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Address for Correspondence

Editor (Technical)
Editorial and Publication Section
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur 1701
Bangladesh

Phone : 88-02-49270038
E-mail : editor.bjar@gmail.com

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CHARACTERIZATION, IDENTIFICATION AND ANTIBIOGRAM STUDIES OF ENDOPHYTIC BACTERIA FROM COWPEA [*Vigna unguiculata* (L.) Walp]

L. W. MARZAN[1], R. ALAM[2] AND M. A. HOSSAIN[3]

Abstract

This study included isolation, characterization and identification of endophytic bacteria from cowpea [*Vigna unguiculata* (L.) Walp] roots from Hathazari upazilla, Chittagong, Bangladesh and three specis of bacteria, *Staphylococcus intermedius, Staphylococcus caprae* and *Staphylococcus saprophyticus* were finally identified based on their morphological and biochemical characteristics according to established protocol. Results of antibiotic sensitivity pattern of those endophytic bacteria suggested that they can be utilized as a cost-effective biological control agent in future applications, such as delivery of enzymes for controlling certain plant diseases against various pathogens. The findings of this study may help to determine the potential application of those endophytic bacteria in biotechnology, medicine and agriculture.

Keywords: Endophytic bacteria, biochemical identification, *Staphylococcus intermedius, Staphylococcus caprae*, *Staphylococcus saprophyticus,* biocontrol agent.

Introduction

Bacteria defined as 'endophyte' are those that live within a plant for at least a part of their life without causing any apparent harm (Anderson *et al*., 2008) and could also establish a mutualistic association (Azevedo *et al*., 2000) to their host. Plants constitute vast and diverse niches for these endophytic organisms. It is worth mentioning that each plant species is a host to a number of bacteria which are living inside plant tissues, form associations ranging from pathogenic to symbiotic. Beneficial relationships include symbiosis; endophytes supply the plants with fixed nitrogen and other endophytic associations that promote plant growth by producing phytohormones, volatiles, defense compounds and enzymes (Hooper, 2001; De Matos *et al*., 2001). Endophytes are sheltered from environmental stresses and microbial competition by the host plant and they seem to be ubiquitous in plant tissues, having been isolated from flowers, fruits, leaves, stems, roots, rhizomes and seeds of various plant species (Sturz *et al*., 2000). Some endophytic bacteria exert several beneficial effects on host plants, such as stimulation of plant growth (Kobayashi and Palumbo, 2000), nitrogen fixation (Sturz *et al*., 1997) and induction of resistance to plant pathogens (Liu,

[1&2]Department of Genetic Engineering and Biotechnology, Faculty of Biological Sciences, University of Chittagong, Chittagong- 4331, [3]Department of Genetic Engineering and Biotechnology, Jagannath University, Dhaka 1100, Bangladesh.

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1995; Sturz and Matheson, 1996). The potential for practical applications of endophytes has led to studies addressing the bacteria's ability to control both disease and insect infestations, as well as promoting plant growth (Kavino *et al*., 2007).

Cowpea is major legumes, grown in Bangladesh which contributes a prominent portion of total pulse production of Bangladesh, providing an average yield of 871 kg/ha and net return to 11,805 BDT/ha (Salam and Kamruzzaman, 2016). It is an annual herb having a strong principal root and many spreading lateral roots in surface soil (Sheahan, 2012). They are rich in potassium, calcium, magnesium, phosphorus and also small amount of iron, sodium, zinc, copper, manganese, selenium, vitamin A, B_6 and C, as well as thiamin, riboflavin, niacin and pantothenic acid.

Cowpea suffers from its natural enemies. Various types of insects are the worst of these enemies, but nematodes, bacterial diseases and viruses also cause losses. Reliable published data are available which show evidence that insects cause devastating losses in cowpea yields. Aphids - pre harvest pest can affect cowpea at the growing season. Weevils - post harvest pest, can destroy a granary full of cowpeas within two or three months. But people need to have the grain to eat for 12 months in a year (Sheahan, 2012).

A large number of bacterial and fungal pathogens have been reported to infect crop plants which ultimately decrease their yield and hence reduce profit (Heath, 1998). Chemical treatment to prevent such incidence seems to be an easy solution but with an effect to the healthy environment and even our lives. Soil degradation and groundwater pollution are the ultimate results of over dependence on pesticides. Moreover, pesticide residues also sometimes raise food safety concerns (Gupta and Dikshit, 2010). Considering these adverse outcomes, biological controls to plant pathogens are getting immense importance day by day. Based on microorganisms, biopesticides specific to a target pest offer an ecologically sound and effective solution to pest problems. They pose less threat to eco-friendly approach to pest control (Gupta and Dikshit, 2010). Several endophytic bacteria were found to exert antimicrobial as well as antifungal effects on a number of crops (*Oryza sativa, Glycine max*), that contain several enzymes which will act as an inhibitor of their pest's digestive system and can be effective for pest control (Sunkar and Nachiyar, 2013).

Therefore, the aim of this study is to detect and isolate the eco-friendly endophytic bacteria from the roots of *Vigna unguiculata*, (L.) Walp to study their morphological and biochemical characteristics to identify those bacteria up to species level; and finally antibiotic susceptibility were tested in order to use them as a biocontrol agent (spray) (Nandakumar *et al*., 2001, Damodaran *et al*., 2017) in bioremediation scheme.

Materials and Methods

Sampling area and collection of samples

Twenty (20) root samples from cowpea [*Vigna unguiculata* (L.) Walp] plants were collected from various agricultural fields of Hathazari Upazila, Chittagong, Bangladesh (Figure 1). Collected root samples were sealed in sterile zipper bags and labeled. All samples were brought to the Molecular Biology Laboratory of the Department of Genetic Engineering and Biotechnology, University of Chittagong, Bangladesh, by maintaining cold chain and stored them in the refrigerator (4°C) for further analysis.

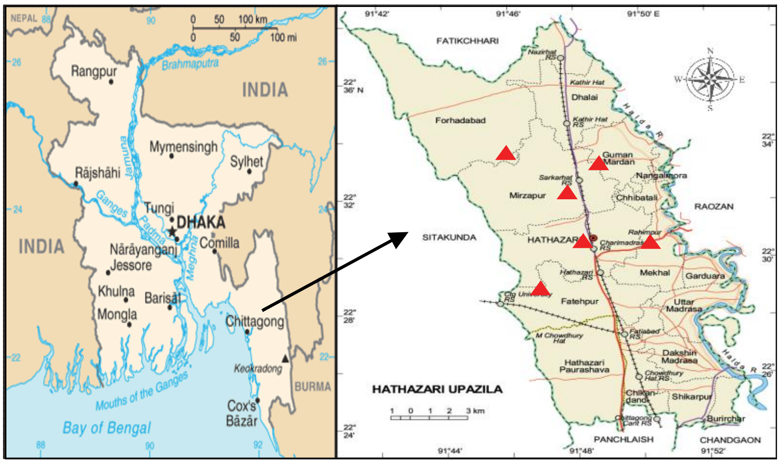

Fig. 1. Sampling sites (▲) of Hathazari Upazila

Isolation of Endophytic Bacteria from cowpea roots

The total procedure were done according to Anderson *et al*. (2008), where samples [healthy fresh roots of *Vigna unguiculata* (L.) Walp] were collected and cleaned under running tap water to remove debris and then air dried. About 25.0 gm of 2-3 cm length of roots were cut and surface sterilization was carried out by rinsing them in Tween-20 for 10 minutes, followed by further washing with dH_2O for at least 7 times. After that, root samples were dipped into 70% alcohol for 30 seconds, and then the samples were washed with dH_2O. Twenty (20.0) ml of 0.2% Hg_2Cl_2 solution was added to the samples and the beaker was put on a shaker at 240 rpm for 5 minutes at 27°C. Then the samples were washed again with dH_2O for at least 7 times. The final root rinsed water, was used as control and spread onto nutrient agar plate (Addisu and Kiros, 2016), which contained (g/L) - peptone 5.00, beef extract 2.00, yeast extract 3.00, NaCl 5.00 and agar 18.00, where pH was adjusted to 7.0. For the isolation of endophytic bacteria, root pieces were further triturated in sterile Phosphate buffer saline (PBS) (Anderson *et al*., 2008) containing (g/L) - NaCl 8.00, KCl 0.20, Na_2HPO_4 1.44 and KH_2PO_4 0.24, where pH was adjusted to 7.4 and maintained at 28°C under

