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Short communication

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ROLE OF WEATHER PARAMETERS ON SEASONAL ABUNDANCE OF INSECTS IN A MANGO-BASED AGROFORESTRY IN BANGLADESH, WITH PARTICULAR REFERENCE TO MANGO HOPPER

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Abstract

Weekly sweeping was done by sweep net in order to collect insects to study the effect of weather parameters on the seasonal abundance of total insect species as well as mango hopper population in a mango-based agroforestry in Bangladesh during January to June 2013. The total insect species abundance was the highest during April to May, following the flushing of inflorescence and fruit set. At that time temperature and relative humidity were comparatively higher and there was rainfall. Mango hopper population was the highest in May and synchronized to fruit set. The abundance of total insect species and mango hopper population showed significant positive correlation with temperature, and relative humidity, while significant negative correlation with light intensity and non-significant positive correlation with rainfall. Multiple linear regression equation based on weather parameters revealed 59.2% and 61.7% role on population build up of total insect species and mango hopper, respectively. Temperature was found to be the most important effect which individually contributed 31.3% on population abundance of total insect species and 29.9% on mango hopper.

Keywords: Abiotic factors, agroforestry, insects, *Mangifera indica.*

Introduction

Mango (*Mangifera indica* L.) is one of the most popular fruits of Bangladesh and also popular in the tropical and subtropical countries of the world like Pakistan, India, South China and Malaysia (Joshi and Kumar, 2012). This fruit is very popular due to its delicious taste, captivating flavor with multifarious color and excellent source of nutritive values. Mango is not only a delicious fruit but also a rich source of carbohydrate, fiber, carotene, thiamine, riboflavin, niacin, ascorbic acid, tryptophan, lysine and minerals (Ojokoh, 2007). Many insect species damage mango crops by feeding on leaves, stems, flowers, and fruits. Also, many insect species play a vital role on pollination as well as fruit set, and predator-prey interactions keep balance between pest incidence and fruit production.

Agricultural land in Bangladesh is being converted to non-agricultural purposes like housing, transportation, establishment of educational institutions, offices, hospitals etc. to fulfill the demands for increasing population. Due to the

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conversion of agricultural lands to commercial establishments, it is necessary to diversify and maximize yield per unit area. On the contrary, intensive agricultural system is creating disturbance on natural habitats, and affects species richness, abundance and community structure of insects (Debinski and Holt, 2000). Therefore, strategies are taken by the farmers to grow lower storied crops under upper storied trees which are known as agroforestry system.

Agroforestry technology is a diversified agricultural system which serves as a tool in nature conservation with maximum utilization of natural resources viz., land, sunlight, air and water (Donald, 2004; Putz *et al.*, 2001). This practice can increase the overall diversity of plants and physical structure in a landscape that provides habitat for native pollinators, which are linked to crop productivity. About two decades ago, mango plants were grown in homesteads, nurseries and traditional orchards in Bangladesh. But in the recent years, mango-based agroforestry system has been developed and due to its increased production, it has become a popular concept. It includes cultivation practices of mango along with guava, pineapple, garlic, turmeric, bitter gourd, carrot, kangkong, okra, etc.

In Bangladesh, vegetative growth of mango plants starts from July and continues up to December. Here, the plants produce flower buds in January, full bloom period ranges from February to March, fruit formation occurs from March to April, and the fruits become mature in June. Insect pests play a significant role on yield and quality of mangoes in Bangladesh. A total of 30 insect species damage mango crops in Bangladesh and mango hopper is the most destructive insect (Hossain, 1989). Many insects in the order Diptera and Hymenoptera help in pollination of this crop (Singh, 1997; Dag and Gazit, 2000). Seasonal variations of the weather factors play a vital role in multiplication, growth, development and distribution of insects, and influence on their population dynamics (Qayyum and Zalucki, 1987; Dhaliwal and Arora, 2001). Joshi and Kumar (2012) reported that comparatively higher temperature and lower relative humidity increased hopper population.

The mango-based agroforestry constitutes with mango trees, crops, weeds, insect pests, predators and pollinators. Weeds and the cultivated ground cover crops provide shelter and food for pests, predators, pollinators and parasites (Bugg and Waddington, 1994; Desaeger *et al.*, 2004). So, yield and quality of mangoes grown in an agroforestry are partially related to insect abundance and diversity. However, no study on this matter in Bangladesh has been made so far. Therefore, with a view to providing information to mango growers on insect abundance, especially mango hopper in respect to weather parameters, the study was conducted in a mango-based agroforestry.

Materials and Method

Study site and conditions: The study was conducted from January to June 2013 in a mango-based agroforestry field laboratory of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur (25°25′ North

latitude and 89°5′ East longitude), Bangladesh. The site is surrounded by sal, *Shorea robusta* Gaertn forest. The climate of this area is seasonally characterized by a well-defined dry season (February to May), rainy season (June to September) and short winter (December and January). Annual mean maximum and minimum temperature, relative humidity and rainfall are 36.0 °C and 12.7 °C, 65.8% and 237.6 cm, respectively. The mango-based agroforestry system is interrupted by different management intensity, grasslands, paddy and vegetable fields. The area of the study agroforestry is 2205 m², and constituted with 45 mango trees (variety Amrapali) each 11 years old, 3-4 m height and 7 m apart. During the study, bitter gourd, *Momordica charantia* (Family: Cucurbitaceae) and kangkong, *Ipomea reptans* (Family: Convolvulaceae) were cultivated as middle and lower storied crops, and 20 weed species emerged.

Collection of weather data: Light intensity in the mango-based agroforestry system throughout the study was measured with a digital light meter (Model 401025, Extech Instruments Corporation, USA). Data were collected weekly and in between 10.00 and11.00 am at the canopy area of the trees. Mean daily temperature, relative humidity and rainfall data were collected from the weather station of BSMRAU.

Insect collection and identification: To assess the seasonal changes of insect abundance in the mango-based agroforestry system, sampling protocol was targeted on free-living insects foraged during the daytime. Insects were collected using a 30 cm diameter sweep net having1.5 mm mesh, and attached with a 2 m long rod. Every week, sweeping was done in between 09.00 and 11.00 am, and each sample consisted of 30 sweeps encompassing an area from ground level to the top of the trees. The collected insects were brought from the experiment field to the Entomology Laboratory of BSMRAU for counting total abundance as well as mango hopper population/30 sweeps.

Statistical analysis: One way analysis of variance (ANOVA) followed by Duncun's Multiple Range Test (DMRT) was employed for analyzing monthly abundance. Correlation coefficients were calculated for total species abundance and hopper population with meteorological parameters. All the analyses were performed using IBM SPSS 19.0.

Results

Table 1 shows that monthly mean temperature, light intensity, relative humidity and rainfall during the study varied from 19.0 ± 0.5 to 32.2 ± 0.4 °C, 1625 ± 480 to 11580 ± 1790 lux, 69.0 ± 4.7 to 83.0 ± 1.7 % and 0.0 ± 0.0 to 4.9 ± 4.9 mm, respectively. There was significant difference ($F_{5, 16} = 9.8$, $p < 0.0001$) among the monthly abundances of insect population, which varied from 36.5 ± 5.5 to 125.0 ± 10.9 /30 sweeps. Hopper abundance during the study varied from 1.0 ± 1.0 to 100.8 ± 10.6 /30sweep. Total insect abundance was the lowest in January and peaked in May when the mean temperature, light intensity, relative humidity and

rainfall were 28.2 ± 0.5 ℃, 4500 ± 957 lux, 83.0 ± 1.7% and 1.5 ± 0.9 mm. respectively. Abundance of hopper was the lowest in January and reached to the peak in May.
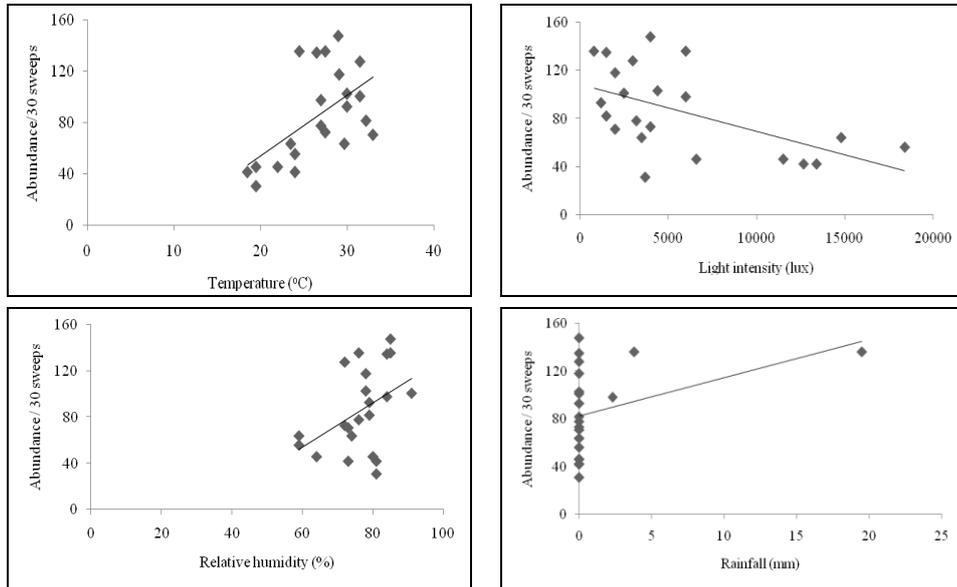
Fig. 1. Relationship between weather parameters and total insect abundance in a mango-based agroforestry in Bangladesh during January to June 2013.
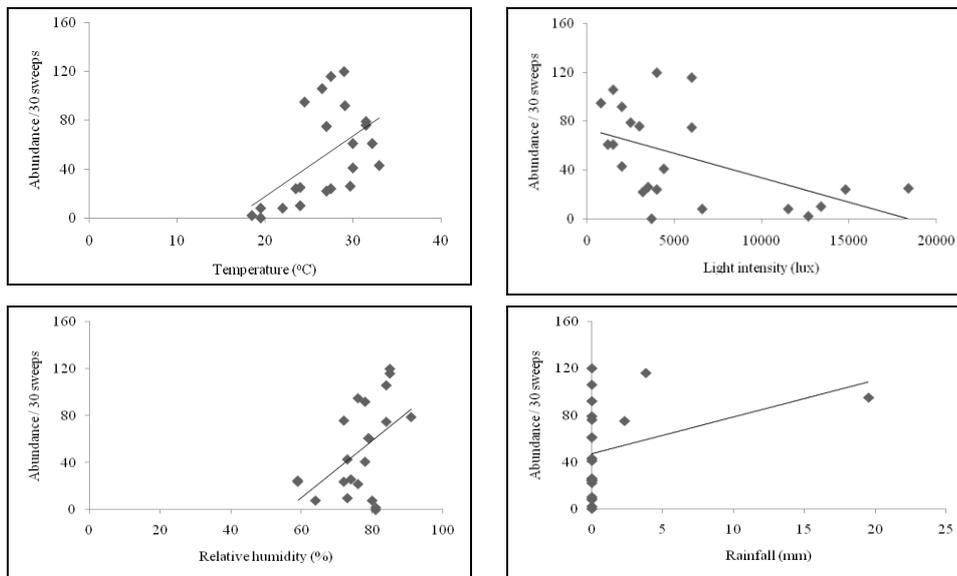
Fig. 2. Relationship between weather parameters and mango hopper population in a mango-based agroforestry in Bangladesh during January to July 2013.

Relationship between total insect abundance and weather parameters presented in figure 1 revealed that insect abundance had significant positive correlation with temperature ($y = -40.02 + 4.72x$, $r = 0.56$, $F_{1,20} = 9.1$, $p < 0.01$), significant negative correlation with light intensity ($y = 108.5 - 0.003x$, $r = 0.55$, $F_{1,20} = 8.7$, $p < 0.01$), significant positive correlation with relative humidity ($y = -60.80 + 1.918x$, $r = 0.43$, $F_{1,20} = 4.6$, $p < 0.05$), and non-significant positive correlation ($y = 82.20 + 3.22x$, $r = 0.38$, $F_{1,20} = 4.2$, $p = 0.08$) with rainfall.

Figure 2 showed that the hopper abundance during the study revealed significant positive correlation with temperature ($y = -82.77 + 5.00x$, $r = 0.547$, $F_{1,20} = 8.5$, $p < 0.01$), significant negative correlation with light intensity ($y = 73.688 - 0.004x$, $r = 0.55$, $F_{1,20} = 7.3$, $p < 0.05$), significant positive correlation with relative humidity ($y = -134.52 + 2.420x$, $r = 0.503$, $F_{1,20} = 6.8$, $p < 0.05$), and non-significant positive correlation with rainfall ($y = 46.960 + 3.159x$, $r = 0.34$, $F_{1,20} = 2.62$, $p = 0.12$).

Table 1. Monthly distribution of meteorological parameters and insect population buildup in a mango-based agroforestry in Bangladesh during January to June 2013

Month	N	Temperature (ºC)	Light intensity (lux)	Relative humidity (%)	Rainfall (mm)	Total abundance/30 sweeps	Hopper abundance/30 sweeps
January	2	19.0 ± 0.5	8185 ± 4485	81.0 ± 0.0	0.0 ± 0.0	36.5 ± 5.5 d	1.0 ± 1.0 d
February	4	22.3 ± 1.0	11580 ± 1790	69.0 ± 4.7	0.0 ± 0.0	49.5 ± 4.9 cd	12.5 ± 3.9 cd
March	5	27.6 ± 1.1	6700 ± 2932	71.8 ± 3.4	0.0 ± 0.0	74.8 ± 8.0 bc	27.6 ± 3.4 c
April	4	28.1 ± 1.6	1625 ± 480	77.8 ± 2.5	4.9 ± 4.9	123.0 ± 10.2 a	84.5 ± 9.9 ab
May	4	28.2 ± 0.5	4500 ± 957	83.0 ± 1.7	1.5 ± 0.9	125.0 ± 10.9 a	100.8 ± 10.6 a
June	2	32.2 ± 0.4	2000 ± 289	81.0 ± 5.3	0.0 ± 0.0	84.7 ± 8.8 b	61.0 ± 10.4 b

N = Number of collection in a month. Data expressed as mean ± SE. Means within a column followed by same letter (s) are not significantly different (DMRT, $p \le 0.05$).

Table 2. Multiple linear regression models along with coefficients of determination (R^2) regarding the impact of weather parameters on the seasonal abundance of total insects in a mango-based agroforestry in Bangladesh during January to June 2013

Regression equation	R^2	$100 R^2$	%Role of individual factor	F statistic	
$Y = 40.02 + 4.77 X_1$	0.313	31.3	31.3	$F_{1,20} = 9.1$	$p < 0.01$
$Y = 18.337 + 3.054 X_1 - 0.002X_2$	0.388	38.8	7.5	$F_{2,21} = 6.0$	$p < 0.05$
$Y = -89.49 + 3.559X_1 - 0.001X_2 +1.130X_3$	0.426	42.6	3.8	$F_{3,21} = 4.5$	$p < 0.05$
$Y = -178.24 +5.053X_1 + 0.001X_2 +1.572X_3 + 3.794X_4$	0.592	59.2	16.6	$F_{4,21} = 6.2$	$p < 0.05$

Y, insect population /30 sweeps; X_1, temperature (ºC); X_2, light intensity (lux); X_3, relative humidity (%); X_4, rainfall (mm).

The multiple linear regression analysis presented in table 2 showed that temperature individually contributed 31.3% abundance and its effect was significant. The combination effect of temperature and light intensity was significant and exerted 38.8% abundance. The individual contribution of light intensity was 7.5%. The relative humidity along with temperature and light intensity contributed 42.6% abundance of insect which was statistically significant. The individual effects of humidity and rainfall on insect abundance were 3.8% and 16.6%, respectively. The multiple linear regression analysis showed that all the weather parameters together contributed 59.2% population abundance of insects in the mango-based agroforestry and the equations were significant.

Table 3. Multiple linear regression models along with coefficients of determination (R^2) regarding the impact of weather parameters on the seasonal abundance of mango hopper in a mango-based agroforestry in Bangladesh during January to June 2013

Regression equation	R^2	$100\ R^2$	%Role of individual factor	F statistic
$Y = -82.77 + 5.00\ X_1$	0.299	29.9	29.9	$F_{1,\ 20} = 8.2$ $p < 0.05$
$Y = -25.52 + 3.393\ X_1 - 0.002X_2$	0.358	35.8	5.9	$F_{2,\ 21} = 5.3$ $p < 0.05$
$Y = -216.241 + 4.281X_1 + 0.00009X_2 + 1.989X_3$	0.457	45.7	9.9	$F_{3,\ 21} = 5.1$ $p < 0.05$
$Y = -310.75 + 5.871X_1 + 0.002X_2 + 2.459X_3 + 4.041X_4$	0.617	61.7	16.0	$F_{4,\ 21} = 6.9$ $p < 0.05$

Y, insect population /30 sweeps; X_1, temperature (ºC); X_2, light intensity (lux); X_3, relative humidity (%); X_4, rainfall (mm).

Table 3 showed that temperature individually exerted 29.9% population abundance of mango hopper and its effect was significant. The temperature with combination of light intensity revealed 35.8% abundance, which was statistically significant. The individual effect of light intensity demonstrated 5.9% abundance. The combination effect of temperature, light intensity and relative humidity depicted 45.7% abundance and the result was statistically significant. The individual contribution of rainfall on mango hopper abundance was 16.0%. The multiple linear regression analysis showed that all the weather parameters together contributed 61.7% abundance of mango hopper and the equations were significant.

Discussion

For development of an agroforestry technology it is important to understand the diversity, abundance, damage threshold and biology of the insect species in the locality (Epila, 1988). Information on different insect species abundance due to variations in meteorological parameters are to be noted for effective management of the pests and proper use of pollinators. This is the first report on the effect of weather parameters on insect abundance in a mango-based agroforestry in

Bangladesh. During 3rd week of January to 3rd week of June 2013 a total of 1751 insects were collected in 21 working days. A total of 1114 hopper population was found among the collected insects. The lowest abundance of total insect species as well as hopper population was observed in January and the results were significantly different from other months. The total insect species abundance was the highest from April to May, and hopper population reached to the peak in May. The increased abundance of the insect population during April to May was associated with increased temperature, relative humidity, rainfall and flushing of inflorescence. The insect population was the lowest in January and February due to higher light intensity. High light intensity occurred in these months because of clear sunshine and deciduous plant characteristics of the mango based agroforestry. Paul and Lalnunsalgi (2011) studied insect population abundance at some agroforestry systems in Mizoram, India during 2000 to 2002 and found significantly higher and lower abundances in summer and winter seasons, respectively.

Kannan and Rao (2006) conducted a field experiments in Andhra Pradesh, India and reported that the host plants and weather parameters played role on the abundance and population dynamics of mango hopper, *Amritodus atkinsoni*. They observed the peak incidence of the hopper during third week of January (85.0 hopper/12 inflorescence). They also observed negative correlations between the incidence of hopper and minimum temperature, relative humidity, evening rainfall, and positive relationship with maximum temperature, and morning relative humidity. High temperatures (18-28˚C) and relative humidity (> 90%) favored the incidence of mango hopper (Gan *et al.,* 2000). Shekh *et al.* (1993) carried out field studies in Gujarat, India and reported that temperature < 20˚C kept population of *A. atkinsoni* under control and pest outbreak occurred when the temperature ranged between 20 and 25˚C. They also found that fruit fly, *Ceratitis cosyra* population was positively and negatively correlated with temperature and humidity, respectively while the population of *Bactrocera invadens* showed vice versa.

Higher abundance of hopper was observed covering 63.6% of the total abundance. It may be due to the perennial nature of the crop, large scale monoculture, high plant density and excessive use of fertilizer, irrigation, and pesticides favoring the multiplication of this pest. It has been reported that plant species diversity in an agro-forestry influences the survival and abundance of insects by modifying the microclimate in the agro-ecosystem and could reduce pest attack, however the natural enemies decrease (Ram *et al.,* 1989). On the contrary, crop species sometimes may create favorable conditions for pest incidence and damage (Ram *et al.,* 1989). So, plant species combinations for cropping pattern of a mango-based agroforestry technology must be on the basis of least favorable conditions for the survival and multiplication of major pest species.

In the study field, two vegetable species *M. charantia* and *I. reptans* were cultivated as middle and lower storied crops, while 20 herb species were found as weeds. These crops and weeds species may have provided habitat for insects or interrupted their abundance. Mango hopper was abundant throughout the study and reached to the peak at flowering and fruiting stage (March-May).

This study showed that overall population abundance was lower during cold and dry months and started to increase with the onset of the rainy season, coinciding with the blooming. The highest records were noticed during the monsoon, possibly with the addition of the new individuals emerged from the overwintering population of the dormant eggs and pupae. The present study also showed that total insect abundance as well as hopper population was positively correlated with temperature, relative humidity and rainfall. Pushpalatha *et al.* (2008) observed positive correlation between hopper population and maximum temperature and negative correlation with relative humidity.

Occurrence of different insect species in significant numbers in an agroforestry could influence the productivity and sustainability of the system. Mango hopper was the most abundant because they prevailed dominantly on mango flower panicles during cooler and dry season. Higher fecundity and rapid generation ability of this pest contributed to higher abundance. The present findings showed harmony with Kaushik *et al.* (2012) who observed significant abundance of hopper on mango plants.

This study clearly focused the seasonal abundance of insects particularly mango hopper in a mango-based agroforestry in Bangladesh, which could be helpful to mango growers for development of IPM program emphasizing on the restoration of predator and pollinator species.

Acknowledgments

References

Bugg, R. L. and C. Waddington. 1994. Using cover crops to manage arthropod pests of orchard: a review. *Agric. Ecosyst. Environ.* **50**: 11-28.

Dag, A. and S. Gazit. 2000. Mango pollinators in Israel. *J Appl. Hort.* **2**: 39-43.

Debinski, D. M. and R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. *Conserv. Biol.* **14:** 342-355.

Desaeger, J., M. R. Rao and J. Bridge. 2004. Nematodes and other soil borne pathogens in agroforestry. In: van Noordwijk, M., G. Cadisch and C. K. Ong (eds). Below-ground interactions in tropical agroecosystems: concepts and models with multiple plant components. Wallingford, CABI. Pp. 263-283.

Dhaliwal, G. S. and R. Arora. 2001. Integrated Pest Management Concepts and Approaches. Kalyani Pulishers, New Delhi, India. Pp. 27-60.

Donald, P. F. 2004. Biodiversity impacts of some agricultural commodity production systems. *Conserv. Biol.* **18**: 17-37.

Epila, J. S. O. 1988. Wind, crop pests and agroforestry design. *Agric. Syst.* **26**: 99-110.

Gan, X. G., X. B. Qing, G. G. Xie and B. Q. Xie. 2000. The damage of leaf hopper for mango and its control. *South China.* **29**: 37.

Hossain, A. K. M. A. 1989. A field guide on insect pests and diseases of mango in Bangladesh and their control. Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. P. 44.

Joshi, P. C. and S. Kumar. 2012. Effect of some meteorological factors on seasonal abundance of *Idioscopus nitidulus* (Walker) (Hemiptera: Cicadellidae) in mango orchards of Haridwar (India). *New York Sci. J.* **5**: 101-103

Kannan, M. and N. V. Rao. 2006. Seasonal incidence of Lepidopteran pests in relation to weather parameters in mango (*Mangifera indica*). *Crop Res.* **33**: 198-203.

Kaushik, D. K., U. Baraiha, B. S. Thakur and O. P. Parganiha. 2012. Pest complex and their succession on mango (*Mangifera indica*) in Chhattisgarh, India. *Plant Archives.* **12**: 303-306.

Ojokoh, A. O. 2007. Effect of fermentation on the chemical composition of mango (*Mangifera indica* L.) peels. *African J. Biotech.* **6**: 1979-1981.

Paul, D. and R. Lalnunsangi. 2011. Insect natural enemy complex in some agroforestry systems of Mizoram, India. *Sci. Vision.* **11**: 90-95.

Pushpalatha, S., C. Kathirvelu and R. M. Nachiappan. 2008. Correlation of seasonal incidence of mango hopper, *Amritodus atkinsoni* and weather parameters on certain varieties of mango. *Indian J. Trop. Biodiverse.* **15**: 81-83.

Putz, F., E. G. M. Blate, K. H. Redford, R. Fimbel and J. Robinson. 2001. Tropical forest management and conservation of biodiversity: an overview. *Conserv. Biol.* **15**: 7-20.

Qayyum, A. and M. P. Zalucki. 1987. Effects of high temperature on survival of eggs of *Heliothis armigera* (Hubner) and *H. punctigera* Wallengren (Lepidoptera: Noctuidae). *J. Aus. Entomol. Soc.* **26**: 295-298.

Ram, S., M. P. Gupta and B. D. Patil. 1989. Pest management in fodder cowpea (*Vigna unguiculata* L. Walp.) through mixed and intercropping in India. *Trop. Pest Manag.* **33**: 345-347.

Shekh, A. M., H. C. Ratanpara, J. R. Patel and S. N. Patel. 1993. Effect of weather on mango hopper population in middle Gujrat. *Gujrat Agric. Univ. Res. J.* **2**: 2-3.

Singh, G. 1997. Pollination, pollinators and fruit setting in mango. *Acta Hort.* **455**: 116-123.

MORPHOLOGICAL CHARACTERIZATION OF CHILLI GERMPLASM IN BANGLADESH

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Abstract

An experiment was conducted using 60 chilli germplasm in the experimental field of Plant Genetic Resources Centre (PGRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during winter 2013-14 to characterize the germplasm based on morphological traits. Data were recorded as per the descriptor developed by Biovarsity International (BI) and Minimal Descriptor of Agri-Horticultural Crops. The germplasm were collected from different parts of Bangladesh and evaluated for 22 qualitative and 5 quantitative characters. Distinct variation among the germplasm was observed in all the qualitative parameters except cotyledonous leaf shape and fruit persistence. The maximum variation was observed in fruit colour both at mature and immature stage. Fruit colour was observed in four categories, namely green, black, green with blackish blush and dark green. The germplasm AMS-42, AMS-45, RI-35 and AH-5 showed black coloured fruit indicating their high carotenoid content. Leaf pigmentation was found in AMS-39, AMS-44, AMS-45, AH-1and RI-2 germplasm. Purple coloured corolla observed in AMS-42, AMS-45, AH-1 and AH-2 showing their high pollen fertility. The highest quantitative variation was observed in yield per plant suggesting that the evaluated germplasm could be used in developing high yielding variety. Considering the yield and yield contributing parameters the germplasm AI-1, AI-2 and RI-2 were found better among the 60 germplasm.

Keywords: Characterization, chilli, germplasm, Bangladesh.

Introduction

Chilli is one of the important commercially grown spice crops in Bangladesh. The crop belongs to the genus *Capsicum* which includes 30 species, out of which five are domesticated: *C. annuum, C. frutescens, C. baccatum, C. chinense* and *C. pubescens* (Hernández*, et al.*,1999). Among them, *C. annuum and C. frutescens* have more economic importance since these species are widely distributed in the world. Now it is fact that without chilli spices, all Bangladeshi and Indian cuisine would be incomplete. Chilli is used with or without the stalks, whole or chopped, with seeds or deseeded. These are consumed in fresh, dried, powdered, pickled or in sauces as vegetables or spices. Most of the Bangladeshi usually intake chilli as either raw or cooked and used as additives in their stored food preparations (Pino *et. al.*, 2006). The fruits are an excellent source of health-

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related compounds, such as ascorbic acid (vitamin C), carotenoids (pro-vitamin A), tocopherols (vitamin E), flavonoids, and capsaicinoids (Marti *et al*., 2011). Chilli provides a number of health benefits such as relief pain, fight inflammation, reduce cardiovascular diseases, clear congestion, lose weight, boost immunity, lower the risk of diabetes, prevent stomach ulcers and stop the spread of prostate cancer (Maheshwari *et al*., 2014).

A number of chilli cultivars are grown in Bangladesh differing in habit, size, shape, color, pungency and yield which indicating their wide range of variability (Farhad *et al*., 2010). Chilli is grown practically all over the country but the yield is comparatively low due to the lack of improved varieties. To develop a variety through a hybridization program characterization is definitely significant for finding out genetic information. Not only that characterization is also a fundamental task to provide information for plant breeding programs (Lin, 1991). Morphological characterization is necessary to recognize the variability and to improve the local germplasm. It is also equally important for easy and rapid evaluation of collected germplasm. Plant breeders over the years have relied heavily on phenotypic characterization for cultivation (Elias *et al.*, 2001 and Zacarias *et al.*, 2004)

Morphological characterization is still used in crop improvement programme, particularly where the capacity to use molecular markers is not yet fully developed to carry out *in situ*. It is relatively inexpensive and easy to carry out (Hoogendijk and Williams, 2001). There are many released cultivars that are developed based on morphological descriptors (Asare *et al.*, 2011). Morphological characterization is a highly recommended preliminary step that should be made before more in-depth biochemical or molecular studies are attempted.

Different morphotypes of chilli are available in Bangladesh. Plant Genetic Resources Centre (PGRC) of Bangladesh Agricultural Research Institute (BARI) collected and conserved various types of chilli germplasm from different districts of Bangladesh. Chilli accessions, lines and old cultivars are important reservoirs of useful genes and can be used to enrich the commercial chilli cultivars with the desired genes for useful traits (Zeng *et al.*, 2003). However, landraces and accessions are heterogeneous and include several genotypes within a population (Frankel and Soule, 1981). Chilli germplasm are in threats of extinction due to the high competition with hybrid chilli varieties introduced by different seed companies. Therefore, the present investigation was carried out to characterize the collected indigenous chilli germplasm through qualitative and quantitative traits as well as to identify desirable genotypes of chilli for breeding programs.

Materials and method

The experiment was carried out in the experimental field of Plant Genetic Resources Centre (PGRC), Bangladesh Agricultural Research Institute (BARI),

Joydebpur, Gazipur during winter 2013-14. Sixty chilli germplasm collected from different parts of Bangladesh were included in this study. Twenty-seven agro-morphological traits including 22 qualitative and 5 quantitative parameters were evaluated. The germplasm or genotypes under study are listed in the Table 1.

Table 1. List of chilli genotypes used in characterization

Collectors' number	Cultivar/Local name	Areas (District)	Collectors' number	Cultivar/Local name	Areas (District)
AH-1	Unknown	Gazipur	AMS-11	Deshi morich	Patuakhali
AH-2	Unknown	Gazipur	AMS-12	Deshi morich	Barguna
AH-5	Unknown	Gazipur	AMS-13	Deshi morich	Barguna
AH-6	Unknown	Gazipur	AMS-21	Deshi morich	Patuakhali
AI-1	Bot morich	Jenaidaha	AMS-26	Deshi morich	Patuakhali
AI-11	Khalkuli morich	Magura	AMS-27	Deshi morich	Patuakhali
AI-12	Tengakhali	Magura	AMS-30	Deshi morich	Patuakhali
AI-13	Tenga khali	Magura	AMS-31	Deshi morich	Patuakhali
AI-14	Kalo zia	Magura	AMS-32	Deshi morich	Patuakhali
AI-15	Zia morich	Magura	AMS-33	Deshi morich	Barisal
AI-16	Tenga khali	Magura	AMS-35	Deshi morich	Barisal
AI-2	Unknown	Jenaidaha	AMS-39	Deshi morich	Jhalkati
AI-21	Charkheda	Magura	AMS-4	Deshi morich	Patuakhali
AI-22	Matukda	Magura	AMS-42	Zhia morich	Barisal
AI-23	Alamdanga morich	Magura	AMS-44	Local morich	Barisal
AI-24	Jamalpur	Magura	AMS-45	Local morich	Barisal
AI-25 (2)	Unknown	Magura	AMS-5	Deshi morich	Patuakhali
AI-25(1)	Kalo zia	Magura	AMS-6	Deshi morich	Patuakhali
AI-26	Ubda morich	Magura	AMS-7	Deshi morich	Barguna
AI-27	Toba morich	Magura	AMS-8	Khet morich	Barguna
AI-28	Sada zia	Magura	AMS-9	Khet morich	Barguna
AI-36	Chuto morich	Magura	AR-1	Unknown	Chittagong
AI-37	Kalo zea	Magura	RI-12	Bangla morich	Khagrachari
AI-39	Shariatpur morich	Magura	RI-15	Babujhuri	Khagrachari
AI-40	India morich	Magura	RI-2	Jhum morich	Khagrachari
AI-41	Mota morich	Faridpur	RI-21	Chittagong morich	Khagrachari
AI-42	Kalozea morich	Faridpur	RI-35	Bumbai morich	Khagrachari
AI-8	Baltu jhal	Jenaidaha	RM-4	Asham morich	Joypurhat
AI-9	Zia jhal	Jenaidaha	RT-20	Churi morich	Jamalpur
AMS-10	Deshi morich	Patuakhali	RT-22	Deshi morich	Jamalpur

Seeds were sown in well-prepared seed beds on 24 October, 2013. Thirty-five days old seedlings were transplanted in the prepared pits of main experimental field on 27 November, 2013. The unit plot size was 3m×2m. Each germplasm was planted in a plot of three rows having five pits in each row. Row to row and plant to plant distance was 70 cm × 60 cm. Fertilizer were used 10 t/ha cow-dung, 210 kg/ha Urea, 33 kg/ha TSP, 200 kg/ha MoP and 5 kg/ha Borax (Mondal *et al.*, 2011). Weeding and mulching were done four times at 20 days interval starting from mid-December. Individual net was used per plot to avoid the cross pollination. Sevin 75 WP @ 0.1 g/pit, Sumithion 60 EC @ 2.5 ml/L and Vertimac 18 EC @ 1.2 ml/L were sprayed to control insect and mite, respectively. The data were collected from five randomly selected plants in each plot. Data on 22 qualitative and 5 quantitative characters were recorded from five randomly selected plants in each plot following the descriptor developed by the Bioversity International (IBPGR, 1983) and Minimal descriptors of agro-horticultural crops (Srivastava *et al.*, 2001).

Data analysis:

Mean values of germplasm were used for analysis. The data after compiling was statistically analyzed using MSTAT- C package version 1.2 and Least Significance Difference (LSD) test was applied to test the significance of genotypic differences at 5% level of probability.

Results and Discussion

Sixty germplasm of chilli were planted for morphological characterization. The germplasm were characterized on the basis of qualitative and quantitative characters.

A. Qualitative characters

A total of 22 qualitative characters were recorded and evaluated to know the variability among the studied germplasm (Table 2). All the characters showed distinct variation among the germplasm except cotyledonous leaf shape and fruit persistence. The maximum variation was observed in fruit colour at mature and immature stage.

Stem traits: Most of the germplasm exhibited as bushy plant since 80% of them were in compact growth habit. The remaining (20%) germplasm showed erect type of growth habit. The taller germplasm were AMS-42, AMS-44, AMS-45, AR-1, AI-13, AI-23, AI-24, RI-2, AI-28, AI-36, AI-42 and AI-26. Three categories stem colour such as green (75.00%), purple (6.67%) and their mixture (18.33%) were observed before transplanting. But after transplanting it was found only two categories such as green (15%) and purple (85%). Purple colour of chilli plant indicates the presence of high amount of anthocyanin content, which is an effective antioxidant for human body (Moon and Shibamoto, 2009).

The present study clearly revealed that in chilli plant anthocyanin content increases at maturity. For this reason, most of the stem of chilli germplasm exhibited as purple at mature stage. The germplasm having purple coloured stem at immature stage also remained purple at mature stage. These germplasm were AMS-44, RI-35, AH-1 and RI-2. Pubescence in plant part mostly acts as a defensive organ against pest (Novriyanti *et al.,* 2010). Glabrous, sparse and intermediate type stem pubescence was found where majority of the germplasm exhibited glabrous pubescence. Branching habit determines the canopy size of the plant. All the germplasm were found dichotomously branched but their habit was found as sparse (15.00%), intermediate (40.00%) and abundant (45.00%) types. Abundant branching habit showed higher fruit bearing capacity.

Leaf traits: Leaf shape exhibited as deltoid, ovate and lanceolate (Fig. 1) category, where lanceolate shape was found in the maximum germplasm (75.00%). The germplasm AI-11 showed deltoid type leaf shape only. Majority of the leaf exhibited as green colour (56.67%) and the rest were dark green (35.00%) and mixture of green and violate (8.33%). Germplasm AMS-39, AMS-42, AMS-44, AMS-45 and AH-1 showed mixture coloured leaf. Eighty percent of the germplasm showed glabrous and remaining 20.00% showed sparse type leaf pubescence. Out of 60 germplasm only 5 germplasm namely AMS-39, AMS-44, AMS-45, AH-1, RI-2 showed pigmentation in leaves.

| (a) | (b) | (c) |
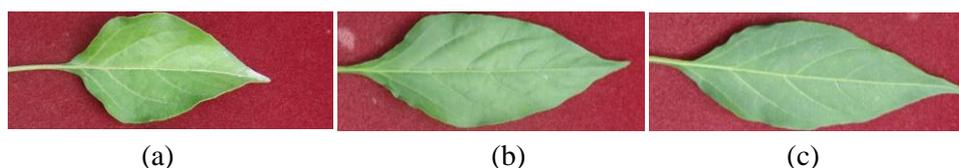
Fig. 1. Different types of leaf shape: (a) deltoid, (b) ovate and (c) lanceolate.

Inflorescence and flower traits: At anthesis period majority of the accessions showed intermediate (55.00%) pedicel position. Pendant and erect type pedicel position were found in 23.33% and 21.67% of the germplasm, respectively. Corolla colour of chilli germplasm exhibited as white (43.33%) light yellow (50%) and purple with white margin (6.67%). This corolla colour is related to pollen fertility. Coloured corolla provides more fertile pollen than colourless one (Taylor and Mo, 1998). The germplasm AMS-42, AMS-45, AH-1 and AH-2 showed purple coloured corolla with white margin. It might be suggested that these germplasm have high pollen fertility than the others. Not only that these germplasm also have high percentage of delphinidin (a kind of anthocyanidin) content which is a good reducer of prostate cancer of human being (Freyre *et al.*, 2015). Only 6.67% germplasm showed dentate calyx margin and the rest (93.33%) were intermediate type. The germplasm those have dentate calyx margin were AH-2, AH-5, AH-6 and AI-1. Annular constriction was present in 65% germplasm and absent in the rest.

Fruit traits: Fruit colour, fruit shape and its nodal position of chilli were investigated. Fruit colour observed in four types viz. green, black, green with

blackish blush and dark green. Green colour observed in maximum germplasm (51.67%) at both stages (Fig. 2.).
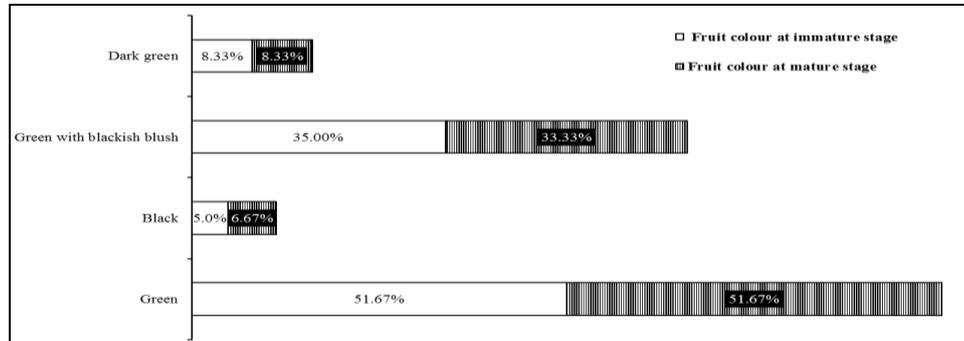
Fig. 2. Status of fruit colour in chilli germplasm at mature and immature stage.

Colour of chilli fruit is the result of a combination of pigments: chlorophylls, carotenoids, and anthocyanins accumulating in the fruit wall or pericarp of the fruit resulting in green, yellow, or purple fruit at physiological immature stages and yellow, red, or orange fruit at mature stages (Guzman *et al.*, 2011). Black or violet peppers metabolize and accumulate the anthocyanin delphinidin as both an aglycone and a glycosylated compound. The intense black pigmentation in pepper fruit is characteristic of high concentrations of delphinidin, chlorophyll, and carotenoids. Other than delphinidin, there are no other anthocyanins known to accumulate in peppers (Lightbourn *et al.*, 2008). In this investigation, the germplasm AMS-42, AMS-45, RI-35 and AH-5 showed black coloured fruit.

Fruit position varied in three categories viz. declining (43.33%), intermediate (50%) and erect (6.67%). The erect types have high level of pungency and are widely used in ornamental purposes (Stommel and Bosland, 2007). Two broad categories fruit shapes (Fig. 3) were observed such as elongate (75.00%) and conical (25.00%). Fruit shape near the peduncle attachment was mostly acute (71.67%) and the rest were obtuse (28.33%). Majority of the germplasm produce pointed shape (86.67%) at the base of the fruits and the rest were blunt (8.33%) and sunken (5.00%).

(a)   (b)

Fig. 3. Different type of fruits shape: (a) elongate and (b) conical

The germplasm AI-2, AH-2, AH-5 and RI-35 produced erect type fruit. Eleven germplasm showed neck at the base of fruit but in the rest germplasm (49) it was absent.

Table 2. Variability of different qualitative characters in chilli germplasm

Fruit position varied in three categories viz. declining (43.33%), intermediate (50%) and erect (6.67%). The erect types have high level of pungency and are widely used in ornamental purposes (Stommel and Bosland, 2007).

Character	Descriptor state	Number of germplasm	% of germplasm
1. Cotyledonous leaf shape	Lanceolate	60	100.00
2. Plant growth habit	Compact	48	80.00
	Erect	12	20.00
3. Stem color before transplanting	Green	45	75.00
	Purple	4	6.67
	Mixture	11	18.33
4. Stem color after transplanting	Green	9	15.00
	Purple	51	85.00
5. Stem pubescence	Glabrous	41	68.33
	Sparse	13	21.67
	Intermediate	6	10.00
6. Leaf shape	Deltoid	1	1.67
	Ovate	14	23.33
	Lanceolate	45	75.00
7. Leaf colour	Green	34	56.67
	Dark green	21	35.00
	Mixture	5	8.33
8. Leaf pubescence	Glabrous	48	80.00
	Sparse	12	20.00
9. Leaf pigmentation	Absent	55	91.67
	Present	5	8.33
10. Branching habit	Sparse	9	15.00
	Intermediate	24	40.00
	Abundant	27	45.00
11. Pedicel position at anthesis	Pendant	14	23.33
	Intermediate	33	55.00
	Erect	13	21.67
12. Corolla colour	White	26	43.33
	Light yellow	30	50.00
	Purple with white margin	4	6.67

Character	Descriptor state	Number of germplasm	% of germplasm
13. Calyx margin shape	Intermediate	56	93.33
	Dentate	4	6.67
14. Annular constriction	Absent	21	35.00
	Present	39	65.00
15. Fruit position	Declining	26	43.33
	Intermediate	30	50.00
	Erect	4	6.67
16. Fruit colour at immature stage	Green	31	51.67
	Black	3	5.00
	Green with blackish blush	21	35.00
	Dark green	5	8.33
17. Fruit colour at mature stage	Green	31	51.67
	Black	4	6.67
	Green with blackish blush	20	33.33
	Dark green	5	8.33
18. Fruit shape	Elongate	45	75.00
	Conical	15	25.00
19. Fruit shape at peduncle attachment	Acute	43	71.67
	Obtuse	17	28.33
20. Fruit shape at blossom end	Pointed	52	86.67
	Blunt	5	8.33
	Sunken	3	5.00
21. Neck at base of fruit	Absent	49	81.67
	Present	11	18.33
22. Fruit persistence	Persistent	60	100.00

Quantitative characters

The chilli germplasm evaluated in the present study showed the variability for all the quantitative traits studied. Marked variation was observed for number of fruits per plant, fruit length (cm), fruit width (cm), individual fruit weight (g) and yield per plant (g). The quantitative data of chilli is presented in the Table 4 and their range, mean, standard deviation and CV% are presented in Table 3. The highest quantitative variation was observed for yield per plant (CV% 111.68) which was followed by number of fruits per plant (CV% 84.25) and fruit width (CV% 68.98). The minimum variation was observed in fruit length (CV% 29.24).

Number of fruits per plant: Significant differences were observed in number of fruits per plant. It ranged from 1.00 to 70.50 fruits with an average of 16.64 fruits

per plant (Table 3). The average fruit number/plant (168.85±9.54) reported by Manju and Sreelathakumary (2002) was greater than the present investigation. This variation might be due to the diverse genotypes and environment. However, the highest number of fruits per plant was observed in germplasm RI-2 (70.50), followed by AI-1 (55.14), AI-39 (52.00) and AI-26 (49.50) and the lowest in germplasm RM-4 (1.00) (Table 4).

Fruit length: The fruit length varied significantly among the studied germplasm. Fruit length ranged from 1.00 to 7.20 cm and the average fruit length was found 4.07 cm (Table 3). The maximum fruit length observed in germplasm AMS-13 followed by RI-15 while the minimum fruit length was in AMS-8 (Table 4). A similar findings for fruit length of chilli in Bangladesh was reported by Uddin *et al.* (2015).

Fruit width: Fruit width ranged from 0.54 to 5.0 cm with an average of 0.90 cm (Table 3). Manju and Sreelathakumary (2002) observed at least two times bigger width (5.27-10.37 cm) than the present record. The germplasm AI-16 (5.00 cm) and AI-15 (0.54 cm) showed the wider and narrowed fruit, respectively (Table 4).

Individual fruit weight: Wide variation was found in individual fruit weight. Fruit weight raged from 0.80 to 3.60 g (Table 3). The average fruit weight was found 1.77 g. The heaviest fruit was found in germplasm AI-40 and the lightest fruit in AH-1, AI-15, AI-21 and AI-25(2). Therefore, a wide variation was found in respect of individual fruit among the germplasm. Individual fruit weight in this investigation was found considerably higher than the record of Uddin *et al.* (2015) in Bangladesh and Manju and Sreelathakumary (2002) in India.

Yield per plant: Highly significant differences were observed for fruit yield per plant. Yield per plant ranged from 10.9 to 155.57 g (Table 3). The average yield was found 24.34 g per plant. The highest yield per plant was found in germplasm AI-1 (155.57 g) significantly followed by AI-2 (112.07 g) and RI-2 (91.83 g) (Table 4). The lowest yield per plant was found in RM-4 (1.09 g) preceded by AI-8 (2.09g). Manju and Sreelathakumary (2002) reported the yield 51.31-1649.72 g per plant in India. The maximum yield is much higher than that in the present study which indicated that the germplasms in present study are not good yielder. This variation might be due to the variation in genotypes and growing seasons.

Table 3. Quantitative variation of different characters in chilli germplasm

Character	Range	Mean	SD	CV%
No. of fruits per plant	1.00 -70.50	16.64	14.02	84.25
Fruit length (cm)	1.00 -7.20	4.07	1.19	29.24
Fruit width (cm)	0.54 – 5.00	0.90	0.62	68.98
Individual fruit weight (g)	0.80 – 3.60	1.77	0.61	34.76
Yield per plant (g)	1.09 – 155.57	24.34	27.18	111.68

Table 4. Quantitative characters of different chilli germplasm

Collectors' number	No. of fruits per plant	Fruit length (cm)	Fruit width (cm)	Individual fruit weight (g)	Yield per plant (g)
AH-1	27.36	3.1	0.76	0.8	27.57
AH-2	18.00	3.6	0.84	1.2	20.29
AH-5	1.64	2.5	0.70	1.6	3.45
AH-6	5.46	3.2	0.76	2.4	6.00
AI-1	55.14	4.2	0.98	2.4	155.57
AI-2	35.71	5.0	0.98	2.4	112.07
AI-8	1.27	4. 1	0.95	2.0	2.09
AI-9	24.64	3.1	0.80	1.2	61.82
AI-11	8.21	3.6	0.66	1.6	9.86
AI-12	1.77	6.4	0.78	2.0	2.77
AI-13	8.43	4.2	0.76	1.2	9.86
AI-14	15.71	5.0	0.79	1.6	38.29
AI-15	9.09	4.1	0.54	0.8	16.18
AI-16	3.80	4.1	5.00	2.4	9.47
AI-21	8.58	3.6	0.72	0.8	27.33
AI-22	10.21	4.1	0.84	2.4	17.29
AI-23	32.23	5.2	0.83	1.2	54.62
AI-24	28.55	4.1	0.98	1.6	38.00
AI-25(1)	8.50	4.3	0.76	1.2	10.17
AI-25 (2)	16.17	4.2	0.68	0.8	18.33
AI-26	49.50	5.2	0.64	1.2	50.67
AI-27	7.77	3.6	3.00	2.4	16.62
AI-28	8.08	3.8	0.83	1.6	11.69
AI-36	14.36	3.9	0.75	1.2	25.57
AI-37	34.13	3.7	0.93	1.6	40.27
AI-39	52.00	4.6	0.72	1.6	67.73
AI-40	16.31	5.3	0.79	3.6	22.85
AI-41	5.31	6.0	0.84	2.8	7.85
AI-42	18.85	4.5	0.75	1.6	31.23
AMS-4	3.93	3.4	0.84	1.6	6.57
AMS-5	9.00	4.5	0.72	1.6	12.43
AMS-6	14.64	4.9	0.78	1.6	17.64
AMS-7	15.73	3.3	0.88	2.4	18.93
AMS-8	13.77	1.0	0.76	1.6	20.46
AMS-9	18.00	4.5	0.79	2.2	17.25
AMS-10	13.21	1.2	0.83	1.2	12.57
AMS-11	4.47	4.2	0.74	2.7	4.00
AMS-12	20.00	3.6	0.77	2.0	22.92

Collectors' number	No. of fruits per plant	Fruit length (cm)	Fruit width (cm)	Individual fruit weight (g)	Yield per plant (g)
AMS-13	20.71	7.2	0.8	1.8	26.29
AMS-21	18.17	4.2	0.72	2.0	16.17
AMS-26	23.64	3.7	0.68	1.6	15.57
AMS-27	14.22	4.3	0.77	1.3	8.00
AMS-30	12.93	1.5	0.8	1.2	12.43
AMS-31	8.30	3.7	0.71	1.4	4.00
AMS-32	10.83	2.0	0.85	1.6	8.83
AMS-33	13.92	6.0	0.8	2.8	14.15
AMS-35	12.00	3.0	0.81	1.8	19.08
AMS-39	19.44	3.8	0.73	2.4	14.89
AMS-42	19.85	3.5	0.7	1.8	20.62
AMS-44	4.44	3.8	0.72	1	5.78
AMS-45	17.42	4.5	0.8	1.2	17.17
AR-1	1.62	6.4	1.2	2.6	6.00
RI-2	70.50	3.6	0.66	2.2	91.83
RI-12	6.25	3.5	0.84	2.7	7.67
RI-15	29.89	6.5	0.75	3.0	32.22
RI-21	9.17	4.8	0.84	2.0	28.00
RI-35	10.38	2.5	0.84	1.6	13.08
RM-4	1.00	4.2	0.72	1.6	1.09
RT-20	31.00	4.6	0.75	1.2	46.00
RT-22	3.45	3.9	0.77	1.2	3.09
SE(±)	4.02	0.74	0.32	0.38	3.24
LSD (0.05)	8.05	1.48	0.64	0.76	6.50

The results obtained in this study are in close agreement with those of Uddin *et al.* (2015), who recorded highly significant variability among different chilli genotypes in Bangladesh. The current results of morphological evaluation of chilli germplasm are supported by the study of Hill *et al.* (2013). The findings of Hornero-Méndez *et al.* (2002), Thul *et al.* (2009) and Ibiza *et al.* (2012) further strengthen the current findings, who also found valuable and highly significant and positive variability among their studied genotypes.

Conclusion

Based on the above discussion most of the qualitative characters showed distinct variation among the germplasm. The maximum variation was observed in fruit colour. Significant variation was observed in quantitative parameters and the highest variation was observed in yield per plant. The present finding shows the great genetic potential of the studied genotypes. The promising genotypes identified such as AI-1, AI-2, RI-2, AI-39, AI-9, AI-23 and AI-26 have the

potential to be used in future breeding programs for getting productive and quality traits. Moreover, the variability observed in the current study could be used in crop improvement program. In addition, the germplasm was also categorized into different groups following descriptor state on the basis of morphological variability. So plant breeders and horticulturists can choose germplasm according to their needs.

References

Asare, P. A., I. K. A. Galyuon, J. K. Sarfo and J. P. Tetteh. 2011. Morphological and molecular based diversity studies of some Cassava (*Manihot esculenta* crantz) germplasm in Ghana. *African J. Biotech.* **10** (63): 13900-8.

Elias, M., D. McKey, O. Panaud, M. C. Anstett and T. Robert. 2001. Traditional management of cassava morphological and genetic diversity by the makushi amerindians (Guyana, South America): Perspectives for On-farm Conservation of Crop Genetic Resources. *Euphytica*. **120**: 143-57.

Farhad, M., M. Hasanuzzaman, B. K. Biswas, M. Arifuzzaman and M. M. Islam. 2010. Genetic divergence in chilli *(Capsicum annuum* L.). *Bangladesh Res. Pub. J.* **3**(3): 1045-1058.

Frankel, O. and M. E. Soulé. 1981. *Conservation and evolution*. CUP Archive. Pp. 222-235.

Freyre, R., S. B. Wilson, G. W. Knox, C. Uzdevenes, L. Gu and K. H. Quesenberry. 2015. Breeding and genetic studies of *Ruellia simplex* (Mexican Petunia). *Intl. EUCARPIA Symp. Section Ornamentals: Crossing Borders.* **1087**:113-120.

Guzman, I., P. W. Bosland and M. A. O'Connell. 2011. Heat, color, and flavor compounds in *Capsicum* fruit. *The Biological Activity of Phytochemicals*, Springer, New York. Pp. 109-126

Hernández, V., S. A. P. Dávila and K. Oyama. 1999. *Síntesis del conocimiento taxonómico, origen y domesticación del género Capsicum. Bol. Soc. Bot. Mex.* **64**: 65-84.

Hill, T. A., H. Ashrafi, S. Reyes-Chin-Wo, J. Yao, K. Stoffel, M. J. Truco and A. Van-eynze, 2013. Characterization of *Capsicum annuum* genetic diversity and population structure based on parallel polymorphism discovery with a 30K unigene Pepper Gene Chip. *PLoS One*. **8**(2): e56200.

Hoogendijk, M. and D. Williams. 2001. Characterizing genetic diversity of home garden crop species, some examples from the Americas. *In Proceedings of the Second International Home Gardens Workshop,* 17-19 July, 2001, Germany*,* 34-40*.*

Hornero-Méndez, D., J. Costa-García and M. I. Mínguez-Mosquera. 2002. Characterization of carotenoid high-producing *Capsicum annuum* cultivars selected for paprika production. *J. Agril. Food Chem.* **50**(20): 5711-5716.

Ibiza, V. P., J. Blanca, J. Cañizares, and F. Nuez. 2012. Taxonomy and genetic diversity of domesticated Capsicum species in the Andean region. *Genetic Resources and Crop Evolution*. **59**(6): 1077-1088.

IBPGR. 1983. Descriptors for Chilli (*Capsicum sp.* L.). International Board for Plant Genetic Resources. Rome, Italy.

Lightbourn, G. J., R. J. Griesbach, J. A., Novotny, B. A. Clevidence, D. D. Rao, and J. R. Stommel. 2008. Effects of anthocyanin and carotenoid combinations on foliage and immature fruit color of *Capsicum annuum* L. *J. Hered*. **99**:105-111

Lin, M.S. 1991. Genetic base of japonica rice varieties released in Taiwan. *Euphytica.* **56**: 43-46.

Maheshwari, R. K., A. K. Chauhan, L. Mohan and M. Maheshwari. 2014. Spice up for scrumptious tang, cologne & wellbeing. .*J. Global Biosci.* **3**: 304-313.

Manju, P. R. and I. Sreelathakumary. 2002. Genetic variability, heritability and genetic advance in hot chilli (*Capsicum chinense Jacq*.). *J. Trop. Agric*. **40**: 4-6.

Marti, M. C., D. Camejo, F. Vallejo, F. Romojaro, S. Bacarizo, J. M. Palma, F. Sevilla and A. Jiménez. 2011. Influence of fuit ripening stage and harvest period on the antioxidant content of sweet pepper cultivars. *Plant Food Hum. Nutr.* **66**: 416-423.

Mondal, M. R. I., M. S. Islam, M. A. J. Bhuiyan, M. M. Rahman, M.S Alam and M. H. H Rahman. 2011. Krishi Projucti Hatboi (5th edition). Bangladesh Agricultural Research Institute, Gazipur-1701.

Moon, J. K. and T. Shibamoto. 2009. Antioxidant assays for plant and food components. *J. Agril. Food Chem.* **57**(5): 1655-1666.

Novriyanti, E., C. Aoyama, M. Watanabe and T. Koike. 2010. Plant defense characteristics and hypotheses in birch species. *Eurasian J. Forest Res.* **13**(2): 77-85.

Pino, J., E. Sauri-Duch and R. Marbot. 2006. Change in volatile compounds of Habanero Chilli pepper (*Capsicum chinense* Jack. Cv. Habanero) at two ripening stages. *Food Chem.* 94: 394–398.

Srivastava, U., R.K. Mahajan, K.K. Gangopadhyay, S. Mahendra and B.S. Dhillon. 2001. Minimal Descriptors of Agri-Horticultural Crops (Part II: Vegetable Crops). National Bureau of Plant Genetic Resources. Pusa Campus, New Delhi-110012, India.

