGES AND PEST MANAGEMENT
PRACTICES IN RICE**

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Abstract

In order to measure the diversity of insect pests and natural enemies in rice ecosystem, the present study was conducted in the research farm of Patuakhali Science and Technology University, Dumki, Patuakhali during the period from January to June, 2012 in boro rice season. Diversity indices of insect pests and their natural enemies were found to be affected by the combined effect of rice growth stages and management practices. Diversity indices of insect pests and their natural enemies differed according to treatments and crop growth stages. In case of insect pests, the untreated control treatment showed the highest diversity index (1.67) at maximum tillering stage and spray (Bipolar 55EC @ 10 ml/10 L of water) + perching at early tillering stage also showed highest richness (26.14) and the highest evenness (0.921) in spray at seedling stage. The highest reciprocal form of Berger-Parker's Dominance index (D) was found in untreated control at maximum tillering stage (3.03) for insect pests. In case of natural enemies, perching showed the highest diversity index (1.88) at reproductive stage. Spraying of insecticide at early tillering stage also showed highest richness (5.06) and the highest evenness (0.982) was in perching at seedling stage. The highest D value was found in perching at reproductive stage (4.67) for natural enemies.

Keywords: Diversity, growth stage, insect pest, natural enemies, pest management practices

Introduction

Rice is the most important source of the food energy for more than half of the global human population. Rice is grown in 114 countries across the world on an area about 150 million hectares with annual production of over 525 million tons, constituting nearly 11 percent of the world's cultivated land (Rai, 2006). In Bangladesh, about 90% of the population depends on rice as their major food (DAE, 2011). Rice contributes 91.1% of the total grain production and covers 74% of the total calorie intake for the people of Bangladesh (MOA, 2001). Rice is cultivated in about 11534 thousand ha land and total annual production is 33542 thousand M. tons, with an average of 2907 kg ha⁻¹ in Bangladesh (BBS, 2011).

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Rice is grown round the year in Bangladesh and so, rice is an ideal host for many insect pest species. So far, 266 species of insect have been recorded as rice pests, of these 42 species are economically important in Bangladesh (Islam *et al.*, 2003). The estimated annual loss of rice in Bangladesh due to insect pests and diseases amounts 1.5 to 2.0 million tons (Siddique, 1992). As some of major insect pests are considered very devastating to rice plants, they need to be controlled in the field. The main pest management method in Bangladesh is application of synthetic chemical pesticides. However, the application of chemical pesticides has got many limitations and create undesirable side effects, reduce the biological control efficacy, resulting in resurgence (Heinrichs, 1994), insecticide resistance and environmental hazard (Yoo *et al.*, 1997; Campiche *et al.*, 2006).

In Bangladesh, rice fields are strictly monoculture, and the lack of ecological diversity could be the major cause of insect pest problems because the food, hosts, prey and hibernating or over wintering sites of most of the natural enemies are reduced, thereby limiting natural biological control. According to Root's enemies hypothesis (Root, 1973), general and special natural enemies are expected to be more abundant in polycultures and therefore suppress herbivore population densities more than in monocultures. Both general and special natural enemies should be more abundant in polycultures than monocultures because, more pollen and nectar resources are available throughout the season in polycultures than monocultures (Root, 1973; Topham and Beardsley, 1975). Anbalagan and Narayanasamy (1999) reported that population abundance and species diversity of the spiders were directly related to the growth stages of the rice plant. Khan and Alam (2007) also reported that the diversity indices, species richness and equitability of insect pests and natural enemies were affected by the combined effect of management practices and rice growth stages. Considering the above facts the present study was undertaken to measure the diversity of insect pests and their natural enemies at different growth stages of rice in boro season

Materials and Method

The present study was conducted in research farm of Patuakhali Science and Technology University, Dumki, Patuakhali to measure the diversity of insect pests and their natural enemies in rice ecosystem. The study was done in the month of January to June, 2012 during boro rice season. Different management practices viz., spray (Bipolar 55 EC @ 10ml per 10 liter of water), perching, spray (Bipolar 55 EC @ 10ml per 10 litre of water) + perching and untreated control were applied in rice field of BRRI Dhan 29 rice variety. The whole experimental field was divided into four equal plots (8m x 5m) as per number of treatments with 1.0 m distance between the plots. All treatments were applied once in each growth stage of rice plant. Only water was sprayed for untreated

control plot. Data on insect pest and their natural enemies were collected after 7 days of treatment application. The insect pests of rice and their natural enemies were collected by a fine nylon cloth sweep net (30 cm diameter). Sweeping was done from the plant canopy level including the interspaces between plants as well as close to basal region of the plants as far as possible. In each field, 10 complete sweeps were made to collect the insect pests and their natural enemies at each date of sampling at 15 days intervals. Sampling was done at four growing stages of rice viz. seedling, early tillering, maximum tillering and panicle initiation stages in boro season. Two samplings were taken at each growth stage of rice plant. Sampling was done during morning hours at all study fields on all sampling dates. The insect pests and natural enemies of 10 sweeps from each field were collected separately in labeled container. The collected samples were properly sorted, counted, identified and preserved in the laboratory of the Department of Entomology. The samples were sorted and identified under stereoscopic microscope and magnifying glass.

Diversity reflects two common components: species richness and species evenness or equitability. Diversity indices attempt to combine both components. With some further thought it becomes clear that the relative abundance of each species is related to diversity. There are measures of species richness, and there are measures of relative abundance (also called "evenness" or "dominance"), and there are mixtures of both (De Jong, 1975). Interpreting measures of diversity can get complicated, and different mathematical measures have different sensitivities and bias. For the present experiment, the following indices were used to measure diversity of insect pests and their natural enemies and all the diversity indices were calculated from the original data.

Species diversity

Menzies *et al.* (1973) defined diversity as a community ecological concept which refers to the heterogeneity (or lack of it) in a community or assemblage of different organisms. Thus diversity is dependent upon the number of species present (Species richness, S) and the distribution of all individuals among the species (Equitability or Evenness). Indices to measure diversity are so numerous that confusion is rampant (Sanders, 1968; Whittaker, 1972; Fager, 1972; Hurlbert, 1971, Pielou, 1975). Generally a decrease in diversity is expected with pollution impact. To provide an overview of diversity, the Shannon-Weaver index of Diversity (H) was calculated (Shannon and Weaver, 1963). The index is expressed as-

$$H = -\sum_{i=1}^{ST} P_i \log P_i$$

Where,

P_i = the proportion of individual *i*th species

ST = the total species

$$[P_i = \frac{n_i}{N}; n_i = \text{the number of individuals observed for each species}$$

$N = \text{the total number of individuals in each study area}]$

This index is based on 'information' theory, where diversity is equated to the amount of uncertainty which exists as to the identity of an individual collected at random from a community. The more species and the more evenly representation of individuals, the greater the uncertainty and hence the greater the diversity.

Species richness

Although a variety of indices to estimate species richness are available, none, except the actual number of species collected (S), are widely used. To provide a cohesive overview of species richness, Margalef's Index was also calculated along with S .

Margalef's index of richness (MI) (Margalef, 1958) assumes a theoretical relationship between the number of individuals (N) and the number of species (S) in a sample and is expressed as follows:

$$M. I. = \frac{S - 1}{\log eN}$$

The index logarithmically scales the value of S , and hence provides a means of comparison between stations with different ratios of S and N .

Equitability or Evenness

Equitability is considered a component of diversity, in that it provides an idea about the evenness of species distribution at a site. Usually a positive correlation exists between diversity and equitability (De Jong, 1975) i.e. a high equitability would indicate a high diversity and probably, a 'healthy condition' of a fauna. Reduction of equitability almost occurs with an increase in oligomixity. Pielou's (1966) evenness index (J') method of measuring equitability is most widely used.

The computational formula is:

$$J' = \frac{H}{\log eS}$$

Where,

$H = \text{Shanon's index}$

$S = \text{Total species collected}$

The index value ranges from 0 to 1, with a value of 1 being the maximum possible evenness in the community.

Reciprocal form of Berger-Parker's Dominance index

Another diversity index was calculated using the Berger-Parker's Dominance Index (d) The reciprocal form of Berger-Parker's Dominance index i.e., (1/d) indicates an increase diversity and reduction in dominance (Margurran, 1988). Berger-Parker's dominance index (Berger and Parker, 1970) is expressed as:

$$d = \frac{N_{MAX}}{N_T}$$

Where,

N_{max} = the total no. of individuals of the most abundant species

N_T = Total no. of individuals of all species collected

Hence, the reciprocal form of the index is,

$$D = 1/d$$

Where,

d = Berger-Parker's Dominance index (Southwood, 1978).

Results and discussion

Since measures of diversity involve a number of indices, analyses and interpretation should rationally be interpolated back to the original numerical data. Several diversity indices used to measure the diversity of insect pests and natural enemies in different crop growth stages and different treatments. Shannon and Weaver (1963) diversity index (H), Pielou's (1966) evenness index (J) and Margalef's (1958) index of richness (M.I.) was calculated from the original data. Results of diversity indices are given below:

Diversity of insect pests and natural enemies at different growth stages of boro rice

Early tillering stage showed higher diversity in terms of diversity index (1.48) compared to other three stages (Table 1). But evenness was also highest in same stage (0.826) indicating the highest equability among insect pests in that stage. Richness index was highest at early tillering stage (18.51) and lowest at maximum tillering stage (10.55). The values of D also differed within different stage and appeared as the highest at early tillering stage (2.42) and lowest at reproductive stage (1.08). However, 4 diversity indices viz., diversity index (H), Richness (M.I.), Evenness (J) and D were found highest at early tillering stage thus seemed to be more stable than other.

Table 1. Diversity indices, richness, evenness and equitability of insect pests community recorded by sweeping net at different stages of rice crop

Stages	Shannon diversity index (H)	Richness (M.I.)	Evenness (J)	D
Seedling stage	1.27	13.5	0.789	1.89
Early tillering stage	1.48	18.51	0.826	2.42
Maximum tillering stage	1.26	10.55	0.703	1.73
Reproductive stage	0.386	13.12	0.215	1.08

Table 2 indicates the diversity indices of natural enemies in boro rice at different stages. Diversity index (H), Evenness (J) and D were found highest at seedling stage (1.64, 0.916 and 3.57, respectively) and the lowest at early tillering stage (1.46, 0.815 and 2.12, respectively). This indicates that in boro rice, the diversity of insects was highest at early tillering stage due to low diversity of natural enemies.

Table 2. Diversity indices, richness, evenness and equitability of natural enemies community recorded by sweeping net at different stages

Stages	Shannon diversity index (H)	Richness (M.I.)	Evenness (J)	D
Seedling stage	1.64	9.89	0.916	3.57
Early tillering stage	1.46	9.41	0.815	2.12
Maximum tillering stage	1.5	11.16	0.837	2.79
Reproductive stage	1.54	11.23	0.859	2.5

D=Reciprocal form of Berger Parker's dominance index

Diversity of insect pests and natural enemies in different stages influenced by management practices

Table 3 indicates diversity indices of insect pests and their natural enemies at different growth stages under different treatments. The diversity index showed higher in untreated control at maximum tillering stage (1.67) and the lowest was recorded in spray + perching treatment at reproductive stage (0.882). In richness, the highest value was found in spray + perching treatment at early tillering stage (26.14) while in perching treatment at maximum tillering stage showed the lowest richness value (9.04). In case of evenness, with spray of Bipolar 55EC @ 10 ml/10 L of water at seedling stage showed the highest evenness value (0.921) and spray + perching treatment at reproductive stage was found the lowest value of evenness (0.548) followed by untreated control at same stage (0.598). In case of equitability, the highest value showed in untreated control at maximum tillering stage (3.03) and lowest in spray + perching treatment at reproductive stage (1.34).

Table 3 also indicates diversity indices of insect pests and their natural enemies at different growth stages under different treatments. The diversity index was found highest in perching treatment at reproductive stage (1.88) followed by untreated control at maximum tillering stage (1.87) and the lowest was recorded in spray + perching treatment at maximum tillering stage (1.19). In richness, the highest value was found in the treatment of spraying of Bipolar 55EC @ 10 ml/10 L of water at early tillering stage (34.79) while spray + perching treatment at maximum tillering stage showed the lowest richness value (3.87). In case of evenness, perching treatment at seedling stages showed the highest evenness value (0.982) and spray + perching treatment at maximum tillering stage showed the lowest value of evenness (0.739). In case of equitability, the highest value was observed in perching treatment at reproductive stage (4.67) and lowest in spray + perching treatment at maximum tillering stage (2.11).

Table 3. Diversity indices, richness, evenness and D value of insect pests and natural enemies recorded by sweeping net at different growth stages of rice influenced by management practices

Stages	Treatment	Diversity index (H)		Richness (M.I.)		Evenness (J)		D	
		Pests	Natural enemies	Pests	Natural enemies	Pests	Natural enemies	Pests	Natural enemies
Seedling stage	Spray	1.651	1.68	15.35	21.37	0.921	0.938	2.79	3.18
	Perching	1.506	1.76	14.42	14.75	0.84	0.982	2.23	4.36
	Spray + Perching	1.62	1.67	17.2	21.3	0.904	0.932	2.5	3.55
	Control	1.42	1.73	14.97	15.72	0.792	0.965	2.04	3.83
Early tillering stage	Spray	1.55	1.82	18.63	34.79	0.865	0.935	2.25	3.67
	Perching	1.49	1.78	15.26	26.02	0.832	0.915	2.06	3.4
	Spray + Perching	1.36	1.63	26.14	21.99	0.759	0.909	1.83	3.0
	Control	1.42	1.82	10.75	29.01	0.792	0.935	2.0	4.09
Maximum tillering stage	Spray	1.48	1.77	18.93	34.67	0.826	0.909	2.17	3.43
	Perching	1.32	1.83	9.04	33.07	0.82	0.94	2.05	3.78
	Spray + Perching	1.39	1.19	23.59	3.87	0.776	0.739	2.0	2.11
	Control	1.67	1.87	19.1	22.9	0.858	0.96	3.03	4.5
Reproductive stage	Spray	1.05	1.78	16.95	31.81	0.652	0.915	1.5	3.86
	Perching	1.25	1.88	16.39	25.56	0.697	0.966	1.68	4.67
	Spray + Perching	0.882	1.71	13.04	25.6	0.548	0.954	1.34	3.43
	Control	0.962	1.82	13.3	23.07	0.598	0.935	1.45	3.93

D=Reciprocal form of Berger Parker's dominance index.

These results are agreed with Hurlbert *et al.* (1989) who studied the diversity of the arthropod communities in paddy fields and found that the numbers of species and individuals, and the values of the diversities and evenness were distinctly different according to habitat, type of field and growth stage of the rice. This result also agreed with the findings of Khan and Alam (2007) where they reported that diversity indices of insect pests and natural enemies were found to be affected by the combined effect of management practices and growth stages of rice plant. Rahman *et al.* (2004) found that the abundance of insect pest and natural enemies was influenced by different growth stages of rice plant. They observed that the highest abundance was at reproductive stage and lowest was at mid tillering stage. Population abundance and species diversity of the spiders were found directly related to the growth stages of the rice plant. They also found that transplanted rice fields are richer both in species diversity and species richness.

Conclusion

Diversity indices of insect pests and natural enemies differed according to treatments and crop growth stages. In case of insect pests, untreated control showed the highest diversity index at maximum tillering stage and spray + perching at early tillering stage also showed highest richness and the highest evenness in spraying of Bipolar 55EC at seedling stage. The highest reciprocal form of Berger-Parker's Dominance index (D) was found in untreated control at maximum tillering stage for insect pests. In case of natural enemies, Perching showed the highest diversity index at reproductive stage and spraying of Bipolar 55EC at early tillering stage also showed highest richness and the highest evenness in perching at seedling stage. The highest D value was found in perching at reproductive stage for natural enemies. If we create better environment for natural enemies by using non-chemical control methods like perching and applying less toxic insecticides at different growth stages of rice, then greater number of natural enemies may suppress pest populations which may bring benefits to the farmers. The findings of the present study may be helpful in developing components of Integrated Pest Management (IPM) program through ecological pest management practices.

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EVALUATION OF SOME ADDITIVES FOR ACCEPTABILITY WITH ZINC PHOSPHIDE BAIT AGAINST RODENT

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Abstract

Laboratory and field study were conducted to evaluate the effects of some bait additives namely molasses, sugar, dry fish and powder milk mixed with wheat flour to increase the acceptability of additives mixed bait and the efficiency of poison bait. The findings showed that the additives mixed plain bait led to an increase the palatability and consumption rate. The most accepted plain bait for rodent was the bait combination molasses + wheat flour followed by sugar + wheat flour. The highest mortality was observed from the bait in the treatment combination powder milk + dry fish + wheat flour + Zn₃P₂ (90%) followed by (powder milk + molasses + dry fish + wheat flour + Zn₃P₂) (80%) in laboratory. The average zinc phosphide bait consumption was highest in the treatment dry fish + wheat flour + Zn₃P₂ (1.56 g/rat/day) followed by molasses + dry fish + powder milk + wheat flour + Zn₃P₂ (0.80 g/rat/day). All these additives mixed with zinc phosphide increase the consumption rate and the efficacy of bait. In field trial the higher population reduction (76-86%) was achieved from the bait dry fish + wheat flour + Zn₃P₂ followed by dry fish + powder milk + wheat flour + Zn₃P₂ (76-80%) and the lowest in powder milk + wheat flour + Zn₃P₂ (30%). All these additives mixed with zinc phosphide increased the consumption rate and the efficacy of poison bait.

Keywords: Additives, acceptability, consumption, zinc phosphide, rat.

Introduction

Rodents constitute the largest order of the existing mammals. They are the most destructive vertebrate pest of the agriculture products (Barnett and Prakash, 1975). Rodent damage buildings, household's good, electrical wire, irrigation channel etc. and they are also involved in the transmission of numerous human diseases (WHO, 1974). Mainly three to four species of rats cause damage to crops among them lesser bandicoot rat *Bandicota bengalensis* is the pre dominant species in Bangladesh. Zinc phosphide bait, snap trap and live traps are most commonly used in Bangladesh to minimize the losses. Zinc phosphide is reported to be an effective acute rodenticide. Numerous researchers have reported bait acceptance problems due to bait shyness related to bitter taste or sub-lethal illness and subsequent conditioned aversion (Prakash and Ghosh, 1992, Reidinger,

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1995). Effect of bait shyness may persist more than a year even zinc phosphide removed from the bait.

Bait shyness problems may be over come by using attracting palatable bait. Some studies have been performed to upgrade the present rodent control tactics to make it more efficient through mixing different locally available palatable food or bait additives (Pervez *et al.*, 2005; Johnston *et al.*, 2005; Naeem *et al.*, 2011). El-Gawad and Ali (1982 a) improved the efficiency of zinc phosphide bait by adding molasses to crushed maize bait. El-Rahmen (1991) studied the effect of some aromatic plants on the palatably of crushed maize. Asran (1993) enhanced bait consumption by adding sesame oil to crushed maize. Abdel-Rehman (1999) increase zinc phosphide consumption by adding powder milk, bone meal, fishmeal with crushed maize.

The present study was aimed to investigate the palatability and consumption of additives mixed zinc phosphide bait and the efficacy of poison (Zn_3P_2) bait by adding different additives such as molasses, sugar, dry fish and powder milk mixed with wheat flour in the laboratory and field condition.

Materials and Method

The study was carried out during 2012 and 2013 in the field and the laboratory of Vertebrate Pest Division, Bangladesh Agricultural Research Institute, Gazipur. Lesser bandicoot rat, *Bandicota bengalensis* was used as test animal. The animals were kept under the laboratory condition at least one week for acclimatization before starting the experiment. All the animals were starved for 6 hours before applying the treatments.

Observation of food consumption

All the baits were compared with standard bait (wheat grain). For each treatment 10 rats (5 males & 5 females) were used and they were individually caged. For all testing method 20 g of bait was provided in individual food cups and consumption rate was recorded to the nearest g on a daily basis for each rat to each food type presented. Paper was placed under each cage to recover spilled grain and to ensure accurate measurements of consumption. Daily food intake was determined by subtracting the spilled grain and the food remaining in the cup from the quantity originally given to each rat.

Preparation of zinc phosphide baits with different additives

For preparing 2% zinc phosphide bait with different additives, following combination of the ingredients were used such as powder milk (7.5%), sugar (20%), molasses (20%) dry fish (10%) mixed with wheat flour. The treatment combinations are –

T₁ = Molasses + dry fish + powder milk + wheat flour, T₂ = Sugar + dry fish + powder milk + wheat flour, T₃ = Dry fish + powder milk + wheat flour, T₄ = Molasses + dry fish + wheat flour, T₅ = Molasses + powder milk + wheat flour, T₆ = Molasses + wheat flour T₇ = Powder milk + wheat flour, T₈ = Dry fish + wheat flour, T₉ = Sugar + wheat flour

Laboratory efficacy test

All the baits were compared with standard plain bait (wheat grain). The feeding test was conducted in the laboratory using acclimatized ten adults rats for each treatment. Two cups of bait were offered to each rat, one cup containing 20 g of plain wheat grain and another cup containing 20 g additive mixed Zn₃P₂ bait. The poison bait was supplied for three consecutive days and the plain wheat grains were provided up to the end of the experiment. Spilled bait material or wheat grains were collected in a paper placed beneath the cage and weighed for both the cups. Water was supplied at *ad libitum*. Consumption of bait additive, plain bait, mortality, and baits acceptance of the rats was recorded everyday. Tested bait acceptance was calculated using the EPPO (1982) modification equation.

$$\text{Tested bait acceptance (\%)} = \frac{\text{Tested bait uptake(g)}}{\text{Tested bait uptake(g)} + \text{Standard bait uptake(g)}} \times 100$$

Field Efficacy test

The experiments were carried out at farmer's wheat fields in two different areas at Dinajpur and Rajshahi district of Bangladesh. In all the locations clear signs of rodent infestation were detected. Additive mix 2% zinc phosphide (Zn₃P₂) was used for this experiment. However, in the field test top ranking first six combinations along with wheat flour mixed with zinc phosphide were selected for the next test.

So, The treatments combination are:

T₁ = Molasses + dry fish + powder milk +wheat flour + Zn₃P₂, T₂ = Dry fish + powder milk + wheat flour + Zn₃P₂, T₃ = Molasses +dry fish + wheat flour + Zn₃P₂, T₄ = Powder milk + wheat flour + Zn₃P₂, T₅ =Dry fish + wheat flour + Zn₃P₂, T₆ =Plain wheat + Zn₃P₂ (Standard poison bait)

Two methods were namely, the active burrow count method (El-Gawad and Ali 1982 b) and the foot tracks activity (using tracking tile) method (El-Sherbiny and Awad, 1987) were used to determine the population density in each location. Twenty active burrows/spots were used for each treatment. Before applying treatment all the active burrows were identified properly. Twenty tracking tiles (20 X 20cm) for foot tact activity were used for each treatment. Foot tracks

activity were taken for two nights for both pre and post treatment operation. The pre and post treatment rodent population were determined by using both of this method.

Additives mixed zinc phosphide 10g bait was placed near the burrow opening on a piece of paper. Bait was given in the evening and was collected in the next morning. Bait was placed for consecutive three days. Each treatment was replicated in three places in each location. Consumption was recorded everyday. Efficacy of the treatment was judged on the basis of rodent activity and percent reduction in population was calculated.

Data analysis

Daily consumption of each combination of additives mix diet was converted to gram. Additives mixed plain bait uptake was compare with Student t-test. The means with standard error were also calculated. Field data were analysis by one way analysis of variance and means were separated by LSD at 0.05% probability level. In all statistical test percentage data were transformed to arcsine to stabilize variance. STAR software version 2.0.1 (2014) was used to analyze the data.

Results and Discussion

Palatability and consumption of different additives mixed plain bait

The rat consumed a significantly greater amount of additives mixed plain bait than the plain wheat grain bait. Table 1 revealed that molasses mixed with wheat flour was the most accepted bait, followed by molasses mixed with dry fish and wheat flour and the less acceptable bait was powder milk mixed with wheat flour. Bait acceptance was arranged descending order as follows: 79.15% for molasses + wheat flour > 78.07% for molasses + dry fish + wheat flour > 77.86% for Sugar + wheat flour > 71.41% for molasses +dry fish + powder milk + wheat flour > 63.36% for dry fish + wheat flour > 61.80% for sugar +dry fish +powder milk + wheat flour > 50.40% for dry fish +powder milk +wheat flour > 45.95% for powder milk + wheat flour > 45.36% for molasses + powder milk + wheat flour. It is obvious from the results that by adding additives enhanced the consumption and acceptance of bait for *B. bengalensis*.

The obtained results urged us to investigate the effect of the tested additives on the acceptance of *B. bengalensis* to 2% zinc phosphide bait loaded on wheat flour as an attempt to overcome the bait shyness phenomenon and increase the reduction of rodent population as a primary step before using other control measurements such as anticoagulant rodenticides.

Table 1. Effect of feeding test additives mixed with wheat flour and standard plain wheat on bandicoot rat *Bandicota bengalensis*

Treatment	Average body weight (g) (Mean ± SE)	Average consumption/ rat/day (g) (Mean ± SE)		Acceptance (%)
		Additives mixed bait	Plain wheat bait	
T ₁ = Molasses + dry fish + powder milk + wheat flour	231±5.72	5.32 ± 0.34 ^s	2.13 ± 0.81	71.41
T ₂ = Sugar + dry fish + powder milk + wheat flour	200 ± 9.57	8.50 ± 1.39 ^{ns}	5.25 ± 1.49	61.80
T ₃ = Dry fish + powder milk + wheat flour	232.5± 15.16	4.39 ± 1.13 ^{ns}	4.33 ± 0.80	50.40
T ₄ = Molasses + dry fish + wheat flour	217±6.72	7.94 ± 1.34 ^s	2.23 ± 0.67	78.07
T ₅ = Molasses + powder milk + wheat flour	197.1 ± 5.12	4.99 ± 1.70 ^{ns}	6.01 ± 1.69	45.36
T ₆ = Molasses + wheat flour	221.6±7.96	9.11 ± 1.99 ^s	2.40 ± 0.62	79.15
T ₇ = Powder milk + wheat flour	230.8±11.89	4.32 ± 1.40 ^{ns}	5.08 ± 1.67	45.95
T ₈ = Dry fish + wheat flour	197±5.78	5.88 ± 0.87 ^{ns}	3.4 ± 1.30	63.36
T ₉ = Sugar + wheat flour	210 ± 10.77	9.32 ± 1.64 ^s	2.65 ± 0.88	77.86

ns- non significant, s- significant differences between mean values; P = 0.05, student *t*-test, SE = Standard Error.

The effects of different additives mixed with zinc phosphide poison bait in the laboratory are presented in Table 2. It revealed that adding different additives mixed with Zinc Phosphide bait increased the efficacy of bait. The highest mortality (90%) was observed from the treatment combination where zinc phosphide was mixed with dry fish powder milk and wheat flour followed by molasses + dry fish + powder milk + wheat flour + Zn_3P_2 , and molasses + dry fish + wheat flour + Zn_3P_2 respectively. The lowest mortality (30%) was observed from the treatment combination where zinc phosphide was mixed with sugar + dry fish + powder milk + wheat flour, molasses + powder milk + wheat flour and molasses + wheat flour, respectively.

The highest zinc phosphide poison bait consumption (1.56 g/rat/day) was recorded from the treatment combination dry fish + wheat flour) followed by molasses + dry fish + powder milk + wheat flour (0.80 g/rat/day). The lowest poison bait consumption (0.14g/rat/day) was observed from the the treatment combination sugar + wheat flour.

The most accepted (33.21%) poison bait for *B. bengalensis* was the treatment combination molasses +dry fish + powder milk + wheat flour + Zn_3P_2 followed by dry fish + wheat flour + Zn_3P_2 (29.24%) (Table 2). The acceptability of the poison baits in descending order were 33.21% for molasses + dry fish + powder milk + wheat flour) > 29.24% for dry fish + wheat flour > 25.64% for dry fish + powder milk + wheat flour > 21.30% for (powder milk + wheat flour > 17.34% for molasses + dry fish + wheat flour > 17.26% for plain wheat + Zn_3P_2 .

Table 3 revealed that the total consumption of additives mixed poison bait differed significantly among the treatments. The highest poison bait consumption was recorded from the treatment combination dry fish + wheat flour + Zn_3P_2 (144g and 182.7g) in both the location at Dinajpur and Rajshahi and the lowest consumption was recorded in molasses + powder milk + wheat flour + Zn_3P_2 (50.91g) at Dinajpur and Powder milk + wheat flour + Zn_3P_2 (48.69g) at Rajshahi. The daily consumption/spot (g) of additive mixed poison bait was followed the same trend as total consumption and significantly different among the treatments.

The efficacy of different additives mixed with zinc phosphide poison bait is presented in table 4 and 5. The highest population reduction of rat was achieved from the treatment combination of zinc phosphide mixed with dry fish + wheat flour (76-86%) and dry fish + powder milk + wheat flour (76-80%) in both the location. The lowest population reduction was observed in the treatment combination zinc phosphide mixed with powder milk and wheat flour (30%) in both the location.

Table 2. Effect of choice feeding test with additives mixed with wheat flour (zinc phosphide) poison bait on the bandicoot rat *Bandicota bengalensis*

Treatments	Average body weight (g) (Mean ± SE)		Total consumption (g)		Average consumption g/rat/day (Mean ± SE)		Rat mortality (%)	Bait acceptance (%)
	Poison bait	Plain bait	Poison bait	Plain bait	Poison bait	Plain bait		
T ₁ = Molasses + dry fish + powder milk + wheat flour + Zn ₃ P ₂	241.6±10.03	7.98	16.05	0.80±0.15	1.61±0.40	80	33.21	
T ₂ = Sugar + dry fish + powder milk + wheat flour + Zn ₃ P ₂	163.2±2.86	1.81	48.19	0.18±0.06	4.82±0.32	30	3.62	
T ₃ = Dry fish + powder milk + wheat flour + Zn ₃ P ₂	238±12.85	6.9	20.01	0.69±0.09	2.01±0.61	90	25.64	
T ₄ = Molasses + dry fish + wheat flour + Zn ₃ P ₂	181.6±5.15	6.17	29.40	0.62±0.12	2.94±0.65	80	17.34	
T ₅ = Molasses + powder milk + wheat flour + Zn ₃ P ₂	223.1±5.32	3.68	56.91	0.37±0.12	5.69±0.73	30	6.07	
T ₆ = Molasses + wheat flour + Zn ₃ P ₂	221.6±7.96	2.41	151.21	0.24±0.07	15.12±1.68	30	1.57	
T ₇ = Powder milk + wheat flour + Zn ₃ P ₂	280.4±11.7	7.59	28.04	0.76±0.08	2.80±0.11	80	21.30	
T ₈ = Dry fish + wheat flour + Zn ₃ P ₂	247 ± 8.16	15.64	37.84	1.56±0.51	3.78±0.86	80	29.24	
T ₉ = Sugar + wheat flour + Zn ₃ P ₂	190.7±9.85	1.44	156.53	0.14±0.05	15.6±1.39	40	0.91	
T ₁₀ = Plain wheat + Zn ₃ P ₂	157.6±5.89	5.46	25.16	0.55±0.11	2.51±0.71	80	17.26	

Table 3. Consumption of additives mixed (zinc phosphide) poison bait by rat in field condition

Treatments	Consumption of additives mixed zinc phosphide poison bait (g) *		Consumption of additives mixed poison bait /day/spot (g)	
	Dinajpur	Rajshahi	Dinajpur	Rajshahi
T ₁ = Molasses + dry fish + powder milk + wheat flour + Zn ₃ P ₂	74.1±5.56bc	85.8±7.58bc	1.24±0.23 bc	1.43±0.47 bc
T ₂ = Dry fish + powder milk + wheat flour + Zn ₃ P ₂	123.8±12.27 a	157.8±16.59 a	2.06±0.23 b	2.63±0.59 ab
T ₃ = Molasses + powder milk + wheat flour + Zn ₃ P ₂	50.91 ±27.34 c	59.31±6.14 cd	0.85 ±0.27 c	0.99±0.29c
T ₄ = Powder milk + wheat flour + Zn ₃ P ₂	62.48±5.41 c	48.69±6.41 d	1.04 ±0.20 c	0.81±0.36 c
T ₅ = Dry fish + wheat flour + Zn ₃ P ₂	144.0±7.85 a	182.7±6.42a	2.40 ±0.33 a	3.05±0.73 a
T ₆ = Plain wheat + Zn ₃ P ₂ (Standard bait)	90.0±5.77 b	114.09±5.97 b	1.50 ±0.25 abc	1.901±0.55 abc

Mean followed by same letter does not differ significantly at 5% by LSD, SE = Standard Error.