150 rpm agitation. All plates including control were incubated at 37°C for 5 days and the number of CFU was determined to estimate bacterial population density according to Addisu and Kiros (2016).

Following purification, morphologically distinct colonies were identified by observing colony characteristics such as gram nature, color, shape using a binocular biological microscope (XSZ-107BN), where colonies of similar morphological features were grouped into the same species (Castillo *et al*., 2003; Beiranvand *et al*., 2017). Then isolates were selected, cultured, purified and stored in the laboratory at -80°C in glycerol stock (50%) solution for further studies.

Phenotypic and biochemical characterization of endophytic bacterial isolates

Standard morphological and biochemical tests were performed for the identification of endophytic bacteria. They were characterized by gram staining and biochemical tests as described in the Cowan and Steel's Manual for the identification of Medical Bacteria (Barrow and Feltham, 1993). For the activities of oxidase, catalase, coagulase, citrate and carbohydrate (Maltose, Sucrose, Mannitol, D-Xylose and L-Rhamnose) fermentation, isolates were biochemically analyzed (Barrow and Feltham, 1993). Then according to Bergey's Manual of systemic Bacteriology the isolates were provisionally identified up to species level (Claus and Berkeley, 1986).

Determination of antibiotic sensitivity

Susceptibility of three (3) finally identified isolates to different antibacterial agents was measured *in vitro* by employing the modified Kirby-Bauer (Bauer *et al*., 1966) method. This method allows for the rapid determination of the efficiency of a drug by measuring the diameter of the zone of inhibition that results from diffusion of the agent into the medium surrounding the disc (Wayne, 2009). Commercially available eight (8) antibiotic discs (Himedia, India) were used for the tests. The antibiotics that were tested against three isolates of this study have been listed in Table 2.

Statistical analysis

Triplicate experiments were done in all the cases during isolation, biochemical analysis and antibiotic sensitivity tests of the selected isolates. The results were measured as the mean value ± standard deviation (SD) in triplicate. Data were captured into Microsoft Excel Software, version 2010 to calculate means and standard deviations.

Results

Screening and Isolation of endophytic bacteria

After preliminary screening of the collected samples, surface sterilization was done as described previously (Anderson *et al*., 2008), then root extraction was prepared to isolate distinct bacterial colonies and plated them on NA (Nutrient agar) medium. Then three different morphologies and colored isolates were finally selected for further studies named as W (white), PW (pale-white) and Y (yellow) (Figure 2).

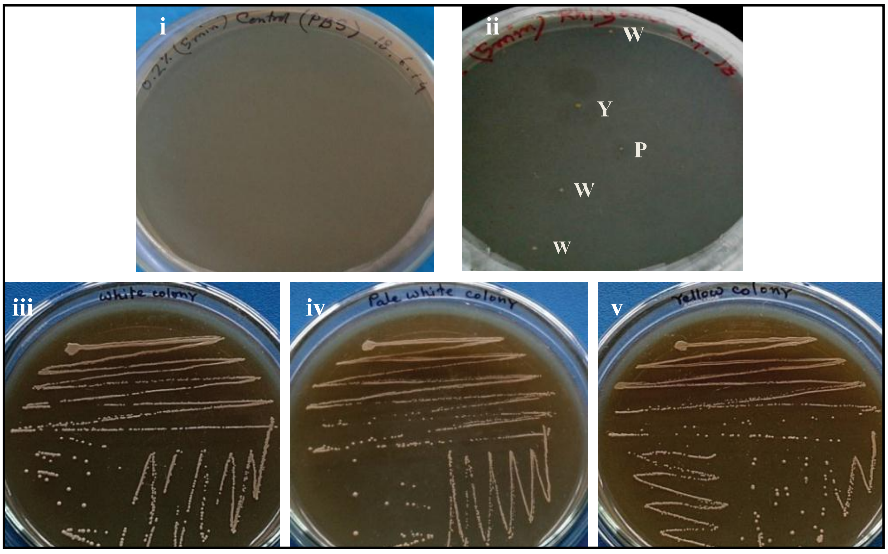

Fig. 2. Control (i) and mixed culture plate (ii); Subculture of bacterial isolate from white, pale white and yellow colony (iii, iv, v).

Characterization and identification

Three selected potential endophytic isolates (W, PW and Y) were characterized on the basis of their morphological and biochemical characteristics (Table 1). They were compared with standard description of Bergey's Manual of determinative bacteriology 9th edition (Bergey *et al*., 1974; Bergey and Holt, 1994), the isolates were provisionally identified up to species level and are consistent with past field studies (Claus and Berkeley, 1986).

Table 1. Morphological and Biochemical Characteristics of Endophytic Bacteria

Bacterial isolates	W	PW	Y
Morphological characteristics			
Colony color	White	Pale-white	Yellow
Gram Nature	Positive	Positive	Positive
Cell Shape	Cocci	Cocci	Cocci
Biochemical Test Results			
Catalase	+	+	+

Coagulase	+	-	-
Oxidase	-	-	-
Citrate	+	+	+
Utilization of Carbohydrates			
Maltose	+	-	-
Sucrose	+	-	+
Mannitol	-	-	+
D-Xylose	-	-	-
L-Rhamnose	-	-	-
Provisionally Identified Bacteria	*Staphylococcus intermedius*	*Staphylococcus caprae*	*Staphylococcus saprophyticus*
Claus and Berkeley (1986)			

Note: (+) and (-) indicates positive and negative results respectively

Antibiotic sensitivity test

All three different isolates were tested for their antibiotic susceptibility against the eight (8) commonly prescribed antibiotics: Ampicillin (AMP), Bacitracin (B), Kanamycin (K), Penicillin G (P), Rifampicin (RIF), Streptomycin (S), Trimethoprim (TR) and Vancomycin (VA) according to the protocol mentioned previously. The antibiotic response was measured by inhibition zone creating by selected endophytes (sample and control), which revealed that all (n=3) were susceptible to 7 (seven) antibiotics (Wayne, 2009; CLSI M100-S21), whereas they (n=3) were resistant to Ampicillin (AMP) and only PW isolate were resistant to Bacitracin (B) (Table 2; Figure 3).