Stommel, J. R. and P. W. Bosland. 2007. Ornamental pepper. *In Flower Breeding and Genetics*, Springer, The Netherlands. pp. 561-599.

Taylor, L.P. and Y. Mo. 1998. Washington State University Research Foundation. *Methods for the regulation of plant fertility*. U.S. Patent. **5**:733-759.

Thul, S. T., R. K. Lal, A. K. Shasany, M. P. Darokar, A. K. Gupta, M. M. Gupta, R. K. Verma and S. P. S. Khanuja. 2009. Estimation of phenotypic divergence in a collection of Capsicum species for yield related traits. *Euphytica.* **168** (2): 189-196.

Uddin, A. J., M. S. Hussain, S. S. Rahman, H. Ahmad and M. Z. K. Roni. 2015. Growth, yield and quality of SAU-Agni and SAU- SAU Cayenne chilli variety. Bangladesh residues. Pub. J. **11**(3): 198-203.

Zacarias, A. M., A. M. Botha, M. T. Labuschagne and I. R. M. Benesi. 2004. Characterisation and genetic distance analysis of Cassava (*Manihot esculenta* Crantz) germplasm from Mozambique using RAPD fingerprinting. *Euphytica*. **138**: 49-53.

Zeng Y. W., S. Q. Shen, Z. C. Li, Z. Y. Yang, X. K. Wang, H.L. Zhang, and G. S. Wen. 2003. Ecogeographic and Genetic diversity based on morphological character of indigenous rice (*O. sativa* L.) in Yunnan, China. *Resour. Crop Evol.* **50**: 566-577.

ASSESSMENT OF ARBUSCULAR MYCORRHIZAL ASSOCIATION IN SOME FRUIT AND SPICE PLANTS OF RANGAMATI HILL DISTRICT

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Abstract

Rhizosphere soils of some fruit and spice plants from the Hill Agricultural Research Station, Bangladesh Agricultural Research Institute, Raikhali, Rangamati were collected during 2011-12 and 2012-13 for counting Arbuscular Mycorrhizal (AM) spore population, determining colonization (%) in their roots and studying AM structure. Assessment of spore population was done by following the Wet Sieving and Decanting Method. The percentage of AM infection was estimated by root slide technique. The spore number of 100g rhizosphere soil was recorded ranging from 120 in rhizosphere soil of Malta plant to a maximum of 410 in Atafal and Sofeda plants during 2011-12 and from 75 in rhizosphere soil of Phalsa plant to a maximum of 327 in Amlaki plant during 2012-13. Different fruit and spice plants showed different percentages of root colonization by AM fungi. Among the fruit and spice plants, the highest colonization (40%) was found in Jabotica, Phalsa and Sofeda plant, and the lowest colonization (6.6%) was found in Rambutan plant during 2011-12, but in 2012-13 the highest (61.3%) was result was observed in Bilatigab plant and the lowest (18.7%) was in Misti lebu, Malta and Tetul plant. The AM fungal structure in the root system of the selected fruit and spice plants varied in irrespective of fruit and spice species. Some plants had vesicles. Hyphae were present in most of the plants. Some plant species recorded Arbuscules. Both oval and spherical shape vesicles were found in this study.

Keywords: Arbuscular mycorrhiza, spore population, root colonization, fruit & spice plants

Introduction

Mycorrhizae are symbiotic association between beneficial soil fungi and plant roots. Vesicular-arbuscular mycorrhizae (VAM) are the mycorrhizae of crop plants and most annual and woody natives. They do not produce visible mushroom-type reproductive structures, but form spores that are the largest of any fungi. They cannot be grown in laboratory conditions, but they can grow with a wide variety of host plants. They have an important role in increasing plant uptake of poorly mobile nutrients such as P, Zn and Cu (O'Keefe and Sylvia, 1991). Mycorrhizal plants are more resistant to some pathogens, have altered production of plant hormones, and have more highly branched root systems than non-mycorrhizal plants. Cuttings of some species have an improved

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rooting ability when the medium contains mycorrhizal fungi. Many of the benefits, even those which seem unrelated to phosphorus, appear to actually be side benefits of improved phosphorus nutrition. The soil, as well as the plants, is affected by mycorrhizal fungi. The hyphae are an important component of soil structure, holding together crumbs that allow penetration of water and air, and encourage the growth of roots through the soil. Out of the different types of mycorrhizae, the AM fungi are the most widely occurring mycorrhizae and are very important in relation to the improvement of agricultural and horticultural crops and forest trees in hilly areas (Mridha and Xu, 2001).

Arbuscular mycorrhizal fungi (AMF) that form symbiotic relationships with the roots of most terrestrial plants are known to improve the nutritional status of their host and to protect plants against several soil-borne plant pathogens (Smith and Read, 1997; Harrison, 1999; Bi *et al*., 2007). The major effect of mycorrhizal fungi in undisturbed ecosystems is to improve by the growth of mycorrhizal plants compared to non-mycorrhizal plants (Plenchette *et al*., 1983). It covers the root of plants so it makes protective physical barrier against diseases also (McAllister *et al.,* 1997; Karagiannidis *et al.,* 2002).

There are many disease management methods such as crop rotation, use of resistant varieties and chemical pesticides. However, frequent and indiscriminate use of these pesticides affects the physical, chemical and biological property of the soil. It also affects the non-target organisms and has developed resistance among the pathogen against these chemicals (Arwry and Quandt, 2003). Biocontrol potential of AM fungi against various phytopathogens is well documented (Singh *et al*., 2000; Kasiamdari *et al*., 2002; Azcón-Aguilar *et al*., 2002; Bodker *et al*., 2002; Xavier and Boyetchko, 2014; St-Arnaud and Elsen, 2005; St-Arnaud and Vujanovic, 2007). Arbuscular Mycorrhizal Fungi (AMF) are the major component of the rhizosphere of most of the plants and play a very important role as biocontrol agent and help in decreasing plant disease incidence (Akthar and Siddiqui, 2008).

They form three-way associations involving plants, fungi and soils. Bangladesh produces a variety of fruits and spices. It seems that there is an important role of arbuscular mycorrhizal fungi in nutrient availability for these fruit and spice plants. But still no work has been done to assess the mycorrhizal association with different fruit plants. So, this present work was undertaken to know the percent root colonization of fruit and spice plants and the number of AM spores in the rhizosphere soils for producing suitable inoculum for future use in different crops.

Materials and Method

Rhizosphere soils of some fruit and spice plants from the Hill Agricultural Research Station (HARS), Bangladesh Agricultural Research Institute (BARI), Raikhali, Rangamati were collected during 2011-12 and 2012-13 for the

assessment of arbuscular mycorrhizal association. Rhizosphere soils with thin roots were collected from the plants, the list is presented in Table 1.

Table 1. List of plants collected from HARS, Raikhali, Rangamati during 2011-12 and 2012-13

Local name	English name	Scientific name	Family
Aam	Mango	*Mangifera indica*	Anacardiaceae
Amlaki	Aonla	*Phyllanthus emblica*	Euphorbiaceae
Amra	Hog plum	*Spondias mangifera*	Anacardiaceae
Anar	Pomegranate	*Punica granatum*	Punicaceae
Alubukhara	Pulm/Peach	*Prunus persica*	Rosaceae
Arboroy	Star gooseberry	*Phyllanthus acidus*	Euphorbiaceae
Ashfal	Longan	*Nephelium longana*	Sapindaceae
Atafal	Bullock's heart	*Annona reticulata*	Annonaceae
Avocado	Avocado	*Persea americana*	Lauraceae
Batabilebu	Pummelo	*Citrus grandis*	Rutaceae
Bael	Wood apple/Bael	*Aegle marmelos*	Rutaceae
Bilatigab	Velvet apple	*Diospyros discolor*	Ebenaceae
Bilimbi	Bilimbi	*Averrhoa bilimbi*	Oxalidaceae
Bokful	Heron flower	*Sesbania grandiflora*	Fabaceae
Chalta	Indian dillenta	*Dillenia indica*	Dilleniaceae
Cherryfal	Cherry	*Prunus avium*	Rosaceae
Coco	Cocoa	*Theobroma cocoa*	Malvaceae
Cowfal	Cowa	*Garcinia cowa*	Clusiaceae
Dalim	Pome granate	*Punica granatum*	Punicaceae
Dewa	Monkey jackfruit	*Artocarpus lakoocha*	Moraceae
Gab (Deshi)	River ebony	*Diospyros peregrina*	Ebenaceae
Golapjam	Rose apple	*Syzygium jambos*	Myrtaceae
Jabotica	Jabuticaba	Myrciaria cauliflora	Myrtaceae
Jalpai	Indian oliva	*Olea europaea*	Oleraceae
Jam	Jamun	*Syzygium cumini*	Myrtaceae
Jamrul	Wax jambu	*Syzygium samarengense*	Myrtaceae
Jamir	Rough lemon	*Citrus jambhiri*	Rutaceae
Jilapifal	Jungle jalebi	*Pithecellobium dulce*	Fabaceae
Kamranga	Carambola	*Averrhoa carambola*	Oxalidaceae
Karamcha (Misti)	Carunda (sweet)	*Carissa carandas*	Apocynaceae
Khejur	Date palm	*Phoenix dactylifera*	Palmae
Kodbel	Elephant apple	*Feronia elephantum*	Rutaceae
Komola	Orange/Mandarin	*Citrus reticulata*	Rutaceae
Lebu (Misti)	Sweet lime	*Citrus limettioides*	Rutaceae

Local name	English name	Scientific name	Family
Lotkan	Burmese grape	*Baccaurea sapida*	Euphorbiaceae
Macadamia	Macadamia nut	*Macadamia integrifolia*	Proteaceae
Mahuafal	Butter fruit	*Madhuka indica*	Sapotaceae
Malta	Sweet orange	*Citrus sinensis*	Rutaceae
Panifal	Water chestnut	*Trapa bispinosa*	Trapaceae
Peachfal	Peach	*Prunus persica*	Rosaceae
Persimmon	Persimmon	*Diospyros kaki*	Ebenaceae
Peyara (Thai)	Guava	*Psidium guajava*	Myrtaceae
Peyara (Seedless)	Guava	*Psidium guajava*	Myrtaceae
Phalsa	Phalsa/Dhamani	*Grewia asiatica*	Tilaiaceae
Rambutan	Rambutan	*Nephelium lappaceum*	Sapindaceae
Sajna	Drumstick	*Moringa oleifera*	Moringaceae
Satkara	Satkara	*Citrus macroptera*	Rutaceae
Sharifa	Custard apple	*Annona squamosa*	Annonaceae
Sofeda	Sapota	*Manilkara achras*	Sapotaceae
Tarokafal	Star apple	*Chrysophyllum cainito*	Sapotaceae
Tetul	Tamarind	*Tamarindus indica*	Fabaceae
Tuthfal	Mulberry	*Morus indica*	Moraceae

Assessment of spore population density

Assessment of spore population was done by following the Wet Sieving and Decanting Method (Gerdemann and Nicolson, 1963). Soil samples from the rhizosphere of the respective plant species were mixed thoroughly by breaking up any large lumps. Any large unwanted particles such as stone, roots, twigs etc. were removed. Then 100 g of mixed soil was kept in a series of buckets (8-litre) and filled three quarters with tap water. The soil with water was agitated by stirring vigorously by hand and left to settle for some minutes. Two sieves (400 μm and 100 μm mesh) were used throughout the experiment. The supernatant was poured through a 100 μm sieve into the second bucked (10-litre) to avoid the loss of useful materials. The supernatant was decanted into the 400 μm sieve. This time water was discarded and the material was back washed from the sieve into a beaker (250 mL) with a small quantity of water. The solution with spores was distributed in 4 equal size test tubes evenly and balanced up the tubes with water for equal weight. The tubes were plugged properly and then centrifuged for 4 minutes at 3,000 rpm. The supernatant was poured in test tubes and the test tubes were filled with sucrose solution and stirred vigorously with the round-ended spatula to re-suspend the precipitate. The plugged test tubes were centrifuged for 15 seconds at 3,000 rpm. After centrifuge, the sucrose supernatant was poured through a 400 μm sieve and rapidly washed with water to remove the

sucrose from AM spores by back washing the materials from the sieve into watch glass for observation.

Counting of AM spores

All the AM spores were isolated from the extract with the help of a fine forcep into a watch glass with small quantity of water. The extract, with AM spores, was observed under stereomicroscope and the number of spores was counted. Spore numbers from the three replicates per samples were averaged and the result was expressed as number per 100 g of dry soil basis.

Assessment of root colonization infection

The percentage of AM infection was estimated by root slide technique (Read *et al.*, 1976). One hundred root segments were examined for each sample. The stained root pieces were mounted in acidic glycerol on slides and the cover slip was placed, and slightly pressed. The roots were observed under microscope. A root segment was considered as positively infected, if it showed mycelium, vesicles and arbuscules or any other combination of these structural characteristics of AM infection. The presence or absence of infection in the root pieces was recorded and the percent infection was calculated as follows:

$$\% \text{ root colonization} = \frac{\text{Number of AM positive segments}}{\text{Total number of segments observed}} \times 100$$

Methods of chemical analysis:

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by wet oxidation method (Page *et al.*, 1982). Total N was determined by modified Kjeldahl method (Page *et al.*, 1982). Calcium, K and Mg were determined by NH_4OAc extraction method. Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method. Sulphur was determined by $CaH_4(PO_4)_2.H_2O$ extraction followed by turbidimetric turbidity method with $BaCl_2$. The soil had pH value 5.7 with organic matter 1.83%, exchangeable Ca 6.0 meq $100g^{-1}$, exchangeable Mg 2.1 meq $100g^{-1}$, exchangeable K .18 meq $100g^{-1}$, Total N 0.10%, available P 16 $\mu g\ g^{-1}$, available S 12 $\mu g\ g^{-1}$, available B 0.16 $\mu g\ g^{-1}$, available Cu 1.90 $\mu g\ g^{-1}$, available Fe 48 $\mu g\ g^{-1}$, available Mn 10.4 $\mu g\ g^{-1}$, available Zn 2.87 $\mu g\ g^{-1}$.

Results and Discussion

Spore population of AM fungi

Arbuscular mycorrhizal spores were assessed from different fruit and spice plants (Tables 2 and 3). During 2011-12, the highest spore number (410 per 100 g soil)

was obtained from the rhizosphere soil of Atafal and the lowest spore number (120 per 100 g soil) was obtained from Malta plant (Table 2). Some of the fruit and spice plants like Anar, Atafal, Bael, Bilimbi, Jam, Jamrul, Jilapifal, Kamranga, Khejur, Peyara (Thai), Rambutan, Sajna, Sofeda and Tetul plants recorded more than 300 spores per 100 g rhizosphere soil during the first year (2011-12). During 2012-13, the highest spore number (327 per 100 g soil) was obtained from the rhizosphere soil of Amlaki plant and the lowest spore number (75 per 100 g soil) was obtained from Phalsa plant (Table 3). Some of the plants like Amlaki, Cherryfal and Lotkan plant recorded more than 300 spores per 100 g rhizosphere soil during the second year. There were wide variations in shape, size and colour of spores. Different shape and sizes of spore like round, oval, spherical etc. were found among the rhizosphere soils of different fruit and spice plants. In case of colours, like deep brown, light brown, radish, black, etc. were recorded in rhizosphere soils of different fruit and spice plants.

Table 2. Spore population of arbuscular mycorrhizae in rhizosphere soil and root infection of different fruit and spices plants of HARS, Raikhali, Rangamati during 2011-12.

Local name	English name	Spore number per 100 g soil[a]	Root colonization[a] (%)	AM structure[b]			
				H	A	V	VS
Aam	Mango	205.0 ± 8.7	10.0 ± 1.2	+	+	-	-
Amlaki	Aonla	185.0 ± 11.5	9.3 ± 1.2	+	-	-	-
Amra	Hog plum	280.0 ± 11.5	38.0 ± 4.2	+	-	-	-
Anar	Pomegranate	322.0 ± 12.7	20.0 ± 2.9	+	-	-	-
Alubukhara	Pulm/Peach	325.0 ± 8.7	10.0 ± 1.2	+	-	-	-
Arboroy	Star gooseberry	210.0 ± 11.5	28.7 ± 1.9	+	-	-	-
Ashfal	Longan	275.0 ± 8.7	20.0 ± 2.3	+	-	+	O
Atafal	Bullock's heart	410.0 ± 11.5	10.0 ± 1.2	+	-	-	-
Avocado	Avocado	250.0 ± 8.7	20.0 ± 2.9	+	-	-	-
Batabilebu	Pummelo	270.5 ± 11.5	18.7 ± 1.9	+	-	-	-
Bael	Wood apple/Bael	350.0 ±11.5	20.0 ± 2.9	+	-	-	-
Bilatigab	Velvet apple	195.0 ± 8.7	20.0 ± 2.9	+	-	-	-
Bilimbi	Bilimbi	320.0 ± 11.5	18.7 ± 4.1	+	-	-	-
Bokful	Heron flower	170.0 ± 8.7	20.0 ± 2.9	+	-	-	-
Chalta	Indian dillenta	180.0± 11.5	10.7 ± 1.2	+	-	-	-
Cherryfal	Cherry	140.0 ± 8.7	9.3 ± 0.6	+	+	-	-
Coco	Cocoa	195.0 ± 8.7	6.9 ± 1.2	+	-	-	-
Cowfal	Cowa	265.0 ± 8.7	30.0 ± 2.9	+	-	-	-
Dalim	Pome granate	225.0 ± 14.4	20.0 ± 2.9	+	-	-	-
Dewa	Monkey jackfruit	290.0 ± 17.3	10.0 ± 1.2	+	-	-	-
Gab (Deshi)	River ebony	210.0 ± 5.8	30.0 ± 2.9	+	-	-	-

Local name	English name	Spore number per 100 g soil[a]	Root colonization[a] (%)	AM structure[b]			
				H	A	V	VS
Golapjam	Rose apple	180.0 ± 5.8	20.0 ± 2.9	+	-	-	-
Jabotica	Jabuticaba	185.0 ± 14.4	40.0 ± 5.8	+	-	-	-
Jalpai	Indian oliva	195.0 ± 8.7	28.7 ± 3.2	+	-	-	-
Jam	Jamun	320.0 ± 11.5	21.6 ± 0.9	+	-	-	-
Jamrul	Wax jambu	320.0 ± 17.3	10.0 ± 1.2	+	-	-	-
Jamir	Rough lemon	250.0 ± 5.8	28.7± 3.2	+	+	+	S
Jilapifal	Jungle jalebi	300.0 ± 28.9	20.0 ± 2.3	+	-	-	-
Kamranga	Carambola	325.0 ± 14.4	18.7 ± 2.2	-	+	-	-
Karamcha (Misti)	Carunda (sweet)	190.0 ± 11.5	10.0 ± 0.6	+	-	+	O
Khejur	Date palm	321.7 ± 14.8	20.0 ± 1.2	+	-	-	-
Kodbel	Elephant apple	210.0 ± 5.8	18.7 ± 0.9	+	-	-	-
Komola	Orange/Mandarin	215.0 ± 8.7	28.7 ± 1.3	+	-	-	-
Lebu (Misti)	Sweet lime	185.0 ± 8.7	28.3 ± 1.2	+	-	-	-
Lotkan	Burmese grape	210.0 ± 17.3	28.7 ± 0.9	+	-	-	-
Macadamia	Macadamia nut	190.0 ± 17.3	20.0 ± 1.2	+	+	-	-
Mahuafal	Butter fruit	200.0 ± 23.1	20.0 ± 1.7	+	-	-	-
Malta	Sweet orange	120.0 ± 8.7	18.7 ± 1.3	+	+	-	-
Panifal	Water chestnut	270.0 ± 8.7	20.0 ± 1.7	+	-	-	-
Peachfal	Peach	230.0 ± 5.8	10.0 ± 1.2	+	-	-	-
Persimmon	Persimmon	220.0 ± 11.5	10.0 ± 1.2	+	-	+	S
Peyara (Thai)	Guava	300.0 ± 23.1	30.0 ± 1.7	+	-	-	-
Peyara (Seedless)	Guava	251.7 ± 41.1	20.0 ± 2.9	+	-	-	-
Phalsa	Phalsa/Dhamani	292.0 ± 4.6	40.0± 2.9	+	-	-	-
Rambutan	Rambutan	318.0 ± 6.9	6.6 ± 0.9	+	+	-	-
Sajna	Drumstick	300.0 ± 17.3	30.0 ± 1.7	+	-	-	-
Satkara	Satkara	190.0 ± 5.8	18.3 ± 3.3	+	-	-	-
Sharifa	Custard apple	172.0 ± 4.6	10.0 ± 0.6	+	-	-	-
Sofeda	Sapota	410.0 ± 11.5	40.0 ± 2.9	+	-	-	-
Tarokafal	Star apple	250.0 ± 28.9	20.0 ± 1.7	+	-	-	-
Tetul	Tamarind	327.0 ± 15.6	18.7 ± 1.7	+	-	-	-
Tuthfal	Mulberry	175.0± 8.7	30.0 ± 1.7	+	-	-	-

[a]Percent root colonization & spore population are the means ± S.E. of three independent counts.

[b]H= Hypae, A=Arbuscle, V=Vesicle, VS= Vesicle Shape, O=Oval, S=Spherical

Table 3. Spore population of arbuscular mycorrhizae in rhizosphere soil and root infection of different fruit and spices plants of HARS, Raikhali, Rangamati during 2012-13.

Local name	English name	Spore number per 100 g soil [a]	Root colonization[a] (%)	AM structure[b]			
				H	A	V	VS
Aam	Mango	266.0 ± 22.5	31.0 ± 3.8	+	-	+	O
Amlaki	Aonla	327.0 ± 1.7	30.0 ± 2.9	+	-	-	-
Amra	Hog plum	257.3 ± 29.2	20.0 ± 2.9	+	-	-	-
Anar	Pomegranate	96.0 ± 6.4	20.7 ± 3.5	+	-	-	-
Alubukhara	Pulm/Peach	140.3 ± 14.1	20.7 ± 3.5	+	-	-	-
Arboroy	Star gooseberry	195.0 ± 14.4	20.0 ± 2.9	+	-	-	-
Ashfal	Longan	200.0 ± 17.3	21.3 ± 4.1	+	-	-	O
Atafal	Bullock's heart	175.0 ± 17.3	21.3 ± 4.1	+	-	-	-
Avocado	Avocado	223.0 ± 7.5	20.0 ± 2.9	+	-	-	-
Batabilebu	Pummelo	205.3 ± 14.1	20.0 ± 2.9	+	-	-	-
Bael	Wood apple/Bael	190.0 ± 23.0	21.3 ± 1.9	+	-	-	-
Bilatigab	Velvet apple	240 ± 11.5	61.3 ± 4.1	+	-	-	O
Bilimbi	Bilimbi	92.3 ± 7.2	20.0 ± 2.9	+	+	+	+
Bokful	Heron flower	155.3 ± 11.8	21.0 ± 3.8	+	-	-	-
Chalta	Indian dillenta	198.3 ± 4.9	21.0 ± 4.1	+	-	-	-
Cherryfal	Cherry	316.7 ± 23.3	20.0 ± 2.9	+	+	+	S
Coco	Cocoa	82.3 ± 7.2	21.0 ± 3.8	+	-	-	-
Cowfal	Cowa	156.0 ± 17.9	21.3 ± 4.1	+	-	-	-
Dalim	Pome granate	262.3 ± 38.9	30.0 ± 2.9	+	-	-	-
Dewa	Monkey jackfruit	287.3 ± 47.6	20.0 ± 2.9	+	-	-	-
Gab (Deshi)	River ebony	134.7 ± 35.0	20.7 ± 3.5	+	-	-	-
Golapjam	Rose apple	158.3 ± 0.9	21.0 ± 3.8	+	-	-	-
Jabotica	Jabuticaba	125.0 ± 2.9	20.0 ± 2.9	+	-	-	-
Jalpai	Indian oliva	291.7 ± 20.5	20.0 ± 2.0	+	-	-	-
Jam	Jamun	217.3 ± 7.2	30.0 ± 2.9	+	-	-	-
Jamrul	Wax jambu	215.3 ± 26.0	30.0 ± 2.9	+	-	-	-
Jamir	Rough lemon	204.0 ± 44.5	20.0 ± 2.9	+	-	-	-
Jilapifal	Jungle jalebi	89.3 ± 8.3	20.7 ± 3.5	+	-	-	-
Kamranga	Carambola	155.0 ± 1.2	20.0 ± 2.9	+	-	-	-
Karamcha (Misti)	Carunda (sweet)	280.0 ± 5.8	28.7 ± 1.9	+	-	-	-
Khejur	Date palm	283.0 ± 27.1	21.0 ± 3.8	+	-	-	O
Kodbel	Elephant apple	154.0 ± 0.6	28.7 ± 1.9	+	-	-	-
Komola	Orange/Mandarin	122.3 ± 21.7	18.7 ± 1.9	+	+	-	-

Local name	English name	Spore number per 100 g soil [a]	Root colonization[a] (%)	AM structure[b]			
				H	A	V	VS
Lebu (Misti)	Sweet lime	310.0 ± 11.5	20.0 ± 2.9	+	-	-	-
Lotkan	Burmese grape	239.0 ± 19.6	18.7 ± 1.9	+	-	-	-
Macadamia	Macadamia nut	188.3 ± 10.7	20.0 ± 2.9	+	-	-	O
Mahuafal	Butter fruit	202.3 ± 4.3	30.0 ± 2.9	+	-		-
Malta	Sweet orange	215.0 ± 31.8	18.7 ± 1.9	+	-	-	-
Panifal	Water chestnut	188.3 ± 18.2	20.0 ± 2.9	+	-	-	-
Peachfal	Peach	220.0 ± 5.8	30.0 ± 2.9	+	-	-	-
Persimmon	Persimmon	167.3 ± 4.3	21.3 ± 4.1	+	-	-	-
Peyara (Thai)	Guava	108.3 ± 10.7	30.0 ± 2.9	+	-	-	-
Peyara (Seedless)	Guava	182.3 ± 13.0	20.0 ± 2.9	+	-	-	-
Phalsa	Phalsa/Dhamani	75.0 ± 11.5	21.3 ± 4.1	+	-	-	O
Rambutan	Rambutan	97.3 ± 4.3	30.0 ± 2.9	+	-	-	-
Sajna	Drumstick	131.3 ± 2.6	20.0 ± 2.9	+	-	-	-
Satkara	Satkara	290.3 ± 11.6	28.7 ± 1.9	+	-	-	-
Sharifa	Custard apple	160.3 ± 12.7	20.0 ± 2.9	+	-	-	-
Sofeda	Sapota	282.3 ± 7.2	20.0 ± 2.9	+	-	+	S
Tarokafal	Star apple	101.3 ± 3.8	30.0 ± 2.9	+	-	-	-
Tetul	Tamarind	186.7 ± 19.3	18.7 ± 1.9	+	-	-	-
Tuthfal	Mulberry	166.0 ± 22.5	30.0 ± 2.9	+	-	-	-

[a]Percent root colonization & spore population are the means ± S.E. of three independent counts.

[b]H= Hypae, A=Arbuscle, V=Vesicle, VS= Vesicle Shape, O=Oval, S=Spherical.

In the present study, the spore density in the rhizosphere soil varied in different fruit and spice plants which were supported by Howeler *et al*. (1987) who reported that the intensity of spore density varied on different factors like plant species and genera and nature of rhizosphere soil. Moreover, higher spore population was observed in some fruit and spice plants. The stimulating effects of organic matter, comparatively higher level of N and P might have created a favourable condition for the maximum sporulation of AM fungi in that particular field.

Root colonization

Different fruit and spice plants showed different percentages of root colonization by Arbuscular mycorrhizal fungi (Tables 2 and 3). During the first year study (2011-12), the root colonization varied from 6.6% to 40.0% (Table 2). More than 30% colonization was recorded with Amra, Cowfal, Gab, Jabotica, Peyara

(Thai), Phalsa, Sajna, Sofeda and Tuthfal rhizospheres. The lowest colonization (6.6%) was recorded in Rambutan plants. During the second year (2012-13), root colonization varied from 18.7% to 61.3% (Table 3). Similar to the first year, above 30% colonization was noted with Aam, Amlaki, Bilatigab, Dalim, Jam, Jalpai, Mahuafal, Peyara (Thai), Rambutan, Tarakafal and Tuthfal plants. Among them, the highest colonization (61.3%) was found in Bilatigab plant. The lowest colonization (18.7%) was recorded in Malta, Lebu (Misti) and Tetul plant. A large variation was observed in the colonization among different fruit and spice plants. This variation might be due to the differences in the structure of root system and P uptake (Hetrick *et al.*, 1992) and also might be due to genetic variations (Mercy *et al.*, 1990).

AM structure

The AM fungal structure in the root system of the selected fruit and spice plants varied in irrespective of fruit and spice species (Tables 2 and 3). There were some plants which had vesicles. Hyphae were present in most of the plants. Some plant species recorded Arbuscules. Both oval and spherical shape vesicles were found in this study, which was supported by Khanam *et al.* (2003, 2004).

Spore number and root colonization varied from plant to plant in the present study. But variations in spore number in different plants were not related to per cent root colonization which is in agreement with Khalil *et al.* (1992). As a wide range of host, fungal and environmental factors are known to influence AM formation and subsequent spore production; these two phenomena may not necessarily be related.

Conclusion

It is evident from the study that spore number and root colonization varied from plant to plant. Variations in spore numbers in different plants were not related to per cent root colonization. The AM fungal structure in the root system of the selected spices and fruit plants also varied in irrespective of fruit and spice species. A wide range of host, fungal and environmental factors might have influenced AM formation and subsequent spore production. Higher root colonization of fruit and spices plants and higher number of AM spores in the rhizosphere soils can be selected for producing suitable inoculum for future use.

References

Akthar, M. S. and Z. A. Siddiqui. 2008. Arbuscular mycorrhizal fungi as potential bioprotectants against plant pathogens. *In*: Mycorrhizae; Sustainable Agriculture and Forestry, Siddiqui, Z. A., M. S. Akhtar and K. Futai (eds.). Springer Netherlands, Dordrecht, the Netherlands.

Arwry, T. A. and S. A. Quandt. 2003. Pesticides at work and at home: Exposure of migrant farmworkers. *Lancet*. **362**: 2021-2021.

Azcón-Aguilar, C., M. C. Jaizme-Vega and C. Calvet. 2002. The contribution of Arbuscular Mycorrhizal Fungi to the control of soilborne plant pathogens. *In*: Gianinazzi, S., H. Schuepp, J. M. Barea and K. Haselwandter (eds). *Mycorrhizal Technology in Agriculture*. Birkhauser, Switzerland, Pp. 187-197.

Bi, H. H., Y. Y. Song and R. S. Zeng. 2007. Biochemical and molecular responses of host plants to mycorrhizal infection and their roles in plant defense. *Allelopath. J.* **29**: 15-27.

Bodker, L., R. Kjoller, K. Kristensen and S. Rosendahl. 2002. Interactions between indigenous Arbuscular Mycorrhizal Fungi and *Aphanomyces euteiches* in field-grown pea. *Mycorrhiza*. **12**: 7-12.

Gerdemann, J. W. and T. H. Nicolson. 1963. Species of mycorrhizal endogone species extracted from soil by wet sieving and decanting method. *Trans. Brit. Mycol. Soc.* **46**: 235-246.

Harrison, M. J. 1999. Molecular and cellular aspects of the arbuscular mycorrhizal symbiosis. *Plant Mol. Biol.* **50**: 361-389.

Hetrick, B. A. D., G. W. T. Wilson and T. C. Todd. 1992. Relationship of mycorrhizal symbiosis, rooting strategy, and phenology among tallgrass prairie forbs. *Can. J. Bot.* **70**: 1521-1528.

Howeler, R. H., E. Seiverding and S. Saif. 1987. Practical aspects of mycorrhizal technology in some tropical crops and pastures. *Plant Soil.* **100**: 249-283.

Jackson, M. L. 1958. *Soil Chemical Analysis.* Constable and Co. Ltd., London.

Karagiannidis, N., F. Bletsos and N. Stavropoulos. 2002. Effect of Verticillium wilt (*Verticillium dahliae* Kleb.) and mycorrhiza (*Glomus mosseae*) on root colonization, growth and nutrient uptake in tomato and eggplant seedlings. Scientia Horticulturae, **94(1-2)**: 145-156.

Kasiamdari, R. S., S. E. Smith, F. A. Smith and E. S. Scott. 2002. Influence of the mycorrhizal fungus, *Glomus coronatum* and soil phosphorus on infection and disease caused by binucleate *Rhizoctonia* and *Rhizoctonia solani* on mung bean (*Vigna radiata*). *Plant Soil*. **238**: 235-244.

Khalil, S., T. E. Loynachan and H. S. McNabb. 1992. Colonization of soybean by mycorrhizal fungi and spore population in Iowa soils. *Agron. J.* **84**: 832-836.

Khanam, D., A. R. M. Solaiman, M. A. U. Mridha and A. J. M. S. Karim. 2003. Arbuscular mycorrhizal fungi association with some agricultural crops grown in four agro-ecological zones of Bangladesh. *Bangladesh J. Soil Sci.* **27-28**: 1-12.

Khanam, D., A. R. M. Solaiman and M. A. U. Mridha. 2004. Biodiversity of arbuscular mycorrhizal fungi in agricultural crops grown under different agro ecological zones of Bangladesh. *Bull. Inst. Trop. Agr., Kyushu Univ.* **27**: 25-33.

McAllister, C. B., J. M. Garcia-Garrido, I. Garcia-Romera, A. Godeas and J. A. Ocampo. 1997. Interaction between *Alternaria alternata* or *Fusarium equiseti* and *Glomus mosseae* and its effects on plant growth. *Plant Soil.* **24(3)**: 301-305.

Mercy, M. A., G. Shivashankar and D. J. Bagyaraj. 1990. Mycorrhizal colonization in cowpea is host dependent and heritable. *Plant Soil.* **121**: 292-294.

Mridha, M. A. U. and H. L. Xu. 2001. Nature Farming with vesicular arbuscular mycorrhizae in Bangladesh. *J. Crop Prod.* **3**: 303-312.

O'Keefe, D. M. and D. M. Sylvia. 1991. Mechanisms of the vesicular arbuscular mycorrhizal plant growth response. *In:* Handbook of Applied Mycology. D. K. Arora (ed.). Marcel Dekker, New York, pp. 35-54.

Plenchette, C., J. A. Fortin and V. Furlan. 1983. Growth responses of several plant species to mycorrhizae in a soil of moderate P fertility. I. Mycorrhizal dependency under field conditions. *Plant Soil.* **70**: 199-209.

Page, A. L., R. H. Miller and D. R. Keeney. 1982. *Methods of Soil Analysis*. Part 2. 2nd Ed. Amer. Soc. Agron., Inc., Medison, Wisconsin, USA.

Read, D. J., H. K. Koucheki and J. Hodgaon. 1976. Vesicular arbuscular mycorrhiza in natural vegetation systems. *New Phytol.* **77**: 641-653.

Singh, A., J. Sharma, K. H. Rexer and A. Varma. 2000. Plant productivity determinants beyond minerals, water and light: *Piriformospora indica* − A revolutionary plant growth promoting fungus. *Curr. Sci.* **79**: 1548-1554.

Smith, S. E. and D. J. Read. 1997. Mycorrhizal symbiosis. Academic Press, London.

St-Arnaud, M. and A. Elsen. 2005. Interaction of arbuscular mycorrhizal fungi with soil-borne pathogens and non-pathogenic rhizosphere micro-organisms. *In*: Declerck, S., D. G. Strullu and J. A. Fortin (eds). *In vitro culture of mycorrhizas*. Springer, Heidelberg, pp. 217-223.

St-Arnaud, M. and V. Vujanovic. 2007. Effect of the arbuscular mycorrhizal symbiosis on plant diseases and pests. *In*: Hamel, C. and C. Plenchette (eds). *Mycorrhizae in crop production: applying knowledge*. Haworth, Binghampton, N.Y., USA, pp. 67-122.

Xavier, L. J. C. and S. M. Boyetchko. 2014. Arbuscular mycorrhizal fungi in plant disease control. *In*: Arora, D. K. (ed). *Fungal biotechnology in agricultural, food, and environmental applications*. Dekker, New York, pp. 183-194.

UTILIZATION OF SPECIALIZED AGRICULTURAL CREDIT ON ONION AND GARLIC CULTIVATION IN SELECTED AREAS OF BANGLADESH

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Abstract

Specialized Agricultural Credit (SAC) policy implemented by the Bangladesh Bank played a significant role to increase agricultural production specially spices. But documentation in this regard is scarce in Bangladesh. Therefore, this study captured the impacts of specialized credit on onion and garlic cultivation at Faridpur and Natore district respectively. The survey was conducted on two hundred farmers of which fifty were credit recipient farmers and fifty were non-recipient farmers of each district. Credit recipient farmers received on an average Tk. 26,255 for spices cultivation. Average cost to complete the process from receiving to repaying credit was Tk. 515. Farmers in the study areas utilized their maximum part of credit for spices cultivation (96.2%) followed by other crop cultivation (2.15%), family expenditure (1.4%) and business (0.25%). Due to getting credit facility farmers cultivated 16 decimals more land compared to previous years for spices, 42% of the farmers increased number of spices crop for cultivation, and farmers also increased amount of input use with better quality. For these, credit recipient farmers harvested spices with higher yield which finally helped in getting higher farm income. Credit recipient farmers received 7% higher net return from onion and 16% higher net return from garlic cultivation. Highest percentage of farmers (82%) mentioned that lack of information about spices credit was the main reason behind not receiving credit facility by large number of farmers. Specialized credit facility for farmers need to be widened through spreading information of spices credit facility among the farmers and increasing amount of credit.Therefore, domestic production of spices will increase and imports of spices from abroad will decrease.

Keywords: Specialized agricultural credit, onion, garlic, impact, utilization pattern and spices production.

1. Introduction

Agricultural credit is considered as one of the strategic resources for increasing the crop production consequently raises the living standard of our rural poor farming community. When farmers faced capital constraints the amounts and combinations of inputs used may deviate from optimal levels that can hamper the optimum production. Therefore, the contribution of credit brings input levels

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closer to the optimal levels and increases yield and output (Feder *et al.*, 1990).Timely and easy access to credit enables farmers (including marginal farmers) to purchase the required inputs and machinery for carrying out farm operations and increase production (Abedullah, 2009; Saboor *et al.,* 2009).

Spices have a great popularity in Bangladesh. The major spices grown and consumed in Bangladesh are onion, garlic, chilli, ginger, coriander, turmeric, black cumin and fenugreek. In Bangladesh, the total cultivated land under spices cultivation is 3.25 lakh hectares and production is 17.56 lakh tons (BBS, 2012). This production is not available to meet the demands of Bangladeshi people. According to the Department of Agriculture Extension (DAE), Bangladesh imports about 50 % of its total consumption of spices and annualy about Tk. 25 billion is expensed for import payment. Among the spices, production, consumption and import of onion and garlic are higher. Area of onion and garlic in Bangladesh are 1.36 lakh and 0.44 lakh hectares and production are 11.59 lakh and 2.34 lakh tons respectively which are comparatively more than other spices (BBS, 2012).

Realizing this situation, Bangladesh government has taken initiative to reduce the import of spices by increasing domestic production. The government decided to give subsidy to the banks at 6.0% of the amount of their special argil-credit disbursement to enable them to get an aggregate of 10% as rate of interest by disbursing such credit to the farmers. The credit is being given to discourage import of the items and thus reduce the amount of their import payment. In this perspective, Bangladesh Bank disbursed credit for SAC (import alternative crops such as pulse, oilseed, spices and maize) but in a small amount. In fiscal year 2013, Bangladesh Bank has disbursed Tk. 146.67 billion for agricultural credit in which only Tk. 0.75 billion was for SAC which was 0.51% of total agricultural credit (BB, 2013). The government re-fixed 4.0 % rate of interest in the previous fiscal (2011-12), in place of the earlier rate of 2.0 %, on specialized agricultural credit, to be disbursed for cultivation of pulses, oil seeds, spices and maize.
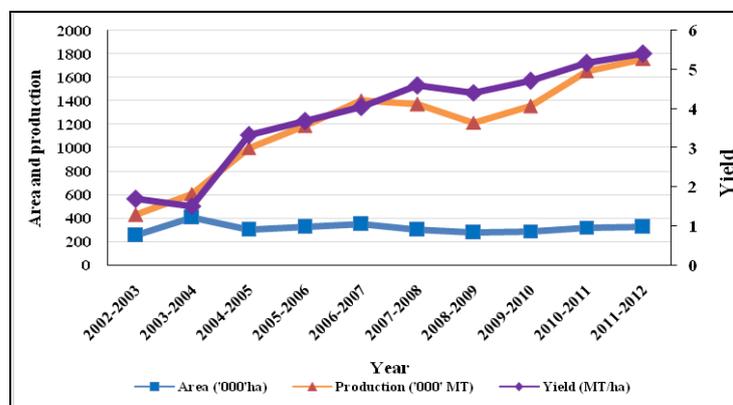
Fig. 1. Area, production and yield of spices in Bangladesh, 2002-03 to 2011-12.
Source: Various issues of BBS.
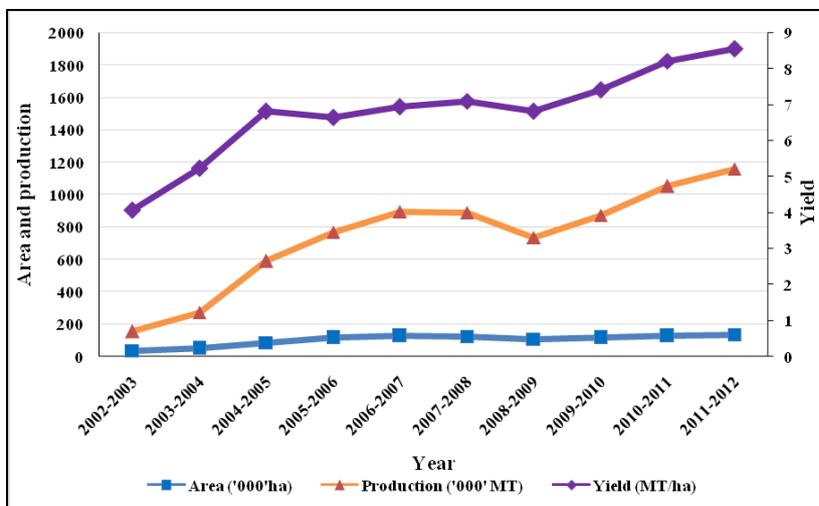
Fig. 2. Area, production and yield of onion in Bangladesh, 2002-03 to 2011-12.
Source: Various issues of BBS
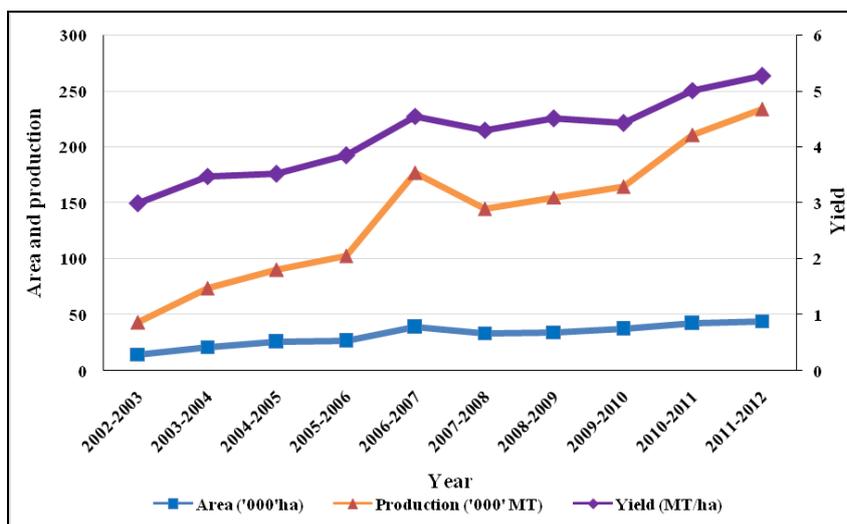
Fig. 3. Area, production and yield of garlic in Bangladesh, 2002-03 to 2011-12.
Source: Various issues of BBS.

Owing to taking government initiative (special credit programme on spices cultivation), farmers are gradually becoming more and more interested in cultivating spices, availing the credit facility on easy terms and thus, the area and production of spices are increasing year after year (Fig. 1). Area and production of onion and garlic are also increasing year after year (Figs. 2 & 3).

For further improvement of the credit policy on spices production it is necessary to evaluate the efficiency of credit recipient farmers and productivity of spices.

Therefore, the present study was undertaken to evaluate the performance of agricultural credit policy for spices (onion and garlic) production with the following objectives.

Objectives

The objectives of this study were as follows.

i. To explore the utilization pattern of specialized credit for spices cultivation;

ii. To measure the impacts of specialized agricultural credit on spices cultivation;

iii. To find out the limitations of access to specialized agricultural credit; and

iv. To suggest policy options for the improvement of credit policy.

2. Methodology

2.1 Description of the study areas

Faridpur and Natore districts were purposively selected according to the high intensity of onion and garlic production (BBS, 2012). Nagorkanda upazila from Faridpur and Gurudaspur upazila from Natore district were selected according to the availability of specialized credit users.

2.2 Sampling technique

A multi-stages sampling procedure was followed to collect sample farmers for this study. Two spices crops, namely onion and garlic were purposively selected for this study. Fifty credit recipients in spices production was selected from each upazila. An equal number of credit non-recipients (50) were also selected from each district for the sake of comparison. Thus, the total number of respondents was 200.

2.3 Period of the study

The study was mainly based on primary data collection through face to face interview which was conducted through field survey during the month of February to March 2014.

2.4 Analytical techniques

The collected data were edited and managed to fit with proposed analytical technique of the study. Descriptive statistics such as averages and percentages were used in this study. Profitability of onion and garlic was analyzed to compare the return received by the credit recipient and non-recipient farmers. To measure the significant difference between recipient and non-recipient farmers Z- test was used.

Measurement of cost and return from crop cultivation

Equations for cost analysis were as follows:

$$TC_{ij} = TVC_{ij} + TFC_{ij}$$

$$TV_{ij} = VC_{ij} + 10C_{ij}$$

$$VC_{ij} = \sum_{l=1}^{n} X_{ij} P_{ij}$$

$$IOC_{ij} = (AI_{ij} \times r \times t)$$

Where, TC_{ij} = Total cost (Tk/ha)

TVC_{ij} = Total variable cost (Tk/ha)

TFC_{ij} = Total fixed cost (Tk/ha)

VC_{ij} = Variable cost (Tk/ha)

IOC_{ij} = Interest of operating capital (Tk/ha)

X_{ij} = Quantity of inputs

P_{ij} = Price of inputs

AI = (Total investment)/2

r = Rate of interest

t = Length of crop period in months

j = Number of crops (Garlic and Onion)

i = Number of farmers (1.2.3……..n)

Equation for profitability analysis

Gross Return = $GR_{ij} - Y_{ij} P_{ij}$

Net return = $GR_{ij} - TC_{ij}$

Gross margin = $GR_{ij} - VC_{ij}$

Where,

GR_{ij} = Gross return (Tk/ha)

P_{ij} = Price (Tk/ha) of *j* th crops received by *i*th farmer

Y_{ij} = Quantity (kg/ha) produced from crops

3. Results and Discussion

3.1. Receiving and Utilization Pattern of Spices Credit

Amount of credit received by the recipient farmers: Highest percentage of farmers received credit within the range of Tk. 6,000 to Tk. 20,999 and their average received money was Tk. 14,631 (Table 1). The average amount of credit was Tk. 26,255. The highest percentage of Faridpur farmers received on an average Tk. 14,879 whereas it was Tk. 28,475 for Natore farmers.

Table 1. Amount of credit taken by the farmers

Range of credit received (Tk.)	Faridpur		Natore		Average	
	Amount (Tk.)	Recipient (%)	Amount (Tk.)	Recipient (%)	Amount (Tk.)	Recipient (%)
6000-20999	14879	58	14077	26	14631	42
21000-35999	28214	28	28615	52	28475	40
36000-50999	42200	10	43750	16	43154	13
51000-65999	60000	4	60500	4	60250	4
66000-80999	-	-	70000	2	70000	1
Grand Total	23150	100	29360	100	26255	100

Types of collateral ensured by the recipient farmers: It is revealed that highest percentage of farmers provided the document or record of their own land as collateral for getting spices credit (Table 2). As farmers of Faridpur district applied for credit personally, 98% of them provided own land record as collateral for credit. Farmers of Natore managed spices credit through forming a groupso, sometimes they didn't need any collateral for getting credit.

Table-2: Types of collateral keeping in bank by the farmer

Types of Collateral	Recipient (%)		Total Recipient (%)
	Faridpur	Natore	
1. Own land record	98	90	94
2. Rented in land record	-	4	2
3. No collateral was needed	2	6	4
Grand Total	100	100	100

Cost of credit: Credit recipient farmers in the study areas also paid some extra money to complete the process fromreceiving to repaying credit. Highest cost of credit was Tk. 614 in Natore district and average cost was Tk. 515 (Table 3). Highest percentage of cost (30%) for credit was spent in deed purpose, 22% of cost for collateral preparation, and also spent 16% for transportation. Another cost of credit was for revenue stamp (10%), form charge (9%) and others purpose (13%).

Table 3. Cost associated with the entire process of getting to repayment credit

Cost items	Faridpur		Natore		All farmers	
	Amount (Tk.)	%	Amount (Tk.)	%	Amount (Tk.)	%
1. Deed purpose	123	28	174	28	153	30
2. Collateral preparation	89	21	162	26	111	22
3. Transportation cost	74	17	95	15	84	16
4. Revenue stamp	50	12	50	8	50	10
5. Form charge	26	6	70	11	48	9
6. Others	70	16	63	10	69	13
Total	432	100	614	100	515	100

Farmer's acceptance of extra cost for getting credit: Every credit service has some amount of necessary charges which is given by the credit receiver. The farmers of the study areas mentioned that they also spent some money as service charge for receiving the credit (Table 4). In question of acceptability of the service charges, 55% of recipient farmers mentioned that the service charge was at acceptable range. But requiring extra expenses was less acceptable mentioned by 22% of recipient and unacceptable mentioned by 23% of farmers.

Table 4. Acceptability of extra expense to get credit

Acceptability	Recipient (%)		Total
	Faridpur	Natore	Recipient (%)
Acceptable	50	60	55
Less acceptable	14	30	22
Unacceptable	36	10	23
Grand Total	100	100	100

Credit utilization pattern of the farmers: Farmers utilized their capital in different purposes. It is revealed that farmers in the study areas utilized their maximum part of credit for spices cultivation (96.2%) followed by other crop cultivation (2.15%), a family expenditure (1.4%) and business (0.25%). Both the farmers of Faridpur and Natore districts also utilized their credit in a same pattern (Table 5). To make the appropriate use of credit Rahman *et al.* (2010) suggested that agricultural credit should be advanced at the beginning of crops farming, livestock and poultry raring, fish farming etc. and repayment should be made after getting returns from the investment. In this study, farmers got credit at the beginning of the crops cultivation and they had utilized their capital properly.

Table 5. Spices credit utilization pattern (%)

District	Spices cultivation	Others crop cultivation	Family expenditure	Business	Total
Faridpur	95.2	3.6	1.2	-	100
Natore	97.2	0.7	1.6	0.5	100
All farmers	96.2	2.15	1.4	0.25	100

3.2 Overall Impacts of Spices Credit

3.2.1 Change in sources of working capital

Share of capital source used by the recipient farmers

Farmers of Bangladesh suffer from lack of capital for crop cultivation. Providing credit facility helps them significantly to overcome this problem and invest the money for crop cultivation efficiently and timely. When the farmers suffered from lack of capital they managed the capital from various source. The farmers of the study area also did the same before getting credit facility from the government. The study explored that before getting credit facility the spices farmers managed 58.75% of their capital from the income of other crop

cultivation, 17.7% from off-farm income, and 14.55% from saving of agriculture (Table 6). Farmers managed only 2.8% of capital from borrowed money and 0.4% from NGOs. This indicated that, income and savings from agriculture of a farmer contributed largely to manage capital for the next crop cultivation when a farmer couldn't get any kind of credit.

Farmer's share of capital source changed largely after getting credit for spices cultivation. It is revealed that farmers managed 49.85% of required capital from the credit, and 36.8% of capital from other crop cultivation income. Their percentage share of borrowed money was also changed and reduced from 2.8% to 0.35% (Table 6).

Table 6. Share of capital sources used in spices cultivation of recipient farmers

Sources of capital (%)	Before getting credit			After getting credit		
	Faridpur	Natore	Total	Faridpur	Natore	Total
1. Spices credit	-	-	-	48.9	50.8	49.85
2. Income from other crops cultivation	50.7	66.8	58.75	34.4	39.2	36.8
3. Income from off-farm activities	15	20.4	17.7	7.4	5.4	6.4
4. Savings from agriculture	20.1	9	14.55	4.8	3.8	4.3
5. Savings from off-farm activities	9.8	1.8	5.8	3.6	0.8	2.2
6. Borrowed money from others	4.4	1.2	2.8	0.7	-	0.35
7. Other agricultural credit	-	-	-	0.2	-	0.1
8. NGO credit	-	0.8	0.4	-	-	-
Total	100	100	100	100	100	100

Share of capital source used by the non-recipient farmers: The source of capital managed by the non-recipient farmers revealed that 51.15% of the capital was sourced from other crop cultivation income and 16.15% of capital was from off-farm activities. Non-recipient farmers borrowed money to cover 4.35% of their required capital and take credit from NGOs to cover 2.5% of the capital. Some farmers also bought required inputs with credit which shared 3.95% of the required capital (Table 7).

Table 7. Share of capital source used in spices cultivation of non-recipient farmers

Sources of capital (%)	Non-recipient		Total Non-recipient
	Faridpur	Natore	
1. Income from other crops cultivation	44.5	57.8	51.15
2. Income from off-farm activities	16.8	15.5	16.15
3. Savings from agriculture	18.7	13.7	16.2
4. Savings from off-farm activities	9.6	2	5.8
5. Borrowed money	4	4.7	4.35
6. Buy input in credit	2.2	5.7	3.95
7. NGO credit	3.7	0.6	2.15
8. Agricultural credit	0.5	0	0.25
Total	100	100	100

3.2.2 Proper utilization of spices income

Distribution of income from spices cultivation: Spices farmers spent large share of their spices cultivation income for other crop cultivation (29%) and family purpose (29%). The major share of the rest of the income was allocated for the spices crop cultivation (28%). Credit recipient farmers used 12% of their income to repay the credit. Both the farmers of Faridpur and Natore had similar expenditure pattern of spices cultivation income (Table 8).

Table 8. Percentdistribution of income from spices cultivation

Income distribution	Recipient		Total Recipient	Non-recipient		Total Non-recipient	All farmers
	Faridpur	Natore		Faridpur	Natore		
a. Spices cultivation	22	36	29	23	32	27	28
b. To repay credit	15	9	12	6	3	4	8
c. Other crops cultivation	33	31	32	32	21	27	29
d. Family expenditure	26	21	24	33	34	34	29
e. Other expenditure	4	3	3	6	10	8	6
Total	100	100	100	100	100	100	100

3.2.3 Increase in input use and spices productivity

A significant change was observed in the farm economy especially due to having credit facility for spices cultivation. The impact of getting credit was observed through counting change in the farming and economy. Highest percentage of farmers (85%) mentioned that the yield of spices increased due to getting credit facility. After getting credit facility, 23% farmers increased amount of fertilizer use, 18% of farmers' increased labour use, and 17% of farmers increased amount of quality seed use on their land (Table 9). Due to increasing spices yield and getting higher return, 72% of farmers mentioned that their family income also increased.

Table 9. Changes apparent in input use and productivity of spices after getting credit

Changes	Recipient		Total Recipient
	Faridpur	Natore	
1. Increased use of input (%)			
a. Fertilizer	24	22	23
b. Labour	26	10	18
c. Quality seed	24	10	17
d. Irrigation	6	10	8
e. Others	-	6	3
2. Increased yield (%)	88	82	85
3. Increased family income (%)	60	82	72

3.2.4 Increase in spices area and production

Credit recipient farmers have increased on an average 16 decimal of land under spices cultivation. 42% of farmers mentioned that due to getting credit they increased number of spices crops for cultivation. Highest percentage of farmers (32%) introduced garlic in to current cropping pattern, 14% of farmers cultivated onion (Table 10). A small percentage of farmers started to cultivate black cumin, coriander, and turmeric. Most farmers of Faridpurand Natorecultivated onion and garlic respectively due to getting credit facility. This indicated that the objective of providing special credit facility to the farmers was fulfilled to a great extent. Farmers were encouraged to cultivate spices on their land.

Table 10. Farmers increased spices cultivation area and production after getting credit facility

Particulars	Recipient		Total Recipient
	Faridpur	Natore	
1. Increased land (decimal)	13.67	18.29	15.98
2. Increased number of spices (%)	38	46	42
Name of spices (%)			
Garlic		32	16
Onion	28		14
Black cumin		4	2
Coriander	4		2
Coriander, Black cumin	2		1
Coriander, Black cumin, Fenugreek	2		1
Garlic, Black cumin	2		1
Onion, Coriander, Black cumin		2	1
Onion, Garlic		2	1
Onion, Black cumin		4	2
Turmeric		2	1
Total responses (%)	38	46	42

3.2.5 Increase in spices income

Returns and profitability of credit ingarlic cultivation

Profitability of garlic production: Due to using comparatively higher inputs in production, credit recipient farmers have got higher yield (7563kg/ha) of garlic than non-recipient farmers (6970 kg/ha) where have significant differences (Z= 3.02, p = 0.001). Gross return of credit recipient farmers was Tk. 3, 24,798 and non-recipient farmers was Tk. 2, 9,697 (Table 11).