*Average of three places, 20 spot or burrows places⁻¹

Table 4. Field efficacy of different additives mix poison bait for controlling rodent using active burrow count method

Treatments	No. of pre-treatment active burrow		No. of post-treatment active burrow		% Population reduction	
	Dinajpur	Rajshahi	Dinajpur	Rajshahi	Dinajpur	Rajshahi
T ₁ = Molasses + dry fish + powder milk + wheat flour + Zn ₃ P ₂	60	60	26	25	56.66	58.33
T ₂ = Dry fish + powder milk + wheat flour + Zn ₃ P ₂	60	60	14	12	76.67	80.00
T ₃ = Molasses + powder milk + wheat flour + Zn ₃ P ₂	60	60	34	32	43.33	46.67
T ₄ = Powder milk + wheat flour + Zn ₃ P ₂	60	60	42	41	30.00	31.66
T ₅ = Dry fish + wheat flour + Zn ₃ P ₂	60	60	11	08	81.66	86.66
T ₆ = Plain wheat + Zn ₃ P ₂ (Standard bait)	60	60	28	29	53.33	51.67

Table 5. Field efficacy of different additives mix poison bait for controlling rodent using foot tracts activity method

Treatments	No. of pre-treatment foot tracts activity		No. of post-treatment foot tracts activity		% Population reduction	
	Dinajpur	Rajshahi	Dinajpur	Rajshahi	Dinajpur	Rajshahi
T ₁ = Molasses + dry fish + powder milk + wheat flour + Zn ₃ P ₂	112	100	50	44	55.36	56.00
T ₂ = Dry fish + powder milk + wheat flour + Zn ₃ P ₂	110	102	26	22	76.36	78.43
T ₃ = Molasses + powder milk + wheat flour + Zn ₃ P ₂	116	114	62	62	46.55	45.61
T ₄ = Powder milk + wheat flour + Zn ₃ P ₂	104	106	74	74	28.85	30.19
T ₅ = Dry fish + wheat flour + Zn ₃ P ₂	118	120	28	22	76.27	81.66
T ₆ = Plain wheat + Zn ₃ P ₂ (Standard bait)	110	118	57	59	48.18	50.00

The results of this study are supported by Parasad *et al.* (1985) who found that rodents consumed significantly less poison baits than the plain alternative. In wet condition pungent effect of zinc phosphide increased which increased the bait shyness problem in rat. Molasses probably may absorbed moisture in the open field which increased the pungency of zinc phosphide and it is one of the causes for lower consumption of zinc phosphide poison bait. Behavioral change may play an important role in formulating attractive bait. Increase in bait consumption depends on addition of different additives (Naeem *et al.*, 2011). By adding sugar (glucose or sucrose) with bait increase the acceptability and palatability of cereal bait (Smith and Wilson, 1989). Use of 2% butter oil greatly enhance intake of cracked millet and this combination would yield significant control of *B. bengalensis* used as poison bait (Naeem *et al.*, 2011). El-Gawad and Ali (1982 a) enhanced the acceptance of crushed maize bait to rodent species by adding sucrose and molasses. Abdel-Rahmen (1999) increased acceptability of zinc phosphide by adding powder milk, fishmeal and blood meal to crushed maize against house mouse, *Mus musculus*. Additives added bait improve poison bait acceptance to the lesser bandicoot rat, *Bandicota bengalensis* and egg mixed zinc phosphide bait has more potential in enhancing bait acceptance of zinc phosphide against field rodents of Sindh, Pakistan (Pervez *et al.*, 2005).

Conclusion

The findings of the present study revealed that significant control of field rats in wheat might be achieved and the usage of dry fish (fish meal) based additive mix of zinc phosphide bait may be suggested for high consumption rate. However, the present findings indicate that adding additives with bait can increase bait consumption and increase the efficacy of zinc phosphide bait.

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YIELD PERFORMANCE OF STRAWBERRY GENOTYPES

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Abstract

Five strawberry genotypes ('Rabi 3', 'Camarosa', 'BARI Strawberry 1', 'BADC Strawberry' and 'Festival') were evaluated for their field performance. The maximum number of leaves/plant (14.2), canopy spread (31.82 cm) and runners/plant (7.2) were found with 'Camarosa', 'Festival' and 'Rabi 3' respectively. Festival took the lowest number of days to flower initiation (32.5). The highest number of flowers (23.64) and fruits/plant (19.98) were found in 'Camarosa'. The heaviest (21.83 g) and the largest sized individual fruit (1539.31 mm²) were produced by 'Festival'. Fruit TSS (%) was the highest (15.83) in BARI Strawberry 1. Genotype 'Festival' gave the highest fruit yield (12.94 t/ha) and 'BADC Strawberry' yielded the lowest (6.15 t/ha). Considering growth, yield and quality of fruit, genotypes 'Festival' and 'Camarosa' were found promising under the climatic condition of Salna.

Keywords: Strawberry genotype, plant growth, fruit yield, fruit quality.

Introduction

Strawberry (*Fragaria×ananassa* Duch.) is a natural hybrid species that is cultivated worldwide for its aggregate accessory fruits. It is a perennial, stoloniferous herb belonging to the Rosaceae family. The fruit is widely cultivated in the temperate and subtropical regions in many parts of the world. They are grown throughout Europe, the United States, as well as in Canada and South America. In India, it is generally cultivated in the hills of some states. The wide variation in climates within these regions and the wide adaptation of the strawberry plant permit harvesting and marketing the fruit during greater part of the year (Rahman, 2011). Strawberry is a minor exotic fruit in Bangladesh. A small scale research and development in the public and private sector is now going on. Bangladesh Agricultural Research Institute (BARI) has developed a variety named BARI Strawberry 1, Rajshahi University has developed three varieties, namely Rabi 1, Rabi 2 and Rabi 3 and BAU also developed a variety viz. FTIP-BAU-Strawberry. It is now cultivated in many parts of Bangladesh. There has been a bright prospect of farming strawberry, a high-value crop, everywhere in the country except the coastal districts. Strawberry farming has started gaining popularity in all over the country. In Bangladesh, only a few

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varieties of strawberry are being cultivated, besides there are some other genotypes too; which have higher yield compared to the released varieties (Biswas *et al.*, 2010). Early fruit bearing flower initiation, more number of fruit set, runner production, fruit weight, size, shape etc. are inherent characters; all of these contribute to yield. Different genotypes have different genetic potential. Potential yield of strawberry is not possible mainly due to climatic factors. Genotypes which have high adapting power to a wide range of environmental conditions i.e. biotic and abiotic and got better acclimatizing capacity will surely perform better. As strawberry is a temperate fruit its performance in terms of growth, yield, quality, and propagation in the tropics and subtropics are required to find out the most suitable genotype. To cultivate strawberry in Bangladesh, research on selection of appropriate genotype is the prerequisite for its commercialization. Hence, the present investigation has been carried out to find out the best genotype for optimum growth and higher yield of strawberry.

Materials and Method

The present investigation was carried out at the Horticulture Research Farm, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during the period from November 2011 to March 2012. Five genotypes, 'Rabi 3', 'Camarosa', 'BARI Strawberry 1', 'BADC Strawberry' and 'Festival', respectively were used as treatments. The experiment was laid out in a Randomized Complete Block Design with four replications. The whole experimental area was divided into four blocks representing four replications. The unit plot size was 6.0 m × 1.2 m accommodating 40 plants in each plot having row and plant spacing of 60 cm × 30 cm respectively. The unit plots and blocks were separated by 0.5 m and 0.75 m respectively. Full dose of cow dung (37 t/ha) and DAP (640 kg/ha) and half of MoP (333 kg/ha) were applied at final land preparation and rest of MoP in two installments. Intercultural operations are done as necessity. Data collection was started after 20 days of sapling planting i.e. January 08, 2012 at 10 days interval. Ten plants were selected randomly from each plot and data were recorded on individual plant basis from the selected plants in respect of: number of leaves/plant, canopy spread (cm), number of runners/plant, days to flower initiation, number of flowers/plant, number of fruits/plant, weight of individual fruit (g) and size of fruit (mm²) from 10 randomly selected matured fruits of the selected plants. Fruit color (1= Very light red, 3= Light red, 5= Intermediate red, 7= Dark red and 9= Very dark red) and shape (1= Kidney shape, 2= Oblate, 3 = Round, 4= Conical, 5= Bi-conical, 6= Almost cylindrical, 7 = Wedged, 8= Ovoid, 9= Cordate) was recorded by eye observation according to IBPGR (1986) scale, yield/plant (g), yield/plot (kg), yield (t/ha) and TSS (%). The collected data were analyzed with the help of computer using MSTATC program and mean

separation was done by Duncan's Multiple Range Test (DMRT) at 5% level of probability.

Results and Discussion

The results obtained from the present investigation have been presented and discussed character wise under separate headings.

A. Qualitative Characters

Table 1. Qualitative characteristics of strawberry genotypes

Genotypes	Fruit colour		Fruit shape	
	Score*	Remarks	Score**	Remarks
Rabi 3	5.25	Intermediate red	5.07	Bi conical
Camarosa	4.98	Intermediate red	5.68	Bi conical to Almost cylindrical
BARI Strawberry 1	5.88	Intermediate to Dark red	5.03	Bi conical
BADC Strawberry	4.04	Light to Intermediate red	4.87	Conical to Bi conical
Festival	4.67	Light to Intermediate red	5.62	Bi conical to Almost cylindrical

*Fruit color score: 1 = Very light red, 3 = Light red, 5 = Intermediate red, 7 = Dark red, 9 = Very dark red.

**Fruit shape score: 1 = Kidney, 2 = Oblate, 3 = Round, 4 = Conical, 5 = Bi-conical, 6 = Cylindrical, 7 = Wedged, 8 = Ovoid, 9 = Cordate

B. Quantitative Characters

Number of leaves per plant

The number of leaves per plant differed significantly among genotypes (Table 2). The maximum number of leaves (14.20) per plant was recorded from the genotype 'Camarosa' which was statistically identical to 'Festival' and the minimum per plant was from the genotype 'BADC Strawberry' (8.59) which was statistically identical to 'Rabi 3'. The number of leaves per plant in different genotypes varied mainly due to inherent characters of the genotypes. In Fig. 2. all the genotypes showed more or less similar increasing trend up to 50 DAP and then a tremendous increase in number of leaves in the genotype 'Camarosa' and 'Festival' up to 80 DAP. Other genotypes 'BARI Strawberry 1', 'Rabi 3' and 'BADC Strawberry' showed a similar trend of increasing number of leaves up to 80 DAP.

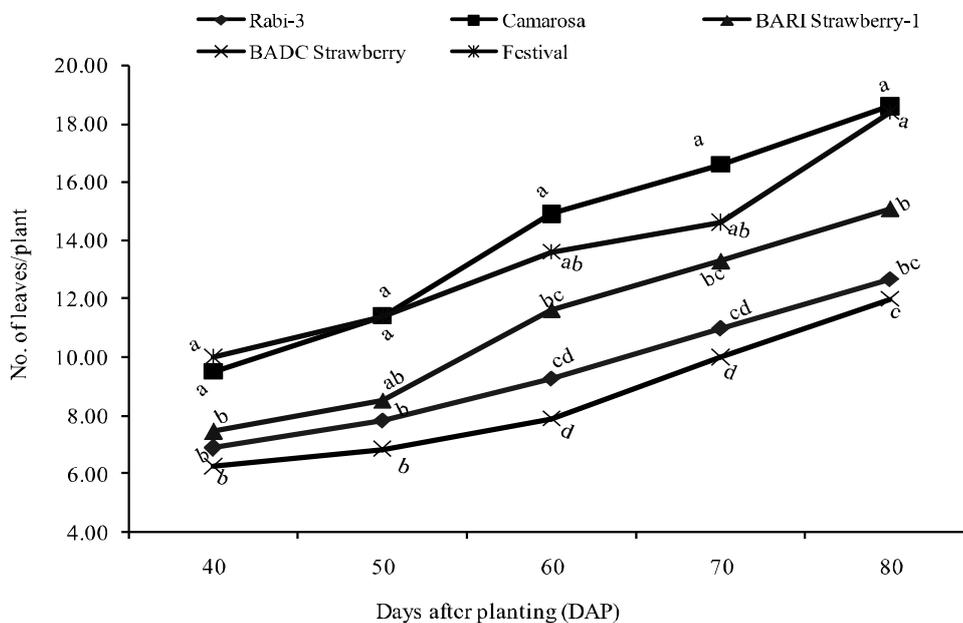


Fig. 1. Number of leaves per plant of strawberry genotypes at different days after planting.

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

Canopy spread

Canopy spread was significantly influenced by different genotypes (Table 2). Maximum (31.82 cm) canopy spread was produced by genotype 'Festival' followed by 'Rabi-3' (29.94 cm) and 'Rabi 3' (23.99 cm). Whereas minimum canopy spread was found in 'BADC Strawberry' (22.45 cm) which was statistically identical to the genotype 'BARI Strawberry 1'. Variation in canopy spread was mainly due to inherent characters of the genotypes. Canopy spread was in an uprising trend for all genotypes at different days after planting (DAP) (Fig. 2). It is noted that at 70 and 80 DAP canopy spread for all the genotypes became static.

Runners per plant

The number of runners per plant of strawberry genotypes differed significantly (Table 2). The maximum number of runner was found in 'Rabi 3' (7.20) and whereas the minimum was in genotype 'Camarosa' (1.20) and no runner was produced by genotype 'Festival' which was statistically inferior. Genotypes 'BARI Strawberry 1' and 'BADC Strawberry' were statistically identical which produced moderate number of runners. Das *et al.* (2007) found that the average number of

runners per plant in different genotypes varied from 0.3 to 9.4 and Biswas *et al.* (2010) reported it between 0.0 to 31.33. Number of runners per plant had an increasing trend for all the genotypes up to 60 DAP (Fig. 4) except for 'Camarosa' and 'Festival'. At 70 DAP all the genotypes had a declining trend which was mainly due to end of growing season and vegetative growth.

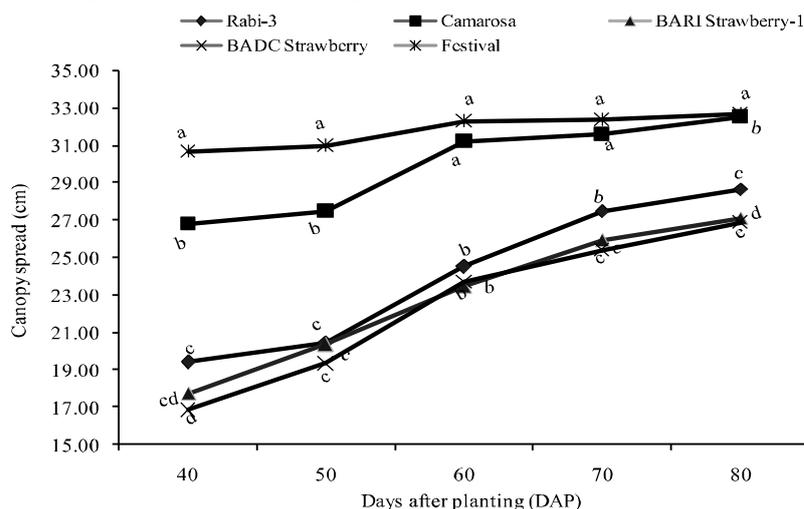


Fig. 2. Canopy spread of strawberry genotypes at different days after planting.

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

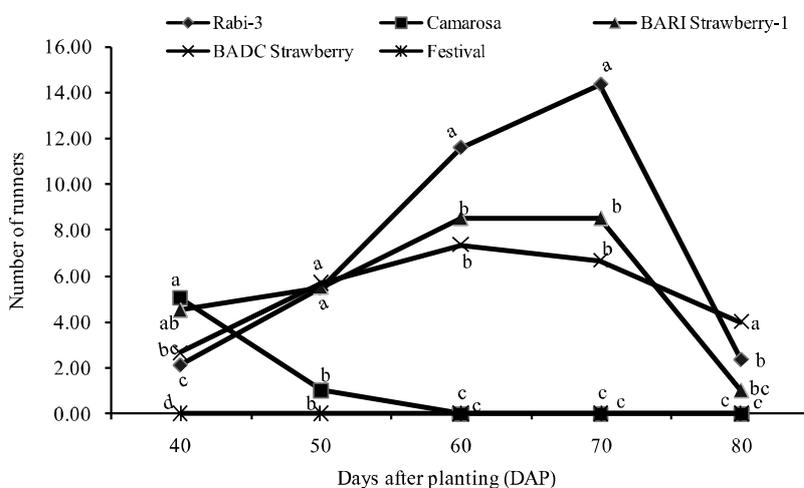


Fig. 3. Number of runners per plant of strawberry genotypes at different days after planting.

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

Table 2. Growth characteristics of five strawberry genotypes

Genotypes	No. of leaves/plant	Canopy spread (cm)	No. of runners/plant	Days to flower initiation	No. of flowers/plant	No. of fruits/plant
Rabi 3	9.53 c	23.99 c	7.20 a	44.95 c	15.45 b	11.28 b
Camarosa	14.20 a	29.94 b	1.20 c	36.80 d	23.64 a	19.98 a
(BARI Strawberry 1	11.20 b	22.94 d	5.60 b	49.63 b	11.49 c	7.41 c
BADC Strawberry	8.59 c	22.45 d	5.30 b	62.29 a	6.06 d	3.45 d
Festival	13.60 a	31.82 a	0.00 d	32.50 e	10.56 c	6.86 c
Level of Significance	*	*	*	*	*	*
CV %	4.82	1.77	16.14	2.23	4.83	5.43

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

Days to flower initiation

Days to flower initiation differed significantly among the genotypes (Table 2). The maximum days of 62.29 were required for flower initiation by the genotype 'BADC Strawberry' followed by 'BARI Strawberry 1' (49.63 days), 'Rabi 3' (44.95 days) and 'Camarosa' (36.80 days). The minimum days to flower initiation were in genotype 'Festival' (32.50 days) which was statistically different to other four genotypes. Days to flower initiation in different genotypes varied mainly due to inherent characters of the genotypes, stage of growth, day length and temperature. Rahman and Ahmad (2010) found that days to flower initiation in fifteen strawberry lines were between 44 to 90 days.

Flower per plant

Significant influence of genotypes was observed on flowers per plant (Table 2). The maximum number of flowers per plant of 23.64 recorded in V₂ (Camarosa) which was followed by 'Rabi 3'. Genotype 'BARI Strawberry 1' and 'Festival' was statistically identical and produced almost equal number of flowers per plant. The minimum number of flower (6.06) was produced by the genotype 'BADC Strawberry'; which was statistically inferior. The number of flowers/plant in different genotypes varied mainly due to inherent characters of the genotypes. Verma *et al.* (2002) found the number of flowers/plants ranged from 3.20-6.69 in different genotypes. Whereas, Rahman and Ahmad (2010) found 1 to 24 flowers per stalk in fifteen strawberry lines.

Fruit per plant

Fruits per plant is one of the most important yield contributing characters in all fruits and as well as strawberry. The genotypes significantly differed for fruit set per plant (Table 2). The highest 19.98 fruits per plant was observed in the genotype 'Camarosa' and the lowest in the genotype 'BADC Strawberry' 3.45. Rahman and Ahmad (2010) recorded 4 to 27 fruits per plant in fifteen strawberry lines which are in agreement with the present investigation.

Weight of individual fruit

As regards to the individual fruit weight, it was observed that it varied significantly differed for genotypes and ranged from 11.64 g to 21.83 g (Table 3). The heaviest fruit weight of 21.83 g was found in the genotype 'Festival' and the lightest of 11.64 g was recorded in 'BADC Strawberry' which was statistically identical to the genotype 'BARI Strawberry 1' and 'Rabi 3'. This result agrees with the findings of Maurer and Umeda (1997). They harvested strawberry fruit weight ranged from 10.6 g to 11.63 g. Biswas *et al.* (2010) in another experiment found that, fruit weight in five genotypes ranged from 12.03 g to 24.13 g.

Size of fruit (length and width)

The fruit size is varied significantly among the genotypes (Table 3). The largest fruit size of 1539.31 mm² was recorded in the genotype 'Festival' which was significantly different from rest of the genotypes. The smallest fruit size of 921.29 mm² was recorded in the genotype 'BADC Strawberry'. Asrey and Singh (2004) found fruit size (fruit length and width) of different genotypes ranged from 1016 mm² to 1431.4 mm². Biswas *et al.* (2010) reported that fruit size of five strawberry genotypes varied between 738 mm² to 2072.02 mm²; which supports the present findings.

Total Soluble Solids (TSS)

A significant variation was observed regarding the TSS (%) among the genotypes (Table 3). The highest TSS (15.83 %) was recorded from the genotype 'BARI Strawberry 1'. The minimum fruit TSS (9.98%) was in the genotype 'Festival' which was statistically similar to the genotype 'Camarosa'. Fruit TSS percent varied mainly due to inherent control of the genotypes. Waliullah *et al.* (2011) found fruit TSS per cent of strawberry ranged from 9.33 to 12.33 in different genotypes including BARI Strawberry 1.

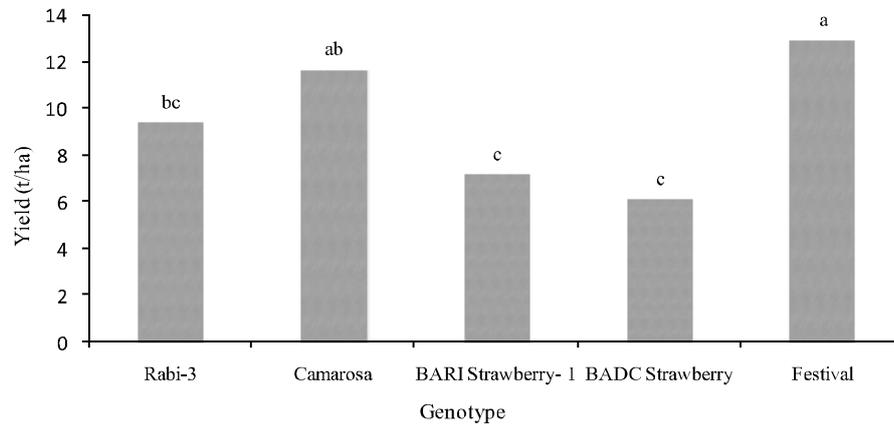
Table 3. Fruit characteristics of five strawberry genotypes

Genotypes	Weight of individual fruit (g)	Size (mm ²)	Fruit TSS (%)
Rabi 3	13.86 bc	1014.99 b	12.74 b
Camarosa	16.38 b	1139.02 b	12.20 bc
BARI Strawberry 1	13.31 bc	1027.02 b	15.83 a
BADC Strawberry	11.64 c	921.29 b	13.16 b
Festival	21.83 a	1539.31 a	9.98 c
Level of Significance	*	*	*
CV %	11.44	12.40	9.34

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

Fruit yield per hectare

Fruits yield per hectare was significantly differed in different strawberry genotypes. Among the entries, the genotype 'Festival' produced the highest fruit yield of 12.94 ton per hectare which was statistically similar to Camarosa. The lowest yield of 6.15 ton per hectare was obtained from the genotype 'BADC Strawberry' which was inferior. Legard *et al.* (2000) harvested fruits of three strawberry cultivars and obtained a yield ranged from 14.81 - 22.38 ton per ha which supports the above findings of the present investigation.

**Fig. 4. Yield of different strawberry genotypes.**

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

Conclusion

Among the five genotypes studied, 'Festival' was the highest yielder compared to others genotypes. Genotype 'Camarosa' had the maximum number of flower and

fruit set. The number of runners per plant increased up to 60 DAP for all genotypes except 'Camarosa' and 'Festival'. So, these two genotypes are difficult to propagate through runners.

Acknowledgments:

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ADOPTION OF WHEAT VARIETIES IN BANGLADESH: EXPERT ELICITATION APPROACH

M. A. RASHID¹ AND TANVIR M. B. HOSSAIN²

Abstract

The study was undertaken to find out variety wise adoption rate of wheat in Bangladesh through expert elicitation procedure. Many varieties have been developed by Wheat Research Centre (WRC) but in details of varietal information and adoption information database was not developed which is very important and valuable for the scientist and policy planner. This study through expert elicitation for constructing detail varietal development and adoption database is timely and necessary for the research institute. From all over the Bangladesh 14 experts was invited to share their valuable knowledge and experience on wheat cultivation and adoption in the country. The average age of the experts were 54 yrs and average experience on wheat adoption was 22.65 yrs. The wheat expert informed that 13 major varieties are adopted by the farmers in the recent year(2013-14). Among those varieties, BARI Gom 24 (Prodip) covered highest cultivated area (186026 ha) which shared 41.03% of total wheat cultivated area. BARI Gom 21 (Shatabdi), BARI Gom 26 and BARI Gom 23 (Bijoy) ranked 2nd, 3rd and 4th position according to the share of cultivated area covered. The seed production information showed that BADC the only wheat seed producer supplied 24912.60 mt of wheat seed in the year 2013-14. The trend of seed production by different wheat variety revealed that over the period 2010-14, the seed production of BARI Gom 24 (Prodip) increased and BARI Gom 21 (Shatabdi) decreased. Increased seed production trend of Prodip variety led to highest adopted area of that variety. The main reason behind highest adopted area of Prodip variety was its very attractive attributes like high yield, big spike, large grain and lodging tolerance character. Although the Prodip covered highest area but other newly developed variety like BARI Gom 25, BARI Gom 26, BARI Gom 27 and BARI Gom 28 were the most promising varieties which showed increasing adoption path among the expert. These varieties have very good potentiality due to having short duration, tolerance to terminal heat stress, tolerant to salinity and lodging attributes. Satisfying higher demand for wheat consumption and ensuring food security through providing alternative to rice are the major concerning issue of the policy planner and the scientist. Therefore, the study have been undertaken to fulfill this issues.

Keywords: economics, expert elicitation, varietal adoption.

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1. Introduction and background

1.1. Position of wheat and change over time

Wheat is third highest growing cereals on the basis of cultivation area. Farmers of Bangladesh cultivated wheat on 453421 ha of cultivated land and produced 1375270 mt of wheat in the year 2014 (Fig.1). The average yield of wheat was 3.03 mt/ha. Wheat cultivation area shared 4.77% of net cropped area and 2.5% of total cropped area of Bangladesh in year 2010-11. Irrigated wheat cultivated area covered 3,46,558 ac of land which was 5.06% of total irrigated area of Bangladesh in the year 2010-11. The average per capita per day intake of rice was 416 gm and wheat was 26 gm. Wheat contributes 2.6% of per capita per day total consumption of Bangladesh people. Wheat consumption was increased by 2.14 times in 2010 compare to consumption amount of the year 2005 (BBS, 2010). Wheat grows in the sub-tropic and tropic region of Bangladesh. In that region the mean temperature during growing period (November to April) of wheat range from 18.8 °C to 25.3 °C. Prior to 1975–76, wheat was grown sporadically and was almost an unknown crop in Bangladesh (Banglapedia, 2006). Between 1970–71 and 1980–81, the cropped area under wheat jumped from 0.126 million ha to 0.591 million ha and production rose 10-fold from 0.11 million tons to 1.07 million tons, a 24.93 % annual mean growth rate (BARI, 2010).

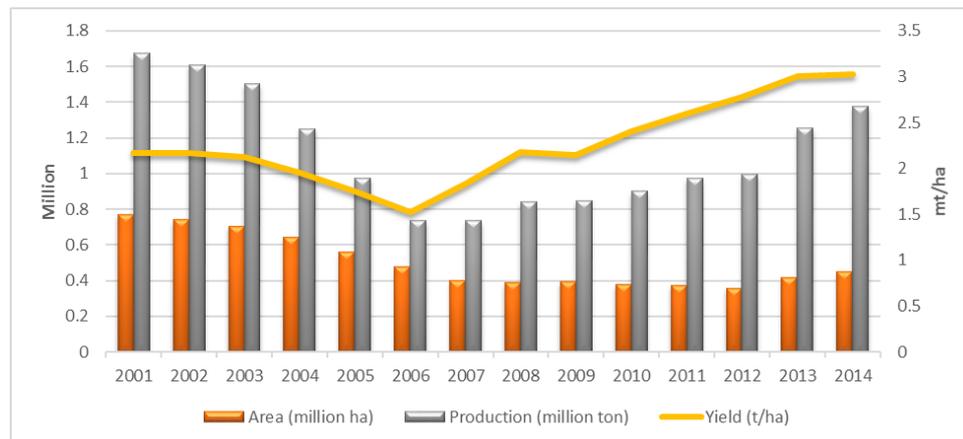


Fig.1. Area, production and yield of wheat cultivation in the period 2001-14.

Reason of change in consumption

Even though most of the wheat varieties developed by the researcher in Bangladesh are high yielding varieties, but due to slow increase of cultivation area and production those wheat varieties did not keep pace sufficiently to match with the increasing demand of wheat created by increased population. The

changing habit of cereal consumption also helped to increase demand for wheat compare to rice (WRC, 2009). In this situation, to meet the demand of an increasing population and to secure future food security, the government of Bangladesh imported more wheat between 2008 and 2011.

Import history

Bangladesh is net importer of wheat and the country imported wheat 31,12,314 mt (Fig-2) in the year 2011 (FAOStat, 2014) and from the national statistical source the imported wheat was worth of Tk. 86,46,84,88,000 in the year 2010-11 (BBS, 2011). Wheat import increased with growth rate 11.52% per year over the period 2007-11. After the time of independence (1971), Bangladesh had become highly dependent on wheat imports while dietary preferences were changing such that wheat was becoming a highly desirable food supplement to rice. Wheat also accounted for the greatest bulk of imported food grains, exceeding 1 million tons annually and rising above 1.8 million tons in 1984, 1985 and 1987 (Index Mundi, 2012a). The great bulk of wheat importation is financed under aid programmes of the USA, the European Union and the World Food Programme (Index Mundi, 2012b). A 3-year (2008–09 to 2010–11) examination by O'Brien (2011) indicated that Bangladesh imported 3.1 million metric tons of wheat each year to ensure local demand.

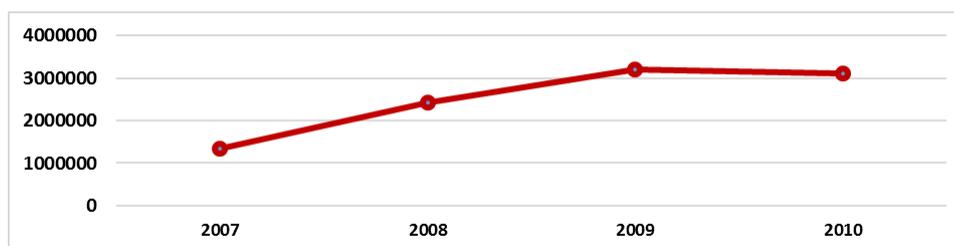


Fig.2. Trend line of wheat import in the period 2007-10.