Table 2. Antibiotic Susceptibility Tests

Antimicrobial Agent	Disc code	Disc potency (µg)	Bacterial isolates		
			W	PW	Y
			Zone ranges (mm)		
Ampicillin	AMP	10	12 (R)	17 (R)	10 (R)
Bacitracin	B	10 units	24 (S)	15 (R)	21 (S)
Kanamycin	K	30 µg	29 (S)	28 (S)	35 (S)
Penicillin G	P	10	34 (S)	33 (S)	28 (S)
Rifampicin	RIF	5 µg	34 (S)	35 (S)	39 (S)
Streptomycin	S	10	21 (S)	25 (S)	25 (S)
Trimethoprim	TR	25	17 (S)	26 (S)	32 (S)
Vancomycin	VA	30	22 (S)	22 (S)	23 (S)

Note: R= Resistance, S= Susceptible

Ref.: Wayne, (2009)

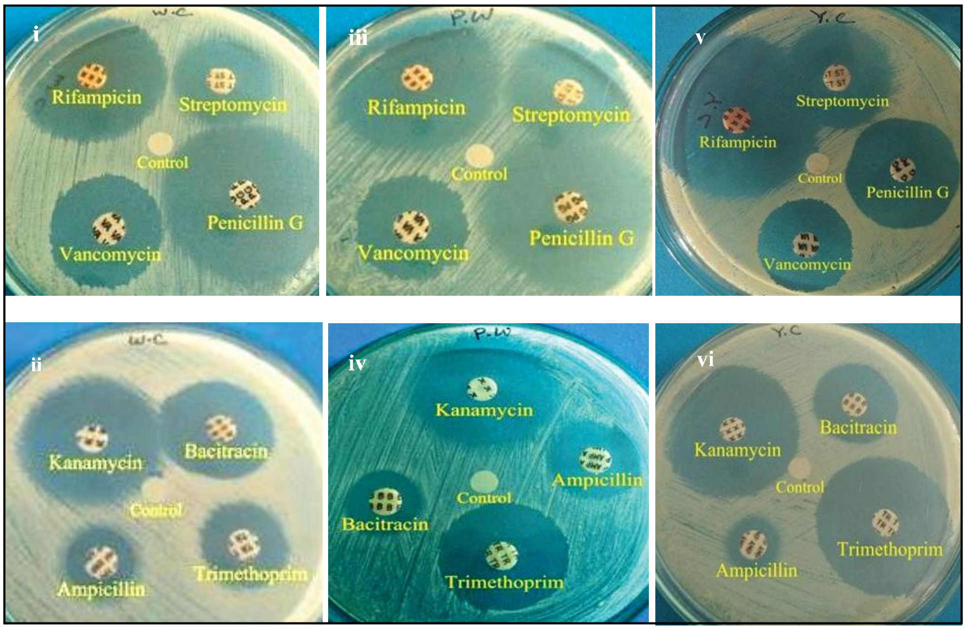

Fig. 3. Antibiotic sensitivity tests; WC= i and ii; PW= iii and iv; YC= v and vi

Discussion

Plants harbor a number of endophytic bacteria and fungus species. Of the nearly 300,000 plant species on earth, each is likely to be the host to at least one endophyte (Strobel, 2003); but relatively few of their endophytes have been characterized so far. So, the major focus of this study was to isolate, characterize and identify the endophytic bacteria from healthy cowpea [*Vigna unguiculata* (L.) Walp] roots which can be used as bio-control agent as an alternative to pesticides that may mitigate environmental pollution as well.

After sample collection, following purification and visual observation of growth, three different types and colors of colonies were selected initially from culture plate as: W (white), PY (pale-white) and Y (yellow) (Figure 2).

The bacterial isolates were then characterized by morphological and biochemical characteristics (Table 1). Identification of bacterial isolates was done according to Bergey's Manual of determinative bacteriology 9th edition (Bergey *et al.*, 1974; Bergey and Holt, 1994; Barrow and Feltham, 1993).

Depending on gram staining, three isolates (W, PW and Y) were identified as gram positive bacteria (Table 1) by detecting peptidoglycan which is present in a thick layer in bacteria (Marzan *et al.*, 2017).

During oxidase test all three isolates showed negative results (Thelwell *et al.*, 1998). Catalase positive results indicate the three bacterial isolates (W, PW and

Y) may be either *Micrococcus* or *Staphylococcus.* Besides, isolates PW and Y were found coagulase negative, where W was found coagulase positive. Beside this, negative result in mannitol salt fermentation test for W, PW found similarities to *Micrococcus* spp. or *Staphylococcus* spp. respectively. To confirm, two isolates were observed for their pigmentation properties on mannitol salt agar media, where lack of yellow pigmentation identified both isolates as *Staphylococcus* spp. During citrate utilization all three isolates showed positive results.

Five carbohydrate utilization tests (Maltose, Sucrose, Mannitol, D-Xylose and L-Rhamnose) were done, where PW showed negative result in all cases, which is strongly indicative of *Staphylococcus caprae* (Tille, 2017). On the other hand, the positive result for maltose and sucrose, as well as negative for the other three carbohydrates found for the isolate W, strongly match with *Staphylococcus intermedius*. Besides, the isolate Y showed positive result for sucrose and mannitol, but negative for the other three carbohydrates, strongly match with *Staphylococcus saprophyticus* (Tille, 2017; Bergey *et al*., 1974).

It was observed that W, PW and Y colony have a close resemblance with *Staphylococcus intermedius*, *Staphylococcus caprae* and *Staphylococcus saprophyticus,* respectively. Bacterial genus *Staphylococcus*, were found previously as endophyte in various agronomic crops (Costa *et al*., 2012; Jasim *et al*., 2013); *Staphylococcus caprae* and *Staphylococcus saprophyticus* were found as endophyte in *Phaseolus vulgaris* (Tille, 2017). The genera isolated in the present study that have been previously reported as endophytes are *Staphylococcus caprae* and *Staphylococcus saprophyticus*, where *Staphylococcus intermedius* is found to be new in our research.

The multidrug resistance problems in microbes increase the demand for further research on novel metabolites obtained from endophytes (Rathod *et al*., 2012). Eight (8) antibiotic discs were used to assess antibiotic sensitivity, where those endophytes can be a good candidate (inhibition zone against antibiotic in maximum cases) to act as a biocontrol agents; where there is a suitable chance to apply directly (spray) in the agricultural environment (Damodaran *et al*., 2017). Here all three isolates were showed antibiotic sensitivity against seven (7), and are harmless to environment for suitable application (Alström and Vuurde, 2001) and their antimicrobial activity could be exploited in biotechnology, medicine and agriculture (Gashgari *et al*., 2016) to control pathogen attack in cowpea and possibly in other plants. A number of endophytic bacteria were reported to prevent the deleterious effects of certain pathogens by producing antimicrobial compunds or inducing systemic resistance in the host plant (Kandel *et al*., 2017). Hence, discovery of novel and effective antibiotics are necessary (O'Donnell *et al*., 2010). Some of the pathogenic microorganisms now a day become resistant to the effective antibiotics (Bisht *et al.*, 2009). Recent data showed that endophytes have a novel source to development of highly effective antibiotics

(Shukla *et al.*, 2015). Hence, invention of effective bio-controlling techniques by using eco-friendly endophytic bacteria, will open a new platform for further studies to fulfill the future demand of cost effective agro-based bio-control agents for plants (Egamberdieva *et al.*, 2017) as well as agricultural systems.

Conclusion

Depending on morphological and biochemical characteristics three isolates collected from cowpea were provisionally identified as *Staphylococcus intermedius*, *Staphylococcus caprae* and *Staphylococcus saprophyticus*. All the results presented in this study support the concept that three endophytic bacteria have significant antibiotic sensitivity which might be used to formulate them as biocontrol agent against pest, insect or pathogen in bioremediation scheme for agricultural environment.