Table 11. Per hectare profitability of garlic cultivation for recipient and non-recipient farmers

Particulars	Recipient	Non-recipient	Z-test value	P-value	Results
A. Yield (Kg/ha)	7563	6970	3.02	0.001	Difference
B. Price (Tk/kg)	42.95	42.78	0.20	2.501	No difference
C. Gross return (Tk.)	324798	296976	1.98	0.040	Difference
D. Total variable cost (Tk.)	192469	182240	3.27	0.001	Difference
E. Gross margin (C-D)	132328	114736	1.59	0.180	No difference
F. Fixed Cost (Tk.)	23729	23153	1.01	0.389	No difference
G. Total cost (D+F)	216198	205393	3.33	0.001	Difference
H. Net return (C-G)	108600	91583	2.20	0.023	Difference
I.BCR on cash cost (C÷D)	1.69	1.63	0.095	8.052	No difference
J. BCR on full cost (C÷G)	1.513	1.459	0.79	1.032	No difference
K. Production Cost (Tk/kg)	25.70	26.31	-0.72	1.015	No difference
L. Profit per kg	17.25	16.47	1.05	0.356	No difference
M. Returns to credit	13.59				

There was a significant difference of gross returns between the two groups ($Z=1.98$, $p<0.05$). Credit recipient farmers received on an average Tk. 1,08,600 as net return which was higher compared to non-recipient farmers (Tk.91,583) and there is also have a significant difference ($Z=2.20$, $p<0.05$).This higher return was due to higher yield of the produce. BCR on both full cost and cash cost basis was higher in recipient farmers but there was no significant difference between the two groups of farmers. There was no significant difference in profit per kg between the recipient farmers (17.27 Tk.) and non-recipient farmers (16.47 Tk.). Credit recipient farmers received Tk. 13.59 as return from the utilization of one taka credit.

Returns and Profitability of Credit in Onion Cultivation

Profitability of onion cultivation: Due to using comparatively higher inputs in production, credit recipient farmers had got higher yield (14136 kg/ha) than non-recipient farmers (13,232 kg/ha) showing significant differences ($Z= 2.96$, $p = 0.010$) (Table-12). Gross return of credit recipient farmers was Tk. 5,99,184 and non-recipient farmers was Tk. 5,64,290 (Table-12). There was a significant difference of gross returns between the two groups ($Z=2.03$, $p<0.05$). Credit recipient farmers received on an average Tk. 4,07,910 as net return which was higher compared to non-recipient farmers (Tk. 3,79,026) and there is also have a significant difference ($Z=2.49$, $p<0.05$).This higher return was due to higher yield and higher price of the onion. BCR on both full cost and cash cost basiswas higher in recipient farmers but there was no significant difference between the two groups of farmers. There was no significant difference in profit per kg between the recipient farmers (Tk. 30.61) and non-recipient

farmers (Tk. 30.22). Credit recipient farmers received Tk. 32.08 as return from the utilization of one taka credit.

Table 12. Per hectare profitability of onion cultivation for recipient and non-recipient farmers

Particulars	Recipient	Non-recipient	Z-test value	P-value	Results
A. Yield (Kg/ha)	14136	13232	2.96	0.010	Difference
B. Price (Tk/kg)	42.90	42.70	0.09	8.052	No difference
C. Gross return (Tk.)	599184	564290	2.03	0.039	Difference
D. Total variable cost (Tk.)	173185	165789	2.45	0.023	Difference
E. Gross margin (C-D)	426000	398501	2.37	0.026	Difference
F. Fixed Cost (Tk.)	18089	19475	-2.50	0.020	Difference
G. Total cost (D+F)	191274	185264	2.01	0.042	Difference
H. Net return (C-G)	407910	379026	2.49	0.020	Difference
I. BCR on cash cost(C÷D)	3.46	3.40	1.45	1.002	No difference
J.. BCR on full cost(C÷G)	3.16	3.06	1.35	1.002	No difference
K.Production Cost (Tk/kg)	12.29	12.48	-0.57	5.062	No difference
L.Profit per kg	30.61	30.22	0.05	8.630	No difference
M. Returns to credit	32.08				

3.3 Limitations of access to specialized agricultural credit and farmers' perceptions on its improvement

Limitations of access to credit: Non-recipient farmers mentioned various reasons of not getting credit from the bank (Table 13). Highest percentage of farmers (87%) mentioned they did not know about the credit giving facility as a main reason of not getting credit. 30% of farmers mentioned that they couldn't enlist their name in the credit list. 22% of farmers mentioned that they don't have communication with the UAO for this they didn't get credit. The other reasons mentioned by some farmers were they didn't have any need to take credit (8%), they didn't receive credit due to its complex system (6%), didn't have ability to keep collateral (3%), couldn't manage to include their name in the group (3%), didn't want to pay interest (2%).

Farmers' perceptions on credit policy improvement: Providing credit facility to the farmers had very significant positive impact on the farm economy. There is no doubt that capital support is the most effective support for the farmers to improve their main source of income from agriculture. But still there were some gaps and problems in the widening of credit facility among the farmers. Farmers were suggested some policy reform options to remove the gap and problems in credit facility which need to be counted for its further improvement.

Table 13. Reasons of not getting spices credit

Reasons	Non-recipient (%)		Total
	Faridpur	Natore	Non-recipient
1. Lack of knowledge about spices credit	88	86	87
2. Couldn't enlist name to the credit list	22	38	30
3. Don't have Communication with UAO	26	18	22
4. No need of taking credit	8	8	8
5. Complexity in taking credit	6	6	6
6. Have no ability to keep collateral in bank	6	0	3
7. Couldn't include in a group	0	6	3
8. Didn't want to pay interest	2	2	2

Table 14. Farmers' perceptions on specialized agricultural credit policy improvement

Options	Recipient (%)		Total Recipient
	Faridpur	Natore	
1. Widespread broadcast of specialized bank credit by bank	52	22	37
2. Bank should need work properly	20	10	15
3. Should increase time of repayment	22	8	15
4. Increase the amount of credit (according to land size or production cost)	-	28	14
5. Should make the system easy for giving credit	2	20	11
6. Should increase monitoring of bank credit by BB	12	8	10
7. Increase the number of recipient	8	10	9
8. Have to reduce reference facility of UP chairman	8	8	8
9. Broadcasting bank credit facility by government	14	2	8
10. Should make yearly repayment system	12	2	7
11. Introducing collateral free credit	-	14	7
12. SAAO should inform farmer directly about credit	-	12	6
13. UAO should work actively to disseminate information	8	-	4
14. Need to reduce cost of Deed Promissory Note (DPN)	-	6	3
15. Repayment yearly only interest not principal amount	-	4	2
16. Introducing system of one time DPN cost	-	2	1

Highest percentage of farmers (37%) suggested publicising the special credit facility information among the farmers (Table 14). It is identified in this study that the main reason of not getting credit by the non-recipient farmers was lack of

information of credit facility. The study reveals that, 15% farmer suggested improving credit giving facility of the bank, 15% farmers suggested to increase repayment time and 14% farmers suggested increasing amount of credit according the farm size of a farmer. Farmers also suggested to many other option for the improvement of the credit facility given by the government i.e. need to make the system easy for the farmers, need to strengthen central bank monitoring system to evaluate the outcome of providing credit facility to the farmers, the bank authority should reduce referencing facility from the UP chairman. The other farmers suggested options are presented in the (Table 14).

The non-recipient farmers also suggested some options to increase number of recipient of this specialized credit facility. Highest percentage of farmers (43%) suggested that the credit giving system need to be more easy and flexible (Table-15). Another 43% farmers suggested that the authority should introduce interest free credit for the poor farmers and 14% farmers suggested to widen the information of special credit facility among the farmers. This indicated that farmers need more easy system of getting credit, lower or zero interest rate credit and finally they need to have that information on their hand so that they can take decision to receive any credit when they need.

Table 15. Credit non-recipient farmers' demand in improving the credit policy

Options	Faridpur	Natore	Total Non-recipient
Should make easy the system of giving credit	-	75	43
Introducing Interest free credit system	100	-	43
Popularization of specialized credit by bank	-	25	14

4. Conclusions and Recommendations

Specialized credit facility for the spices farmers has created a wide range of impacts among the farmers. Due to getting credit facility farmers increased their cultivable land for spices cultivation, increased number of spices crop for cultivation, increased input use in quantity and quality. For these, the yield of cultivated spices increased in the farmer's field which finally increased the income of farmers. Net return of credit recipient farmers for both crops was higher. Most of farmers mentioned lack of information about spices credit as a reason behind not getting credit. According to the farmers' perceptions credit facility for farmers can be widen through spreading information of spices credit facility among the farmers and increase amount of credit.

Since this policy has positive impacts on the increasing of area and production of spices, Bangladesh bank and government authorities should increase the total amount of credit under specialized credit scheme. To increase the number of farmers under this credit policy, government and banks should take initiatives to disseminate the information about special credit facility for spices cultivation among the farmers. Bank should increase the amount of credit according to the

land size or production cost. Credit disbursement system should make easy and transparent. Bank should disburse collateral free credit and repayment system should be yearly. If these initiatives are undertaken each farmer would get opportunities of receiving more amounts and the number of beneficiaries will also be increased. Therefore, domestic production of spices will increase and imports of spices from abroad will decrease which is the ultimate goal of this specialized credit policy.

References

Abedullah. N. M., M. Khalid and S. Kouser. 2009. The role of agricultural credit in the growth of livestock sector: a case study of Faisalabad Pakistan. *Vet. J.* **29**(2): 81-84.

BB. 2013. Annual Report FY 2013, Bangladesh Bank, Bangladesh.

BBS. 2012. Bangladesh Bureau of Statistics, Statistical Year Book of Bangladesh, Statistics Division, Ministry of planning, Government of People's Republic of Bangladesh, Dhaka.

Feder, G., L. Lau, J. Lin and X. Luo. 1990. "The Relationship between Credit and Productivity in Chinese Agriculture: A Microeconomic Model of Disequilibrium." *American Journal ofAgricultural Economics* **72**(5): 1151-1157.

Rahman M. W., J. Luo and E. Cheng. 2010. Policies and performances of agricultural/rural credit in Bangladesh: what is the influence on agricultural production? *African Journal of Agricultural Research*. **6**(31). Pp. 6440-6452.

Saboor A, Hussain M, Munir M (2009). Impact of micro credit in alleviating poverty: An Insight from rural Rawalpindi, Pakistan, *Pak. J. Life Soc. Sci.* **7**(1): 90-97.

COMBINED EFFECT OF SULPHUR AND BORON ON YIELD AND YIELD CONTRIBUTING CHARACTERS, NUTRIENT AND OIL CONTENT OF MUSTARD

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Abstract

This experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during 2014-2015 to know the combined effect of different levels of sulphur (S) and boron (B) on yield and yield contributing characters, nutrient and oil content of mustard and to find out the suitable combination of sulphur (S) and boron (B) for yield maximization of mustard. There were 16 treatment combinations comprising four levels each of S (S_0= 0, S_1=10, S_2= 20 and S_3= 30 kg S ha^{-1}) and B (B_0= 0, B_1= 1, B_2= 2 and B_3= 3 kg B ha^{-1}). It was replicated thrice in a randomized complete block design. Results showed that the combination of S and B (20 kg S ha^{-1} and 3 kg B ha^{-1}) contributed positively for better performance of yield contributing characters of mustard. The combination S_2B_3 (20 kg S ha^{-1} and 3 kg B ha^{-1}) produced the highest grain yield (2180 kg ha^{-1}) followed by S_3B_2 and S_3B_3 treatment combination. The highest protein and oil content of mustard were recorded from S_3B_3 (30 kg S ha^{-1} and 3 kg B ha^{-1}) treatment followed by S_2B_3 treatment combination. Therefore, the combination of S and B (20 kg S ha^{-1} and 3 kg B ha^{-1}) might be suitable dose for cultivation of mustard in tejgaon series soils under agro-ecological zone of 28 (Madhupur Tract) Bangladesh.

Keywords: Mustard, sulfur and boron, oil and nutrient content, yield.

Introduction

Mustard (*Brassica rapa*) is one of the important oilseed crops grown in Bangladesh, covers almost 60% of the total oil seed demand. The annual production of mustard is 3.34 lakh metric tons from the area of 3.52 lac hectares against the total oilseed production of 5.48 lakh tons (BBS, 2011). Local production of mustard oil meets nearly 25% oil requirement of Bangladesh. The average seed yield of mustard is very low in Bangladesh compared to other countries due to inheritance, environmental and poor fertilizer management. However, Bangladesh Agricultural Research Institute has developed high yielding mustard varieties viz., BARI Sharisha-8, BARI Sharisha-9 and BARI Sharisha-11. Hence, high yielding varieties with appropriate fertilizer management can be increased the productivity of mustard in Bangladesh. In

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general, mustard is considered as sulphur (S) loving crop and is highly susceptible to S deficiency and responds well to S fertilization (Haque, 2000). Sulphur is greatly influenced the synthesis of amino acids (cystine, cysteine and methionine), co-enzymes (biotin, coenzyme A, pyrophosphate, lipoic acid and thiamine) and some secondary metabolites (FRG, 2012). It also helps in chlorophyll formation and enhances the vegetative growth. Sulphur played a vital role for yield maximization and oil content of mustard. It also influenced the oil quality of mustard by increasing protein content and some fatty acids (Aulakh and Pasricha, 1997). Moreover, S contributes the uptake of nitrogen (N), phosphorous (P) and potassium (K). About 97% soils of Bangladesh are deficient in S due to use sulphur free fertilizer (Khan *et al.*, 2008). Boron deficiency is another problem for cultivation of oil seed crops. More than one million hectares of land showed B deficiency which are caused lower yield of oil seeds (Khan *et al.*, 2008; Islam *et al.*, 1999). Among micronutrients- boron has taken third place due to total B concentration in seed and stem of oilseed crops (Robinson, 1973). Boron helps the assimilation of N, P and K and rate of water adsorption and carbohydrate translocation in plant. It is extensively involved in the synthesis of protein and oil (Malewar *et al.*, 2001). Thus, B deficiency affects the equilibrium state of N, P and K. Boron application markedly increases pod number and seed set. Seed yield of mustard increased from 16 to 69% due to B application (Islam and Sarker, 1993).

Several researches have been carried out on the effect of N, P and K fertilizers on mustard and other oil seed crops. But a few research works have been done to know the effect of S and B on production of oil seed crops in Bangladesh. The above discussion suggests that the limiting nutrients need to be identified in order to increase the production and nutritional value of mustard. Keeping the above mentioned facts, the study was undertaken to compare the yield and yield contributing characters and quality performance of mustard by using different doses of S and B and to find out the optimum dose of S and B for achieving its maximum yield potential at Tejgaon series soil of Modhapur Tract.

Materials and Method

The experiment was conducted at the Central Farm of the Sher-e-Bangla Agricultural University, Dhaka during November 2014 to February 2015. Experimental site- Sher-e-Bangla Agricultural University, Dhaka (90.2^O N latitude and 23.5^0E altitude) lies at an elevation of 8.2 m above the sea level. The terrace soils of Dhaka belongs to Tejgaon series under the agro ecological zone Madhupur Tract and texture is silty loam. There were 16 treatment combinations comprising four levels each of S ($S_0= 0$, $S_1=10$, $S_2= 20$ and $S_3= 30$ kg S ha^{-1}) and B ($B_0= 0$, $B_1= 1$, $B_2= 2$ and $B_3= 3$ kg B ha^{-1}). The treatments were S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and

S_3B_3. The blanket doses of 120 kg urea ha^{-1}, 145 kg TSP ha^{-1}, 45 kg MoP ha^{-1}and 5 kg Z_nSO_4 ha^{-1} were used. Soil samples (0-20 cm) before initiation of the experiment was analyzed for soil pH (Jackson, 1973), organic matter (Nelson and Sommers,1982), total N (Bremner and Mulvaney, 1982), exchangeable K (Pratt, 1965), available P (Olsen & Sommers, 1982), available S (Fox *et al*., 1964) and available B (Page *et al*., 1982). The results of the soil properties are shown in Table 1.

Table 1. Soil properties of the experimental field

Location	pH	OM (%)	K meq. 100 g^{-1}	Total N (%)	P	S	B
					μg g^{-1}		
SAU, Dhaka	5.8	0.78	0.10	0.038	17	20	0.16
Critical level (FRG, 2012)	-	-	0.12	0.12	10	10	0.2

The land was prepared thoroughly by country plough followed by laddering. The treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. The unit plots size was 2 m x 2.5 m. Gypsum and boric acid were used as the sources of S and B, respectively. The whole amount of triple super phosphate (TSP), muriate of potash (MoP), zinc sulphate and 50% of urea were incorporated into soil at the time of final land preparation. Gypsum and boric acid were applied as per treatment. The remaining urea was applied at 25 days after seed germination. Seeds of mustard (BARI Sharisha-9) were sown on the 7 November, 2014. The seed rate was 6 kg ha^{-1}. Weeding was done at 20 and 35 days after sowing. Insecticide Sumithion 50EC at the rate of 2 ml L^{-1} water was sprayed for controlling pod borer. Crop was harvested after maturity. Data on yield contributing characters were collected from randomly selected five plants in each plot excluding border plants. Data on yields (kg ha^{-1}) were recorded from the whole plot technique. Harvest index (%) was calculated. Ground stover and seed samples were digested with di-acid mixture (HNO_3-$HClO_4$) (5: 1) as described by Piper (1966) for the determination- concentration of N (Micro-Kjeldahl method), P (spectrophotometer method), K (atomic absorption spectrophotometer method), S (turbidity method using $BaCl_2$ by spectrophotometer) and B (spectrophotometer following azomethine-H method). Oil content of seed was determined by Soxhlet method and expressed in percentage (%). Nitrogen content was determined by Kjeldahl method. Protein content was measured by estimating the N content and then multiplying the N value by 6.25. Collected data were analyzed statistically with MSTATC programme and the mean difference was adjusted by Duncan's Multiple Range Test (Gomez and Gomez, 1984) at 5% level of probability.

Results and Discussion

Yields and yield contributing characters of mustard

Combination of sulphur and boron were exhibited significant effect on yields and yield contributing characters of mustard (Table 2). The highest plant height (166.3 cm) was recorded from the treatment of S_2B_3 (20 kg S ha^{-1} and 3 kg B ha^{-1}), which was significantly different over others treatment combinations but statistically identical to S_3B_3 treatment. The lowest height (125 cm) was found in S_0B_1 (0 kg S ha^{-1} and 1 kg B ha^{-1}) treatment. Result is in agreement with the findings of some researchers such as Mohiuddin (2007) reported that the maximum height of mustard plants (93.0 cm) under combined application of N (80) + S (24) kg ha^{-1}. The shortest plant (72.0 cm) was noted under no application of N and S. Islam (2003) also observed that the highest plant height (74.23 cm) was recorded from the treatment of 30 kg S + 20 kg Mg ha^{-1} and the lowest (56.67 cm) was from control treatment. Number of branches per plant was ranged from 4.08-5.25. The highest number of brunches per plant (5.25) was recorded from the treatment S_2B_3 whish was significantly different over the other treatment but statistically identical to S_3B_1, S_3B_2, S_3B_3 and S_2B_2 and lowest (4.08) was in S_0B_0. In case of pod length and number of capsules per plant showed the similar trend of number of branches per plant (Table 2). These results are in agreement with the findings of Mohiuddin (2007) and Haq (2012).

The maximum number of seeds per capsule (15.9) was recorded from the combination of S_2B_2 (20 kg S ha^{-1} and 2 kg B ha^{-1}) which showed significantly variation with others treatment combinations but it was statistically similar to S_2B_3 (20 kg S ha^{-1} and 3 kg B ha^{-1}) treatment. Lowest number of seeds per capsule (9.29) was found in control plot. The above result is supported by the observation of Singh *et al.* (2007); Mohiuddin, (2007). Islam (2003) reported the highest number seeds pod^{-1} (17.6) was found in the treatment of 30 kg S + 20 kg Mg ha^{-1} and lowest (12.42) was in control treatment.

The 1000 seed weight due to different treatment combination varied from 8.0-15.4 g. The highest 1000 seed weight was obtained from the treatment S_2B_3 followed by S_3B_2 and S_3B_3 treatment. The lowest 1000 seed weight was recorded from S_0B_0 treatment. Karthikeyan and Shukla (2011) obtained the highest dry matter of mustard seed from $S_{60}B_2$ treatment. Mohiuddin (2007) observed the highest weight of 1000 seed (2.86 g) from the treatment combination N_2S_3 comprising of 80 kg N ha^{-1} + 24 kg S ha^{-1} and the lowest (1.60g) was recorded in N_0S_0 treatment. Islam (2003) reported the highest 1000-seed weight (2.75 g) from the treatment of 30kg S + 20kg Mg ha^{-1}.

The grain yield of mustard was varied from 1806-2180 kg ha^{-1} due to different treatment combinations. The highest grain yield was recorded from the treatment combination S_2B_3 (20 kg S ha^{-1} and 3 kg B ha^{-1}) which was showed significantly different among the treatments but statistically identical with S_3B_2, S_3B_0 and S_3B_3 treatments combination. The lowest yield was obtained from control (S_0B_0)

treatment (Table 2). Karthikeyan and Shukla (2011) reported that highest yield seed (20.6 g pot^{-1}) was obtained from the treatment $S_{60}B_2$ (60 g S kg^{-1} and 2 mg B kg^{-1}). Mohiuddin (2007) also found the highest yield (1738 kg ha^{-1}) from the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha and the lowest (850 kg ha^{-1}) from N_0S_0. Similar observation occurred by Islam (2003). The highest stover yield (2800 kg ha^{-1}) found in treatment of S 30 kg ha^{-1} and Boron 1 kg ha^{-1} which was significantly different over the other treatment combinations and lowest (2726 kg ha^{-1}) in S_0B_0 treatment. The result is in agreement with the findings of Mohiuddin (2007).

Harvesting index was positively influenced by different combinations of S and B. The combined dose of 20 kg ha^{-1} S and 3 kg ha^{-1} B contributed significantly to get highest (40.3%) harvest index of mustard and lowest harvest index (39%) was calculated from the treatment of S_0B_1 (0 kg S ha^{-1} and 1 kg B ha^{-1}) (Table 2).

Table 2. Combined effect of sulphur and boron on yield and yield contributing characters and harvest index (%) of mustard

Treatment	Plant height (cm)	No. of branches plant^{-1}	Pod length (cm)	No. of capsules plant^{-1}	No. of seeds capsule^{-1}	1000-seed wt. (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
S_0B_0	126.1^g	4.08^d	3.66^d	228^f	9.29^d	8.0^f	1806^h	2726^e	39.1^e
S_0B_1	125.0^g	4.29^c	3.79^c	230.2^e	9.34^d	9.2^e	1842^{fg}	2748^d	39^f
S_0B_2	131.3^f	4.42^{bc}	3.85^{bc}	230.8^e	9.57^d	10.7^{cd}	1879^f	2762^c	39.6^{cd}
S_0B_3	132.1^{ef}	4.61^b	3.89^b	234.3^c	10.43^{cd}	11.5^c	2048^c	2772^{bc}	40^b
S_1B_0	132.6^{ef}	4.46^{bc}	3.95^b	228.9^f	9.38^d	10.8^{cd}	1925^e	2791^b	39.9^b
S_1B_1	138.5^e	4.51^b	4.04^{ab}	230.5^e	10.82^{cd}	9.3^e	1992^d	2745^d	39.5^d
S_1B_2	141.3^d	4.49^{bc}	4.12^{ab}	232.6^d	11.48^c	10^d	1984^d	2760^{cd}	39.8^{bc}
S_1B_3	139.4^e	4.56^b	4.16^a	235.5^c	11.48^c	10.4^d	2037^{cd}	2777^{bc}	39.8^{bc}
S_2B_0	138.9^e	4.43^{bc}	4.08^{ab}	237.4^b	10.43^{cd}	10.9^{cd}	1939de	2781^b	40.1^{ab}
S_2B_1	145.1^{cd}	4.6^b	4.15^a	238^b	12.32^{bc}	11.7^c	1925^e	2769^c	39.4^{de}
S_2B_2	154.5^b	5.01^{ab}	4.2^a	238.4^b	15.9^a	13.3^c	2050^c	2763^c	39.9^b
S_2B_3	166.3^a	5.25^a	4.19^a	241.3^a	15.75^a	15.4^a	2180^a	2747^d	40.3^a
S_3B_0	145.1^{cd}	5.11^{ab}	4.17^a	237^b	10.35^{cd}	12.8^{bc}	2170^a	2779^{bc}	40.1^{ab}
S_3B_1	147.9^c	5.21^a	4.16^a	239.8^{ab}	12.14^{bc}	13.6^b	2140^b	2800^a	39.7^c
S_3B_2	148.7^c	5.17^a	4.17^a	241^a	13.63^b	14^{ab}	2170^a	2752^{cd}	39.6^{cd}
S_3B_3	152.9^{ab}	5.08^{ab}	4.19^a	240^{ab}	13.5^b	14.5^a	2150^{ab}	2761^c	39.3^e
Level of significance	*	*	*	*	*	*	*	*	*

Mean value within the column with different superscripts are significantly different by DMRT.

S_0B_0= control; S_0B_1= 0 kg S and 1 kg B; S_0B_2= 0 kg S and 2 kg B; S_0B_3= 0 kg S and 3 kg B; S_1B_0= 10 kg S and 0 kg B; S_1B_1= 10 kg S and 1 kg B; S_1B_2= 10 kg S and 2 kg B; S_1B_3= 10 kg S and 3 kg B; S_2B_0= 20 kg S and 0 kg B; S_2B_1= 20 kg S and 1 kg B; S_2B_2= 20 kg S and 2 kg B; S_2B_3= 20 kg S and 3 kg B; S_3B_0= 30 kg S and 0 kg B; S_3B_1= 30 kg S and 1 kg B; S_3B_2= 30 kg S and 2 kg B; S_3B_3= 30 kg S and 3 kg B.

Nutrient content in stover and seed of mustard

Different combinations of sulphur and boron were influenced significantly the nutrient (N, P, K, S and B) contents in stover and seed of mustard (Table 3). A range of N content 1.2-1.51% and 3.41-3.69% respectively were observed in stover and seed. The highest N content was found in S_2B_3 treatment (20 kg S ha^{-1} and 3 kg B ha^{-1}) followed by S_2B_2, S_2B_3, S_3B_1, S_3B_2 & S_3B_3 and the lowest in control plot. In case of other nutrient content varied from 0.21-0.44% P, 2.41-2.68% K, 0.08-0.88% S and 42.11-46.89 ppm B in stover and it were ranged from 0.45-0.57% P, 1.09-1.38% K, 0.52-0.79% S and 47.67-59.89 ppm B in seed of mustard (Table 3). The content of P, K, S and B due to different combinations of sulphur and boron followed almost the same trend of N content (Table 3). The result is in agreement with the results of Karthikeyan and Shukla (2008); Ganesharmurthy (1996), Chand *et al.* (1997) and Sarker *et al.* (2002).

Table 3. Combined effect of sulphur and boron on nutrient contents in stover and seed of mustard

Treatment	Nitrogen (%)		Phosphorous (%)		Potassium (%)		Sulphur (%)		Boron(ppm)	
	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed
S_0B_0	1.20^d	3.41^{cd}	0.21^d	0.45^b	2.41^{cd}	1.09^c	0.08^d	0.52^{cd}	42.11^f	47.67^{fg}
S_0B_1	1.22^{cd}	3.43^{cd}	0.21^d	0.46^b	2.43^c	1.09^c	0.11^{cd}	0.57^c	42.38^{ef}	47.79^f
S_0B_2	1.26^{cd}	3.43^{cd}	0.24^{cd}	0.46^b	2.44^c	1.10^c	0.12^{cd}	0.57^c	42.67^e	47.99^f
S_0B_3	1.29^c	3.45^c	0.26^c	0.47^b	2.47^c	1.11^c	0.13^{cd}	0.61^{bc}	42.99^e	48.46^f
S_1B_0	1.23^{cd}	3.44^c	0.27^c	0.46^b	2.51^{bc}	1.10^c	0.14^c	0.63^{bc}	43.18^d	48.93^f
S_1B_1	1.31^c	3.48^c	0.29^c	0.46^b	2.51^{bc}	1.14^c	0.15^c	0.67^b	43.23^d	50.12^{de}
S_1B_2	1.34^b	3.53^b	0.36^{ab}	0.47^b	2.55^b	1.17^c	0.16^c	0.67^b	43.34^d	51.34^{de}
S_1B_3	1.37^b	3.55^b	0.37^{ab}	0.48^b	2.56^b	1.23^b	0.17^c	0.67^b	43.88^{cd}	52.67^d
S_2B_0	1.31^c	3.48^c	0.35^b	0.47^b	2.58^b	1.25^{ab}	0.18^c	0.68^b	43.97^{cd}	52.89^d
S_2B_1	1.41^{ab}	3.56^b	0.39^{ab}	0.52^{ab}	2.61^{ab}	1.29^{ab}	0.24^b	0.71^{ab}	44.89^c	54.62^c
S_2B_2	1.44^a	3.59^{ab}	0.41^a	0.55^a	2.63^{ab}	1.34^a	0.29^{ab}	0.72^{ab}	45.65^b	57.17^b
S_2B_3	1.51^a	3.69^a	0.44^a	0.57^a	2.68^a	1.38^a	0.38^a	0.79^a	46.89^a	59.89^a
S_3B_0	1.40^{ab}	3.63^{ab}	0.42^a	0.55^a	2.67^a	1.35^a	0.33^{ab}	0.76^a	46.46^{ab}	59.18^b
S_3B_1	1.45^a	3.63^{ab}	0.43^a	0.56^a	2.67^a	1.36^a	0.37^a	0.79^a	46.68^{ab}	59.33^{ab}
S_3B_2	1.46^a	3.65^a	0.43^a	0.55^a	2.68^a	1.37^a	0.36^a	0.78^a	46.78^a	59.92^a
S_3B_3	1.49^a	3.69^a	0.44^a	0.56^a	2.68^a	1.38^a	0.36^a	0.78^a	46.87^a	59.98^a

Mean value within the column with different superscripts are significantly different by DMRT.

S_0B_0= control; S_0B_1= 0 kg S and 1 kg B; S_0B_2= 0 kg S and 2 kg B; S_0B_3= 0 kg S and 3 kg B; S_1B_0= 10 kg S and 0 kg B; S_1B_1= 10 kg S and 1 kg B; S_1B_2= 10 kg S and 2 kg B; S_1B_3= 10 kg S and 3 kg B; S_2B_0= 20 kg S and 0 kg B; S_2B_1= 20 kg S and 1 kg B; S_2B_2= 20 kg S and 2 kg B; S_2B_3= 20 kg S and 3 kg B; S_3B_0= 30 kg S and 0 kg B; S_3B_1= 30 kg S and 1 kg B; S_3B_2= 30 kg S and 2 kg B; S_3B_3= 30 kg S and 3 kg B.

Combined effect of sulphur and boron on protein and oil content in mustard

Protein content in stover and seed of mustard was significantly affected by the treatment combination of S and B (Table 4). The highest protein content (9.44%)

in stover and (23.06%) in seed were found in S_2B_3 treatment (20 kg S ha^{-1} and 3 kg B ha^{-1}) which showed significant variation over the others treatment combination, but statistically similar to S_3B_3 in stover and S_3B_3 & S_3B_2 in seed. The lowest protein content (7.50% in stover and 21.31% in seed) was observed in control treatment. This result is in agreement with the observation of Brady (1996). Similar finding was also corroborated by Tomar *et al.* (1996) who recorded the highest amount of protein in increasing S fertilization. Verma *et al.* (2002) reported the higher amount of protein was obtained from the combination of S 60 kg ha^{-1} + B 1.0 kgha^{-1} followed by S 40 kg ha^{-1} + B 1.0 kg ha^{-1}.

Table 4. Combined effect of sulphur and boron on protein content in stover and seed & oil content in seed of mustard

Treatment	Protein (%)		Oil content (%)
	Stover	Seed	seed
S_0B_0	7.50[i]	21.31[g]	41.67[d]
S_0B_1	7.62[h]	21.44[f]	41.69[d]
S_0B_2	7.87[g]	21.44[f]	41.83[c]
S_0B_3	8.06[f]	21.56[ef]	41.88[c]
S_1B_0	7.69[h]	21.5[ef]	42.87[bc]
S_1B_1	8.19[de]	21.75[e]	42.88[bc]
S_1B_2	8.37[de]	22.06[d]	42.97[b]
S_1B_3	8.56[d]	22.19[cd]	43.01[b]
S_2B_0	8.19[de]	21.75[e]	43.73[b]
S_2B_1	8.81[c]	22.25[cd]	43.75[b]
S_2B_2	9.00[bc]	22.44[c]	43.78[b]
S_2B_3	9.44[a]	23.06[a]	43.80[b]
S_3B_0	8.75[d]	22.69[b]	44.90[a]
S_3B_1	9.06[b]	22.69[b]	44.93[a]
S_3B_2	9.12[b]	22.81[ab]	44.95[a]
S_3B_3	9.31[ab]	23.06[a]	44.98[a]

Mean value within the column with different superscripts are significantly different by DMRT.

S_0B_0= control; S_0B_1= 0 kg S and 1 kg B; S_0B_2= 0 kg S and 2 kg B; S_0B_3= 0 kg S and 3 kg B; S_1B_0= 10 kg S and 0 kg B; S_1B_1= 10 kg S and 1 kg B; S_1B_2= 10 kg S and 2 kg B; S_1B_3= 10 kg S and 3 kg B; S_2B_0= 20 kg S and 0 kg B; S_2B_1= 20 kg S and 1 kg B; S_2B_2= 20 kg S and 2 kg B; S_2B_3= 20 kg S and 3 kg B; S_3B_0= 30 kg S and 0 kg B; S_3B_1= 30 kg S and 1 kg B; S_3B_2= 30 kg S and 2 kg B; S_3B_3= 30 kg S and 3 kg B.

Combinations of S and B demonstrated positive effect on oil content of mustard (Table 4). The percent oil content due to different treatment combination was ranged from 41.67-44.98%. Percent oil content gradually incraesed with the increasing of combination of S and B. The highest oil content (44.98%) was recorded from the treatment S_3B_3 (30 kg S ha^{-1} and 3 kg B ha^{-1}) followed by S_3B_2, S_3B_1 and S_3B_0. The lowest oil amount (41.67%) was found in control treatment

(Table 4).This finding was supported by Havlin *et al.* (1999) and Babhulkar *et al.*(2000). In contrast, Khatik *et al.* (1992) observed that S appliaction decreased the oil content. But Malewar *et al.* (2001) and Noor *et al.* (1997) reported that oil is synthesised by B nutrient with combination of other nutrient.

Conclusion

The combination of S_2B_3 (20 kg S ha^{-1} and 3 kg B ha^{-1}) with blanket dose of 120 kg urea ha^{-1}, 145 kg TSP ha^{-1}, 45 kg MoP ha^{-1} and 5 kg ZnSO4 ha^{-1} gave higher grain yield of mustard. The treatment combination S_3B_3 (30 kg S ha^{-1} and 3 kg B ha^{-1}) contributed the highest protein and oil content in mustard seed. Thus, combined application of S and B at 20 and 3 kg ha^{-1} can be recommended for yield maximization and quality improvement of mustard in Tejgaon series soil of Madhupur Tract (AEZ 28).

References

Aulakh, M.S. and Pasricha N.S. 1997. Combined effect of S and P on growth and nutrient content of moog (*Phaseolus aureus* L.). *Plant and Soil*. **47:** 141-143.

Babhulkar, P. S., Dineshkar, W. P. Badole and S. S. Balpande. 2000. Effect of Sulphur and zinc on yield, quality and nutrient uptake by safflower in vertisol. *J. Ind. Soc. Soil Sci*. **48**(3): 541-543.

BBS (Bangladesh Bureau of Statistics). 2011. Statistical Yearbook of Bangladesh Stat. Div., Minist. Planning, Govt. Repub. of Bangladesh, Dhaka.

Brady, N.C. 1996. The nature and properties of soils. 11th edition. McMillan Publishing Company, Ivc. New York, 444-487.

Bremner, J.M. and C.S. Mulvaney.1982. Total nitrogen, In: Methods of Soil Analysis, Part 2, 2nd Ed., Page, A.L., Miller, R.H., Keeney, D.R., Am. Soc. Agron. Madison, USA. Pp. 599-622.

Chand, L., A.S. Sharma and S.C. Jat. 1997. Quality and uptake of nutrients in mustard as affected by foliar spray of urea and Sulphur application. *Ann. Biol. Ludhiana*. **13:** 103-106.

Fox, R.L., R.A. Olsen and H.F. Rhoades. 1964. Evaluating the sulphur status of soil by plant and soil test. Soil Sci. Soc. Am. Proc. **28:** 243–246.

FRG. 2012. Fertilizer Recommendation Guide. Published by Bangladesh Agricultural Research Council Dhaka, Bangladesh.

Ganeshamurthy, A.N. 1996. Critical plant Sulphur content and effect of S application on grain and oil yield of rainfed soybean in vertic ustochrepts. *J. Indian Soc. Soil Sci*. **44:** 290-294.

Gomez, K.A. and Gomez A.A. 1984. Statistical Procedures for Agricultural Research. International Rice Research Institute, John Wiley & Sons, NY.

Haq, M.O. 2012. Effect of Sulphur and Boron on seed yield of sesame (*Sesamum indicum* L.). *MS thesis*. Bangladesh Agricultural University, Mymensingh.

Haque, M. A. 2000. Effects of Sulphur and Boron on yield, oil content and nutrient uptake of mustard. M.S. Thesis. Dept. of Soil Science, BAU, Mymensingh, 80.

Havlin, L. J., D. J. Beaton, L.S. Tisdale and L.W. Nelson. 1999. Soil Fertility and Fertilizers. Prentice Hall of Indian. 6th edition, 220-228, 277, 319-346.

Islam, M. B. and M. A. Z. Sarker. 1993. Effect of different levels of Boron on the yield of Mustard. Research Report 1992-93. BARI, Rangpur station, 1- 4.

Islam, M. R., M. S. Islam, M. Jahiruddin and M. S. Hoque. 1999. Fffect of Sulphur, zinc and Boron on yield, yield components and nutrient uptake of wheat. *Pak. J. Sci. Ind. Res*. **42**(3): 137-140.

Islam, M.N. 2003. Effect of Sulphur and magnesium on growth, yield, nutrient (N, P, K, Ca, Mg, S & B) and oil content in mustard (Brassica campestries L.) var. Tori-7. MS theis. Bangladesh Agricultural University, Mymensingh.

Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall of India Private Limited, New Delhi. Pp. 498.

Karthikeyan, K. and L.M. Shukla. (2011). Different forms of Boron and Sulphur and their effect on B and S contents in mustard *(Brassica juncea* L.) and sunflower *(Helianthus annus* L.). *Agropedology*, **21**(1): 28-34

Khan, M.S., M.M. Rahman, R.A. Begum, M.K. Alam, A. T. M. A. I. Mondol, M.S. Islam, and N. Salahin. 2008. Research Experiences with Problem Soils of Bangladesh (eds). Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Pp. 1-176.

Khatik, S.K., S.K. Vishwakarma and S.K. Sharma. 1992. Effect of phosphorous and Sulphur application on nutrient use efficiency and uptake by soybean in chromustert soil. *J. Soils and Crops*. **2:** 25-29.

Malewar, G.V., S.D. Kate, S.L. Waiker and S. Ismail. 2001. Combined effect of zinc and Boron on yield, nutrient uptake and quality of mustard (*Brassica juncea* L.) on a Typic Haplustert. *J. Indian Soc. Soil Sci*. **49:** 763-765.

Mohiuddin, M. 2007. Effect of nitrogen and Sulphur growth and yield of mustard (SAU Sharisha-1). *MS thesis*. Sher-E-Bangla Agricultural University, Dhaka-1207.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon and organic matter. *In*: Methods of Soil Analysis. Part 2. 2nd Edition. Page, A.L, Miller, R.H., Keeney, D.R. (eds), Am. Soc. of Agron. Madison, USA. Pp. 539-580.

Noor S., M.A. Hannan and M.S. Islam. 1997. Effect of molybdenum and Boron on the growth and yield of groundnut. *Indian J. Agric. Res*. **31:** 51-58.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorus. *In*: Methods of Soil Analysis, Part 2. 2nd Edition. Page, A.L., Miller, R.H., Keeney, D.R. (eds), Am. Soc. Agron. Madison, USA. Pp. 403-427.

Page, A.L., R.H. Miller and D.R. Keeney (eds.). 1982. Methods of Soil Analysis. Part 2. Chemical and microbiological properties. 2nd Edition. Agronomy series 9 ASA, SSSA. Madison Wis. USA.

Piper, C.S. 1966. Soil and Plant Analysis. Adelaide University Press, Australia.

Pratt, P.F. 1965. Methods of Soil Analysis, Chemical and Biological properties part 2. Am. Soc. Agron. Madison, USA. P. 1023.

Robinson, R.G. 1973. Elemental Composition and Response to Nitrogen of Sunflower and Corn1. *Agronomy J.* **65**(2).

Sarker, S.K., M.A.H. Chowdhury and H.M. Zakir. 2002. Sulphur and Boron fertilization on yield quality and nutrient uptake by Bangladesh Soybean-4. *Online Journal of Biological Sciences*. **2**(11): 729-733.

Singh, R.N., Surendra S. and Kumar B. 2007. Combined effect of S and B on yield, nutrient uptake grown in acidic upland soil. *J. Indian Soc. Soil Sci*. **54**(4): 516-518.

Tomer, S., T.V.S. Tomer, S. Kumer, M. Singh and S. Singh 1996. Response of Indian mustard (*Brassica juncea*) varieties to nitrogen, phosphorus and potassium fertilizers. *Indian J. Agron*. **41**(4): 624-626.

Varma, S.C., R.K. Srivastava, S. Rajesh S.K. Singh, P.K. Bisen and R. Singh. 2002. Effect of varying levels of Sulphur and potassium on yield and oil content of Indian mustard (*Brassica Juncea*). *Research on Crops*. **3**(3): 650-652.

ASSESSMENT OF GENOTYPE-BY-ENVIRONMENT INTERACTIONS OF WHITE QUALITY PROTEIN MAIZE HYBRIDS IN BANGLADESH

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Abstract

Present study assessed genotypes and their interactions with environments (GEI) for plant height, days to maturity and grain yield of 40 maize hybrids including two local checks across five different locations of Bangladesh. Thirty eight white QPM (Quality Protein Maize) hybrids were collected from CIMMYT, Mexico. The AMMI (additive main effect and multiplicative interactions) and GGE (genotype + genotype × environment) model were used to assess the additive and multiplicative effects of the interactions. Significant variations were found for genotypes (G), environments (E) and GEI for all the studied characters. The environment of Gazipur is poor while those of Ishurdi and Rangpur are rich for QPM hybrids production. Considering three parameters viz., mean, bi and S^2di, it was evident that all the genotypes showed different responses of adaptability under different environmental conditions. Among the hybrids E21, E23, E30 and E22 exhibited bi~1 and S^2di~0 for all the characters under study, which clearly indicated that the hybrids are stable across the environments. The hybrids E11, E25, E37 and E4 had bi value significantly different from the unity with non significant S^2di value for one or more characters studied, indicating high responsiveness of the hybrid but suitable for favorable environments only. E5 was a good yielder and stable over environments. Considering the yield potentiality and stability parameters five hybrids were found promising over the locations.

Keywords: QPM, AMMI, stability, hybrids, GEI, adaptability.

Introduction

Maize (*Zea mays* L.) plays a significant role in human and livestock nutrition worldwide. In Bangladesh, it is an important cereal crop that ranks third and first position in terms of acreage and production, respectively. Due to high yield potentiality coupled with versatile uses, almost year round grow ability and higher yield compared to other cereals, area and production of maize is increasing every year. Its production has also increased significantly in the country because of the fast growing poultry and poultry feed industry and price hike of food materials. During 2011-12, 4,87,000 acres of hybrid maize were

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cultivated in Bangladesh and 12,98,000 tons of hybrid maize were produced (BBS, 2014)

Commonly, the yellow and yellow orange kernel maize is being cultivated in Bangladesh. BARI has only one variety (BARI Hybrid Maize-5) with increased protein percentage which is yellow colored. Now-a-days people are interested to uptake white colored flour either mixing with wheat or solely from maize. Considering this concern, white maize with quality protein can be a good player amongst the human consumption food material, because general people prefer white flour compared to yellow flour.

Customarily we know that cereals grain are lacking in essential amino acids particularly lysine and tryptophan. But CIMMYT evolved QPM hybrid maize certainly contain elevated percentage of lysine and tryptophan compared to normal maize. Under UN charter of "Sustainable Development Goals (SDG)" more emphasis has been laid down for nutritional replenishment of food grains. Hence, HYV as well as QPM white floured hybrid maize unquestionably would be able to fulfill those demands in near future.

The most used methods to interpret genotype stability are based on regression analyses (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Silva and Baretto, 1985; Cruz *et al*., 1989). Agronomic zoning is used to stratify environments in sub-regions within which the interactions are not significant (Duarte and Zimmermann, 1999). These methods are dependent on the genotypes and environments under study and may not be much informative if linearity fails (Crossa, 1990). The additive nature of the common analysis of variance (ANOVA) allows for an adequate description of the main effects (genotypic and environmental effects). The multi-location testing, however, usually results in genotype-by-environment (G×E) interactions that often complicate the interpretation of results obtained and thereby reduce efficiency in selecting the best genotypes (Annicchiarico and Perenzin, 1994).

Plant breeders and geneticists, as well as statisticians, have a long-standing interest in investigating and integrating G and GE in selecting superior genotypes in crop performance trials. Many statistical methods have purposefully been developed for GEI analyses, including AMMI analysis and GGE biplot analysis (Yan and Kang, 2003). In the initial assessment, maize hybrids were tested in relatively few environments, and interaction can interfere in the performance results leading to errors in selection where promising materials are discarded because of the lack of a more careful analysis of the data obtained. The relative performance of the genotypes can be altered with changes in the environments and these different responses are due to the genotype-environment interactions (GE) because there are environments that are either more or less favorable to certain genotypes. The objective of this study was to test the performance of CIMMYT developed white QPM hybrids, under different agro-ecological zones of Bangladesh and select better one(s).

Materials and Method

The experiment was conducted at five locations viz., Barisal, Jamalpur, Gazipur, Ishurdi and Rangpur during *rabi* 2011-12. Thirty eight CIMMYT developed white-QPM hybrids and two local checks, viz. BARI Hybrid Maize-5 (BHM 5) and BARI Hybrid Maize-9 (BHM-9) were evaluated in this trial. Seeds were sown on November to December, 2011 at 5 locations following Alpha lattice design with 3 replications. The unit plot size was 5.0 X 1.5 m. Spacing adopted was 75 cm $\times$ 20 cm between rows and hill, respectively. One healthy seedling per hill was kept after proper thinning. Fertilizers were applied @ 250, 120, 120, 40 and 5 kg ha^{-1} of N, P_2O_5, K_2O, S and Zn, respectively. Standard agronomic practices were followed (Quayyum, 1993) and plant protection measures were taken as required. Two border rows were used to minimize the border effect. Data on days to tasseling and days to silking were recorded on whole plot basis. Ten randomly selected plants were used for recording observations on plant and ear height. All the plants in two rows were considered for plot yield. The grain yield (t ha^{-1}) data was assessed and corrected to 12% moisture. The CIMMYT hybrids are: CLWN210/CML494, CLWN224/CML494, CLWN208/CML494, CML494/CML495, CML491/CML503, CLWN221/CML494, CLWN216/CML494, CLQRCWQ124/CML491, CLWN211/CML494, CLWQ222/CML503, CL04368/CLSPLW04, CLWN205/CML494, CLWN209/CML494, CLWQ238/CML491, CLWN228/CML495, CLWN212/CML494, CLWN219/CML494, CLWN217/CML494, CLWQ223/CML503, CLWN227/CML495, CLRCW104/CML494, CLWN218/CML494, CLRCW105/CML494, CLWN215/CML494, CLQRCWQ123/CML491, CLWN204/CML494, CLWN222/CML494, CLWN207/CML494, CLWN206/CML494, (CLQ-6203xCL-04321)-B-7-1-2-4-B/CL-FAWW11)-B-6-1-2-B-B-B-B/CML491, CLWN220/CML494, CLWQ221/CML503, CLWN213/CML494, CLWN214/CML494, CLRCW107/CML494, CLWN223/CML494, CLWN201/CML495, CLRCW109/CML494. All the materials were marked as E and considered as individual entry.

Statistical Analysis

The analysis of variance (ANOVA) was used and the GE interaction was estimated by the AMMI model (Duarte and Vencovsky, 1999). Thus, the mean response of the genotype *i* in environment *j* (*Yij*) is modeled by: $Yij = \mu + gi + aj + \Sigma\lambda k\gamma ik\alpha jk + \rho ij + eij$; where μ is a common constant to the responses (normally the general mean); *gi* is the fixed effect of genotype *i* (*i* = 1, 2, ..., g); *aj* is the fixed effects of environment *j* (*j* = 1, 2, ..., a); $\Sigma\lambda k\gamma ik\alpha jk$ is the fixed significant effect or pattern of the specific interaction of the genotype *i* with environment *j* (*gaij*), where, λk is the k-th singular value (scalar), γik and αjk are the correspondent elements, associated to λk, of the singular vectors (rows vector and column vector) of the matrix of interaction estimated by ANOVA. For the same matrix, ρij is the non-significant effect or noise of (*ga*)*ij*, which is an additional residue, and *eij* is the pooled experimental error, assumed independent

and *eij* ~ N(0, σ2). In this procedure, the contribution of each genotype and each environment to the GE interaction is assessed by the biplot graph display in which yield means are plotted against the scores of the first principal component of the interaction (IPCA1). The stability parameters, regression coefficient (bi) and deviation from regression (S^2di) were estimated according to Eberhart and Russell (1966). Significance of differences among bi value and unity was tested by t-test, between S^2di and zero by F-test. All the data were subjected to analysis using statistical analysis package software Cropstat7.2 version (AMMI, SSA and BANOVA models).

Results and Discussion

Results pertaining to various statistical analyses can be depicted below: There were highly significant (*P*<0.01) mean squares (MS) for plant height, days to maturity and yield for all sources of variations (Table 1). AMMI analysis in five environments (Table 2) shows that AMMI has partitioned main effects into genotypes, environments and G×E with all the components showing highly significant effects (*P*<0.01). The highly significant effects of environment indicate high differential genotypic responses across the different environments. The variation in soil structure and moisture across the different environments were considered as a major underlying causal factor for the G×E interaction. Environment relative magnitude was much higher than the genotype effect, suggesting that genotype performance is influenced more by environmental factors.

Table 1. Mean squares from combined analysis of variance (ANOVA) for maize yield and yield components analyzed over 5 locations during 2011-2012

Source of variation	df	Mean sum of square		
		PH (cm)	DM	Y (ton ha^{-1})
Loc	4	27663.2**	1299.96**	183.80**
Entry	39	1020.88**	6.074	5.86**
Loc*entry	156	152858	3.858	1.08
Loc*rep*entry	400	117.187	6.30	1.02
Error	599	369.26	14.29	2.57

* *P*<0.05, ** *P* < 0.01; PH, Plant Height; DM, Days to maturity; Y, Yield.

Results of stability and response of the genotypes under different environments according to Eberhart and Russell (1966) model are discussed character-wise as follows where stability parameters i.e. regression coefficient (bi) and deviation from regression (S^2di) for plant height, days to maturity and yield of the individual genotypes are presented in Tables 3, 4, and 5, respectively.

Table 2. Full joint analysis of variance including the partitioning of the G × E interaction of maize

Source of variation	df	Mean sum of squares			
		DT	PH (cm)	DM	Y (ton ha^{-1})
Gen (G)	39	7.20	340.29*	2.02	1.95*
Env (E)	4	1419.94**	9221.05**	433.31**	61.26**
Inter (GEI)	156	0.94	50.95	1.28	0.36
AMMI Comp 1	42	1.29**	72.23**	1.68**	0.59***
AMMI Comp 2	40	1.24**	57.20**	1.66**	0.43
AMMI Comp 3	38	0.89**	51.62	1.05	0.21
AMMI Comp 4	36	0.27	18.47	0.64	0.15
G×E (Linear)	39	1.12	48.70	0.95	0.36
Pool dev	117	0.89	51.70	1.39	0.35
Pooled error	199	30.69	291.98	10.11	1.89

* $P<0.05$, ** $P < 0.01$; DT, Days to tasseling, PH, Plant Height; DM, Days to maturity; Y, Yield.

The plant height along with the value of phenotypic indices (Pi), environmental indices (Ei), regression coefficient (bi) and stability (S^{2}di) are presented in Table 3. The environmental mean and genotypic mean ranged from 187.9 cm to 228.2 cm and 120.6 cm 227.4 cm, respectively. Twenty two hybrids showed positive phenotypic index while the other genotypes had negative phenotypic index for plant height. Thus, positive phenotypic index represents the taller plant and negative represents the shorter plant height among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favorable and poor or unfavorable environments for this character, respectively. The environmental index (Ij) directly reflects the poor or rich environment in terms of negative and positive Ij, respectively. Thus the environment Gazipur was poor and Ishurdi was rich environments for higher plant height.

The regression coefficient (bi) values of these genotypes ranged from 0.51 to 1.50. These differences in bi values indicated that all the genotypes responded differently to different environments. Considering the three parameters mean, bi and S^{2}di, it was revealed that all the genotypes showed different response of adaptability under different environmental conditions. Among the hybrids E6, E8, E15, E18, E24, exhibited short plant height, bi~1 and S^{2}di~0 indicated that the hybrids are stable across the environment. The hybrids E10, E12 and E31 had bi value significantly different from the unity with non significant S^{2}di value for one or more characters studied indicating a high responsiveness of the hybrid but suitable for favorable environments. So these hybrids are expected for short stature character.

Table 3. Stability analysis for Plant height (cm) of 40 white hybrids of maize over 5 environments

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E1	183.3	214.3	200.6	238.1	215.9	210.5	1.5	1.14	19.02
E2	181.7	203.0	212.4	230.2	219.9	209.4	0.4	1.19	34.85
E3	190.7	205.7	203.5	232.1	210.5	208.5	-0.5	0.90	7.61
E4	174.0	204.0	212.4	234.4	228.7	210.7	1.7	1.50	230.27
E5	186.7	202.7	223.7	232.4	215.0	212.1	3.1	1.15	23.01
E6	167.7	169.7	190.1	208.4	203.6	187.9	-21.1	1.14	18.52
E7	179.7	181.7	218.7	226.0	202.3	201.7	-7.3	1.26	66.18
E8	168.3	198.7	209.3	222.3	192.6	198.2	-10.8	1.20	39.07
E9	177.3	191.7	210.6	227.3	214.3	204.3	-4.7	1.29*	78.08
E10	171.0	190.0	208.9	218.5	210.5	199.8	-9.2	1.23	51.58
E11	206.7	213.0	221.8	243.8	226.3	222.3	13.3	0.90	8.80
E12	174.7	197.0	216.1	224.6	214.1	205.3	-3.7	1.27	70.16
E13	203.3	201.7	217.1	229.1	210.2	212.3	3.3	0.65	108.49
E14	197.7	209.0	217.5	232.8	221.1	215.6	6.6	0.86	16.82
E15	167.7	176.3	206.2	208.9	208.4	193.5	-15.5	1.20	38.56
E16	196.0	201.0	223.6	228.6	210.5	211.9	2.9	0.85	19.45
E17	185.7	202.3	194.1	223.3	216.7	204.4	-4.6	0.85	19.06
E18	162.7	197.3	203.6	215.3	208.4	197.5	-11.5	1.26	63.01
E19	191.0	198.0	201.9	231.0	211.5	206.7	-2.3	0.94	3.26
E20	201.0	201.3	219.8	233.2	216.0	214.3	5.3	0.84	22.17
E21	195.7	213.7	216.5	234.8	220.7	216.3	7.3	0.90	8.25
E22	198.0	208.0	215.7	245.7	235.8	120.6	11.6	1.20	39.04
E23	213.7	215.0	233.9	250.0	224.3	227.4	18.4	0.90	8.43
E24	186.0	198.7	214.9	218.9	211.2	205.9	-3.1	0.86	17.43
E25	193.7	200.3	205.1	232.0	219.7	210.2	1.2	0.94	3.06
E26	185.3	202.3	214.4	223.0	224.4	209.9	0.9	1.00	0.01
E27	190.0	204.3	218.5	227.9	201.6	208.5	-0.5	0.87	14.49
E28	189.3	220.3	226.7	234.6	205.6	215.3	6.3	0.95	1.70
E29	194.7	203.0	218.9	223.2	216.0	211.2	2.2	0.76	51.97
E30	207.3	211.3	215.6	235.0	212.1	216.3	7.3	0.60	141.29
E31	187.7	182.7	210.5	215.1	206.4	200.5	-8.5	0.83	25.94
E32	193.0	195.7	225.7	228.3	228.5	214.2	5.2	1.07	4.99
E33	187.7	210.0	225.1	230.7	212.2	213.1	4.1	1.02	0.79
E34	190.0	192.7	212.4	222.5	213.5	206.2	-2.8	0.89	10.07
E35	207.7	210.0	223.5	227.2	215.7	216.8	7.8	0.51*	121.59
E36	181.7	199.3	225.4	235.7	217.3	211.9	2.9	1.39	141.77

Entry	Environment						Pi	bi	S²d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E37	165.7	198.0	209.9	215.9	211.7	200.3	-8.7	1.25	57.65
E38	207.3	221.7	221.3	243.7	223.1	223.4	14.4	0.79	40.32
E39(L.C.1)	173.3	199.7	198.7	213.4	204.9	198.0	-11.0	0.91	6.90
E40(L.C.2)	210.7	203.3	202.5	228.7	206.	208.5	-0.5	0.57	165.92
Mean	187.9	201.2	213.7	228.2	214.2	209.0			
Ei (Ij)	-21.1	-7.8	4.7	19.2	5.2				
LSD (0.05)	20.56	18.5	5.07	9.39	21.48				

Gaz= Gazipur, Jam= Jamalpur, Bur= Burirhat, Isr= Ishurdi, Bar= Barisal.