Regional status and history of wheat cultivation

Wheat cultivation area is grouped by zone on the basis intensive growing districts. Highest wheat growing zone in the year 2011-12 was Rangpur zone (62.8%) followed by Rajshahi (16.96%), Jessore (8%), Barisal (7.98%) and others (4.26%). The trend analysis revealed changing scenario of wheat cultivation area, production and yield of the different zone

Wheat cultivation in Bangladesh within the period 2007-12 is grouped into 5 regions. Bangladesh experienced increased wheat cultivation area by 7.48% per annum within the period 2007-12. With per year change rate, wheat cultivation area has been increased at Rajshahi (0.28%), Rangpur (18.53%), and Barisal (2.76%) region and decreased at Jessore zone (-1.4%). The large number of

growth rate in those regions helped to increase wheat cultivation area in Bangladesh. Increased wheat production (mt) per year was observed at Rajshahi (7.33%), Rangpur (3.85%), Jessore (6.69%), and Barisal (13.37%) regions. In spite of having negative growth rate in other zone the country as whole achieved increase production (5.57%) per year with in that period 2007-12.

The wheat cultivation area and production didn't kept pace with positive relation. Highest rate of wheat yield (mt/ha) growth was observed of Barisal (10.62%), Jessore (8.38%) and Rajshahi (7.05%) zone. Although, there is an increase and decrease trend of yield among the zones. But Bangladesh as a whole couldn't manage to increase yield per year (-1.9%) with in the period 2007-12.

1.2. Background of introducing wheat research in Bangladesh

Wheat breeding research started in Bangladesh after the liberation war. The 'Noori 70', 'Balaka' and 'Doel' were first varieties developed by the scientists of BARI with the support of CIMMYT. The variety Noori 70 was developed in the year 1976 and 'Balaka' and 'Doel' were developed in the year 1980. In the initial stages of wheat growing in Bangladesh, several Mexican varieties, especially 'Sonora 64' and 'Kalyansona', were successfully introduced in collaboration with the International Maize and Wheat Improvement Center (CIMMYT). However, the release of 'Sonalika' created a true breakthrough in wheat production in the year 1972. This fast maturing and high-yielding variety (yield = 2 tons ha⁻¹) became very popular among wheat growers and adapted well to different production environments, and was adopted in 80% of the wheat area by the early 1980s (WRC, 2009). In 1983, the Wheat Research Centre (WRC) of Bangladesh Agricultural Research Institute (BARI), released four more high-yielding (yield = 2–3 tons ha⁻¹) varieties ('Ananda', 'Kanchan', 'Barkat', and 'Akbar'). Among these, 'Kanchan' proved particularly adaptable and gradually replaced 'Sonalika' to become the predominant variety in Bangladesh by the early 1990s. Two other high-yielding varieties, 'Aghrani' and 'Protiva', were recommended by the Bangladesh National Seed Board in 1987 and 1993, respectively. These varieties were more responsive to a wider range of weather conditions as well as crop management practices such as fertilizers, irrigation and intercultural operations. Therefore, by the mid-1990s, adoption of high-yielding varieties were almost 100%, thereby increasing wheat productivity substantially.

However, breeding efforts to develop high-yielding varieties still continued. Several more high-yielding varieties were developed. These included 'BARI Gom 19' ('Sourav') and 'BARI Gom 20' ('Gourab') released in 1998; 'BARI Gom 21' ('Shatabdi') in 2000; 'BARI Gom 22' ('Sufi'), 'BARI Gom 23' ('Bijoy') and 'BARI Gom 24' ('Prodip') in 2005 (Pandit *et al.*, 2011); and 'BARI Gom 25' and 'BARI Gom 26' released in 2010 (BARI, 2012*b*). In 2012, two varieties, 'BARI Gom 27' and 'BARI Gom 28', were released and also in

2014, another two more varieties, 'BARI Gom 29' and 'BARI Gom 30' were released.

1.3 Statement of the problem

BARI has released good number of high yielding varieties and improved management technologies of wheat crop. The Department of Agricultural Extension (DAE) has been involved in developmental programs for the technology transfer of this crop through its countrywide networks. This initiatives make the productivity growth of wheat increasing to a great extent. This impressive information indicates the immediate need of strengthening the current efforts of improved variety adoption at farm level. Although the released varieties have been found to be suitable for farmers, for various unknown reasons, a large number of farmers throughout the country are still reluctant to adopt these improved varieties that need to be evaluated properly. Since many farmers have not adopted these varieties, the level of wheat production remains far below of its potential.

With the detailed adoption information, the concern authority and agencies can formulate appropriate policy for the development of wheat crop across the country. Again, potential adoption of the improved varieties would generate employment and additional income for the rural poor and save foreign exchange through producing more of this crop utilizing fallow and under used lands in the country. Therefore, nationally representative and up-to-date data and information on the adoption of wheat cultivation are lacking in Bangladesh. This information could be useful for both government and donor agencies in investing more on wheat improvement programs in Bangladesh.

1.5 Objectives of the study

- i) To document and process on varietal release at the national level
- ii) To find out variety wise adoption rate of wheat in Bangladesh and
- iii) To suggest policy implication from the findings

2. Methodology

2.1 Data and data sources

The main approach is to assemble relevant information and data of most recent year from multiple sources. This study collected time series data from national data sources i.e Bangladesh Bureau of Statistics, Department of Agricultural Extension. This study heavily collected for varietal development information from Wheat Research Centre (WRC), of Bangladesh Agricultural Research Institute. The collected varietal information were sourced from different annual research report of WRC and BARI, Handbook of BARI developed crop varieties

and technologies. The authors of this study gathered very valuable information from scientist consultation and expert elicitation (EE) workshop.

2.2 Details of experts

A panel of knowledgeable experts about the adoption of wheat cultivars in the zones (ecosystem, season or administrative zone) was formed. The expert panel consisted of 14 experts including scientists (breeders, agronomists, and agricultural economists), extension workers, seed producers & traders, think tank and farmers. The expert informed about wheat production systems in the region as well as at national level. Among the experts, 35.7% were from different national agricultural research institutions (Table 2.1).

Table 2.1. Experts involved in elicitation for wheat cultivation and production workshop

Discipline of experts	No. of experts by discipline	No of experts from NARS	No of experts from non NARS
Scientist	5	5	-
Extension	3	-	3
Seed producer	1	-	1
Think tank	3	-	3
Farmers	2	-	2
Total	14	5	9

Source: Expert elicitation workshop, 2014.

Wheat is grown all over the country sporadically. In spite of that there are some districts where wheat cultivation share is significantly large. Higher wheat cultivation shared district were grouped in to four zones i.e Rajshahi, Rangpur, Jessore and Barisal (Table-2.2). These four zones covered 94% of total wheat cultivation area of Bangladesh.

Table 2.2. Zone wise gross cropped areas and production of wheat in Bangladesh in the year 2014

Zone	Cultivated Area (ha)	Cultivated Area (%)	Production (MT)	Yield (t/ha)
Rajshahi Zone	166782	36.78	539967	3.24
Rangpur Zone	124921	27.55	365873	2.93
Jessore Zone	63417	13.99	186389	2.94
Barisal Zone	71136	15.69	205838	2.89
Other zone	27165	5.99	77203	2.84
Total	453421	100.00	1375270	3.03

Source: DAE, 2014.

3. Results and Discussion

3.1 More details about experts

Age of expert plays an important role to share knowledge regarding the varietal adoption in EE workshop. Average age of expert was 54 yrs old and the range of expert's age was from 44 yrs to 72 yrs. The expert had 22.65 yrs of experience on crop and the range of expert's experience year was from 3.5 yrs to 48 yrs. The maximum years of experiences in present institute was 45 yrs and minimum was 3 yrs in the EE workshop. The average year of experience of expert in present institute was 19.25 yrs (Table 3.1).

Table 3.1. Quantification of expert's characteristics

Expert characteristics	Mean	Min	Max
Age (years)	54	44	72
Years of experience on crop	22.65	3.5	48
Years of experience in present institute	19.25	3	45

Source: Expert elicitation workshop, 2014.

Table 3.2. Number of varieties developed in different period

Period	Total varieties listed in data set 1	No. of MV's
Pre 1965	-	-
1965-1970	2	2
1971-1975	6	6
1976-1980	4	4
1981-1985	4	4
1986-1990	4	4
1991-1995	2	2
1996-2000	8	8
2001-2005	4	4
2006-10	2	2
2010 till now	6	6
Total	40	40

Source: BARI, 2010-12.

3.2 Trends in varietal release

By the time of independence (1971), Bangladesh had become highly dependent on wheat imports while dietary preferences were changing such that wheat was becoming a highly desirable food supplement to rice. In the initial stages of

wheat growing in Bangladesh, the release of ‘Sonalika’ in 1972 created a true breakthrough in wheat production. Between 1971–75 and 1986–1990 BARI has developed and released 18 modern varieties of wheat in Bangladesh with the collaboration of CIMMYT (Table 3.2). By the mid-1990s to till now, adoption of high-yielding varieties was almost 100%, thereby increasing wheat productivity substantially. However, breeding efforts to develop high-yielding varieties still continued. Several more high-yielding varieties were developed by BARI.

Seed Certification Agency of Ministry of Agriculture officially releases variety developed by public, private and NGO. In the Table-3.3, it is observed that 83% of variety used by the farmers were officially released variety. The variety developed by the NARS or together with CGAIR, 100% of them are improved variety. Among the improved or modern varieties (40) of wheat, the top most contributor was NARS (80%) of the total contribution followed by CGIAR (47.5%) and private sector (15%).

Table 3.3. Share of contribution and linkage of different organization in varietal development

Crop	Total number of varieties	Number of varieties linked with CGIAR	Number of varieties linked with NARS	Number of varieties linked with Private Sector companies/ institutions
Wheat	40	19 (47.5%)	34 (85%)	6 (15%)

Source: Own calculation.

Table 3.4. Number of varieties linked with CGIAR, NARS and Private Seed Companies

Period	Total MV's	Number of varieties linked with CGIAR	Number of varieties linked with NARS	Number of varieties linked with Private Sector companies/ institutions
Pre 1965	-	-	-	-
1965-1970	2	1	2	1
1971-1975	6	5	6	-
1976-1980	4	2	3	1
1981-1985	4	3	4	1
1986-1990	4	2	4	2
1991-1995	2	1	2	1
1996-2000	8	3	3	-
2001-2005	4	-	3	-
2006-2010	2	-	2	-
2011 till now	4	2	4	-
Total	40	19	34	6

Source: BARI, 2010-12.

By time and source

Among the modern varieties (40), CGIAR was the key role player (19) to develop wheat varieties during 1965-2014 followed by NARS (34) and private sector (6) in Bangladesh (Table-3.4).

3.3 Trends in varietal adoption

An attempt was made to assess the level of adoption of wheat variety in terms of area cultivated by farmers adopted at farm level. The level of adoption of wheat variety was mostly depended on the dissemination process used by BARI in association with the DAE. The scientists of BARI has been developed and disseminated 40 wheat varieties to the farmers since 1973. The finding of the EE workshop revealed that the farmers adopted wheat varieties such as BARI Gom 24 (Prodip), BARI Gom 21 (Shatabdi), BARI Gom 26, BARI Gom 23 (Bijoy), BARI Gom 25, BARI Gom 19 (Sourav), BARI Gom 18 (Protiva), and BARI Gom 27 etc. Among those adopted varieties, BARI Gom 24 (Prodip) was highly adopted variety (41.03%) followed by Shatabdi (24.97%), BARI Gom 26 (11.43%), Bijoy (11.06%) and BARI Gom 25 (4.45%). Others varieties such as Sourav, Protiva, and BARI Gom 27 etc. occupied 7.07% of the total wheat areas in Bangladesh (Table 3.5).

Table 3.5. Adoption area and share of area identified by the expert

List top Modern Variety (MV) as identified in EE	Total country/ domain cropped/ net sown area (ha)	% Area adopted under the variety (ha) by EE
BARI Gom 24 (Prodip)	186026	41.03
BARI Gom 21 (Shatabdi)	113221	24.97
BARI Gom 26	51814	11.43
BARI Gom 23 (Bijoy)	50170	11.06
BARI Gom 25	20165	4.45
BARI Gom 19 (Sourav)	8175	1.80
BARI Gom 18 (Protiva)	5160	1.14
BARI Gom 27	4938	1.09
Kanchan	3627	0.80
BARI Gom 28	3249	0.72
BARI Gom 20 (Gourav)	2802	0.62
Others	2135	0.47
BARI Gom 22 (Sufi)	1519	0.34
Inkilab	419	0.09

Source: Expert elicitation workshop, 2014.

3.4 Different from the adoption statistics seen in literature

There is no detail wheat varietal adoption level study in Bangladesh. A very recent study conducted by WRC (2014) revealed the adoption level information of wheat varieties in the Bangladesh. The study showed that BARI Gom 24 (Prodip) is the dominant variety occupied across the country which covered 39% of total wheat areas (Table 3.6). This results supported by the EE workshop results but there was a little bit differences (2.03). BARI released other improved wheat variety BARI Gom 21 (Shatabdi) covered 35% of total wheat area which was much higher differences (-10.03) than the EE workshop results due to that adoption rate was for the some specific areas results. Same scenario was observed in case BARI Gom 23 (Bijoy). Another improved variety BARI Gom 26 covered 12% of the total wheat areas which was more or less same (-0.57) to the EE workshop results.

Table 3.6. Adoption area and their difference with other sources

List top MV variety as identified in EE	% Area adopted under the variety (ha) by EE	% Area adopted under the variety (ha) as seen in literature/ national survey/ other source	% difference between the two
Kanchan	0.80	-	-
BARI Gom 18 (Protiva)	1.14	-	-
BARI Gom 19 (Sourav)	1.80	-	-
BARI Gom 20 (Gourav)	0.62	-	-
Inkilab	0.09	-	-
BARI Gom 21 (Shatabdi)	24.97	35.00	-10.03
BARI Gom 22 (Sufi)	0.34	-	-
BARI Gom 23 (Bijoy)	11.06	6.00	5.06
BARI Gom 24 (Prodip)	41.03	39.00	2.03
BARI Gom 25	4.45	6.00	-1.55
BARI Gom 26	11.43	12.00	-0.57
BARI Gom 27	1.09	-	-
BARI Gom 28	0.72	-	-
Others	0.47	2.00	-1.53

Source: Expert elicitation workshop, 2014 & BARI, 2012a.

3.5 Variety wise quantities of foundation or breeder seed

The public seed production system includes many organization i.e National Agricultural Research System (NARS), Bangladesh Agricultural Development

Corporation (BADC), private seed company, NGO's, contract farmers and seed dealers. The crop research institutes of NARS are responsible for producing breeder seed of any crop variety which they developed and released. BADC multiplies the foundation seed from the breeder seed through its own seed producing farms. BADC multiplies foundation seed to certified seed and truthfully label seed (TLS) through their own seed multiplication farms or through contract farmers. BADC purchased seed from the contract grower and sell it to the farmers through the licensed seed dealers, and NGOs. Private seed companies also multiply foundation seed to truthfully label seed and sell those to the farmers.

The Table 3.7 presented amount of seed production in the year 2013-14 and 4 yrs (2009-13) average amount of seed production by the BADC (Table 3.8). Highest amount of certified and TLS seed (21041.15 mt) (84%) of BARI Gom 24 (Prodip) was produced by BADC which covered 84% of total seed production in the year 2013-14 FY. This indicated that Prodip had higher demand among the farmers in the year 2013-14 and it was followed by BARI Gom 23 (1571.45 mt) and BARI Gom 26 (859.02 mt). The certified and TLS seed production trend line (Fig. 4) showed that seed production of BARI Gom (Prodip) increased over the period 2009-14. On the other hand, seed production of BARI Gom 21 (Shatabdi) reduced gradually. Very minor change is observed in production of BARI Gom 23 (Bijoy).

Table 3.7. Seed production by the BADC according to various wheat variety

Variety name	Breeder seed (MT)		Foundation seed (MT)		Certified & TLS seed (MT)	
	2009-13 (avg)	2013-14	2009-13 (avg)	2013-14	2009-13 (avg)	2013-14
BARI Gom 19 (Sourav)	-	-	-	-	219.28	-
BARI Gom 20 (Gourav)	-	-	-	-	277.16	-
BARI Gom 21 (Shatabdi)	67.98	-	589.88	-	9535.04	776.08
BARI Gom 23 (Bijoy)	67.15	-	233.89	124.75	1480.52	1571.45
BARI Gom 24 (Prodip)	171.84	-	815.52	940.71	10564.91	21042.15
BARI Gom 25	47.42	223	45.03	386.9	256.60	663.91
BARI Gom 26	50.18	346.53	54.63	273.92	326.69	859.02
Total Seed production	404.58	569.63	1738.95	1726.28	22660.21	24912.60

Source: BADC, 2014.

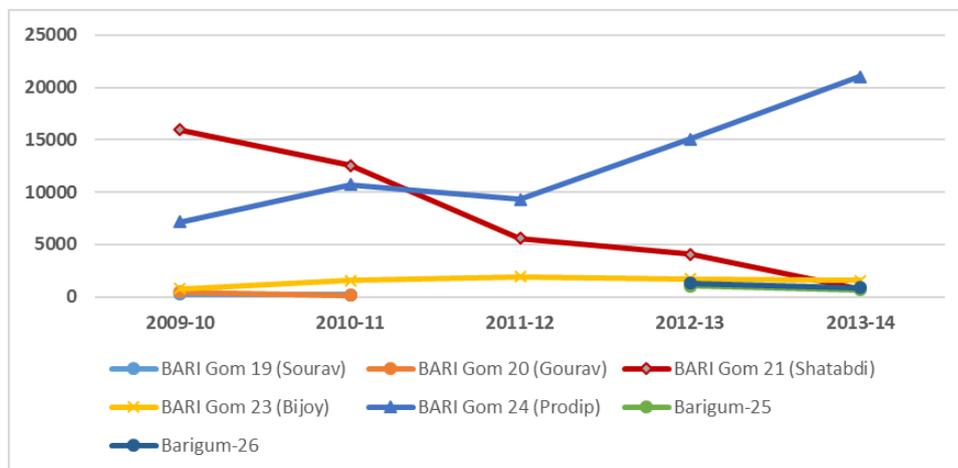


Fig. 4. Trend of seed production in the period 2010-14.

3.6 Varieties attributes

Farmers adopted wheat varieties due to some favorable varietal attributes. Different varieties have many type of different attributes. The experts in EE workshop explained the major reason behind adoption of any specific variety through identifying their main attributes. The major varietal attributes that attracted wheat farmers were mostly high yielder, bold and larger grain, short duration, tolerance to terminal heat stress and lodging. The early maturity, tolerant to salinity, and high yielding attributes of BARI Gom 25 were attracted by the farmers which led to a significant adoption level. BARI Gom 26 is well adopted due to its heat tolerant, short duration and disease resistant attributes. BARI Gom 27 and BARI Gom 28 are in increasing trend due to its special attributes like disease resistant to leaf and stem rust and also heat tolerant, and high yield.

3.7 Reasons for popular varieties were phasing

There are many varieties which have phased out from the farmer's field. Varieties were phased out due to releasing new wheat varieties by the researcher and adopting by the farmers. The new varieties are better than old varieties considering higher yield, tolerance to terminal heat stress and lodging, easy seed production and storage, tolerant to leaf rust disease and change in consumption preferences.

4. Conclusion and Recommendations

Many varieties have been developed by WRC but in details of varietal information and adoption information database was not developed which is very

important and valuable for the scientist and policy planner. This study through expert elicitation for constructing detail varietal development and adoption database is timely and necessary for the research institute. The information provided through this study would help the breeder for improving variety considering reason of non-adoption by the farmers. This valuable information will also help the government and donor agencies in investing more on wheat improvement programs in Bangladesh.

From all over the Bangladesh 14 experts was invited to share their valuable knowledge and experience on wheat cultivation and adoption in the country. The average experience of the experts on wheat adoption was 22.65 yrs.

The number of total variety released in the Bangladesh was 40 in the period 1965-2014 and highest number of variety released in the period 1996-2000. Very recently, the WRC of BARI developed and released 6 improved varieties from 2010 to till now. In development process of modern varieties WRC of NARS shared 85% of linkage and CGIAR shared 47.5% of linkage. Number of released variety linked with CGIAR was highest in the period 1971-1975 and NARS also had linkage in highest number of released variety on the same period.

The wheat expert informed that 13 major varieties are adopted by the farmers in the recent years. Among those varieties, BARI Gom 24 (Prodip) covered highest cultivated area (186026 ha) which shared 41.03% of total wheat cultivated area. BARI Gom 21 (Shatabdi), BARI Gom 26 and BARI Gom 23 (Bijoy) ranked 2nd, 3rd and 4th position according to the share of cultivated area covered. There is a very minor difference between the expert opinion and published information about percentage of area adopted for wheat cultivation.

The seed production information showed that BADC the only wheat seed producer supplied 24912.60 mt of wheat seed in the year 2013-14. The trend of seed production by different wheat variety revealed that over the period 2010-14, the seed production of BARI Gom 24 (Prodip) increased and BARI Gom 21 (Shatabdi) decreased. Increased seed production trend of Prodip variety led to highest adopted area of that variety. The main reason behind highest adopted area of Prodip variety was its very attractive attributes like high yield, big spike, large grain and lodging tolerance character. Although the Prodip covered highest area but other newly developed variety like BARI Gom 25, BARI Gom 26, BARI Gom 27 and BARI Gom 28 were the most promising varieties which showed increasing adoption path among the expert. These varieties have very good potentiality due to having short duration, tolerance to terminal heat stress, tolerant to salinity and lodging attributes.

Satisfying higher demand for wheat consumption and ensuring food security through providing alternative to rice are the major concerning issue of the policy planner and the scientist. Although many high yielding promising varieties were

developed through devoted effort of scientist of Bangladesh, but due to lack of proper planning and implementation the adoption rate of those varieties are very low and speed of adoption are slow. Effective planning to increase seed production and extension are the most important and demanding issue for increasing area adoption and production of high yielding wheat varieties thus consequently ensure food security through increase consumption and reduce import dependency on wheat.

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EFFECT OF PRETREATMENTS AND PACKAGING ON THE GROWTH OF BACTERIA IN VALUE ADDED SUMMER ONION PRODUCTS

M. M. ALAM¹ AND M. N. ISLAM²

Abstract

The experiment was carried out to investigate the bacteria in fresh and different processed onion. Total number of viable bacteria (cfu/g) in fresh onion and dehydrated processed onion packed in High Density Polyethylene (HDPE) and Aluminum foil (ALF) was estimated at 0, 6 and 12 month interval following storage at room temperature (RT, 20-25°C) and refrigerated temperature (RFT, 5°C). Samples tested were fresh onion (S₀), dried onion (S₁), blanched and dried (S₂), blanched + sulphited and dried (S₃), 25% salt osmosed and dried (S₄), 60% sugar osmosed and dried (S₅) and 55/15% sugar-salt osmosed dried onion (S₆). It was found that the lowest bacterial count (2×10^1 and 9×10^1 cfu/g) was given by 25% salt osmosed onion (S₄) and the total number of viable bacteria (TVB) count in the other samples varied in the order of S₃ < S₆ < S₅ < S₂ < S₁ ($45-97 \times 10^3$ cfu/g) and sample S₁ having no pretreatment before drying gave the highest TVB among the samples and the preservation effect was only due to reduction of a_w during drying.

Keywords: Pretreatments, packaging, bacteria, value added summer onion

Introduction

Onion is a herbal crop used as a spice in various food items principally in Indian Sub-continent and some other part of Asia. Onion is a bulb growing on the upper surface of the soil where the leaves of the onion become thick and watery starting from the stem and tapering to the top forming a bulb. Soil is the store house of all kinds of microorganisms and when soil adheres to the outer surface of the bulb the onion is contaminated. Water, air and handling may also contaminate onion. Microorganisms thus transferred in freshly harvested onion may find their way to processed product. The number and kind of spoilage microorganisms could be reduced by avoiding or removing contaminated outer leaves, by chemical preservative, heat treatment of onion, careful dehydration, sizing and milling the onions (Sheneman, 1973).

The aerobic mesophilic bacteria are important for measuring the microbiological quality of the fresh and processed product. Hence the growth of microorganisms in fresh and processed onions is important to develop high quality preserved onion especially from safety and hygienic view point (Sheneman, 1973).

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Vaughn (1951) investigated the effect of various production factors on microbiological population of onions and other dehydrated vegetables. He showed that steam blanching of raw vegetables could reduce 99.9 % of total plate count. Dehydrated unblanched onions had higher bacterial population, than those of all blanched vegetables. Vaughn (1951) also studied the incidence and significance of several groups of bacteria in dehydrated onion and garlic and observed that it was difficult to select a meaningful quantitative index for microbiological quality of dehydrated onion products.

A number of bacteria can grow in high concentrations of sugar or salt called osmophilic organisms. Some of them are able to grow at water activity as low as 0.60 (Frazier and Westhoff, 1978). Nunheimer and Fabian (1940) stated that the growth and activity of staphylococci are inhibited at 15 % salt concentration and cannot survive at 20 % salt concentration.

A study showed that 36 nonpathogenic bacteria did not grow over 16% salt and 31 pathogenic organisms did not grow at 10 % salt solution. Among the yeast genus, *Rhodotorula* were found most resistant to salt. *Clostridium botulinum*, an anaerobic bacterium, was inhibited under certain conditions in 10 percent salt concentration (Weiser, 1967).

The sugar and its concentrations have been shown to determine its ability to accelerate or prevent the growth of micro-organisms. Usually sugar concentration from 1 to 10 percent will materially influence the growth of certain kinds of organisms, while a strength of 50 % sugar stopped the growth of most bacteria and yeasts. Bacteria rarely survive in 20 to 25 % sugar concentrations; usually 70 % sugar stopped the growth of all micro-organisms (Weiser, 1967).

The incidence of microorganisms in vegetables may be expected to reflect the sanitary quality of the processing steps and the microbiological condition of the raw product at the time of processing. Splittstoesser *et al.* (1961) showed that the total counts ranged from log 5.60 to over 6.00 in green beans before blanching in 2 production plants. After blanching, the total numbers were reduced to log 3.00-3.60/g. After passing through the various processing stages and packaging, the counts (after packaging) ranged from log 4.72-5.94/g.

Jay (1978) stated that blanching or scalding is a vital step prior to dehydration. This may be achieved by immersion in hot water at 100°C for 1-8 min, depending upon the particular type of product. The primary function of this step is to destroy enzymes that may bring about undesirable changes in the finished products. Leafy vegetables generally require less time for blanching than peas, beans, or carrots. It has been shown that for many vegetables safe drying temperature ranges from 60-63°C. The moisture content of vegetables could be reduced below 4% in order to satisfactory quality and storage. Vegetables may

also be treated with SO₂ or a sulfite for better product. The drying of vegetables is usually done using tunnel, belt, or cabinet driers.

Fanelli *et al.* (1965) found that reconstituted dehydrated onion soup contain a mean total bacterial count of log 5.11/ml, with log 3.00 coliforms, log 4.00 aerobic sporeformers and log 1.08/ml of yeast and molds. On cooking the total counts were reduced to a mean of log 2.15 while coliforms were reduced to less than log 0.26, sporeformers to log 1.64 and yeasts and molds to less than log 1.00/ml.

McBean (1976) and Stafford *et al.* (1972) showed that sulfur dioxide preserves the texture, flavor, vitamins content and color of food. Sulphiting is widely used in the food industry to reduce fruit darkening during drying and storage. The sulfur dioxide from sulphiting displaces air from the tissue in plant materials, softens cell walls so that drying occurs more easily, destroys enzymes that cause darkening of cut surfaces, shows fungicidal and insecticidal properties, and enhances the bright attractive color of dried fruits. It also inhibits enzymatic and non enzymatic browning in dried fruit during storage and preserves ascorbic acid and carotene.

The overall objective of the research work was bacterial studies of fresh and dehydrated summer onion.

Materials and Method

Onion used in this study were washed and sliced into 5 mm thickness and initial moisture content was determined by oven drying method. Initial weight of each slice were taken. Some slices osmosed in 60% sucrose, 25% salt and 55/15% sucrose-salt up to 24 hr and weighted and subsequently individually marked by using different coloured threads. After the end of each definite time the slices were removed and quickly rinsed in water. Subsequently, surface water was removed by gently blotting with tissue-paper. The ratio of sugar to onion slices was 5:1 w/w.

The pieces which were used in this study were fresh onion, dried onion, blanching in hot water for 2 min. and dried, blanching and sulphiting with 1500 ppm KMS and dried, immersed into 60% sucrose, 25% salt and 55/15% sucrose-salt solutions and dried.

The fresh and processed onion were packed in high density polyethylene (HDPE) and aluminium foil (ALF) and stored at room temperature (RT) and at refrigeration temperature (RFT). The stored dehydrated products (treated and untreated) were observed and analysed for growth and activity of bacteria at an interval of 6 months.

The bacteria count was done in the laboratory of Seed Pathology Center and the department of Food Technology and Rural Industries, Bangladesh Agricultural University (BAU), Mymensingh.

Determination of total viable Bacteria

The total viable bacteria present in the fresh, dried and osmo-dehydrated onion were calculated following the standard plate count methods and technique as describe by Ranganna (1991) and Harrigan (1998).

Preparation of agar media

About 23.5 g of agar mix powder (containing, Casein-5 g, Yeast extract 2.5 g, Dextrose 1.0 g and Agar 15.0 g) was taken in a conical flask and 1000 ml distilled water was added to it. It was heated to boiling for few minutes and then cooled to about 40⁰ C temperature.

Preparation of ringer solution

About 2.15 g of sodium chloride, 0.075 g of potassium chloride, 0.12 g of calcium chloride and 0.5g sodium thiosulphate were taken in a conical flask and mixed with 1000 ml distilled water.

Sample preparation

The reliability of the analysis and interpretation of the results depend largely on the correct manner in which the sample was taken. The sample must be a true representative of the whole mass. For this purpose the product is thoroughly well mixed so that the sample would be the representative of the whole mass of the products. 10g of well mixed onion were taken in 100 ml volumetric flask and the volume was made up to 100 ml with the ringer solution and mixed well by up-and-down or to-and-fro movement.

At the same time to avoid contamination all the apparatus, solutions and other tools used were sterilized by heating in steam at 121°C under 15 psi atmospheric pressure for 15 minutes. The prepared sample which already become diluted to 10 times was used as stock solution.

Dilution

A series of dilution were made as follows using 9 ml blanks.

- a) The initial $\frac{1}{10}$ dilution (10 g in 90 ml ringer solution) was performed
- b) This was mixed well in a vortex mixer. It becomes 10^{-1} time's dilution.
- c) 1 ml from (b) was taken and added to the next tube containing 9 ml ringer solution and mixed well. It become 10^{-2} times dilution

d) 1 ml from (c) was taken and added to next tube containing 9 ml ringer solution and mixed well. It then becomes 10^{-3} time's dilution.

In this way, the dilution was made up to 10^{-6} times. The scheme is shown in fig.1

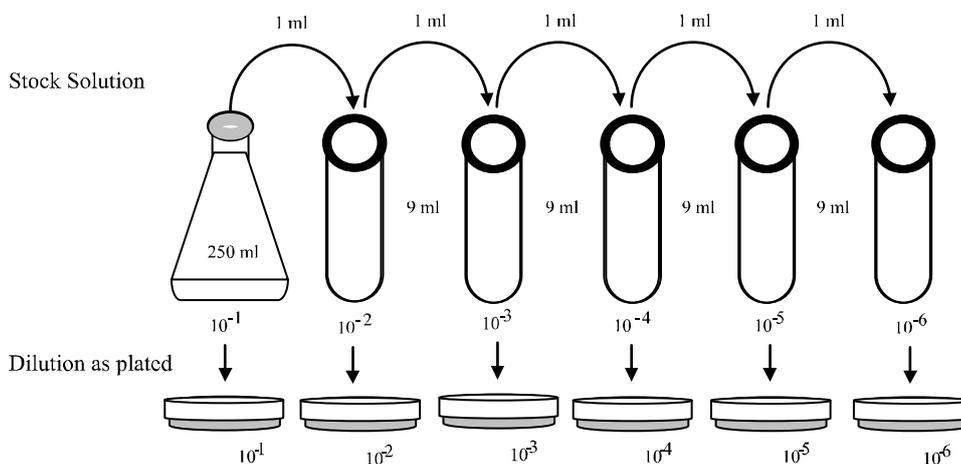


Fig.1 Simple serial dilution series using 9 ml blanks and plating.