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SOCIO-ECONOMIC PERFORMANCE OF *BT* EGGPLANT CULTIVATION IN BANGLADESH

M. A. RASHID[1], M. K. HASAN[2] AND M. A. MATIN[3]

Abstract

A study was conducted in 35 districts of Bangladesh during 2016-17 winter season for assessing the farm level performance of *Bt* eggplant in reducing pesticide use, cultivation cost and increase farm income. Five hundred five *Bt* eggplant farmers were selected purposively and 350 non-*Bt* eggplant farmers were selected randomly for the study. Net returns per hectare were Tk. 179,602/ha for *Bt* eggplant as compared to Tk. 29,841/ha for non-*Bt* eggplant. Pesticides were applied 11 times to *Bt* eggplant where as it was 41 times to non-*Bt* eggplant for controlling sucking pests. The *Bt* eggplant farmers saved 61 percent of the pesticide cost compared to non-*Bt* eggplant farmers, experienced no losses due to fruit and shoot borer, and received higher net returns. The experience with *Bt* eggplant technology was good for most of the locations and up to the mark and off course this technology will be significantly improved to their socio-economic conditions in future as reported by the *Bt* respondents. All *Bt* and 86% non-*Bt* farmers wanted to cultivate *Bt* eggplant in the next year if they can obtain the seeds/seedlings from the research station. For getting higher yield and economic benefits, in the course of technology dissemination, the importance of good production practices must be emphasized.

Keywords: economics, pesticides, farm income and eggplant.

1. Introduction

Eggplant (*Solanum melongena L.*) is one of the most important vegetables cultivated and consumed in Bangladesh (Saifullah *et al.*, 2012). Also known as brinjal and aubergine, the quantity consumed ranks third after potato among vegetables in the country and its consumption and price have grown over time. It is produced on approximately 50,000 hectares and by about 150,000 farmers (BBS, 2014). Due in part to the prevalence of insect pests and diseases, the eggplant productivity in Bangladesh is the lowest in the world (Choudhary and Gaur, 2009). Available data at the national level indicate that eggplant yield is currently about eight tons per ha in Bangladesh (BBS, 2014). Despite modest progress in raising yields through improved cultivation techniques and varietal resistance to diseases, eggplant productivity could be raised substantially if the crop's major insect pest, the fruit and shoot borer (FSB, *Leucinodes orbonalis*), could be managed effectively. Over the years, the area under eggplant

[1]Principal Scientific Officer, Agricultural Economics Division, [2]On-Farm Research Division and [3]Chief Scientific Officer, Agricultural Economics Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh.

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production, both in summer and winter season, has declined significantly compared to other vegetablesbecause of the significant losses caused by the FSB (Choudhary *et al.*, 2014).

FSB causes losses of up to 70 percent in commercial plantings. It is estimated that the FSB alone reduces marketable produce by about two-thirds (ABSP-II, 2007; Rahman *et al.*, 2009). As a result, farmers are left with little choice except controlling it with insecticides, which are often ineffective as the pest bores into the fruit. Farmers often apply insecticides every other day, or up to 80 sprays per season, at a steep monetary ($180 hectare) and environmental/health cost (Meherun nahar and Paul, 2009). A study of the impact of FSB in Jessore district of Bangladesh indicated that 98 percent of the farmers relied exclusively on pesticides to manage it, with more than 60 percent of farmers spraying their crop 140 times or more per season (Alam *et al.*, 2003). Such use of pesticide is not common in all districts of Bangladesh. Similar to Jessore study, other studies are necessary for various districts to determine the number of spraying in non-*Bt* eggplant for controlling FSB by the farmers. Pesticides alone contribute to one third of the total cost of production of eggplant and farmer and consumer exposure to chemical insecticides (Choudhary and Gaur, 2009). Despite frequent use of insecticides, farmers still experience significant yield losses due to FSB.

Table 1.Area, production and yield of Kharif and Rabi eggplant in Bangladesh

Year	Area (‘000 ha)	Production (‘000 MT)	Yield (t/ha)
Kharif season:			
2007-08	18.40	122.73	6.67
2008-09	18.10	123.78	6.84
2009-10	17.96	125.08	6.96
2010-11	17.92	124.38	6.94
2011-12	16.84	126.99	7.54
Rabi season:			
2007-08	29.35	215.28	7.33
2008-09	28.28	213.79	7.56
2009-10	28.75	216.18	7.52
2010-11	28.63	215.41	7.52
2011-12	27.54	224.04	8.14

Source: BBS (2014).

In recent years, the productivity of eggplant slightly increased. The data available in national level indicated that during 2011-12 the yield of kharif season eggplant was 7.54 ton per hectare and that of rabi season eggplant was 8.14 ton per hectare with about one ton per hectare yield increment from previous five years (BBS, 2014) (Table 1). Despite the decreasing trends of area in both kharif and rabi season, increasing trend of total production was observed mainly due to adoption of high yielding varieties. In spite of some progress in improving the productivity of eggplant in Bangladesh through new vegetable cultivation techniques, recent studies have shown that the productivity of eggplant could be more than tripled in Bangladesh by growing genetically modified eggplant (*Bt* eggplant) with resistance to brinjal shoot and fruit borer.

Price of eggplant fluctuates among the growing seasons (Figure 1.1). It is also observed that average eggplant price gradually increased over the last few years.

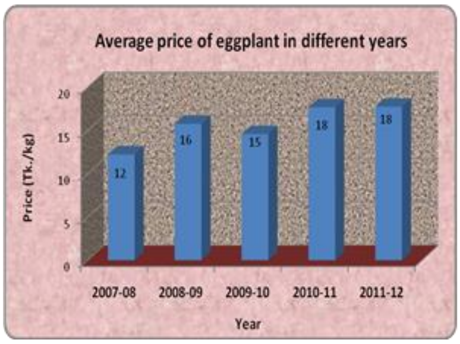

Figure 1.1 Price variation of eggplant in Bangladesh

2. Development of *Bt* eggplant

A potential solution to control eggplant Fruit and Shoot Borer (FSB) is *Bt* eggplant, a genetically modified eggplant that carries an additional gene that provides built-in protection against the insect pest. This transgenic eggplant was created by inserting a crystal protein gene, *Cry 1 Ac*, which expresses an insecticidal protein to confer resistance against FSB. The *Cry 1 Ac* gene is sourced from an environmentally friendly and ubiquitous soil bacterium called *Bacillus thuringiensis (Bt)*, which has been used as a biological pest control in granular or powder form for many years. The *Cry 1 Ac* gene along with two other supporting genes, *nptII* and *aad*, are combined such that they work together to produce an insecticidal protein that is toxic to FSB (Choudhary and Gaur, 2009).

The Agricultural Biotechnology Support Project II (ABSP-II) at Cornell University facilitated the transfer of Bt eggplant event EE-1 from an Indian seed company, Mahyco, to BARI (ABSP-II, 2007; ABSP-II, 2014). BARI then introgressed *Bt* eggplant event EE-1 into locally adapted and commercially popular open-pollinated eggplant varieties of Bangladesh. Out of the nine popular varieties that were introgressed with Bt event EE-1, four were approved for commercial cultivation in October 2013. The released varieties were BARI Bt Begun-1, BARI Bt Begun-2, BARI Bt Begun-3 and BARI Bt Begun-4. The Bt varieties underwent seven years of greenhouse and field trials in various geographic locations in Bangladesh to test their efficacy and environmental safety.