E1=CLWN210/CML494, E2=CLWN224/CML494, E3=CLWN208/CML494, E4=CML494/CML495, E5=CML491/CML503, E6=CLWN221/CML494, E7=CLWN216/CML494, E8=CLQRCWQ124/CML491, E9=CLWN211/CML494, E10=CLWQ222/CML503, E11=CL04368/CLSPLW04, E12=CLWN205/CML494, E13=CLWN209/CML494, E14=CLWQ238/CML491, E15=CLWN228/CML495, E16=CLWN212/CML494, E17=CLWN219/CML494, E19=CLWN217/CML494, E1=CLWQ223/CML503, E20=CLWN227/CML495, E21=CLRCW104/CML494, E22=CLWN218/CML494, E23=CLRCW105/CML494, E24=CLWN215/CML494, E25=CLQRCWQ123/CML491, E26=CLWN204/CML494, E27=CLWN222/CML494, E28=CLWN207/CML494, E29=CLWN206/CML494, E30= ((CLQ-6203xCL-04321)-B-7-1-2-4-B/CL-FAWW11)-B-6-1-2-B-B-B-B/CML491, E31=CLWN220/CML494, E32=CLWQ221/CML503, E33= CLWN213/CML494, E34=CLWN214/CML494, E35=CLRCW107/CML494, E36=CLWN223/CML494, E37=CLWN201/CML495, E38=CLRCW109/CML494, E39= BARI Hybrid Maize 5, E40= BARI Hybrid Maize 9.

The days to maturity along with the value of phenotypic indices (Pi), environmental indices (Ei), regression coefficient (bi) and stability (S²di) are presented in Table 4. The environmental mean and genotypic mean ranged from 150.3 days to 158.2 days and 152.5 days to 155.0 days, respectively. Twenty one hybrids showed positive phenotypic index while the other genotypes had negative phenotypic index for days to maturity. Thus, positive phenotypic index represents the long duration hybrids and negative represents short duration among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favorable and poor or unfavorable environments for this character, respectively. The environmental index (Ij) directly reflects the poor or rich environment in terms of negative and positive Ij, respectively. Thus, the environment Ishurdi was poor and Barisal was rich environments for high plant duration.

The regression coefficient (bi) values of these genotypes ranged from 0.72 to 1.40. These differences in bi values indicated that all the genotypes responded differently to different environments. Considering the three parameters mean, bi and S²di, it was evident that all the genotypes showed different response of

adaptability under different environmental conditions. Among the hybrids E8, E18, E33, E39, exhibited the short duration hybrids, bi~1 and $S^2di\sim0$ indicated that the hybrids are stable across the environment. The hybrids E3, E10 and E15 had bi value significantly different from the unity with non significant S^2di value for one or more characters studied indicating high responsiveness of the hybrid but suitable for favorable environments. So these hybrids are expected for short duration character.

Table 4. Stability analysis for days to maturity of 40 white hybrids of maize over 5 environments

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E1	156.0	152.0	154.0	152.7	158.3	154.6	0.6	0.76	2.49
E2	156.0	154.3	154.7	150.3	157.7	154.7	0.7	0.77	2.13
E3	156.0	152.7	153.0	151.0	157.0	153.9	-0.1	0.72	3.18
E4	156.3	152.7	155.3	151.0	158.0	154.7	0.7	0.84	1.06
E5	157.7	152.0	154.0	150.3	157.0	154.2	0.2	0.91	0.33
E6	157.0	149.3	154.3	150.3	159.3	154.1	0.1	1.27	3.25
E7	157.7	153.0	152.0	151.3	158.7	154.5	0.5	0.92	0.24
E8	154.0	150.0	154.3	149.0	157.3	152.9	-1.1	0.99	0.00
E9	156.0	153.3	154.3	149.3	158.3	154.3	0.3	0.95	0.08
E10	155.3	150.0	155.7	147.3	159.3	153.5	-0.5	1.40	6.92
E11	158.3	151.3	155.3	152.7	160.0	155.5	1.5	1.08	0.30
E12	155.3	150.0	155.7	150.0	158.7	153.9	-0.1	1.11	0.53
E13	157.7	153.3	155.0	148.7	158	154.5	0.5	1.06	0.19
E14	157.7	153.3	153.0	152.3	157.7	154.8	0.8	0.72	3.30
E15	156.7	150.0	154.7	148.7	157.0	153.4	-0.6	1.12	0.73
E16	156.7	151.3	154.7	152.7	159.7	155.0	1.00	0.96	0.05
E17	156.0	152.0	153.7	150.3	159.0	154.2	0.2	1.02	0.02
E18	154.3	150.3	152.3	150.0	158.0	153.0	-1.0	0.97	0.03
E19	157.0	150.0	155.3	149.3	157.3	153.8	-0.2	1.12	0.65
E20	156.3	150.3	154.0	149.0	157.0	153.3	-0.7	1.06	0.17
E21	157.0	151.0	151.7	151.3	160.0	154.2	0.2	1.14	0.95
E22	157.0	150.7	153.7	150.0	158.3	153.9	-0.1	1.12	0.63
E23	157.3	151.0	154.0	150.3	158.0	154.1	0.1	1.05	0.14
E24	154.3	149.3	154.3	151.7	159.3	153.8	-0.2	1.02	0.03
E25	156.3	150.3	155.3	150.7	158.7	154.3	0.3	1.08	0.31
E26	156.3	151.3	154.7	152.3	158.7	154.7	0.7	0.88	0.62
E27	157.0	152.0	155.3	149.7	159.0	154.6	0.6	1.12	0.72
E28	156.3	151.3	154.3	150.3	159.0	154.3	0.3	1.08	0.28
E29	156.7	150.7	155.0	150.3	157.3	154.0	0.00	0.97	0.02

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E30	157.3	150.0	155.3	150.3	157.7	154.1	0.1	1.08	0.33
E31	156.0	151.7	154.3	150.3	160.0	154.5	0.5	1.13	0.84
E32	155.0	151.3	154.0	150.3	157.7	153.7	-0.3	0.88	0.58
E33	155.7	149.3	153.3	150.7	156.3	153.1	-0.9	0.88	0.55
E34	155.3	151.0	151.7	152.0	158.0	153.6	-0.4	0.81	1.51
E35	158.0	150.0	153.7	150.3	157.0	153.8	-0.2	1.05	0.14
E36	156.3	150.0	152.0	151.0	158.0	153.5	-0.5	1.01	0.01
E37	154.0	154.7	153.7	149.3	158.0	153.9	-0.1	0.73	2.98
E38	155.0	150.3	151.7	150.3	158.3	153.1	-0.9	1.01	0.01
E39(L.C.1)	153.0	150.7	153.7	148.3	156.7	152.5	-1.5	0.91	0.33
E40(L.C.2)	155.0	151.7	153.0	147.7	158.0	153.1	-0.9	1.11	0.62
Mean	156.2	151.2	154.0	150.3	158.2	154.0			
Ei (Ij)	2.2	-2.8	0.00	-3.7	4.2				
LSD (0.05)	2.91	3.09	3.83	2.71	1.31				

Gaz= Gazipur, Jam= Jamalpur, Bur= Burirhat, Isr= Ishurdi, Bar= Barisal.

E1=CLWN210/CML494, E2=CLWN224/CML494, E3=CLWN208/CML494, E4=CML494/ CML495, E5=CML491/CML503, E6=CLWN221/CML494, E7=CLWN216/CML494, E8=CLQRCWQ124/CML491, E9=CLWN211/CML494, E10=CLWQ222/CML503, E11= CL04368/CLSPLW04, E12=CLWN205/CML494, E13=CLWN209/CML494, E14= CLWQ238/CML491, E15=CLWN228/CML495, E16=CLWN212/CML494, E17= CLWN219/CML494, E19=CLWN217/CML494, E1=CLWQ223/CML503, E20= CLWN227/CML495, E21=CLRCW104/CML494, E22=CLWN218/CML494, E23= CLRCW105/CML494, E24=CLWN215/CML494, E25=CLQRCWQ123/CML491, E26= CLWN204/CML494, E27=CLWN222/CML494, E28=CLWN207/CML494, E29= CLWN206/CML494, E30= ((CLQ-6203xCL-04321)-B-7-1-2-4-B/CL-FAWW11)-B-6-1-2-B-B-B-B/CML491, E31=CLWN220/CML494, E32=CLWQ221/CML503, E33=CLWN213/ CML494, E34=CLWN214/CML494, E35=CLRCW107/CML494, E36=CLWN223/ CML494, E37=CLWN201/CML495, E38=CLRCW109/CML494, E39= BARI Hybrid Maize 5, E40= BARI Hybrid Maize 9.

The grain yield along with the value of phenotypic indices (Pi), regression coefficient (bi) stability (S^2di), and are presented in Table 5. The environmental mean and genotypic mean ranged from 7.93 t/ha to 10.95 t/ha and 8.96 to 11.47 t/ha, respectively. Twenty two hybrids showed positive phenotypic index while the other genotypes had negative phenotypic index for yield. Thus, positive phenotypic index represents the higher yield and negative represents the lower yield among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favorable and poor or unfavorable environments for this character, respectively. The environmental index (Ij) directly reflects the poor or rich environment in terms of negative and positive Ij, respectively. Thus the

environment Gazipur was poor and Rangpur and Ishurdi were rich environments for QPM hybrids production.

The regression coefficient (bi) values of these genotypes ranged from 0.43 to 1.68. These differences in bi values indicated that all the genotypes responded differently to different environments. Considering the mean, bi and S^2di it was evident that all the genotypes showed different response of adaptability under different environmental conditions. Among the hybrids E21, E23, E30 and E22 exhibited the higher grain yield, bi~1 and S^2di~0 indicated that the hybrids are stable across the environments. The hybrids E11, E25, E37 and E4 had bi value significantly different from the unity with non significant S^2di value for one or more characters studied indicating high responsiveness of the hybrid but suitable for favorable environments.

Table 5. Stability analysis for yield (t/ha) of 40 white hybrids of maize over 5 environments

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E1	8.00	11.43	10.79	11.14	9.19	10.11	0.06	1.00	0.00
E2	6.66	9.71	10.21	10.11	9.36	9.21	-0.84	1.17	0.19
E3	8.33	11.07	1087	10.93	9.18	10.08	0.03	0.85	0.13
E4	8.00	10.67	11.43	12.16	10.33	10.52	0.47	1.24	0.35
E5	8.36	10.67	11.47	11.19	10.79	10.50	0.45	0.99	0.00
E6	7.00	9.23	9.80	10.93	9.05	9.20	-0.85	1.09	0.06
E7	7.06	10.61	11.13	9.26	9.86	9.58	-0.47	1.09	0.05
E8	7.36	10.19	9.91	10.58	9.59	9.35	-0.7	0.97	0.00
E9	7.20	9.60	10.17	10.12	8.75	9.17	-0.88	0.96	0.01
E10	7.50	10.01	9.92	9.70	8.60	9.15	-0.9	0.78	0.29
E11	8.66	10.95	11.43	12.59	11.61	11.05	1.00	1.10	0.07
E12	7.40	9.78	11.08	10.17	9.89	9.66	-0.39	1.07	0.03
E13	8.66	10.74	10.85	10.44	10.13	10.16	0.11	0.67	0.64
E14	8.20	10.06	10.83	11.13	10.45	10.13	0.08	0.91	0.04
E15	7.50	9.86	10.04	9.99	9.35	9.35	-0.7	0.85	0.13
E16	7.76	10.13	10.31	12.02	10.17	10.08	0.03	1.11	0.08
E17	8.33	10.86	10.08	10.40	10.12	10.16	0.11	0.82	0.19
E18	6.66	9.45	10.90	9.53	9.50	9.21	-0.84	1.18	0.22
E19	6.66	8.69	9.34	11.22	9.96	9.17	-0.88	1.18	0.21
E20	8.40	9.85	10.63	11.33	9.85	10.01	-0.04	0.82	0.18
E21	8.76	11.01	11.60	12.32	12.26	11.19	1.14	1.07	0.04
E22	8.66	10.44	12.10	12.36	11.76	11.07	1.02	1.16	0.16
E23	9.66	11.45	12.57	12.20	11.45	11.47	1.42	0.88	0.08
E24	7.33	9.86	10.69	10.62	9.98	9.69	-0.36	1.10	0.07

Entry	Environment						Pi	bi	S²d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E25	9.33	10.64	11.49	11.84	10.67	10.79	0.74	0.74	0.39
E26	7.66	9.88	11.51	11.66	10.46	10.24	0.19	1.27	0.45
E27	8.33	9.76	11.63	10.26	10.03	10.01	-0.04	0.84	0.15
E28	8.76	10.11	10.88	11.31	9.18	10.05	0.00	0.72	0.45
E29	9.00	10.44	8.96	11.52	10.18	10.02	-0.03	0.43	1.99
E30	8.00	11.53	12.84	11.59	11.83	11.16	1.11	1.42	1.12
E31	9.00	9.84	9.62	11.76	9.66	9.97	-0.08	0.52	1.36
E32	8.00	9.46	10.62	10.55	9.45	9.61	-0.44	0.83	0.18
E33	7.00	11.08	11.60	10.99	9.81	10.10	0.05	1.44	1.22
E34	8.66	10.34	11.37	10.66	10.97	10.40	0.35	0.78	0.27
E35	7.96	10.92	11.53	10.34	10.79	10.31	0.26	1.02	0.00
E36	7.33	9.78	11.31	10.23	11.03	9.93	-0.12	1.16	0.16
E37	9.00	11.77	12.12	10.85	9.98	10.55	0.5	0.80	0.23
E38	6.73	11.30	11.72	11.80	11.40	10.39	0.34	1.68	2.84
E39(L.C.1)	6.33	8.86	10.55	8.92	10.18	8.96	-1.09	1.16	0.16
E40(L.C.2)	8.00	10.36	11.16	10.32	10.75	10.12	0.07	0.93	0.02
Mean	7.93	10.26	10.95	10.93	10.19	10.05			
Ei (Ij)	-2.12	0.21	0.90	0.88	0.14				
LSD (0.05)	1.95	1.26	1.45	1.57	1.31				

Gaz= Gazipur, Jam= Jamalpur, Bur= Burirhat, Isr= Ishurdi, Bar= Barisal.

E1=CLWN210/CML494,   E2=CLWN224/CML494,   E3=CLWN208/CML494,   E4= CML494/CML495,   E5=CML491/CML503,   E6=CLWN221/CML494,   E7=CLWN216/ CML494,   E8=CLQRCWQ124/CML491,   E9=CLWN211/CML494,   E10=CLWQ222/ CML503,   E11=CL04368/CLSPLW04,   E12=CLWN205/CML494,   E13=CLWN209/ CML494,   E14=CLWQ238/CML491,   E15=CLWN228/CML495,   E16=CLWN212/ CML494, E17=CLWN219/CML494, E19=CLWN217/CML494, E1=CLWQ223/CML503, E20=CLWN227/CML495, E21=CLRCW104/CML494, E22=CLWN218/CML494, E23= CLRCW105/CML494, E24=CLWN215/CML494, E25=CLQRCWQ123/CML491, E26= CLWN204/CML494,   E27=CLWN222/CML494,   E28=CLWN207/CML494,   E29= CLWN206/CML494, E30= ((CLQ-6203xCL-04321)-B-7-1-2-4-B/CL-FAWW11)-B-6-1-2-B-B-B-B/CML491,   E31=CLWN220/CML494,   E32=CLWQ221/CML503,   E33= CLWN213/CML494,   E34=CLWN214/CML494,   E35=CLRCW107/CML494,   E36= CLWN223/CML494, E37=CLWN201/CML495, E38=CLRCW109/CML494, E39= BARI Hybrid Maize 5, E40= BARI Hybrid Maize 9.

The AMMI biplot provides a visual expression of the relationship between the first interaction principal component axis (AMMI component 1) and mean of genotypes and environment (Figs. 1 and 2) with the biplot according for up to 78.6% of the treatment sum of squares. The first interaction principal component

axis (AMMI component 1) was highly significant and explained the interaction pattern better than other interaction axis.
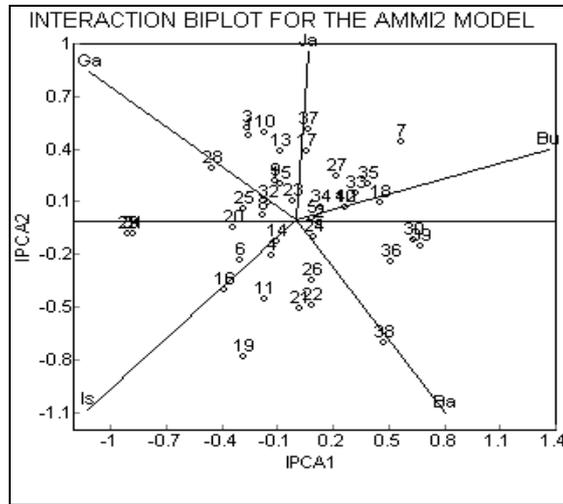

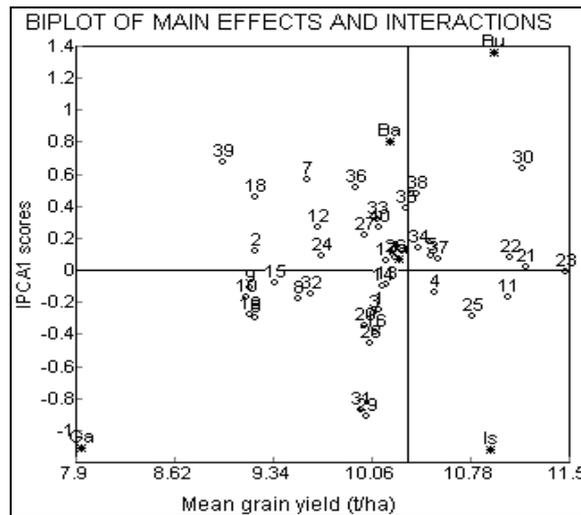**Fig. 1. AMMI model 2 biplot for 40 maize hybrids and 5 environments.**

Fig. 2. Plotted IPCA1 and IPCA2 scores of maize hybrids evaluated.

In Figure 1 the IPCA 1 scores for both the hybrids (number) and the environments (upper case) were plotted against the mean yield for the hybrids and the environments, respectively. By plotting both the hybrids and the environments on the same graph, the associations between the hybrids and the 5 environments can be seen clearly. The IPCA scores of a genotype in the AMMI analysis are an indication of the stability or adaptation over environments. The greater the IPCA scores, negative or positive, (as it is a relative value), the more

specific adapted is a genotype to certain environments. The more the IPCA scores approximate to zero, the more stable or adapted the genotype is over all the environments sampled.

Conclusion

Considering the yield potentiality and stability parameter five QPM hybrids (E21, E23, E30, E22 and E11) were found promising over the locations and could go for the processes of variety selection. This study also recommends for the prospect of quality maize production in Bangladesh. The AMMI statistical model has been used to diagnose the G×E interaction pattern of yield of hybrid maize. Burirhat with a relatively stable genotype performance could be regarded as a good selection site for identifying broad based and adaptable maize genotypes and other improvement work on maize.

Reference

Annicchiarico, P. and M. Perenzin. 1994. Adaptation patterns and definition of macro environment for selection and recommendation of common wheat in Italy. Plant Breed. **113:**197-205.

Bangladesh Bureau of Statistics (BBS). 2014.Yearbook of Agricultural Statistics- 2012, 24th Series. P. 3.

Crossa, J. 1990. Statistical analyses of multilocation trials. Advances in Agronomy. **44:**55-85.

Cruz, C. D., R. A. A. Torres and R. Vencovsky. 1989. To the stability analysis proposed by Silva and Barreto. Revista Brasileira de Genética. **12:**567-580.

Duarte, J. B. and R. Vencovsky. 1999. Interação Genótipos x Ambientes Uma Introdução à Análise "AMMI". Série Monografias, n.9. Sociedade Brasileira de Genética, Ribeirão Preto.

Duarte, J. B. and M. J. de O. Zimmermann. 1999. Selection of locations for common bean (*Phaseolus vulgaris* L.) germoplasm evaluation. Revista *Brasileira de Genética*. **14**(3):765-770.

Eberhart, S. A. and W. A. Russel. 1966. Stability parameters for comparing varieties. *Crop Science*. **6:**36-40.

Finlay, K. W. and G. N. Wilkinson. 1963. The analysis of adaptation in a plant-breeding programme. Australian Journal of Agricultural and Resource Economics. **14:**742-754.

Quayyum, M. A. 1993. Bhuttar Chash Padhati. *In:* Bhuttar Utpadan O Babahar eds. M.K. Chowdhury and M. A. Islam. Bangladesh Agricultural Research Institute. P.43-48.

Silva, J. G. C. and J. N. Barreto. 1985. Aplicação de regressão linear segmentada em estudos da interação genótipo x ambiente. p.49-50. *In*: Resumo do Simposio de statística Aplicada à Experimentação Agronômica, 1st, Cargill, Campinas.

Yan. W, M. S. Kang. 2003. GGE biplot analysis: a graphical tool for breeders, geneticists and agronomists. CRC. Press, Boca Raton, FL.

EFFECT OF VARIED PLANTING TIME AND DEHAULMING ON THE YIELD POTENTIAL, PROCESSING QUALITY AND ECONOMIC BENEFIT IN POTATO*

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Abstract

A field experiment was conducted for producing higher processing grade tuber yield and quality by evaluating in relation to different planting times (31 October, 15 and 30 November) and dehaulming dates (80, 90 and 100 days after planting) during 2012-13 potato growing season at Bangladesh Agricultural Research Institute, Gazipur. Results revealed that different growth parameters like plant height, leaves number per hill and foliage coverage were significantly influenced by planting times. Processing and non processing grade tuber number and yield were significantly affected by all the treatments and their interaction. Significantly higher yield of processing grade tuber were recorded in November 15 planting in combination with all the dehaulming dates, ranged from 20.67 to 21.50 t/ha. Processing quality parameters like specific gravity, dry matter, reducing sugar content were significantly varied by planting times, dehaulming dates and their interaction. Whereas the potato chips colour score were not affected by the planting time and dehaulming but all the processing quality parameters were remained in acceptable range. The highest net return (Tk 1,68,404/ha) with a BCR of 1.93 was obtained in November 15 planting with dehaulming at 90 days after planting.

Introduction

The potato (*Solanum tuberosum* L.) is one of the most important food crop in the world (Braun, 2010). Potato can be cultivated in many regions of the world and used for many purposes. Potato cultivation contributes to meeting the increasing need for food created by world population growth. Potato tubers accumulate large amounts of starch and are low in fat, and their protein content is comparable to that of grains. In addition, potatoes contain vitamin C (Rodriguez-Falcon *et al.*, 2006). Processing potatoes need some quality such as high dry matter, low reducing sugar etc. It is reported that desirable processing attributes greatly varied with location (Kumar *et al.*, 2003), time of sowing (Kumar *et al.*, 2007), cultivars, time of dehaulming (Marwaha, 1998; Marwaha *et al.*, 2005) and

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prevailing temperature during crop season (Pandey *et al.*, 2008). Among them, date of planting and haulm killing are the important practices for cultivating processing potatoes. Matured tubers are usually of high specific gravity and this is closely connected with high yield and quality of chips. Moreover, mature potatoes are less susceptible to damage during transport, storage and reconditioning. Maturity of potato tubers is closely connected with the date of planting and harvesting in particular regions, as well as weather condition prevailing in a given year (Lisinka and Leszezynski, 1989). The optimum temperature for potato growth is 15–20ºC, with a lower limit of 5–10ºC and an upper limit of 25ºC (Haverkort, 1990; Prange *et al*., 1990). Temperature and photoperiod during the growing season affect sugar and dry matter content of potatoes and, therefore, the chipping quality (Burton, 1989). Yamaguchi *et al*. (1964) reported that yield, specific gravity and starch content of tubers were the highest and sugar content lowest, when tubers were grown in soil temperature between 15 and 24ºC, compared with tubers grown at higher temperatures. So, date of planting should be standardized based on the environmental factors for producing processing potato in any region. Delayed planting dates caused yield reduction (Krishnappa, 1991; Peter *et al*., 1988). Muthuraj and Ravichandran (2014) and Muthuraj *et al*. (2005) opined that the planting time greatly affected tuber size distribution like- large, medium and small tuber yield in a locality differently within the varieties. Haulm killing is one of the methods used in potato production that regulate tuber size and quality. Dehaulming can be used to obtain a suitable tuber size, strengthen tuber skins before harvesting leading storage quality of potato (Struik and Wiersema, 1999). Interaction between date of planting and date of haulm killing maintained growth period which ultimately affect yield, tuber size distribution and quality. However, information regarding date of planting and dehaulming on processing grade tuber yield and quality is scanty in Bangladesh condition. Under such situations, need was felt to develop optimum planting time and crop growth duration for the maximization of processing grade tuber yield with quality and economical returns to potato growers and processors.

Materials and Method

This field experiment was conducted at the research field of Tuber Crops Research Center of Bangladesh Agricultural Research Institute, Gazipur during October 2012 to March 2013. The maximum and minimum mean air temperature of 23.1^0C and 18.2^0C was in November 2012 and January 2013, respectively. The soil of the experimental field was well drained sandy loam having a pH of 6.3. The variety was BARI Alu-28 (Lady Rosetta). The treatment consisted of 3 planting times of October 31 (D_1), November 15 (D_2) and November 30 (D_3) along with 3 dehaulming dates of 80 (M_1), 90 (M_2), 100 (M_3) days after planting (DAP). The treatments were arranged in a factorial

Randomized Complete Block Design with 3 replications. The unit plot size was 3.0 m × 3.0 m and tubers were planted at a spacing of 60 cm × 25 cm. Two outer rows of plants were treated as border rows, while the three middle rows in each plot were regarded as experimental row plants. The land was fertilized with 161-32-150-19-4-1.7 kg/ha, respectively of NPKSZnB fertilizers in addition to 6 t/ha of cowdung (Hossain et al., 2007). The NPKSZnB fertilizers were applied in the forms of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, Zinc sulphate and boric acid. The full amount of cowdung, TSP, MoP, gypsum, Zinc sulphate, boric acid, respectively and half of urea was applied at furrow and mixed up with soil by a tine before planting seed tubers. The rest half of urea was applied as top dress at 33 days after planting followed by irrigation. The well pre-sprouted, healthy, whole seed tubers of around 40±5 g sized were planted as per treatment in 2012. All other intercultural operations, like irrigation, weeding, earthing up and crop protection measures were adopted as per recommendation of TCRC, BARI. Plant stand was monitored and the final emergence count was taken at 30 days after planting. Dehaulming was done manually as per treatment and potato tubers were harvested after 10 days of dehaulming. Data on growth like plant height, number of compound leaves per hill, stem per hill were taken at 60 DAP from randomly selected 10 plants per plot, and yield per hectare was calculated during harvest from the middle rows yield. Foliage coverage was recorded at 60 DAP by using green method (Groves et al., 2005). Harvested potato tubers were sorted to different size grades of <40 mm as non-process grade and ≥40 mm as processing grade. The weight and number of tubers in each size fraction was recorded. Tuber dry matter was estimated just after harvest with dried in oven at 80^0 C to a constant weight. Reducing sugars were estimated following the method of Nelson (1944). For chipping, potatoes were hand peeled and cut into slices of 1.5-1.8 mm thickness with a manual slicing machine. The slices were washed thoroughly in cold water, air dried and immediately fried in soybean oil at 180^0C till the bubbling on the chip surface stopped. The chips were scored visually for colour and assigned a value on a scale of 1–10, where 1 being the lightest and 10 dark brown (Ezekiel et al., 2003). The cost of cultivation and gross returns from the crop were calculated on the basis of local market prices of inputs and farm gate price of potato. Net returns (Tk/ha) were worked out by subtracting the total cost of cultivation under each treatment from the gross return of respective treatment. Benefit cost ratio (BCR) was worked out by dividing the gross return with total cost of production (Kumar et al., 2014; Kushwah and Singh, 2011). The data on growth, yield components and yield were statistically analysed by using computer package programme of MSTAT-C and means were compared by using Duncan's Multiple Range Test at 5% level of significance.

Results and Discussion

Growth attributes

Nearly 100% emergence was recorded at 30 days after planting (DAP) and the emergence was not significantly affected by date of planting, dehaulming schedule and their interaction (Table 1). This might be due to around same size and healthy seed tubers were planted. Besides, more or less favourable soil temperature and moisture condition were prevailed same in all the plots. As dehaulming schedule treatments were started after 80 days of planting, so obviously it did not affect plant emergence as well as other growth parameters like plant height, compound leaves per hill, stem per hill and foliage coverage (%). Plant height was significantly influenced by date of planting. The result showed that plant height decreased as the advancement of date of planting. Thirty first October planting (D_1) recorded the highest plant height (80.7 cm) as compared to D_2 and D_3 planting dates (Table 1). These differences in plant height can be attributed to the differences in the prevailing weather conditions. The highest plant height in D_1 planting can be attributed to the most favourable environment i.e. long period of high temperature for plant growth during the cropping season. The lowest plant height was recorded at D_3 planting can be due to the lower temperature experienced by the plants after emergence compared to other planting dates, thus lower temperature might have reduced allocation of assimilates for growth than the remaining two planting dates. Similar findings have also been reported by Sandhu *et al.* (2012), Singh and Khurana (1997) and Ezekiel and Bhargava (1992). Leaf number per hill was significantly influenced by date of planting and was insignificant in dehaulming schedule and by the interaction between them (Table 1). The highest number of leaf per hill (67.1) was observed in D_2 planting followed by D_1 planting (63.5) and they did not differ significantly with each other. The lowest leaf number per hill (55.4) was recorded in D_3 planting. This can be ascribed due to first two planting dates experienced more favorable environmental conditions apparently longer period than D_3 planting. The leaf number per hill was ranging from 51.1 to 71.8 in the nine treatment combinations but their differences were non-significant. Stem per hill was not significantly influenced by dates of planting and dehaulming and their interactions (Table 1). The stem per hill was ranged from 3.8 to 4.4 in the nine treatment combinations. This might be due to seed tuber size was more or less same. Per cent foliage coverage was not significantly influenced by date of planting, dehaulming schedule and their interaction (Table 1). Around 100% foliage coverage was recorded by the main effects of date of planting, dehaulming schedule and their interaction.

Table 1. Effect of dates of planting and dehaulming on growth of potato

Treatments	Plant emergence (%)	Plant height (cm)	Leaf /hill (no.)	Stem/hill (no.)	Foliage coverage (%)
A. Date of planting					
D_1	99.4	80.7a	63.5a	4.2	100.0a
D_2	99.6	69.1b	67.1a	4.2	100.0a
D_3	99.8	61.1c	55.4b	4.0	99.3b
B. Dehaulming schedule					
M_1	99.6	70.8	62.9	4.2	99.8
M_2	99.4	69.4	62.0	4.3	99.7
M_3	99.8	70.6	61.1	4.0	99.7
Interaction between A & B					
D_1M_1	99.3	80.8	59.2	4.2	100.0
D_1M_2	99.7	79.6	63.1	4.0	100.0
D_1M_3	99.3	81.9	68.1	4.4	100.0
D_2M_1	99.7	69.0	71.8	4.1	100.0
D_2M_2	99.0	70.0	65.4	4.1	100.0
D_2M_3	100.0	68.3	64.2	4.1	100.0
D_3M_1	99.7	62.8	57.7	4.2	99.3
D_3M_2	99.7	58.7	57.4	4.1	99.0
D_3M_3	100.0	61.7	51.1	3.8	99.0
CV (%)	0.79	6.19	8.65	9.29	0.35
SE (A×B)	0.13	1.75	1.51	0.07	0.08

Figure(s) in a column having common letter(s) do not differ significantly at 5% level by DMRT.

D_1 = 31October, D_2 = 15 November & D_3 = 30 November , and M_1 = 80 days after planting (DAP), M_2 = 90 DAP, D_3 = 100 DAP

Grades of tubers

Significantly higher non-processing grade tuber number per hill (4.1) was recorded when the crop was planted at 31 October (D_1) and it differed significantly with the other two planting datesl (Table 2). The data shows that non processing grade tuber number per hill decreased significantly as lengthening the crop growth period by delaying dehaulming (Table 2). The highest number of non processing grade tuber number per hill (3.7) was recorded at M_1 (dehaulming at 80 DAP) and the lowest (2.9) was observed at M_3 (dehaulming at 100 DAP). Similar results were reported by Kumar and Lal (2006). The combined effect of date of planting and dehaulming schedule was significantly influenced non processing grade tuber number per hill (Table 2). The results revealed that non processing grade tuber number per hill was steadily decreased at every planting

dates by the dehaulming schedule except D_3M_3 treatment combination. The highest number of non-processing grade tuber per hill (4.8) was recorded in D_1M_1 closely followed by D_1M_2 (4.6), but the differences were statistically similar. The lowest number of non processing grade tuber per hill (2.7) was observed in D_2M_3 followed by D_2M_2 and D_3M_2. At dehaulming of 80 DAP, the crop period was comparatively short resultant full bulking not completed. As a consequence, non-processing grade tuber number per hill was higher in D_1M_1 and D_1M_2 treatment combination.

For processing grade tuber number per hill, the results were reversed in respect of non processing grade tuber number per hill. Processing grade tuber number per hill was highest (4.9) when the crop was planted at November 15 (D_2) closely followed by D_3 planting, but the differences were non-significant. With regard to dehaulming, processing grade tuber number per hill was the highest (4.8) in M_3 (dehulming at 100 DAP) followed by M_2 (4.5) and M_1 (4.3). The combined effect of date of planting and dehaulming was significantly influenced the processing grade tuber per hill (Table 2). The highest number of processing grade tuber per hill (5.0) was observed in D_2M_2, but it was statistically similar with D_2M_3, D_2M_1, D_1M_3, D_3M_1, D_3M_2 and D_3M_3. The lowest number of processing grade tuber per hill (3.6) was recorded at D_1M_1 which was statistically at par with D_1M_2 (3.7). Total tuber number per hill was not statistically influenced by combined effect of date of planting and dehaulming (Table 2). In that case, total number of tuber per hill was ranged 7.5 to 8.4.

The highest weight of non processing grade tuber per hill (97.5 g) was recorded at D_1 planting and the lowest (70.0 g) was observed at D_2 planting closely followed by D_3 planting (70.9 g) (Table 2). This might be due to lesser growth period was received by the D_1 planting for bulking compared to others that caused smaller size of tuber. The results showed that the increase the crop growth period, the decrease the non-processing grade tuber weight per hill significantly. The highest weight of non-processing grade tuber weight per hill (90 g) was observed at M_1 dehaulming which was at par with M_2 (84.4 g). However, the lowest weight of non-processing grade tuber (64.0 g) was observed in D_3 planting. It might be due to lengthen the crop growth period, which provided more accumulation of photosynthates for tuber bulking resulted more bigger size tuber and lessen the non-processing grade tuber . The combined effect of date of planting and dehaulming was significantly influenced the non processing grade tuber weight per hill (Table 2). The highest weight of non-processing grade tuber per hill (114.4 g) was recorded in D_1M_1 which was also remained at par with D_1M_2 (111.1 g). Whereas, the lowest (67.6 g) was observed in D_3M_2 followed by D_3M_3 (68.0 g) and these were not significant.

Table 2. Effect of dates of planting and dehaulming on yield components of potato

Treatments	Grades of tubers per hill (by number)			Grades of tubers per hill (by wt. (g))		
	<40 mm	≥40 mm	Total	<40 mm	≥40 mm	Total wt.
A. Date of planting						
D_1	4.1 a	4.0 b	8.1	97.5 a	242.6 c	340.1 c
D_2	2.9 b	4.9 a	7.8	70.0 b	327.3 a	396.9 a
D_3	3.0 b	4.8 a	7.8	70.9 b	292.7 b	364.6 b
B. Dehaulming schedule						
M_1	3.7 a	4.2 b	7.9	90.0 a	272.7 c	362.7
M_2	3.4 b	4.5 ab	8.0	84.3 a	286.9 b	371.2
M_3	2.9 c	4.8 a	7.6	63.9 b	303.9 a	367.8
Interaction between A & B						
D_1M_1	4.7 a	3.6 b	8.4	114.4 a	207.8 f	322.1 d
D_1M_2	4.6 a	3.7 b	8.3	111.1 a	231.8 e	342.9 c
D_1M_3	2.9 bc	4.7 a	7.6	67.1 bc	288.3 d	355.4 bc
D_2M_1	3.3 b	4.6 a	7.9	78.4 b	317.6 bc	396.0 a
D_2M_2	2.7 c	5.0 a	7.7	74.1 b	326.7 ab	400.8 a
D_2M_3	2.7 c	5.0 a	7.7	56.5 c	337.5 a	394.1 a
D_3M_1	3.1 bc	4.7 a	7.8	77.0 b	292.9 d	369.9 b
D_3M_2	2.9 bc	5.0 a	7.9	67.6 bc	302.4 cd	370.0 b
D_3M_3	3.0 bc	4.7 a	7.7	68.0 bc	285.8 d	353.8 bc
CV (%)	6.85	7.60	4.74	7.99	3.17	2.45
SE (A×B)	0.15	0.11	0.08	1.13	1.09	1.54

Figure(s) in a column having common letter(s) do not differ significantly at 5% level by DMRT.

<40 mm = Non processing grade tuber, ≥40 mm = Processing grade tuber.

D_1 = 31 October, D_2 = 15 November & D_3 = 30 November , and M_1 = 80 days after planting (DAP), M_2 = 90 DAP, M_3 = 100 DAP.

Processing grade tuber weight per hill was the highest (327.3 g) in D_2 planting followed by D_3 planting (292.7 g) and the lowest (242.6 g) in D_1 planting (Table 2). On the contrary, the results showed that the early the dehaulming, the decrease the weight of processing grade tuber per hill significantly. In that case, the weight of processing grade tuber per hill was ranged between 272.7 to 303.9 g. The maximum weight of processing grade tuber per hill (337.5 g) was recorded in D_2M_3 which was statistically similar to D_2M_2 (326.7 g) while the

lowest (207.8 g) was observed in D_1M_1. Similar to processing grade tuber weight per hill, the highest total weight of tuber per hill (396.9 g) was obtained with D_2 planting, which was significantly higher than all other planting dates (Table 2). However, total weight of tuber per hill did not significantly influence by dehaulming. These results revealed that processing and non processing grade tubers differed due to bulking period that regulates photosynthates transferred to tubers. The results are supported by the earlier findings of Kushwah and Singh (2008). There was significant variation was observed in total weight of tuber per hill by the combined effect of date of planting and dehaulming (Table 2). The highest weight of total tuber per hill (400.8 g) was obtained in D_2M_2 followed by D_2M_1 (399.1 g) and D_2M_3 (394.1 g) and these were not differed significantly. However, the lowest (340.2 g) was observed in D_1M_1.

Yield

Yield of non-processing grade tubers was statistically differed with dates of planting and dehaulming and their interaction (Table 3). The highest yield of non-processing grade tuber (7.2 t/ha) was recorded in D_1 planting, which was significantly higher than the other two planting dates and it was around 32% of the total produce. Similarly, the higher yield of non- processing grade tuber (6.5 t/ha) was obtained with dehaulming at 80 DAP (M_1), which was significantly higher than all other dehaulming dates, it was around 28%. These results corroborate the earlier findings of Singh and Kushwah (2010) where higher production of small size tubers obtained at earlier dehaulming may be due to lesser time available for bulking. The maximum yield of non processing grade tuber (8.8 t/ha) was obtained in D_1M_1 followed by D_1M_2 (8.4 t/ha) and these were statistically similar and it was around 42% and 35% of the total yield, respectively (Table 3). Whereas, the lowest (3.8 t/ha) was observed in D_2M_3 which was around 26%. The data shows that at every planting date, yield of non-processing grade tuber was decreased by the delayed of dehaulming except D_3M_3.

Yield of processing grade tuber was the highest (21.1 t/ha) in D_2 planting which was superior to all other dates of planting whereas percent contribution to total yield did not differ statistically (Table 3). That might be attributed to receive the longer period and optimum cold temperature during the bulking period resultant obtaining higher plant growth with the higher number and weight of tuber per hill. With regard to dehaulming, although a little higher yield of processing grade tuber was recorded at M_3 in comparison to M_2 but these differences were not statistically significant. Whereas, the lowest (16.8 t/ha) was exhibited in M_1 dehaulming. But the percentage of processing grade tuber to total yield did differ statistically (Table 3). There was consistent increase in per cent of processing grade tubers with delay in dehaulming from 80 to 100 DAP and was highest

Table 3. Effect of dates of planting and dehaulming on graded, total and percent of graded yield of potato

Treatments	Grade wise tuber yield (t/ha)			% of grade wise tuber yield	
	<40 mm	≥40 mm	Total	<40 mm	≥40 mm
A. Date of planting					
D₁	7.2 a	14.7 c	21.9 c	31.9 a	68.1 b
D₂	4.7 b	21.1 a	25.8 a	17.6 b	82.4 a
D₃	4.7 b	18.6 b	23.3 b	19.3 b	80.7 a
B. Dehaulming schedule					
M₁	6.5 a	16.8 b	23.3	27.6 a	72.4 c
M₂	5.8 b	18.3 ab	24.1	23.5 b	76.5 b
M₃	4.3 c	19.3 a	23.6	17.6 c	82.4 a
Interaction between A & B					
D₁M₁	8.8 a	11.3e	20.1 d	41.8 a	58.2 e
D₁M₂	8.4 a	14.5 d	22.9 c	35.2 b	64.8 d
D₁M₃	4.5 c-e	18.2 c	22.7 c	18.8 cd	81.2 bc
D₂M₁	5.4 b	20.9 ab	26.3 a	20.1 cd	80.0 bc
D₂M₂	4.7 b-d	21.4 a	26.1 a	17.4 cd	82.6 ab
D₂M₃	3.8 e	21.5 a	25.3 ab	14.3 e	85.7 a
D₃M₁	5.1 bc	18.5 c	23.6 bc	20.9 c	79.2 c
D₃M₂	4.2 de	19.2 bc	23.4 c	17.2 de	82.8 ab
D₃M₃	4.7 b-d	18.1c	22.8 c	19.8 cd	80.2 bc
CV (%)	8.03	5.82	4.39	8.18	2.43
SE (A×B)	0.34	0.64	0.39	1.72	1.72

Figure(s) in a column having common letter(s) do not differ significantly at 5% level by DMRT.

<40 mm = Non processing grade tuber, ≥40 mm = Processing grade tuber.

D₁ = 31 October, D₂ = 15 November & D₃ = 30 November , and M₁ = 80 days after planting (DAP), M₂ = 90 DAP, D₃ = 100 DAP.

(around 82%) when dehaulming was done at 100 DAP then it declined significantly up to 80 DAP. It has been ascribed that the increase the proportion of processing grade tuber probably mainly because of the lengthening the growing period that resulted more accumulation of photosynthates in the tuber and ultimately increase larger tuber. The results are in agreement with Sandhu *et al*. (2012) where they reported that total and processing grade tuber yield

increased significantly as the crop duration was increased from 70 to 90 days. Where the proportion of processing grade tubers yield was increased in 39% and 28% and total yield was increased in 19% and 9% when the crop was dehaulmed at 70 to 80 and 80 to 90 days after planting, respectively. Significant variation was observed among the treatment combinations in processing grade tuber yield (Table 3). The results show that significantly higher yield of processing grade tuber was observed in D_2 planting under all the dehaulming dates. Whereas, the lowest processing grade tuber yield (11.3 t/ha) was recorded in D_1M_1 which was around 58% of the total yield. The data shows that, the processing grade tuber yield was statistically similar in D_2 planting under all the dehaulming dates but their per cent contributions to total yield was statistically differed. The highest proportion of processing grade tuber yield (around 86%) was obtained in D_2M_3 which was statistically similar to D_3M_2 (around 83%) and D_2M_2 (around 83%). Kushwah and Govindakrisnan (1993) reported that maximum tubreization takes place at mean temperatures of day and night about 20^0C and it was inhibited at day temperatures above 29^0C. Our results are in favour of this statement, in D_2M_2 and D_2M_3 treatment combination were received just mean temperatures of around 20^0C in their tuberization and maturation period that might be helped in good processing grade tuber formation and on the contrary in D_3M_3 combination was fetched above 29^0C temperatures resulting the lower processing grade as well as total yield.

The data of the table 3 shows that total yield was followed the exact same trend of processing grade tuber yield. The highest total yield (25.9 t/ha) was recorded in D_2 planting than all other dates of planting. The second highest total yield (23.2 t/ha) was observed in D_3 planting followed by D_1 planting (21.9 t/ha) and these were statistically significant. The lower yield at earlier planting (D_1, 31 October) might be due to exposure of crop to high temperature at the time of planting and early growth period (Roy and Jaiswal, 1998; Singh *et al*., 1974) and has received short duration of low temperature in bulking period. The highest yield at November 15 planting has been reported under similar climatic and edaphic conditions by Akhter *et al*. (2013). The results also corroborated with Singh *et al*. (2004) where they reported that planting at 5 November decreased not only the total and processing grade tubers, but also the percentage of the processing grade tubers in the total tuber yield at Modipuram, India. For dehaulming, it was observed that although a little higher total yield (24.1 t/ha) was recorded in M_2 dehaulming closely followed by M_3 dehaulming (23.6 t/ha) and M_1 dehaulming (23.4 t/ha), these differences were not statistically significant (Table 3). There was significant variation among treatment combinations in total tuber yield (Table 3). The results showed that significantly higher total yield was observed in D_2 planting under all the dehaulming dates and the second higher total yield was recorded in D_3 planting under all the

dehaulming dates except M_3. The results also showed that third higher total yield was recorded in D_1 planting under all the dehaulming schedules except M_1 with the D_3 planting in combination with M_3. Whereas, the lowest total yield (20.1 t/ha) was obtained in D_1 planting with M_1 dehaulming. Short period of low and high prevailing temperature might have limited tuber bulking in D_1 and D_3 planted crop, respectively.

Processing quality parameters

For processing potatoes into chips and French fries, dry matter content should be 20 % or above because it determines the recovery of finished products, oil uptake and energy consumption for frying (Ezekiel *et al.*, 1999; Gaur *et al.*, 1999; Marwaha *et al.*, 2005). Potato tuber dry matter, sugar and reducing sugar content mostly influenced by the varietal genetic make up but environmental and cultural factors are reported to affect the resulting sugar accumulation in freshly harvested tubers (Sowokinos, 1973). The results show that specific gravity and dry matter content were followed the same trend by the date of planting and

dehaulming and their interaction (Table 4). The highest specific gravity as well as dry matter content (1.089 and 22.6 %, respectively) was observed in D_2 planting followed by D_1 planting (1.086 and 22.0%, respectively) whereas, the lowest specific gravity (1.083) and dry matter (21.4 %) was recorded in D_3 planting (Table 4). These findings are in line with earlier works of Akhter *et al.* (2013) who reported higher dry matter and chipping quality were obtained in November 15 planting. In case of dehaulming, both specific gravity and dry matter content (1.087 and 22.3 %, respectively) were higher in tubers M_1 which was at par with M_2 and the lowest (1.085 and 21.7 %, respectively) was obtained in M_3. The highest specific gravity (1.090) as well as dry matter content (22.9 %) was recorded in D_2M_2 followed by D_2M_3 (1.090 and 22.8 %, respectively), D_2M_1 (1.087, and 22.2 %, respectively) and D_1M_1 (1.088 and 22.6 %, respectively). Whereas, the lowest specific gravity (1.081) and dry matter content (21.0 %) was obtained in D_3M_3. It may be occurred in this combination due to slightly higher temperatures in the mid of spring season could have resulted in faster maturity of foliage and lesser translocation of dry matter in tubers in the last phase of crop life which ultimately lower the dry matter content (Kumar *et al.*, 2007; Marinus and Bodlaender, 1975). The level of reducing sugars in potato tuber is an important factor affecting the colour of processed products (Roe *et al.*, 1990). The contents of reducing sugars should be below 200 mg/100g fresh weight for producing acceptable quality chips while for French fries the upper limit may be as high as 500 mg/100g fresh weight (Ezekiel *et al.*, 2003). The results showed that the reducing sugar content was much lower than the acceptable limit for processing into chips and French fries.

Table 4. Effect of dates of planting and dehaulming on processing quality of potato

Treatments	Specific gravity	Dry matter (%)	RS (mg/100 g fresh wt.)	Chip colour score
A. Date of planting				
D_1	1.086 b	22.0 b	36.5 b	3.1
D_2	1.089 a	22.64 a	32.5 c	3.0
D_3	1.083 c	21.4 c	41.1 a	3.2
B. Dehaulming schedule				
M_1	1.087 a	22.3 a	34.9 b	3.1
M_2	1.086 ab	22.0 ab	37.5 a	3.1
M_3	1.085 b	21.7 b	37.6 a	3.2
Interaction between A & B				
D_1M_1	1.088 ab	22.6 ab	37.7 c	3.1
D_1M_2	1.087 b	22.1 b	37.3 c	3.1
D_1M_3	1.083 c	21.4 c	34.5 d	3.2
D_2M_1	1.087 ab	22.2 ab	33.0 e	3.1
D_2M_2	1.090 a	22.9 a	31.7 f	3.0
D_2M_3	1.090 a	22.8 a	32.8 e	3.1
D_3M_1	1.086 b	22.0 b	34.1 d	3.2
D_3M_2	1.082 c	21.1 c	43.5 b	3.2
D_3M_3	1.081c	21.0 c	45.6 a	3.2
CV (%)	0.34	3.73	7.33	8.05

Figure(s) in a column having common letter(s) do not differ significantly at 5% level by DMRT.

D_1 = 31 October, D_2 = 15 November & D_3 = 30 November ; and M_1 = 80 days after planting (DAP), M_2 = 90 DAP, D_3 = 100 DAP ; RS = Reducing sugar

The highest reducing sugar (41.1 mg/100 g fresh wt.) was obtained in D_3 planting followed by D_1, while the lowest (32.5 mg/100 g fresh wt.) was recorded in D_2 planting (Table 4). In case of dehaulming, the highest reducing sugar (37.6 mg/100 g fresh wt.) was obtained in M_3 which was statistically similar to M_2. While the lowest (34.9 mg/100g fresh wt.) was recorded in M_1. The highest reducing sugar (45.6 mg/100 g fresh wt.) was recorded in D_3M_3 followed by D_3M_2, while, the lowest reducing sugar (31.7 mg/100 g fresh wt.) was obtained in D_2M_2 followed by D_2M_3 and D_2M_1. Reducing sugar content was increased in D_3M_2 and D_3M_3 might be due to effect of high soil temperature. Timm *et al.* (1968) reported that sugar content increases if tuber is exposed to soil temperatures above 25^0C. Chips colour, the most important visual criterion for evaluating the quality of fried products, was mainly dependent on Millard

reaction between reducing sugars and amino acids present in the tuber (Roe *et al*., 1990; Marwaha, 1999). The results showed that chips colour scores were remained significantly unaffected by date o planting, dehaulming schedule and their interaction (Table 4). The chips colour scores were around 3 which belong to acceptable range. However, Kumar *et al*. (2003) categorized the chips colour as a score of 1-2 are considered excellent, 3-4 are considered good and >5 is considered unacceptable.

Table 5. Economics of processing potato production as influenced by dates of planting and dehaulming

Treatments	Total cost of production (Tk/ha)	Gross return (Tk/ha)	Net return (Tk/ha)	BCR
D_1M_1	1,80,886	2,22,176	41,291	1.23
D_1M_2	1,80,886	2,66,933	86,048	1.48
D_1M_3	1,80,886	3,00,149	1,19,263	1.66
D_2M_1	1,80,886	3,42,665	1,61,779	1.89
D_2M_2	1,80,886	3,49,290	1,68,404	1.93
D_2M_3	1,80,886	3,45,114	1,64,228	1.91
D_3M_1	1,80,886	3,08,763	1,27,877	1.71
D_3M_2	1,80,886	3,12,447	1,31,561	1.73
D_3M_3	1,80,886	2,98,770	1,17,884	1.65

Considering local market price of 2012-13, Urea, TSP, MOP, Gypsum, Zinc sulphate, Boric acid and cowdung @ Tk 15, 23, 17, 7, 170, 295 and 1/kg, respectively; Seed of potato @ Tk 30/kg, labour @ Tk 300/man-day; Sale of potato @ Tk 15/kg for ≥40 mm and Tk 6/kg for <40 mm size; $D_1 M_1$ = 31 October × 80 DAP; $D_1 M_2$ = 31 October × 90 DAP ; $D_1 M_3$ = 31 October × 100 DAP ;$D_2 M_1$ = 15 November × 80 DAP ; $D_2 M_2$ = 15 November × 90 DAP ; $D_2 M_3$ = 15 November × 100 DAP ; $D_3 M_1$ = 30 November × 80 DAP ; D_3M_2 = 30 November × 90 DAP ; $D_3 M_3$ = 30 November × 100 DAP

Economics

Cost of cultivation were remained same for all the treatment combinations because date of planting and dehaulming dates did not vary any input cost and the requirement of labourers (Table 5). Maximum gross returns (Tk 3,49,290) was recorded in D_2M_2 followed by D_2M_3 (Tk 3,45,114) and D_2M_1 (Tk 3,42,665). The minimum gross return (Tk 2,22,176) was observed in D_1M_1. Net return showed marked difference among the treatment combinations and was followed the same trend of gross return as the total cost of cultivation was remained same in all the treatment combination. Net return was the highest (Tk 1,68,404) in D_2M_2 followed by D_2M_3 (Tk 1,64,228) and D_2M_1 (Tk 1,61,779) while the lowest (Tk 41,291) in D_1M_1. Higher net returns were mainly attributed to higher yield specially processing grade which got premium price associated with that treatment combinations. The maximum benefit cost ratio (BCR) (1.93) was obtained in D_2M_2 closely followed by D_2M_3 (1.91) and D_2M_1 (1.89) while the minimum (1.23) was

in D_1M_1. The cost and return analysis revealed that November 15 (D_2) planting regardless of dehaulming schedule economically superior to November 30 and October 31 planting in terms of net income and BCR.

Conclusion

The above results revealed that processing quality especially dry matter and reducing sugar differed significantly by dates of planting and dehaulming. Processing grade tuber yield were the higher in November 15 planting with all the dehaulming dates with high dry matter content and low reducing sugar. But we can prefer dehaulming at 90 DAP considering higher processing grade tuber yield with higher dry matter including higher net return and BCR. Besides it, the land can be available 10 days earlier for next crops without affecting processing quality and processing grade tuber yield as well as total yield. Based on the results of the experiment, it can be concluded that farmers at the areas of agro-ecological zone 28 can grow potato following November 15 planting time plus dehaulming at 90 days after planting for achieving higher processing grade tuber yield and net returns.

Acknowledgement

References

Akhter, S., M. M. Islam, M. A. K. Azad, M. A. Hakim, M. S. Alam and M. W. Rahman. 2013. Effects of planting time and variety on the yield and processing quality of potato. *J. Food, Agric. and Env.* **11**(1): 401-405.

Braun, J. V. 2010. Food insecurity, hunger and malnutrition: necessary policy and technology changes. *Nat. Biotechnol.* **27**: 449–452.

Burton, W. G. 1989. Yield and content of dry matter: The underlying physiological processes. *In*: The Potato (W.G. Burton, Ed.). Longman Scientific and Technical, New York, USA. Pp. 84-155.

Ezekiel R., B. Singh and D. Kumar. 2003. A reference chart for potato chip colour for use in India. *J. Indian Potato Asso.* **30**: 259-265.

Ezekiel, E. and S. C. Bhargava. 1992. Physiological analysis of growth of potato in relation to planting date. *Indian J. Plant Physiol.* **35**(1): 56-63.

Ezekiel, R., S. C. Verma, N.P. Sukumaran and G.S. Shekhawat. 1999. A Guide to Potato Processors in India. Technical Bulletin No. 48, Central Potato Research Institute, Shimla, India. 39 p.

Gaur, P. C., S. K. Pandey, S. V. Singh and D. Kumar. 1999. Indian potato varieties for processing. Technical Bulletin No. 50, Central Potato Research Institute, Shimla, India. 25 p.