Standard plate counts (SPC)

Six sterilised petridishes were taken and each petridish was marked with each dilution number. About 15-20 ml nutrient agar media was taken in each petridish. 1 ml of the diluted sample was then pipetted into each of these sterile petridishes. The contents of the plates were mixed well by swirling on a flat surface. Each dilution was plated in triplicate. After solidification of the media the plates were kept in incubator invertedly and incubated at 37°C for 24 to 72 hrs.

Counting and recording

After incubation for stipulated time the petridishes were taken out and checked. The plates containing segregated, overlapping and confusing colonies were avoided. The plates containing 30 to 250 bright, cleared and countable colonies were selected for easy counting of the colony.

Number of colony forming unit (cfu)/g or ml. = average cfu/plate \times dilution factor

Results and Discussion

Total number of viable bacteria present in fresh onion and processed onion packed in HDPE and aluminum foil (ALF) was estimated at 0, 6 and 12 month interval following storage at room temperature (RT, $20-25^{\circ}\text{C}$) and refrigerated temperature (RFT, 5°C). The total number of viable bacteria (TVB) present per g of different types of dehydrated onion samples were calculated by multiplying

the total number of colony forming units (cfu) on the plate with its dilution factor. The results for TVB are given in Table 1 and the results and discussion for bacterial growth are presented below.

From Table 1, it is seen that initial number of viable bacteria was highest (9.5×10^4 TVB) in fresh onion (S_0) compared to dried onion samples (S_1 to S_6) and was successively followed by dried onion without pretreatment (S_1) with 4.5×10^4 TVB, only blanched and dried onion (S_2) with 7.5×10^3 TVB, 60% sugar osmosed and dried onion (S_5) with 4.7×10^3 TVB, 55/15 % sugar-salt osmosed and dried (S_6) with 2.5×10^3 TVB, blanched, sulphited and dried onion (S_3) with 2.5×10^2 TVB, while the lowest bacterial count (2×10^1 TVB) was given by 25% salt osmosed and dried onion (S_4).

Table 1. Growth of bacteria in fresh and dried onion in different packaging materials during 12 month of storage at RT and RFT

Types of sample	Bacteria count on the day of preparation of dried onion	No of bacteria in Room temperature (RT)				No of bacteria Refrigeration temperature (RFT)			
		Packed in HDPE		Packed in aluminum foil		Packed in HDPE		Packed in aluminum foil	
		6 month	12 month	6 month	12 month	6 month	12 month	6 month	12 month
		cfu/g	cfu/g	cfu/g	cfu/g	cfu/g	cfu/g	cfu/g	cfu/g
S_0	9.5×10^4								
S_1	4.5×10^4	7.8×10^4	9.7×10^4	4.6×10^4	4.6×10^4	5.0×10^4	5.2×10^4	4.5×10^4	4.5×10^4
S_2	7.5×10^3	8.8×10^3	9.2×10^3	7.5×10^3	7.6×10^3	7.8×10^3	7.9×10^3	7.5×10^3	7.6×10^3
S_3	2.5×10^2	5.5×10^2	6.7×10^2	2.7×10^2	2.7×10^2	3.0×10^2	3.2×10^2	2.6×10^2	2.6×10^2
S_4	2×10^1	7×10^1	9×10^1	3×10^1	3×10^1	4×10^1	5×10^1	2×10^1	2×10^1
S_5	4.7×10^3	6.5×10^3	8.5×10^3	4.9×10^3	4.8×10^3	5.4×10^3	5.8×10^3	4.7×10^3	4.7×10^3
S_6	2.5×10^3	3.9×10^3	5.4×10^3	2.7×10^3	2.7×10^3	2.7×10^3	3.8×10^3	2.5×10^3	2.6×10^3

S_0 = Fresh onion, S_1 = Dried onion, S_2 = Blanching in hot water for 2 min. and dried, S_3 = Blanching + Sulfiting with 1500ppm KMS and dried, S_4 = Osmosed with 25% salt solution and dried, S_5 = Osmosed with 60% sugar solution and dried, S_6 = Osmosed with 55/15% Sugar- salt solution and dried.

From Table 1, it is found that upon 12 month storage in HDPE at RT the highest no. of bacteria was found in sample without pretreatment S_1 (9.7×10^4) followed successively by S_2 (9.2×10^3), S_5 (8.5×10^3), S_6 (5.4×10^3), S_3 (6.7×10^2) and the lowest number (9×10^1) was given by S_4 (25% salt osmosed and dried). On the other hand, the highest number of bacteria for the same duration in ALF at RT was found again in sample S_1 (4.6×10^4) followed in descending order by S_2 (7.6×10^3), S_5 (4.8×10^3), S_6 (2.7×10^3), S_3 (2.7×10^2) and S_4 (3×10^1). It is thus

seen that number of viable bacteria/g (TVB) in all samples were lower in ALF compared to HDPE upon 12 month storage at RT. In case of RFT it was also seen that the highest number of bacteria in HDPE was found in sample S₁ (5.2×10^4) followed by S₂ (7.9×10^3), S₅ (5.8×10^3), S₆ (3.8×10^3), S₃ (3.2×10^2) and S₄ (5×10^1). It is also seen that the above samples gave lower bacterial count up to 12 month in ALF compared to HDPE (both at RFT), as well as maintained similar sample order as noted for HDPE at RFT (i.e highest in S₁ and the lowest in S₄) in respect of bacterial growth. The highest number was 45×10^3 in S₁ and the lowest number was 2×10^1 in S₄. It is thus found that for a given sample in similar packaging material gave lower number of bacteria for a given storage period at RFT than at RT. While keeping other conditions (such as storage time and temperature) constant, any one of the samples gives lower bacterial count in ALF than in HDPE. Again, at a given identical packaging and temperature conditions, 25% salt osmosed product gave the lowest bacterial count among the samples for a given period. In general the initial bacterial count and that following storage were the highest in S₀/S₁ and was followed in descending order by S₂, S₅, S₆, S₃ and S₄ after a specific period at constant conditions such as temperature and packaging.

From Table 1, it is also seen that all processed samples in HDPE as well as ALF shows higher number of total bacteria count as storage time at RT as well as RFT increases. It was thus of interest to analyze dependence of bacterial growth on time to show whether it follows first order reaction kinetics. Data were analyzed as per Heldman (1977) and Villota and Hawkes (1992) and rate constants were calculated and shown in Table 2.

Table 2. Rate constant of growth of bacteria in different film and storage condition.

Organism	Storage Condition	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆
Bacteria	RT +HDPE	0.768	0.204	0.986	1.504	0.592	0.770
	RT+ALF	0.022	0.013	0.077	0.405	0.062	0.077
	RFT+HDPE	0.145	0.052	0.247	0.916	0.210	0.419
	RFT+ALF	-	0.013	0.039	-	-	0.039

S₁= Dried onion, S₂ = Blanching in hot water for 2 min. and dried, S₃ = Blanching + Sulfiting with 1500ppm KMS and dried, S₄ = Osmosed with 25% salt solution and dried, S₅ = Osmosed with 60% sugar solution and dried, S₆ = Osmosed with 55/15% Sugar- salt solution and dried.

From Table 2 it is seen that amongst the samples the highest rate constant (K) was found in S₄, at any constant storage condition such as: RT +HDPE, RT+ALF etc. and varied from 0-1.504^{-yr}. Rate constants were very low and in some cases even zero for RFT+ALF. For a given sample at RT or RFT, K value

is much higher for a given product packed in HDPE than in ALF. Again for any one of the samples packed either in HDPE or in foil, K value is quite higher at RT compared to RFT. Rate constant values suggest that TVB count and position shown earlier may be shifted after storage period longer than one year.

The observation that the lowest bacterial count is given by 25% salt osmosed onion and the TVB count in the other samples varied in ascending order such as S_3 , S_6 , S_5 , S_2 and S_1 may be attributed to the differences of the effect of pretreatment prior to drying (with resultant a_w depression) such as infusion of salt during osmosis (S_4), presence of sulphur + heat inactivation (in S_3), infusion of salt-sugar following osmosis (S_6), infused sucrose (S_5), blanching or heat inactivation (S_2) and sample receiving no pretreatment (S_1) before drying gave the highest TVB among the samples and the preservation effect in this case (S_1) is only due to reduction of a_w during drying.

Sodium chloride when infused in food system reduces water activity when compared to original food with similar moisture content. Additionally microorganisms are sensitive to the toxicity of NaCl (Nickerson and Sinsky, 1997). Sodium actually combines with protoplasmic anions of the cell and thus exerts a toxic effect upon the organisms (Winslow and Falk, 1923). Another concept is the toxicity of the Cl ion. Kadam *et al.* (2009) found almost similar result (bacteria 18.33 cfu/g) after 5 month of storage of dried onion, when onions were treated with KMS and sodium chloride. Salt has a marked effect in suppressing the growth of many undesirable organisms in food products. The micro-organisms may grow but their enzyme systems may be altered in such a way that no noticeable change takes place in the food. NaCl has a very fixed lethal action in the presence of heat (as in drying) against many kinds of micro cocci. It is observed that likewise, alkaline solutions of salt tend to reduce the thermal death times of spores. Several investigators opined that NaCl in concentrations used in food preservation is not a bactericide but serves as a bacteriostatic agent against most varieties of microorganisms. As reported by Weiser, (1967), the U.S Department of Agriculture (USDA), however stated that 18-25 % brine solution would prevent microbial growth.

The observed highest rate constant (1.5/yr) given by 25% salt osmosed onion (S_4) in RT+HDPE may be due to low initial bacterial count resulting in lower level of competition as well as dilution of salt following water uptake during storage. However due to initial lowest TVB after 1 yr. of storage TVB is still the lowest and negligible (2×10^1 - 9×10^1 TVB/g).

Sulfur dioxide or salts of sulfur are used in foods in order to prevent enzymatic and non enzymatic browning but these are also used in numerous instances to prevent the growth of undesirable microorganisms (Arsdel *et al.*, 1973, Nickerson and Sinsky, 1977). The preservative action of SO_2 has been attributed

to its reaction with the carbonyls of carbohydrates, thus preventing their utilization as a source of energy, or the reduction of S-S linkages in enzyme proteins, thus preventing enzyme activities (Joslyn and Braverman, 1954). Rehm (1964) showed that nicotinic amide adenine dinucleotide (NAD)-dependent factors concerned with the metabolism of certain carbohydrates by some yeast and bacteria are inhibited by sulfurous acid, probably due to the formation of additional compounds between the two components. While discussing preservative action of sulfur dioxide, Rahman (1999) mentioned that sulphiting is widely used in the food industry to reduce fruit darkening during drying and storage. The sulfur dioxide from sulphiting displaces air from the tissue in plant materials, softens cell walls so that drying occurs more easily, destroys enzymes that cause darkening of cut surfaces, shows fungicidal and insecticidal properties, and enhances the bright attractive color of dried fruits. McBean (1976) also reported that SO_2 inhibits enzymatic and non enzymatic browning in dried fruit during storage and preserves ascorbic acid and carotene.

However, a disadvantage of sulphite is that it may be detected by some people at very low concentration in the reconstituted product and consider the taste objectionable (Arsdel *et al.*, 1973).

Blanching inactivates enzymes, reduces of microorganisms and displaces entrapped air in the plant tissues. It has been claimed by Jay (1978) that initial microbial loads as high as 99% will be reduced by blanching. Similar effect of blanching on microbial load has been indicated by Arsdel *et al.* (1973). Fuselli *et al.* (2004) showed that the use of additional barriers such as blanching or brine immersion produces an important effect on the microbiological stability in garlic and onion products. Thus combined effect of blanching and sulphiting was more pronounced as in S_3 (with 6.7×10^2 TVB) compared to S_2 (with 9.2×10^3 TVB) securing after 12 month in HDPE at RT (the worst condition).

Lower number of bacteria in S_5 and S_6 compared to both S_1 and S_2 may be attributed to infused sugar and sugar-salt respectively during osmosis. Salt and sugar act very much in the same way upon microorganisms. If the salt and sugar concentration are sufficiently high it acts as preservative by increasing the osmotic pressure. The moisture content of the food is withdrawn and the tissues are plasmolyzed thus there is insufficient moisture for the growth of microorganisms. Erickson and Fabian (1942) investigated the germicidal action of various sugars and reported that addition of sugar and salt could reduce the water activity (a_w) of a food.

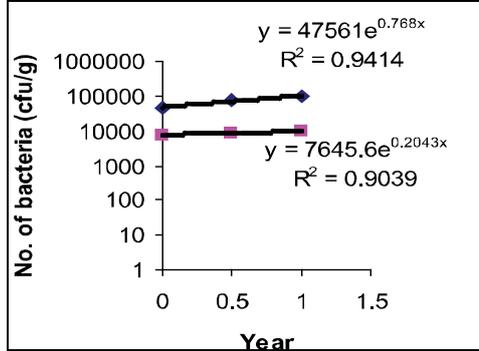


Fig. 1. TVB in HDPE at 0, 6 and 12 month for RT for S₁ & S₂.

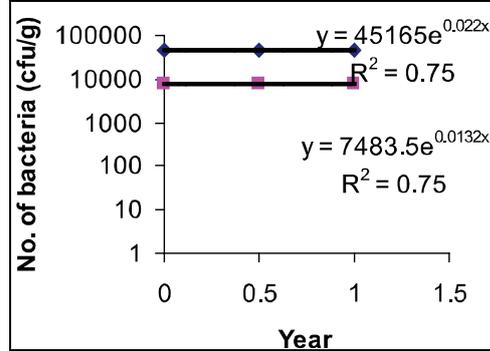


Fig. 4. TVB in ALF at 0, 6 and 12 month for RT for S₁ & S₂.

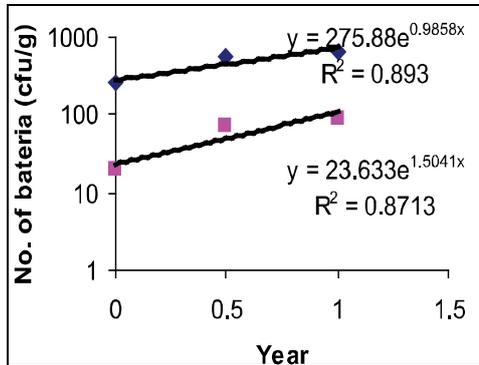


Fig. 2. TVB in HDPE at 0, 6 and 12 month for RT for S₃ & S₄.

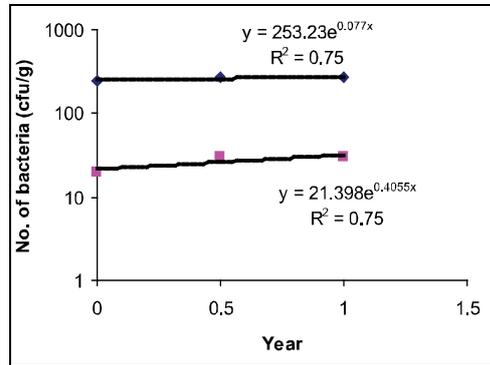


Fig. 5. TVB in ALF at 0, 6 and 12 month for RT for S₃ & S₄.

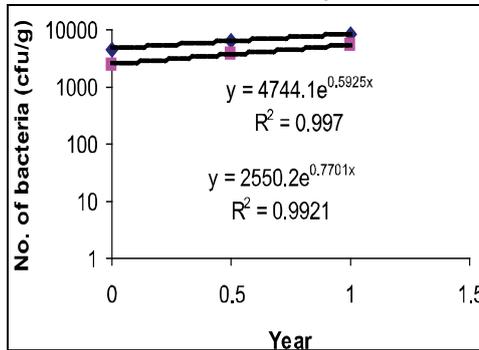


Fig. 3. TVB in HDPE at 0, 6 and 12 month for RT for S₅ & S₆.

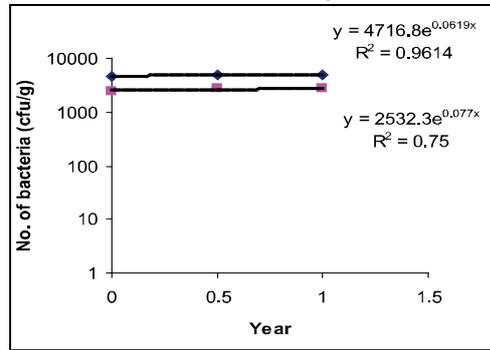


Fig. 6. TVB in ALF at 0, 6 and 12 month for RT for S₅ & S₆.

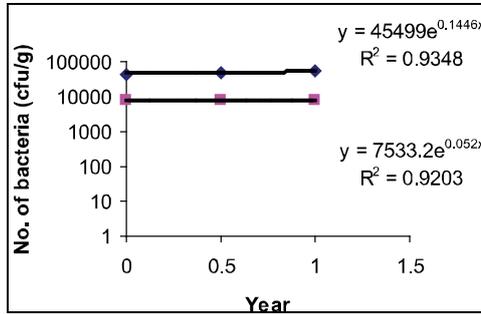


Fig. 7. TVB in HDPE at 0, 6 and 12 month for RFT for S₁ & S₂.

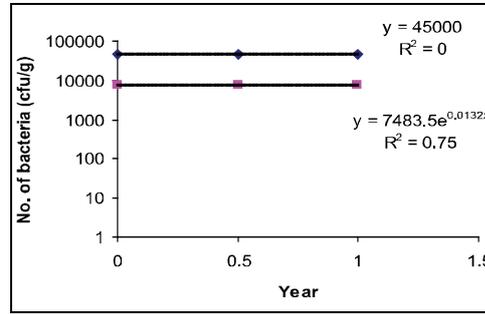


Fig. 10. TVB in ALF at 0, 6 and 12 month for RFT for S₁ & S₂.

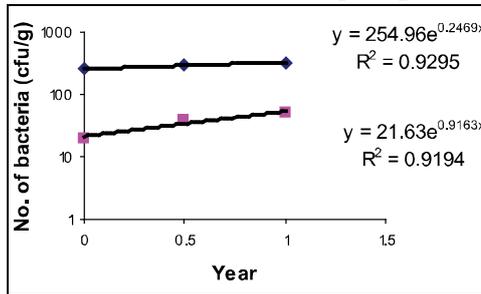


Fig. 8. TVB in HDPE at 0, 6 and 12 month for RFT for S₃ & S₄.

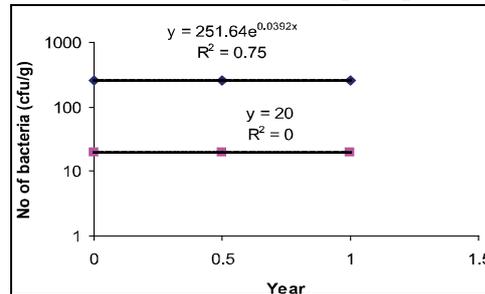


Fig. 11. TVB in ALF at 0, 6 and 12 month for RFT for S₃ & S₄.

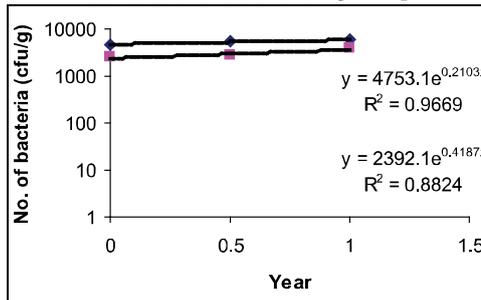


Fig. 9. TVB in HDPE at 0, 6 and 12 month for RFT for S₅ & S₆.

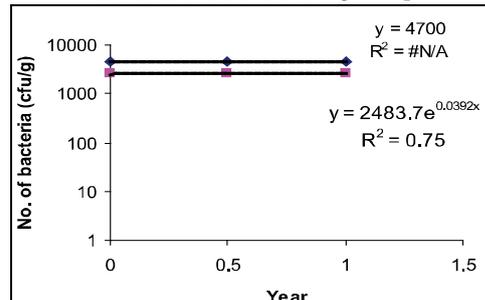


Fig. 12. TVB in ALF at 0, 6 and 12 month for RFT for S₅ & S₆.

The observed lower TVB in S₆ (2.7×10^3) and S₅ (4.8×10^3) compared to S₁ (4.6×10^4 TVB) and S₂ (7.6×10^3) in ALF at RT (12 month) may be attributed to infusion of salt and sugar respectively. Salt is more effective chemical to inhibit bacteria by a_w depression and toxicity, where as sugar is not that effective. The results are in agreement with the finding of Jay (1978) who stated that sugars, such as sucrose, exerted their preserving effect in essentially the same manner as salt, but it generally requires about 6 times sucrose than NaCl to effect the same degree of inhibition. It should be pointed out that the bacterial count in dehydrated sample without pretreatment (S₁) is also not that high particularly

after 12 months in ALF at RT (46×10^3 TVB) due to low moisture content (following drying) and resultant a_w (0.2) and the product is shelf-stable (Islam and Flink, 1982 b, Nickerson and Sinskey 1977).

Higher rate constant as well as TVB for samples in HDPE compared to ALF at both RT and RFT storage is due to more water migration through HDPE than ALF. Comparatively higher moisture uptake by HDPE than ALF with resultant increased a_w , depends on permeability, thickness and temperature.

The observation that the bacterial load of all treated sample in RFT storage either packed in HDPE or ALF showed comparatively lower bacterial count as well as lower rate constant (Table 1 and Table 2) than those stored at RT is due to the fact that bacterial activity is lower at low temperature such as 5°C compared to room temperature ($20\text{-}25^{\circ}\text{C}$). In fact rate constant of bacterial growth has an Arrhenius type relationship with absolute temperature (Heldman, 1977, Villota and Hawkes, 1992).

Conclusion

For long time storage Alaminus Forl (ALF) may be used at Room Temperature (RT). The pretreated samples particularly 25% salt osmosed + dried onion, 55/15 % sugar/salt osmosed dried, blanched sulphited dried onion, blanched dried are recommended for drying and storage from microbial stability point of view, cost of osmosis solution etc.

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**ORGANOGENESIS IN OKRA (*Abelmoschus esculentus* L. Moench.):
A PLANT RECALCITRANT TO TISSUE CULTURE**

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Abstract

Seedling-derived cotyledonary nodes and hypocotyl explants of BARI Dherosh-1 were cultured *in vitro* on MS medium supplemented with varying concentrations of 2, 4-Dichlorophenoxy acetic acid (2, 4-D), 6-Benzylaminopurine (BAP), Thidiazuron (TDZ), BAP with 1-Nepthaleneacetic acid (NAA), BAP with Indole 3-butyric acid (IAA) and Zeatin with IAA along with a control. Shooting response (100%) with callus was only observed from cotyledonary nodes on thidiazuron (TDZ) where hypocotyls produced only callus or callus with roots on different concentrations of plant growth regulators. Considering the shooting response, the cotyledonary nodes of BARI Dherosh-1 were cultured on various concentrations of TDZ for regeneration. The highest percentage (64.0) with maximum number (6.8) of shoots per explant were observed in 0.044 μ M TDZ in 8.4 days. The regenerated shoots were rooted on ½ strength MS, MS supplemented with 2.46 μ M IBA and 0.53 μ M NAA. The highest percentage (83.3) and minimum days (9.7) required for root induction were recorded in 2.46 μ M IBA. The rooted plantlets were transferred to soil and hardened in the plastic pots under green house conditions. The rooted shoots grew normally under natural conditions following acclimatization.

Keywords: *Abelmoschus esculentus*, cotyledonary node, TDZ, IBA.

Introduction

Okra (*Abelmoschus esculentus* L Moench.) is cultivated in tropical, subtropical and warm temperate regions around the world including Bangladesh. It belongs to the Malvaceae family and is known by many local names in different parts of the world. It is called lady's finger outside of the United States, gumbo in parts of the United States and English-speaking Caribbean and in Southern Asia, its name is usually a variant of bhindi or vendi. It is a good source of protein, vitamin C and A, iron, calcium (Aworh *et al.* 1980; Ihekoronye and Ngoddy 1985) and dietary fiber (Adom *et al.*, 1996). It is known as powerhouse of valuable nutrients having low calories and is fat-free. Its ripe seeds are roasted, ground and used as a substitute of coffee in some countries. Extracts from the seeds of okra is viewed as alternative source for edible oil. The oil content of the seed is high at about 40%. Therefore, considerable attention should be given for the improvement of this vegetable.

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In 2012-13, okra production was 44.0 thousand metric tons from 10.66 thousand hectares of land in Bangladesh (BBS, 2015). Despite of its importance, the production of okra is very low in Bangladesh compared to other countries in the world because it is frequently infected by a number of systemic diseases caused by fungi, viruses, bacteria, mycoplasma and nematodes. Among of them Yellow Vein Mosaic Virus (YVMV) transmitted by whitefly (*Bemisia tabaci*) is the most serious disease of okra. It may reduce the production up to 90% (Pullaiah *et al.*, 1998; Kucharek, 2004). Vectors usually attack the young okra plants at the vegetative stage for virus transmission. Frequent use of pesticides by the farmers, without recognizing the vector(s) may create toxic residues in the food chain. Recognizing its economic importance there is a massive scope of utilizing modern biotechnology for further improvement of okra, because conventional plant breeding methods are difficult and time consuming. Therefore, genetic transformation technology could be used to overcome this problem; hence a regeneration protocol is prerequisite (Mitra, 2011). But a very few number of regeneration protocol has been reported to date (Dhande *et al.*, 2012; Ganesan *et al.*, 2007; Haider *et al.*, 1993) probably due to low percentage of regeneration, excretion of mucilage and phenolic compounds from explants to medium and browning of callus. Therefore, the present research was undertaken to develop a simple and efficient regeneration protocol of okra aiming at future genetic transformation.

Materials and Method

Plant materials, explants sterilization and culture conditions: BARI Dherosh 1 seeds were collected from Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur. Clean and healthy seeds were washed with 100% ethanol and sterilized for 20 minutes in 1% (v/v) sodium hypochlorite containing 3-4 drops Tween 20 in a laminar air flow cabinet. Afterwards, they were rinsed 4 times with sterile distilled water and transferred to ½ strength MS medium (Murashige and Skoog, 1962) supplemented with 30 g/L sucrose, vitamins and 8.5 g/L agar and kept at dark condition. The pH of the medium was adjusted to 5.8 before autoclaving at 121°C, 15 psi for 20 min. Seeds started to germinate after 2-3 days and transferred to growth chamber maintained at 24±2°C under a 16/8-h (light/dark) photoperiod.

Regeneration: Cotyledonary nodes and hypocotyls of seedlings were carefully excised and cultured on MS medium supplemented with varying concentrations of 2,4-D (2.26, 4.52, 6.78 and 9.04 µM), BAP (2.22, 4.44, 6.66 and 8.88 µM), TDZ (0.022, 0.044, 0.22, 0.45 and 2.25 µM), BAP and NAA in combinations (4.44+0.53, 8.88+0.53 µM), BAP and IAA in combinations (4.44+0.57, 8.88+0.57 µM), Zeatin and IAA in combinations (4.56+0.57, 9.12+0.57 µM) along with a control treatment without any growth regulators. Based on the

response of two different types of explants the cotyledonary nodes were cultured on media having five different concentrations of TDZ for further regeneration. Four explants were placed on each petridish (15 X 90 mm) containing about 30 ml medium. The petridishes were sealed with parafilm and kept at $24\pm 2^{\circ}\text{C}$ under a 16/8-h (day/night) photoperiod with a light intensity 1500 lux. Explants were subcultured in every 14 days on the same media and kept under same conditions. When shoots attained a height of 2.0-2.5 cm they were cleaned, excised and transferred to $\frac{1}{2}$ strength of MS, MS supplemented with 2.46 μM IBA and 0.53 μM NAA for root induction.

Acclimatization: Well developed rooted shoots were transferred to pots with sterile soil mix and enclosed with polythene bags to maintain high humidity. The plantlets were kept in the greenhouse and watered once or twice a week while keeping covered. After 2 weeks, the bags were removed and the plantlets were transferred to the field for growing to maturity.

Data analysis: The experiment was set up in a completely randomized design with three independent replicates. The analysis of variance for different parameters was performed and the means were compared by R programme using STAR software at 5% level of significance.

Results and discussion

Shoot induction: Cotyledonary nodes and hypocotyl explants of 10-12 day old *in vitro* grown seedlings (Fig.1a) were cultured on MS medium containing varying concentrations and combinations of plant growth regulators. Callus with shoots was only obtained from cotyledonary nodes where hypocotyl explants did not produce any shoots (Table 1). Mangat and Roy (1986) also observed shoot induction from cotyledon and cotyledonary node explants of okra cultured in a medium supplemented with benzyladenine and NAA. In another study, cotyledonary node (CN) explants showed the best response with regard to induction of multiple shoots among various explants used for morphogenesis of *Abelmoschus moschatus* Medik. L. (Sharma and Shahzad, 2008).

The cotyledonary node explants showed better shooting response than hypocotyls and hence, they were further cultured on five different concentrations of TDZ for regeneration (Table 2). During every subculture, dead and brown portions of calli were removed and only the greenish parts were transferred for further proliferation. The results showed that the highest percentage (64.0%) of shooting and minimum days (8.4) required for shoot induction were observed in MS medium supplemented with 0.044 μM TDZ which is statistically different from treatments with other concentrations of TDZ (Table 2 and Fig.1b). Previously, it was observed that the biological activity of TDZ is higher than, or compatible to that, of the most active adenine type cytokinins (Mok *et al.*, 2007; Khawar *et al.*,

2004). In contrast, Anisuzzaman *et al.* (2008) found 95% callogenic response from hypocotyl explants of okra and 65% callus produced shoots over a period of 7 weeks in the MS medium containing 8.88 μM BAP plus 0.5 μM IBA which differ from the present study. The highest number of shoots (6.8) per explant was also recorded from MS medium supplemented with 0.044 μM TDZ followed by 0.022 μM (4.3) and the shoot multiplication did not rise with further increase in the concentrations of TDZ (Table 2 and Fig. 1c). The concentration of TDZ used for tissue culture is generally lower than that normally used for inducing adventitious shoot formation (Lu, 1993). Similar results were also obtained by Sharma and Shahzad (2008) where MS medium supplemented with 0.022 μM TDZ proved to be the best for multiple shoot induction from cotyledonary node explants of *Abelmoschus moschatus* Medik. L. However, Caramori *et al.* (2001) found the highest number (5.8) of shoots on 0.02 μM TDZ in cotton (*Gossypium hirsutum* L.). Both of these two findings were correlated with the present research, because all of them are from Malvaceae family.

Root formation: Root growth was observed within 2 weeks after the transfer of elongated shoots (2.0-2.5 cm) to rooting medium. The frequency of rooting on three different concentrations of media was variable (Table 3). The highest rooting percentage (83.3) was recorded in media supplemented with 2.46 μM IBA followed by 0.53 NAA (75.0) (Table 3 and Fig 1d) where Rahman *et al.* (2008) obtained 63.5% microshoots initiated roots in $\frac{1}{2}$ MS + 0.5 μM IBA medium from hypocotyl explants of okra. Additionally, leaf disc and hypocotyl derived callus of okra produced 50% and 55% rooting frequency in 2.46 μM IBA, respectively (Kabir *et al.*, 2008). Thus, the present study showed that cotyledonary node explants performed better in rooting of *in vitro* regenerated okra shoots.