BARI *Bt* Begun-1

BARI *Bt* Begun-2

BARI *Bt* Begun-3

BARI *Bt* Begun-4

Bt eggplant was subjected to standard food and environmental safety tests in the standard national and accredited foreign laboratories (ref). The nutritional composition of *Bt* eggplant was the same as that of non-*Bt* (conventional) eggplant. The new *Bt* varieties are self-pollinating and therefore farmers can save their seeds and reuse them. Experiments conducted at various stations of BARI have found that the *Bt* varieties reduce FSB infestation and the number of insecticide applications and improve yield. With no reports of any detrimental effect on human health, bio-diversity, and environment, the technology was approved for commercial release.

3. Objectives

This study was undertaken to evaluate the performance of *Bt* eggplant during the 2016-17 winter season, with a focus on pesticide use as a potential impact of *Bt* eggplant is the health and environmental benefits due to reduced pesticide use.

The specific objectives of the study are to:

1. To assess the level of BSFB and sucking pests infestation and their control in *Bt* eggplant cultivation
2. To estimate the profitability of *Bt* eggplant as compared to non-*Bt* eggplant cultivation and
3. To evaluate the impacts of *Bt* technologies on input use, productivity and profitability

4. Materials and Methods

4.1 Study areas

The study was undertakenthirty five districts in Bangladesh viz.,Dinajpur, Rangpur, Kurigram, Bogra, Joypurhat, Gaibandha, Rajshahi, Pabna, Khulna, Kushtia, Jessore, Meherpur, Chuadanga, Satkhira, Barisal, Patuakhali, Bhola, Gopalganj, Faridpur, Rajbari, Madaripur, Gazipur, Sherpur, Kishoreganj, Mymensingh, Tangail, Manikgonj, Narshingdi, Munshiganj, Chittaganj, Comilla, Feni, Bandarban, Cox' Bazer and Sylhet where *Bt* eggplant varieties were planted in farmers' fields.

4.2 Sample size

The sample farmers were both *Bt* and non-*Bt* eggplant together constituted 855 farmers. *Bt* farmers refers to those farmers who cultivated eggplant during Rabi 2016-17 season by using seedlings of *Bt* eggplant distributed by BARI. *Non-Bt* farmers are the traditional eggplant producers and they were selected fromthe same locations cultivating same varietiesfor comparative analysis.Data were collected from 505*Bt* eggplant growers and 350 *non-Bt* eggplant growers. The survey covered 105 villages from the selected districts. Face to face interview technique was followed to collect the primary data from the selected farmers. A pre-designed and pre-tested interview schedule was used for this purpose.

4.3 Analytical techniques

The farm-level survey data collected were checked, summarized, and analyzed. Descriptive statistics were provided with comparison of means, and budgets were calculated to assess economic benefits.

Measurement of financial costs and returns

In this study, costs and returns analyses will be done on both variable and total cost basis. The following equation (Π) will be used to assess the financial profitability of eggplant cultivation.

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

Where,

Π = Profit or value addition from eggplant production

Q_i = Quantity of eggplant of ith farmers (kg/ha)

P_i = Average price of eggplant of ith farmers (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 eggplant from the view points of individual farmers was measured in terms of gross return, gross margin and net return.

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 return: The analysis considered fixed cost (which included lend rent and family supplied labour). Net margin was calculated by deducting all costs (Variable and Fixed) from gross return.

5. Results and Discussion

5.1 Socioeconomic characteristics of the sample farmers

Socio-economic characteristics of the eggplant farmers in the survey are reported in Table 2.

The *Bt* eggplant growers was slightly younger on average than the non-*Bt* eggplant growers. Most of the *Bt* and *non-Bt* farmers belonged to the age group 31-45 (46% and 48% respectively) and age group 46-60 years (34% and 40% respectively). Most of the farmers had at least primary level education, most *Bt* eggplant farmers had at least secondary level education, and, on-average, *Bt* eggplant growers were more educated than non-*Bt* growers. Non-*Bt* farmers had, on average, more years of eggplant cultivation experience and slightly larger households. Average hectares of land owned by *Bt* and non-*Bt* farmers were 0.816 and 0.477 ha respectively. However, *Bt* farmers rented in landmore than that of non-*Bt* farmers.

Table 2. Summary socioeconomic statistics for eggplant growers in sample

	***Bt* farmers**	***Non-Bt* farmers**
Sample size (No.)	505	350
Farmers age (%)		
Below 30 years	15	5
31-45 years	46	48
46-60 years	34	40
Above 60 years	5	7
Level of Education (%)		
Illiterate	12	27
Primary	32	50
Secondary	36	23
Above secondary	18	-
Eggplant cultivation experience (%)		
1-5 years	54	40
6-10 years	28	46
11-15years	7	7
16-20 years	3	4
Above 20 years	8	3
Household size (No.)	5	6
Land farmed (hectare)		
Owned land	0.816	0.477
Leased in	0.448	0.254
Leased out	0.087	0.014

5.2 Level of BSFB infestation and their control in eggplant cultivation

It was interesting that the BSFB infestation in shoot 1.44 percent (ranged from 0.27-3.88 %) and in fruit (by no.) 2.00 % (range from 0.21-4.17 %) along with infestation in fruit (by wt.) 1.90 % (varied from 0.29-3.55 %) in *Bt* eggplant whereas 25.18 % shoot and 49.37 % fruit (by no.) as well as 51.88 % fruit (by wt.) infestation in non-*Bt* counterpart in the study areas. On the other hand, 87 % of *Bt* farmers and 97 % of non-*Bt* farmers mentioned about infestation by the sucking pests in eggplant cultivation (Table 3).

Table 3. Infestation by BSFB and sucking pests in the study areas

	Bt farmers			*Non-Bt farmers*		
	BSFB infestation (%)			BSFB infestation (%)		
Region	Shoot	Fruit (by no.)	Fruit (by wt.)	Shoot	Fruit (by no.)	Fruit (by wt.)
Rangpur	0.27	0.59	0.63	25.85	49.83	49.12
Rajshahi	0.69	1.24	1.22	23.14	48.79	52.18
Khulna	0.68	2.94	2.53	25.81	40.56	44.89
Barisal	1.73	0.21	0.29	26.54	51.49	55.45
Dhaka	1.41	2.84	3.55	24.15	50.12	53.15
Chittaganj	3.88	4.17	3.15	25.56	55.45	56.47
All	**1.44**	**2.00**	**1.90**	**25.18**	**49.37**	**51.88**
Range	0.27-3.88	0.21-4.17	0.29-3.55	23.14-26.54	40.56-55.45	49.12-56.47
			Sucking pest infestation (%)			
	87			97		

To protect eggplant from the pests, both *Bt* and non-*Bt* farmers of the selected areas applied several pesticides (Table 4). The specific pesticides applied and the percent of *Bt* eggplant and non-*Bt* eggplant farmers reporting their applications were for aphids, jassids, whiteflies, epilachna beetles, thrips, and red mites were: Admire (51% and 67%), Sevin 85SP (18% and 22%), Dasban (around 15% and 25%), Marshal 20EC (around 14% and 32%), Actara 25WG (10% and 35%), Tundra (around 9% and 20%), Vertimax (6% and14%), Volume Flexi (5% and 10%), and Kinolux(5% &10%). For FSB, only *non-Bt* farmers applied pesticides, and the specific products used were: Suntaf 50SP (by 65% of the non-*Bt* farmers), Emituf 50SP (45%), Ostad 10EC (40%), Corolux (32%), Marshal 20EC (28%), Sumithion (22%), and Tufgor 40EC (15%).