Groves, S, J. Wiltshire, A. Briddon and A. Cunnington. 2005. Managing maturity to improve crop processing quality and storage. Project Report, British Potato Council, London, p 48. Available at: http://www.potato.org.uk/sites/default /files/%5Bcurrent-page%3Aarg%3A%3F%5D/20055%20Managing%20Maturity%20236%20Final%20report.pdf (Accessed 12 December 2012)

Haverkort, A.J. 1990. Ecology of potato cropping systems in relation to latitude and altitude. *Agricultural Systems*. **32**: 251-272.

Hossain, M. M., S. Akhter, M. K. R. Bhuiyan, E. H. M. S. Rahman, M. Hossain and S. N. Begum. 2007. Improved Production Technology of Potato (in Bengali). Tuber Crops Research Center, Bangladesh Agricultural Research Institute,Joydebpur, Gazipur. 6 p.

Krishnappa, K. S. 1991. Effect of planting time on the yield and yield attributes of potato in Eastern Karnataka. *Current Res.* **16**: 239-40.

Kumar, D., S. V. Singh and S. K. Pandey. 2003. Chemical maturity of potato processing cultivars grown in western Uttar Pradesh. *J. Indian Potato Assoc.* **30**(3-4): 225-32

Kumar, D., S. V. Singh, S. K. Pandey, B. P. Singh and S. Rawal. 2007. Effect of growing season on chipping quality of potatoes under sub-tropical climates. *Potato J.* **34**(3-4): 180-86

Kumar, D. and S. S. Lal. 2006. Effect of planting geometry, N and P levels and haulms cutting on the production of small size tubers of potato. *Potato J.* **33**(1-2):97-98.

Kumar, P., B. P. Singh, R. Kumar, K. S. Sandhu, D. Kumar, S. K. Pandey and S. V. Singh. 2014. Optimizing crop geometry in Kufri Chipsona-3 and Kufri Himsona for higher grade tuber yield and quality. *Potato J.* **41**(2):152-159.

Kushwah, V. S. and P. M. Govindakrishnan. 1993. Cultural practices for potato production. *In*: Advances in Horticulture Vol. 7- Potato. K. L. Chadha and J. S. Grewal (eds.). Malhotra Publishing House, New Delhi, India. Pp. 157-177.

Kushwah, V. S. and S. P. Singh. 2008. Effect of intra-row spacing and date of haulm cutting on production of small size tubers. *Potato J.* **35**(1-2): 88-90.

Kushwah, V. S. and S. P. Singh. 2011. Relative performance of low input and high input technology for potato production in India. *Potato J.* **38**(1): 56-60.

Lisinka, G. and W. Leszezynski. 1989. Potato Science and technology. Elsevier Applied Science, England. 391 p.

Marinus, J. and K. B. Bodlaender. 1975. Response of some potato varieties to temperature. *Potato Res.* **18**: 189-204.

Marwaha, R. S., S. K. Pandey, S. V. Singh and S. M. P. Khurana. 2005. Processing and nutritional qualities of Indian and exotic potato cultivars as influenced by harvest date, tuber curing, pre-storage holding period, storage and reconditioning under short Days. Adv. Hort. Sci. **19**(3): 130-40.

Marwaha, R. S. 1998. Factors determining processing quality and optimum processing maturity of potato cultivars grown under short days. *J. Indian Potato Assoc*. **25**(3-4): 95-102.

Marwaha, R.S. 1999. Chipping quality and related processing characteristics of Indian potato varieties grown under short day conditions. *J. Food Sci. Technol*. **36**(2): 157-159.

Muthuraj, R. and G. Ravichandran. 2014. Effect of date of planting on potato seed yield in the Indian southern hills. *Potato J.* **41**(1): 91-93.

Muthuraj, R., G. Ravichandran, K. S. K. Prasad, and S. Singh. 2005. Effect of planting date on seed size tuber yield of potato in Nilgiris. *Potato J.* **32**(3-4): 239.

Nelson N. 1944. A photometric adaption of the Somogy method for determination of glucose. *J. Biol. Chem.* **153:**375-380.

Pandey, S. K., S. V. Singh, D. Kumar, R. S. Marwaha, P. Manivel and P. Kumar. 2008. Performance of newly released Kufri Chipsona-3 Indian potato variety during different crop seasons in west-central plains. *Indian J. Agri. Sci.* **78**(2): 116-21

Peter, J., W. Cerng and L. Hruska, 1988. Yield Formation in the Main Field Crops. Elsevier Publication. Pp. 268-296

Prange, R.K., K.B. McRae, D.J. Midmore, and R. Deng. 1990. Reduction inpotato growth at high temperature: role of photosynthesis and dark respiration. *Amer. Potato J.* **67**: 357-369.

Rodríguez-Falcón, M., J. Bou and S. Prat. 2006. Seasonal control of tuberization in potato. *Ann. Re. Plant Biol.* **57**: 151–80.

Roe, M. A., R. M. Faulks and J. L. Beldtan. 1990. Role of reducing sugars and amino acids in fry colour of chips from potatoes grown in different regimes. *J. Sci. Food Agri.* **52**: 207-214.

Roy, S. K. and V. P. Jaiswal. 1998. Response of potato (*Solanum tuberosum*) to planting dates and nitrogen. *Indian J. Agron.* **43**(4): 484-488.

Sandhu, K. S., G. S. Chinna, R. S. Marwaha, S. K. Pandey, P. Kumar and R. K. Singh. 2012. Effect of staggered planting and dehaulming schedule on yield and processing quality of potato cultivars in Punjab. *Potato J.* **39**(1): 39-47.

Singh, J. and S. C. Khurana. 1997. Effect of date of planting and gibberellic acid on potato seed crop. *Haryana J. Hort. Sci.* **25**: 246-248.

Singh, P., M. Singh, A. K. Singh and J. S. Grewal. 1974. 25th Annual Scientific Report. Central Potato Research Institute, Shimla, India. Pp. 39-41.

Singh, S. P. and V. S. Kushwah. 2010. Effect of size of seed tubers and date of haulm cuttings on production of small seed tubers. *Potato J.* **37**(3-4): 167-170.

Singh, S. V., S. K. Pandey, D. Kumar and P. Kumar. 2004. Optimization of planting time of processing varieties of potato (*Solanum tuberosum*) in relation to yield and quality in west-central plains. *Indian J. Agril. Sc.* **74**(12): 633-636.

Sowokinos, J. R. 1973. Maturation of *Solanum tuberosum* 1. comparative sucrose and sucrose synthetase levels between several good and poor processing varieties. *Amer. Potato J.* **50**: 234-247.

Struik, P. C. and S. G. Wiersema. 1999. Seed Potato Technology. The Netherlands: Wageningen Pers.

Timm, H., M. Yamaguchi, M. D. Clegg and J. C. Bishop. 1968. Influence of high temperature exposure on sugar content and chipping quality of potatoes. *Amer. Potato J.* **45**: 359-65.

Yamaguchi, M., H. Timm and A. R. Spurr. 1964. Effects of soil temperature on growth and nutrition on potato plants and tuberization, composition and periderm structure of tuber. *Proc. Amer. Soc. Hort. Sci.* **84**: 412-23.

FINANCIAL PROFITABILITY OF IMPROVED WHEAT SEED STORAGE AT HOUSEHOLD LEVEL IN SOME SELECTED AREAS OF BANGLADESH

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Abstract

Small and marginal farmers have little access to improved seed from institutional sources and are thus largely excluded from the benefits of new varieties. The production and storage of improved varieties seeds at the household (HH) level can overcome this problem. The study assessed the wheat seed storage systems used at HH level, with a particular emphasis on how the farmers are financially benefited by doing the seed storage business. The study analyzed data collected at random from Cereal Systems Initiative for South Asia in Bangladesh (CSISA-BD) project supported 210 farmers spread over three wheat growing Hubs namely Mymensingh, Faridpur and Rangpur. The study revealed that wheat growing farmers used different types of storage containers and showed the highest level of preference (score 7.2) on plastic/metal drum lining with polythene bag due to lower cost of storage, longevity, and seed quality maintenance. Wheat farmers retained on an average 95.7 kg of improved seed at household level. Majority of the retained seeds at HH level (64%) are being marketed and sold to neighbouring farmers, local markets, and dealers. Wheat seed storage at household level was a profitable business to most of the respondent farmers. They earned a reasonable net income (Tk.420-Tk.1471) from seed storage. The farmers who stored seed in *plastic sac+poly bag* received the highest net income (Tk.1471) due to less storage cost, and higher seed price. Respondent farmers did not face any critical problem during seed storage.

Keywords: Wheat, seed storage, storage system, protection measure, profitability.

Introduction

Wheat is one of the important cereal crops after rice in Bangladesh. It has versatile uses and a very good substitute of rice. The per capita wheat consumption increased to 26.09 gram/day in 2010 from 12.08 gram/day in 2005 at the national level (HIES, 2010). Rice self-sufficiency in Bangladesh is always fraught with uncertainty as the country suffers from different natural calamities. Therefore, to keep pace with the future demand of the growing population, the

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current production and productivity of wheat must be raised for maintaining the country's food security without substantial and unaffordable imports.

The area and production of wheat continuously fluctuated over the years due to various reasons. Its production got a new momentum in the mid '90s and continued up to 1999. During this period, the area, production and yield of wheat registered highly significant positive growth rates due to introduction of modern seed-water-fertilizer technologies (Miah *et al.*, 2015). Unfortunately, the area production and yield of wheat registered highly significant negative growth rates during 2000-2007 (Fig 1).
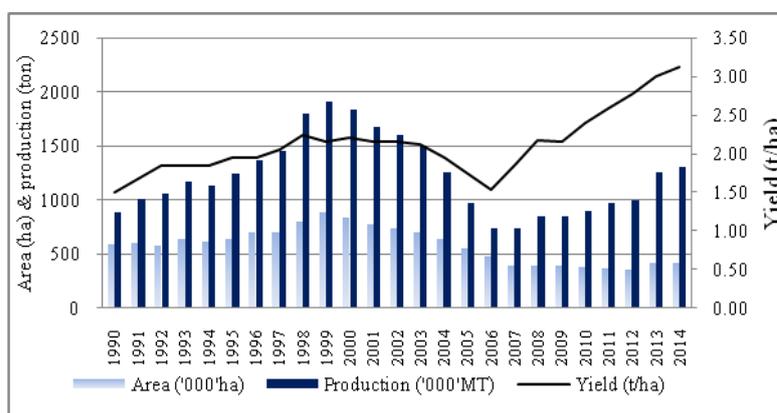

Fig 1. Area, production and yield of wheat in Bangladesh, 1990-2014

Source: BBS, 2011& 2013; www.indexmundi.com (for year 2014).

Many wheat growers started shifting their wheat lands to *Boro* rice during this period (2000-07) because of stable and higher yield, higher return, and for food security (Hussain and Iqbal, 2011). Besides, vast wheat areas were also replaced by maize in this period (Miah *et al.,* 2013). Considering these depressing situations, Bangladesh Government gave due emphasis to increase wheat production throughout the country as a source of sustaining food security. The scientists of Wheat Research Centre (WRC) have developed a number of improved wheat varieties for farm level use. However, due to the initiatives of BARI and CIMMYT and the higher adoption of high yielding varieties at farm level, the area, production and yield of wheat further got momentum from 2007 and started increasing at the rate of 0.94, 7.77, and 6.84% respectively during 2007-2014 (Fig. 1).

Seed security is the key to the attainment of household food security among resource poor farmers in developing countries (Wambugu *et al.,* 2009). In 2015, Bangladesh Agricultural Development Corporation (BADC) produced 27,208 tons of wheat seed which was 48.4% of the total seed requirement (Maswood, 2014; Nuruzzaman, 2015). Food insecure, marginal, and landless farmers have little access to the improved seeds from BADC and are thus largely excluded

from the benefits of any new variety (Page and Jafry, 2007). But, the production and storage of improved varieties of seed at the household level has successfully overcome this problem.

Over the past three years (2011-13), CIMMYT under the CSISA-BD project activities has facilitated the dissemination of the new wheat varieties through seed production and storage trainings, as well as, on-farm trials and demonstrations among small and marginal wheat farmers. Additional supporting activities (e.g. farmer field days, market linkage workshops) were also conducted with the aim of encouraging farmers to store seeds of these new varieties at their level for own use and earning income by selling surplus portion. This 'bottom-up' seed dissemination has enabled hundreds of trained wheat farmers to gain profit from producing and selling high quality seed to neighbours, wheat farmers, relatives, and traders. Therefore, it is now essential to assess the financial gain accrued by the farmers through wheat seed storage and evaluate the knowledge learned in order to inform scale-out efforts designed to reach farmers in other areas.

Objectives

1. To identify and delineate the prevailing systems used in storing wheat seed at the household level in the study areas.

2. To estimate the financial profitability of wheat seed storage at the household level for different storage devices.

3. To explore the problems and prospects encountered with respect to wheat seed storage at the household level and provide some policy recommendations.

Materials and Method

Method of data collection and period of study: Data for the present study were gathered from both primary and secondary sources. Primary data were collected from selected farmers with the aid of a pre-tested interview schedule during February-April, 2015. CSISA-BD project personnel in respective district assisted researchers and enumerators in collecting the required primary data. Secondary data were collected from different published sources, such as Bangladesh Bureau of Statistics (BBS), journal articles, and internet services.

Sampling procedure and sample size: The improved wheat seed storage and distribution activities of the CSISA-BD project were launched in the three hubs namely Mymensingh, Faridpur and Rangpur. Therefore, the above mentioned hubs were purposively selected for this study. Secondly, Trisal, Mymensingh Sadar, and Iswargonj Upazilas under Mymensingh hub, Nagorkanda, Kashiani, and Faridpur Sadar Upazilas under Faridpur hub, and Pirgonj, Nilphamari Sadar, Lalmonirhat Sadar, and Rajarhat Upazila under Rangpur hub were also purposively selected for this study. Before selecting sample respondents, a

complete list of improved wheat seed storing farmers was prepared with the help of CSISA-BD project personnel working under respective hubs. Finally, a total of 210 small and marginal (having land size 0.50-2.49 acres) project supported wheat farmers[2] taking 70 farmers from each hub were randomly selected from the list for interview.

Analytical technique: The collected data were edited and tabulated for analysis. Descriptive statistics were mostly used in analysing collected data and information. The cost of storage included the annual cost of container and protection measures. Due to very small number of samples, protection cost was not considered to calculate net income from storage. The annual cost of a container was calculated by estimating depreciation cost applying straight-line method for one year. In this study, the salvage value of storage container was reported to be zero.

Again, the gross income of storage was estimated by multiplying the quantity stored (kg/farm) with increased price (Tk/kg) of seed due to storage. Increased price is the difference between two prices that prevailed during seed selling and seed storing.

Results and Discussion

Distribution Pattern of Wheat Grain and Seed

In 2013-2014, sample farmers in the study areas produced on an average 894 kg of wheat of which 11.52% was retained for seed and the rest wheat grains were sold and consumed at household level. The purposes of retaining seed were to ensure quality seed for own use, getting higher price, timely sowing of seed, higher yield, meet up the costs of cultivation and inputs of wheat or the next crop (Miah *et al.,* 2015). They sold 64% of seed to others and used 32% seed for their own cultivation. A small percentage (4%) of seed was also consumed in the case of unsold or time of need (Table 1).

Respondent farmers sold seed to neighbouring farmers, other farmers at local market, and local fertilizer/pesticides dealers[3]. Data in Table 2 show that 60% seeds were sold to the neighbouring farmers, 31% to other farmers at local markets, and 9% to local fertilizer & pesticides dealers. Farmers received higher price (Tk.40/kg) when they could sell seed to dealers and received the lowest price (Tk.31.1/kg) when they sold it to local markets. Again, most respondent farmers could sell their new variety seed to the neighbouring farmers at higher price (Tk.34.3/kg). Neighbouring farmers and local dealers usually pay higher

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[2] Supported farmers were those wheat farmers who took supports like seed storage training, storage device, and improved wheat seed from CSISA-BD project.

[3] Some local fertilizer/pesticides dealers in the study areas collect seed of improved variety wheat from known farmers and sell them at higher price.

price for improved variety seed only because of better confidence about seed quality.

Table 1. Wheat grain and seed use pattern at household level during *rabi* season, 2013-2014

Particulars	Mymensingh (*n=70*)	Faridpur (*n=70*)	Rangpur (*n=70*)	All area (*n=210*)
1. Average wheat area (ha/HH)	0.247	0.268	0.178	0.246
2. Average production (kg/HH)	1007	1028	648	894
3. Yield (ton/ha)	4.08	3.84	3.64	3.63
4. Use of grain (kg/HH)	891 (100)	906 (100)	577 (100)	791 (100)
a. Sale	763 (86)	646 (71)	528 (92)	646 (82)
b. Consumption	128 (14)	260 (29)	49 (8)	145 (18)
5. Use of seed (kg/HH)	116 (100)	122 (100)	71 (100)	103 (100)
a. Own use	44 (38)	33 (27)	21 (30)	33 (32)
b. Sale	68 (58)	83 (68)	48 (67)	66 (64)
c. Consumption	3 (3)	6 (5)	2 (3)	4 (4)
d. Gifted to others	1 (1)	--	--	--

Note: Figures in the parentheses indicate the percent of total production. HH= Household.

Table 2. Distribution pattern of sold seed and price received in 2013-2014

Study area	Farmer		Local market		Local dealer		Total quantity sold (kg/HH)
	Quantity sold (kg/HH)	Price (Tk/kg)	Quantity sold (kg/HH)	Price (Tk/kg)	Quantity sold (kg/HH)	Price (Tk/kg)	
Mymensingh	46.2 (68)	41.3	4.6 (7)	39.1	17.4 (25)	40.0	68.2 (100)
Faridpur	40.9 (49)	28.4	41.9 (51)	27.6	--	--	82.8 (100)
Rangpur	32.4 (68)	35.7	14.3 (30)	32.8	1.2 (2)	40.0	47.9 (100)
All area	39.8 (60)	34.3	20.3 (31)	31.1	6.2 (9)	40.0	66.3 (100)

Note: Figures in the parentheses indicate the percentages of total quantity. HH= Household.

Preference of Storage Systems

The respondent farmers were asked to give preference scores that ranged from 1 to 8 considering seed quality maintenance (color and luster), cost, availability, longevity, and usability. The average score on preference ranking was found to be the highest for *metal/plastic drum* (7.2) due to cost effectiveness and getting better quality seed. The next best preferred devices were *metal/plastic drum+poly bag* (7.1), *plastic sac+poly bag* (6.0), and *jute sac+poly bag* (5.2). The lowest preference was reported to be on using *jute sac* and *plastic sac* alone (Table 3). The most crucial causes of dissatisfaction (low preference) were the possibility of damaging the container by rats and inclusion of air in the container. Some wheat farmers also mentioned that the use of jute or plastic sac needed 2/3 times checking of seed in a season, possibility of insect-pest infestation, and quality deterioration of seed.

Table 3. Average score on preference ranking for different storage devices

Study area	Types of storage devices							
	Jute sac	Plastic sac	Poly bag	Plastic sac + poly bag	Jute sac + poly bag	Metal/plastic drum	Drum + poly bag	Earthen pot
Mymensingh	1.3	2.7	3.6	5.3	5.6	7.1	7.5	2.8
Faridpur	1.1	2.6	3.7	6.4	4.6	7.2	6.9	3.5
Rangpur	1.1	2.6	3.7	6.1	5.3	7.3	6.8	3.0
All area	1.1	2.6	3.7	6.0	5.2	7.2	7.1	3.1

Note: Score ranged from 1.0 to 8.0. Scores 1 and 8 mean the lowest and highest choice/preference, respectively.

Quantity of Wheat Seed Stored

Quality character of wheat seed is influenced by various factors such as germination rate, moisture content, color and seed-borne fungal prevalence during storage (Malaker *et al.,* 2008). Type of storage container is one of the important factors that determine the quality of seed to a great extent. Respondent farmers stored wheat seed using different types of containers with different techniques. At least eight types of different storage containers were reported to use by the sample farmers. Among these devices, plastic/metal drum, jute sac, and plastic sac along with poly bag were highly used by the wheat farmers. Table 4 revealed that the highest percentage of farmers (44%) stored on an average 98.2 kg of wheat seed using *plastic/metal drum+poly bag* followed by stored 99 kg of wheat seed using *jute sac+poly bag*. The highest amount of wheat seed was stored per household through *plastic sac + poly bag*, although the number of users was low compared to other devices. However, the average storage quantity and duration were 95.7 kg/HH and 31.4 weeks, respectively.

Table 4. Quantity of wheat seed stored and storage duration using different storage devices

Storage device	% of HH	Quantity stored (kg/HH)	Storage duration (week)	Storage loss (kg)
1. Plastic/metal drum+ poly bag	44 (92)	98.2	30.8	2.0 (1)
2. Jute sac + poly bag	42 (89)	99.0	32.0	3.0 (3)
3. Plastic sac + poly bag	7 (15)	118.3	30.7	--
4. Plastic sac	0.5 (1)	80.0	28.0	--
5. Jute sac	0.5 (1)	40.0	28.0	5.0 (1)
6. Poly bag	0.5 (1)	35.0	31.0	
7. Earthen pot	5 (10)	40.6	32.2	--
8. Other device	2 (4)	50.0	31.8	
Average	--	95.7	31.4	--

Note: Other device includes jar cane, biscuit tin, and soybean oil container. Figures in the parentheses indicate number of respondent farmer. HH= Household.

Type of Protection Measures Adopted

In the case of air tight container and appropriate moisture content of seed, no protection measure is needed for getting quality seed. However, the wheat farmers of Mymensingh and Faridpur took some protection measures against insects. Among different protection measures, the dust/powder of *Neem* leaves was highly used by the farmers (17.1%) as protection measure in the study areas. Usually, no cost was involved with this traditional measure. However, the average costs incurred for other less used protection measures ranged from Tk.15 to Tk. 72 per household (Table 5).

Table 5. Farmers' responses on protective measures taken against pests during storage

Protective measures	% respondents opined				Average cost	
	Mymensingh (n=70)	Faridpur (n=70)	Rangpur (n=70)	All area (n=210)	Tk/HH	Tk/kg
1. *Neem* leaf powder	35.7	15.7	--	17.1	--	--
2. *Biskatali* leaf powder	4.3	--	--	1.4	--	--
3. White powder	4.3	1.4	--	1.9	57.9	0.61
4. Phostoxine	2.9	1.4	--	1.4	62.5	0.65
5. Naphthalene	--	7.1	--	2.4	15.3	0.16
6. Insecticides	2.9	--	--	1.0	16.7	0.17
7. Others*	2.9	18.5	--	7.2	--	

Note: Others included sand, ash, rice bran, tobacco powder

Profitability of Seed Storage at Household level

Wheat seed storage at household level was opined to be a profitable business to most of the respondent farmers. On an average, supported and non-supported farmers stored about 97.2 kg and 90.5 kg of seed per season, respectively. The range of increased seed prices due to storage was found to be Tk.10.9 to Tk. 12.7 for supported farmers, whereas it was Tk. 9.4 to Tk. 17.1 for non-supported farmers. The higher increased price received by supported farmers might be due to improved variety and reliability of seed producers. On an average, supported and non-supported farmers earned gross income of Tk. 1223 and Tk. 1157, respectively.

The average annual cost of storage device or container was more or less same for both categories of farmers. The highest cost incurred for *jute sac+poly bag* (Tk.32.9) and the lowest cost was for *earthen pot* (Tk.23.0) might be due to the low longevity and low price of the devices respectively. Again, the cost of storage device per kilogram of seed was estimated the lowest for plastic/metal drum for both categories of farmers. The unit price of plastic or metal drum was

reported to be high in the study areas and many respondent farmers had no capacity to purchase it. However, the annual cost for *plastic or metal drum* was low which was about Tk.26 per year. This lower price was attributed to higher longevity of the device (Table 6).

The wheat seed storing farmers earned, on an average, gross income of Tk. 1233. The average net return was Tk.1204. The farmers who stored seed in *plastic sac+poly bag* system received the highest net income (Tk.1471/HH) followed by the method storing seed in *plastic/metal drum* due to storing higher quantities, less storage cost, and higher price. Storing wheat seed in earthen pot generated the lowest net return for the farmers. The farmers who stored seed in poly bag or jute sac also received lower net return.

The average net returns received by supported and non-supported farmers were Tk.1194 and Tk. 1127, respectively. The non-supported farmers who stored seed in *plastic/metal drum* received the highest net income (Tk.1817/year) due to store higher quantities, less storage cost, and higher price of seed. Again, the supported farmers who stored seed in *plastic sac+poly bag* received the highest net income (Tk.1471/year) due to store higher quantities of seed (Table 6).

Table 6. Profitability of wheat seed storage under different storage devices in 2014

Storage device	N	Quantity stored (kg/farm)	Price before storage (Tk/kg)	Increased price due to storage (Tk/kg)	Gross income from seed sold (Tk/farm)	Cost of storage device		Net income (Tk/farm)
						Tk/year	Tk/kg	
A. Supported farmer	*206*	*97.2*	*21.7*	*12.58*	*1223*	*28.3*	*0.32*	*1194*
1. Plastic sac + poly bag	15	118.3	21.1	12.7	1502	31.1	0.26	1471
2. Jute sac + poly bag	89	99.0	22.3	11.1	1099	32.9	0.33	1066
3. Plastic/metal drum	92	98.2	21.3	14.6	1429	26.3	0.27	1403
4. Earthen pot	10	40.6	21.1	10.9	443	23.0	0.57	420
A. Non-supported farmer	*61*	*90.5*	*20.7*	*12.78*	*1157*	*29.6*	0.33	*1127*
1. Plastic sac + poly bag	10	57.5	21.1	13.9	799	31.1	0.54	768
2. Jute sac + poly bag	23	72.4	20.6	9.4	681	32.9	0.45	648
3. Plastic/metal drum	26	122.9	20.5	15.0	1843	26.5	0.22	1817
4. Earthen pot	2	42.5	21.2	17.1	727	23.0	0.54	704

Note: Others included kerosene tin, edible oil jerkin, biscuit tin, etc.

   Due to very small number of sample, protection cost was not considered in calculating net income

The income earned from seed storage was spent for different purposes. The net income was mostly spent for land preparation (45%), buying inputs for wheat cultivation (18%), purchase of food items (16%), other expenses (14%), and spent for education (Table 7).

Table 7. Pattern of farmers' seed storage income utilization on different items in 2014

Expenditure head	Average amount spent (Tk.)			
	Mymensingh	Faridpur	Rangpur	All area
1. Met up land preparation cost	1376 (40)	1399 (57)	852 (38)	1209 (45)
2. Purchase food items	733 (21)	190 (8)	363 (16)	418 (16)
3. Purchase fertilizers	269 (8)	236 (10)	210 (9)	238 (9)
4. Expenses for education	256 (7)	286 (12)	25 (1)	189 (7)
5. Purchase agricultural instrument	--	7 (0)	588 (26)	199 (7)
6. Settle irrigation cost	110 (3)	84 (3)	--	64 (2)
7. Other expenses	694 (20)	265 (11)	197 (9)	377 (14)

Note: Figures in the parentheses indicate percent of total income

Problems of Seed Storage

Both supported and non-supported farmers faced different problems to some extent during seed storage. About 17% households did not have plastic tripals for drying wheat seed. Some respondent farmers faced problem with scavenging poultry and birds during seed drying (5.2%). However, some of the supported farmers were found to use old variety (6.3%), not rouging their wheat plot (7.0%), use traditional device in seed storage (4.8%), and placing seed container on ground (Table 8). These are some factors of good storage of seed. Most wheat farmers dried wheat grain properly before retaining it as seed. Some farmers dried seed on tripal which were made of plastic or cement bags. Some farmers dried seed on ground (covered with cowdung solution). They had little access to *Pacca Chatal* for drying seed.

Table 8. Problems faced by sample wheat storage households in the study areas

			(% of responses)
Problem faced	Supported farmer *(n=210)*	Non-supported *(n=60)*	All category *(n=270)*
Lack of tripal for drying	14.3	26.7	17.0
Attack of poultry and birds	5.2	5.0	5.2
Using old wheat variety	4.8	11.7	6.3
Practice no roughing	6.7	8.3	7.0
Use traditional storage container	4.3	6.7	4.8
Placing seed container on ground	1.4	1.7	1.5

Conclusions and Recommendations

Conclusions

The study assessed the wheat seed storage systems used at household level, with a particular emphasis on how the farmers are financially benefited by doing the seed storage business. On average, wheat production was about 900kg/HH; and out of the three study areas trend in production was better in Faridpur area probably due to better soil fertility. The bulk of the total outputs at farm level (82%) are being marketed. In the case of stored seed, nearly 64% are often sold out by the households. The wheat farmers in the study areas use nine types of storage containers and show the highest level of preference on plastic/metal drum and plastic/metal drum along with poly bags due to cost effectiveness and better quality seed. They sell most of their seeds to neighbouring farmers, local markets, and dealers. Wheat seed storage at household level is a profitable business to most of the sample farmers. They can earn a reasonable net income (Tk.1127-Tk.1194/HH) from seed storage. The farmers who stored seed in plastic/metal drum receive the highest net income due to higher storage capacity, less storage cost, and higher seed price. Respondent farmers did not face any critical problem during seed storage.

Recommendations

Based on the above findings, the following recommendations are made.

(i) Most marginal farmers do not have capability to buy plastic/metal drum. Therefore, interested small and marginal wheat farmers should be provided plastic/metal drum with subsidized price.

(ii) Present study strongly recommends that the existing training and seed dissemination program should be extended to other new and promising areas for fostering wheat cultivation as well as improving farmers' income in Bangladesh.

References

BBS. 2011. *Yearbook of Agricultural Statistics of Bangladesh*, Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division, Ministry of Planning, Dhaka, Bangladesh.

BBS. 2013. *Statistical Yearbook of Bangladesh*, Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division, Ministry of Planning, Dhaka, Bangladesh.

HIES. 2010. Household Income and Expenditure Survey 2010, Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division, Ministry of Planning, Dhaka, Bangladesh.

Hussain, S. G. and A. Iqbal. 2011. Research priorities in Bangladesh agriculture. Report submitted to Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka.

Malaker, P.K, I.H. Mian, K.A. Bhuiyan, A.M. Akanda and M.M.A. Reza. 2008. Effect of storage containers and time on seed quality of wheat. *Bangladesh J. Agril. Res*. **33**(3): 469-477, September 2008.

Maswood, M.H. 2014. BADC's seed production capacity underutilised. The Daily NewAge, July 24, 2014. Last accessed: June 09, 2015 on http://newagebd.net/34264/badcs-seed-production-capacity- underutilised/ #sthash. KGXjHiRQ.dpuf

Miah, M.A.M., T.M.B Hossain, M.A. Matin, S. Hossain, Moniruzzaman and R.Kumar. 2013. Assessments of the maize situation, outlook and investment opportunities to ensure food security in Bangladesh. Research report submitted to National Academy of Agricultural Research Management (NAARM), Indian Council of Agricultural Research (ICAR), Hyderabad, Andhra Pradesh, India.

Miah, M.A.M., Q.M.S. Islam, M.E. Baksh, F.J. Rossi, and T.P. Tiwari. 2015. Socioeconomic impacts of wheat seed storage at household level in Bangladesh. In: Annual Research Report 2014-15, Agricultural Economics Division, BARI, Gazipur. Research report submitted to CIMMYT-Bangladesh, 2015.

Nuruzzaman, 2015. The seed marketing channels of BADC. Internship report submitted to the Department of Business Administration, Green University of Bangladesh. January, 2015. Last accessed: June 09, 2015 on http://www.slideshare.net/ nuruzzamanmahd/internship-rep

Page, S. L. J. and T. Jafry. 2007. Proceedings of technical review and planning workshop: "Assessing the impact of resource conserving technologies in the indo-gangetic plain: identifying agricultural knowledge systems and overcoming blockages to enhance uptake of agricultural technologies to optimize pro-poor development" 5-7 May 2004, Hotel Eastern Residence, Banani, Dhaka, Bangladesh. CABI-Europe, Egham, UK (2007), 43 Pp.

Wambugu, P. W., P. W. Mathenge, E. O. Auma and H.A.V. Rheenen. 2009. Efficacy of traditional maize (*Zea mays L.*) seed storage methods in Western Kenya, in African. African Journal of Food, Agriculture, Nutrition and Development. **9**(4): 1110-1128.

OPTIMUM SAMPLING PLAN OF YIELD CONTRIBUTING CHARACTERS OF POINTED GOURD

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Abstract

To improve efficiency in collecting data from field experiment on fruit attributes of pointed gourd (Patal) the sample size was studied for determining optimum sample size at Olericulture Division, Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI) Gazipur during 2013-14. Fruit length, breadth and weight data were used to design optimum sampling plan for equal number of observations per cell. The observation on fruit length (cm), breadth (cm) and weight (gm) were taken from 7 plots/treatments at random. A randomized complete block design (RCBD) with 2 replications and seven treatments/varieties were used in this experiment. A sampling plan of selecting 3 plants at random and measuring 9 fruits per selected plant (27 fruits per plot and plots were 5m^2 i.e. 2.5m long and 2m wide) was found to be optimum and economy for the measurement of fruit attributes of pointed gourd. It saves time required for constant vigilance opening of flower and subsequent observations.

Keywords: Optimum sample size, Sampling technique, Relative efficiency, Variance component and Pointed gourd.

Introduction

Pointed gourd (*Trichosanthes dioica*) locally known as 'patal' is a common vegetable and its yield depends on various characteristics like fruit length, breadth, weight etc. Determination of optimum sample size is a major issue and challenge in any field experiment. According to Islam *et al*. (2000), it is necessary to determine the optimum samples as well as optimum number of replications for collecting data under any sampling plan in a field experiment. In any field experiments, it is necessary to determine the optimum sample size as well as optimum number of replications if researchers have to use sampling techniques for collecting data from such experiments (Islam *et al.,* 2000). Frequently, it is not possible to measure yield and yield contributing characteristics on the whole of each experimental unit. In any field experiment, the researcher has to face the problem in determining optimum (efficient) sample size for measuring plant characters (Federer, 1963) and (Islam, 2001). The optimum sampling technique depends on the variability associated with variable and the cost of reducing the variability (Kempthorne ,1952). Rigney and Nelson

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(1951) in cotton, Patel and Dalal (1992) in okra and Hossain *et al.* (2005) in Brinjal, Hossain *et al.* (2008) in Teasle gourd, Islam *et al.* (2012) in Sweet gourd , Islam *et al.* (2013) in Bitter gourd and Mohammad *et al.* (2015) in Bottle gourd estimated sample sizes on their respective plant characters. No such information is available for patal. As such the researchers are intended to conduct a field experiment deals with sample size study in pointed gourd particularly for taking measurements of fruit character like length, breadth and weight of patal. The investigation was carried out at Horticulture Research center (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2013-2014. The objective of the study is to find out optimum sample size for estimating yield contributing characters of patal through proper field experiment.

Material and Method

Estimation of sample sizes depend on number of variables, replications and cost involvement in an experiment. Because an experimenter is always intended to reduce the cost and time of the experiment. Thus, it is necessary to choose optimum sample size and number of replications in a good experiment. Estimation of optimum sample size and number of replications are obtained by maximizing the information for a given cost.

The experiment was conducted at Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2013-2014. There were seven treatments/varieties used as treatment in this experiment. The treatments/varieties were PG014xM1, PG008xM2, PG009xM2, BARI Patal-2, PG018xM2, PG027xM2 and BARI Patal-1. Experimental plot was 5m^2 (2.5m long and 2m wide) and spacing was (1.5 x1.0)m. Fruit length, breadth and weight of pointed gourd (Patal) data were collected from the experimental plot. This data were used to calculate optimum sampling plan from equal observation per cell. The observation on fruit length (cm), breadth (cm) and weight (gm) were taken from 7 plots or treatments selected at random. The fruit length, breadth and weight of ten fruits from each selected plant utilized in this analysis. There were 30 fruits (3 plants per plot x 10 fruits per plant) per plot and 210 fruits per replication. Considering the time factor, the data of two replications were collected for deriving optimum sampling plan (Optimum in the sense of time involved in taking fruits measurements). A randomized complete block design (RCBD) with 2 replications was used for this experiment. The data were analyzed replication wise by two-way analysis of variance (ANOVA) technique (Table 1) to estimate variance components associate with plots ($\hat{\sigma}_p^2$) , plants ($\hat{\sigma}_q^2$) and fruits ($\hat{\sigma}_n^2$).

Analytical Model

According to the objective of the study of a field experiment should be conducted using a proper statistical model. In this experiment p treatments (plots) are taken

at random, then q plants are selected randomly from each treatment of n sampling unit.

Therefore, the statistical model is as

$$Y_{ijk} = m + a_i + \beta_{ij} + \eta_{ijk} \tag{1},$$

where, i= 1, 2 …...... p, j = 1, 2, ……,q and k = 1, 2, ….., n

where

m = the general mean

α_i=the treatments effect

β_{ij} = the plants effect due to the (ij)th experimental unit.

η_{ijk} = the sampling effect due to the (ijk)th observation

For the study we suppose that the η_{ijk}'s are normally and independently distributed with variance σ_n^2, β_{ij}'s are normally and independently distributed with variance σ_q^2 and α_i's are normally and independently distributed. The η_{ijk}'s will be independent of the β_{ij}'s and α_i's if the sampling random.

The least square estimates are obtained as follows:
$$\hat{m} = \bar{y}...$$
$$\hat{a}_i = (\bar{y}_{i...} - \bar{y}...)$$
$$\hat{\beta}_{ij} = (\bar{y}_{ij.} - \bar{y}_{i...})$$
$$\hat{\pi}_{ijk} = (\bar{y}_{ijk} - \bar{y}_{ij.})$$

Also

$$\bar{y}_{...} = \frac{\sum_{j=1}^{p} \sum_{j=1}^{q} \sum_{k=1}^{n} y_{ijk}}{pqn} \quad \bar{y}_{i...} = \frac{\sum_{j=1}^{q} \sum_{k=1}^{n} y_{ijk}}{pn} \quad \bar{y}_{ij...} = \frac{\sum_{k=1}^{n} y_{ijk}}{n}$$

Putting these values in equation (l) and squaring and summing on both sides. Then the total sum of squares can be partitioned as:

$$\sum_{i=1}^{p}\sum_{j=1}^{q}\sum_{k=1}^{n}(y_{ijk} - \bar{y}_{...})^2 = nq\sum_{i=1}^{p}(\bar{y}_{i...} - \bar{y}_{...})^2 = n\sum_{i=1}^{p}\sum_{j=1}^{q}(\bar{y}_{ij} - \bar{y}_{i...})^2 + \sum_{i=1}^{p}\sum_{j=1}^{q}\sum_{k=1}^{n}(y_{ijn} - \bar{y}_{ij..})^2 + producttern$$

But product terms are usually zero.

Thus, Total (SS)= Treatment (SS) + Plant (SS)+ Sampling (SS)

With their degrees of freedom (npq-1) = (p-1) + p (q-1) + pq (n-1)

Table 1. The analysis of variance

Sources of Variation (SV)	Degrees of Freedom (D.F.)	Sum of Squares (S.S)	Mean Sum of Squares (MSS)	Expected Mean Sum of Squares (EMSS)
Plots/Treatment (Levels A)	$(p-1)$	$nq\sum_i\left(\overline{y_{i..}}-\overline{y_{...}}\right)^2 = S_p^2$	$\dfrac{S_p^2}{(p-1)}=T$	$\sigma_n^2+n\sigma_q^2+nq\sigma_r^2$
Plants/Plot(Level B within A)	$p(q-1)$	$n\sum_i\sum_j\left(\overline{y_{i..}}-\overline{y_{...}}\right)=S_q^2$	$\dfrac{S_q^2}{p(q-1)}=p$	$\sigma_n^2+n\sigma_q^2$
Fruits/Plant/Plot Sampling	$pq(n-1)$	$\sum_i\sum_j\sum_k\left(y_{ijk}-\bar{y}_{ij}\right)^2=S_n^2$	$\dfrac{S_n^2}{pq(n-1)}=S$	σ_n^2
Total	$pqn-1$	$\sum_i\sum_j\sum_k\left(\overline{y_{ijk}}-\overline{y_{...}}\right)^2$		

Where, p = number of plot or treatment, q = number of plants/plot and, n = number of fruits/plant/plot. Also T= The mean sum of square of Treatment, P= The mean sum of square of Plant, S= The mean sum of square of Sampling respectively.

According to estimation of optimum sampling plan, Snedecor and Cochran (1967), the variance component may be estimated as.

The components of variance $\sigma_n^2, \sigma_q^2 and \sigma_p^2$ estimated by

$$\hat{\sigma}_n^2 = S, P = \bar{\sigma}_n^2 + n\sigma_q^2 and\ T = \sigma_n^2 + n\sigma_q^2 + nq\sigma_p^2 \text{ i.e.}$$

$$\hat{\sigma}_q^2 = \frac{P-S}{n} and\ \hat{\sigma}_p^2 = \frac{T-P}{nq}$$

Estimation of optimum sampling plan

The concept of variance of mean $(S^2_{\bar{y}})$ was used in driving optimum sampling plan (Patel & Dalal, 1992).

Thus variance of mean ($S^2\bar{y}$) is worked out using the relation:

$$S_y^2 = \frac{\hat{\sigma}_p^2}{P} + \frac{\hat{\sigma}_q^2}{pq} + \frac{\hat{\sigma}_n^2}{npq} \tag{2}$$

$\hat{\sigma}_p^2, \hat{\sigma}_q^2$ and σ_q^2 for the character were obtained from the analysis of variance table.

The same variance of mean can be altered for the mean by using various combinations of q and n in equation (2)

$$S_{\bar{y}}^2 = \frac{\hat{\sigma}_p^2}{p} + \frac{\hat{\sigma}_q^2}{pq'} + \frac{\hat{\sigma}_n^2}{n'q'p} \tag{3},$$

where q´ and n´ are the altered values of q and n respectively.

The component $\hat{\sigma}_p^2$ was assumed as constant, as it represented variation due to treatments.

Efficiency of new sampling plan,

$$E = \frac{S_{\bar{y}}^2}{S_{\bar{y}}'^2} \tag{4},$$

The formula of saving the work/time load i.e time factor (TF) without sacrificing precision as compared with original plan i.e 30 fruits (3plant/plot x 10fruits/plant) per plot is defined as

$$TF(\%) = \frac{q'n' - qn}{q'n'} \times 100 \tag{5}$$

where, q´=3, n´=15, q=1,2,------,3 and n=1,2,-------,10. In this experiment, 30 fruits per plot is considered as the control or original plan.

Results and Discussion

In search of alternative sampling plan, a total of 45 sampling plants per plot have been investigated for the value of q from 1 to 3 plant per plot and from 1 to 15 fruits per plant. The estimated variance components under two-way classification model of equation 1 are shown in the Table 2.

Table 2. The estimated variance components for plots ($\hat{\sigma}_p^2$), plants ($\hat{\sigma}_q^2$) and fruits ($\hat{\sigma}_n^2$)

Variance component	Fruit Length	Fruit Breadth	Fruit Weight
$\hat{\sigma}_p^2$	0.12	2.58	2.07
$\hat{\sigma}_q^2$	0.03	0.25	0.17
$\hat{\sigma}_n^2$	25.97	276.18	183.37

The relative efficiency of each plants both for original plan (3 plants per plot and 10 fruits per plants). Using equation-4 the relative efficiency of new alternate sampling plans is given in Table-3. The computed relative efficiency and TF (%) are given in the Table 3.

The other alternate plan with 3 plant per plot and 9 fruits per plant (total 27 fruits per plot) had also 98.80 percent efficiency in comparison to original plan but had 10 percent less amount field work (Using equation 5). The other plan which can be employed with same efficiency is to select 3 plants at random per plot and measure 8 fruits each selected plant (24 fruits per plot) had 97.47 but work load will be about 20 percent less than the plan with 3 plants x 10 fruits per plot.

The results revealed that work load for field operation like lagging of flowers, harvesting and measurement of individual fruit could be reduced effectively without sacrificing efficiency by selecting proper sampling plan.

Table 3. The relative efficiency for some of the alternative sampling plants

Number of		Fruit Length (cm)	Fruit Breadth (cm)	Fruit Weight (cm)	Average over traits	Work/Time load (%)
Plants per plot	Fruits per plant					
1	12	35.82	40.45	38.46	38.24	60
1	13	35.99	40.60	38.60	38.40	57
1	14	36.13	40.73	38.73	38.53	53
1	15	36.26	40.85	38.83	38.65	50
2	10	67.99	72.78	70.47	70.41	33
2	11	68.41	73.13	70.81	70.78	27
2	12	68.77	73.42	71.10	71.11	20
2	13	69.07	73.67	71.34	71.36	13
2	14	69.34	73.88	71.56	71.59	7
2	15	69.57	74.07	71.74	71.79	0
3	**7**	**95.40**	**98.00**	**96.31**	**96.57**	**30**
3	**8**	**96.51**	**98.82**	**97.14**	**97.47**	**20**
3	**9**	**98.38**	**99.77**	**98.20**	**98.80**	**10**
3	**10**	**100**	**100**	**100**	**100**	**0**
3	11	98.68	100	98.78	99.29	10
3	12	99.18	100.43	99.15	99.71	20
3	13	99.60	101.11	99.47	100.06	30
3	14	99.97	101.37	99.74	100.36	40
3	15	100.29	101.61	99.98	100.59	50

Conclusion

To search the optimum sampling plan for yield contributing characters of pointed gourd, we have been selected a two-way analysis of variance model in this research. According to this objective and research question various variance components on the selected attributes of the plant and together with the relative efficiency has been computed.

Among different sampling plans a plan of 3 plants per plot and 7 fruits (total 21 fruits per plot) are found to be on an average 96.57 percent efficient in compared with original sampling plan of 3 plants/plot and 10 fruits per plant (30 fruits per plot). By adopting this new plan 30 percent work load (time) could be saved without compromising with its precision.

References

Federer, W. T. 1963. Experimental design. Theory and application, Oxford and IBH Publishing Co. New Delhi, India.

Hossain,M.I., M.S. Islam, M.A. Hossain, S.Nasrin, and S.Yesmin. 2005. Determination of optimum sampling plant characters of brinjal. *International J. Sustainable Agril. Technol.* **1**(6): 25-29.

Hossain,M.I.,Muhammad Shuaib, Kabita, Muhammad Tareq, M.S. Kabir and M. A. Uddin. 2008. Optimum sampling for measuring different plant characters of Teasle gourd. *Eco-friendly Agril. J.* **1**(3): 172-175.

Islam, M.S., N. Mohammad, K.S. Rahman, M.M. Rahman and A.K.M.A. Hoque. 2013. Optimum sampling for measuring different plant characters of bitter gourd. *Eco-friendly Agril. J.* **6**(11): 234-237.

Islam, M.S., N. Mohammad, K.S. Rahman, M.M. Rahman and A.K.M.A. Hoque. 2012. A study of optimum sampling for measuring different plant characters of sweet gourd. J. Bangladesh Soc. *Agril. Sic. Technol.* **9**(1 &2):195-199.

Islam, M.S., K. Sen and K. Rahim. 2000. Estimation of optimum sample size and number of replications in RCBD with unequal observation per cell. Dhaka University J. Sci. **48**(1): 89-94.

Islam, M. S. 2001. Statistical development of field plot technique for agronomic experiments. Unpublished Ph. D. thesis, Dhaka University, Dhaka, Bangladesh.

Kempthorne, O. 1952. Design and analysis of experiment, John Wiley and Sons, Inc, New York, USA.

Mohammad, N., M.S. Islam, K.S. Rahman, M. M. Rahman and S. Nasrin. 2015. Determination of optimum sample for measuring the contributing characters of bottle gourd. *Bangladesh J. Agril. Res.* **40**(4): 703-709.

Patel, J.N. and K.C. Dalal. 1992. Sampling technique for measuring pod characters of okra. Gujarat Agricultural University Research Journal. **18**(1): 81-84.

Rigney, J.A. and WI L. Nelson. 1951. Some factors affecting the accuracy of sampling cotton for fibre determinations. Agronomy J. **43:** 531-535.

Snedecor, G.W and W.G. Cochran. 1967. Statistical Methods. Sixteen Edition, The Iowa State University Press, Ames, Iowa, USA.

ABUNDANCE OF ARTHROPOD INSECT PESTS AND NATURAL ENEMIES IN RICE FIELD AS INFLUENCED BY RICE GROWTH STAGES AND NEIGHBORING CROPS

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Abstract

Studies were conducted to record the abundance of arthropod insect pests and natural enemies in rice fields as influenced by rice growth stages and neighboring crops at the experimental farm of Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali during 2012 in Boro rice season following randomized complete block design. Results indicated that rice-tree habitat showed the highest abundance of leafhoppers (100.75) followed by cricket (16.50), grasshoppers (15.25) and stink bugs (15.25). The lowest abundance of all insect pests was in rice-sesame habitat. No significant differences were found on the abundance of rice bug, rice hispa and stem borer populations. At seedling stage, the highest abundance of leafhopper (94.25) was recorded followed by grasshopper (47.00) and stink bug (26.50) while the lowest was stem borer (0.57) and rice hispa (6.00). At early tillering stage, maximum number of grasshopper (17.25) was recorded followed by cricket (7.00). At maximum tillering stage, the highest abundance of leafhoppers (122.5) was obtained followed by rice bug (62.00) and the lowest was the stink bug (7.00). At panical initiation stage, the highest abundance of rice bug (334.00) was recorded which was followed by leafhoppers (65.25) and the lowest was the cricket (15.75). No population of rice hispa and stem borer was recorded at maximum tillering and panical initiation stages. In case of natural enemies, the highest abundance of lady bird beetle (45.27) and damselfly (16.73) was found in rice-rice habitat. The highest abundance of ichneumonid wasp (57.53) was in rice-tree habitat and ground beetle (28.80) was in rice-sesame habitat. No significant differences were observed on the abundance of dragonfly, spider and dipteran fly among different habitats. Among different growth stages of rice plant, significantly the highest abundance of lady bird beetle was recorded at maximum tillering stage. The highest abundance of ichneumonid wasp and ground beetle was recorded at seedling stage. The highest abundance of damselfly, spider and dipteran fly was at early tillering stage. No significant difference was observed on the abundance of dragonfly among different rice growth stages.

Keywords: Abundance, insect pest, natural enemies, neighbouring crop, rice growth stage.

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Introduction

Bangladesh is an agricultural country and its agriculture is predominantly rice based. The average yield of rice in Bangladesh is quite low which is 3.02 t ha^{-1} (BBS, 2014) compared to other rice growing countries like China (6.23 t ha^{-1}), Korea (6.59 t ha^{-1}), Japan (6.79 t ha^{-1}) and USA producing (7.04 t ha^{-1}), respectively (FAO, 2004). The majority of rice growing area of Bangladesh is covered by boro rice comprising 58% of the total rice area. Rice is grown round the year in Bangladesh. So, this crop is an ideal host for many insect pest species. So far, 175 species of insects have been identified on rice from seed sowing to crop harvest (Kamal, 1998). Among them, only 20 species are considered as pest (Pathak, 1968) and 20-30 species are economically important (Miah and Karim, 1984). All of the fauna present in rice fields are not harmful. Many of them are beneficial. These beneficial fauna categorized as predators and parasitoids collectively known as natural biological enemies. In most of the cases, these enemies are able to interact with their prey or host populations and regulate them at economically lower level.

Arthropods in the rice ecosystem vary widely depending on the distribution of rice and other crops and wild habitats. The dynamics of pests and natural enemies in the area is influenced by the crop management. Xiaoping *et al*. (1995) reported that the size and composition of non-rice habitats adjacent to rice fields may have positive roles on natural enemies in rice fields. As the population development of some species in rice fields seems to be related to non-rice habitats adjacent to rice fields (Chiu, 1979), undoubtedly the biodiversity of fauna and flora exerts an important role in integrated pest management of rice (Way and Heong, 1994). However, relatively little work has been conducted on the understanding how neighboring crops affect pest biology and ecology. There is a need for rice IPM tailored to complex farming systems. Considering the above facts, the present study was undertaken to assess the abundance of insect pests and these natural enemies in rice fields as influenced by rice growth stage and neighbouring crops.

Materials and Method

The studies were conducted to record the abundance of arthropod insect pests and natural enemies in rice fields as influenced by rice growth stages and neighboring crops at the experimental farm of Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali during the period from January to June 2012 in Boro rice following randomized complete block design (RCBD) with four replications. The rice variety, BRRIdhan 29 was used for the study. A variety of non-rice crops viz., sesame and maize were grown widely along with rice as a neighbouring crops. To study the effect of different adjacent crop habitats on the abundance of rice arthropod population in rice fields, 4 types of rice fields were selected. These were: (a) rice field adjacent to sesame field designated as rice-

sesame habitat, (b) rice field adjacent to maize field designated as rice-maize habitat, (c) rice field adjacent to trees designated as rice-tree habitat and (d) rice field adjacent to rice field designated as rice-rice habitat. Crop production procedure and other intercultural operations were done. No pesticide was used in the experimental fields.

Data collection

The insect pests of rice and their natural enemies were collected by a fine mesh nylon sweep net. Sweeping was done from the plant canopy level including the interspaces between plants and close to basal region of the plants as far as possible. In each field, l0 complete sweeps were made to collect the insect pests and their natural enemies. Sampling was done at four stages of rice viz. at seedling, early tillering, maximum tillering and panicle initiation stages. Sampling was done during morning hours at all study fields on all sampling dates.

The insect pests and nafural enemies of l0 complete sweeps from each field were collected separately in labeled container. The samples were sorted, counted and identified in the laboratory of the Department of Entomology, PSTU under microscope.

Statistical analysis

The data collected on different parameters used in the experiment were statistically analyzed to obtain the level of significance using the MSTAT-C computer package programme developed by Russell (1986). The analysis of variance (ANOVA) of the results on various insect pests and natural enemies was done after square root transformation ($y=\sqrt{x}$). The means were compared by Duncan's Multiple Range Test (DMRT).

Results and Discussion

The abundance of insect pests and natural enemies in rice field influenced by rice growth stage and neighbouring crops are presented in Table 1-4.

Abundance of arthropod insect pests

Grasshopper

Grasshopper population differed significantly within the four rice habitats (Table 1). Rice-tree habitat exhibited the highest population of grasshopper (15.25) which was statistically similar with rice-rice (15.00) habitats followed by rice-maize habitat (12.34). The rice-sesame habitat carried the lowest population (8.78). In case of different growth stages, the highest abundance of grasshopper was found at seedling stage (47.00) and the lowest abundance was recorded at

early tillering stage (17.25) which was statistically similar with other two stages (Table 2).

Rice bug

Rice bug population did not varied significantly (P<0.05) within different rice habitats (Table 1). The mean number of rice bug ranged from 11.38 to 14.75. Rice-tree habitat showed the highest rice bug population (14.75) followed by rice-rice habitat (12.25) and the lowest abundance was found in rice-sesame habitat (11.38). On the other hand, significant difference was found on the rice bug population at different rice growth stages (Table 2). The highest rice bug population was found at panicle initiation stage (334.00) followed by maximum tillering stage (62.00) and the lowest was found at early tillering stage (0.75). No rice bug population was observed at seedling stage.

Stink bug

Stink bug population differed significantly (P<0.05) among different rice habitats with the means ranged from 8.56 to 15.25 (Table 1). The abundance of stink bug population was recorded in rice-tree habitat (15.25) which was statistically similar with rice-rice habitat (15.00). The lowest abundance was found in rice-sesame habitat (8.56) which was statistically similar with rice-maize habitat (9.75). In case of different growth stages, significant differences of stink bug population was found (Table 2). The highest abundance was found at seedling stage (26.50) followed by panicle initiation stage (18.25) and the lowest abundance was found at maximum tillering stage. No stink bug population was observed at early tillering stage.

Leafhopper

Among different habitats, leafhopper population differed significantly (p<0.05) with the means ranged from 53.00 to 100.75. The highest abundance was recorded in rice-tree habitat (100.75) followed by rice-rice habitat (76.00). Rice-maize and rice-sesame showed statistically similar abundance and exhibited the lowest population of 56.00 and 53.00, respectively (Table 1). In case of different growth stages, leafhopper also differed significantly (Table 2). The highest abundance was found at maximum tillering stage (122.50) which was statistically similar with that of seedling stage followed by panicle initiation stage and the lowest (3.75) at early tillering stage.

Cricket

Significant difference of cricket population was found in different rice habitats (Table 1). The highest abundance was found in rice-rice habitat (21.00 crickets/40 sweeps) followed by rice-tree habitat (16.50) and the lowest

abundance was found in rice-maize habitat (9.00) which was statistically similar with rice-sesame habitat (10.00). In case of different rice growth stages, the highest abundance of cricket was found at maximum tillering stage (20.50 crickets/40 sweeps) followed by panicle initiation stage (15.75) which was statistically similar with seedling stage (13.25) (Table 2). The lowest abundance of cricket was found at early tillering stage (7.00 crickets/40 sweeps).

Rice hispa

No significant differences were found on the abundance of rice hispa population among the four rice habitats indicating all the habitats gave similar support to the rice hispa population (Tables 1). The highest population was observed in rice-maize (2.75 rice hispa/40 sweeps) habitat while the lowest was found in rice-sesame (0.00 hispa/40 sweeps). In case of different growth stages, seedling stage carried the highest population of rice hispa (6.00 hispa/40 sweeps). The abundance of rice hispa population in other three stages were statistically similar (Table 2).