Rooting response variation may be affected by different conditions of shoots used for root induction, variations in the medium used for multiplication before root induction, the number of subcultures before root induction and the culture period on multiplication medium before transfer to root induction medium (Pal *et al.*, 2007). The differences in rooting response may be a result of genotype or cultural conditions. Pathi and Tuteja, (2013) observed root induction between 10-15 days on media supplemented with 4.92 μM IBA in cotton. In the present research, minimum days (9.7) required for rooting was recorded in media supplemented with 2.46 μM IBA following 0.53 μM NAA (12.7) where $\frac{1}{2}$ strength of MS medium without any growth regulators took more days (16.7) for root induction (Table 3). The healthy rooted plantlets were transferred to greenhouse for hardening (Fig. 1e). After 2-3 weeks the plantlets were transferred to the large pot for further growth (Fig. 1f).

Table 1. Response of cotyledonary nodes and hypocotyl explants of BARI Dherosh-1 on media having varying concentrations of plant growth regulators

Concentration (μ M)	Cotyledonary node		Hypocotyl		
	% of response	Type of response	% of response	Type of response	
Control	0.0	NR	83.3	R	
2,4-D					
2.26	100.0	C	100.0	C+R	
4.52	94.4	C	100.0	C+R	
6.78	72.2	C	95.0	C+R	
9.04	77.8	C	75.0	C+R	
BAP					
2.22	95.0	C	100.0	C	
4.44	95.0	C	100.0	C	
6.66	75.0	C	100.0	C	
8.88	100.0	C	100.0	C	
TDZ					
0.022	100.0	C+Sh	100.0	C	
0.044	100.0	C+Sh	100.0	C	
0.22	100.0	C+Sh	100.0	C	
0.45	100.0	C+Sh	100.0	C	
2.25	100.0	C+Sh	100.0	C	
BAP NAA					
4.44	0.53	100.0	C+R	100.0	C+R
8.88	0.53	100.0	C+R	100.0	C+R
BAP IAA					
4.44	0.57	50.0	C	0.0	NR
8.88	0.57	50.0	C	0.0	NR
Zeatin IAA					
4.56	0.57	83.3	C	94.4	C
9.12	0.57	94.4	C	100.0	C

(S-Shoot, C-Callus, R-Root, C+Sh-Callus with shoots, C+R-Callus with root, NR-No response).

Table 2. Effect of different concentrations of TDZ on shoot induction from cotyledonary node explants of BARI Dherosh-1

Concentration (μM)	% of shooting	Days required for shoot initiation	No. of shoots/explant
0.022	33.3 ^c	10.3 ^{bc}	4.3 ^b
0.044	64.0 ^a	8.4 ^d	6.8 ^a
0.22	50.0 ^c	9.7 ^c	2.7 ^{bc}
0.45	58.3 ^b	11.5 ^a	2.8 ^{bc}
2.25	41.7 ^d	10.1 ^{bc}	1.9 ^c

The data followed by the same letter(s) did not differ significantly at $p < 0.05$.

Table 3. Effect of different concentrations of plant growth regulators on root induction from cotyledonary node explants of BARI Dherosh-1.

Concentration (μM)	% of rooting	Days required for root initiation
$\frac{1}{2}$ MS	58.3 ^c	16.7 ^a
2.46 IBA	83.3 ^a	9.7 ^b
0.53 NAA	75.0 ^b	12.7 ^{ab}

The data showed the same letter(s) do not differ significantly at $p < 0.05$.

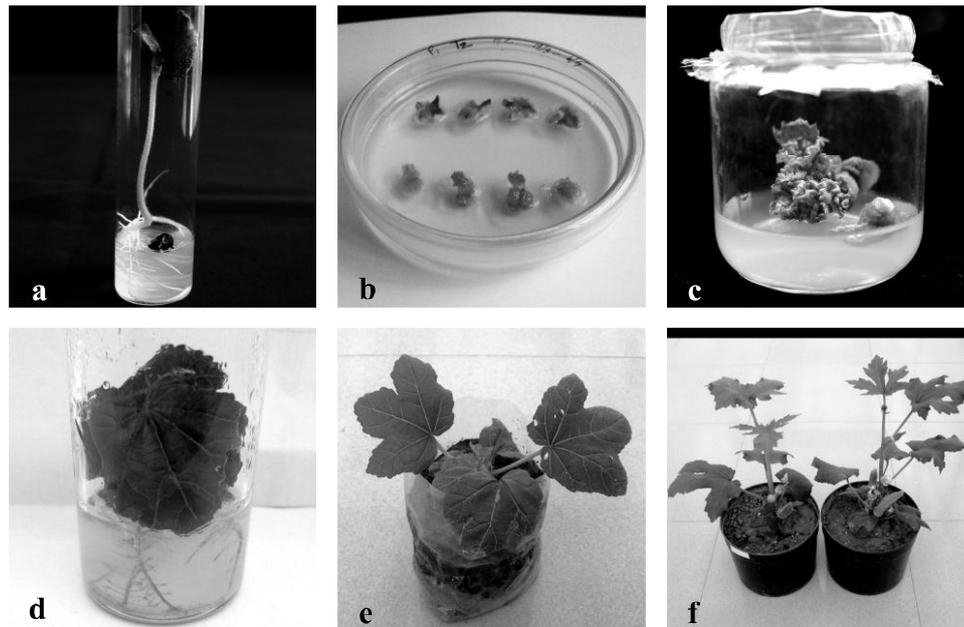


Fig. 1. Regeneration of BARI Dherosh 1. a) 10-12 day's old germinated seedling b) shoot initiation on 0.044 μM TDZ c) multiple shoots on 0.044 μM TDZ d) rooted shoots on 2.46 μM IBA e) hardening of plantlet in green house and f) seedlings with fruits.

Conclusion

Development of a highly efficient regeneration protocol based on using cotyledonary nodes as explants for the induction of multiple shoots from 0.044 μ M TDZ in okra is described here. The time taken from culture initiation to the establishment of plants in the greenhouse was shorter (about 3 months) as compared with the longer periods reported in previously published regeneration protocols. The important feature of the present protocol is shortening of regeneration time, as well as the induction of high number of multiple shoots per explant. Besides, this stable and reliable regeneration protocol is expected to be helpful for future research on genetic transformation on okra.

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RESYNTHESIS OF NEW R LINES IN *Brassica napus* L.

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Abstract

Identification of male fertility restorer genotypes for rapeseed CMS lines towards hybrid development in spring habit rapeseed (*Brassica napus* L.) adapted for short day winter season was studied. The experiment was conducted at the experimental farm and laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during October, 2008 to March, 2011. An exotic CMS-based F₁ hybrid of rapeseed was selfed to get F₂ generation with a view to resynthesizing restorer line. As a result a restorer line for Nap248A Z₁ and Nap248A Z₂ cytoplasmic male sterile lines was identified in the F₃ generation of the exotic F₁ rapeseed hybrid which appears as the first case so far reported as achievement in Bangladesh in this regard. Genetic analysis further revealed fertility restoration for Nap248A Z₁ and Nap248A Z₂ cytoplasmic male sterility was controlled by a single dominant nuclear gene as a simple genetic phenomenon.

Keywords: Fertility restorer, *Brassica napus* L., dominant gene.

Introduction

Rapeseed (*Brassica napus* L.) is a major source of edible or industrial oil. *B. napus* varieties have high seed and oil productivity with bold seeds. High yield potential of *B. napus* is mainly due to elongate flower raceme with moderate number of large silique accommodating more number of bold seeds and also due to higher number of plants that can be accommodated per unit area. The yield of rapeseed and mustard is generally low in Bangladesh as compared with the world average. The main problems for this low yield are the use of low yielding local indigenous cultivars, unavailability of locally developed hybrids and low management practices. The present yield of mustard in Bangladesh is 867 kg/ha which is far below the level attained in the developed countries (1907 kg/ha) of the world (FAO, 2011).

Cytoplasmic male sterility is a maternally controlled mechanism which causes failure in pollen formation. Several CMS systems such as pol- (Fu, 1981), ogu- (Ogura, 1968), nap- (Thompson, 1972; Shiga and Baba, 1973) and tour-CMS (Rawat and Anand, 1979; Sodhi *et al.*, 1994; Daniell *et al.*, 2004) have been developed in rapeseed. CMS-based hybrid rapeseed cultivars have been grown

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on a commercial scale in China. But very few research works have been done in Bangladesh to increase yield and production through exploitation of heterosis in rapeseed. Utilization of heterosis in developing hybrid cultivars could lead to increased productivity of this crop. However, some rapeseed CMS systems have drawbacks such as sensitivity of sterility to low or high temperature, inconsistency of hybridity, difficulty in finding restorer genes and poor restoration of fertility.

A- and B-lines of *B. napus* were available in the department of Genetics and Plant Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University. But no complete restorer (R-) lines of aforesaid A-lines have been developed in Bangladesh. So, identification of restorer lines may open the scope of hybrid variety development of rapeseed in Bangladesh. Identification of restorer lines having different cytosources is a prerequisite of hybrid variety development program. Investigations leading to identification of restorer lines and development of new restorer lines in *B. napus* have a bright scope for development of commercial hybrid varieties. Considering the scope of work in this line, a new programme of hybrid rapeseed breeding was initiated in the 2008. The present investigation was undertaken with the following objectives: 1) To identify restorer (R) lines for *napus* CMS systems (Z_1 and Z_2), 2) To develop new restorer (R) lines from Chinese *B. napus* hybrid and 3) To determine the inheritance of fertility restorer gene.

Materials and Method

The research work was conducted at the experimental farm, Department of Genetics and Plant Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur during the period from October 2008 to March, 2011. The seed of CMS-based rapeseed hybrid were collected from China. The CMS line Nap248A Z_1 , Nap248A Z_2 and its maintainer Nap248B were received from the Department of Genetics and Plant Breeding, BSMRAU, Salna, Gazipur. The seeds of CMS-based rapeseed hybrid as a source of restorer gene, CMS line Nap248A Z_1 and Nap248A Z_2 and their maintainer were sown in October 2008 to November 2008 in the experimental field. Ten rows of 3m each constituted an experimental unit. The plant spacing was 50 cm \times 15 cm. Recommended doses of manures and fertilizers were applied. The exotic hybrid seed of *B. napus* was sown in separate plot in the experimental field on 22 October, 2008 and the seed of the line Nap248A Z_1 and Nap248A Z_2 and their maintainer were sown on 5th November, 2008 in separate plots of the same experimental field. Twenty plants of F_1 hybrid were selected for selfing to develop F_2 generation. The CMS line Nap248A Z_1 and Nap248A Z_2 were pollinated with pollen from CMS-based F_1 hybrid which were known as backcrosses. Removal of sepal and petal from the upper portion of buds of both

Brassica genotypes was done in the evening to expose stigma for pollination and bagged to prevent out-crossing. Hand pollination was carried out in the following morning by dusting pollen from the same F_1 hybrid plant (known as bud selfing). On the other hand, for crossing (Nap248A $Z_{1 \text{ or } 2} \times F_1$), pollen of F_1 was dusted to the stigma of a single plant of Nap248A Z_1 and Nap248A Z_2 each. In all cases, the pollinated flowers were paper bagged for three days to prevent unwanted pollination and tagged carefully. The self (F_2) and cross seeds (Nap248A $Z_1 \times F_1$ and Nap248A $Z_2 \times F_1$) were collected after physiological maturity followed by threshing and drying and preserved in cold storage for next year experimentation. Number of viable pollen grains in ten fields per slide was counted. A drop of 2% aceto-carmin with ferric iron was put on a slide (Yan *et al.*, 2009). The anthers were cut into halves and the pollen grains squeezed out and stained for 1 min (Liu *et al.*, 2005). Slides were then observed under a light microscope at a magnification of 400 \times . Viable pollen grains were stained red while the non-viable ones remained pale yellow. The pollen grains of various types were counted and pollen stainability expressed as a percentage. Two anthers from each of three flowers per plant were used for analysis and average number of viable pollen grains per microscopic field was calculated for each plant. Data on five plants were collected and average number of viable pollen grains per microscopic field per plant was calculated. Number of nonviable pollen grains in ten fields per slide was counted. F_2 generation of 20 plants and backcross generation of Nap248A $Z_1 \times F_1$, Nap248A $Z_2 \times F_1$ were grown during November 2009 to March 2010 in the experimental field, Department of Genetics and Plant Breeding, BSMRAU. The seeds of F_2 , Nap248A $Z_1 \times F_1$, Nap248A $Z_2 \times F_1$ and Nap248B obtained from previous year experiment were used as plant materials. The 20 F_2 families were sown in 20 non-replicated plots. Each plot consisted of three rows of 3m long each. The row to row and plant to plant distances were 30 and 15 cm, respectively. The two BC populations were grown in separate plots along with their maintainer. Each plot consisted of two rows of 3 m length. The row and plant spacing were 30 and 10 cm, respectively. Seeds of different entries were sown in separate plots in the experimental field on 8th November, 2009. The seedlings emerged out within four days after sowing. Four F_2 families out of thirteen were selected. One plant from each of four F_2 families was selected on the basis of male fertility for self- and cross-pollination. The selected plants of F_2 families were bud-selfed to develop F_3 generation. The CMS line Nap248A Z_1 and Nap248A Z_2 were pollinated with pollen from selected F_2 plants (progeny of CMS-based F_1 hybrid). The resultant progeny were designated as F'_1 (Nap248A $Z_1 \times P_1$), F'_1 (Nap248A $Z_1 \times P_2$), F'_1 (Nap248A $Z_1 \times P_3$), F'_1 (Nap248A $Z_1 \times P_4$), F'_1 (Nap248A $Z_2 \times P_1$), F'_1 (Nap248A $Z_2 \times P_2$), F'_1 (Nap248A $Z_2 \times P_3$) and F'_1 (Nap248A $Z_2 \times P_4$). Removal of sepal and petal from the upper portion of buds of both *Brassica*

genotypes was done in the evening to expose stigma for pollination and bagged to prevent out-crossing. Hand pollination was carried out in the following morning through dusting pollen of selected F_2 plant (known as bud pollination). On the other hand, for crossing (Nap248A $Z_{1 \text{ or } 2} \times F_2$), pollen of F_2 plant was dusted on the stigma of Nap248A Z_1 and Nap248A Z_2 . In all cases, the pollinated flowers were paper bagged for three days to prevent unwanted pollination and tagged carefully. The self (F_3) and cross (Nap248A $Z_1 \times F_2$ and Nap248A $Z_2 \times F_2$) seeds were collected after physiological maturity followed by threshing and drying and preserved in cold storage for next year experimentation. Data were collected from each of 20 F_2 families on whole plot basis on the following aspects: counting of total number of plants in each plot, counting of fertile plant, counting of sterile plant and counting of viable and non-viable pollen. The recorded data for different characters were analyzed statistically using Microsoft Excel worksheet functions. χ^2 -tests were performed according to the formula described by Zaman *et al.* (1982). Eight F_1' and four F_3 families were grown during November 2010 to March 2011 in the experimental field, Dept. of Genetics and Plant Breeding, BSMRAU. Seeds of eight F_1' (Spring \times Winter) and four F_3 families obtained from previous year experiment were used as plant materials. The four F_3 families were sown on four non-replicated plots. Each plot consisted of two rows of 3m long each. The row to row and plant to plant distances were 50 and 15 cm, respectively. The eight hybrids F_1' (Nap248A $Z_1 \times P_1$), F_1' (Nap248A $Z_1 \times P_2$), F_1' (Nap248A $Z_1 \times P_3$), F_1' (Nap248A $Z_1 \times P_4$), F_1' (Nap248A $Z_2 \times P_1$), F_1' (Nap248A $Z_2 \times P_2$), F_1' (Nap248A $Z_2 \times P_3$) and F_1' (Nap248A $Z_2 \times P_4$) were grown in separate plots. Each plot consisted of two rows. The row and plant spacing were 50 and 15 cm, respectively. Seeds of different entries were sown in separate plots in the experimental field on 5 November, 2010. The seedlings emerged out within four days after sowing. Data were collected from each of eight hybrids (F_1') populations on whole plot basis on the following aspects: counting of total number of plants in each plot, counting of fertile plants and counting of sterile plants. The recorded data for different characters were analyzed statistically using Microsoft Excel worksheet functions. χ^2 -tests were performed following Bagdonavicius (2011).

Results and Discussion

The detailed results of this study have been presented in tables and figures and discussed as follows: The different populations used in this experiment were divided into two groups on the basis male sterility and male fertility. Ten floral traits were studied for determination of male fertility and male sterility. The male sterile plants produced crinkled petals and short stamens bearing small conical anthers of pale green colour. The pollen grains of these plants were shriveled

and did not stain with aceto-carmin (Fig. 1a and Fig. 1b). Singh (2006) also reported narrow petals and non-viable pollen grains in CMS *B. juncea*. Whereas the fertile plants produced normal petals and stamens bearing yellow coloured normal anthers. The pollen grains of these plants were round and stained with aceto-carmin (Fig. 1.c, Fig. 1.d and Fig. 1.e). Mean data on floral traits of fertile and sterile genotypes found in different populations are presented in Tables 1 and 2, respectively and described below:

Petal width (mm), petal length (mm), long filament length (mm), short filament length (mm), style length (mm), stigma diameter (mm), anther length (mm), anther width (mm), total number of pollen/field, viable pollen and non-viable pollen in sterile CMS genotypes were lower than male fertile genotypes found in F_2 segregating and backcross population (Saha *et al.*, 2011). Petal width ranged from 3.31mm and 4.95mm. The highest petal width was observed in Nap248A $Z_1 \times F_1R$ (sterile) and the lowest in F_2 (sterile) (Table 1). The highest petal length exhibited by Nap248A $Z_1 \times F_1R$ (sterile) (9.05mm) and the lowest in F_2 (sterile) (7.65mm). The highest long filament length was the highest in Nap248A $Z_2 \times P_4R$ (sterile) (2.78mm) followed by Nap248A $Z_2 \times P_3R$ (sterile) and the lowest in F_2 (sterile) (1.52mm). Nap248A $Z_2 \times F_1R$ (sterile) showed the highest short filament length (1.22mm) followed by Nap248A $Z_2 \times P_3R$ (sterile) and F_2 population showed the lowest (0.73mm) for this trait. Style length was the highest in Nap248A $Z_2 \times P_3R$ (sterile) (10.10mm) followed by F_2 (sterile) and it was the lowest in Nap248 A Z_1 (7.02mm). The genotype Nap248A $Z_2 \times F_1R$ (sterile) exhibited the highest stigma diameter (1.13mm) followed by Nap248A $Z_1 \times F_1R$ (sterile) and Nap248 A Z_1 the lowest. Anther length ranged from 1.70 to 1.94mm. The highest value for anther length was showed by the genotype Nap248A $Z_2 \times P_3R$ (sterile) followed by Nap248A Z_2 and the lowest by Nap248 A Z_1 . Anther width ranged from 0.73 to 0.86mm. Saha *et al.* (2011) also reported low anther length and breadth in CMS Z_1 and CMS Z_2 lines of *B. napus*. Total number of pollen per microscopic field at 400 \times magnification ranged from 4.0 to 5.3. The highest % of viable pollen was observed in Nap248A $Z_1 \times F_1R$ (sterile) (60.38%) followed by Nap248A $Z_1 \times P_4R$ (sterile) and the lowest value for this trait was 0.00% showed by the genotype F_2 (sterile). F_2 (sterile) population showed the highest % of nonviable pollen (100%) followed by Nap248A $Z_2 \times P_3R$ (sterile). However, Nap248A Z_1 showed the lowest % of nonviable pollen (30.95%). The average petal width (mm), petal length (mm), long filament length (mm), short filament length (mm), style length (mm), stigma diameter (mm), anther length (mm), anther width (mm), total number of pollen/field, % viable pollen and non-viable pollen in CMS genotypes were found as 4.43, 8.26, 2.15, 1.08, 8.72, 1.11, 1.84, 0.77, 4.4, 43.99% and 56.01%, respectively.

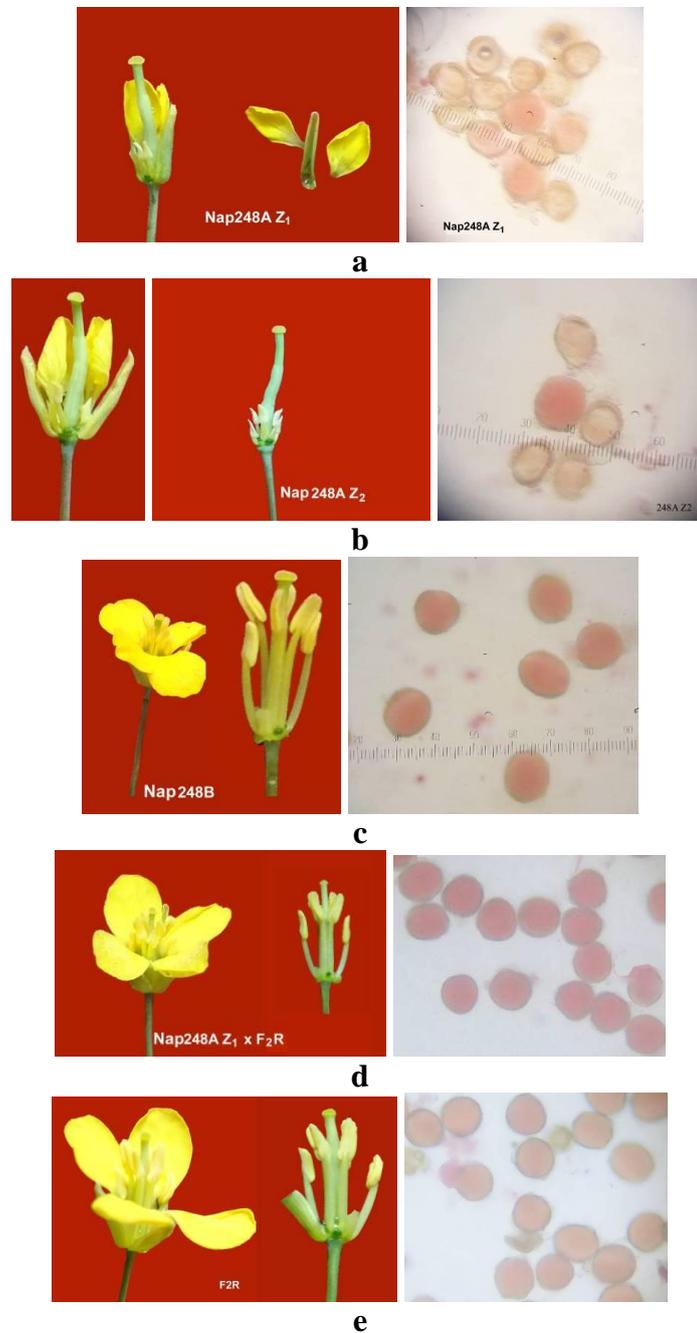


Fig. 1. (a-e) Stamen and anther morphology and pollen grain

a) Nap248A Z₁ (*B. napus* L.), b) Nap248A Z₂ (*B. napus* L.), c) Nap248B (*B. napus* L.),
 d) Nap248A Z₁×F₂R (*B. napus* L.) e) F₂R (*B. napus* L.)

The performance of male fertile genotypes was found extremely high compared to that of sterile ones for all studied floral traits except % nonviable pollen. It might be due to the presence of “Rf” genes in the nucleus which suppressed the activity of extranuclear gene present in fertility restored genotypes. The genotype F₂ (fertile), a product of self-fertilization in exotic F₁s, was found to produce the widest (8.78mm) petal whereas the narrowest (7.25mm) petal was found in the genotype Nap248A Z₂ × F₁R (fertile) (Table 2). The minimum petal length was produced by the genotype Nap248A Z₂ × F₁R (fertile) (12.7mm) and maximum petal length was produced by F₁R (fertile) (14.65mm). The hybrid population F₁R (fertile) produced the longest (14.65mm) petal followed by F₂ (fertile) and Nap248A Z₂ × F₁R (fertile) produced the shortest (12.7mm) petal. Similar trend was observed in case of long filament length and short filament length. The long filament length ranged from 5.50 to 10.80mm while the short filament length ranged from 4.40 to 7.55mm. The genotype Nap248A Z₂ × F₁R (fertile) produced the longest (13.35mm) style followed by Nap248A Z₂ × P₁R (fertile) and the genotype Nap248A Z₁ × F₁R (fertile) produced the shortest style. The highest (1.77mm) stigma diameter was found in the genotype Nap248A Z₂ × F₁R (fertile) and the lowest (1.61mm) was found in Nap248A Z₁ × F₁R (fertile). The longest (4.90mm) anther was produced by the hybrid F₁R (fertile) followed by F₂ (fertile) and the shortest (4.58mm) anther was produced by Nap248A Z₂ × P₃R (fertile). Anther width ranged from 1.50 to 1.60mm. The highest (34.30) total number of pollen grain per microscopic field at 400× magnification was observed in case of genotype F₁R (fertile) followed by the plants obtained in segregating F₂ (fertile) population and the lowest (22.10) was in the genotype Nap248A Z₂ × P₁R (fertile) and this trend was similar to the trait short filament length. Nearly similar trend was observed in case of % viable pollen grain and % nonviable pollen grain. However, % of viable pollen grain was found the highest (89.13%) in Nap248A Z₁ × F₁R and Nap248A Z₁ × P₃R (fertile) and it was found the lowest (79.88%) in the hybrid F₁R (fertile). The % of nonviable pollen grain ranged from 10.87 to 20.12%.

The mean values for petal width indicated that the petal width of fertile genotypes were 70.65% higher than sterile genotypes (Tables 1 and 2). Likewise, all other floral traits studied in this investigation showed higher per cent increase in fertile genotypes over sterile genotypes except % of nonviable pollen. The fertile genotypes showed the highest per cent (486.36%) increase over sterile genotypes for total number of pollen grain per microscopic field followed by the short filament length (366.67%) and the long filament length (200.93%) and the lowest per cent increase (48.85%) over sterile genotype was observed for the style length. However, % nonviable pollen grain decreased by -75.98% in the fertile genotypes over the sterile ones.

Table 1. Floral traits of sterile rapeseed genotypes of different populations/ generations

Genotype	Petal width (mm)	Petal length (mm)	Long filament length (mm)	Short filament length (mm)	Style length (mm)	Stigma diameter (mm)	Anther length (mm)	Anther width (mm)	Total number of pollen /field	% viable pollen	% nonviable pollen	Growing season	Remarks
Nap248 A Z ₁	4.82	8.91	1.86	1.13	7.02	1.08	1.7	0.75	4.2	69.05	30.95	Rabi, 2008-09	Sterile
Nap248A Z ₂	4.68	8.04	2.68	1.19	10.08	1.1	1.92	0.75	4	35.00	65.00	Rabi, 2008-09	„
F ₂	3.31	7.65	1.52	0.73	10.1	1.13	1.9	0.86	4.5	0.00	100.00	Rabi, 2009-10	„
Nap248A Z ₁ × F ₁ R	4.95	9.05	1.85	1.2	7.55	1.13	1.8	0.81	5.3	60.38	39.62	Rabi, 2010-11	„
Nap248A Z ₂ × F ₁ R	4.7	8.14	2.67	1.22	9.53	1.13	1.86	0.74	5	48.00	52.00	Rabi, 2010-11	„
Nap248A Z ₁ × P ₄ R	4.85	8.95	1.82	1.16	7.12	1.13	1.82	0.81	4.6	69.57	30.43	Rabi, 2010-11	„
Nap248A Z ₂ × P ₃ R	4.68	8.11	2.69	1.2	10.1	1.12	1.94	0.73	4.2	33.33	66.67	Rabi, 2010-11	„
Nap248A Z ₂ × P ₄ R	4.61	7.88	2.78	1.15	9.95	1.1	1.91	0.75	4.1	36.59	63.41	Rabi, 2010-11	„
Minimum	3.31	7.65	1.52	0.73	7.02	1.08	1.7	0.73	4	0.00	30.43		
Maximum	4.95	9.05	2.78	1.22	10.1	1.13	1.94	0.86	5.3	69.57	100.00		
Mean	4.58	8.34	2.23	1.12	8.93	1.12	1.86	0.78	4.49	43.99	56.01		

Table 2. Floral traits of fertile rapeseed genotypes of different populations/ generations

Genotype	Petal width (mm)	Petal length (mm)	Long filament length (mm)	Short filament length (mm)	Style length (mm)	Stigma diameter (mm)	Anther length (mm)	Anther width (mm)	Total number of pollen /field	% Viable pollen	% Non-viable pollen	Growing season	Remarks
F ₁ R	8.8	14.65	10.8	7.55	12.9	1.76	4.9	1.56	34.3	79.88	20.12	Rabi, 2008-09	Fertile
F ₂	8.78	14.48	10.5	7.48	12.8	1.75	4.88	1.55	33.2	80.42	19.58	Rabi, 2009-10	”
Nap248A Z ₁ × F ₁ R	7.28	12.9	5.65	4.4	12.2	1.61	4.63	1.5	23	89.13	10.87	Rabi, 2010-11	”
Nap248A Z ₂ × F ₁ R	7.25	12.7	5.58	4.5	13.35	1.77	4.6	1.6	24.8	87.90	12.10	Rabi, 2010-11	”
Nap248A Z ₁ × P ₁ R	7.31	12.9	5.51	4.48	13.1	1.71	4.68	1.55	25.8	87.21	12.79	Rabi, 2010-11	”
Nap248A Z ₁ × P ₂ R	7.3	12.89	5.52	4.49	13.15	1.74	4.65	1.57	24.7	87.85	12.15	Rabi, 2010-11	”
Nap248A Z ₁ × P ₃ R	7.25	12.78	5.5	4.43	13.06	1.68	4.65	1.52	23	89.13	10.87	Rabi, 2010-11	”
Nap248A Z ₂ × P ₁ R	7.29	12.85	5.51	4.52	13.2	1.73	4.61	1.55	22.1	88.24	11.76	Rabi, 2010-11	”
Nap248A Z ₂ × P ₂ R	7.3	12.81	5.53	4.49	13.1	1.74	4.68	1.55	24.8	86.69	13.31	Rabi, 2010-11	”
Nap248A Z ₂ × P ₃ R	7.32	12.82	5.5	4.53	13	1.77	4.58	1.6	24.3	88.89	11.11	Rabi, 2010-11	”
Nap248A Z ₂ × P ₄ R	7.3	12.86	5.54	4.52	12.9	1.73	4.65	1.54	24	86.67	13.33	Rabi, 2010-11	”
Minimum	7.25	12.7	5.5	4.4	12.2	1.61	4.58	1.5	22.1	79.88	10.87		
Maximum	8.8	14.65	10.8	7.55	13.35	1.77	4.9	1.6	34.3	89.13	20.12		
Mean	7.56	13.15	6.47	5.04	12.98	1.73	4.68	1.55	25.8	86.55	13.45		
% increase over sterile genotype	70.65	59.20	200.93	366.67	48.85	55.86	154.35	101.30	486.36	96.75	-75.98		

Table 3. Segregation pattern of fertility and sterility of F₁, F₂, BC and F₁' generations of rapeseed

Generation	Combination	Plants observed			Expected ratio	χ^2	P	Growing season
		Total	Fertile	Sterile				
F ₁ R	Unknown	100	100	0	1:0	-	-	Rabi, 2008-09
F ₁ R	unknown	75	75	0	1:0	-	-	Rabi, 2008-09
F ₂ R	F ₁ R × F ₁ R	578	430	148	3:1	0.11	0.74	Rabi, 2009-10
BC ₁	Nap248A Z ₁ × F ₁ R	45	24	21	1:1	0.20	0.65	Rabi, 2010-11
BC ₁	Nap248A Z ₂ × F ₁ R	42	22	20	1:1	0.10	0.76	Rabi, 2010-11
F ₁ ' (S × W)	Nap248A Z ₁ × P ₁ R	35	35	0	1:0	-	-	Rabi, 2010-11
F ₁ ' (S × W)	Nap248A Z ₁ × P ₂ R	33	33	0	1:0	-	-	Rabi, 2010-11
F ₁ ' (S × W)	Nap248A Z ₁ × P ₃ R	34	18	16	1:1	0.12	0.73	Rabi, 2010-11
F ₁ ' (S × W)	Nap248A Z ₁ × P ₄ R	35	17	18	1:1	0.03	0.87	Rabi, 2010-11
F ₁ ' (S × W)	Nap248A Z ₂ × P ₁ R	38	38	0	1:0	-	-	Rabi, 2010-11
F ₁ ' (S × W)	Nap248A Z ₂ × P ₂ R	36	36	0	1:0	-	-	Rabi, 2010-11
F ₁ ' (S × W)	Nap248A Z ₂ × P ₃ R	36	19	17	1:1	0.11	0.74	Rabi, 2010-11
F ₁ ' (S × W)	Nap248A Z ₂ × P ₄ R ²	39	21	18	1:1	0.23	0.63	Rabi, 2010-11

P₁, P₂, P₃ and P₄ stand for a selected male fertile plant in four different F₂ families, respectively. One plant was taken from each family.