Most *Bt* and non-*Bt* eggplant farmers visit their fields and scout for pest infestation levels before spraying. The *Bt* farmers reported no attacks by FSB in their fields and therefore did not spray. Most *non-Bt* farmers assumed that beneficial insect populations probably decrease in their fields due to pesticide sprays for FSB. *Bt* farmers sprayed only for sucking pests than did non-*Bt* eggplant farmers even though the number of farmers who reported sucking pests was similar for the two groups of farmers. All of the *Bt* eggplant farmers and all of the non-*Bt* eggplant farmers reported home consumption of *Bt* eggplant, the latter even though the eggplants were heavily sprayed. All of the *Bt* and most (86%) the non-*Bt* farmers said they would be willing to adopt *Bt* technology in the coming year if they can obtain the seeds/seedlings.

Table 4. Brand names of pesticides and targeted pests for eggplant cultivation

Targeted pests	Names of pesticides used	Farmer responded (%)	
		Bt farmers	***Non-Bt farmers***
Aphid, Jassid, Whitefly, Epilachna beetle, Thrips, Red mite	Admire	51	67
	Sevin 85SP	18	22
	Dasban	15	25
	Marshal 20EC	14	32
	Actara 25WG	10	35
	Tundra	9	20
	Vertimax	6	14
	Volume Flexi	5	10
	Kinolux	5	10
Brinjal shoot and fruit borer	Suntaf 50SP	-	65
	Emituf 50SP	-	45
	Ostad10EC	-	40
	Corolux	-	32
	Marshal 20EC	-	28
	Sumithion	-	22
	Tafgor 40EC	-	15

Table 5. Per hectare input use on eggplant in the study areas

Items	Input use	
	Bt farmer	***Non-Bt farmer***
Human labour (man-days):		
Family	147	156
Hired	190	256
Mechanical power (Tk.)	10685	11126
Fertilizers (kg):		
Farmyard manure	11225	15624
Urea	335	415
TSP	239	398
MoP	245	320
DAP	46	56
Gypsum	107	146
Zinc sulphate	10	24
Boric Acid	10	18
Seedling (no.)	6916	9535
Irrigation (no.)	6	8
Weeding (no.)	4	6
Spray (no.)	11	41
Harvest (no.)	21	26

5.3 Input use and costs

Input usage for cultivation of *Bt* and non-*Bt* eggplant is summarized in Table 5. Most of the *non-Bt* farmers purchased seedlings for their cultivation. *Bt* farmers used seedlings that supplied from the government research farms free of cost. However, the cost of *Bt* eggplant seedlings was considered the same as the cost of non-*Bt* seedlings for purposes of this study. On average, non-*Bt* farmers applied fertilizers at higher rates than non-*Bt* farmers, perhaps due to instructions when *Bt* seedlings were delivered. Non-*Bt* farmers also applied more labor due to the additional pesticide and fertilizer applications. Non-*Bt* farmers applied insecticides 41 times and the *Bt* farmers applied insecticides 11 times (only for other pest control) during crop cultivation.

Table 6. Per hectare cost ofeggplant production in the study areas

Items	**Cost of cultivation (Tk./ha)**	
	***Bt* farmer**	**Non-*Bt* farmer**
A. Variable cost:		
Human labour (Hired)	46800 (21.77)	69000 (24.37)
Mechanical power	8982 (4.18)	11227 (3.97)
Fertilizers:		
Farm yard manure	11225 (5.22)	15624 (5.52)
Urea	5360 (2.49)	6640 (2.35)
TSP	5736 (2.67)	7680 (2.71)
MoP	3920 (1.82)	5120 (1.81)
Gypsum	1070 (0.50)	1460 (0.52)
Zinc sulphate	2000 (0.93)	4200 (1.48)
Boric Acid	4000 (1.86)	6000 (2.12)
Furadan	3750 (1.74)	0 (0.00)
Bleching powder	3000 (1.40)	0 (0.00)
Seedling	6916 (3.22)	8535 (3.01)
Irrigation	14820 (6.89)	19760 (6.98)
Pesticides	14215 (6.61)	36057 (12.74)
Support and netting	11030 (5.13)	15570 (5.50)
Interest on operating capital	3095 (1.44)	4482 (1.58)
Total variable cost	**145919 (67.88)**	**211355 (74.66)**
B. Fixed cost:		
Rental value of land	24949 (11.61)	24949 (8.81)
Family labour	44100 (20.51)	46800 (16.53)
Total fixed cost	**69049 (32.12)**	**71749 (25.34)**
Total cost (A+B)	**214968 (100)**	**283104 (100)**

Figures in the parenthesis indicate percent of total cost

5.4 Cost of eggplant production

The cost of production, including cash expenses and imputed family labor costs, are shown in Table 5. Higher variable costs were recorded with the non-*Bt* farmers due to higher use of labour, fertilizer, and pesticides. Human labour was the largest cost item for both *Bt* and non-*Bt* farmers followed by fertilizer and pesticides (Table 6). Pesticide cost of non-*Bt* eggplant was more than three times higher compared to *Bt* eggplant. The total variable costs of *Bt* and non-*Bt* eggplant cultivation were Tk. 145,919 per hectare and Tk. 211,335 per hectare respectively. The total cost of (variable costs and fixed costs) *Bt* eggplant cultivation was Tk. 214,968 per hectare whereas it was Tk. 283,104 per hectare for non-*Bt* eggplant.

Table 7. Regional yield of *Bt* and non-*Bt* eggplant varieties during winter 2016-17

Region	Yield (t/ha)									
	BARI *Bt* Begun-1	**BARI Begun-1 (Uttara)**	**BARI *Bt* Begun-2**	**BARI Begun-4 (Kazla)**	**BARI *Bt* Begun-3**	**BARI Begun-5 (Nayan-tara)**	**BARI *Bt* Begun-4**	**BARI Begun-6 (ISD006)**	***All***	
									***Bt* varieties**	***Non-Bt* varieties**
Rangpur	-	-	22.35	-	-	22.48	24.92	-	23.64	22.48
Rajshahi	17.68	13.59	30.28	24.86	-	17.35	29.31	22.65	25.76	19.52
Khulna	-	-	24.72	23.28	17.35	16.33	18.29	16.88	20.12	18.83
Barisal	-	-	26.60	21.54	27.24	15.33	19.56	16.25	24.47	17.71
Dhaka	-	-	24.23	22.62	19.62	17.38	22.30	-	22.05	20.00
Chittagong	-	-	27.79	25.28	20.17	-	21.69	19.87	23.22	22.58
All	**17.68**	**14.39**	**26.00**	**23.52**	**21.10**	**17.77**	**22.68**	**18.91**	**23.21**	**20.19**

Note: *Bt* eggplant event *EE-1* was introgressed into four open pollinated varieties BARI Begun-1 (Uttara), BARI Begun-4 (Kazla), BARI Begun-5 (Nayantara) and BARI Begun-6 (ISD006) and released as BARI *Bt* Begun-1, BARI *Bt* Begun-2, BARI *Bt* Begun-3 and BARI *Bt* Begun-4, respectively.