Rice yellow stem borer

No significant variation was found on the abundance of yellow stem borer (YSB) population among the four rice habitats indicating all the rice habitats gave similar support to the YSB population (Tables 1). The highest abundance was found in rice-sesame habitat (1.25) followed by rice-maize (1.00), and the lowest abundance of YSB was found in rice-rice habitat which was identical to rice-tree habitat (0.50). Similarly, among different growth stages, early tillering stage showed the highest abundance of YSB (1.62) followed by seedling (0.57) and there was no stem borer population in maximum tillering and panicle initiation stage (Table 2).

Abundance of arthropod natural enemies

Ladybird beetle

There was significant (P<0.05) differences in the lady bird beetle (LBB) population among rice habitats (Table 3). The highest population of LBB was observed in rice-rice habitat (45.27 LBB /40 sweeps) followed by rice-tree habitat. The lowest population of LBB was found in rice-maize habitat (21.75 LBB/40 sweeps) which was statistically similar with rice-sesame habitat (26.25). In case of different rice growth stages, LBB showed significant differences where the highest population was found in maximum tillering stage (46.00 LBB/40 sweeps) followed by panicle initiation and seedling stage, and the lowest population was found at early tillering stage (6.50 LBB/sweeps) (Table 4).

Table 1. Abundance of insect pests in rice field as influenced by neighbouring crops

Habitats	Mean no. of insect pests /40 sweeps						
	Grasshopper	Rice bug	Stink bug	Leafhopper	Cricket	Rice hispa	Rice yellow stem borer
Rice – Maize	12.34 ab	11.52	9.75 b	56.00 c	9.00 c	2.75	1.00
Rice – Sesame	8.78 b	11.38	8.56 b	53.00 c	10.00 c	0.00	1.25
Rice - Tree	15.25 a	14.75	15.25 a	100.75 a	16.50 b	1.75	0.50
Rice - Rice	15.00 a	12.25	15.00 a	76.00 b	21.00 a	0.75	0.50
CV %	63.74	56.31	65.29	59.28	45.22	–	–
Level of significance	*	NS	*	*	*	NS	NS

NS= Non Significant   *= Significant at 5% level

Within column means followed by same letter(s) did not differ significantly at P<0.05 by DMRT

Data were transformed by square root transformation.

Table 2. Abundance of arthropod insect pests in rice field as influenced by different rice growth stages

Rice growth stages	Mean no. of insect pests /40 sweeps						
	Grasshopper	Rice bug	Stink bug	Leafhopper	Cricket	Rice hispa	Rice yellow stem borer
Seedling	47.00 a	0.00 c	26.50 a	94.25 a	13.25 b	6.00 a	0.57
Early tillering	17.25 b	0.75 c	0.00 c	3.75 b	7.00 c	1.25 b	1.62
Maximum tillering	17.50 b	62.00 b	7.00 bc	122.5 a	20.50 a	0.00 b	0.00
Panicle initiation	18.75 b	334.00 a	18.25 ab	65.25 ab	15.75 b	0.00 b	0.00
CV %	44.29	28.65	65.74	59.28	91.51	91.15	–
Level of significance	*	*	*	*	*	*	**NS**

NS= Non Significant   *= Significant at 5% level

Within column means followed by same letter(s) did not differ significantly at P<0.05 by DMRT

Data were transformed by square root transformation.

Table 3. Abundance of arthropod natural enemies in rice field as influenced by neighbouring crops

Habitats	Mean no. of natural enemies/40 sweeps						
	Lady bird beetle	Damselfly	Dragonfly	Ichneumonid wasp	Spider	Ground beetle	Dipteran fly
Rice – Maize	21.75 b	8.75 c	1.50	26.75 c	12.50	25.60 ab	5.00
Rice – Sesame	26.25 b	10.41 b	0.75	32.02 bc	9.50	28.80 a	4.25
Rice - Tree	38.68 ab	13.02 ab	0.42	57.53 a	12.00	19.63 b	5.75
Rice - Rice	45.27 a	16.73 a	0.75	39.25 b	11.75	18.35 b	3.50
CV %	26.65	58.71	—	66.59	38.23	50.66	37.62
Level of significance	*	*	NS	*	NS	*	NS

NS= Non Significant   *= Significant at 5% level

Within column means followed by same letter(s) did not differ significantly at P<0.05 by DMRT

Data were transformed by square root transformation.

Table 4. Abundance of arthropod natural enemies in rice field as influenced by different rice growth stages

Rice growth stages	Mean no. of natural enemies/40 sweeps						
	Lady bird beetle	Damselfly	Dragonfly	Ichneumonid wasp	Spider	Ground beetle	Dipteran fly
Seedling	25.25 b	15.75 a	0.56	129.00 a	18.25 a	67.75 a	0.00 c
Early tillering	6.50 c	18.50 a	0.00	20.75 b	19.25 a	16.25 b	13.50 a
Maximum tillering	46.00 a	9.00 ab	0.75	10.50 b	5.50 b	47.25 ab	4.25 b
Panicle initiation	32.00 b	5.25 b	2.25	6.75 b	2.75 b	65.00 a	0.75 c
CV %	26.65	49.77	—	66.59	38.23	50.95	37.62
Level of significance	*	*	NS	*	*	*	*

NS= Non Significant   *= Significant at 5% level

Within column means followed by same letter(s) did not differ significantly at P<0.05 by DMRT

Data were transformed by square root transformation.

Damselfly

Damselfly population varied significantly (P<0.05) among different habitats with the means ranged from 8.75 to 16.73 (Table 3). Rice-rice habitat carried the highest population of damselfly (16.73) while the lowest abundance (8.75) was found in rice-maize habitat. In case of different growth stages, the highest population of damselfly (18.50) was found at early tillering stage which was statistically similar with seedling stages (15.75). The lowest abundance of damselfly was found at panicle initiation stage (5.25 damselfly/40 sweeps) followed by maximum tillering stage (9.00) (Table 4).

Dragonfly

Dragonfly population did not differ significantly within rice habitats. The maximum number of dragonfly was observed in rice-maize habitat (1.50 dragonfly/40 sweeps) followed by rice-sesame and rice-maize habitats. The minimum number of dragonfly was observed in rice-tree habitat (0.42 dragonfly/40 sweeps) (Table 3). In case of different growth stages, dragonfly population also did not differ significantly (Table 4). The highest abundance was at panicle initiation stage (2.25 dragonfly/40 sweeps) and the lowest was found at seedling stage. No dragonfly population was observed at early tillering stage.

Ichneumonid wasp

Ichneumonid wasp population differed significantly (P<0.05) among rice habitats with the means ranged from 26.75 to 57.53 (Table 3). Rice-tree habitat carried the highest ichneumonid wasp population (57.53) followed by rice-rice habitat (39.25). The lowest population was found in rice-maize habitat (26.75) followed by rice-sesame habitat. In case of different rice growth stages, seedling stage carried the highest population (129.0) and the lowest population was found at panicle initiation stage (6.75) which was statistically similar with maximum and early tillering stages (Table 4).

Spider

No significant variation of spider population was found among different habitats. The highest abundance was found in rice-maize habitat (12.50 spider/40 sweeps) followed by rice-tree habitats and the lowest abundance was found in rice-sesame habitat (9.50) followed by rice-rice habitat (Table 3). Spider population varied significantly (P<0.05) among different rice growth stages. The highest population was found at early tillering stage (19.25 spider/40 sweeps) which was statistically similar with seedling stage and the lowest population was found at maximum tillering stage (5.50) which was statistically similar with panicle initiation stage (Table 4).

Ground beetle

Significant difference (P<0.05) of ground beetle (GB) population was found among different habitats (Table 3). The highest abundance was found in rice-sesame habitat (28.80 GB/40 sweeps) followed by rice-maize habitat and the lowest abundance was found in rice-rice habitat (18.35) which was statistically similar with rice-tree habitat (19.63). Among different rice growth stages, significant difference was also found (Table 4). The highest population of GB was found at seedling stage (67.75 GB/40 sweeps) which was statistically similar with panicle initiation stage (65.00) and the lowest population was found at early tillering stage (16.25) followed by maximum tillering stage (47.25).

Dipteran fly

No significant difference of dipteran fly population was found among different habitats (Table 3). The highest population was found in rice-tree habitat (5.75 flies/40 sweeps) followed by rice-maize habitat (5.00) and the lowest population was found in rice-rice habitat (3.50 flies/40 sweeps). In case of different growth stages, dipteran fly population showed significant difference (Table 4). The highest population was found at early tillering stage (13.50 flies/40 sweeps) followed by maximum tillering stage (4.25 flies/40 sweeps) and the lowest population was found at panicle initiation stage. No dipteran fly was observed at seedling stage.

Several studies indicated that increased habitat diversity in crops leads to increased population densities of indigenous predators and other arthropods and this enhanced biological control. Conglong (1995) intercropped sugarcane with sorghum and maize and this increased the population density of indigenous predators and arthropods in the intercrops as compared with pure stands of sugarcane. Elton (1958) reported that the abundance of arthropod insect pest population was more in monoculture habitat where polyculture habitat contains the lower abundance. Liu *et al.* (2001) studied population changes of major insect pests, natural enemies, and detritivores in rice habitats through habitat diversity. They found that soybean neighboring paddy fields was a beneficial habitat for conserving natural enemies of insect pests of rice without sharing the insect pest species with the rice habitat. Cheng *et al.* (1998) studied the role of non-rice habitats in predator conservation and found that non-rice habitats provided habitats for the development of predator population.

In case of different rice growth stages, the present study indicated that the abundance of most of the insect pests is high at panicle initiation stage where rice yellow stem borer population is highest at early tillering stage which is supported by Ragini *et al.* (2000) who found that yellow stem borer population was predominant at early tillering to maximum tillering stage. In present study, the

highest rice bug population was found at panicle initiation stage and this result was agreed with Tsueda *et al*. (2002) who showed the ricebug abundance was peak at heading to early ripening stage. Some leaf feeders like grasshopper, rice hispa population showed the highest abundance at seedling stage which was agreed with the result of BRRI (1985) but the result of rice hispa population of this study was not supported by Amit *et al.* (2001) who found the abundance of rice hispa population was the highest at the mid tillering stage. The abundance of leafhopper population was the highest at maximum tillering stage which was more or less similar with the result of BRRI (1985) where highest leafhopper population was found at early heading stage. Among different rice growth stages, the present study showed that the abundance of natural enemies was the highest at seedling stage where spider population was the highest at early tillering stage which supported by Luong (1987) who studied the population was highest at tillering stage. In case of ladybird beetle (*Micraspis spp*) the highest population was found at maximum tillering stage which was more or less similar with the result of Rahman *et al.* (1991) who found that Lady bird beetle, *Micraspis discolor* was the highest at the flowering stage. Wang *et al*. (2001) investigated on dynamics of spatial distribution of mixed spider populations in early season rice fields and late season rice fields. They found that the spatial distribution of mixed spider populations in rice fields was different at different developmental stages of paddy rice. The main factors influencing spider spatial distribution in rice fields were spider dispersal level and reproduction, the number of net-weaving spiders and wandering spiders, the number of main target pests and their distribution, variations of habitats and farming practices, density of spider populations and extent of inter-specific competition in rice fields.

References

Amit, C., Indira, D, Sharma, P.K., Kaul, B.K., Choudhary, A. and Dogra, I. 2001. Population build up of rice hispa. *Dicladispa armigera armigera* Oliv. (Coleoptera: Chrysomelidae) in Kangra valley of Himachal Pradesh (India). *J. Entomol. Res*. **25**(4): 299-302.

BBS. 2014. Staistical Pocket Book Bangladesh, Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. Pp. 384.

BRRI, 1985. Annual Report for 1984. Bangladesh Rice Research Institute, Gazipur, 207p.

Cheng, J.A.; Lou, Y.G., Hamid, A.A., Yeang, L.K. and Sadi, T. 1998. Integrated science and people in rice pest management: proceedings of the Rice Integrated Pest Management (IPM) Conference, Kualalampur, Malaysia, 18-21 November 1996. 64-68p.

Chiu, S.C. l979. Biological control of the brown planthopper. In: Brown plant hopper: threat to rice production in Asia. Manila (Philippines): Internat. Rice Res. Inst. Pp.335-355.

Conglong, D.E. 1995. Results of preliminary pitfall trapping trials for potential arthropod predators of *Eldana saccharina.* Proc. South African Sug. Technologies Assoc. **69**: 79-82.

Elton, C.S. 1958. The Ecology of Invasions by Animals and Plants. 181p. London, Chapman and Hall.

FAO. 2004. Production Yearbook. Food and Agriculture Organization of the United Nations. Rome, Italy. **57:**76-77.

Kamal, N.Q. 1998. Brown Plant Hopper (BPH), *Nilaparvata lugens* Stal. Situation in Bangladesh. A report of IPM ecology expert. DAE-UNDP/FAO IPM project. Khamarbari, Farmgate, Dhaka, Bangladesh.

Liu, G., Lu, Z., Tang,J., Shen, J.; Jiang,Y., Sheng, X., Yang, B., Chen, J., and.Xu, H. 2001. Managing insect pests of temperate japonica rice by conserving natural enemies through habitat diversity and reducing insecticide use. Exploiting Biodiversity for Sustainable Pest Management. IRRI, 43-50 p.

Luong, M.C. 1987. Predators of brown plant hopper *Nilaparvata lugens* Stal (BPH) in rice fields of the Mekong Delta, Vietnam. *Internat. Rice Res. Newslet.* **l2**(2): 31- 32.

Miah, S.A. and Karim, A.N.M.R. 1984. Rice pest management technology, In: Proc. Workshop on Experience with modern rice cultivation in Bangladesh, BRRI. Gazipur. Pp. 43-49.

Pathak, M.D. 1968. Ecology of common insect pests of rice. *Annual Review of Ent.* **13**:257-294.

Ragini, J.C., Thangaraju, D. and David, P.M.M. 2000. Relative abundance of rice stem borer species in Tamil Nadu. *Madras Agril. Jour. Publ* 2001 . **S7**(4-6): 228-234.

Rahman, M.H., Sardar, M.A. and Haque, M.R. 1991. Population dynamics of *Micraspis discolor* (Coccinellidae: Coleoptera) in rice and its susceptibility to insecticides. *Bangladesh J. Ent.* **l**: 27-33.

Russell, D.F. 1986. MSTAT-C package programme. Crop and Soil Science Department, Michigan State University, USA.

Tsueda,,H., Yajima, M., Taguchi, Y. and Suzuki, T. 2002. Occurrence tendency of rice sting bugs in South, flat area of Gifu Prefecture. Proc. of the Kansai Plant Protection Soc. **4:** 13-20.

Wang, Z., Yan, H.M, and Wang, H.Q. 2001. Studies on the dynamics of spatial distribution of mixed spider populations in rice fields. *Plant Protection.* **27**(6): 9-11.

Way, M.J. and Heong, K.L. 1994. The role of diversity in the dynamics and management of insect pests of tropical irrigated rice: a review. *Bull. Entomol. Res.* **84**: 567-587.

Xiaoping, Y., Heong, K.L., Cui, H. and Barrion, A.T. 1995. Role of non rice habitats for conserving egg parasitoids rice planthoppers and leafhoppers. In: Hokyo N, Norton G, editors. Proceeding of the International Workshop on Pest Management Strategies in Asian Monsoon Agroecosystem (Kumamoto 1995). 63-77p.

IMPORT AND EXPORT PARITY PRICE ANALYSES OF SELECTED VEGETABLES AND SPICES IN BANGLADESH

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Abstract

The study was undertaken to find out the export potentialities of selected vegetables and import substitution of selected spices in Bangladesh. Seven hundred twenty vegetables and 320 spices growers, 25 suppliers, and 25 exporters were randomly selected for the study.Net margin analysis was done on both variable and total cost basis. Domestic resource cost (DRC) analysis was also done for estimating comparative advantage of the selected vegetables and spices. The study revealed that net returns were positive for all vegetables and spices producers. However, the highest net return was estimated for brinjal producers (Tk. 273799/ha) followed by bittergourd producers (Tk152145/ha). In the case of spices, the highest net return was received by ginger producers (Tk. 231399/ha) followed by onion producers (Tk. 122308/ha).Comparatively lower net returns were found for okra (Tk51830/ha) and garlic producers (Tk 99352/ha). Vegetables exporters received the highest net margin (Tk32852/ ton) from UK market which was higher than the Middle East market (Tk22869/ton).The highest benefit cost ratio (BCR) was calculated for brinjal (1.9) followed by ash gourd (1.8). For spices, BCR were 2.1and 1.8 for ginger and garlic respectively. Bangladesh had comparative advantage for producing all selected vegetables as the estimates of domestic resource cost (DRC) were less than one. The value of DRC for all selected spices were less than unity implied that the production of these spices would be highly efficient for import substitution. Therefore, the study have been undertaken to find out this issues.

Keywords: Import parity, export parity, domestic resource cost, benefit cost ratio.

1. Introduction

1.1 Vegetables situation in Bangladesh

Vegetable is one of the most essential food items for growth and maintenance the health of human beings. Bangladesh is pre-dominantly an agricultural country with rich soil and climatic condition. But it is the matter of regret that after four decades of independence, the country could not produce enough vegetables for the people. Bangladesh has potential for doubling or trebling its present production of vegetables to meet domestic demand and leave a substantial surplus for export. Currently, it can meet only 2-3% of the demand of vegetables in international markets. But this market share has all the possibilities of

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increasing fast provided proper plans are made and pursued effectively. This amount is, however, a pittance compared to the potential. Growing of vegetables for export can soon prove to be a highly rewarding activity provided supportive policies are adopted. Many educated unemployed persons are taking up vegetable growing as a form of self employment. This is, no doubt, helping to increase production. The quantity of export is not big, but sizeable enough to create market for the large ethnic population of the South Asian sub-continent residing in the UK and Gulf region. A large portion of all vegetables were exported and demand for Bangladeshi vegetables is increasing in the South Asian sub-continent and gulf region day by day. So the exporters could be able to earn more foreign exchange by exporting vegetables. The annual trend of vegetables export and their total value during 2000-2011 has been shown in Fig. 1. It was observed that the vegetables export from Bangladesh started declining from 2007 and continued up to 2009. After that period the export situation is fluctuating. This situation caused by many reasons, such as reduced outflow of migrant workers, higher air freight charge, and quality deterioration of vegetables.
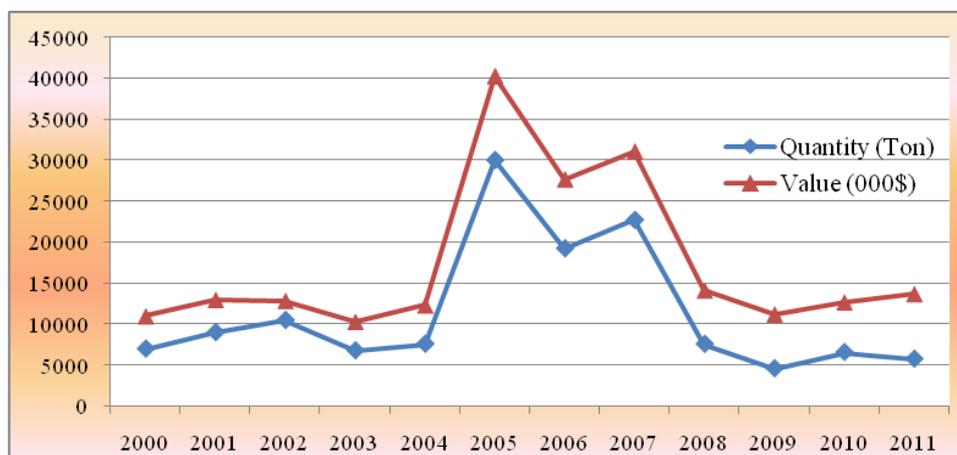

Fig. 1. Trend of vegetable exports in Bangladesh.

1.2 Spices situation in Bangladesh

Spices are popular as cash crops in Bangladesh. It has multipurpose uses. The major spices grown in the country are onion, garlic, chili, turmeric, and ginger. Onion, garlic and chili are short duration crops, whereas turmeric and ginger are long duration crops. Due to its higher demand the domestic production of spices cannot fulfill the country's demand. Therefore, a huge amount of spices has to importfrom foreign countries year after year. Different economic studies showed that the cost of production varied in a wide range among the spices produced in the country. In order to increase the domestic spices production, Bangladesh Government offers a lucrative credit facility on spice production at a lower interest rate. Unlike other agricultural crops, spices producers receive

concessional credits at the rate of 2% annual interest since it is relatively most costly to produce. The trend of annual imports of spices and their values in Bangladesh during 2003-2011 have been shown in Fig. 2. It reveals that spices imports in Bangladesh started increasing from 2005 and continued up to 2009. After that period the quantity and value of imports reduced to a great extent due to the initiatives taken by the Government.
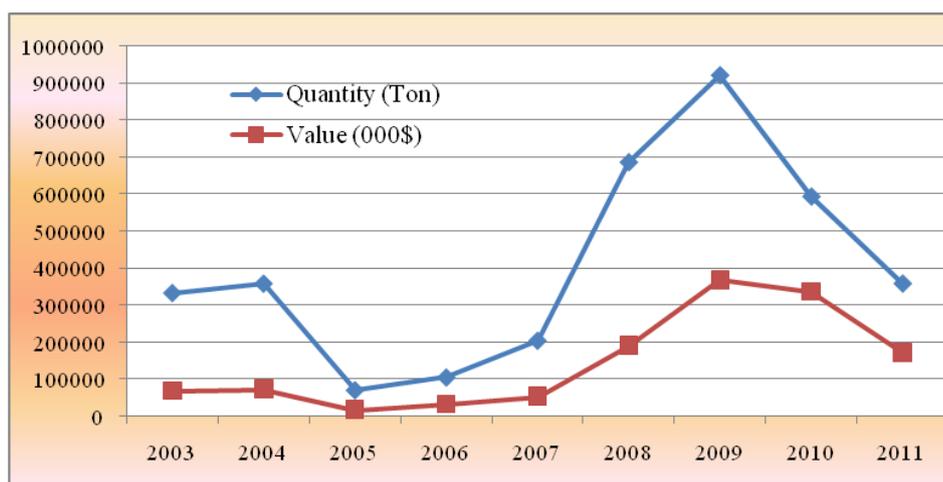

Fig. 2. Trend of spices import in Bangladesh.

1.3 Export potentialities of vegetables and import substitution of spices in Bangladesh

Export potentialities of vegetables and import substitution of spices would determine the position of the Bangladeshi cultivators in respect of production of commodities by using scarce resources. Farmers' perceptions of potentiality and constraints, public policies concerning irrigation, water control, technology and prices can influence their choice of crop growing. An evaluation of producing vegetables and spices relative to other crops for example, is required to address the issue of vegetables and spices self-sufficiency in the country both under the medium and long-term perspective. Again, the trading opportunities of the country's products depend on the comparative advantage, without subsidies or with limited subsidies that are permitted for all trading partners by the rules governing the new trading environment (Huda 2001). All these information would be of much help to the planners and policy-makers in formulating appropriate policies for optimum and efficient resource allocation within agriculture and between agriculture and non-agricultural sectors, consistent with a balanced and integrated development of Bangladesh economy. In order to formulate an appropriate policy for exporting vegetables and import substituting spices. Therefore, the present study was undertaken to highlight the economic performance of vegetables and spices.

1.4 Objectives

i)   To find out the export potentialities of selected vegetables in different locations;

ii) To estimate the import substitution status of the selected spices crops and

iii) To examine the policy implications from the above.

2. Materials and Method

2.1 Selection of Sample Farmers

The vegetables and spices growing farmers, suppliers, and exporters were considered as the population for this study. Keeping in view the objectives and time constraint of the study, altogether 720 vegetables taking 40 from each vegetable and each location, and 320 spices growers taking 40 from each location, 25 suppliers, and 25 exporters were randomly selected for the present study. The study areas were purposively selected based on intensive vegetables and spices growing pockets in Bangladesh. The distribution of crops and their respective locations and sample size are shown in Table 2.1.

Table 2.1 Crops and locations wise sample size of selected vegetables and spices

Name of the crops	Study location	Sample size
Vegetables		
Bitter gourd	Jessore and Narshingdi	80
Pointed gourd	Rangpur and Narshingdi	80
Ash gourd	Comilla and Narshigdi	80
Cucumber	Comilla and Narshigdi	80
Brinjal	Jessore and Narshingdi	80
Potato	Rangpur and Munshigonj	80
Country bean	Jessore and Narshingdi	80
Okra	Comilla and Narshingdi	80
Pumpkin	Barisal and Mymensingh	80
Spices		
Onion	Rajshahi and Faridpur	80
Garlic	Natore and Nilphamari	80
Ginger	Natore and Nilphamari	80
Green chilli	Magura and Pabna	80
Total		1040

Based on the availability of data, easy road communication, and nearest to Airport, Ulokhola of Kaligonj *Upazila* of Gazipur district was selected for

selecting vegetable traders. Again, on the basis of collection of exportable items and the presence of export oriented trading firms, Motijheel, Kakrail, Shantinagar, Khilgaon and Shambazar of Dhaka city were selected for the study.

2.2 Analytical Technique

In this study, value addition or costs and returns analyses were done on both variable and total cost basis. The following equation (Π) was developed to assess the value addition of the vegetables and spices producers.

$$\Pi_i = \sum_{i=1}^{n} P_iQ_i - TC = \sum_{i=1}^{n} P_iQ_i - (VC + FC)$$

Where,

Π_i = Profit or value addition from i[th] vegetables and spices production

Q_i = Quantity of the ith product (kg/ha)

P_i = Average price of ith product (Tk/kg)

TC = Total cost (Tk/ha)

VC = Variable cost (Tk/ha)

FC = Fixed cost (Tk/ha)

i = 1, 2, 3, ………., n

Per hectare profitability of growing vegetables and spices from the view points of individual farmers was measured in terms of gross return, gross margin and value addition.

Gross return: Gross return was calculated by simply multiplying the total volume of output with it's per unit of price in the harvesting period.

Gross margin: Gross margin calculation was done to have an estimate of the difference between total return and variable costs. The argument for using the gross margin analysis is that the farmers of Bangladesh are more interested to know their return over variable costs.

Net margin: The analysis considered fixed cost (which included lend rent, cost of equipment). Net margin was calculated by deducting all costs (Variable and Fixed) from gross return. Net margin of supplier and exporter is:-

Net margin = Gross margin -Marketing cost

Gross margin = Sale price -Purchase price

2.3 Export and Import Parity Analysis

The estimates of world price at import parity level are based on the assumption that imports compete with domestic production at the producer level. In case of exportable commodity, domestic-to-border price comparison has been made at

producer level. The border prices of selected commodities have been adjusted for marketing cost (which includes handling, transportation, storage cost) and price spent between the wholesale market to the farmers level. Border prices of commodities are used as reference or shadow prices in measuring the effects of government intervention polices. Without government intervention, the domestic producer prices are expected to be closely related to the border prices.

Export parity:The export parity price at farm gate is estimated by using the following formulae:

$$P_i = P_i^b E_0 - C_i$$

Where,

P_i = Producer price of ith exportable,

P_i^b = World price at the port of entry (f.o.b) in foreign currency

E_0 = Exchange rate

C_i = All components of the marketing margin from border to farm gate level

Import parity: Import parity price at farm level is estimated using the following formulae

$$P_j = P_j^b + C_{jm} - C_{jd}$$

Where,

P_j= producer price of jth importable commodity,

P_j^b=world price at port of entry (c.i.f),

C_{jm}= marketing margin from the port of entry to the wholesale market and

C_{jd}= Components of the marketing spread between the wholesale market and farm gate.

2.4 Measures of Comparative Advantage

Comparative advantage or efficiency of producing different crops in Bangladesh agriculture is analyzed here using Domestic Resource Cost (DRC) analysis. This indicator is formally defined as follows:

Domestic resource cost (DRC): The DRC is the ratio of the cost in domestic resources and non-traded inputs (valued at their shadow prices) of producing the commodity domestically to the net foreign exchange earned or saved by producing the good domestically.

Formally DRCs is defined as:

$$DRC = \frac{\text{Cost of domestic resource and non-traded inputs for producing per unit of output}}{\text{Value of tradable output - Value of tradable inputs}}$$

$$DRC = \frac{\sum f_{ij} P_j^d}{U_i - \sum a_{jk} P_k^b}$$

Where,

$f_{ij} =$ Domestic resource and non-traded inputs j used for producing per unit commodity i

$P_j^d =$ Price of non-traded intermediate inputs and domestic resource

$U_i =$ Border price of output i

$a_{ik} =$ Amount of traded intermediate inputs for unit production of i

$P_k^b =$ Border price of traded intermediate input

If DRC < 1, the economy saves foreign exchange by producing the good domestically either for export or for imports substitution. This is because the opportunity cost of domestic resources and non-traded factors used in producing the good is less than the foreign exchange earned or saved. In contrast, if DRC > 1, domestic costs are in excess of foreign exchange costs or savings, indicating that the good should not be produced domestically and should be imported instead.

3. Results and Discussion

3.1 Cost of Production of Different Vegetables

Variable Cost: The cost of production included all kinds of variable costs such as human labour, mechanical power, seed/seedling, manure, fertilizers, irrigation, pesticides, etc. used for the production of selected vegetables. Both cash expenses and imputed value of family supplied inputs were included in the variable cost. The total variable cost of selected vegetables was Tk.168527 per hectare which was 82% of total cost of production. Higher variable cost was recorded with the brinjalfarmers (Tk.217885/ha) than that of other vegetables due to higher level of input used by the brinjal farmers and lower variable cost was recorded with the pumpkin farmers. Among the different cost items, human labourwas the major cost item which accounted for about 45%of total variable cost and 37% of total cost. The second highest cost item was support (Macha/bamboo) cost which accounted for about 29% of total variable cost and 24% of total cost. Fertilizer and irrigation cost shared about 11% and 4% of total cost and ranked third and fourth cost item, respectively. There was no wide variation of different locations of the farms in the cost of selected vegetables cultivation. The uses of some inputs such as Urea, TSP and MoP were found very minimum in the study areas (Table 3.1).

Fixed Cost: Rental value of land was considered as fixed cost of production. The cost of this item was Tk.37193 per hectare which was accounted for about 18% of total cost of production (Table 3.1). Rental value of land was found highestincountry bean cultivation (Tk.74800/ha) andbrinjal cultivation (Tk. 61393/ha) due more crop duration.

Table 3.1. Per hectare production cost of different vegetables for producer

Cost item	Bitter gourd	Pointed gourd	Ash gourd	Cucumber	Brinjal	Potato	Country bean	Okra	Pumpkin	All vegetables
A. Variable cost (Tk/ha)										
Human labour (man-days)	61500	64400	56024	53000	125200	74600	126494	76000	40074	75255
Mechanical power (Tk/ha)	7426	7161	7993	8284	8234	9282	8483	6503	5331	7633
Seed cost	8196	4649	7553	2787	16894	54750	5364	4100	4706	12111
Ash (Tk/ha)	578	-	578	-	555					570
Cowdung (Tk/ha)	3488	6170	3109	3794	4645	4877	5339	1960	3991	4153
Fertilizer (Kg/ha):										
Urea	8670	7323	9688	5163	7763	5063	1597	3760	4940	5996
TSP	18400	9458	8222	5103	5913	2943	2495	4131	3024	6632
MoP	5928	3363	4250	2338	3196	3417	1085	1309	1445	2926
DAP		739		-	1760			448	-	982
Zipsum	1077	4393	660		880	772	287		-	1345
Zinc sulphate	4738	6845		216		975			-	3194
Boron	1200		145						-	673
Pesticides (Tk/ha)	14143	6845	2519	1824	19235	11530	11227	4629	4215	8463
Irrigation (Tk/ha)	17472	13604	8829	6362	11601	4734	6483	5987	4917	8888

Cost item	Bitter gourd	Pointed gourd	Ash gourd	Cucumber	Brinjal	Potato	Country bean	Okra	Pumpkin	All vegetables
Macha cost	52106	50832	55008	59537	-	-	29065	-	-	49310
Int. on operating capital	5806	5009	7066	6326	12010	5765	8324	3083	2058	6161
Total variable cost	210728	181799	176639	158133	217885	178706	206243	111910	74701	168527
B. Fixed cost (Tk/ha)										
Land use cost	23703	28734	23955	28734	61393	24921	74800	49920	18580	37193
Total fixed cost	23703	28734	23955	28734	61393	24921	74800	49920	18580	37193
Total cost (A+B)	234430	210533	200594	186867	279278	203627	281043	161830	93281	205720

Source: Field survey, 2012-13 to 2014-15

Total Cost: Total cost of production included variable costs and fixed costs incurred for selected vegetables cultivation. On an average, the total cost of production for selected vegetables cultivation was Tk.205720 per hectare where 18% were fixed costs and 82%were variable cost (Table 3.1). The highest total cost of production was incurred for country bean (Tk.281043/ha) followed by brinjal(Tk.279278/ha) and the lowest total cost of production was for pumpkin cultivation (Tk. 93281/ha).

3.2 Cost of Production of Different Spices

Variable cost: The averagetotal variable cost of spices cultivation was Tk.139840 per hectare which was 83% of total cost of production. Thehighest variable cost was recorded with the farmers of ginger (Tk. 173110/ha) than that of other spices due to use higher level of inputs. Among different cost items, human labour was the major cost item which accounted for about 40% of total variable cost and 33% of total cost (Table 3.2). The second highest cost item was seed which accounted for about 25% of total variable cost and 21% of total cost. Fertilizerand irrigation cost accounted for about 13% and 5% of total cost and ranked third and fourth cost item, respectively. The uses of some inputs such as Urea, TSP and MoP were found very minimum in the study areas for producing selected spices.

Table 3.2. Per hectare production cost of different spices for producer

Cost item	Onion	Garlic	Ginger	Chilli	All spices
A. Variable cost (Tk/ha)					
Human labour	57200	52600	51600	62600	56000
Mechanical power	6737	5838	9731	9402	7927
Seed cost	38959	9772	90388	2700	35455
Ash	555				555
Cowdung	5039	4877		6506	5474
Fertilizer					
Urea	6630	3060	3888	5900	4870
TSP	5188	5125	3767	5265	4836
MoP	4384	3216	2678	3179	3364
DAP	4995			4288	4642
Zipsum	552	804	132	560	512
Zinc sulphate	1005	938	244	1200	847
Boron	1350	3600		1160	2037
Pesticides	11916	2882	520	3909	4807
Irrigation	17941	4749	3105	8981	8694
Machha cost	-			-	
Int. on operating capital	4688	2761	7057	3277	4446
Total variable cost (Tk/ha)	167137	100221	173110	118927	139849
B. Fixed cost (Tk/ha)					
Land use cost	26393	31851	37303	17465	28253
Total fixed cost (Tk/ha)	26393	31851	37303	17465	28253
Total cost (A+B)	193529	132072	210413	136392	168102

Source: Field survey, 2012-13 to 2014-15.

Table 3.3. Per hectare net return from different vegetables production

Particulars	Bitter gourd	Pointed gourd	Ash gourd	Cucum-ber	Brinjal	Potato	Country bean	Okra	Pump kin	All vegetable
Yield (kg/ha)	27613	26621	29167	26121	35675	29265	21100	14244	18200	25334
Per unit price (Tk/kg)	14	13	12	13	16	9	18	15	8	13
A. Gross return (Tk/ha)	386575	346073	349998	326841	553075	263385	379800	213660	145600	329445
B. Variable cost (Tk/ha)	210728	183943	176639	158133	217884	178706	206243	111910	74701	168765
C. Gross margin (A-B)	175848	162130	173359	168709	335192	84679	173557	101750	70899	160680
D. Net return (Tk/ha)	152145	133396	149405	139975	273799	59758	98757	51830	52319	123487
E. Fixed cost (Tk/ha)	23703	28734	23955	28734	61393	24921	74800	49920	18580	37193
F. Total cost (B+E)	234430	212677	200594	186867	279276	203627	281043	161830	93281	205958
G. BCR (Cash cost basis)	1.83	1.88	1.98	2.07	2.54	1.47	1.84	1.91	1.95	1.95
H. BCR(Full cost basis)	1.60	1.70	1.80	1.70	1.90	1.30	1.35	1.32	1.56	1.58

Source: Field survey, 2012-13 to 2014-15.

Fixed cost: The average rental value of land of selected spices was Tk. 28253 per hectare which incurred 17% of the total cost of production (Table 3.2). Rental value of land was found highestinginger cultivation (Tk. 37303/ha) compared to other selected spices cultivation.

Total cost: On an average, the total cost of production of selected spices was Tk.168102 per hectare, where 17% was fixed costs and 83% was variable cost (Table 3.2). The highest total cost of production was incurred for ginger (Tk.210413/ha) followed by onion (Tk.193529/ha).

3.3 Net Returns of Different Vegetables Cultivation

The average gross return of different vegetables was estimated at Tk.329445/ha (Table 3.3). Thehighest gross return was obtained from brinjal cultivation (Tk.553075/ha) compared to bitter gourd cultivation (Tk. 386575/ha). The highest gross return from brinjalcultivation was attributed to the highest yield and higher market price. Average gross margin was Tk.160680 per hectare which varied from Tk.335192/ha to Tk.70899/ha. Net return was also followed similar trend. It was evident that the average net returnofselected vegetables production wasestimated at Tk.123487 per hectare which was very high compared to other vegetables. As the production cost was also very high, the resource poor farmers could not afford such high cost. The average benefit cost ratio (BCR) was 1.6 on full cost basis, the highest being with the brinjal growers (1.9). Although the brinjal growers obtained the highest gross margin, BCR was also highest compared to others vegetable.

Table 3.4. Per hectare net return from different spices production

Particulars	Onion	Garlic	Ginger	Chilli	All
Yield (kg/ha)	17547	6172	8350	7180	9812
Per unit price (Tk/kg)	18	38	52	33	35
A. Gross return (Tk/ha)	315837	231424	429973	236940	303544
B. Variable cost (Tk/ha)	167137	100221	181271	118927	141889
C. Gross margin (A-B)	148701	131203	248702	118013	161655
D. Net return (Tk/ha)	122308	99352	231399	100548	138402
E. Fixed cost (Tk/ha)	26393	31851	17303	17465	23253
F. Total cost (B+E)	193529	132072	198574	136392	165142
G.BCR (Cash cost basis)	1.89	2.31	2.37	1.99	2.14
H. BCR(Full cost basis)	1.60	1.80	2.10	1.73	1.81

Source: Field survey, 2012-13 to 2014-15

3.4 Net Returns of Different Spices Production

The average gross return from selected spicesproduction was estimated at Tk.303544 per hectare (Table 3.4). The highest gross return was obtained by the

ginger growers (Tk.429973/ha) than that of onion growers (Tk.315837/ha). The highest gross return from gingerproduction was attributed tothe highest yield and higher market price. Average gross margin was found to be Tk.161655 per hectare which varied from Tk. 248702/ha to Tk. 118013/ha. Similar trend was found in calculating net returns. The average net return from selected spicesproduction was Tk.138402 per hectare. The average benefit cost ratio (BCR) was 1.81 on full cost basis.

3.5 Marketing Cost and Margin of Vegetables Supplier

A supplier was the part time or full time agent of the different exporters in the production area. Therefore, marketing cost was only calculated for supplier in the study areas. The marketing costs of selected vegetables are shown in Table 3.5. The estimated average marketing costs per ton of vegetables incurred by suppliers were Tk. 3730.

Table 3.5. Marketing cost of vegetables incurred by supplier

Cost item	Cost (Tk/ton)	Percent of total cost
Transportation	2000	53.62
Loading and unloading	400	10.72
Grading	250	6.70
Wastage/loss of weight	425	11.39
Market toll	275	7.37
Tips and donation	100	2.68
House rent	80	2.14
Personal expenses	200	5.36
Total	3730	100

Field survey, 2014

The net margin of supplier is shown in the Table 3.6. The average purchase price of suppliers was Tk. 13,111 per ton and the average sale price was Tk. 19,333 per ton. Thus the gross margin of suppliers was Tk. 6,111 per ton. The total marketing cost of suppliers was Tk. 3730 per ton. So, the net margin of suppliers was Tk. 2381 per ton of vegetables.

3.6 Marketing Cost and Margin of Vegetables Exporters

Of the total costs, the highest cost was incurred by the airfreight charge followed by packet/carton, terminal and handling charge, carrying from exporters go-down to airport, clearing and forwarding. The per unit cost of many items were fixed irrespective of importing countries. The exporters incurred higher cost for exporting vegetables to UK followed by Middle East (Table 3.7).

Table 3.6. Net margin of different vegetables suppliers

Particulars	Bitter gourd	Pointed gourd	Ash gourd	Cucumber	Brinjal	Potato	Country bean	Okra	Pumpkin	All vegetable
A. Average purchase price (Tk/ton)	14000	13000	12000	13000	16000	9000	18000	15000	8000	13111
B. Average sale price (Tk/ton)	21000	21000	19000	18000	22000	14000	24000	22000	13000	19333
C. Gross margin (B-A)	7000	7000	7000	5000	6000	5000	6000	7000	5000	6111
D. Marketing cost (Tk/ton)	3730	3730	3730	3730	3730	3730	3730	3730	3730	3730
E. Net margin (C-D)	3270	3270	3270	1270	2270	1270	2270	3270	1270	2381

Source: Field survey, 2012-13 to 2014-15.

Table 3.7. Marketing cost (Tk/ton)of exporters for different vegetables export

Cost items	United kingdom	Middle East
Packet/Carton	4000	4000
Packaging materials e.g. rope, cost tape, thin paper etc.	350	300
Carrying from exporters godown to airport	1500	1500
Clearing and forwarding (C&F)	1500	1500
Terminal and handling charge (THC)	3450	3450
Bank services	70	70
Airway bill charge	552	216
GSP certificate charge	350	-
Airfreight charge	153000	101000
EXP (Export perform)	300	300
Salary and wages	1000	1000
Office, godown rent and taxes	1400	1200
Telephone, fax, telex	800	500
Loading and unloading charge	300	300
Quarantine	500	500
Phyto-sanitary certificate	200	-
Metropolitan chamber of commerce office charge	500	500
Dhaka chamber of commerce office charge	1500	1500
Commission agent	500	500
Entertainment	120	90
Miscellaneous	70	50
Total cost	171962	118476

Source: Vegetable exporters and different airlines from airport 2014.

Net margin by exporters consisted of the profit from the export of vegetables. Exporters performed the function of purchasing exportable vegetables from supplier/selected agents and supply them to different foreign buyers of the world. The average net margin of the exporters is depicted in Table 3.8. It is revealed that net marginwas very high in the UK market (Tk. 32852/ton) followed by Middle East (Tk. 22869/ton).

Table 3.8. Net margin (Tk/ton) of vegetables exporters

Particulars	United Kingdom	Middle East
A. Average selling price in abroad (Tk/ton)	224147	160678
B. Average purchase price (Tk/ton)	19333	19333
C. Gross margin (A-B)	204814	141345
D. Marketing cost (Tk/ton)	171962	118476
E. Net margin (C-D)	32852	22869

Source: Field survey, 2012-13 to 2014-15.

Table 3.9. Domestic resource cost (DRC) of selected vegetables at export parity level

Items	Bitter gourd	Pointed gourd	Ash gourd	Cucumber	Brinjal	Potato	Country bean	Okra	Pumpkin
A. Traded input (Tk/MT)	1970	1254	1105	704	685	576	415	1020	824
B. Non-Traded inputs and domestic resources (Tk/MT)	7020	7040	5919	6533	7281	6508	11683	10684	4608
Human labour	2227	2419	1921	2029	3509	2549	5995	5336	2202
Mechanical power	269	269	274	317	231	317	402	457	293
Seed	297	175	259	107	474	1871	254	288	259
Ash	-	-	20	-	16	-	-	-	-
Manure	126	232	107	145	130	167	253	138	219
Pesticides	512	257	86	70	539	394	532	325	232
Irrigation	633	511	303	244	325	162	307	420	270
Macha	1887	1909	1886	2279	-	-	-	-	-
Int. on operating capital	210	188	242	242	337	197	395	216	113
Land rent	858	1079	821	1100	1721	852	3545	3505	1021
C. Output price (Tk/MT)	37010	34125	33080	34987	40573	34150	36610	40615	41877
D. Value added (Tradable) (Tk/MT) (C-A)	35040	32871	31975	34283	39888	33574	36195	39595	41035
E. DRC (B/D)	**0.200**	**0.214**	**0.185**	**0.191**	**0.183**	**0.194**	**0.322**	**0.270**	**0.112**

Source: Authors' calculation.

3.7 Comparative Advantages of Vegetables and Spices Production

DRC indicates whether the domestic economy has a comparative advantage in vegetables and spices crops production relative to other countries. If the DRC is greater than one, it implies that the economy loses foreign exchange through domestic production of the vegetables and spices (in the sense that it uses more domestic resources than it generates net value added to tradable goods and services), while DRC is less than one implies that the production is efficient and make positive contribution to domestic value addition. The estimates of DRCs for selected vegetables and spices during the period from 2012-13 to 2014-15 are presented in Table 3.9 & 3.10. The DRCs for selected vegetables and spices were observed to be less than unity implying that Bangladesh had comparative advantage in vegetables production for export promotion and spices production for import substitution. The study results supported in the earlier study by Rashid *et al.,* 2010.

Table 3.10. Domestic resource cost (DRC) of selected spices

Items	Onion	Garlic	Ginger	Chilli
	Import Parity	Import Parity	Import Parity	Export parity
A. Traded input (Tk/MT)	2001	3099	1838	3190
B. Non-Traded inputs and domestic resources (Tk/MT)	9624	18686	22499	15994
Human labour	3260	8522	6180	8719
Mechanical power	384	946	1165	1309
Seed	2220	1583	10825	376
Ash	-	-	-	-
Manure	287	790	-	906
Pesticides	679	467	62	544
Irrigation	1022	769	372	1251
Macha			-	-
Int. on operating capital	267	447	1823	456
Land rent	1504	5161	2072	2432
C. Output price (Tk/MT)	30694	125251	58849	57325
D. Value added (Tradable) (Tk/MT) (C-A)	28693	122152	57011	54135
E. DRC (B/D)	0.335	0.200	0.395	0.295

Source: Authors' calculation.