F₁' = Hybrid between spring and winter type rapeseed. S = Spring, W = Winter

The F₁ plants grown from exotic seed were examined for male fertility and male sterility. The floral traits clearly indicated that all the plants were male fertile (Table 2). It was confirmed from the pollen viability test of the F₁ plants where the ratios of male fertile to male sterile plants were 1:0 (Table 3). Four hundred thirty plants were found male fertile out of a total of 578 plants in F₂ generation. The backcross Nap248A Z₁ × F₁R showed 24 male fertile and 21 male sterile plants out of 45 plants. Likewise Nap248A Z₂ × F₁R showed 22 male fertile and 20 male sterile out of 42 plants. The male fertile plants showed floral features typical of Nap248B, the maintainer of Nap248A Z₁ and Nap248A Z₂ (Fig. 1.c and Fig. 1.e). The pollen grains were not shriveled and normally stained with aceto-carmin while the male sterile plants showed floral features typical of Nap248A Z₁ and Nap248A Z₂ i.e. crinkled petals and short stamens bearing small conical anthers. The pollen grains were shriveled and did not stain with aceto-carmin (Fig. 1.a and Fig. 1.b). Nap248A Z₁ × P₁R, Nap248A Z₁ × P₂R, Nap248A Z₂ × P₁R and Nap248A Z₂ × P₂R hybrid populations produces all male fertile plants while Nap248A Z₁ × P₃R, Nap248A Z₁ × P₄R, Nap248A Z₂ × P₃R and Nap248A Z₂ × P₄R populations produces a mixture of male fertile and male sterile plants (Table 3).

The ratios of male fertile to male sterile plants in all F₁ generations were tested with χ^2 statistic. The values of P for χ^2 test of fertile:sterile ratio in case of F₂ generation, backcross population and F₁ generation indicated that the segregation of male fertility trait follows Mendelian monogenic inheritance and also the plant number 1 (designated as P₁R) and the plant number 2 (designated as P₂R) were homozygous dominant for male fertility restorer gene (Rf). Thus the selfed progeny of P₁R (the F₃ generation) and P₂R (the F₃ generation) were identified as new male fertility restorer lines. These findings are in accordance with that of Liu *et al.* (2005) that fertility restoration for 681A cytoplasmic male sterility was controlled by a single dominant nuclear gene which might originate from *B. juncea*. Verma *et al.* (2000) stated that restorer gene for polima CMS in *B. campestris* was controlled by a single dominant gene.

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**NUTRITIVE VALUE AND YIELD POTENTIAL OF OKRA
(*Abelmoschus esculentus* L. Moench) GENOTYPES**

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Abstract

Two experiments were conducted at the research field and laboratory of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, during April 2012 to September 2013 to find out the yield performance and nutritional quality of seven genotypes of okra in Bangladesh. The results revealed that the highest yield of okra obtained from BARI Dherosh1 (14.9 t/ha) and the lowest yield was obtained from Hybrid Raja (5.76 t/ha). The highest fruits per plant were recorded from BARI Dherosh1 (24.27 fruits/plant). The genotype Green Hybrid produced the lowest edible fruit per plant (10.27). Maximum virus infestation was recorded in genotype Hybrid Raja (100%) and the lowest in Arka Anamika (76.67%) as well as Arka Anamika performed well in many aspect such as yield (12.95 t/ha), fruits per plant (19.83), number of branches per plant (6). The highest content of free ascorbic acid was recorded in Nabik (3.35 mg/100gm) and the minimum ascorbic acid content was observed in Green Hybrid (1.987 mg/100g). Hybrid Moti had the maximum amount of β -carotene (0.15 IU/100 g), while minimum amount of β -carotene was found in IPSA Okra (0.09IU/100 g). The highest K content was observed in IPSA Okra (1.091%) and the lowest in Hybrid Raja (1.06%). The highest amount of Fe was observed in Hybrid Moti (139.60 ppm) and the lowest amount of Fe was observed in Green Hybrid (111.80 ppm). The present results revealed that the yield was maximum in BARI Dherosh1 while Hybrid Moti was superior in nutritive value.

Keywords: Okra genotype(s), nutritive value, yield potentiality.

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a popular green fruit vegetable in Bangladesh. It is commonly known as bhendi or lady's finger in Bangladesh (Rashid, 1999). It is the choicest fruit vegetable grown extensively in tropical, subtropical and warm area of the temperate zones of the world (Tindall, 1983; Siemonsma and Kouame, 2004). Being native of tropical Africa, it is widely cultivated as an important vegetable crop in Bangladesh. Okra is very popular for

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its delicious, tasty, gelatinous, tender, fruits as vegetable. 3-5 days old tender green pods are used as a vegetable, generally marketed in the fresh state. It is the best source of iodine and calcium. Consumption of 100 g of fresh okra fruit provides 20, 15 and 50% of the daily requirement of calcium, iron and ascorbic acid, respectively (Schipper, 2002). Okra is a popular health food due to its high fiber, and vitamin C content. It is also known for being high in antioxidants. It is also a good source of calcium and potassium (Duvauchelle, 2011). Greenish-yellow edible okra oil is pressed from okra seeds; it has a pleasant taste and odor, and is high in unsaturated fats such as oleic acid and linoleic acid (Franklin, 1982).

Average yield of okra in this country is quite low because of the commercially cultivated low yielding varieties. High yield potential genotype with good characteristics is the basis of successful crop production and is important for increasing the productivity. So, in case of genotypes yield potential must be considered for commercial production. Different okra genotypes differ significantly for most of the traits like number of fruits, fruit length, fruit weight and fruit yield per plant, those ultimately determine overall yield of the variety or cultivar. A number of okra varieties are under cultivation in Bangladesh. Besides the improved cultural practices, there is a need to grow high yielding cultivars to increase the green fruit yield per plant and per unit area. In the present study seven okra genotype from local and exotic sources were evaluated for their yield potentiality and determined the nutritional quality of okra genotypes.

Materials and Method

The experiment was conducted at the Horticultural Research Farm, BSMRAU, Gazipur during the period from April 2012 to September 2013. Seven genotypes of okra viz. BARI Dherosh1, IPSA Okra 1, Green Hybrid, Nabik, Hybrid Raja, Arka Anamika and Hybrid Moti were used in this experiment. The field experiment was laid out in a Randomized Complete Block Design with three replications and the lab experiment was laid out in completely randomized design with three replications. The unit plot size was 4m x 1.5m. The genotypes of okra were collected from the respective organizations and the market of Siddique bazaar of Dhaka. The land was manured and fertilized with Cowdung, Urea, TSP, MoP and Molybdenum @ 1000, 150, 100, 150 and 1kg/ha, respectively. The entire amount of Cow dung, $\frac{1}{2}$ Urea, TSP, $\frac{1}{2}$ MoP and Molybdenum were applied at the time of final land preparation and the rest of urea and MoP were applied as top dressing in three equal split at 20, 40 and 60 days after germination. The seeds of seven genotypes were sown on 11 April 2012 in the plots. The row spacing was 60 cm having plant spacing of 40 cm within the row. Weeding, irrigation and other cultural practices were done as and when necessary. The collected data on various parameters were statistically analyzed

using MSTAT-C program and the significance was tested by ANOVA. The means of different parameters were compared by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussions

The analysis of variance showed that the genotypes under study differed significantly among themselves for all characters which are presented below:

Plant height

Plant height varies significantly at 25DAS, 40DAS, 55DAS and 70DAS among the genotypes (Table 1). Plant height obtained from genotypes at 25 DAS ranged from 11.31 to 16.13cm, at 40 DAS ranged from 27.17 to 37.77cm, at 55 DAS ranged from 43.43 to 64.33 cm and at 70 DAS ranged from 78.67 to 108 cm. Highest plant height obtained from Hybrid Moti (16.13) which was statistically similar to Nabik (15.27 cm), Arka Anamika (14.27 cm) BARI Dherosh1 (14.1cm), IPSA Okra (14.1cm) while the lowest plant height obtained from Hybrid Raja (11.31 cm) which was statistically identical with Green hybrid (12.83 cm) at 25 DAS.

At 40 DAS Highest plant height obtained from Hybrid Moti (37.77 cm) which was statistically identical with Arka Anamika (35.59cm) and BARI Dherosh1 (35.17cm). The lowest plant height obtained from Hybrid Raja (27.17 cm) which was statistically identical with Nabik (29.47 cm).

Table 1. Plant height of different genotypes of okra at different days after sowing

Genotype	Plant height(cm)			
	25 DAS	40 DAS	55 DAS	70 DAS
BARI Dherosh1	14.10ab	35.17ab	64.33a	106.4a
IPSA Okra	14.10ab	33.43bc	60.93a	94.87b
Green Hybrid	12.83bc	31.97cd	54.50b	86.20bc
Nabik	15.27a	29.47de	52.47b	82.33c
Hybrid Raja	11.31c	27.17e	43.43c	70.07d
Arka Anamika	14.67ab	35.59ab	63.27a	108.0a
Hybrid Moti	16.13a	37.77a	63.13a	78.67cd
Level of significance	*	*	*	*
CV%	8.51	5.13	4.56	5.91

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

At 55 DAS after sowing highest plant height obtained from BARI Dherosh1 (64.33cm) which was statistically similar with Arka Anamika (63.27 cm), Hybrid Moti (63.13cm) and IPSA Okra (60.93 cm). Lowest plant height obtained from Hybrid Raja (43.43 cm).

At 70 DAS highest plant height obtained from Arka Anamika (108.00cm) which was statistically identical to BARI Dherosh1 (106.33 cm). Lowest plant height obtained from Hybrid Raja (70.07cm) which was statistically identical with Hybrid Moti (78.67cm). Plant height of different genotypes varied due to inherent characteristics of genotype. Karri and Pinaki (2012) reported that the highest plant height during summer season was 100.62cm. Rahman *et al.* (2012) found highest plant height 91.33cm under the evolutionary field trial of five okra genotype. Kuwar *et al.* (2001) reported highest plant height was 130.4 cm; the present result is within the range of reported result. Plant height varied probably due to genotypical variation.

Number of leaves

Significant difference in number of leaves per plant was noticed among the genotypes (Table 2). The maximum number of leaves per plant obtained from IPSA Okra (8.83) which was statistically similar with BARI Dherosh1 (8.60), Arka Anamika (8.50) and Nabik (8.40) and minimum number of leaves obtained from Hybrid Raja (7.54) at 25DAS.

At 40 DAS maximum number of leaves obtained from Hybrid Moti (12.37) and minimum number of leaves obtained from Hybrid Raja (10.57) which was statistically similar with Arka Anamika (10.77) and IPSA Okra.

Table 2. Number of leaves of different genotypes of okra at different days after sowing

Genotype	Number of leaves			
	25DAS	40DAS	55DAS	70DAS
BARI Dherosh 1	8.60ab	11.10bc	23.93a	33.87a
IPSA Okra	8.83a	10.97cd	22.80ab	30.67b
Green Hybrid	8.23bc	11.27bc	19.93cd	24.20d
Nabik	8.40abc	11.53b	20.67bcd	27.73c
Hybrid Raja	7.54d	10.57d	18.93d	27.73c
Arka Anamika	8.50abc	10.77cd	21.90abc	33.47a
Hybrid Moti	8.03c	12.37a	20.90bcd	27.07c
Level of significance	*	*	*	*
CV%	3.20	7.57	5.89	3.71

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

At 55 DAS after sowing maximum number of leaves obtained from BARI Dherosh 1(23.93) which was statistically similar with IPSA Okra (22.80) and Arka Anamika (21.90). Minimum number of leaves obtained from Hybrid Raja (18.93) which was statistically similar with Green Hybrid (19.93), Nabik (20.67) and Hybrid Moti (20.90).

At 70 DAS maximum number of leaves obtained from BARI Dherosh1 (33.87) which was statistically similar with Arka Anamika (33.47) and minimum number of leaves obtained from Green Hybrid (24.20). Falusi *et al.* (2012) reported that average number of leaves at the time of maturity were 12.40. The present result is higher than the reported result because of different genotype.

Number of branches per plant

The number of branches per plant showed significant variation (Fig.1) and Green Hybrid (6.27) was highest in this respect followed by Arka Anamika (6.00), BARI Dherosh1 (5.93). The lowest number of branches obtained from IPSA Okra (3.47) which was identical with Hybrid Moti (4.13) and Hybrid Raja (4.60). Number of branches per plant in this study varied from 3.47 to 6.27. Similar result was also reported by Kuwar *et al.* (2001).

Days to anthesis

As regards to days to anthesis, it was observed that it varied significantly among the genotypes and ranges from 41.33 to 46.67 days (Fig. 2). Earliest first opening of flower was recorded in BARI Dherosh1 (41.33 days) which was at par with Hybrid Moti (42.33 days), Arka Anamika (42.33 days) and IPSA Okra (43 day) while late first opening of flower was observed in Hybrid Raja (46.67 days) which was identical with Green Hybrid (46 days). Muhammad *et al.* (2001) reported the earliest flowering in 45 days in four high yielding okra genotypes.

Days to 50% flowering

Seven genotypes showed significant variation in respect of 50% flowering. All the genotypes required 44.33 days to 49.67 days for 50% flowering (Fig. 3). The earliest 50% flowering was recorded from BARI Dherosh1 (44.33 day) which was at par with IPSA Okra (45.33 day), Arka Anamika (45.33 days) and Hybrid Moti (45.33 days) while late 50% flowering were observed in Green Hybrid (49.67 days) and Hybrid Raja (49.67 days). The present result is in agreement with the findings of Reddy *et al.* (2012)

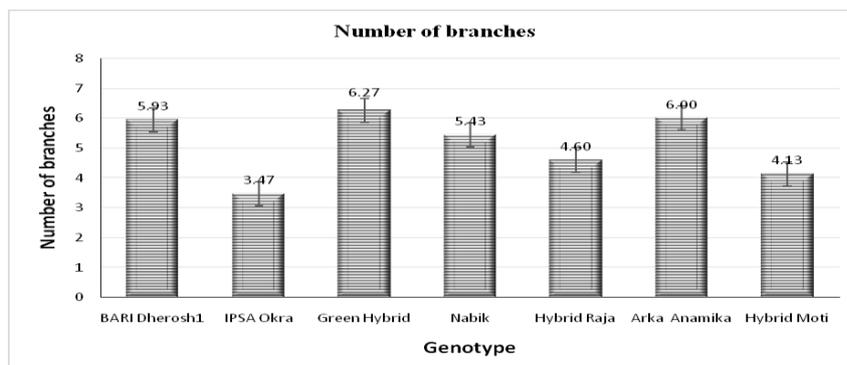


Fig. 1. Number of branches of seven genotypes of okra.

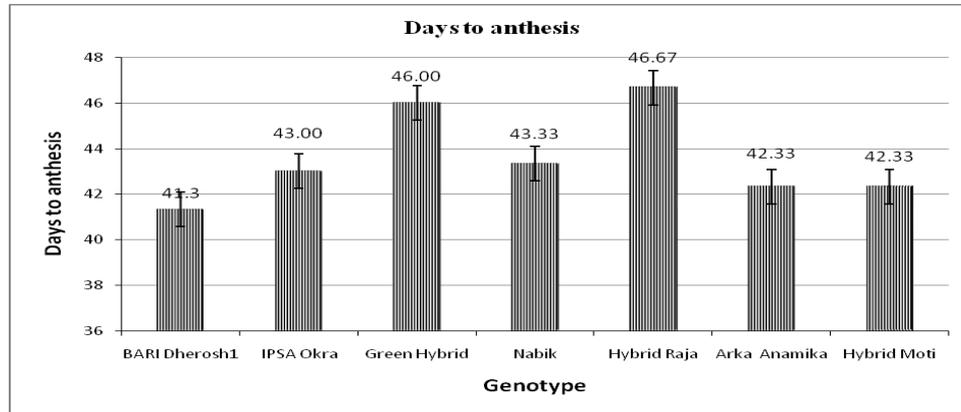


Fig. 2. Days to anthesis of different genotypes of okra.

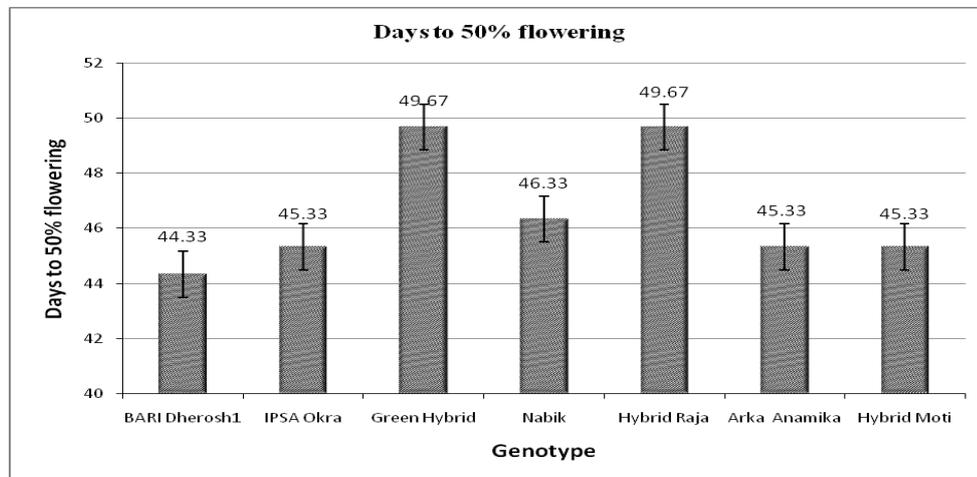


Fig. 3. Days to 50% flowering of seven genotype of okra.

Fruit length (cm)

Seven genotypes showed significant variation in respect of fruit length (Fig.4). The longest fruit length was observed in Arka Anamika (13.80 cm) followed by Hybrid Moti (12.57cm), BARI Dherosh1 (12.23 cm). The fruit length of Green Hybrid (9.13 cm) was found to be shortest. This result was in agreement with the result obtained by Kuwar *et al.* (2001) who found that maximum fruit length were 13.86 cm

Fruit diameter (mm)

Fruit diameter varied significantly among the genotypes (Fig.5). The widest fruit diameter found in genotype Arka Anamika (17.83 mm) which was at par with BARI Dherosh1 (17.06 mm.) and IPSA Okra (16.87 mm.) while Hybrid Raja

(15.1 mm.) had the shortest fruit diameter and similar with genotypes Green Hybrid (15.65 mm.) and Nabik (16.14 mm.). Kuwar *et al.* (2001) reported that maximum fruit diameter were 14.7 cm.

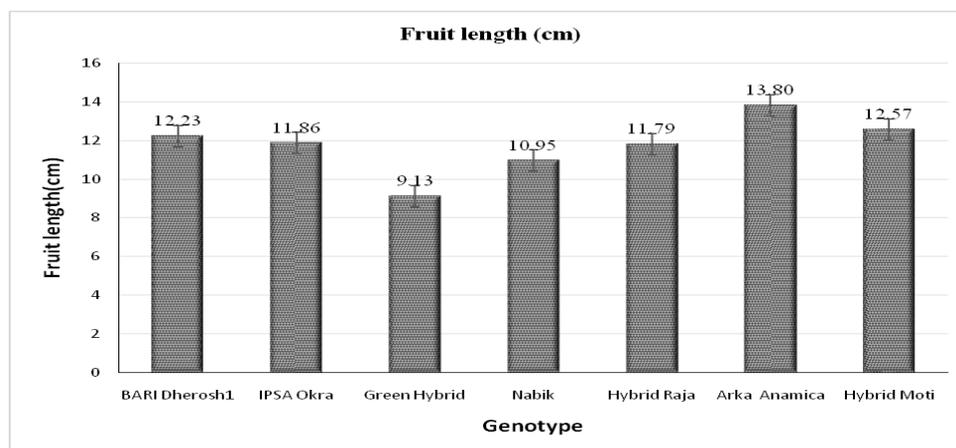


Fig. 4. Fruit length of different genotypes of okra.

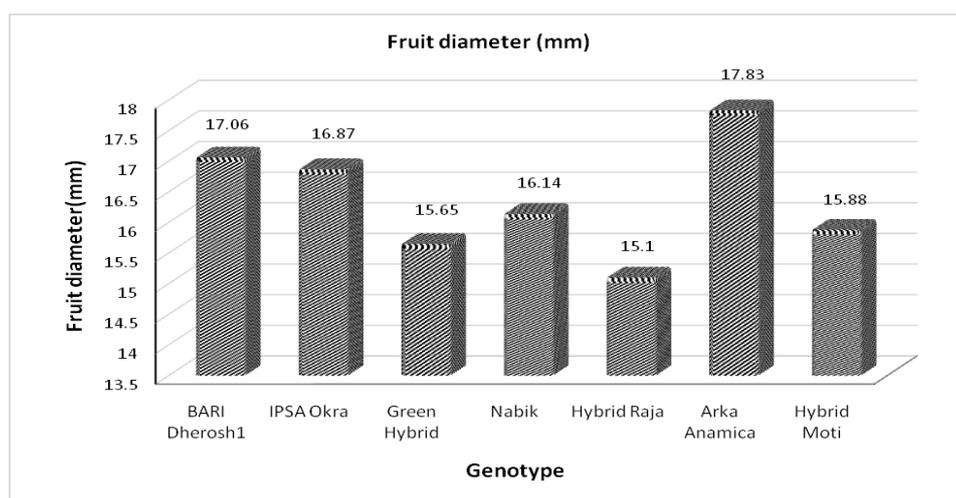


Fig. 5. Fruit diameter of seven genotypes of okra.

Numbers of fruit per plant

Fruit per plant varied significantly among the genotypes (Fig. 6). Fruit per plant in this study varied from 10.27 to 24.27. The highest fruits per plant were recorded from BARI Dherosh1 (24.27). The genotype Green Hybrid (10.27) produced the lowest edible fruit per plant which was statistically identical with Hybrid Raja (11.27). The present result is within the range of the findings reported by Rahman *et al.* (2012).

Fruit weight (g)

Significant difference was observed among the okra genotypes in respect of fruit weight (Fig. 7). Fruit weight varied from 12.31 to 15.84 g. The highest fruit weight was observed in IPSA Okra (15.84 g) which was at par with Green Hybrid (15.44g), Nabik (15.45 g) and Arka Anamika (15.66 g). The lowest Fruit weight was observed in Hybrid Raja (12.31 g). This result was in agreement with the result obtained by Karri and Pinaki (2012).

Picking duration (days)

The seven genotypes showed significant variation in respect of picking duration (Fig. 8). Duration of picking in this study varied from days 36.33 to 43.33 days. Among all genotypes, fruit harvesting continued for the longest period in case of BARI Dherosh1 (43.33 days). The genotypes Green Hybrid (41.33 days) and Arka Anamika (42 days) carried out longer time while the Nabik (36.33 days) had shortest duration.

Yield per plant

Fruit yield per plant differed significantly among the tested genotype (Fig. 9). Yield per plant in this study varied from 138.30 to 357.70 g. The highest fruit yield per plant was observed in BARI Dherosh1 (357.70 g) which was at par with Arka Anamika (310.90 g) and Hybrid Moti (281.50 g). The lowest fruit yield per plant was observed in Hybrid Raja (138.30 g). Reddy *et al.* (2012) reported that yield per plant was 242.61 g. The present result is within the range of reported result. Yield per plant probably vary due to genotype, management practice, number of fruit per plant fruit length, fruit diameter etc.

Yield (t/ha)

The fruit yield significantly varied ranging from 5.76 t/ha to 14.90 t/ha among the genotypes (Fig. 10). The genotype BARI Dherosh1 (14.90 t/ha) produced the highest yield which was at par with Arka Anamika (12.95 t/ha) and Hybrid Moti (11.73 t/ha). The lowest yield was found in Hybrid Raja (5.76 t/ha). These results are in full conformity with Rahman *et al.* (2012), Firoz *et al.* (2011) and Amanullah *et al.* (1999) who found significant varietal differences in yield.

Dry weight (%)

Dry weight varied significantly among the genotypes (Fig. 11). Dry weight varied in this experiment 12.28 to 19.90 %. The highest dry weight was observed in IPSA Okra (19.9 %). While lowest dry weight was observed in Hybrid Raja (12.28 %) followed by Green Hybrid (13.13 %).

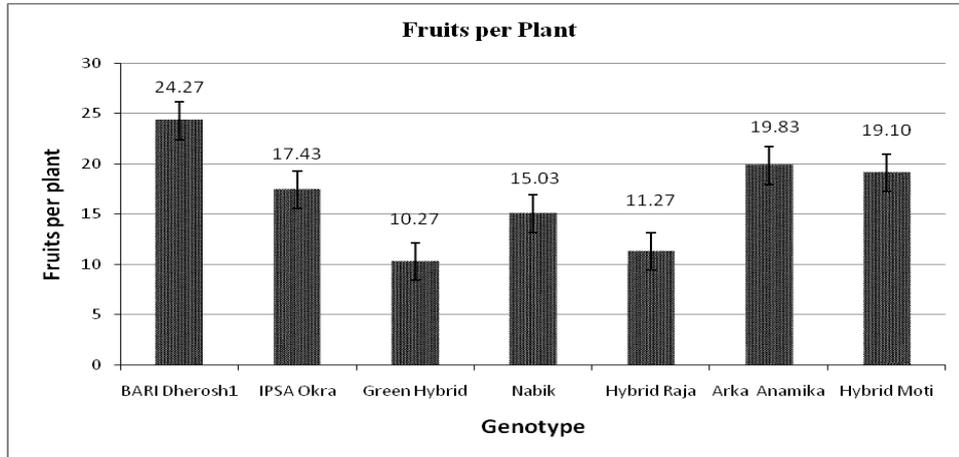


Fig. 6. Fruits per plant of seven genotypes of okra.

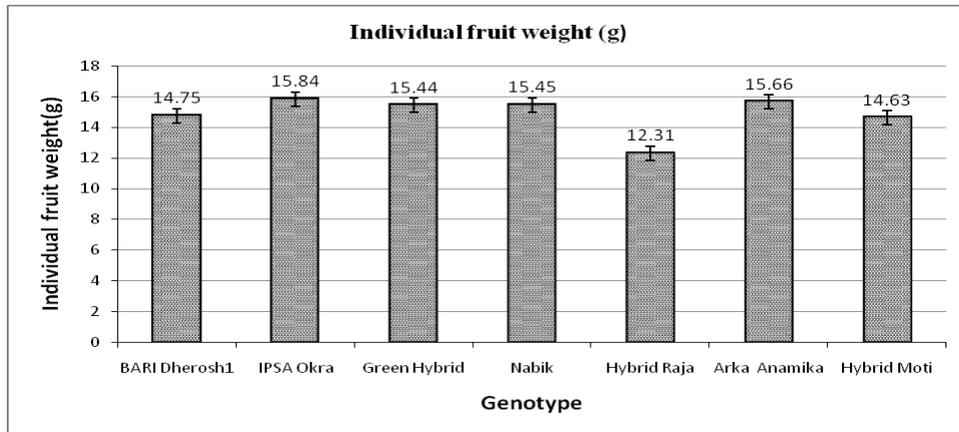


Fig. 7. Individual fruit weight of different genotypes of okra.

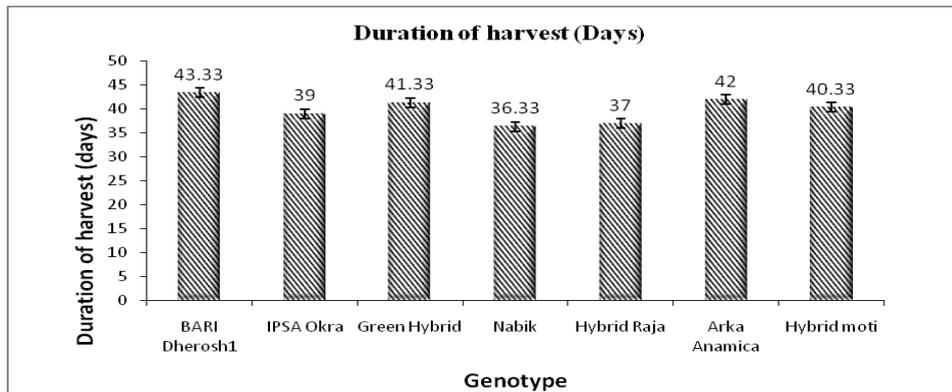


Fig. 8. Duration of harvest of seven genotype of okra.

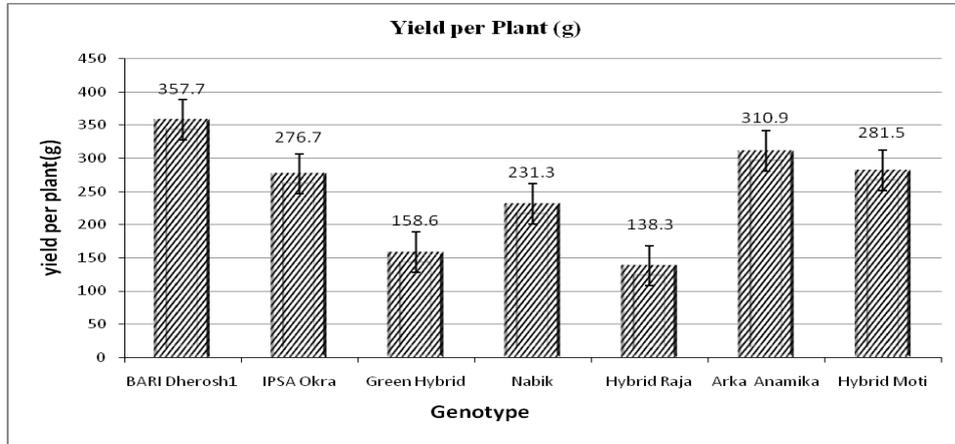


Fig. 9. Yield per plant of seven genotypes of okra.

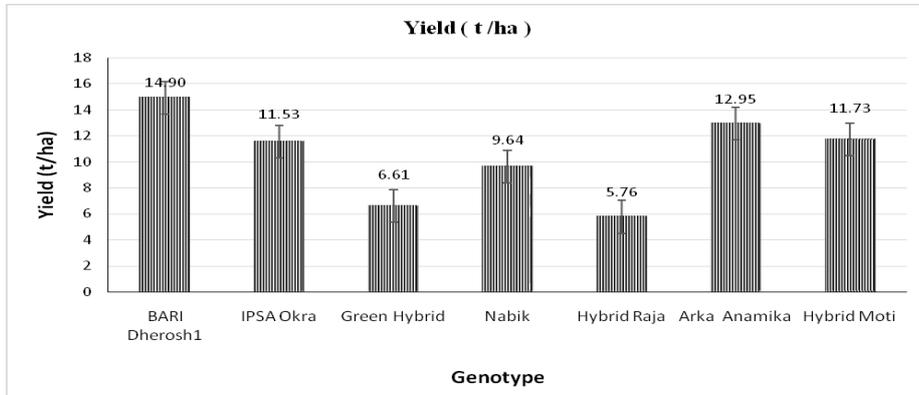


Fig. 10. Yield of seven genotypes of okra.