5.5 Yield

On average *Bt* eggplant varieties produced 23.21 tons fresh eggplant per hectare against 20.19 ton per hectare in non-*Bt* eggplant. This difference was smaller than that found in prior on-farm *Bt* eggplant trials in Bangladesh, although the smaller difference in this study might be due to higher fertilizer use on the non-*Bt* eggplant fields and difficulty in separating marketable from non-marketable produces through recall survey methods. Among the *Bt* varieties, BARI *Bt* Begun-2 gave the highest yield (26.0 t/ha) followed by BARI *Bt* Begun-4 (22.68 t/ha) and BARI *Bt* Begun-3 (21.10 t/ha) (Table 7). The lowest fresh yield of *Bt* varieties was obtained from BARI *Bt* Begun-1 (17.68 t/ha), likely due to its susceptibility to bacterial wilt. Among the non-*Bt* varieties, BARI Begun-4 (Kazla) produced the highest fruit yield (23.52 t/ha) followed by BARI Begun-6 (ISD006) (18.19 t/ha) and BARI Begun-5 (Nayantara) (17.77 t/ha). The lowest fresh yield of non-*Bt* varieties was recorded from BARI Begun-1 (Uttara) (14.39 t/ha). Among the regional locations, *Bt* eggplant planted in Rajshahi districts produced the highest fresh eggplant yield (25.76 t/ha) closely followed by Barisal (24.47 t/ha) and Rangpur (23.64 t/ha). The lowest yield was obtained from Khulna (20.12 t/ha). Similar yield results by location were observed for the non-*Bt* varieties.

Comparing actual and percent yield differences across all locations, the largest difference (19%) was recorded between BARI *Bt* Begun-1 and BARI Begun-1 (Uttara) (Table 8). About 10% yield difference was found between BARI *Bt* Begun-2 and BARI Begun-4 (Kazla), about 16% for BARI *Bt* Begun-3 and BARI Begun-5, and about 17% for BARI-*Bt* Begun 4 and Bari-Begun-6.

Table 8. Yield difference between *Bt* and non-*Bt* eggplant varieties during winter 2016-17 in the study areas

Variety	Yield (t/ha)	Difference in yield between *Bt* and non-*Bt* varieties (t/ha)	Yield difference (%)
BARI *Bt* Begun-1	17.68	3.29	18.61
BARI Begun-1 (Uttara)	14.39		
BARI *Bt* Begun-2	26.00	2.48	9.53
BARI Begun-4 (Kazla)	23.52		
BARI *Bt* Begun-3	21.10	3.33	15.78
BARI Begun-5 (Nayantara)	17.77		
BARI *Bt* Begun-4	22.68	3.77	16.62
BARI Begun-6 (ISD006)	18.91		

5.6 Gross and net returns

Gross returns from *Bt* eggplant cultivation was Tk. 394,570/ha as compared to Tk. 312,945/ha for non-*Bt* eggplant (Table 9). Net returns per hectare were Tk. 179,602/ha for *Bt* eggplant as compared to Tk. 29,841/ha for non-*Bt* eggplant (5 times larger for *Bt* eggplant farmers). The yield difference between the two groups was only 3.02 tons, but the non-*Bt* farmers applied almost three times more pesticides to maintain the yields as well as more fertilizer. Pesticide costs were Tk. 14215/ha for *Bt* eggplant and *Tk*. 36,057for non-*Bt* eggplant. Therefore, the higher net returns for *Bt* eggplant as compared to non-*Bt* eggplant was due more to lower production costs than to higher yields. On the basis of total cost, production cost per kilogram of *Bt* eggplant was Tk. 9.26 and for non-*Bt* eggplant it was Tk. 14.20. On the basis of variable cost, production cost per kilogram of *Bt* eggplant was Tk. 6.29 and for non-*Bt* eggplant it was Tk. 10.47.

Table 9. Per hectare return from eggplant production in the study areas

Items	Return (Tk./ha)	
	***Bt* eggplant**	**Non-*Bt* eggplant**
Fresh eggplant yield (ton/ha)	23.21	20.19
Gross return	394570	312945
Gross margin	248651	101590
Net return	179602	29841
Benefit cost ratio	1.84	1.11
Production cost (Tk./kg):		
Total cost basis	9.26	14.02
Variable cost basis	6.29	10.47

6. Impact of *Bt* Technologies on Input Use, Productivity and Profitability

Bt technology have some more advantages in brinjal cultivation compared to the conventional method (non-*Bt*) of cultivation in terms of efficient inputs-use, cost saving and higher profitability. The impacts of *Bt* technologies on input use, crop yield and farm profitability are discussed in the following sections.

6.1 Eggplant cultivation

The *Bt* farmers in the study areas saved cost 22% in human labour, 20% mechanical power, 19% seedling, 28% organic fertilizer, 29% chemical fertilizer and 25% irrigation than that of non-*Bt* farmers. It was also interesting that *Bt* farmers saved money 61% from pesticides application than that of non-*Bt* farmers in the study areas (Table 10).

The productivity of a crop depends on many factors such as time of sowing, seed quality, variety, crop management, weather, rate of manure and fertilizer use and so on. However, the adopters of *Bt* technologies received 13% higher yield compared to non-*Bt* farmers. There was the higher selling price of *Bt* eggplant, the *Bt* farmers in the study areas obtained significantly higher gross (21%) and net income (83%) compared to non-*B* farmer which was because of higher yield. The benefit cost ratio over total cost was also more than 13% higher for *Bt* farmers (Table 11). The total variable cost (VC) and fixed cost (FC) were also lower for *Bt* farmers compared to non-*Bt* farmers, respectively.

Table 10. Input cost saving in eggplant cultivation by *Bt* farmers over non-*Bt* farmers ***(Figure in Tk/ha)***

Input costs	***Bt farmers***		***Non-Bt farmers***		***Mean difference***	***P (T<=t)***
	Amount	SD	Amount	SD		
Human labour	90900	4412	115800	4858	-24900***	0.000
Mechanical power	8982	526	11227	1686	-2245*	0.029
Seedling	6916	197	8535	386	-1619***	0.000
FYM	11225	785	15624	936	-4399***	0.002
Urea	5360	429	6640	897	-1280**	0.034
TSP	5736	241	7680	330	-1944***	0.000
MoP	3920	268	5120	223	-1200***	0.000
Gysupsum	1070	55	1460	47	-390***	0.000
Boric Acid	4000	105	6000	85	-2000***	0.000
Zinc sulphate	2000	167	4200	223	-2200***	0.000
Pesticides	14215	914	36057	2495	-21842***	0.000
Irrigation	14820	962	19760	620	-4940***	0.000
Support & netting	11030	513	15570	720	-4540***	0.000

Note: Figures with negative sign in mean difference column indicate the costs saving by Bt farmers over non-Bt farmers, while non-negative figures indicate additional cost.

*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

Table 11. Profitability differential in eggplant cultivation by *Bt* farmers vs. non-*Bt* farmers ***(Figure in Tk/ha)***

Particulars	***Bt farmers***		***Non-Bt farmers***		***Mean difference***	***P (T<=t)***
	Amount	SD	Amount	SD		
A. Returns						
Yield (t/ha)	23.21	6.33	20.19	4.23	3.02***	0.000
Gross return	394570	1727	312945	1387	81625***	0.000
Gross margin	248651	1756	101590	1532	14706***	0.000
Net return	179602	2291	29841	3894	149761***	0.000
B. Cultivation cost						
Fixed cost (FC)	69049	2558	71749	1840	-2700	0.142
Variable cost (VC)	145919	827	211355	1970	-65436***	0.000
Total cost (TC)	214968	1136	283104	4048	-68136***	0.000
C. Benefit cost ratio (BCR)						
Over VC	2.70	0.017	1.48	0.011	1.22***	0.000
Over TC	1.84	0.014	1.11	0.015	0.73***	0.000

Note: Figures with negative sign in mean difference column indicate the amount saving Bt farmers over non-Bt farmers, while non-negative figures indicate additional amount.