3.14 Supply Chains for Vegetables Export

```
                          ┌─────────────────────┐
                          │ Seed/seedling supplier │
                          └─────────────────────┘
┌──────────────────┐                                    ┌──────────────────┐
│ Insecticides/     │                                    │ Fertilizer supplier │
│ Pesticides Supplier │                                  └──────────────────┘
└──────────────────┘
                          ┌─────────────────────┐
                          │ Vegetables          │
                          │ producer            │
                          └─────────────────────┘
   ┌──────────────┐                                      ┌──────────────┐
   │ Paikar       │ ───────────────────────────────────▶│ Bepari       │
   └──────────────┘                                      └──────────────┘
                          ┌─────────────────────┐
                          │ Supplier            │
                          └─────────────────────┘
                          ┌─────────────────────┐
                          │ Exporter            │
                          └─────────────────────┘
                          ┌─────────────────────┐
                          │ Foreign buyer       │
                          └─────────────────────┘
                          ┌─────────────────────┐
                          │ Foreign retail ethnic │
                          └─────────────────────┘
                          ┌─────────────────────┐
                          │ Foreign consumer    │
                          └─────────────────────┘
                          ┌─────────────────────┐
                          │ Local retail market │
                          └─────────────────────┘
                          ┌─────────────────────┐
                          │ Local consumer      │
                          └─────────────────────┘
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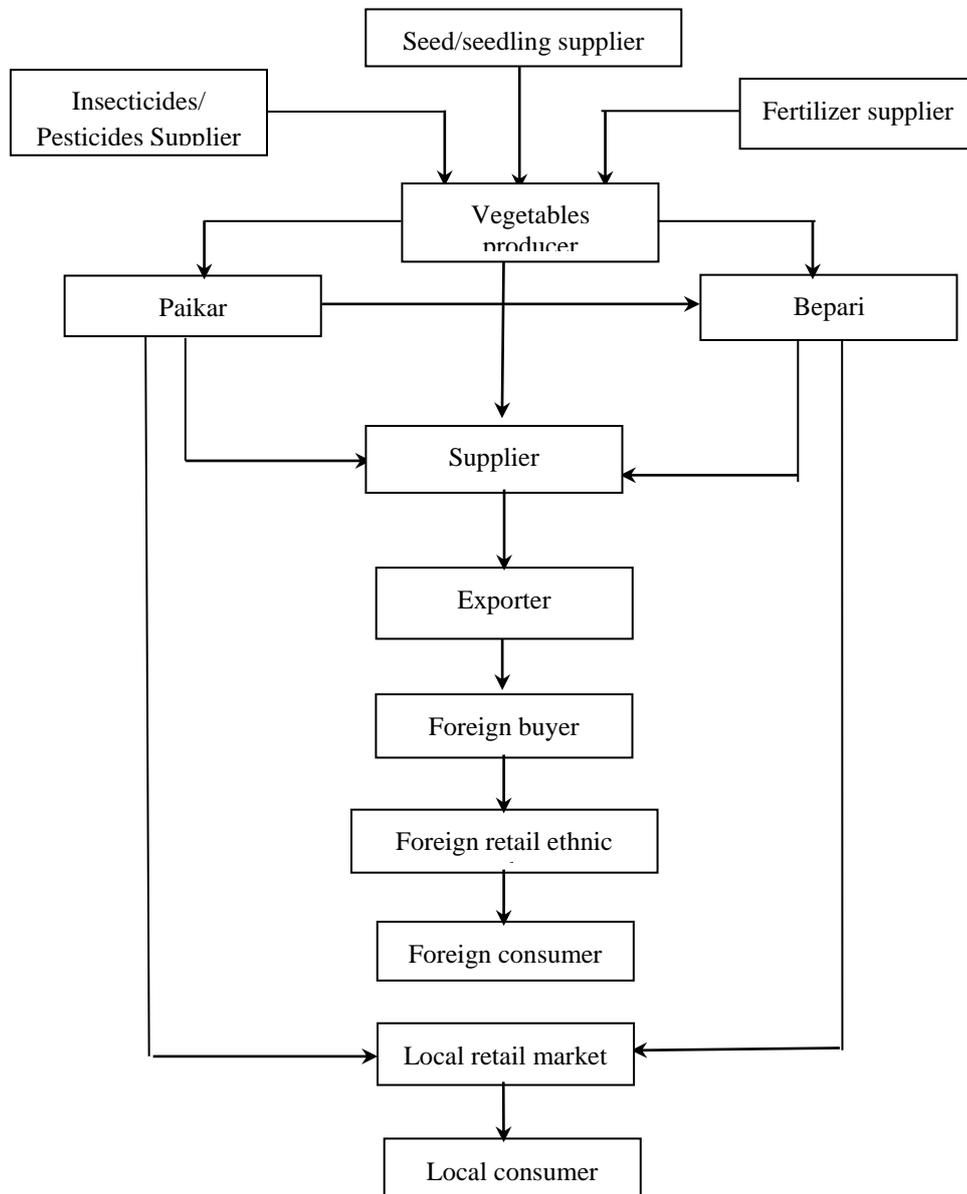
Fig. 2. Supply chains for vegetables export.

4. Conclusions and Recommendations

4.1 Conclusions

The study revealed that net margins were positive for all vegetables and spices producers. However, the highest net return was estimated for brinjal producers

followed by bitter gourd producers. In the case of spices, the highest net return was received by ginger producers followed by onion producers. Comparatively low net returns were found for okra and garlic producers. Vegetables exporters received the highest net margin from UK market which was higher than the Middle East market.The highest benefit cost ratio (BCR) was calculated for brinjal followed by ash gourd. For spices, it the estimated BCR were 2.1 and 1.8 for ginger and garlic respectively. Bangladesh had comparative advantage of producing all selected vegetables and spices as the estimates of domestic resource cost (DRC) were less than one. This is a clear indication that although not yet a major supply source, Bangladesh seemed to have a high potential for export development of horticultural crops, particularly, in vegetables and spices. The country has got some natural advantages like fertile soil, favorable climatic condition, and abundant supply of inexpensive labour force. The export of fresh vegetables is more profitable due to high value addition. Raw materials are not to be imported for vegetables export. Bangladeshi vegetables are still not well known to the foreign consumers. Export expansion and demand from super market was constrained by poor quality of produces and imposition of different sanitary and phyto-sanitary criteria by the importing countries. To familiarize Bangladeshi vegetables to the foreigners and foreign super markets, quality of those vegetables has to be improved by upgrading the packaging, handling, gradingand transportation system. Therefore, quality assurance would be must and it required continuous market research for improving the demand of Bangladeshi fresh vegetables in the international markets.

4.2 Recommendations

Selected vegetables production could be expanded for export promotion by using more improved technology as the country's demand. So emphasis should also be given on local production of selected vegetables as the export parity is favorable for the country.

Domistic resource cost for all spices crops were also less than unity implying that production of these spices would be highly efficient for import substitution.

To survive and sustain in the export market in this context and to ensure and enhance market excess and export competitiveness, the combined efforts of the concerned parties are necessary at the level of policy formulation, planning and implementation of programs.

References

Huda, A. (2001), Analysis of Protection and Comparative Advantage of Selected Agricultural Commodities in Bangladesh. An unpublished MS Thesis. Department of Agricultural Economics, BAU, Mymensingh

Rashid, M. A.; Hasan, M. K. and Rashid, A. K. M. H. (2010).Domestic and international competiveness of production of selected crops in Bangladesh, Final report on the challenge fund project (CF#1/08) of NFPCSP/FAO, Ministry of Food and Disaster Management, Dhaka.

Appendix 1. Total export quantity of vegetables

Year	Quantity (Ton)	Value (000$)	Unit value ($/Ton)
2000	7000	11000	1571
2001	9000	13000	1444
2002	10484	12888	1229
2003	6779	10323	1523
2004	7592	12333	1624
2005	30070	40242	1338
2006	19263	27672	1437
2007	22744	31071	1366
2008	7574	14132	1866
2009	4589	11236	2453
2010	6577	12689	1929
2011	5753	13704	2382

Source: www.faostat.org

Appendix 2. Total import quantity of onion, garlic and ginger

Year	Onion		Garlic		Ginger	
	Quantity (Ton)	Value (000$)	Quantity (Ton)	Value (000$)	Quantity (Ton)	Value (000$)
2003	334521	69003	--	N/A	N/A	N/A
2004	359589	73732	--	N/A	N/A	N/A
2005	72391	17338	N/A	N/A	N/A	N/A
2006	106975	32880	N/A	N/A	N/A	N/A
2007	96446	30809	109443	22248	N/A	N/A
2008	686756	190873	N/A	N/A	N/A	N/A
2009	767548	262244	103884	70699	49496	35595
2010	505886	207150	50898	86622	37585	43065
2011	268109	89611	44072	44231	47939	38061

Source: www.faostat.org

Appendix 3. Import parity border prices of spices 2012-13 to 2014-15

Items	Onion	Garlic	Ginger
A. CIF PRICE (US$ /mt)	409	1702	794
B. CIF price (Tk/mt)	29039	120842	56374
C. Marketing margin from the port of entry to wholesale market	2039	4793	2859
Import handling cost	871	3625	1691
Transportation cost	1016	1016	1016
Domestic trading cost	152	152	152
D. Border price at Wholesale level (B+C)	31078	125635	59233
E. Components of the marketing spread between the wholesale market to the produce level	384	384	384
F. Border price of farm produce at farm gate (D-E)	30694	125251	58849

Source: Authors calculation.

Appendix 4. Export parity border prices of vegetables for 2012-13 to 2014-15

Items	Bitter gourd	Pointed gourd	Ash gourd	Cucumber	Brinjal	Potato	Country bean	Okra	Pumpkin	Chilli
A. F.O.B price at airport (Tk/mt)	41000	38000	37000	39000	45000	38000	41000	45000	46000	63000
B. Costs from border toproducers level	3990	3875	3920	4013	4427	3850	4390	4385	4123	5675
Export handling cost	1230	1140	1110	1170	1350	1140	1330	1350	1380	1890
Transportationcost	1016	1016	1016	1016	1016	1016	1016	1016	1016	1016
Domestictrading cost	152	152	152	152	152	152	152	152	152	152
Costsfrom farm gate toWholesale	1242	1242	1242	1242	1242	1242	1242	1242	1242	1242
Interest rate	350	325	400	433	667	300	750	625	333	1375
F. Border price atproducer level(A-B)	37010	34125	33080	34987	40573	34150	36610	40615	41877	57325

Source: Authors' calculation.

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

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Abstract

The study was conducted in three betel leaf growing districts, namely Noakhali, Rajbari and Khulna during 2015-16 to assess the agronomic practices, profitability and to explore the constraints to betel leaf cultivation. The study revealed that betel leaf cultivation was profitable, although benefit cost ratio (BCR) in the first and second year were below one due to high investment cost and low yield. The highest yield and gross return were received by the farmers in the fourth year. The BCR was found highest in fourth year followed by third year and fifth year. The BCR at 12%, 15% and 20% rate of interest were 1.16, 1.15 and 1.14, respectively. IRR was 59% in current situation, 42% by 5% decrease of return and 52% by 5% increase of cost. The result indicated that betel leaf cultivation was profitable under changing situation of sensitivity analysis. Farmers faced some constraints like leaf rot disease, high price of *boroj* materials, non-availability of modern variety, low price of betel leaf, high price of oilcake, vine died, lack of capital, etc. Therefore, breeders should take initiative to develop high yielding varieties of betel leaf and pathologist may conduct research on betel leaf for controlling diseases.

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

1. Introduction

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

Betel leaf a kind of pepper used in wrapping the pellets of betel nut and lime, is commonly chewed in the orient. The cultivation of this crop is spread throughout Bangladesh. The total betel leaf area is 22413 ha and production is 136284 MT in Bangladesh. The mean of area, production and yield were 16066, 89241 and 5.52 t/ha, respectively. The standard deviation of area was 2569, production was 21224 and yield was 0.41. The growth rate of area, production and yield were

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2.27%, 3.06% and 0.79% respectively during the period from 1991 to 2013 (Table 1).

Table 1. Area, production and per hectare yield of betel leaf in Bangladesh from 1990-91 to 2012-13

Year	Area (ha)	Production (MT)	Yield/ha (ton)
1990-91	13320	67460	5.06
1991-92	13524	68810	5.09
1992-93	13628	70350	5.16
1993-94	13842	71485	5.16
1994-95	13949	72460	5.19
1995-96	13943	71910	5.16
1996-97	14595	77035	5.28
1997-98	15832	79080	5.33
1998-99	13820	73525	5.32
1999-00	15063	78780	5.23
2000-01	15346	82260	5.36
2001-02	14696	80540	5.48
2002-03	15472	83830	5.42
2003-04	16480	93425	5.67
2004-05	16771	93820	5.59
2005-06	16275	97415	5.99
2006-07	16536	101240	6.12
2007-08	17346	97947	5.65
2008-09	17643	105448	5.98
2009-10	17871	91681	5.13
2010-11	18247	105953	5.81
2011-12	22917	151814	6.62
2012-13	22413	136284	6.07
Mean	16066	89241	5.52
Standard deviation	2569	21224	0.41
Growth rate (%)	2.27	3.06	0.79

Source: BBS, 2013. MT= metric ton.

Betel leaf is an important cash crop in our country and is considered to be one of the ingredients for social entertainment. It has also a sharp taste and good smell, improves taste and appetite, tonic to the brain heart, liver, strengthens the teeth and clears the throat. The country may earn a huge amount of foreign currency every year by exporting betel leaf in different countries. However, data and information regarding betel leaf production and the status of local and international marketing system are scarce in the country. A very few studies were conducted (Ahmed, 198; Islam and Elias, 1991 and Moniruzzaman *et. al.*, 2008) regarding the profitability and constraints to higher production as well as export potentiality of betel leaf production in Bangladesh. Thus, the present study is designed to investigate the economics of betel leaf production in Bangladesh. This study provides useful information to the policy makers to make policy

guidelines for enhancing its production as well as its overall development in the near future. Therefore, the present study was undertaken with the following specific objectives:

  i.   To examine the agronomic practices of betel leaf cultivation.
  ii.   To find out the profitability level of betel leaf cultivation.
  iii.   To explore the constraints of betel leaf cultivation.

2. Methodology

Sampling technique: Multi-stage sampling technique was followed for the study. Three betel leaf growing districts namely Noakhali, Rajbari and Khulna were selected purposively in east, mid-western and western areas of Bangladesh. Previously in others studies another 6 betel leaf growing areas were considered. Again from each district three upazilas were selected considering the concentration of betel leaf growers and easy access. From each upazila one block considering intensive betel leaf growing area was selected with consultation of Upazila Agriculture Officer. A list of betel leaf growers from the selected block were collected with the help of DAE personnel. Thus a total of 3 x 3 x 15 = 135 samples were randomly selected for the interview.

Method of data collection: Data were collected by the experienced field investigators with direct supervision of the researchers using a pre-tested interview schedule.

Analytical technique: Data were categorized according to the year of cultivation. The age of the boroj were classified like 1^{st} year, 2^{nd} year, 3^{rd} year, 4^{th} year, 5^{th} year, $6\text{-}10^{th}$ year and $11\text{-}20^{th}$ year. Collected data were edited, summarized, tabulated and analyzed to fulfill the objectives of the study. Tabular methods of analysis using descriptive statistics like average, percentage, ratio etc. were followed in presenting the results of the study. For measuring capital productivity, costs and returns were discounted at 12 %, 15% and 20% rate of interest. The BCR, NPV and IRR in betel leaf cultivation were calculated with the help of following formula.

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

$$\text{Internal rate of return} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0$$

Where,

  B_t = Total benefit (Tk/ha) in t^{th} year, C_t = Total cost (Tk/ha) in t^{th} year, t = Number of year, i = interest (discount) rate.

To make a valid generalization it was necessary to conduct sensitivity analysis. These tables have been reworked separately in this section to see what happens on the profitability of betel leaf under the varying conditions. For all the study areas, all costs of the betel leaf were considered constant while benefit decreases at the rate of 5% or if benefit of the betel leaf remains the same but all costs increase at the rate of 10% then what would be the outcome.

3. Results and Discussion

3.1 Production Technology

Farmers in the study areas prepared their land by spading for betel leaf cultivation. The farmers planted betel leaf from July to September. It was observed that farmers of Noakhali and Rajbari planted betel leaf within September. The farmers used betel leaf vine as seed. Farmers in all the areas cultivated local varieties of betel leaf. Within local varieties, farmers mainly cultivated mohanali and Jhalpaan in Noakhali, mistipaan in Rajbari and Jhalpaan in Khulna district. They did not know about modern varieties of betel leaf, though BARI developed two betel leaf varieties. On an average, per hectare betel leaf seed (vine) was found to be 114838.

On an average, number of earthing up was 3 times, application of oilcake was 4 times, weeding was 2 times, number of spraying was 3 times and irrigation was one time per year (Table 2). It was observed that, weeding was done more in Khulna and insect infestation was found more in Noakhali.

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

Agronomic practices	Locations			
	Noakhali	Rajbari	Khulna	All areas
Time of plantation: (%)				
July	50	33	17	33
August	25	50	50	42
September	25	17	33	14
Earthing (No./year)	2.25	2.00	1.50	1.92
Oilcake application (No./year)	4.00	4.50	3.75	4.08
Weeding (No./year)	1.65	1.50	2.04	1.73
Pesticides application (No./year)	5.78(100)	1.38(89)	1.91(87)	3.02(92)
Irrigation (No./year)	0.44(42)	1.07(67)	1.29(23)	0.93(53)

Figures in the parentheses indicate percent farmer respondent.

3.2 Input use

Human labour was required for land preparation, seed (vine) planting, application of manures, fertilizing, spraying, weeding, irrigation and harvesting of betel leaf.

On an average, 1364 mandays/ha was required for betel leaf cultivation (Table 3). The numbers of human labour varied from one year to another year due to change in number of weeding, spraying pesticides, irrigation, and harvesting. Use of human labour was highest in first year due to land preparation, plantation of seed (vine) and *boroj* making in first year. In the study areas, farmers used 569 kg/ha/year cowdung. Highest (988 kg/ha/year) cowdung was used in 6-10 years while the lowest (76 kg/ha/year) was used in the fourth year. On an average, farmers used 2110 kg/ha/year oilcake in betel leaf cultivation which was highest (2429 kg/ha/year) in the fourth year *boroj*. The betel leaf farmers applied chemical fertilizers like urea 135 kg/ha/year, TSP 229 kg/ha/year and MP only 12 kg/ha/year. The application of urea and MP was highest in fourth year and TSP was observed to be highest in the fifth year old *boroj*.

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

Parameters	Period of cultivation (Year)							
	1st	2nd	3rd	4th	5th	6-10	11-15	All
Sample number	*n=4*	*n=13*	*n=25*	*n=24*	*n=25*	*n=33*	*n=11*	*n=135*
Human labour (mandays)	1447	1409	1393	1434	1349	1317	1243	1364
Own	363	553	547	593	423	460	524	504
Higher	1084	856	845	841	926	857	719	860
Seed (Vine no.)	116245	-	-	-	-	-	-	-
Cowdung(kg)	0	0	640	76	962	988	216	569
Oilcake(kg)	2079	1906	2280	2429	2133	1974	1633	2110
Fertilizer (kg):								
Urea	109	119	114	194	169	125	40	135
TSP	133	137	194	257	286	242	222	229
MP	0	15	0	25	17	5	15	12
Others*	43	45	25	59	21	20	33	32
Pesticides (Tk/year)	6006	6830	11120	5128	10458	8280	8310	8444

* Others indicate Gypsum, Zn etc.

3.3 Cost of production

Cost of production included human labour, *boroj* making materials, seed (vine), manures, fertilizers, pesticides, irrigation, pesticides etc. Rental value of land was treated as fixed cost and was shown in the total costs. Seed (vine) cost was needed only for the first year. The highest cost (Tk 1127272/ha) was observed in the first year due to seed (vine) and *boroj* making. The lowest cost (Tk 882806) was observed in the 11 and above years old *boroj* (Table 4). Among the cost items, human labour incurred the highest (49%) cost followed by *boroj* making cost.

3.4 Return

Betel leaf was harvested round the year but peak harvesting period was June to August. Regarding yield, data were collected from the survey plot on the basis of

local unit like *bira, Sali, gadi, kuri, pon* etc. After that yield data were converted in ton per hectare on the basis of average weight of betel leaf. On an average, 265 number of betel leaf constituted 1(one) kg i.e. 1 ton equal to 265000 number of betel leaf (Moniruzzaman *et. al.,* 2008). It was observed that the yield started increasing during 2nd to 4th year and it declined thereafter. On an average, 8.28 t/ha betel leaf was harvested, which was higher than national yield (6.07 t/ha) (BBS, 2013). The highest yield 9.44 t/ha was found from four year old boroj and lowest yield of 6.81 t/ha from one year old boroj (Table 5). Price was found to vary area to area and season to season. This ranges from Tk. 20 to Tk. 100 per bira (80 no. of betel leaf). The price fall from March to May due to growing new leaves and peak production. Average gross return was obtained Tk. 1203258/ha with highest in 4th year (Tk. 1448751/ha) and lowest in 1st year (Tk. 922178/ha). Average gross margin was found Tk. 689875/ha which was also highest in 4th year (Tk. 941193/ha) and lowest in 1st year (Tk. 304015/ha). Highest BCR on full cost basis was found in 4th year (1.50) followed by 3rd and 5th year 1.27.

3.5 BCR, NPV and IRR

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

Firstly, the cost and benefit streams of 15 years were discounted in order to find their present worth. Dividing the present worth of the gross benefits by the present worth of the gross cost measured benefit cost ratio to be 1.16, 1.15 and 1.14 at 12%, rate of interest.

The most straightforward discounted cash flow measures of the project worth are the net present worth. It is the difference between the present worth of benefits and present worth of costs. The discounted gross benefit has present worth at 12%, rate of interest were Tk.8353017/ha and the discounted gross cost has present worth of Tk 7184153/ha (Table 6). The difference between the two net present worth at 12% discount rate is Tk 1168864/ha. It signifies that betel leaf cultivation is profitable (Table 7).

The internal rate of return for the investment is that discount rate which nullifies the present worth of cash flows and outflows. It represents the average earning power of the money used in the project over the project life. In betel leaf project, the internal rate of return is 59%. It is acceptable, because it is much higher than the opportunity cost of capital.

Table 4. Per hectare cost of betel leaf cultivation in the study areas

Taka/ha

| Parameters | Period of cultivation (Year) | | | | | | | All |
	1st	2nd	3rd	4th	5th	6-10	11-15	
Sample number	*n=4*	*n=13*	*n=25*	*n=24*	*n=25*	*n=33*	*n=11*	*n=135*
Human labour	531255	501728	476455	479802	466543	465355	443219	473850(49)
Seed(Vine)	97612	0	0	0	0	0	0	2892 (0.30)
Boroj materials	339794	326079	343148	313261	336198	318996	300692	325442(34)
Manures:								
Cowdung	0	0	640	76	962	988	216	569 (0.06)
Oilcake	72861	66269	80325	89085	81028	73015	61009	77077(8)
Fertilizers :								
Urea	2131	2067	2122	3258	2969	2232	645	23829 (0.25)
TSP	3335	3886	6128	6937	8586	7592	7038	6860 (0.71)
MP	0	235	0	426	279	101	305	200 (0.02)
Others	1801	1536	1381	1249	1143	1074	1408	1268 (0.13)
Pesticide	6006	6830	11120	5128	10458	8280	8310	8444 (0.88)
Irrigation	3314	2739	2767	4523	2804	2278	2413	2951 (0.31)
Interest on opt. cap.	40441	32806	33563	33205	35659	33372	28827	33586 (3.48)
Rental value of land	28724	28724	28724	28724	28724	28724	28724	28724 (2.98)
Total cost	1127272	972899	986372	965676	975353	942007	882806	964246 (100)

Note: Figures in the parentheses indicate the percentage of total cost.

Table 5. Profitability of betel leaf in the study areas

| Item | Period of cultivation (Year) | | | | | | | All |
	1st	2nd	3rd	4th	5th	6-10	11-15	
Sample number	*n=4*	*n=13*	*n=25*	*n=24*	*n=25*	*n=33*	*n=11*	*n=135*
Yield(t/ha)	6.81	7.08	8.63	9.44	8.53	8.14	6.82	8.28
T. variable cost (Tk/ha)	618164	501462	513040	507558	545069	510116	440642	513383
Gross return (Tk/ha)	922178	941263	1250055	1448751	1234057	1155084	1047648	1203258
Gross margin(Tk/ha)	304014	439801	737015	941193	688988	644968	607006	689875
Rate of return: Cash cost basis	2.41	2.13	2.81	3.37	3.07	2.87	2.53	2.87
Full cost basis	0.82	0.97	1.27	1.50	1.27	1.23	1.19	1.25

Table 6. Benefit cost analysis of betel leaf production in the study areas

| Year | Cost (Tk./ha) | Discount factor (DF) | Discounted cost at | Gross return (Tk./ha) | Discounted benefit at |
		12%	12%		12%
1	1127272	0.89	1006493	922178	823374
2	972899	0.80	775589	941263	750369
3	986372	0.71	702080	1250055	889764
4	965676	0.64	613705	1448751	920708
5	975353	0.57	553442	1234057	700237
6-10	942007	0.51	477250	1155084	585201
11-15	882806	0.29	253786	1047648	301174
Total			7184153		8353017

3.6 Sensitivity Analysis

The results of sensitivity analysis are presented in Table 8. It was revealed that BCR of betel leaf is greater than one. NPV is positive at 12% discount rate and IRR is also higher than the opportunity cost of capital. This implies that if the returns decrease at 5%, the cost of betel leaf remains unchanged and investment in betel leaf is profitable from the point of view of the owner. On the other hand, if gross cost increases at 5% the returns remain same. This means that the owner of betel leaf boroj can also make profitable if all costs slightly increase in near future. The result of the study indicates that the owners of betel leaf boroj can earn profits under changing situation.

3.7 Constraints

Farmer's opinion on the constraints related to cultivation is highlighted in Table 9. Leaf rot disease was a common problem in the study areas. About 83% farmers opined that it is the serious problem for betel leaf cultivation. High price of boroj materials was another problem reported by 74% farmers. Sixty five percent farmers reported that non-availability of modern varieties were the common problem which hampered the betel leaf production. Price of betel leaf is very low during rainy season (June to August). Regarding high price of oilcake, seed (vine) died and lacks of capital were the major problems of betel leaf cultivation. Besides these, some farmers mentioned that insect infestation, excess cold were also the constraints of betel leaf cultivation.

Table 7. BCR, NPV and IRR of betel leaf cultivation in the study areas

Item	Discount factor (DF)		
	12%	15%	20%
BCR	1.16	1.15	1.14
NPV	1168864	935546	664394
IRR	59%		

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

Situation	Discount measures		
	BCR at 12%	NPV at 12%	IRR (percentage)
Current situation	1.16	1168864	59
Decrease of return:			
5%	1.10	751213	42
Increase of gross cost:			
5%	1.11	809652	52

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

Constraints	Percent farmer's responded
1. Leaf rot disease	83
2. High price of boroj materials	74
3. Non-availability of modern varieties	65
4. Low price of betel leaf	55
5. High price of oilcake	41
6. Seed (vine) mortality	38
7. Lack of capital	33
8. Others*	15

* Others indicate insect infestation, excess cold etc.

4. Conclusions and Recommendations

All the betel leaf farmers in the study areas cultivated local varieties. The benefit cost ratio, net present worth and internal rate of return indicate that betel leaf cultivation is profitable for the farmers in the study areas. Sensitivity analysis also indicates that the betel leaf farmers can earn profit under changing situation. Cultivation cost of betel leaf is very high mostly due to more use of labour and high price of boroj materials. Farmers faced various constraints like, leaf rot disease, high price of boroj materials, non-availability of modern variety, low price of betel leaf, high price of oilcake, vine mortality, lack of capital etc.

Pathologist may conduct research on betel leaf for controlling diseases. It is also imperative to carry out more research on developing high yielding varieties of betel leaf and to develop appropriate production technologies for maximizing the yield as well as profit. Strengthening to popularize the BARI released varieties of betel leaf and to expand the cultivation area.

References

Ahmed, A.U. 1985 Disease Problems of Betel Leaf Vine in Kushtia Area, Plant Pathology Division, BARI, Joydebpur, Gazipur.

BBS (Bangladesh Bureau of Statistics). 2013. Yearbook of Agricultural Statistics of Bangldesh.   Statistical Division, Ministry of Planning. GOB. P. 114.

Gittinger, J.P. 1977. Economic Analysis of Agricultural Project. A World Bank Publication.]

Islam, M.N. and S.M. Elias. 1991. Production and Marketing of Betel leaf in selected areas of Bangladesh, Research Report No. 16, Agricultural Economics Division, BARI, Joydebpur, Gazipur.

Moniruzzaman, M.S. Rahman, M.A Hossain and Q.M. Alam. 2008.   Betel Leaf Production and Its Market Potential on National and International Market. Annual Research Report, Agricultural Economics Division, BARI, Joydebpur, Gazipur.

EFFECTIVENESS OF SOME SELECTED INSECTICIDES AND BOTANICALS AGAINST OKRA SHOOT AND FRUIT BORER

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Abstract

An experiment was conducted to evaluate the effectiveness of some selected insecticides and botanicals against okra shoot and fruit borer *Earias vittella* F. under field conditions. The insecticides tested were Relothrin 10EC @ 1ml l^{-1}, Marshal 20EC @ 2ml l^{-1} and Riva 2.5 EC @ ml l^{-1}; and the botanicals were NSKE @ 50g l^{-1}, Neem leaf extract @ 100g l^{-1} and Bishkatali leaf extract @ 100g l^{-1}. An additional treatment of Mechanical control (hand picking) and an untreated control were maintained in the experiment for comparison. All treatments were applied at 15 days interval. Shoot infestation was the lowest in Marshal 20EC treated plot (4.34% at pre-fruiting and 3.55% at fruiting stage) and the highest was in untreated control plot (21.4%). The lowest fruit infestation by okra shoot and fruit borer was obtained with Marshal 20EC (5.07% n/n and 3.65% w/w) followed by Relothrin 10EC (5.43% n/n and 4.27% w/w) and the highest infestation was observed under untreated control plot (19.67% n/n and 19.81% w/w). The reduction of fruit infestation over untreated control ranged from 56.93-81.55% by number and 43.47-74.22% by weight. The highest marketable yield (10.46 t ha^{-1}) was obtained in Marshal 20EC treated plot followed by in Relothrin 10EC 10.30 t ha^{-1} with the maximum benefit cost ratio (BCR) 6.72.

Keywords: Insecticides, botanicals, *Earias vittella,* okra, Okra shoot and fruit borer.

Introduction

Okra (*Abelmoschus esculentus* L.) is an annual widely grown vegetable crop in Bangladesh. But the crop is severely hampered by a number of insect pests, especially okra shoot and fruit borer, jassid and whitefly. Among them, okra shoot and fruit borer, *Earias vittella* F. (Lepidoptera, Noctuidae) is the most damaging pest of okra (Butani and Jotwani, 1984). Srinivasan and Krishnakumar (1983) reported up to 40-50% damage of okra fruits by this pest in some areas of South-East Asian countries. In Bangladesh, *E. vittella* is noted as major insect pest of okra causing tremendous yield losses (Ali, 1992).

Several management practices have been reported to combat this pest (Kabir, 2007; Haque, 1998), however, use of insecticide is the main reliable tool (Parkash, 1988).

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A wide range of organophosphorus, carbamate and synthetic pyrethroids of various formulations have been recommended to control the pest (Chattopadhyay, 1991; Borah, 1997). Sahoo and Pal (2003) reported that spraying carbosulfan at 15 days interval showed the lowest fruit damage of okra. Ambekar *et al.* (2000) reported that cypermethrin at 0.1% showed effective against *E. vittella* and recorded the lowest infestation. Vishwanath and Singh (2008) described that foliar application of Lambda-Cyhalothrin at flowering and fruit initiation stages was the most effective against *E. vittella*. However, indiscriminate and non-judicious use of insecticides may result in a series problem related to both loss of their effectiveness and in the long run, it develops insect resistance (Alam *et al.,* 2003), pollution (FAO, 2003) and health hazards (Chinniah *et al.*, 1998). Various non-chemical approaches like use of botanicals, clean cultivation, mechanical control like hand picking and destroying of infested plant parts particularly shoots and fruits are common practices used for suppressing the insect pests (Hasan, 1994).

Due to lack of knowledge and unavailability of non-chemical pest management approaches, growers of Bangladesh mostly depend on insecticides to keep the crop production steady. Appropriate knowledge and availability of botanical pest management approaches and their integration with selective chemicals may give better results against okra shoot and fruit borer. Considering the circumstances, the present study was conducted to evaluate the effectiveness of three insecticides and three botanicals for effective and economic management of *E. vittella* in okra field.

Materials and Method

Experimental site and design

The study was conducted in the experimental farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during March to July 2010. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3m × 2m and separated by 1m and block to block distance was 2m.

Growing of okra

Seeds of okra cultivar Arka Anamika were soaked in water for 24 hours and sown in the pit in the field. Two to three seeds were sown in each pit maintaining line to line distance of 60 cm and finally plant to plant distance 40 cm. Each unit plot received 21 plants. Gap filling was done by transplanting seedlings from the stock. Manures and fertilizers were applied according to Rashid (1999) and intercultural operations such as irrigation, weeding, mulching, thinning and other operations were done accordingly. One spray with Imitaf 20 SL @ 0.25 ml l^{-1} water within 30 days after seed sowing (DAS) was done to control whitefly (*Bemisia tabaci*).

Preparation of botanicals

Neem seed karnel extract: Mature seeds of neem (*Azadirachta indica*) were collected, sun dried and grounded into powder. The powder was soaked in water @ 50g/300 ml of water for overnight. The mixture was filtered through nylon net and maintained the volume of 1000 ml.

Biskatali and neem leaf extract: Fresh Bishkatali (*Polygonum hydropiper*) and neem leaves (*Azadirachta indica*) were collected for the preparation of leaf extract one day before application. The leaves were cut into small pieces and 500g leaves were blended thoroughly in an electric blender. The blended leaves were mixed with two liters of water and the mixture was kept overnight to enhance extraction. The mixture was then sieved and maintained the volume at 5 liters.

Application of treatments

The experimental field was monitored regularly to observe the initiation of infestation When the pest caused approximately 2% shoot infestation, the application of treatments was started. The experimental treatments were Marshal (Carbosulphan) 20EC @ 2ml l^{-1}, Ripcord (Cypermethrin) 10EC @ 1ml l^{-1} water, Riva 2.5EC (Lambda-cyhallothrin) @ 1ml l^{-1}water, Neem seed kernel extract (NSKE) @ 50 g l^{-1} water, Neem leaf extract @ 100g l^{-1} water, Bishkatali leaf extract @ 100g l^{-1} water, Mechanical control (hand picking). All the treatments were applied at 15 days interval and repeated 4 times up to last harvest.

Collection and analysis of data

Data on shoot infestation and fruit yield by number were recorded. Total number of shoots and the number of infested shoots were recorded from 5 plants randomly selected in each plot at before flowering, after flowering to fruit initiation and at fruiting stages at 7 days interval. The number of healthy and infested fruits and their weight per plot were recorded at each harvest. The infestation of the pest was expressed in percentage based on total number of shoot and fruit (n/n) and weight (w/w) of fruit.

The cumulative yield (g) per plot of healthy as well as infested fruits was computed. The final yield was expressed in ton per hectare. For economic analysis, BCR was calculated on the basis of total expenditure of the respective spray schedule along with the total return from that particular spray schedule. The data were analyzed statistically by analysis of variance (ANOVA) and the means were separated by using Duncan's Multiple Range Test (DMRT).

Results and Discussion

Rate of shoot infestation

Effects of various treatments on percent shoot infestation by okra shoot and fruit borer at pre fruiting and fruiting stages is presented in Table 1. Shoot infestation

ranged 4.34-21.43% at pre-fruiting and 3.55-21.42% at fruiting stages under different treatments. The highest shoot infestation was observed in untreated control plot and the lowest infestation was obtained with Marshall spray at both pre-fruiting and fruiting stages. The reduction of shoot infestation over untreated control ranged from 40.32 to 79.75% at pre-fruiting stage and 49.81 to 83.41% at fruiting stage. The highest reduction in shoot infestation was achieved with Marshal 20EC treated plot followed by Relothrin 10EC (76.33%), Riva 2.5EC (69.03%), NSKE (65.70%), Neem leaf extract (60.84%) and Bishkatali leaf extract (52.92%) treated plots.

At fruiting stage, reduction in shoot infestation over control ranged from 49.81-83.41% under different treatments including untreated control. The highest reduction was also obtained with Marshal 20EC treated plot followed by Relothrin 10EC (79.24%), Riva 2.5EC (76.99%), NSKE (69.89%), Neem leaf extract and Bishkatali leaf extract (58.30%) sprayed plots. The lowest shoot infestation was recorded from Marshal 20EC (3.55%) treated plot, which was statistically similar to Riva 2.5EC (4.93%) and Relothrin 10EC (4.45%) treated plots. The higher shoot infestation was recorded from mechanical control plot (10.75%) which was significantly similar with Bishkatali leaf extract (8.93%) and Neem leaf extract (7.45%) treated plots.

Results revealed that among the treatments the efficacy of insecticides was better than the three plant extracts. Among the insecticides, the most effective was Marshal 20EC followed by Relothrin 10EC and Riva 2.5EC. Of the three botanicals, Neem seed kernel extract (NSKE) was most effective followed by Neem leaf extract and Bishkatali leaf extract (Table 1). In a similar study, In-Hu *et al.* (2004) reported that Proclaim showed 87.00% shoot infestation reduction over control. Islam *et al.* (1999) recommended that the minimum acceptable level of shoot infestation reduction over control was 80.00%.

Table 1. Effect of chemical, botanical and mechanical treatments on the rate of shoot infestation by okra shoot and fruit borer at pre-fruiting and fruiting stages

Treatments	Pre-fruiting stage		Fruiting stage	
	% Shoot infestation	% Infestation reduction over control	% Shoot infestation	% Infestation reduction over control
Marshal 20EC	4.34c	79.75	3.55f	83.41
Riva 2.5EC	6.63bc	69.03	4.93def	76.99
Relothrin 10EC	5.07bc	76.33	4.45ef	79.24
Neem seed kernel extract	7.35bc	65.70	6.45cde	69.89
Neem leaf extract	8.39bc	60.84	7.54cd	65.23
Bishkatali leaf extract	10.00bc	52.92	8.93bc	58.30
Mechanical control	12.79b	40.32	10.75b	49.81
Untreated control	21.43a	-	21.42a	-
CV (%)	8.59	-	16.75	-

Means within the same column with a common letter(s) do not differ significantly (P=0.05) according to DMRT.

Rate of fruit infestation (n/n and w/w)

The lowest rate of fruit infestation (n/n) was obtained in plots sprayed with Marshal 20EC (5.07%) followed by Relothrin 10EC (5.43%) and these were statistically similar but significantly lower compared to other treatments (Table 2). The rate of fruit infestation obtained 6.68% in Riva 2.5EC, 7.46% in Neem seed kernel extract, 9.99% in Neem leaf extracts, 10.25% in Bishkatali leaf extract treated plots. The highest rate of fruit infestation (n/n) was obtained in untreated control plots (19.67%) followed by Mechnical control plots (11.12%) and these were statistically different from each other.

The rate of reduction of fruit infestation (n/n) over untreated control was obtained with Marshal 20EC (74.22%) followed by Relothrin 10EC (72.38%), Riva 2.5EC (66.00%), NSKE (62.04%), Neem leaf extracts (49.21%). The least effective treatments to reduce fruit infestation were Mechnical control (43.47%) followed by Bishkatali leaf extract (47.90%) (Table 2).

The lowest fruit infestation (w/w) was obtained in plots sprayed with Marshal 20EC (3.65%) followed by Relothrin 10EC (4.27%) and Riva 2.5EC (5.51%) differences were statistically significant. The rate of fruit infestation obtained 5.76% in Neem seed kernel extract, 7.37% in Neem leaf extracts, 7.83% in Bishkatali leaf extract treated plots. The highest rate of fruit infestation (w/w) was obtained in untreated control plots (19.81%) followed by Mechnical control plots (8.53%) and these were statistically different with each other.

Reduction (% w/w) of fruit infestation over untreated control ranged from 56.93-81.55%. The highest reduction was achieved with Marshal 20EC followed by Relothrin 10EC (78.41%) and Riva 2.5EC (72.17%). Among the botanicals, 70.91, 62.76 and 60.46% reduction was achieved with foliar spray of NSKE, Neem leaf extract and Bishkatali leaf extract, respectively. The lowest reduction of 56.93% was obtained with Mechanical control (Table 2).

In a similar type of study, Pawar *et al.* (1988) reported that single spray of Endosulfan with concentration 500 g ha^{-1} followed by 3 applications of Cypermethrin or Fenvalerate at 50 g ha^{-1} at an interval of 14 days was the most effective for the control of *E. vitella* infesting okra. On the other hand, Alagar and Sivasubramaniam (2006) recorded the highest percentage of okra fruit damage reduction (48.93%) and higher yield (14.75 tha^{-1}) with 5% NSKE.

Among the materials, Marshal 20EC was noted as the most effective material to suppress okra shoot and fruit borer. Similar study was conducted by Kabir (2007) and obtained 12.76%-92.52% reduction in fruit infestation over control. In the present study, the reduction of infested fruit over untreated control was higher (72.17-81.55%) in three insecticide treated plots compared to botanicals (60.46-70.91%).

Table 2. Effect of insecticides, botanicals and mechanical treatments on rate of fruit infestation by okra shoot and fruit borer

Treatments	Rate of infestation (n/n)		Rate of infestation (w/w)	
	% Infestation	% Reduction over untreated control	% Infestation	% Reduction over untreated control
Marshal 20EC	5.07f	74.22	3.65 f	81.55
Riva 2.5EC	6.68e	66.00	5.51 d	72.17
Relothrin 10EC	5.43f	72.38	4.27 e	78.41
Neem seed kernel extract	7.46d	62.04	5.76 d	70.91
Neem leaf extract	9.99c	49.21	7.37 c	62.76
Bishkatali leaf extract	10.25c	47.90	7.83 c	60.46
Mechanical control	11.12b	43.47	8.53 b	56.93
Untreated control	19.67a	-	19.81 a	-
CV (%)	7.06	-	6.83	-

Means within a column with a common letter(s) do not differ significantly (P=0.05) according to DMRT.

Yield of okra (t ha^{-1})

The plots treated with Marshal 20EC produced significantly the highest marketable yield of okra per hectare (10.46 t ha^{-1}), which was statistically similar to that obtained from the Relothrin 10EC (10.30 t ha^{-1}) treated plot. The marketable fruit yield of okra was obtained from the plot treated with NSKE (9.89 t ha^{-1}) which was significantly different from all other treatments. The yield in Riva 2.5EC treated plot was 8.50 t ha^{-1} and Neem leaf extract treated plot produced 7.92 t ha^{-1}, were significantly different from each other and the rest of the treatments. Comparatively the lower yield of marketable fruit was obtained in Bishkatali leaf extract (7.34 t ha^{-1}) treated plot and Mechanical control (7.35 t ha^{-1}) plot which were statistically similar. The lowest marketable yield was harvested from untreated control plot (6.47 t ha^{-1}) and this was significantly lower compared to all other treatments (Table 3).

Significantly the highest infested fruit yield of okra (1.60 t ha^{-1}) was obtained in untreated control plot followed by mechanical control plot (0.68 t ha^{-1}) which was similar to Neem leaf extract (0.63 t ha^{-1}) treated plot. Statistically similar infested fruit yield was obtained in NSKE (0.60 t ha^{-1}) treated plot, Bishkatali leaf extract (0.62 t ha^{-1}) and also Neem leaf extract treated plots. The lowest infested fruit yield was obtained in Marshal 20EC (0.40 t ha^{-1}), which was significantly different from all other treatments. The lower infested fruit yield was obtained in Riva (0.49 t ha^{-1}) sprayed plot, which was followed by Relothrin 10EC (0.46 t ha^{-1}) and they were statistically similar.

The percent increase of marketable yield over untreated control plot was the highest (61.67%) in the plot sprayed with Marshal 20EC followed by Relothrin 10EC (59.20%) treated plot and NSKE (52.90%). The lowest percent increase in healthy fruit yield over untreated control was Bishkatali leaf extract (13.45%) treated plot which was followed by mechanical control plot (13.65%). Percent marketable yield increase over untreated control was lower in Riva 2.5EC (31.48%) and Neem leaf extract (22.46%).

The present finding of yield increase over control may be discussed with those of other authors. Choudhury and Dadheech (1989) reported that cypermethrin sprayed at weekly interval starting from the first flowering provided 25.00% increased yield over untreated control. Sardana and Kumar, 1989 observed that weekly application of Neem *(Azadirachta indica)* oil at 2% was effective for controlling *E. vittella* on okra. Neem oil was found as effective as Monocrotophos at 0.05%, and can therefore, be recommended for use in an integrated control scheme against this pest. In the present study, the NSKE provided appreciable yield increase (52.90%) over control compared to Relothrin (59.20%) and Marshal (61.67%). But it was considerably higher than that of Riva 2.5EC (31.48%). So, use of NSKE may be an alternate tools for safer management of okra shoot and fruit borer.

Table 3. Okra fruit yield obtained by shoot and fruit borer management using insecticides, botanicals and mechanical treatments

Treatments	Yield (t ha^{-1})		
	Marketable	Infested	% marketable yield increase over untreated control
Marshal 20EC	10.46a	0.40e	61.67
Riva 2.5EC	8.50c	0.49d	31.48
Relothrin 10EC	10.30a	0.46d	59.20
Neem seed kernel extract	9.89b	0.60c	52.90
Neem leaf extract	7.92d	0.63bc	22.46
Bishkatali leaf extract	7.34e	0.62c	13.45
Mechanical control	7.35e	0.68b	13.65
Untreated Control	6.47f	1.60a	-
CV (%)	6.90	6.05	-

Means within the same column with a common letter(s) do not differ significantly (P=0.05) according to DMRT.

Economic analysis of different control measures

The management cost of different treatments used against okra shoot and fruit borer was calculated and presented in Table 4. The highest gross return of Tk. 2,61,500.00 ha^{-1} was obtained with the Marshal 20EC followed by Relothrin 10EC (Tk. 2,57,500.00), NSKE (Tk. 2,47,250.00), Riva 2.5EC (Tk. 2,12,675.00), Neem leaf extract (Tk. 1,98,075.00), mechanical control (Tk. 1,83,825.00) and Bishkatali leaf extract (Tk. 1,83,500.00).

The highest net return of Tk. 2,47,300.00 per hectare was obtained with the Marshal 20EC followed by Relothrin 10EC (Tk. 2,45,100.00), NSKE (Tk. 2,31,350.00), Riva 2.5EC (Tk. 2,03,275.00), Neem leaf extract (Tk. 1,86,395.00), mechanical control (Tk. 1,76,625.00) and Bishkatali leaf extract (Tk. 1,74,484.00).

The highest adjusted net return of Tk. 85,550.00 ha^{-1} was obtained with the Marshal 20EC followed by Relothrin 10EC (Tk. 83,350.00), NSKE (Tk. 69,600.00), Riva 2.5EC (Tk. 41525.00), Neem leaf extract (Tk. 24,645.00), mechanical control (Tk. 14,875.00) and Bishkatali leaf extract (Tk. 12,734.00) (Table 4).

The highest benefit cost ratio (6.72) was obtained with Relothrin 10EC followed by Marshal 20EC (6.02), Riva 2.5EC (4.42), NSKE (4.37), Neem leaf extract (2.11), Mechanical control (2.07) and Bishkatali leaf extract (1.41). The cause of lower of these treatments were due to comparatively lower yield and higher cost of management against okra shoot and fruit borer (Table 4).

The economics of pest management of okra shoot and fruit borer were studied by Srinivasan and Krishnakumar (1983) in Karnataka, India, for 3 growing seasons. Disulfoton granules @ 1 kg a.i. ha^{-1} applied at the time of sowing, followed by 1% carbaryl sprays at 40, 50 and 60 days after germination, gave the maximum crop yield and net income.

The findings of the present study indicated that the insecticide Relothrin 10EC, Marshal 20EC and Riva 2.5EC are effective to manage infestation of okra shoot and fruit borer in okra. The result of this study reveal that NSKE showed effective result in suppressing okra shoot and fruit borer infestation and also cost effective. Although it provides moderate level of economic benefit but it has no hazard to health and environment compared to insecticide application.

Table 4. Benefit cost ratio analysis of selected insecticides and botanicals along with mechanical control for the management of okra shoot and fruit borer

Treatments	Management cost (Tk)	Gross return (Tk)	Net return (Tk)	Adjusted net return (Tk)	BCR
Marshal 20EC	14200.00	261500.00	247300.00	85550.00	6.02
Riva 2.5EC	9400.00	212675.00	203275.00	41525.00	4.42
Relothrin 10EC	12400.00	257500.00	245100.00	83350.00	6.72
Neem seed kernel extract	15900.00	247250.00	231350.00	69600.00	4.37
Neem leaf extract	11680.00	198075.00	186395.00	24645.00	2.11
Bishkatali leaf extract	9016.00	183500.00	174484.00	12734.00	1.41
Mechanical control	7200.00	183825.00	176625.00	14875.00	2.07
Untreated control	0.00	161750.00	161750.00	-	-

References

Alagar, M. and P. Sivasubramanian. 2006. Field efficacy of botanicals, insecticides and their combination against major pests of okra. *Indian J. of Entomol.* **68**(4): 369-374.

Alam, S.N., M.A. Rashid, F.M.A. Rouf, R.C. Jhala, J.R. patel, S. Satpathy, T.M. Shivalingaswamy, S. Rai, I. wahundeniya, A. Cork, C. Ammaranan, and N.S. Talekar. 2003. Development of an integrated pest management strategy for eggplant shoot and fruit borer in south Asia. *Technical Bull.* **28**. AVRDC-The world Vegetable centre, Shanhua, Taiwan. 66p.

Ali, M.I. 1992. Seasonal occurrence of different cotton bolloworms on cotton in Bangladesh. *Bangladesh J. Entomol.* **2**(1 & 2):1-7.

Ambekar, J.S., A.S. Pawar and M.V. Sakhare. 2000. Bio-efficacy of neem certain products against okra fruit borer. *J. Maharashtra Agril. Univ.* Pune, India. **25**(1): 42-43.

Borah, R.K. 1997. Effect of insecticides on pest incidence in cucumber (*Cucumis sativus*) in hill zone of Assam. *Indian J. Agric. Sci.* **67**(8): 332-333.

Butani, D.K. and M.G. Jotwani. 1984. Insects in vegetables. Periodical Expert Book Agency. Vivek-Vihar, Delhi (India). Pp. 45-66.

Chattopadhyay, P. 1991. Keetatatta, keetadaman O Shasya sanrakshan. West Bengal state Book board, Arjo Mansion (9th floor), 6A. Raja Subodh Mollick Sqmare, Calcutta 70013, India. 2nd Edition. (in Bangla). 375p.

Chaudhury, H.R. and L.N. Dadheech. 1989. Incidence of insects attacking okra and the avoidable losses caused by them. *Ann. Arid Zone*. **28** (3-4): 305-307.

Chinniah, C., S. Kuttalam and A. Regupathy. 1998. Harvest time residue oflindane and chlorpyriphos in paddy. *Pestic. Res. J.* **10**(1):91-94.

FAO (Food and Agriculture Organization). 2003. Intercountry programme for integrated pest management in vegetables in South and South-East Asia. Egg plant integrated pest management: An ecological guide. 177p

Haque, M.A. 1998. Seasonal abundance and management of okra shoot and fruit borer in summer. M.S. Thesis, BSMRAU, Gazipur, Bangladesh. Pp 27-45

Hassan, S.A. 1994. Strategies to select *Trichogramma* species for use in biological control. In: Biological control with egg parasitoids, (Eds.): E. Wajinberg and S.A. Hassan. Oxon, U.K.: CAB International. 557p.

In-Hu, C., J. Yong-Seok, K. Gil-Hah and K. Jeong-Wha. 2004. Control effects of some insecticides on different stages of the stone leek leafminer, *Liriomyza chinensis* kato (Diptera: Agromyzidae). *Korean Appl. Entom.* **43**(2): 169-173.

Islam, M.N., N.K. Dutta and M.A. Karim. 1999. Efficacy of different insecticides for the control of okra shoot and fruit borer, *Earias vittella* F. Annual Report. 1998-99. BARI, Joydevpur, Gazipur, Bangladesh. Pp 33-34.

Kabir, M.R. 2007. Effectiveness of some insecticides for the management of okra shoot and fruit borer (*Earias vittella* F.). M.S. Thesis, BSMRAU, Gazipur, Bangladesh. Pp 33-48

Parkash, O. 1988. Schedule of insecticidal application against insect pest complex of brinjal with special reference to brinjal shoot & fruit borer, *Leucinodes orbonalis* Guen. *Indian J. Ent.* **50**(1): 16-19.

Pawer, D.B., P.N. Kale, D.S. Ajri and K.E. Lawande. 1988. Chemical control of fruit borer of okra. *J. Maharashtra Agril. Univ.,* **13**(1): 115-117.

Rashid, M.M. 1999. Bibidh shabji (Dheros), *In*: Shabji Biggan (In Bangla). pp. 466-471

Sahoo, S.K. and P.K. Pal. 2003. Effect of alternate use of pesticides on shoot and fruit borers of okra. *Environ. and Ecol.* **21**(4): 960-963.

Srinivasan, K and N.K. Krisnakumar. 1983. Studies on the extent of loss and economies of pest management in okra. *Tropic. pest manage.* **29**(4): 363-370.

Vishwanath and J.P. Singh, 2008. Evaluation of insecticides and Neem formulations for control of *Earias vittella* of okra. *Annals Plant Protect. Sci.* **16**(1): 206-207.

AGRO ECONOMIC PERFORMANCE OF BIO-SLURRY ON *BORO* RICE CULTIVATION IN SOME SITES OF MOULVIBAZAR DISTRICT

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Abstract

Soil fertility in Bangladesh is gradually diminishing and this is now becoming a critical issue. Biogas slurry is a renewable energy produced organic fertilizer can be applied for maintaining the fertility of soil. In this study, a two years experiment was conducted in the year 2011 and 2012 at the farmer's field of Moulvibazar district under the agroecological zone 20 (AZE-20). The overall objective of the study was to observe the effect of bio-slurry on the agroeconomic performance of *boro* rice cultivation at on-farm condition. Three fertilizer treatments viz., T_1: Soil test based (STB) inorganic fertilizer for high yield goal (HYG), T_2: Integrated Plant Nutrient System (IPNS) based inorganic fertilizer + cowdung bio-slurry 5 tha^{-1} for HYG and T_3: Farmer's practice as control i.e. average of 20 farmers fertilizer application dose in boro rice were considered during experimentation. Results revealed that bioslurry based *boro* rice production is more profitable than chemical fertilizer. The highest grain yield (5.06 t ha^{-1}) was recorded from IPNS with 5 t ha^{-1} cow dung slurry for HYG (T_2) while the lowest yield was obtained from farmer's practice. However, yield increase due to application of 5 t ha^{-1} Cowdung slurry slurry with IPNS based inorganic fertilizer was 115 and 124% compared to STB inorganic fertilizer and farmers followed treatment. Gross margin (Tk.65900 ha^{-1}), benefit cost ratio (2.59) and marginal rate of return (451) were also obtained higher in the same treatment. Thus, nutrient package NPKSZn @102-12-25-18-2 kg + cowdung slurry 5 tha^{-1} might be helpful to get increased yield and improve soil health in AZE-20.

Keywords: Bio-slurry, IPNS, *boro* rice, profitability, soil health, AEZ-20.

Introduction

Soil fertility in Bangladesh is gradually diminishing and this is now becoming a critical issue. One of the reasons is over-use as well as prolonged use of chemical fertilizers in the soil. A good soil should have at least 2.0% organic matter (OM), but in Bangladesh most of the soils have less than 1.5% OM and some soils have even less than 1% OM (FRG, 2012). Sinha and Rahman (2005) stated that the organic matter content in a soil should be over 3%, however it is now less than

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1.5% in many places. Thus, recycling of organic matter is essential for maintaining soil fertility.

Bio-slurry produced from biogas plant rich in nutrients can be used successfully for crop production. It is an important type of organic manure that is applied in the form of semi liquid or compost. It contains considerable amount of plant nutrients than cowdung, poultry manure or even in compost that improves the soil fertility. It has no toxic or harmful effects, the nutrient quality of slurry is higher than that of compost manure and chemical fertilizer as the minimal loss of nitrogen in slurry is more effective as fertilizer than composted cattle dung (Islam, 2006; BCAS, 2009). Joshi *et al.* (1994) reported that use of bio-slurry along with inorganic fertilizers may be a good option for increasing soil fertility. Application of bio-slurry gave significantly higher yield in vegetables. The preliminary experimental results indicated that the yield of crops and vegetables could be increased from 10 to 30 percent through the application of slurry (FAO, 1996). Bio-slurry has proven to have positive effects on yields compared to not using any soil amendments and fertilizers. In comparison with other organic fertilizers such as FYM or compost, the content of readily available N for plants is higher after bio-slurry application (Groot and Bogdanski, 2013). Bonten *et al.* (2014) asserted that nutrients in bio-slurry, especially nitrogen, are more readily available than in manure, leading to a larger short term fertilization effect. Although Moller *et al.* (2008) found that the yields did not significantly differ between the different treatments (Bio-slurry, undigested liquid slurry and solid FYM) except for spring wheat, where the bio-slurry treatment led to higher yields due to immediate use of the readily available NH_4^+-N. However, other study suggested that rice yields increased by 23% compared to synthetic fertilizer application (Warnars and Oppenoorth, 2014). Application of slurry can increase both late and early rice yields to 44.3 and 31% while combined application with ammonium bicarbonate, the rice yields can increase to 12.1% (SNV, 2011). Batsai *et al.* (1979) observed that chemical fertilizer along with organic manure produced the highest cabbage yield. Boro rice is a major crop which contributes more than 50% of total rice production in Bangladesh. To achieve self-sufficiency in food grains production in a sustainable manner by improving the productivity on a short and medium term basis, sustainable intensification of rice along with non rice production are essential. Each year biogas plants are installing all over the Bangladesh by both the government as well as NGOs initiative. Their by-product 'bioslurry' is therefore needed to apply in the soil for helping sustainability of crop production and soil health management. Bio-slurry contains considerable amount of nutrients and the quality is higher than that of compost manure and chemical fertilizer. Thus, use of bio-slurry along with inorganic fertilizers may be a good option for increasing soil fertility in Bangladesh. Research work on the biogas slurry is lacking in acidic soil of Sylhet, Bangladesh. Therefore, the present study was undertaken to evaluate the efficiency of bio-slurry on the performance of *boro* rice

crops with the objectives: to determine the effect of bio-slurry application on soil nutrient status, to find out the effect of bio-slurry use on the yield and yield attributes of *boro* rice, and to estimate the financial performance of bio-slurry in *boro* rice cultivation.

Materials and Method

The experiment was conducted at the farmer's field at multi location testing site, Moulavibazar under On Farm Research Division, Bangladesh Agricultural Research Institute, Sylhet in the year 2011 and 2012. The trial was laid out in a randomized complete block design with three replications. There were three fertilizer treatments viz. T_1: Soil test based (STB) inorganic fertilizer for high yield goal (HYG), T_2: Integrated Plant Nutrient System (IPNS) based inorganic fertilizer + cowdung bio-slurry 5 tha^{-1} for HYG and T_3: Farmer's practice as control i.e. average of 20 farmers fertilizer application dose in boro rice. The initial soil nutrient status of the experimental soil and treatment wise nutrient elements are presented in Tables 1 and 2. The plot size was 6m × 5m the rice variety BRRI dhan29 was used in the trial. Thirty days aged entire amount of cowdung slurry as per treatment were applied 4 days before final land preparation. The whole amount of PKSB and ⅓ of N were applied during final land preparation. The rest of N was top dressed at 21 and 45 days after transplanting of *boro* rice. Twenty seven days old of *boro* rice seedling were transplanted on 15 March in both the years. Plant protection measures and other intercultural operations were done as and when necessary. The crop was harvested on 28 June 2011 and 30 June 2012. Data on yield and yield attributes viz., plant height, tiller per plant, panicle per m^2 and 1000 grain weights were recorded in time. Individual plot wise data on grain and straw yield were recorded and converted into per hectare yield. Biological yield is expressed as the combined yield of grain and straw yields while the harvest index was calculated with the grain yield multiply with 100 and then divided by biological yield. The partial budget and marginal analysis of cost and return was done as per Perrin *et al.* (1979) and Karim and Elias (1992). The collected data were analyzed following the ANOVA technique with the help of MSTAT-C software. The mean differences among the treatment means were adjudged by Least Square Difference (LSD) test (Gomez and Gomez., 1984).

Table 1. Initial soil nutrient status of the experimental plot (average of 2011 and 2012)

Elements	N (%)	P (μg/g soil)	K (meq. /100g soil)	S (μg/g soil)	Zn (μg/g soil)	OM (%)	pH
Value	0.11	3.00	0.08	7.50	0.07	1.95	4.5
Interpretation	Low	Very low	Low	Very low	Low	Moderate	Very strongly acidic

Table 2. Nutrient packages for boro rice cultivation

Treatments	N-P-K-S-Zn (kgha^{-1})
T$_1$: STB inorganic fertilizer dose for HYG	125-22-55-18-2
T$_2$: IPNS basis inorganic fertilizer + cowdung slurry @ 5tha^{-1} for HYG	102-12-25-18-2 + 5 tha^{-1} cow dung (CD) slurry
T$_3$: Farmer's practice as control (average of 20 farmers fertilizer dose)	130-25-45-20-0

Results and Discussion

Two years results did not vary statistically, so pooled analyses were done. Results revealed that the yield attributes and yield of *boro* rice (BRRI dhan29) significantly influenced by different nutrient packages except 1000 grain weight and straw yield (Table 4). The detailed descriptions are furnished below:

Effect of Bio-slurry Application on Soil Nutrients

The post harvest soil test analysis revealed that there were increased in soil nutrients in bio-slurry applied experimental plot (T$_2$: CD slurry @ 5 t ha^{-1} along with IPNS based inorganic fertilizer) compared to initial soil nutrient status and other treatments where bio-slurry were not incorporated (T$_1$ and T$_3$). However, higher doses of fertilizer in farmer's practice slightly deteriorates some of the soil nutrients that might affect on the fertility of the soil. Soil pH was also increased in the bio-slurry treated plot in comparison to others (Table 3). Kumer *et al.* (2015) reported that biogas slurry provides huge nutrient potential for vegetative and reproductive growth of field crops with long term sustainability and help in reducing fertilizer demand and provide an eco-friendly way of maintaining productivity and soil health.