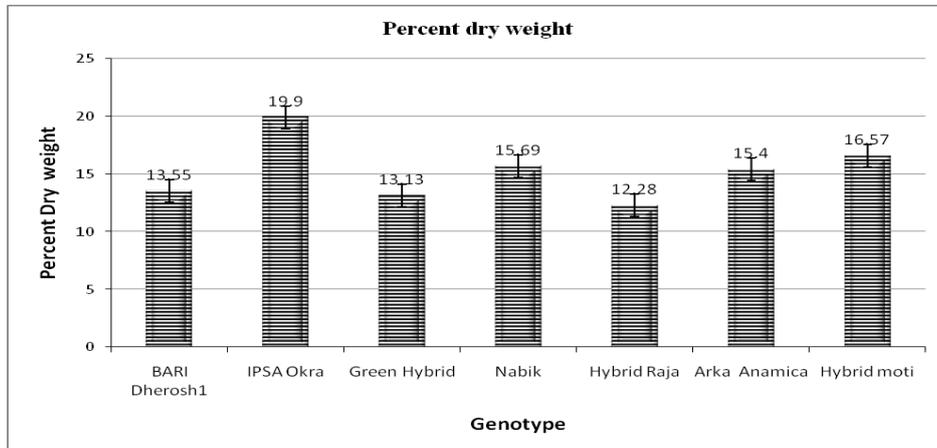


Fig. 11. Percent dry weight of seven genotypes of okra.

Virus Infestation (%)

Significant variation was observed among the genotypes in respect of virus infestation (Table 3). After germination of seedling there was no virus infested plant in experimental plot. With the increases of days infestation of virus was higher. There was no significant variation of virus infestation among the genotypes at 45 DAS.

The highest virus infestation was observed in Hybrid Raja (50%) which was statistically identical with BARI Dherosh1 (43.33%) and Green Hybrid (40%). The lowest virus infestation was observed in Arka Anamika (23.33%) which was statistically identical with IPSA Okra (30%), Nabik (36.67%) and Hybrid Moti (36.67%) at 60 DAS. The Range of virus infestation was 50% to 23.33% at 60 DAS.

At 75 DAS highest virus infestation was observed in Hybrid Raja (76.67%) which was statistically identical with Green Hybrid (73.33%), Hybrid Moti (73.33%) and Nabik (70%). The lowest virus infestation was observed in Arka Anamika (53.33%) which was statistically identical with IPSA Okra (60%) and BARI Dherosh1. The range of virus infestation at 75 DAS was 76.67 % to 53.33%.

At 90 DAS highest virus infestation was observed in Hybrid Raja (100 %) which is statistically identical with Hybrid Moti (96.67 %), Green Hybrid (93.33 %) and BARI Dherosh 1 (90%). Lowest virus infestation was observed in ArkaAnamika (76.67%) which was statistically identical with IPSA Okra (83.33 %) and Nabik (83.33 %). Mathew *et. al.*, (2005) recorded in an investigation of six resistant variety of okra and infestation of virus varied from 2.31% to 54%. Reddy *et al.* (2012) reported that the highest incidence of yellow vein mosaic virus on plants was observed in genotype of IC043279-A and IC043751-B (60.00 %), while the lowest for the genotypes IC90210 and IC018530 (30.00 %). The present result is higher than reported result due to different genotype.

Table 3. Virus infestation of seven okra genotypes at different days after sowing

Genotype	Virus infestation (%)			
	45 DAS	60 DAS	75 DAS	90 DAS
BARIDherosh 1	10.00	43.33 ab	63.33 bc	90.00 ab
IPSA Okra	13.33	30.00 bc	60.00 bc	83.33 bc
Green Hybrid	16.67	40.00 ab	73.33 ab	93.33 ab
Nabik	13.33	36.67 bc	70.00 ab	83.33 bc
Hybrid Raja	16.67	50.00 a	76.67 a	100.0 a
ArkaAnamika	10.00	23.33 c	53.33 c	76.67 c
Hybrid Moti	10.00	36.67 bc	73.33 ab	96.67 ab
Level of significance	NS	*	*	*
CV%	34.64	22.88	11.41	8.72

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

Nutritional effect among the okra genotypes

Ascorbic acid

Ascorbic acid content varied significantly among the genotype. Ascorbic acid content in this study varied from 3.35 to 1.99 mg/100 g (Table 4). The highest content of free ascorbic acid was recorded in Nabik (3.35 mg/100 g) which was statistically identical with Hybrid Moti (3.173 mg/100 g) while lowest ascorbic acid content was observed in Green Hybrid (1.987 mg/100 g). Kokare *et al.* (2006) reported that highest amount of ascorbic acid content was 17.35 mg/100 mg. The present result is quite lower than the reported result.

β -carotene

Significant variations in the amount of β -carotene were found, when considered different genotype effect. It varied from 0.09 to 0.15 IU/100 g (Table 4). Hybrid Moti had the maximum amount of β -carotene (0.15 IU/100 g), while minimum amount of β -carotene was found in IPSA Okra (0.09 IU/100 g).

Table 4. Vitamin and mineral content of seven genotypes of okra

Genotype	Ascorbic Acid (mg/100g)	β -carotene IU/100g	K (%)	Fe (ppm)
BARIDherosh 1	2.91 c	0.14 b	1.09 ab	111.80 c
IPSA Okra	2.93 c	0.09 e	1.09 a	132.60 ab
Green Hybrid	1.99 e	0.10 d	1.09 ab	111.80 c
Nabik	3.35 a	0.11 c	1.08 c	124.00 b
Hybrid Raja	2.64 d	0.10 d	1.07 d	132.60 ab
ArkaAnamika	3.08 bc	0.10 d	1.08 b	127.40 b
Hybrid Moti	3.17 ab	0.15 a	1.09 a	139.60 a
Level of significance	*	*	*	*
CV%	4.00	5.38	1.13	4.61

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

Potassium (K %)

Significant variation in the amount of K % was varied significantly among the genotypes. It varied from 1.066 % to 1.091 % (Table 4). The highest K % was observed in IPSA Okra (1.091 %) which was statistically identical with Hybrid Moti (1.09 %) and Green Hybrid (1.088 %). The lowest K % was observed in Hybrid Raja (1.07 %). Ubi and Osodeke (2006) reported that amount of potassium recorded as 302 mg/kg or 0.03 % which is much lower than the findings of present study.

Iron (Fe)

Amount of iron varied significantly among the genotype. Amount of iron varied from 139.6 to 111.8 ppm (Table 4). The highest amount of Fe was observed in Hybrid Moti (139.6 ppm) which was statistically identical with IPSA Okra (132.6 ppm) and Hybrid Raja (132.6 ppm). The lowest amount of Fe was observed in Green Hybrid (111.8 ppm). Midrar *et al.* (2005) reported slightly higher amount (120.9 mg/ kg) of Fe in Okra.

Conclusions

The result of present study generated some information which may help on efficient vegetable production. Among the seven genotypes, BARI Dherosh1 was the highest yielder, which had the maximum number of fruit per plant. Arka Anamika was second highest yielder and minimum virus infection. The highest percent of dry matter was obtained from IPSA Okra. None of the variety was found resistant against virus infestation. Nutritional status such as ascorbic acid, β -carotene, iron, and potassium of okra varied significantly among the genotypes. The present results revealed that the yield was maximum in BARI Dherosh1 while Hybrid Moti was superior in nutritive value.

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VARIABILITY AND CHARACTER ASSOCIATION IN CINNAMON GERMPLASM

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Abstract

The experiment was conducted at the Regional Spices Research Center, BARI during May 2014 to April 2015 to study the variability and character association in cinnamon germplasm taking the characters - tree growth, leaf characteristics, bark thickness, specific bark weight and quality of bark of cinnamon plants. Range, variance and coefficient of variation of 30 different characters showed variations in 53 cinnamon accessions. High coefficient of variation was found for base girth, main stem height, number of tertiary branches/plant, tree volume, fresh and dry bark weight of tertiary branches. Bark thickness and specific bark weight gradually declined from main stem to lateral branches. The hierarchical cluster analysis with single scaled dendrogram showed eight clusters due to variation among the germplasm. Cluster III contained maximum 14 genotypes followed by cluster I and cluster VII, each having 12 genotypes. Association analysis revealed that significant correlation of base girth with tree volume, and secondary branches/plant had also significant correlation with leaf thickness and tree volume. It also revealed that significant correlation of fresh bark thickness of main stem with fresh bark thickness of primary, secondary and tertiary stems, also with fresh and dry bark weight of main, primary, secondary and tertiary stems. Specific bark weight had also significant correlation with fresh and dry bark weight of main, primary, secondary and tertiary barks.

Keywords: Variability, correlation, cinnamon, germplasm, cluster, dendrogram.

Introduction

Cinnamon (*Cinnamomum* spp) locally known as 'Darchini' belonging to the family Lauraceae is a common tree spice which is obtained from the inner bark of trees. The genus *Cinnamomum* consists of about 32 genera and 2000-2500 species and they are mainly evergreen trees of tropics and subtropics (Tiwari and Agarwal, 2004). The genus has two main species- *Cinnamomum verum* Presl (syn- *C. zeylenicum* Blume) and *C. cassia*. The former is known as 'true cinnamon' and the later as 'Chinese cinnamon'. Cinnamon is used widely in food industry and medicinally since ancient times (Yao, 2015). The flavor of cinnamon is due to an aromatic essential oil that makes up 0.5 to 1% (Chang *et al.*, 2013). It is full of antioxidants, may cut the risk of hurt disease or stoke and has powerful anti-diabetic effect and lower blood sugar level (Anon., 2015). It is

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native to Srilanka and India but also grown commercially in the tropical conditions e.g. Brazil, Java, Madagascar, Vietnam, the West Indies and Zanzebar.

Cinnamon and cassia flourish well in the humid regions with temperature 20°C-30°C, average temperature of 27°C receiving an annual rainfall of 1500-2500 mm. Prolonged spell of dry weather are not conducive for its grown. It can be grown from sea level to 2000 m altitude in Indian conditions. In Srilanka, it is abundant in the regions of 30-220 m and is also grown up to 1200 MSL (Anon., 2015; Tiwari and Agarwal, 2004). Cinnamon is suitable for wide varieties of climatic condition but it specially requires hot and humid climate. It is a hardy plant which can be grown in almost all types of soils. The quality of the bark is highly influenced by the soil and ecological factors. Cinnamon prefers relatively elevated land and a sandy soil is considered best for better quality with lower insect pest incidence but gave lower yield compared to other soils (Anandaraj and Devasabayam, 2004). Bangladesh is an ideal place to grow cinnamon commercially, especially the eastern hilly region of Bangladesh. But so far there is no commercial cultivation of this exotic spice in this country because there is no released variety of this spice and no production technology is available to the farmers.

Germplasm evaluation is a part of selecting high yielding and potential varieties of any crop (Rema *et al.*, 2003). More than 50 cinnamon plants of different origin were collected and planted at different times at the Regional Spices Research Center (RSRC), BARI, Gazipur. All plants were in suitable condition for collection of economic product, bark. The present investigation was therefore, undertaken to study the variability and character association in cinnamon germplasm and finally to evaluate the growth of tress, bark characteristics and bark quality of the present 53 cinnamon plants.

Materials and Method

The experiment was conducted at the Regional Spices Research Center (RSRC), BARI during May 2014 to April 2015. The selected 53 cinnamon plants were given accession number for evaluation. All the cinnamon plants were not planted at the same time. The plants were fertilized two times every year in May and September with cowdung 2 kg, nitrogen 60 g, phosphorus 50 g, potassium 50 g and sulphur 20 g per tree and mixed well with soil with the help of khurpi and spade. As there was no severe attack of disease and insect pest, no pesticide was applied. Some unexpected bushy and dead branches of trees were removed by light pruning. Base girth, main stem height, number of main branches, tree height and tree spread were measured with the help of a long bamboo stick, measuring tape and meter scale. Tree volume was calculated using the formula (Blozan, 2004):

$$\text{Tree volume} = \frac{\text{Plant height} (0.3\pi) (E - W\text{spread} + N - S\text{spread})^2}{4}$$

A little portion (approximately 10 cm × 2.5 cm) of bark from main stem, primary, secondary and tertiary branches were collected detaching with the help of a knife and kota (one type of bended tools) for collecting data. Size (length × width), weight and thickness of fresh collected bark were measured with the help of a digital balances and digital slide callipers. Collected barks were dried under shade followed by sun drying to get a constant dry weight. The area of bark was calculated by direct multiplication of width with length of the bark. The specific bark weight (weight of 100 cm² dry barks) was calculated dividing the dry weight (g) by area (actual bark size) then multiplying by 100. All data were calculated using MS-Excel and analyzed through software SPSS Version 16 and interpreted properly.

Results and Discussion

The existing 53 cinnamon plants were used to measure 30 different characters for evaluation of their growth and bark production. Descriptive statistics on 30 different characters of 53 cinnamon plants are presented in Table 1. The age of plant varied from 4 to 16 years with a mean of 7.23 years, standard deviation 2.30 and CV% 31.86. The base girth ranged from 14.00 to 142.24 cm with mean 37.24 cm, standard deviation 18.02, variance 325.66 and CV% 57.26. The length of trunk or main stem length ranged from 1.65 cm to 152.00 cm with 53.11 cm mean, 36.36 standard deviation, 1322.05 variance and 60.45 CV%. It was more variable due to varied stem length for early branching and late branching somewhat depending on training of plants done at younger stage. Branching increased gradually from primary to tertiary but variation was higher in tertiary branches. The variation of leaf length was also found higher with high variance (3.05) compared to leaf width and thickness. Leaf thickness varied due to maturity e.g. age of leaf. Tree volume ranged from 2.64 m³ to 39.06 m³ with a mean of 9.18 m³, standard deviation 5.43 m³ and CV% 59.35. The variation of tree volume was higher due to different aged tree and planting place was not uniform that differed the tree growth. Fresh bark thickness gradually declined from main stem to lateral branching. Thicker barks obtained from main stem medium from primary branch, medium thin from secondary branch and thinner from tertiary branches.

Fresh and dry bark weight also declined from main stem to distal branches as its thickness varied from main stem to tertiary branches. Fresh bark size showed higher standard deviation and variance due to non-uniform cutting of bark which is not actually a character of the genotype. The specific bark weight (weight of 100 cm² dry bark) was higher in the main stem and gradually it was declined up to tertiary branches. Association analysis revealed significant correlation of fresh weight of bark with dry bark yield (Krishnamoorthy *et al.*, 1992).

Table 1. Descriptive Statistics of 53 Cinnamon accessions for 30 characters

Parameters	Range		Mean	Std. Dev.	Variance	CV%	
	Minimum	Maximum					
Age of plant	4.00	16.00	7.23	2.30	5.31	31.86	
Base girth (cm)	14.00	142.24	31.24	18.05	325.66	57.26	
Main stem height (cm)	1.65	152.40	53.11	36.36	1322.03	60.45	
No. of branch / plant	Primary branch	1.00	5.00	2.21	0.86	0.75	39.10
	Secondary branch	1.00	13.00	4.47	1.90	3.60	42.43
	Tertiary branch	4.00	68.00	11.04	8.64	74.58	78.24
Leaf size	Leaf length (cm)	5.50	16.56	11.22	1.75	3.05	15.57
	Leaf width (cm)	3.50	8.14	6.00	1.03	1.06	17.15
	Leaf thickness (mm)	0.11	0.33	0.23	0.44	0.02	19.00
Tree volume (m ³)	2.64	39.06	9.18	5.43	29.50	59.15	
Fresh bark thickness (mm)	Mainstem	2.60	9.80	5.71	1.54	2.36	26.92
	Primary branch	1.80	7.90	4.07	1.30	1.69	31.93
	Secondary branch	1.57	7.10	3.21	1.13	1.27	35.06
	Tertiary branch	1.00	4.50	2.36	0.90	0.82	38.18
Fresh bark weight (g)	Mainstem	3.61	27.90	14.98	5.69	32.40	38.00
	Primary branch	3.00	15.90	9.67	3.23	10.44	33.41
	Secondary branch	2.08	14.76	7.20	2.70	7.27	37.42
	Tertiary branch	1.06	10.66	4.93	2.21	4.89	44.82
Dry bark weight (g)	Mainstem	1.39	12.86	7.01	2.48	6.13	35.33
	Primary branch	1.24	7.88	4.59	1.60	2.56	34.84
	Secondary branch	0.71	7.19	3.41	1.25	1.56	36.72
	Tertiary branch	0.56	4.98	2.28	1.01	1.02	44.48
Fresh bark size (cm ²)	Mainstem	11.10	42.67	31.09	6.19	38.36	19.42
	Primary branch	13.56	42.93	27.81	5.64	31.84	20.24
	Secondary branch	11.70	39.59	26.34	5.91	34.92	22.44
	Tertiary branch	11.57	37.35	22.91	5.81	33.81	25.18
Specific bark wt.(g/100cm ²)	Mainstem	11.74	66.75	22.88	8.81	77.69	38.52
	Primary branch	6.35	41.29	16.76	5.96	35.51	35.55
	Secondary branch	4.16	29.39	13.18	4.77	22.79	36.22
	Tertiary branch	3.99	18.10	9.91	3.53	12.47	35.62

Hierarchical cluster analysis

Fig. 1. showed the Hierarchical cluster analysis using different growth and bark characters of 53 cinnamon germplasm. The dendrogram using single linkage showed eight clusters of germplasm. The members of different clusters were

given in Table 2. Cluster one and seven consists of 12 germplasm each which has minimum distances among them. Cluster three represented the maximum 14 germplasm. Cluster two has nine germplasm while only one germplasm represented each by the cluster IV, V and VIII.

Table 2. Cluster Membership on the basis of growth and bark characteristics

Cluster	Accessions	No. of accessions
Cluster I	CZ GAZ 001, CZ GAZ 004, CZ GAZ 005, CZ GAZ 010, CZ GAZ 022, CZ GAZ 025, CZ GAZ 026, CZ GAZ 028, CZ GAZ 042, CZ GAZ 043, CZ GAZ 051, CZ GAZ 052	12
Cluster II	CZ GAZ 002, CZ GAZ 003, CZ GAZ 008, CZ GAZ 015, CZ GAZ 023, CZ GAZ 029, CZ GAZ 041, CZ GAZ 046, CZ GAZ 050	9
Cluster III	CZ GAZ 006, CZ GAZ 007, CZ GAZ 009, CZ GAZ 014, CZ GAZ 017, CZ GAZ 018, CZ GAZ 019, CZ GAZ 020, CZ GAZ 021, CZ GAZ 024, CZ GAZ 027, CZ GAZ 031, CZ GAZ 032, CZ GAZ 033	14
Cluster IV	CZ GAZ 011, CZ GAZ 030, CZ GAZ 053	3
Cluster V	CZ GAZ 012	1
Cluster VI	CZ GAZ 013	1
Cluster VII	CZ GAZ 016, CZ GAZ 034, CZ GAZ 035, CZ GAZ 036, CZ GAZ 037, CZ GAZ 038, CZ GAZ 039, CZ GAZ 040, CZ GAZ 044, CZ GAZ 045, CZ GAZ 047, CZ GAZ 049	12
Cluster VIII	CZ GAZ 048	1

The germplasm differed from one cluster to another due to the morphological features of the plant and bark characters. Some parameters were similar with nearby population in a cluster because all other characteristics were similar within the group members. The cluster V was different from other clusters probably belongs from cassia and not true cinnamon. The existence of different clusters in dendrogram represented the inter cluster similarity or dissimilarity. Dendrogram showed two major group of cluster that cluster III, I, V and VI were closer one other while they differed from other group of cluster IV, VII and II.

Correlation among 26 characters (growth and bark characters) of 53cinnamon germplasm

The 2-tailed Pearson correlation co-efficient values and level of significance among 10 growth parameters and 16 bark characteristics of 53cinnamon germplasm are presented in Table 3a and Table 3b. There was highly significant positive correlation ($r= 0.833^{**}$) observed in base girth and tree volume. Negative correlation was found in main stem height with all other growth

parameters. Leaf width also showed negative correlation with base girth and branching. Secondary branch was significantly positively correlated with leaf thickness ($r= 0.606^{**}$) and tree volume ($r= 0.487^{**}$) denoted that plants having more number of secondary branches have higher tree volume and thicker leaves.

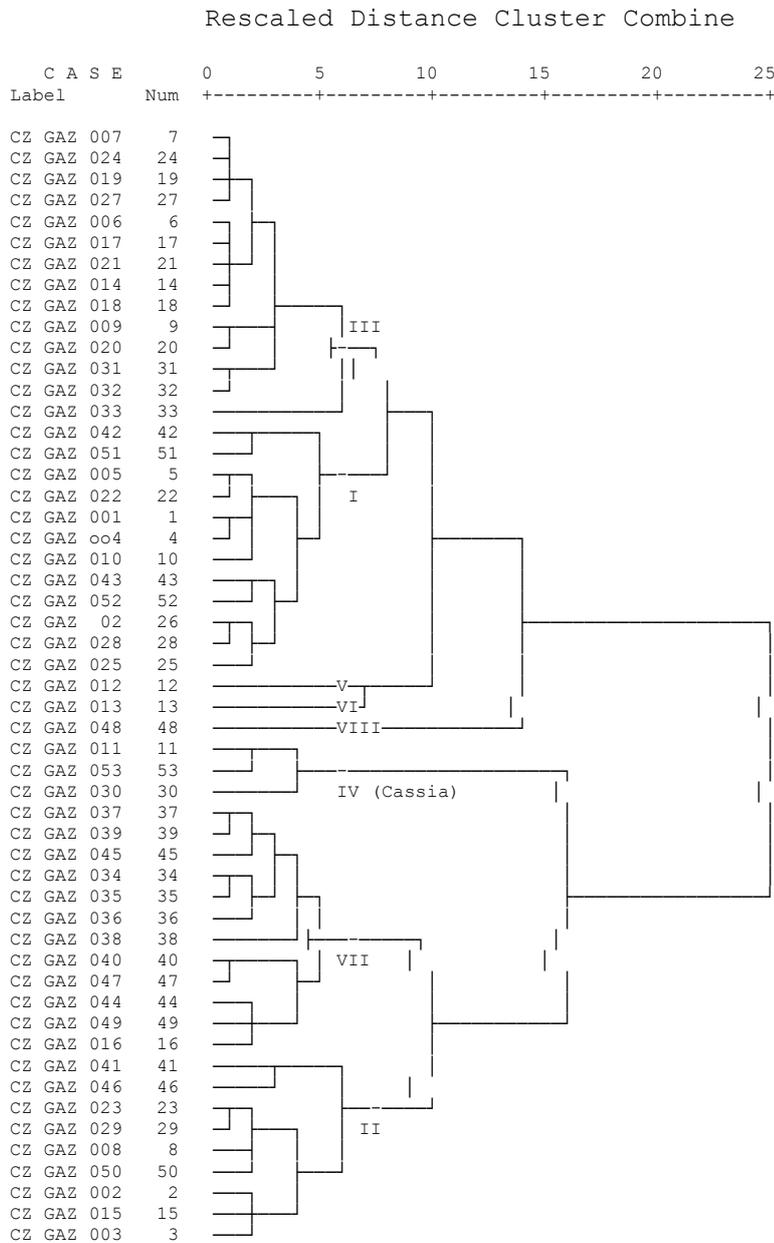


Fig.1. Hierarchical cluster analysis showing Dendrogram using Complete Linkage.

Table 3a. Pearson correlation on the basis of growth parameters

	BG	MSH	PBP	SBP	TBP	LL	LW	LT	Tree volume
Age of plant	0.212	0.226	-0.275*	-0.142	0.396**	0.429**	0.257	-0.065	0.079
Base girth (BG) cm		-0.271*	0.322*	0.369**	0.141	0.317*	-0.016	0.195	0.833**
Main stem height (MSH) cm			-0.417**	-0.327*	-0.056	-0.142	0.048	-0.204	-0.146
Primary branch /plant (PBP)				0.362**	0.053	-0.081	-0.195	-0.053	0.341*
Secondary br./ plant (SBP)					0.127	0.030	-0.333*	0.606**	0.487**
Tertiary branch/ plant (TBP)						0.117	0.090	0.102	0.087
Leaf length (LL) cm							0.478**	0.002	0.198
Leaf width (LW) cm								-0.309*	-0.087
Leaf thickness (LT) mm									0.278*

*, ** represents the level of significance at 5% and 1% level of significance, respectively.

All bark parameters showed significant positive correlation with all other bark characteristics. Fresh bark thickness of main stem (FBTM) showed strong positive correlation with fresh bark thickness of primary stem ($r= 0.756^{**}$), fresh bark thickness of secondary stem ($r= 0.535^{**}$), fresh bark thickness of tertiary stem ($r= 0.679^*$), fresh bark weight of main stem($r=0.609^{**}$), fresh bark weight of primary stem($r=0.558^{**}$), fresh bark weight of secondary stem($r=0.636^{**}$), fresh bark weight of tertiary stem($r=0.606^{**}$), dry bark weight of main stem($r=0.572^{**}$), dry bark weight of primary stem($r=0.543^{**}$),dry bark weight of secondary stem($r=0.537^{**}$) and dry bark weight of tertiary stem($r=0.572^{**}$).

FBTM - Fresh bark thickness of main branch, FBTP - Fresh bark thickness of primary branch, FBTS - Fresh bark thickness of secondary branch, FBTT- Fresh bark thickness of tertiary branch, FBWM- Fresh bark weight of main branch, FBWP- Fresh bark weight of primary branch, FBWS- Fresh bark weight of secondary branch, FBWT- Fresh bark weight of tertiary branch, Fresh bark thickness of main branch, DBWM - Dry bark weight of main branch, DBWP- Dry bark weight of primary branch, DBWS- Dry bark weight of secondary branch . DBWT- Dry bark weight of tertiary branch ,SBWM–Specific bark weight of main branch, SBWP - Specific bark weight of primary branch, SBWS - Specific bark weight of secondary branch, SBWT- Specific bark weight of tertiary branch.

Specific bark weight showed strong positive correlation with fresh and dry bark weight of main, primary, secondary and tertiary barks while weaker but positive correlation showed with the thickness of different stem barks. Raghuet *al.* (2007) observed that leaf area showed the maximum morphological variability; he also found among the six morphometric characters studied, all the characters except inter-nodal length showed significant positive correlation towards each other. This result ensured the assumption of the sources of variation in respect of bark characteristics which were actually the yield attributes of cinnamon are mostly depends on plant growth. Thus the variation seems to be environmental and genetic variation might not be the major exterminator.

Conclusion

Based on the above results, it might be concluded that variability exists among 53 cinnamon germplasm in respect of growth parameters *e.g.* stem height, base girth, leaf size, leaf shape and leaf thickness, fresh bark thickness, specific bark weight. There depicts a phenotypic correlation among growth parameters and bark characteristics of cinnamon. The genotypes are grouped into eight clusters. The genotypes falling into the same cluster are genetically close. The genotypes of cluster III, I or VIII will be further evaluated with special emphasis giving to bark characteristics and their organoleptic taste for selection of suitable cinnamon genotypes which could be emerged as variety(ies) of cinnamon.

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COMBINING ABILITY AND HETEROSIS ON YIELD AND ITS COMPONENT TRAITS IN MAIZE (*Zea mays* L.)

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Abstract

Combining ability and heterosis were studied in a 7×7 half diallel cross in maize for grain yield and yield contributing characters. Significant general and specific combining ability variances were observed for all the characters studied. The significant estimates of GCA and SCA variances suggested the importance of both additive and non-additive gene actions for the expression studied traits. In these studies, variances due to SCA were higher than GCA for all characters, which revealed the predominance of non additive gene action (dominance and epistasis) for controlling these traits. Parents P₁ and P₄ were excellent general combiner for days to tasseling and silking while P₁ and P₅ for early maturity. P₄ for short height and, P₄ and P₇ for higher thousand kernel weight. The parents P₄ and P₆ having good combining abilities for yield. Heterosis estimation was carried out using two commercial varieties NK40 and 900MG. When standard commercial check NK40 was used, the percent heterosis for kernel yield varied from -51.39 to 12.53%. Among the 21 F₁s, 3 crosses exhibited significant positive heterosis for kernel yield. The highest heterosis was exhibited by the cross P₄×P₆ (12.43%), P₆×P₇ (10.89%) and P₂×P₃ (9.87%) respectively. Compared with 900MG as check, the percent heterosis for kernel yield varied from -53.73 to 7.01%. Among the 21 F₁s, none of the crosses exhibited significant positive heterosis for kernel yield. The highest heterosis were exhibited by the crosses P₄×P₆ (7.01%), P₆×P₇ (5.55%) and P₂×P₃ (4.57%). The crosses showed significant positive SCA values could be used for variety development after verifying them across the agro-ecological zones of Bangladesh.

Keywords: Combining ability, heterosis, GCA, SCA, maize (*Zea mays* L.), nature of gene action.

Introduction

Maize is becoming an important crop in the rice based cropping system. Maize continues to expand rapidly at an average rate of 20% year⁻¹ (CIMMYT, 2008). A combination of high market demand with comparatively low cost of production and high yield has generated tremendous interest among the farmers in maize cultivation. The estimated average national grain yield is 5.7 t ha⁻¹, is the highest in Asia, and that compares with average on-farm grain yield of

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around 2 t ha⁻¹ for wheat or 3-4 t ha⁻¹ with boro rice (CIMMYT, 2008). Day by day it is gaining popularity in the country due to huge demand, particularly for poultry feed industry. The acreage and production of maize have an increasing tendency with the introduction of exotic hybrids due to high yield potentials. The farmers are mostly cultivating imported hybrid maize, but they are very expensive. The local hybrids are cheap and farmers can get it easily.

Combining ability estimation are important genetic attributes for maize breeders in anticipating improvement in productivity *via* hybridization and selection. Maize exhibits heterosis for all traits and the extent of heterosis vary significantly depending on the choice of parents and the trait(s) measured. Maize unveiled excessive ability for heterotic expression, even several inbred lines exhibit enough variability to find out appropriate genotypes for a successful breeding program and generating stable inbred lines for production of commercial hybrids. Genetic variability and harboring of excessive hybrid vigour makes maize as a model crop for all kind of studies. Furthermore, the input cost of hybrids can easily be minimized by avoiding losses of resources and time in production of desirable inbred lines, as it is obvious that the breeding community always preferred hybrid maize rather than Open pollinated variety (OPV) or synthetic variety because of its high productivity. Combining ability studies provide information on the genetic mechanisms controlling the inheritance of quantitative traits and enable the breeders to select suitable parents for further improvement or use in hybrid breeding for commercial purposes. In biometrical genetics two types of combining abilities are considered i.e. general combining ability (GCA) and specific combining ability (SCA). General combining ability refers to the average performance of the genotype in a series of hybrid combinations and is a measure of additive gene action whereas; specific combining ability is the performance of a parent in a specific cross in relation to general combining ability (Sharief *et al.*, 2009). Combining ability analysis is of special importance in cross pollinated crops as it helps in identifying potential inbred parents that can be used for producing hybrids. Such studies also help in elucidating the nature and magnitude of different types of gene action governing the expression of quantitative characters of economic importance (Pal and Prodhan, 1994).