Table 3. Soil nutrient status after harvest of boro rice (average of 2011 and 2012)

Treatment	N (%)	P (µg/g soil)	K (meq. /100g soil)	S (µg/g soil)	Zn (µg/g soil)	OM (%)	pH
Initial status	0.11	3.00	0.08	7.50	0.07	1.90	4.50
T$_1$	0.12	3.50	0.09	8.00	0.08	1.92	4.53
T$_2$	0.15	4.12	0.11	9.24	0.10	1.98	4.65
T$_3$	0.10	3.00	0.07	7.40	0.078	1.85	4.48

T$_1$: STB inorganic fertilizer dose for HYG, T$_2$: IPNS basis inorganic fertilizer + CD bio-slurry @5 tha^{-1} for HYG and T$_3$: Farmer's practice (Control)

Effect of Bioslurry Application on Yield attributes

Plant height: Application of fertilizers following IPNS approach gave the longest plant height of boro rice compared to the use of only inorganic fertilizers. The highest plant height (103.91 cm) was obtained from CD slurry @ 5 t ha^{-1} with IPNS based inorganic fertilizer (T_2) which was statistically similar to soil test based inorganic fertilizer treatment (T_3) (101.27 cm). The lowest plant height (98.89 cm) was obtained from farmer's practices treatment (T_3) (Table 4).

Tiller per plant: Like plant height, the highest number of tillers per plant (12.33) was obtained from T_2 treatment (CD slurry @ 5 t ha^{-1} with IPNS based inorganic fertilizer) which was close to T_3 treatment. However, although the result was identical with T_3 and T_1, the lowest tiller per plant was observed in T_1 treatment (Table 4).

Panicle per m^2: The highest number of panicles per m^2 (361) was obtained from T_2 treatment which was followed by T_3 treatment. The lowest panicle per m^2 (297) was recorded in soil test based inorganic fertilizer (T_1) treatment (Table 4).

1000 grain weight: 1000 grain weight of boro rice was not influenced by the different nutrient packages. It might be due to the genetical character of the variety that did not show any difference in 1000 grain weight of boro rice. However, the highest 1000 grain weight (22.59 g) was obtained from T_2 treatment which was statistically similar to T_1 treatment. The lowest 1000 grain weight (21.22 g) was recorded in inorganic fertilizer followed by farmers practice (Table 4).

Effect of Bioslurry Application on Boro rice Yield

Table 4 showed that the highest grain yield (5.06 t ha^{-1}) was obtained from IPNS with 5 t ha^{-1} cowdung slurry for HYG (T_2), while the lowest yield was obtained from farmer's practice (T_3). From this result, it might be evident that cowdung slurry has a great potentiality in increasing boro rice yield. However, yield increase due to application of CD slurry @ 5 t ha^{-1} with IPNS based inorganic fertilizer (T_2) was 115 and 124% compared to soil test based inorganic fertilizer (T_1) and farmers followed treatments (T_3). Results revealed that straw yield of boro rice was non significant among the nutrient management packages. However, the highest straw yield (6.40 t ha^{-1}) was obtained from T_3 treatment, while the lowest straw yield was found in STB inorganic fertilizer package (T_1) treatment. Gnanamani and Kasturi Bai (1992) reported that the yield of rice grain showed a 23% increase when soil was amended with B, compared to SF (containing N, K and P). Similar results were also observed by Bharde (2003). A combination of biogas slurry @ 12.5 tha^{-1} and 100% NPK had pronounced effect on enhanced growth, yield attributes and yield of rice (Gurung, 1997). The results are also in conformity with the findings of Shaheb and Nazrul (2011) who

reported that inorganic fertilizer along with cowdung slurry @ 5 t ha^{-1} in IPNS approach produced the highest yield of cabbage.

Table 4. Effect of bio-slurry on yield and yield attributes of boro rice (var. BRRIdhan29) (pooled of 2011 and 2012)

Treatment	Plant height (cm)	Tiller plant^{-1} (nos.)	Panicle m^{-2} (nos.)	1000 grain weight (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Harvest Index	Biological yield (tha^{-1})
T$_1$	101.27b	10.00b	296.67c	21.55	4.37b	5.83	43	10.13
T$_2$	103.91a	12.33a	361.33a	22.59	5.06a	6.27	45	11.33
T$_3$	98.89b	10.67b	321.00b	21.22	4.07b	6.40	39	10.47
LSD$_{0.05}$	2.53	1.31	17.41	NS	0.51	NS	-	
CV (%)	1.10	5.25	5.06	2.34	5.00	7.37	-	

T$_1$: STB inorganic fertilizer dose for HYG, T$_2$: IPNS basis inorganic fertilizer + CD bio-slurry @5 tha^{-1} for HYG and T$_3$: Farmer's practice (Control).

Higher crop yields due to application of bio-slurry were also reported by Jayakumar *et al.* (1993), Manna and Hazra (1996) and Galli and Lalitpur (2001). Biogas slurry increases agricultural production because of its higher content of plant nutrients, growth hormones and enzymes (FAO, 1996). Garfi *et al.* (2011) asserted that the potato yield was increased by 27.5% with bioslurry compared to the control.

Profitability of *Boro* rice cultivation

The cost and return analysis of different fertilizer treatments are presented in Table 5. The highest gross return (Tk.107470 ha^{-1}) and gross margin (Tk.65900 ha^{-1}) were obtained from T$_2$ (CD slurry @ 5 t ha^{-1} with IPNS based inorganic fertilizer for HYG). The variable cost was also higher in T$_2$ because of additional use of cowdung bio-slurry. Karim and Elias (1992) pointed that the farmers always try to maximize their return up to the point where returns to investment are the highest as the capital is scarce. The purpose of marginal analysis is to reveal how the gross margin from investment increase as the amount of investment decreases (Perrin *et. al.* 1989). The highest BCR (2.59) and marginal rate of return (451) were recorded in T$_2$ (CD slurry @ 5 t ha^{-1} with IPNS based inorganic fertilizer for HYG). It indicates that if a farmer spends additional one hundred taka, he can get an extra income of Tk. 451. Financially profitable production of cabbage and cauliflower were also found from poultry manure slurry @ 3 t ha^{-1} or CD slurry @ 5 t ha^{-1} with IPNS basis inorganic fertilizer in AEZ-28 (BARI, 2008). The results are also in conformity with the findings of Shaheb and Nazrul (2011). Thus, nutrient package NPKSZn @102-12-25-18-2 kgha^{-1} + cow dung slurry 5 t ha^{-1} might be helpful to get higher yield of boro rice in agroecological zone 20 (AZE-20).

Table 5. Cost and return analysis of the effect of bio-slurry application on Boro rice (var. BRRI dhan 29) (average of 2011 and 2012)

Treatment	Gross Return (Tk.ha^{-1})	Total variable cost (TVC) (Tk.ha^{-1})	Gross margin (Tk.ha^{-1})	BCR On TVC	MRR (%)
1	2	3	4 (2-3)	5 (2÷3)	6
T_1	93230	39320	53910	2.37	257
T_2	107470	41570	65900	2.59	451
T_3	87800	37205	50595	2.36	-

T_1: STB inorganic fertilizer dose for HYG, T_2: IPNS basis inorganic fertilizer + CD bio-slurry @5 tha^{-1} for HYG and T_3 : Farmers practice (Control)

N. B. Price of inputs and outputs ((Tk.Kg^{-1})*: Urea-12, TSP-22, MoP-15, Gypsum-10, Zinc sulphate-130, CD slurry-1, Rice seed-33, Rice grain-20, and Rice straw-1.*

Conclusion

From the findings of the study it revealed that bio-slurry based *boro* rice production is more profitable than chemical fertilizer. The highest grain yield (5.06 t ha^{-1}) was recorded from IPNS with 5 t ha^{-1} cow dung slurry for HYG while the lowest yield was obtained from farmer's practice. Yield increase due to application of CD slurry @ 5 t ha^{-1} with IPNS based inorganic fertilizer for HYG was 115 and 124% compared to STB inorganic fertilizer and farmers treatments. According to partial budget and marginal analysis, the same treatment provided the highest gross return (Tk.107470 ha^{-1}) and gross margin (Tk.65900 ha^{-1}). BCR (2.59) and marginal rate of return (451) were also recorded higher in CD slurry @ 5 t ha^{-1} with IPNS based inorganic fertilizer for HYG. Farmers were found to be highly impressed to receive higher yield of rice using cow dung slurry and they wanted to apply bio-slurry in their field in future for receiving sustainable crop production. Thus, it might be recommended that CD bioslurry @ 5 t ha^{-1} along with inorganic fertilizer in IPNS approach could be applied for boro rice cultivation in Moulvibazar. It would be benefited for farmers to contribute more in food security as well as sustainable crop and soil management. Hence, it is also strongly recommended to continue this trial in other field crops including horticultural crops as a regular basis by the concerned organizations covering all agro-ecological zones of Bangladesh.

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References

BARI. 2008. Project report on "Bio-slurry management and its effect on soil fertility and crop production". Soil Science Division & On-Farm Research Division, Bangladesh Agricultural Research Institute, Gazipur 1701, Bangladesh. Pp. 41.

Batsai, S. T., A. A. Polyakev and R. F. Nedbal. 1979. Effect of organic and mineral fertilizers on the yield and quality of irrigated late and white cabbage in the steppe region of the Crimea. *Hort. Abst.* **49**(11): 730.

BCAS. 2009. Biogas user survey 2008 under national domestic Biogas and manure Program (Final report). IDCOL, Dhaka.

Bharde, N. M., Y. S. Shivay and S. Singh. 2003. Effect of bioslurry and neem oil-treated urea sources in rice (*Oryza sativa*)-wheat *(Triticum aestivum)* cropping system. *Indian J. Agron.* **48**(2): 73-75.

Bonten, L.T. C., K. B. Zwart., R. P. J. J. Rietra1., R. Postma and M. J. G. de Haas. 2014. Bio-slurry as fertilizer. Is bio-slurry from household digesters a better fertilizer than manure? A literature review. Alterra report 2519. Alterra Wageningen UR, Wageningen, Pp. 50. www.wageningenUR.nl/en/alterra.

FAO. 1996. Biogas Technology: A Training Manual for Extension. Published by FAO. Rome, Italy.

FRG. 2012. Fertilizer Recommendation Guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhake. p. 58.

Galli, K. and P. Lalitpur. 2001. Response to bio-slurry application on maize and cabbage in Lalitpur District, Nepal. Final Report. October 2001. GPO Box 1309, Kathmandu, Nepal. Pp. 63.

Garfi, M., P. Gelman., J. Comas., W. Carrasco., I. Ferrer. 2011. Agricultural reuse of the digestate from low-cost tubular digesters in rural Andean communities. *Waste Management.* doi:10.1016/j.wasman.2011.08.007.

Gnanamani, A. and R. Kasturi Bai. 1992. Influence of biodigested slurry on rice-gram cultivation. *Bioresource Technol.* **41**(3):217–221.

Gomez, K. A and A.A. Gomez. 1984. Statistical procedures for Agricultural Research. 2nd edn. John Wiley and Sons. New York. Pp. 207-215.

Groot, L. and A. Bogdanski. 2013. Bioslurry = Brown Gold? A review of scientific literature on the co-product of biogas production. Environment and Natural Resources working paper. FAO, Rome, Italy. www.fao.org. P. 1-45.

Gurung, J. B. 1997. Review of Literature on Effects of Slurry Use on Crop production. FINAL REPORT submitted to The Biogas Support Program Post Box 1966 Kathmandu, Nepal. Pp. 109.

Islam, M. S. 2006. Use of bioslurry as organic fertilizer in Bangladesh agriculture. Paper presented in the International Workshop, Bangkok, Thailand, 27-28, September 2006.

Jaykumar, M., M. Eyini and R. Elanogovan. 1993. Effect of biogass slurry on salanity-induced changes in growth and yield of sunflower. *Indian J. Agril. Sci.* **63**(10): 655-657.

Joshi, J. R., J. F. Moncrief, J. B. Swan and G. L. Malzer. 1994. Soil Till. Res. **31**: 225.

Karim, M. R and S. M. Elias. 1992. Application of partial budget technique of fertilizer response data on T. aman and mustard. *Bangladesh J. Agril. Res.* **17**(1): 24-28.

Kumar, S., L. C. Malav, M. K. Malav and S. A. Khan. 2015. Biogas Slurry: Source of Nutrients for Eco-friendly Agriculture. *International J. Ext. Res.* **2**:42-46.

Manna, M. C and J. N. Hazra. 1996. Comparative performance of cowdung slurry, microbial inoculum and inorganic fertilizers on Maize. *J. Indian Soc. of Soil Sci.* **44**: 526-528.

Moller, K., W. Stinner, A. Deuker and G. Leithold. 2008. Effects of different manuring systems with and without biogas digestion on nitrogen cycle and crop yield in mixed organic dairy farming systems. *Nutrient Cycling in Agroecosystems.* **82**: 209-232.

Perrin, R. K., D. L. Winkelman, E. R. Moseardi and J. R. Anderson. 1979. Farm agronomic data on farmer's recommendations. *Information Bulletin 27*, CIMMYT. Mexico.

Shaheb, M. R. and M. I. Nazrul. 2011. Performance of cabbage under IPNS with cowdung bio-slurry in estern Surma-Kushiyara floodplain. *Bangladesh Agron. J.* **14**(1&2): 23-26.

Sinha M. H. and M. M Rahaman. 2005. Environmental management practice of poultry waste. Bangladesh poultry sector development project, 2005.

SNV. 2011. Technology and Mass- Dissemination Experiences from Asia. Biogas compact course PPRE- Oldenburg University. April 26-28, 2011.

Warnars, L. and H. Oppenoorth, 2014. Bioslurry: a supreme fertilizer. A study on bioslurry results and uses. https://www.hivos.org/sites/default/files/bioslurry_book.pdf . P.25-26 (Last accessed on 7 July, 2015).

EFFICACY OF INSECTICIDES IN CONTROLLING POD BORER (*HELICOVERPA ARMIGERA* HUBNER) INFESTING CHICKPEA

MD. SHAHIDUZZAMAN[1]

Abstract

A field experiment was carried out at the Regional Pulses Research Station of Bangladesh Agricultural Research Institute, Madaripur, Bangladesh during *rabi* season of 2013-14 and 2014-15 to select effective insecticides to control pod borer (*Helicoverpa armigera* Hubner) of chickpea (*Cicer arietinum*). Signinificantly the highest insect infestation and yield loss were recorded from untreated control. Spray with every insecticide for 3 times at 7 days interval reduced insect infestation and yield loss significantly over control in both years. Reduction in insect infestation was 11.77-18.77% and 6.34-13.34% and yield loss was 280-393-168-281 kgha^{-1} in 2013-14 and 2014-15, respectively. The highest grain yield was obtained with Tracer 45 SC (Spinosad) (1177 kgha^{-1}) followed by Volium Flexi 300 SC (Thiamethaxam) (1045 kgha^{-1}) and Belt 24 WG (Flubendiamide) (1020 kgha^{-1}) in first year. In second year, Tracer 45 SC produced maximum yield (1396 kgha^{-1}) followed by Volium Flexi 300 SC (1315 kgha^{-1}) and Admire 200 SL (Imidacloprid) (1300 kgha^{-1}). In 2013-14, the highest benefit cost ratio (3.39) was obtained with Volium Flexi 300 SC followed by Belt 24 WG (2.65) and Admire 200 SL (1.67). In 2014-15, the highest benefit cost ratio was also obtained with Voilum Flexi 300 SC (2.38) followed by Admire 200 SL (1.79) and Belt 24 WG (1.63). Comparing two years data considering highest profit, Volium Flexi 300 SC might be applied @ 0.05% at an interval of 7 days to the crop for three times.

Introduction

Chickpea (*Cicer arietinum* L.), commonly known as gram is one of the important major pulse crops in Bangladesh. It is generally grown under rainfed condition in *rabi* season. Among the major pulses grown in Bangladesh, chickpea ranked 7th in terms of area and 6th in terms of production but second in terms of consumption. The national average yield of chickpea is only 1.09 tha^{-1} (Anon., 2015). Among the factors responsible for low yield of the crop, insect pests appeared to be most important. The crop is attacked by eleven species of insect pests (Rahman *et al.,* 1982). Among them pod borer, *Helicoverpa armigera* (Hubner) is major one of chickpea growing areas of the Bangladesh (Begum *et al.,* 1992). Findings of a country wide survey indicate that 30 to 40% pods are damaged by pod borer causing 400 kg grain loss per hectare (Rahman, 1990). Under favourable conditions, pod borer may cause 90-95% pod damage (Shengal and Ujagir, 1990; Sachan and Katti, 1994). The young caterpillar feeds on

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leaves, while grown up caterpillar bores into the pods and feeds on the seeds. Pod borer damages flower, flower bud and developing pods (Hossain, 2012). The management of this noxious pest is primarily based on insecticides (Rahman, 1991). Under the above circumstances, the present piece of research was conducted to find out effective and suitable insecticides against pod borer infesting chickpea and to ensure economic production.

Materials and Method

Five insecticides, namely Admire 200 SL (Imidacloprid) (0.05%), Belt 24 WG (Flubendiamide) (0.04%), Tracer 45 SC (Spinosad) (0.04%), Volium Flexi 300 SC (Thiamethaxam) (0.05%) and Proclaim 5 SG (Emamectin Benzoate) (0.1%) were tested against pod borer infesting chickpea under field conditions. Each of the insecticides represented a treatment. Plots received no spray with any insecticide represented untreated control. The experiment was conducted in the experimental farm of the Regional Pulses Research Station (RPRS) of Bangladesh Agricultural Research Institute, Madaripur, Bangladesh during the *rabi* season of 2013-14 and 2014-15. The land was prepared for good tilth using tractor driven cultivator and harrow. After ploughing, debris was removed from the field. NPK fertilizers were applied at final land preparation @ 20-40-20, respectively in the form of urea, triple super phosphate and muriate of potash, respectively. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3m × 4m. Seeds of a recommended variety BARI Chola-5 were sown in continuous rows maintaining 40 cm row to row spacing. The seedlings were thinned to have plant to plant distance of 10 cm. Insecticidal suspensions were prepared in tap water and sprayed three times at 7 days interval starting from first appearance of the insects at flowering stage. Intercultural operations were done as and when necessary. Control plots were sprayed with tap water.

The experimental field was visited regularly to record infestation of the insect in treated and untreated control plots. For data collection, 10 plants were selected from middle rows of each unit plot at mature stage. The bored (damaged) and total number of pods found on selected plants was counted and percent pod infestation was computed based on total number of pods. After harvest and sunning, grain weight of each plot was recorded and expressed in yield per hectare. The grain yield loss per hectare due to pod borer infestation of each treatment was calculated using a standard formula based on percent pod infestation of actual yield obtained and expected yield in absence of any pod borer infestation for the respective treatment (Hossain *et al.*, 1999). Yield loss of chickpea due to pod borer = Ye-Ya, where Ya= Actual yield (kgha^{-1}) and Ye= Expected yield in absence of any infestation.

$$Ye = \frac{Ya X 100}{100 - P}$$, where P= Percent pod infestation.

Net return and benefit cost ratio were calculated by prevailing market price of the commodity. The experimental data were analyzed after arcsine and square root transformation in 2013-14 and 2014-15, respectively. The means were compared using DMRT.

Results and Discussion

Pod borer infestation and yield loss

Effectiveness of different insecticides tested in the present study to suppress pod borer infestation and yield loss of chickpea are presented in Table 1. All the insecticides significantly reduced insect infestation and yield loss compared to untreated control in both crop seasons.

In 2013-14, significantly the highest pod borer infestation of 39.89% and yield loss of 428 kgha^{-1} were recorded from untreated control. The infestation was reduced to 25.12-28.12% and yield loss to 280-393 kgha^{-1} due to spray with the insecticides. The highest reduction was achieved with Volium Flexi 300 SC and the lowest with Admire 200 SL.

In 2014-15, insect infestation was 24.67% and yield loss of 330 kgha^{-1} recorded in untreated control plot. The two parameters were reduced to 11.33-18.33% and 168-282 kgha^{-1}, respectively. The reduction was significant compared to untreated control. The lowest insect infestation and yield loss were recorded from plots sprayed with Volium Flexi 300 SC (Thiamethaxam) followed by Tracer 45 SC (Spinosad). The effectiveness of Volium Flexi 300 SC and Tracer 45 SC to reduce infestation was not significantly different. The highest insect infestation and yield loss were recorded in Proclaim 5SG treated plots.

Comparatively higher insect infestation was observed in 2013-14 compared to 2014-15. Such variation was due to higher rainfall recorded in 2013-14 which increased bushiness of chickpea plants and insect infestation. The rain fed cropping season of 2014-15 favored optimum growth of chickpea with higher pod setting and disfavor pod borer population increase. This was supported by (Hossain, 2003).

Yield, net return and benefit cost ratio

The Yield, net return and benefit cost ratio are presented in Table 2. The yield of chickpea varied significantly with crop growth, pod setting and pod borer infestation depending on climatic variation of the cropping seasons under study. As indicated earlier, the higher rainfall in 2013-14 cropping season resulted in the vigorous and bushy growth with less pod setting and also higher pod borer infestation in chickpea. In this season, the lowest yield (645 kgha^{-1}) was recorded from untreated control. The highest yield (1177 kgha^{-1}) was obtained from Tracer 45 SC treated plot followed by Volium Flexi 300 SC (Thiamethaxam) treated plot (1045 kgha^{-1}). Volium Flexi 300 SC (Thiamethaxam) treated plot gave the

Table 1. Effect of insecticides application on reduction of pod borer infestation (%) and yield loss of chickpea during the rabi season of 2013-14

Treatments	Pod infestation (%)		Infestation reduction over control (%)		Yield loss (kgha^{-1})	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Admire 200 SL (Imidacloprid)	28.12b (31.06)*	15.00 c (3.87)**	11.77	9.67	362d	229d
Belt 24 WG (Flubendiamide)	27.00 bc (30.36)	15.33 c (3.92)	12.89	9.34	377c	231c
Tracer45 SC (Spinosad)	25.05c (29.13)	12.00 d (3.46)	14.84	12.67	393b	190e
Volium Flexi 300 SC (Thiamethaxam)	21.12 d (26.53)	11.33 d (3.37)	18.77	13.34	280e	168f
Proclaim 5 SG (Emamectin Benzoate)	25.01c (29.10)	18.33 b (4.28)	14.88	6.34	315e	281b
Control	39.89a (37.99)	24.67 a (4.97)	-	-	428a	330a

In a column, treatment means having the same letter(s) didn't differ significantly at 5% level. *Figures in the parentheses are the arcsine transformed mean values, **Figures in the parentheses are the square root transformed mean values.

Table 2. Effect of insecticides application on yield, net return and benefit cost ratio in chickpea production during rabi season of 2013-14 and 2014-15

Treatments	Yield (kg/ha)		Additional yield over control (kg/ha)		Additional income over control (Tk/ha)		Cost of fungicides application (Tk/ha)		Net income (Tk/ha)		Benefit cost ratio (MBCR)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Admire 200 SL (Imidacloprid)	925c	1300c	280	293	19600	20510	7350	7350	12250	13160	1.67	1.79
Belt 24 WG (Flubendiamide)	1020b	1277d	375	270	26250	18900	7200	7200	19050	11700	2.65	1.63
Tracer 45 SC (Spinosad)	1177a	1396a	532	389	37240	27230	17640	17640	19600	9590	1.11	0.54
Volium Flexi 300 SC (Thiamethaxam)	1045b	1315b	400	308	28000	21560	6375	6375	21625	15185	3.39	2.38
Proclaim 5 SG (Emamectin Benzoate)	945c	1253e	300	246	21000	17220	10050	10050	10950	7170	1.09	0.71
Control	645e	1007f	-	-	-	-	-	-	-	-	-	-

In a column, treatment means having the same letter(s) didn't differ significantly at 5% level. For calculating net return and benefit the following market prices were used: Admire 200 SL (Imidacloprid) = Tk.1850/250 ml, Belt 24 WG (Flubendiamide) = Tk.1800/200 gm, Tracer 45 SC (Spinosad) = Tk.5280/200 ml, Volium Flexi 300 SC (Thiamethaxam) = Tk.1525/250 ml, Proclaim 5 SG (Emamectin Benzoate) = Tk.2750/500 g, Chickpea=Tk. 70/kg and Labour wage= Tk. 300/day/labourer (8 hours day).

highest benefit cost ratio (3.39) followed by (2.65) Belt 24 WG (Flubendiamide) treated plots. The plots sprayed with Proclaim 5SG (Emamectin Benzoate) provided lowest benefit cost ratio (1.09).

In 2014-15, the yield performance of chickpea in the experimental plots was better than in 2013-14 crop seasons due to prevailing favorable climatic condition which favored higher pod setting but disfavored the pod borer infestation and population increase. The lowest yield (1007 kgha^{-1}) was recorded from untreated control plot. The highest yield (1396 kgha^{-1}) was obtained in Tracer 45 SC treated plot followed by (1315 kgha^{-1}) Volium Flexi 300 SC (Thiamethaxam). Volium Flexi 300 SC (Thiamethaxam) treated plots gave the highest benefit cost ratio (2.38) followed by (1.79) Admire 200 SL (Imidacloprid). The plot sprayed with Proclaim 5 SG (Emamectin Benzoate) gave benefit cost ratio less than one (0.71). The rest of the treatments had the same effects as in the previous year except Belt 24 WG (Flubendiamide). Chaudhary and Sachan (1995), on the other hand Hossain (2012) showed the significant effect of Cypermethrin application on pod borer population reduction compared to untreated control. Giraddi *et al.* (1994) reported effective control by Endosulfun when 2 sprays were applied at 50% flowering followed by 2 sprays at the green pod stage (Hossain, 2012).

Conclusion

From the above discussion, it was found that, spraying of insecticides significantly reduced pod borer infestation in chickpea. Volium Flexi 300 SC (Thiamethaxam) treated plot resulted the lowest grain yield loss but highest yield obtained from Tracer 45 SC (Spinosad) treated plot in both the years. Due to higher price of this insecticide (Tracer 45 SC), BCR reduced than all other insecticides without Proclaim 5 SG. But Volium Flexi 300 SC (Thiamethaxam) offered the highest BCR in both the years. For getting highest profit, Volium Flexi 300 SC (Thiamethaxam) may be applied @ 0.05% at an interval of 7 days for three times.

References

Anonymou. 2015. Acreage and Production of Pulse Crops, Krishi Diary, Agricultural Information Service. Department of Agricultural Extension. Peoples's Republic of Bangladesh. p.14

Begum, N., M. Hussain, and S. I. Chowdhury. 1992. Effect of sowing date and plant density of pod borer incidence and grain yield of Chickpea in Bangladesh. *Int. Chickpea Newslet.* **27:** 19-21.

Chaudhary, R. R. P. and R. B. Sachan. 1995. Comparative efficacy and economics of some insecticides against gram pod borer, *Heliothis armigera* (Hubner) in chickpea in western plain of Uttor Pradesh. *Bharatiya Krishi Anusandhan Patrika.* **10**(4): 159-164.

Giraddi, R. S., B. S. Goudreddy. and P. B. Patil. 1994. Critical time of spray in chickpea for the control of gram pod borer, *Helicverpa armigera* (Hubner). *Karnataka J. Agril. Sci.* **7**(1): 79-81.

Hossain, M. A. 2003. Management of chickpea pod borer, *Helicoverpa armigera* (Hubner) through intercropping and insecticide spraying. *Thai j. Agric. Sci.* **36**(1): 51-56

Hossain, M. A. 2012. Development of insecticide based management package against insect pests complex of chickpea. Annual Research Report under ACIAR Project, PRC, BARI, Ishwardi, Pabna.

Hossain, M. A., Rahman, M. M. and Islam, M. N. 1999. Effect of intercropping and sowing dates on the incidence of pod borer, *Helicoverpa armigera,* Yield and yield loss of chickpea. *Ann. Bangladesh Agric*. **9**(1): 57-64.

Phokela, A., Dhingra, S. N. Sinha and K. N, Mehrotra. 1990. Pyrethroid resistance in *Heliothis armigera* Hb. Development of resistance in field. *Pesticide. Res. J.* **2**(l):28-30.

Rahman, M. M., M. A. Mannan and M. A. Islam. 1982. Pest survey of major summer and winter pulses in Bangladesh. In: Proceedings of the National Workshop on Pulses. August 18-19, 1981. Edited by A.K. Kaul. Published by Director, Bangladesh Agricultural Research Institute, Joydebpur, Dacca, Pp. 265-273.

Rahman, M.M. 1990. Infestation and yield loss in Chickpea due to pod borer in Bangladesh. *Bangladesh J. Agril. Res.* **15**(2): 16-23.

Rahman, M.M. 1991. Control measures for important insect pests of major pulses. In BARI 1991. Advance in Pulse Research in Bangladesh. Procedings. Second National Workshop on Pulses, 6-8 Jan. 1989. Joydebpur, Gazipur, 139-146.

Sachan, J. N. and G. Katti. 1994. Integrated Pest Management. Proceeding of International Symposium on Pulses Research, April 2-6, IARI, New Delhi, India, Pp. 23-30.

Shengal, V.K. and R. Ujagir. 1990. Effect of synthetic pyrethroids, neem extracts and other insecticides for the control of pod damage by *Helicoverpa armigera* on Chickpea and pod damage-yield relationship at Patancheru in Northern India. *Crop Protec.* **9:** 29-32.

GENETIC DIVERSITY IN MAIZE INBREDS UNDER EXCESS SOIL MOISTURE CONDITION

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Abstract

Genetic diversity study was done in 64 maize inbreds grown under excess soil moisture condition.The genotypes were grouped into eight clusters. It was observed that all intercluster distances were larger than all intracluster distances. Such results indicated that genotypes included within a cluster had less diversity among themselves but wider genetic diversity among the inbreds of different clusters. The highest inter cluster distance was observed between cluster IV & VII followed by IV & V , IV & VIII, II & VII and I & IV. The highest intra cluster distance was noticed in cluster V and the lowest was in cluster VII. The highest yield/plant, cob girth, number of rows/ear, number of grains/plant, SPAD value and number of nodes with brace roots were observed in cluster IV. The lowest mean value for yield/plant yield components and dwarf statured plant were observed in cluster VII. The plant height, ear height,days to 50% tasseling and silking, cob length, cob girth, 100 grain weight and SPAD value contributed considerably to total divergence. The genetically diverged genotypes in these distinct clusters could be used as parents in hybridization program for getting desirable hybrid(s).

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crop in the world as well as developing countries like Bangladesh. It is the highest producing grain crop having multiple uses. Hybrid maize has higher yield potentiality than synthetics and composites. Knowledge of germplasm diversity and of relationship among elite breeding materials has a significant impact on the improvement of crop plants (Hallauer *et al.,* 1988). Maize breeders are consistently emphasizing the importance of diversity among parental genotypes as a significant factor for developing heterotic hybrids (Ahloowalia and Dhawan, 1963; Hallauer, 1972). Customarily D^2 analysis is an useful tool for quantifying the degree of divergence between biological population at genotypic level and also in assessing relative contribution of different components to the total divergence both intra and inter cluster level (Murthy and Arunachalan, 1966; Sachan and Sharma, 1971).

Maize area in Bangladesh is increasing day by day for its versatile use. In the year 2014-15, *rabi* and *kharif* maize production was 19.28 and 4.33 lakh metric ton from 2.84 and 0.71 lakh hactre of land, respectively in Bangladesh (Krishi

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diary, 2016). Area of *kharif-1* maize would be increased dramatically for profitable cropping pattern i.e. maize followed by potato cultivation utilizing residual effects of fertilizers used in potato field. Maize crop considered as queen of the cereals grown during the summer-rainy season in Bangladesh critically face waterlogging caused by contingent flooding, continuous rainfall coupled with inadequate drainage or high water table. In south and south east asia alone,over 18% of of the total maize growing areas are frequently affected by floods and waterlogging problems (Zaidi *et al.,* 2008).

In general, most of our modern high yielding varieties are developed under favorable environments and optimal input conditions. Selection and improvement under optimal conditions may not be suitable for the target areas prone to abiotic constraints (Simmonds, 1991). Therefore, in order to achieve improved and stable yields in stress prone environments it is desirable to improve tolerance to major abiotic constraints prevalent in target environment. This is why the present study was undertaken to analyze the genetic divergence of maize inbreds under excess soil moisture condition and to develop high yielding and excess moisture tolerant maize hybrids

Materials and Method

The experiment was undertaken at Regional Agricultural Research station, Jamalpur during *rabi* season 2009-10 to estimate genetic diversity among 64 genotypes of maize inbred lines. Seeds of each entry were sown on 08 December 2009 in single sow 2 m long. Spacing was maintained 75 X 20 cm from entry to entry and plant to plant respectively. One plant was kept per hill after thinning. Fertilizers were applied @ 120, 80, 20, 5 and 1 Kg/ ha of N, P_2O_5, K_2O, Zn and B respectively. Other intercultural operations were done according to the necessity to raise the crop uniformly. Irrigations were applied continuously for 7 days maintaining with a ponding depth of 9-11cm induced at knee high stage of maize plants. Genetic divergence was estimated following Mahalanobis (1936) generalized distance (D^2) extended by Rao (1952). Tocher's method (Rao,1952) was followed for determining the group constellations. Canonical analysis was also done according to Rao (1964) to confirm the results of cluster and D^2 analysis. Based on D^2 values, sixty four inbreds were grouped into clusters using the GENSTAT 5.0 computer software.

Results and Discussions

Results pertaining to various genetical analysis tools are presented below. Genetic diversity was estimated by Mahalanobis D^2 statistics and the sixty four inbreds were grouped into eight clusters (Table 1).The number of inbreds in the clusters varied from 3 to 12. Maximum 12 inbreds were present in cluster VI and minimum number of inbreds (3) were found in cluster IV. Hemathavy *et al.* (2006) studied with 42 maize inbreds and the lines were fell into 7 cluters and Kadir (2010) worked with 20 maize inbreds and grouped into 4 clusters. From

the Table 2, the highest inter cluster distance was observed between cluster IV & VII followed by IV & V , IV & VIII, II & VII and I & IV. So, selection of parents from those maximum divergent clusters may manifest maximum herterosis . Murthy and Anand (1966) observed a positive corelation between specific combining ability and the degree of genetic diversity. Similar conclusion was also drawn by Ghaderi *et al.* (1979) and Amiruzzaman *et al.* (2008). It was also observed that all intercluster distances were larger than all intra cluster distances. It suggests that genotypes included within a cluster had less diversity among themselves. This is corroborated with the findings of Ivy *et al.* (2007) and Kadir (2010). The highest intra cluster distance was observed in cluster V and the lowest was in cluster VII .

The highest mean value of cluster IV for grain yield/plant along with cob girth, number of grain rows/ear, number of grain/plant, low mean value for plant height, ear height , days to 50% tasseling and days to 50% silking indicated that plants of this clusters were high yielder and low in statured. Ahmed (2007) also observed similar results in maize. The highest SPAD value and 2^{nd} highest number of nodes with brace roots (2.06) along with lowest ASI indicated plants of this clusters are tolerant to excess soil moisture condition. These results showed conformity with those of Zaidi *et al.* (2003) who reported that lower ASI value (<5 days) and higher number of nodes with brace roots along with SPAD value were the important characters for tolerance to excess soil moisture condition in maize . The lowest mean value for yield/plant, cob length, cob girth, number of grain rows/ear, plant height, ear height and low mean value for days to 50% tasseling and silking were observed in cluster VII which indicated that plants of cluster VII were low yielder but were dwarf statured and early maturing.The highest plant height, ear height, days to 50% tasseling and silking were observed in Cluster III. Endang *et al.* (1971) stated that the clustering pattern could be utilized in choosing parents for cross combinations which likely to generate the highest possible variability for effective selection of various economic traits. Under such condition Chaudhury *et al*. (1975) suggested that selection for one type from each cluster and testing them by a series of diallel analysis may prove to be highly fruitful.

The characters cob length, cob girth, 100 grain weight, plant height, ear height, days to tasseling, days to silking and SPAD value showed major contribution towards divergence of the genotypes as shown by positive value of these characters for both the vectors (vector I and vector II).The characters number of grains/plant, ASI and number of nodes with brace roots also showed contribution towards divergence. The results of the present study showed partial agreement with that of Utkhede *et al.* (1975), Hoque *et al.* (2008), Amiruzzaman (2010) and Amiruzzaman and Amin (2010). Utkhede *et al.* (1975) reported the higher contribution of days to tasseling towards total divergence in maize. In contrast, Datta and Mukharjee (2004) reported that very little role was found for days to tasseling and days to silking in the

discrimination of inbred lines in maize. They observed that important yield contributing characters like ear weight, ear length and kernel weight had considerable contribution towards divergence. Hoque *et al.* (2008) observed days to tasseling, cob girth, 100 grain weight and grain yield/plant contributed considerably towards divergence. Amiruzzaman and Amin (2010) found that days to silking, cob length, number of grain/row, 1000 grain weight and grain yield/plant showed major contribution in maize. So, considerable emphasis should be given on those parameters responsible for genetic divergence.

Considering the highest/high inter cluster distance, crosses between genotypes of cluster IV with those of cluster V, VII and VIII are expected to improve yield & short statured plant. But mean values of cluster V (low SPAD value) and VII(>5 days ASI) were not suitable for excess soil moisture condition. Considering cluster mean and medium inter cluster distance crosses between genotypes of cluster III & IV are expected to exploit heterosis for grain yield in maize.

Table 1. Distribution of 64 maize inbreds in different clusters under excess soil moisture condition induced at knee high stage

Cluster	No. of inbreds	Inbred lines included in different clusters
I	11	BML36, BIL30, BIL76, BIL77, BIL104, BIL113, BIL128, BIL175, BIL198, BIL206, BIL208
II	5	BIL19, BIL102, BIL108, BIL110, BIL173
III	8	BIL26, BIL65, BIL79, BIL107, BIL114, BIL127, BIL176, BIL207
IV	3	BIL182, BIL184, BIL199
V	9	BML3, BIL101, BIL109, BIL111, BIL172, BIL183, BIL186, BIL201, BIL205
VI	12	BIL97, BIL168, BIL169, BIL170, BIL171, BIL174, BIL177, BIL178, BIL179, BIL181, BIL193, BIL200
VII	9	BIL180, BIL185, BIL187, BIL188, BIL194, BIL197, BIL202, BIL203, BIL204
VIII	7	BIL43, BIL189, BIL190, BIL191, BIL192, BIL195, BIL196

Table 2. Inter and intra-cluster (bold) distance (D^2) for 64 maize inbred lines obtained by canonical vector analysis under excess soil moisture condition induced at knee high stage

Cluster	I	II	III	IV	V	VI	VII	VIII
I	**0.703**							
II	6.425	**0.911**						
III	3.507	3.732	**0.896**					
IV	13.109	6.780	9.922	**0.916**				
V	3.596	8.727	6.806	15.475	**0.962**			
VI	3.923	4.484	4.373	11.044	4.577	**0.644**		
VII	8.986	13.231	12.046	19.644	5.390	8.747	**0.642**	
VIII	6.020	8.035	7.880	14.181	3.879	3.720	5.529	**0.780**

Table 3. Cluster means for 13 different characters of 64 maize inbred lines under excess oil moisture condition induced at knee high stage

SI. No.	Characteristics	cluster							
		I	II	III	IV	V	VI	VII	VIII
1.	Yield/Plant (g)	42.24	47.73	57.44	62.95	34.21	36.29	30.43	49.64
2.	Cob length (cm)	11.69	11.81	13.33	11.73	10.75	11.00	9.80	10.17
3.	Cob girth (cm)	11.68	11.32	12.24	12.76	11.00	10.44	10.07	11.61
4.	Grain rows/ear (no.)	11.34	13.36	12.47	15.58	11.37	12.06	10.85	11.03
5.	Grains/plant(no.)	200.72	266.49	240.20	337.50	169.74	217.28	136.26	197.75
6.	100 Grain wt (g)	23.58	20.13	24.41	19.51	22.42	20.55	20.45	25.52
7.	Plant height(cm)	119.87	101.10	128.04	89.02	108.26	90.64	76.80	69.34
8	Ear height (cm)	59.14	49.91	59.74	45.63	44.67	39.10	26.22	28.24
9.	Days to 50% tasseling	96.12	91.24	96.34	90.98	94.04	90.32	91.24	91.78
10.	Days to 50% silking	101.35	96.15	102.13	94.40	98.75	94.42	96.52	95.90
11.	ASI (days)	5.23	4.91	4.67	3.42	4.71	4.13	5.27	4.13
12.	SPAD value	11.72	11.40	11.77	13.25	9.89	12.65	10.83	11.18
13.	Nodes with brace roots (no.)	1..3	1.74	1.62	2.06	1.52	1.61	1.79	2.44

Table 4. Relative contributions of the 13 characters to the total divergence in maize under excess soil moisture condition induced at knee high stage

SI. No.	Characteristics	Vector I	Vector II
1.	Yield/Plant (g)	-0.10.37	-0.0265
2.	Cob length (cm)	0.1873	0.1782
3.	Cob girth (cm)	0.1092	0.1000
4.	Grain rows/ear (no.)	-0.0121	0.1312
5.	Grains/plant (no.)	0.1083	-0.0227
6.	100 Grain wt (g)	0.2596	0.1174
7.	Plant height (cm)	0.0151	0.0414
8	Ear height (cm)	0.0038	0.0728
9.	Days to 50% tasseling	0.0251	0.0247
10.	Days to 50% silking	0.0649	0.0179
11.	ASI (days)	-0.2022	0.0874
12.	SPAD value	0.0008	0.1178
13.	Nodes with brace roots (no.)	0.4444	-0.5560

Conclusion

The crosses between inbred lines of cluster IV with those of cluster VIII are expected to exploit heterosis for yield & short statured plant but crosses between the inbred lines of clusters III & IV are expected to high yielding hybrid maize. Cob length, cob girth, 100 grain weight, plant height, ear height, days to tasseling, days to silking and SPAD value contributed maximum towards divergence. Hence major emphasis should be given on them for selecting parents for hybrids in maize. From this study it can also be concluded that promising results concurring diversed gene pool of desired plant traits could be obtained in this piece of research work.

References

Ahloowalia, B.S. and N.I. Dhawan. 1963. Effect of genetic diversity in combining ability of inbred lines of maize. *Indian J. Genet.* **23:** 158-162.

Ahmed, S. 2007. Study of genetic diversity in maize inbreds. Annual Research Report, 2006-2007: Maize and barley improvement, Plant breeding Division, BARI, Joydebpur, Gazipur. P. 16-18.

Amiruzzaman, M., M.A.Y. Akond and M.S. Uddin. 2008. Line × tester analysis of combining ability in hulled and hull-less crosses of barley (*Hordeum vulgare* L.). *Bangladesh J. Agri.* **33:** 15-20.

Amiruzzaman, M. 2010. Exploitation of hybrid vigour from normal and quality protein maize crosses. Ph.D dissertation, Dept. Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh. 200 p.

Amiruzzaman, M. and M.N. Amin 2010. Studies on genetic diversity of yellow inbreds of normal maize. Annual Research Report, 2009-2010: Maize and barley improvement, Plant breeding Division, BARI, Joydebpur, Gazipur. p. 26-33.

Chaudhury, P.D.,Bhat P N and S V P.1975. genetic diversity in cluster bean. *Indian J. Agric. Sci.* **45:** 430-535

Datta, D. and B.K. Mukherjee. 2004. Genetic divergence among maize (*Zea maize* L.) inbreds and restricting traits for group constellation. *Indian J. Genet.* **64** (3) 201-207.

Endang, S., S. Andani and H. Nasoetion. 1971. Multivariate classification of some rice (*oryza sativa* L.) varieties and strain on yield components. Intl. Rice Comm. Newst. **20:** 26-34.

Ghaderi, A., M. Shishegar, A. Regai and B. Ehdaie. 1979. Multivariate analysis of genetic diversity for yield and its components in mungbean. *J. Amer. Soc. Hort. Sci.,* **104**(6): 728-730.

Hallauer, A.R., W.A. Russell and K.R. Lamkey. 1988. Corn breeding. *In*: Sprague G.F. and J.W. Dudley (eds.). Corn and corn improvement, 3rd edn. Agron Monogr. 18. ASA, CSSA, and SSSA, Madison,Wisconsin, USA.

Hallauer, A R. 1972. Third phase yield evaluation of synthetic varieties of maize. *Crop Sci.* **12:** 16-18

Hemavathy, A. Thanga, S.M. Ibrahim and S. Aiyswaraya. 2006. Genetic studies in maize (*Zea mays* L.). *Agric.Sci. Digest.* **26**(4): 303- 305.

Hoque, M.M., M. Asaduzzaman, M.M. Rahman, S. Zaman and S.A. Begum. 2008. Genetic divergence in maize (*Zea mays* L.). *Bangladesh J. Agric.* **19**(1):145-148.

Ivy, N.A., M.S. Uddin, R. Sultana and M.M. Masud. 2007. Genetic divergence in maize (*Zea mays* L.). Bangladesh J. Pl. Breed. Genet., **20:** 53-56.

Kadir, M.M. 2010. Development of quality protein maize hybrids and their adaptation in Bangladesh. PhD dissertation, Dept. Genetics & Plant Breeding, Bangladesh Agricultural University, Mymensingh.

Krishi diary. 2016. Agricultucural Information Service. Khamarbari, Farmgate, Dhaka-1215.

Mahalanobis, P.C. 1936. On the generalized distance in statistics. Proc. Natl. Inst. *Sci. India.* **2:** 49-55.

Murthy, B.R. and I.J. Anand. 1966. Combining ability and genetic diversity in some varieties of *Linum usitatissimum. Indian J. Genet.* **26:** 21-36.

Murthy, B.R. and V. Arunachalam. 1966. The nature of genetic divergence in relation to breeding system in some crop plants. *Indian J. Genet.* **26A:** 188-198.

Rao, C.R. 1952. Advanced Statistical Methods in Biometric Research. John Willey and Sons. Inc. New York.

Rao, C.R. 1964. The use and interception of principal component analysis in applied research. Sankhya. **22:** 317-318.

Sachan, K.S. and L.R. Sharma, 1971. Multivariate analysis of genetic divergence in Tomato. *Indian J. Genet. PI. Breed*. **31:** 86-93.

Simmonds, N.W.1991. Selection for local adaptation in plant breeding program. Theor. Appl. Genet. **82:** 363- 367.

Utkhede, R.S., P.T. Shukla and N.G. Nikolov. 1975. Genetic divergence in relation to geographical origin in maize. *East Afr. Agric. Forest J.* **41:** 177-183.

Zaidi P.H., S. Rafique and N.N. Singh. 2003 Response of maize (*Zea mays* L.) genotypes to excess moisture stress: morpho - physiological effects and basis of tolerance. *Eur. J. Agron.* **19:** 383-399.

Zaidi P.H., Mehrajuddin, M.L. Jat, K. Pixley, R.P. Singh and S. Dass. 2008. Resilient maize for improved and stable productivity of rain-fed environment of South and South-East Asia.*Maize for Asia - Emerging Trends and Technologies*.Proc. 10[th] Asian Regional Maize Workshop, 20-23 October, 2008, Makassar, Indonesia.

GROWTH RATES OF FRUITS CULTIVATION IN HILLY AREAS OF BANGLADESH

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Keywords: Hill regions, fruits, area, production, productivity, trend and growth rate.

The fruits have vital role in making human diet balanced. Standard of living of people generally judged by per capita production and consumption of fruits (Bairwa *et al.,* 2012). Bangladesh is producing a variety of fruits owing to its various agro-climatic conditions. Perennial crops like trees normally remain as grossly under exploited potential resources in hill agriculture. Fruits are usually grown by the hilly farmers and these crops give them few opportunities. Fruits play a unique role in developing countries like Bangladesh, both economic and social sphere for improving income and nutritional status, particularly for hilly people. Besides nutritional advantages, there are other competing reasons for which fruit production in hilly areas deserves preference. These include: (i) due to agro climatic features, horticulture is the only vocation through which higher income per unit of land can be generated. (ii) fruit farming helps in proper utilization of areas (iii) fruit cultivation allows optimum utilization of the gift of nature in making it possible to upgrade inferior fruit trees into superior ones by top working and by adopting other techniques of vegetative propagation (iv) given suitable combination, fruit farming can even be taken as a complementary occupation in hills to a set of other business propositions (Wasim, 2011).

Siddiqu (2001) reported that very good quality litchi grows in the Chittagong district in hill area. But the rate of expansion is extremely slow, which may be due to prevailing social unrest and difficulty in establishing new orchards. Reviewing all these paper, there is a clear thing that there was no such research about growth rates of major fruits in hill regions particularly in upazilla level. This type of study yet not been done in hill areas. The growth rate of area, production and yield of fruits and other analytical aspect in this report would help to facilitate, interpretation and forecasting on the future development of fruits in the hilly areas. Objective of the study is to estimate the trend and growth rates of area, production and productivity of fruits.

The secondary data on area, production, productivity were obtained from DAE (upazila level fruits data are not available in BBS publication) data of covering the period from 2006 to 2012 depending on the availability (data of previous year

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is not found in the upazila level). The information regarding the area and production of selected fruits were collected from respective upazila with the purpose of understanding the present trend of area and production in the recent years (2006/07 to 2011/2012). Growth rate was estimated for selected upazila, namely Juri and Sreemongal upazila of Moulavibazar, Matiranga and Dighinala upazila of Khagrachari, Naniarchar and sadar upazila of Rangamati and Bandarban sadar of Bandarban district. To estimate the growth rate of area, production and productivity of different fruits in selected areas of Bangladesh for the period from 2006-07 to 2011-12, the following semi log exponential form was used (Gujarati, 1998):

$Y = ae^{bti}$

Or In $Y = Ina + bti$

Or In$Y = A + bti$ (here A=lna)

Where, A = Intercept

Y = Quantity of major fruits production, area and productivity

b = Growth rate in ratio scale and when multiplied by 100, it express percentage growth

i.e, annual growth rate

t_i = time, i= 1,2, 3,............, 15 years

In = natural log of the variable

Trends of average area is shown in figure 1 which depicts that more lands was used to cultivate banana over the year 2006-07 to 2011-2012 followed by pineapple, jackfruit, mango, litchi, orange. But the trend of all fruits area was upward. Area under cultivation of banana and mango was increased more compared to pineapple, jackfruit, litchi and orange.
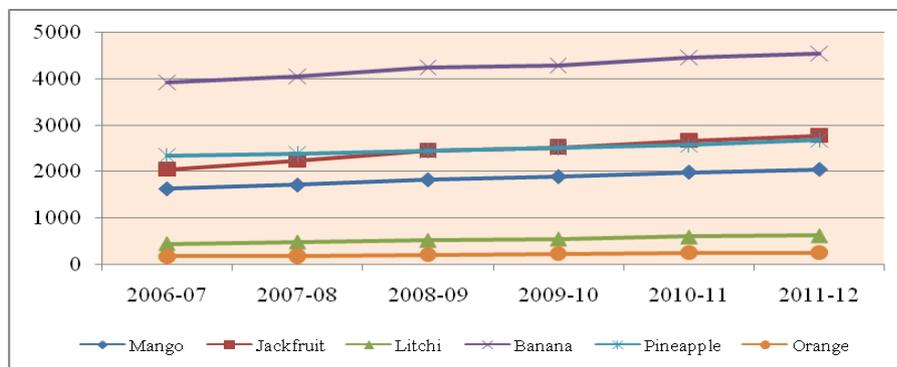
Fig. 1. Trend line of area (ha) of different fruits in all location.

Trends of average production is shown in figure 2 which depicts that production of banana in hill areas over the year 2006-07 to 2011-2012 was more than other fruits as more areas were under the cultivation of banana. It was observed that

the trend of all fruits production was upward. Production of banana and jackfruit was highly increased compared to mango, pineapple, litchi and orange.
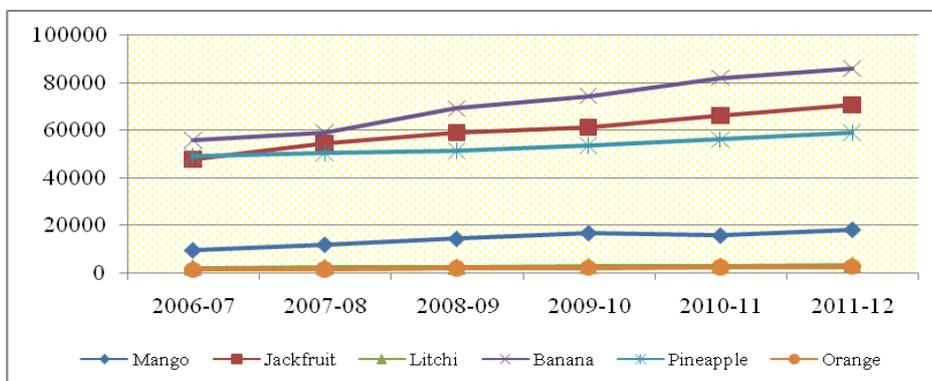
Fig. 2. Trend line of production (ton) of different fruits in all location.

Figure 3 depicts that productivity of fruits in hill region over the year 2006-07 to 2011-2012 was upward. Productivity of banana, mango, pineapple, jackfruit, litchi and orange was slightly increased over the year. The area, production and productivity of different fruits in all study upazilas were found to be increasing. Fruits cultivation is getting popular in hilly areas over the last several years. The farmers were growing local variety instead of high yielding variety with minimum investment. Lack of improved management, poor knowledge of farmers, lack of efficient marketing system, low demand etc. is substantially hindering the higher production.
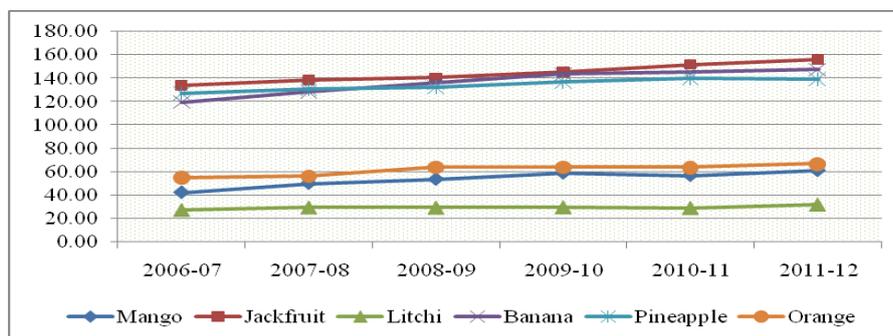
Fig 3. Trend line of productivity (ton/ha) of different fruits in all location.

The growth rates of area, production and productivity of different fruits in different locations are shown in Table 1. From the growth rates of area, production and productivity of mango, it is seen that growth rate of area was increased significantly in all upazilas. Dighinala upazila was found the highest growth rate (11.91%) followed by Juri upazila (5.67%) and the lowest growth rate of area was found for Naniarchar upazila which was about 1.17% per year.

Table 1. Growth rate of area, production and productivity of fruits in selected areas of Bangladesh for the period of 2006/07-2011/12

Fruits	Indicators	Juri	Sreemongal	Matiranga	Dighinala	Naniarchar	Rangamati Sadar	Bandarban Sadar
Mango	Area	5.67**	2.88***	3.69***	11.91**	1.17**	4.75**	3.87**
	Production	12.96***	3.90***	8.94***	15.93**	16.10**	10.70**	11.66**
	Productivity	7.29**	1.02**	5.25***	4.02**	14.93**	5.95**	7.79
Jackfruit	Area	6.03**	-	2.66***	10.84**	7.84*	0.67**	6.06**
	Production	16.30***	-	5.20***	17.99**	14.85***	-0.28	8.62**
	Productivity	10.27**	-	2.54***	7.15**	7.01***	-0.96	2.57
Litchi	Area	7.30**	-	8.01***	5.89***	4.01***	4.69**	8.40**
	Production	14.17***	-	12.54***	7.22***	7.96**	5.01**	14.84**
	Productivity	6.87**	-	4.53	1.34***	3.85	0.33	6.43*
Banana	Area	2.08**	6.77***	3.60***	10.96***	1.69**	5.10**	1.28**
	Production	4.29***	4.29***	4.29***	4.29***	4.29***	4.29***	4.29***
	Productivity	2.21**	2.21**	2.21**	2.21**	2.21**	2.21**	2.21**
Pineapple	Area	11.27***	11.27***	11.27***	11.27***	11.27***	11.27***	11.27***
	Production	13.36***	13.36***	13.36***	13.36***	13.36***	13.36***	13.36***
	Productivity	2.09*	2.09*	2.09*	2.09*	2.09*	2.09*	2.09*
Orange	Area	7.04***	-	14.37***	14.37***	14.37***	14.37***	14.37***
	Production	15.78***	-	12.02***	12.02***	12.02***	12.02***	12.02***
	Productivity	8.74**	-	-2.35	3.66**	2.79	4.22**	1.69***

***, **, * indicates 1% , 5% and 10% level of significance.

Source: DAE

During the study period, the growth rate of production and productivity for mango in different upazilas were significantly increased. Highest production growth rate was found for Naniarchar upazila (16.1%) followed by Dighinala upazila (15.93%) and the lowest (3.9%) for Sreemongal upazila (Table 1). Similarly, the highest growth rate in productivity was obtained for Naniarchar upazila (14.93%) followed by Juri upazila (7.29%) and the lowest for Sreemongal (1.02%) per annum respectively. Dewan *et al.* (2015) reported that, in Khagrachari hill district, average annual growth rate of production was positive in almost all fruits except banana and pineapple. The highest growth rate of production was recorded in mango.

It was observed from table 1 that the growth rate of production and productivity for most of the study areas were increased significantly and the rate of increase was higher for some locations. In most of the locations mango cultivation is increasing but the production and productivity was significantly higher than area increased. The reason behind such results might be due to the adoption of new technologies by the new settlers (Bengalis) in the hill regions.

The growth rate of area for jackfruit in all the locations were significantly positive at different level per annum during the study period. Rangamati sadar and Matiranga

upazila showed significantly positive but lower growth rate in area for jackfruit cultivation. The area of Dighinala, Naniarchar, Juri and Bandarban sadar upazila showed significantly higher growth rate ranging from 6.3% to 10.84% (Table 1). The growth rate of production for all locations were increased significantly except for Rangamati sadar upazila where it decreased by 0.28% per annum during the study period. The growth rate of productivity for jackfruit at Juri, Matiranga, Dighinala, Naniarchar and Bandarban sadar upazila were increased significantly at the rate of 10.27%, 2.54%, 7.15%, 7.01% and 2.57% per annum respectively at 1% and 5% level where as in Rangamati sadar it decreased with negative sign (0.96% per annum) though it is not significant. It was observed that in Rangamati sadar upazila, area increased by 0.67% per annum but production and productivity were decreased. The reason might be due to use of poor quality seeds/local variety as well as poor management practices were followed by the farmers in the study area.

The growth rate of area for litchi in selected upazilas was increased significantly with a range of 4% to 8.4% per annum (Table 1). It was observed that the area of litchi at Juri, Matiranga and Bandarban sadar upazila was increased significantly at an increasing rate (7.3% to 8.4%) and the area of litchi at Rangamati, Dighinala and Naniarchar upazila was increased at decreasing rate (4% to 5.89%). The reason might be due to some other factors like comparative economic advantages of other competitive fruits cultivation in the study areas. The growth rate of production for litchi in the selected upazilas was increased significantly with positive sign for all locations during the period with a range of 5.01% to 14.84% per annum. The growth rate of productivity for different locations were also increased but it was only significant for Dighinala , Juri and Bandarban sadar upazila by 1.34%, 6.87% and 6.43% at 1%, 5% and 10% level respectively. The growth rate of productivity was increased in others upazilas like Matiranga, Naniarchar and Rangamati sadar but not significant.

It can be concluded that the area and production under litchi cultivation are still increasing. But productivity was not increased at satisfactory level. This indicates the lack of proper management practices as well as lack of improved variety in the study area for obtaining higher productivity.

Area of banana for different upazilas was significantly increased with highest growth rate at Dighinala (10.96%) and lowest at Bandarban sadar upazila (1.28%). Increase of banana cultivation was mainly caused due to utilization of fallow hilly land by adopting locally available technologies by the farmers (Table 1). Production and productivity are significantly increased in recent period. Growth rate of production (19.77%) and productivity (8.81%) was also higher in Dighinala upazila. Production growth rate were found higher than the productivity growth rate. Farmers used local variety of *Bangla* and *Chapa* following traditional management practices but obtained satisfactory productivity. However there exists the potentiality of increasing production and productivity by adopting HYV of banana along with appropriate production technologies against existing variety.

The areas for pineapple cultivation in different upazilas are increased significantly with a highest growth rate at Juri upazila (11.27%) and the lowest for Rangamati sadar (1.64%). It might be due to shifting of hilly land area to this fruit cultivation. Suitability for pineapple cultivation may be another reason for

increasing land area under pineapple cultivation in the study areas. (Table 1). The growth rate of production for different upazilas were increased significantly by (2.69% to 16.93%) per annum respectively with a highest production growth rate at Matiranga and the lowest at Rangamati sadar upazila. The productivity growth rate of pineapple in all selected upazilas were also increased significantly at lower rate in compare to area and production per anumm in the study period. The productivity growth rate was the highest at Matiranga (6.29%) and the lowest at Bandarban sadar (0.79%) per annum. The rate of increase was found at satisfactory level in case of area, production and productivity for the recent period which indicates that improved method of cultivation are gradually adopting by the farmers in all hilly areas under existing situation.

The growth rate of area for orange cultivation in all selected upazilas were increased significantly with a highest growth rate at Matiranga upazila (14.37%) per annum while the lowest at Bandarban sadar upazila (4.36%) per annum (Table 1). It is interested to note that, the availability of land area for orange cultivation in different upazila's are increasing at a higher rate due to initiation of orange development project in hilly areas taken by the govement and other different NGO's. Presently, the orange cultivation as a new crop has earned an economic advantage in hilly areas of Bangladesh. Though growth rate in production was increased but productivity was not increased compare to growth rate of area and production. It might be due to the lack of adoption of modern technologies, lack of cooperation with research and extension personnel, lack of proper plant protection measures along with other production practices followed by the farmers. In the recent years demand for hilly orange is increasing in different district markets and in the country as a whole.

In order to more increase of the productivity it is needed to increase the growth rate of production more. To increase the growth rates of production following strategies are proposed:

➢ Availability of high yielding variety and improved cultivation method
➢ Availability of irrigation and storage facilities
➢ Establishment of better marketing infrastructures and facilities like farm to market roads and sale centers
➢ Development of farmers skill about fruits cultivation through extension services
➢ Better utilization of skilled labour and technical knowledge

References

Bairwa K. C., R. Sharma and   T. Kumar. 2012. Economics of Growth and Instability: Fruits Crop of India, Raj. J. Edu. **20:** 128-132.

Dewan B., F. Sarker, M. N. Alam. 2015. Marketing System in Chittagong Hill Tracts. International Journal of Economics, Commerce and Management. United kingdom Vol.III, Issue **5:** 966-977.

Gujarati, D. N. 1998. Basic Econometrics, 4th ed., MC Graw–Hill, inc. P. 169.

Siddiqu. 2001. Litchi Production in Bangladesh.

Wasim, M. P. 2011. Trends, Growth and Variability of Major Fruit Crops in Balochistan-Pakistan: 1989-2009, ARPN Journal of Agricultural and Biological Science, **6**(12): 27-36.

CONTENTS

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