Inbred lines are pre-requisite for hybrid development in maize. Combining ability analysis is of special importance in cross-pollinated crops like maize as it helps in identifying potential parents that can be used for producing hybrids and synthetics (Vasal, 1998). The nature and magnitude of gene action is an important factor in developing an effective breeding program, which can be understood through combining ability analysis. This information is helpful to plant breeders for formulating hybrid breeding program.

Heterosis and combining ability are prerequisites for developing a good economically viable maize variety. Information on the heterotic patterns and

combing ability among maize germplasm is essential in maximizing the effectiveness of hybrid development (Beck *et al.*, 1990). The phenomenon of heterosis has been exploited extensively in crop breeding, leading to significant increase in yield. Heterosis is used to describe this phenomenon when the parents are taken from different populations of the same species; hybrid vigor is used when the parents are taken from different species (Charlesworth and Willis, 2009).

Therefore, the present investigation with 7×7 half diallel cross was undertaken for isolating superior inbred lines and thereby to identify better combining parents to obtain suitable hybrids and determine percent of heterosis using standard commercial checks.

Materials and Method

Seven diverse maize inbred lines *viz.* P₁ (BIL 79), P₂ (BIL 31), P₃ (CML 468-2-B), P₄ (CA03130-1-2-B-B-B), P₅ (CML 481-1-B), P₆ (CML 20-2-B) and P₇ (CML 487-2-B) were crossed in a diallel fashion excluding the reciprocals during the *rabi* season in 2012-13. The resulting 21 F₁'s and their 7 parents were evaluated along with three checks (BARI hybrid maize 9, NK40 and 900MG) in a alpha lattice design with two replications at BARI, Gazipur in the following *rabi* season of 2013- 2014. Each entry planted in one rows of 5 m long plot. The spacing between rows was 75 cm and plant to plant distance was 20 cm. One plant per hill was maintained after proper thinning. Data were recorded on ten randomly selected plants from each plot for plant height (cm), ear height (cm), days to tasseling and silking, days to maturity, yield and 1000 kernel weight. Kernel yield was recorded on whole plot basis and finally converted to t/ha.

Data were analyzed for variance for all the characters studied. The mean performances of all characters were analyzed using Crop Stat software. General combining ability (GCA) and specific combining ability (SCA) were estimated following Model I, Method II of Griffing (1956). The mean squares for GCA and SCA were tested against error variance desired using the mean data of all the single cross hybrids and check variety, was estimated and tested according to Singh and Singh (1994). Percent heterosis was calculated by using the following formula:

$$\text{Standard heterosis (\%)} = [(\overline{F_1} - \overline{CV}) / \overline{CV}] \times 100$$

Where, $\overline{F_1}$ and \overline{CV} represented the mean performance of hybrid and standard check variety. The significance test for heterosis was done by using standard error of the value of check variety.

Results and Discussion

The mean performances of all the crosses along with the checks are presented in Table 1. Significant differences were observed for all the characters except days to maturity and 1000 kernel weight, indicating sufficient genetic variability present among the materials.

Table 1. Mean performance of hybrid maize obtained from 7 × 7 half diallel crosses of maize evaluated at Gazipur during rabi 2013-2014.

Cross/ Hybrids	Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000 kw	Yield (t/h)
P ₁ ×P ₂	95	98	196	96	148	310	10.09
P ₁ ×P ₃	93	96	202	90	144	300	6.75
P ₁ ×P ₄	86	89	183	99	144	340	7.67
P ₁ ×P ₅	95	99	191	99	144	250	4.65
P ₁ ×P ₆	96	100	215	106	148	305	7.59
P ₁ ×P ₇	94	98	200	103	149	295	6.73
P ₂ ×P ₃	93	96	228	112	147	300	10.51
P ₂ ×P ₄	85	88	178	94	145	360	8.46
P ₂ ×P ₅	94	97	229	112	149	325	7.35
P ₂ ×P ₆	95	99	204	104	149	355	9.22
P ₂ ×P ₇	102	107	182	91	149	380	4.71
P ₃ ×P ₄	85	88	208	91	144	360	8.94
P ₃ ×P ₅	93	97	232	110	145	235	6.63
P ₃ ×P ₆	94	98	192	100	148	290	10.07
P ₃ ×P ₇	89	93	211	103	143	280	7.30
P ₄ ×P ₅	90	94	212	107	142	360	8.70
P ₄ ×P ₆	87	91	180	104	145	360	10.76
P ₄ ×P ₇	90	94	215	99	146	330	8.67
P ₅ ×P ₆	96	100	185	101	148	310	8.74
P ₅ ×P ₇	92	94	201	107	145	295	7.78
P ₆ ×P ₇	93	97	183	98	149	300	10.61
BHM9	94	97	198	107	145	305	8.33
NK 40	89	92	210	100	146	415	9.57
900MG	91	95	202	106	149	370	10.05
F-test	**	**	**	**	-	-	**
CV(%)	2.5	2.8	10.4	9.8	2.3	20.4	11.5
LSD _(5%)	3.74	4.08	26.08	15.7	5.4	129.80	1.84

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

The magnitude of mean squares for general and specific combining abilities for studied characters indicated significant differences among the GCA as well as SCA effects. This suggested presence of notable genetic variability among the genotypes for the characters studied. Furthermore, the analysis of variance for combining abilities (GCA and SCA) showed significant variations for all the characters except GCA of 1000 kernel weight, which indicate significant differences among the GCA as well as SCA effects. Highly significant differences for most of the sources of variation were also reported by Narro *et al.* (2003). The significant differences for gca and sca variances for different traits in maize have been reported earlier (Mathur and Bhatnagar, 1995). The mean squares of genotypes (diallel hybrids) were highly significant for all the traits. This indicated an adequate amount of variability present in the materials for these traits. Further, analysis of variance for combining ability showed that estimates of mean squares due to GCA and SCA were highly significant for all the characters. This indicated importance of both additive and non-additive components of genetic variance in controlling these traits. This was confirmed by Debnath and Sarker (1990) and Derera *et al.*, (2007) who reported similar results for yield and yield components in maize. Importance of both additive and non-additive gene effects in maize were also reported by Rokadia and Kaushik (2005).

Table 2. Mean squares due to general and specific combining ability (GCA and SCA) for 7 characters in a 7 × 7 diallel cross of maize

Sources of variation	df	Mean of squares						
		Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000-KW (g)	Yield (t/h)
Genotype	27	41.22**	49.83**	1631.83**	767.05**	43.29**	7690.14*	11.10**
GCA	6	38.12**	38.88**	905.27*	309.48**	33.997**	3971.16	5.67**
SCA	21	43.15**	52.96**	1839.43**	897.78**	45.95**	8752.71*	12.65**
Error	27	2.03	2.74	260.16	81.88	6.34	3197.55	0.78
GCA: SCA		0.88	0.73	0.49	0.34	0.74	0.45	0.45

In these studies, variances due to SCA were higher than GCA for all character, which revealed the predominance of non additive gene action (dominance and epistasis) for controlling these traits. Predominant role of SCA effect i.e. non-additive gene actions in the inheritance of kernel yield was also reported by several workers (Khotyleva *et al.*, 1986, Zelleke, 2000, Lee, 1987 and Singh and Kumar, 2008). The genetic control of different yield contributing characters is finally projected through kernel yield. Therefore, non-additive gene action for kernel yield is expected.

General combining ability (GCA) effects

The estimates of general combining ability effects of the parents are presented in Table 3. For days to tasseling and silking, negative estimates are considered desirable as those were observed to be associated with earliness. The parents P₁ and P₄ showed negative GCA effects for this trait. In case of plant height and ear height, negative estimates are desirable since they are correlated with shorter plant height. Parent P₄ was good combiner having significant negative GCA effects both for plant and ear height. According to Singh and Singh (1979), generally earliness is associated with days to silk and the shorter plants with low ear height are associated with resistance to lodging.

Parents P₄ and P₆ were the best general combiner for yield and also possessed significant positive gca effect. This was supported by Singh *et al.*, (1995) and Hussain *et al.*, (2003). From the GCA effect it was observed that, none of the parents individually showed good general combiner for all the yield component.

The overall study of GCA effects suggests that parents P₁ and P₄ were excellent general combiner for early tasseling and silking, parents P₁ and P₅ were excellent for early maturity and parents P₄ for short height, parents P₄ and P₆ for yield. These parents could be used in future breeding program to improve maize yield with desirable traits.

Specific combining ability (SCA) effects

The SCA effects of the crosses for seven characters are presented in Table 4. For days to 50% tasseling, 5 crosses exhibited significant negative sca effects and for days to 50% silking 5 crosses showed significant negative SCA, indicates early flowering of the hybrids. The SCA effect of the cross P₄×P₅ was positive significant indicating for higher 1000 kernel weight.

For considering yield, among 21 hybrids 8 crosses performed significant positive SCA effects for kernel yield (Table 4) and most of them also possessed high mean values for the same trait (Table 1). Out of 21 crosses eight viz. P₁×P₂, P₂×P₃, P₃×P₆, P₄×P₅, P₄×P₆, P₄×P₇, P₅×P₇ and P₆×P₇ showed significant positive SCA effects for yield. The significant positive SCA effect involved parents where one or both the parents were related to good combiners, indicating GCA of the parental lines plays a key role for high yield. Xingming *et al.*, (2002) also drew similar conclusion. These crosses also possessed high *per se* performances (Table 1). Vasal (1998) also suggested to include one good combiner (especially female parent) during crossing to obtain higher heterosis.

Table 3. General combining ability (GCA) effects and mean performances (in parenthesis) for different characters in a 7 × 7 diallel cross of maize

Parents	Days to tasseling		Days to silking		Plant ht. (cm)		Ear ht. (cm)		Days to maturity		1000-KW (g)		Yield (t/h)	
	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean
P1	-1.47**	91	-1.54**	95	-2.89	190	-1.05	94	-1.33*	141	-6.19	267	-0.94**	3.11
P2	1.42**	93	1.40**	97	-1.67	193	-2.61	94	1.81*	147	23.81	303	0.38	4.45
P3	0.23	91	0.29	94	11.05*	205	-0.44	95	0.14	145	-11.2	261	0.01	4.20
P4	-2.13**	88	-1.98**	92	-8.89*	186	-6.0*	90	-0.80	144	4.92	291	0.49*	4.61
P5	-0.08	92	-0.26	96	2.89	199	4.12	100	-1.36*	140	-12.3	261	-0.40	3.49
P6	1.98**	94	2.13**	97	-6.61	186	-0.62	95	1.92**	147	3.97	265	0.77**	5.18
P7	0.003	92	-0.03	96	6.11	196	6.52*	99	-0.41	145	14.92	286	-0.10	4.13
SE(gi)	0.31		0.36		3.51		1.97		0.54		12.34		0.19	
LSD (5%)	0.76		0.88		8.59		4.82		1.32		30.20		0.46	
LSD (1%)	1.08		1.26		12.28		6.89		1.88		43.17		0.66	

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

Table 4. Specific combining ability (SCA) effects for different characters in 7 × 7 diallel cross in maize

Cross	Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000-KW (g)	Yield (t/ha)
P ₁ ×P ₂	3.08**	3.15**	12.43	8.23	3.65*	7.92	3.46**
P ₁ ×P ₃	2.25*	2.26*	5.71	-0.44	1.31	32.92	0.50
P ₁ ×P ₄	-2.36*	-2.46*	6.65	14.55	2.26	56.81	1.11
P ₁ ×P ₅	5.08**	5.32**	2.88	4.50	2.32	-15.97	-1.20**
P ₁ ×P ₆	4.02**	4.43**	35.88**	16.24	3.54	40.69	0.57
P ₁ ×P ₇	3.97**	4.10**	8.15	5.59	6.38**	1.81	0.58
P ₂ ×P ₃	-0.64	-1.18	30.49**	23.61**	1.21	2.92	2.94**
P ₂ ×P ₄	-5.75**	-6.40**	0.43	10.60	-0.35	46.81	0.58
P ₂ ×P ₅	1.19	0.88	39.65**	19.06**	4.71**	29.03	0.18
P ₂ ×P ₆	0.14	0.48	23.65*	15.79*	0.93	60.69	0.89
P ₂ ×P ₇	8.58**	10.65**	-11.07	-4.85	3.76*	56.81	-2.75**
P ₃ ×P ₄	-5.08**	-5.79**	17.21	5.93	0.82	81.81	1.43
P ₃ ×P ₅	1.36	1.49	29.43**	14.89*	2.37	-25.97	-0.16
P ₃ ×P ₆	-0.19	0.60	-0.51	9.13	2.10	30.69	2.10**
P ₃ ×P ₇	-2.75**	-2.24*	5.21	4.98	-0.57	-8.19	0.21
P ₄ ×P ₅	0.25	0.76	29.87**	17.38**	0.32	82.91*	1.61**
P ₄ ×P ₆	-4.30**	-4.63**	7.37	19.01**	0.04	4.58	2.49**
P ₄ ×P ₇	0.64	0.54	29.15	6.67	3.37*	25.69	1.26*
P ₅ ×P ₆	2.63**	3.15**	0.60	6.07	3.60*	51.80	1.18*
P ₅ ×P ₇	0.08	-0.68	3.38	4.43	-0.07	7.91	1.10
P ₆ ×P ₇	-0.47	-0.57	-5.13	0.16	3.15	14.58	2.76*
SE(ij)	0.91	1.05	10.24	5.74	1.60	35.89	0.56
LSD _(5%)	1.90	2.19	21.36	11.97	3.34	74.87	1.17
LSD _(1%)	2.59	2.99	29.13	16.33	4.35	102.10	1.59

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

The desirable significant SCA effects observed for different characters were exhibited by the crosses involved high × high, high × average, average × average or high × low and low × low general combining parents. High SCA effects manifested by different crosses were of good combiner parents might be attributed to sizeable additive × additive gene action. The high × low combinations, besides expressing the favorable additive effect of the high parent, manifested some complementary gene interaction effects with a higher SCA. An

appreciable amount of the SCA effects expressed by low \times low crosses might be ascribed to dominance \times dominance type of non-allelic gene action produced over dominance and are non-fixable. It appears that superior performance of most hybrids may be largely due to epistatic interaction. The SCA effects of the crosses exhibited no specific trends in cross combinations between parents having high, medium and low gca effects. Any combination among the parents may produce hybrid vigour over the parents which might be due to dominant, over dominant or epistatic gene action. So, the crosses which showing desirable SCA effects can be used in future breeding program.

Heterosis

The standard heterosis expressed by the F₁ hybrids over the two standard checks namely NK40 and 900MG (commercial hybrid) for different characters are presented in Tables 5 and 6. The percent of heterosis in F₁ hybrids varied from character to character or from cross to cross.

Days to tasseling and days to silking

Days to tasseling and silking determine the earliness of flowering of the hybrid. Negative heterosis is desirable for these characters. Considering commercial hybrid NK40 as a check 4 crosses showed significant negative heterosis for days to tasseling and ranged from -0.506 to 14.04%. For days to silking, 3 crosses also showed significant negative heterosis and ranged from -4.37 to 14.97 (Table 5). When we considered 900MG as check, 4 crosses exhibited significant negative heterosis for 50% tassel date which ranged were -6.63 to 12.15. For 50% silk date 4 crosses showed significant negative heterosis out of 21 and ranged were -7.41 to 13.23 (Table 6).

Plant height and ear height

Negative heterosis is desirable for plant height and ear height which helps for developing short statured plant leads to less lodging. Considering commercial hybrid NK40 as a check 11 crosses exhibited significant negative heterosis for plant height indicate dwarfness of the hybrids (Table 5). Some crosses also showed significant positive heterosis for this trait. For ear height, 5 crosses showed significant negative heterosis others are positive (Table 5).

To compare with check variety 900MG, 8 crosses performed significant negative heterosis for plant height. For ear height, 11 crosses expressed significant negative heterosis.

Days to maturity

Negative heterosis is also desirable for days to maturity which helps for adjusting cropping pattern. Considering commercial hybrid NK40 as a check 6 crosses

expressed significant negative heterosis (Table 5). Compare with 900MG as check, 12 crosses expressed significant negative heterosis for the trait (Table 6).

Table 5. Percent heterosis over the check variety NK40 for different characters in 7×7 diallel crosses of maize

Cross/ Hybrids	Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000-KW (g)	Yield (t/h)
P ₁ ×P ₂	6.18**	7.10**	-6.67**	-4.00**	1.72**	-25.30	5.46
P ₁ ×P ₃	3.93**	4.92**	-3.81*	-10.50**	-1.03**	-27.71	-29.44**
P ₁ ×P ₄	-3.93**	-2.73*	-12.86**	-1.00	-1.03**	-18.07	-19.87**
P ₁ ×P ₅	6.74**	7.65**	-9.05**	-1.00	-1.37**	-39.76	-51.39**
P ₁ ×P ₆	7.87**	9.29**	2.14	6.00**	1.72**	-26.51	-20.68**
P ₁ ×P ₇	5.62**	6.56**	-5.00**	2.50	2.06**	-28.92	-29.69**
P ₂ ×P ₃	3.93**	4.37**	8.57**	12.00**	1.03**	-27.71	9.87*
P ₂ ×P ₄	-4.49**	-3.83**	-15.24**	-6.50**	-0.69	-13.25	-11.56**
P ₂ ×P ₅	5.62**	6.01**	9.05**	12.00**	2.41**	-21.69	-23.19**
P ₂ ×P ₆	6.74**	8.20**	-3.10	4.00*	2.06**	-14.46	-3.57
P ₂ ×P ₇	14.04**	16.94**	-13.57**	-9.50**	2.41**	-8.43	-50.76**
P ₃ ×P ₄	-5.06**	-4.37**	-1.19	-9.00**	-1.03**	-13.25	-6.51
P ₃ ×P ₅	4.49**	5.46**	10.24**	10.00**	-0.34	-43.37	-30.64**
P ₃ ×P ₆	5.06**	7.10**	-8.57**	-0.50	1.72**	-30.12	5.23
P ₃ ×P ₇	0.00	1.64	0.24	2.50	-1.72**	-32.53	-23.73**
P ₄ ×P ₅	0.56	2.19	0.95	7.00**	-2.41**	-13.25	-9.02*
P ₄ ×P ₆	-2.25*	-1.09	-14.29**	3.90*	-0.34	-32.53	12.43**
P ₄ ×P ₇	1.12	2.19	2.14	-1.30	0.34	-20.48	-9.39*
P ₅ ×P ₆	7.87**	9.29**	-11.90**	1.00	1.72**	-25.30	-8.63*
P ₅ ×P ₇	2.81*	2.73*	-4.52	6.50**	-0.69	-28.92	-18.68**
P ₆ ×P ₇	4.49**	5.46**	-13.10**	-2.50	2.06**	-27.71	10.89*
Mean	3.40	4.53	-4.26	1.03	0.41	-24.73	-14.42
Minimum	-5.06	-4.37	-15.24	-10.50	-2.41	-43.37	-51.39
Maximum	14.04	16.94	10.24	12.00	2.41	8.43	12.43
Std. Error	1.03	1.09	1.73	1.45	0.34	1.97	3.98
CD _(0.05)	2.14	2.28	3.61	3.03	0.71	4.11	8.31
CD _(0.01)	2.92	3.10	4.93	4.14	0.97	5.60	11.34

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

Kernel yield

When standard commercial check was NK40, the percent heterosis for kernel yield varied from -51.39 to 12.53%. It showed that among the 21 F₁s, 3 crosses exhibited significant positive heterosis for kernel yield (Table 5). The highest heterosis 12.43% was exhibited by the cross P₄×P₆ followed by P₆×P₇ (10.89%) and P₂×P₃ (9.87%).

Table 6. Percent heterosis over the check variety 900MG for different characters in 7×7 diallel cross of maize

Cross/ Hybrids	Days to tassel	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Days to maturity	1000-KW (g)	Yield (t/h)
P ₁ ×P ₂	4.42**	3.70**	-2.97	-9.0**0	-0.34	-16.22**	0.38
P ₁ ×P ₃	2.21*	1.59	0.00	-15.17**	-3.03**	-18.92**	-32.84**
P ₁ ×P ₄	-5.52**	-5.82**	-9.41**	-6.16**	-3.03**	-8.11**	-23.73**
P ₁ ×P ₅	4.97**	4.23**	-5.45**	-6.16**	-3.37**	-32.43**	-53.73**
P ₁ ×P ₆	6.08**	5.82**	6.19**	0.47	-0.34	-17.57**	-24.50**
P ₁ ×P ₇	3.87**	3.17**	-1.24	-2.84	0.00	-20.27**	-33.08**
P ₂ ×P ₃	2.21*	1.06	12.87**	6.16**	-1.01**	-18.92**	4.57
P ₂ ×P ₄	-6.08**	-6.88**	-11.88**	-11.37**	-2.69**	-2.7	-15.82**
P ₂ ×P ₅	3.87**	2.65*	13.37**	6.16	0.34	-12.16**	-26.89**
P ₂ ×P ₆	4.97**	4.76**	0.74	-1.42	0.00	-4.05	-8.22*
P ₂ ×P ₇	12.15**	13.23**	-10.15**	-14.22**	0.34	2.7	-53.13**
P ₃ ×P ₄	-6.63**	-7.41**	2.72	-13.74**	-3.03**	-2.7	-11.02**
P ₃ ×P ₅	2.76*	2.12	14.60**	4.27**	-2.36**	-36.49**	-33.99**
P ₃ ×P ₆	3.31**	3.70**	-4.95*	-5.69**	-0.34	-21.62**	0.16
P ₃ ×P ₇	-1.66	-1.59	4.21*	-2.84	-3.70**	-24.32**	-27.40**
P ₄ ×P ₅	-1.10	-1.06	4.95*	1.42	-4.38**	-2.7	-13.41**
P ₄ ×P ₆	-3.87**	-4.23**	-10.89**	-1.52	-2.36**	-2.7	7.01
P ₄ ×P ₇	-0.55	-1.06	6.19*	-6.45**	-1.68**	-10.81**	-13.75**
P ₅ ×P ₆	6.08**	5.82**	-8.42**	-4.27**	-0.34	-16.22**	-13.03**
P ₅ ×P ₇	1.10	-0.53	-0.74	0.95	-2.69**	-20.27**	-22.59**
P ₆ ×P ₇	2.76*	2.12	-9.65**	-7.58**	0.00	-18.92**	5.55
Mean	1.68	1.21	-0.47	-4.24	-1.62	-15.57	-18.55
Minimum	-6.63	-7.41	-11.88	-15.17	-4.38	-36.49	-53.73
Maximum	12.15	13.23	14.60	6.16	0.34	2.7	7.01
Std. Error	1.01	1.06	1.80	1.38	0.33	2.21	3.79
CD _(0.05)	2.11	2.20	3.75	2.87	0.70	4.61	7.91
CD _(0.01)	2.88	3.01	5.12	3.92	0.95	6.28	10.79

*, ** indicated at 5% and 1% level of significance, KW = Kernel Weight.

When estimated with 900MG as check, the percent heterosis for kernel yield varied from -53.73 to 7.01%. It showed that among the 21 F₁s, none crosses exhibited significant positive heterosis for kernel yield (Table 6). The highest heterosis 7.01% was exhibited by the cross P₄×P₆ followed by P₆×P₇ (5.5%) and P₂×P₃ (4.57%). Debnath (1988) and Roy *et al.*, (1998) reported 43.05 to 96.74% and -16.42 to 71.82% heterobeltiosis.

Conclusion

From the study, the parents like P₁ (for early flowering and short duration), P₄ (for yield, early flowering, short plant and ear height), P₅ (short duration) and P₆ (for yield) may be used as donor for combining high yield with desirable traits. The crosses (P₂×P₃, P₄×P₆ and P₆×P₇) showed the highest heterosis for yield compared to the checks (NK40 and 900MG). The cross combinations manifested significant high SCA effects coupled with *per se* performance and could be more rewarding in a hybrid breeding program after intensive investigation at different agro ecological zones.

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FIELD SCREENING OF KABULI CHICKPEA GENOTYPES AGAINST BOTRYTIS GRAY MOLDM. SHAHIDUZZAMAN¹

Chickpea (*Cicer arietinum* L.) commonly known as gram is one of the important pulse crops in Bangladesh. It is generally grown under rainfed with residual soil moisture conditions in the *rabi* season. Among the major pulses grown in Bangladesh, chickpea ranked seventh in area and sixth in production (Anon., 2015) but second in consumption priority. The national average productivity of chickpea is miserably low (1.09 t/ha) (Anon., 2015). Botrytis gray mold (BGM) caused by *Botrytis ceneria* is an important disease of chickpea in northern India, Nepal, Bangladesh and Pakistan. It was first reported in India in 1915 (Shaw and Ajrekar, 1915). Outside the Indian subcontinent the disease has been reported from Argentina (Carranza, 1965), Australia (Nene *et al.*, 1989), Canada (Kharbanda and Bernier, 1979), and Chile (Sepulveda and Alvarez, 1984). It was first documented in 1981 in Bangladesh (Anon., 1981) but its recurrence after 1985 drastically reduced the chickpea area and production in this country. Nine varieties have been released from Pulse Research Center (PRC), BARI, but they could not create significant impact on chickpea production in the country because of BGM problem. The disease becomes serious following frequent winter rainfall that results in excessive vegetative growth and high humidity, which favor its infection, epidemic and severity. The disease is seed, soil and air borne. In the recent years, this disease has become a great threat to chickpea cultivation. Preventive measures such as low seed rate, chemical spray, wider row spacing, intercropping with linseed help to reduce disease intensity. But resistant cultivars offer the best solution to control the disease. Keeping this view in mind, 32 lines and one released variety were screened for determining their relative susceptibility/resistance to BGM. Suitable resistant chickpea genotypes also prevent spore production build up and able to compensate damage by producing increased number of healthy pods/plant that were taken as parameters for assessing disease-plant relationship in chickpea.

A total of 32 kabuli chickpea lines with a check BARI Chola 5 were evaluated in the field under the natural epiphytic condition. The seeds of chickpea lines were collected from Australian Center for International Agricultural Research (ACIAR), Australia. The land was well ploughed by tractor and properly leveled. Weeds and stubbles were removed from the field. NPK fertilizers @ 20-40-20 kg/ha in the form of urea, triple super phosphate and muriate of potash were applied at final land preparation. The experiment was laid out in Randomized Complete Block Design with three replications. Varieties/lines were considered

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as treatment of the experiment. The seeds of respective lines with check were sown on 20 December, 2010 in rows with 50 cm spacing. Uniform plant population was maintained by keeping 10 cm plant to plant distance. The unit plot size was 4m x 16.5m. Intercultural operations (irrigation, thinning and weeding) were done manually and herbicides application (Rahman and Miah, 1989). The experiment was monitored regularly to observe the onset of disease. The crop was kept completely free from fungicide application. The genotypes were closely examined to identify resistant cultivars to BGM of chickpea. BGM of chickpea was graded on a 1-9 scoring scale (Singh, 1999). The scale described as 1= no infection on any part of the plant, 2= minute lesions on lower leaves, flowers and pods covered under dense plant canopy, 3= lesions on less than 5% of the leaves, flowers and pods covered and under dense plant canopy, 4= lesions and some fungal growth (conidiophores and conidia) can be seen on up to 15% of the leaves, flowers and pods and branches covered under dense plant canopy, 5= lesions and slight fungal growth on up to 25% of the leaves, flowers and pods, stems and branches covered under dense plant canopy, 6= lesions and fungal growth on up to 40% of the leaves, flowers and pods, stems and branches defoliation, 25% of the plant killed, 7= large lesions and good fungal growth on up to 60% of the leaves, flowers and pods, stems and branches defoliation common, drying of branches and 50% of the plants killed, 8= large lesions and profuse fungal growth on up to 80% of the leaves, flowers and pods, stems and branches, severe defoliation, drying of branches and 75% of the plants killed, 9= large lesions, very profuse fungal growth on up to 100% of the flowers, pods, stems, branches, almost complete defoliation, drying of plants and 100% of the plants killed. The interpretation of the scale was 1= Immune (I), 2-3= highly resistant (HR), 4-5= resistant (R), 6-7= susceptible (S) and 8-9= highly susceptible (HS) under artificial inoculation and epiphytic condition. The crop was harvested on 15 March 2011 at matured stage. The pods were then threshed, grains were cleaned and dried in the bright sunshine. The grain yield was obtained from each line converted into kg/ha. The experimental data were analyzed by MSTAT-C software. Mean comparisons for treatment parameters were made Duncan's Multiple Range Test (Steel and Torrie, 1960) at 5% level of significance.

The tested chickpea variety/genotypes differ significantly from one to another in respect of disease score and yield under field condition (Table 1). BGM score among the test entries ranged from 2.66-6.33. Among the 32 lines 9 were graded as tolerant which bear the score 2.66 (3), 3.33 (4) and 3.66 (2) and the rest 23 lines were susceptible to BGM as they bear the score more than 4.00. The check variety BARI Chola 5 had the score 5.00. Among the tolerant genotypes, 7 lines out yielded than check BARI Chola-5 and other lines, due to the susceptibility to BGM, reduced the yield. The yield of the test lines ranged from 265-1232 kg/ha. Seven lines viz. FLIP 01-30C, FLIP 01-34C, FLIP 01-38C, FLIP 01-39C, FLIP

03-42C, FLIP 03-45C, FLIP 03-53C yielded (975, 894, 1180, 1067, 927, 1232, 1149 kg/ha respectively) better than the check (830 kg/ha). All these seven lines showed BGM tolerant score (2.66-3.66). The variation in yield in these seven lines was due to podding potentiality, pod size, seed size and seed weight.

Table 1. Disease score and yield of 32 kabuli Chickpea genotypes and a check BARI Chola 5 under field condition at RPRS, Madaripur in 2010-11

Name of entry	BGM Score (1-9)	Yield (kg/ha)
ILC-1929C	4.16 a-c	478 lm
FLIP 97-173C	4.33 a-c	621 k
FLIP 98-37C	5.66 ab	758 hi
FLIP 98-206C	3.33 bc	619 k
FLIP 00-14C	4.66 a-c	720 ij
FLIP 00-17C	5.00 a-c	745 i
FLIP 01-2C	3.66 bc	395 o
FLIP 01-4C	5.33 ab	283 pq
FLIP 01-30C	3.66 bc	975 d
FLIP 01-32C	4.33 a-c	488 lm
FLIP 01-34C	3.33 bc	894 e
FLIP 01-37C	4.66 a-c	520 l
FLIP 01-38C	2.66 c	1180 b
FLIP 01-39C	2.66 c	1067 c
FLIP 98-502C	5.33 ab	601 k
FLIP 01-54C	5.33 ab	399 o
FLIP 01-56C	5.33 ab	265 q
FLIP 01-60C	4.66 a-c	515 l
FLIP 01-63C	4.66 a-c	485 lm
FLIP 02-39C	6.33 a	446 mn
FLIP 02-40C	5.66 ab	387 o
FLIP 02-47C	4.66 a-c	423 no
FLIP 03-36C	4.33 a-c	790 gh
FLIP 03-42C	3.33 bc	927 e
FLIP 03-45C	2.66 c	1232 a
FLIP 03-53C	2.66 c	1149 b
FLIP 03-103C	5.00 a-c	681 j
FLIP 03-104C	5.00 a-c	805 fg
FLIP 03-106C	5.33 ab	699 j
FLIP 03-118C	4.33 a-c	688 j
FLIP 03-119C	5.00 a-c	836 f
FLIP 03-134C	4.33 a-c	309 p
BARI Chola-5 (Check)	5.00 a-c	830 fg

In a column, treatment means having the same letter(s) didn't differ significantly at 5% level; BGM = Botrytis Gray Mold.

Considering BGM scoring scale and yield together, the relative position of the genotypes with respect to check did not follow any definite trend. Considering overall performance, FLIP 01-30C, FLIP 01-34C, FLIP 01-38C, FLIP 01-39C, FLIP 03-42C, FLIP 03-45C, FLIP 03-53C rated tolerant to BGM attack in comparison to check of which FLIP 03-45C was the best.

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