*'***', '**' and '*' indicate significant at 1%, 5% and 10% level.*

6.2*Bt* trait valuation:

The *Bt* trait valuation was carried out using Partial Budgeting Analysis (PBA). The results of partial budgeting analysis for the introduction of *Bt* eggplant in the place of *non-Bt* eggplant cultivation by the adopters is given in Table 12.

Table 12. Partial budget analysis of producing *Bt* eggplant instead of *non-Bt*

Sl. no.	Benefits due to adoption of *Bt* eggplant	Tk./ha	Costs due to adoption of *Bt* eggplant	Tk./ha
A.	Increase in income (Added income)	81625.00	Added costs	0.00
B.	Reduction in costs	68136.00	Reduction in income	0.00
	Sub total	149761.00	Sub total	0.00

Net change in income per hectare due to adoption of *Bt* eggplant is Tk. 149761.00. Thus, the value of *Bt* trait in *Bt* eggplant is estimated at Tk. 149761.00.

7. Conclusion

The cultivation of non-*Bt* eggplant requires more inputs, especially pesticides, as compared to *Bt* eggplant. Because *Bt* farmers were guided by scientists to use proper inputs. But the non-*Bt* farmers used inputs as of their own choice. On an average, the non-*Bt* eggplant farmers applied insecticides 41 times during the crop life period and the *Bt* eggplant farmers applied insecticides only 11 times for controlling sucking pests. This pesticide use difference is an important factor affecting costs and returns to *Bt* eggplant as well as the human health and environmental advantage of *Bt* over non-*Bt* eggplant. It is likely that the actual marketable yield difference was greater than that was reported because FSB reduces eggplant marketability and non-*Bt* eggplant had more internal damage to the fruits (100% of the non-*Bt* farmers experienced damage by FSB but 0% of the *Bt* farmers experienced such damage). It was observed that *Bt* eggplant fields were free not from FSB infestation either had the infestation ranging from 0.27% to 3.88% (shoot) and 0.21% to 4.17%% (fruit). Therefore, application of pesticides reduced remarkably and economic benefit of the farmers increased significantly. The experience with *Bt* eggplant technology was good for most of the locations and up to the mark as reported by the *Bt* respondents. The cost for pesticides in producing eggplant could be substantially reduced by adopting *Bt* technology. The study clearly indicates huge potential for *Bt* eggplant to provide major environmental and economic benefits not only for farmers but for consumers. Hence the technology is environment friendly.

8. Recommendations

Based on the study findings, some policy recommendations are as follows:

- More awareness among farmers about the *Bt* eggplant variety should be created through application of ICT.

- Extension personnel at all levels and progressive farmers should be trained in the cultivation of *Bt* eggplant on priority basis.
- More awareness may be created among the traders and consumers about the benefits of *Bt* technology so that barriers to consumption may be circumvented
- National research agencies may strengthen research on GMO crops to improve pesticides resistance, weedicides resistance and nutritional improvement of various crops. They may develop international collaboration in bio-technological research to avoid time lag in brining at new products.
- Proper pesticide should be screened to effectively control sucking pest that attack *Bt* eggplant starting from seedling stage.
- For getting higher yield and economic benefits, in the course of technology dissemination, the importance of good production practices must be emphasized.
- *Bt* technology should be introduced on locally popular other commercial eggplant varieties.

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NUTRIENT MANAGEMENT ON THE GROWTH AND YIELD OF BLACK CUMIN (*NIGELLA SATIVA* L.)

M. N. YOUSUF[1], A. J. M. S. KARIM[2], A. R. M. SOLAIMAN[3]
M. S. ISLAM[4] AND M. ZAKARIA[5]

Abstract

A field experiment was carried out at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, during *rabi* (winter) season of 2016-17 to evaluate the effects of fertilizer treatments on black cumin (BARI Kalozira-1). The field belongs to Shallow red-brown terrace soil of Salna series under AEZ-28 (Madhupur Tract). The experiment was laid out in randomized complete block design (RCBD) with three replications. Results showed that the application of nutrient elements had positive effect on plant height, branches per plant, capsule setting, umbels per plant, capsules per plant, capsule size, seeds per capsule, 1000-seed weight and seed yield of black cumin. The highest seed yield (1277 kg ha^{-1}) was obtained from 75% RDCF + 25% cowdung-N treatment followed by 100% RDCF ($N_{80}P_{45}K_{50}S_{20}Zn_5B_2$ kg ha^{-1}) and the lowest seed yield (420 kg ha^{-1}) was recorded with 50% RDCF. Thus, the IPNS treatment 75% RDCF + 25% cowdung-N appeared to be the best suitable package for black cumin cultivation in this location.

Keywords: Black cumin, IPNS, seed yield.

Introduction

Black cumin (*Nigella sativa* L.), belongs to the butter cup family Ranunculaceae (diploid, 2n=12) and it has remarkable aromatic and medicinal properties. The black cumin seeds and oil have commercial significance as spice and medicines. Black cumin is generally short-lived annual herb originated in the Mediterranean region and it is widely cultivated throughout the South Europe, North Africa, countries of Middle East, Turkey, Iran, China, Japan and India Sub-Continent (Rana *et al.*, 2012; Bhutia *et al.*, 2015). In Bangladesh, it covers 14742 hectares of land, with total annual production of 16526 tons (DAE, 2017), over the Faridpur, Sariatpur, Madaripur, Pabna, Sirajganj, Jessore, Kushtia, Bogra, Rangpur and Natore districts (Ali *et al.*, 2015; Noor *et al.*, 2008). The average yield of black cumin is low which might be due to disease and insect infestation, weak nutrient management (Bhutia *et al.*, 2015).

A plant nutritional constraint often restricts yield and qualities of crops. Application of cowdung along with chemical fertilizers improves soil health for the production of subsequent crops (Najm *et al.*, 2012). Al-Saadi and Alhalabi (2012)

[1]PhD (fellow), [2,3&4]Professors, Department of Soil Science, [5]Professor, Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706, Bangladesh.

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reported that application of NPK fertilizers increased yield of black cumin. According to Rana *et al.* (2012), application of $N_{60}P_{120}$ kg ha^{-1}gave the maximum growth, yield and quality of black cumin with the highest net return per hectare. Girma and Taddesse (2013) found that application of 100 kg N and 50 kg P_2O_5 ha^{-1} gave maximum dry matter yield, seed yield and essential oil yield of white cumin. Pariari *et al.* (2012) reported that in Gangetic alluvial plains NAA at 100 ppm with $N_{30}P_{40}K_{45}$ kg $ha^{-1}$and FYM @ 15 t ha^{-1} gave the maximum seed yield of black cumin. Ali *et al.* (2015a) reported that the dry matter weight, number of primary branches, number of fruits, 1000-seed weight and seed yield of black cumin genotypes were significantly influenced by different levels of N-P-K fertilizers. The present study was therefore, done to see the response of black cumin to chemical fertilizers and cowdung application in AEZ-28 (Madhupur Tract) soil.

Materials and Methods

The field experiment was conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur. The experimental field represents on Shallow red-brown terrace soil of Salna series (Plinthic Paleustult) under AEZ-28 (Madhupur Tract). The experiment was set up during rabi (winter) season of 2016-17. The geographic coordinates of the experimental location is $24^0 09^/$ North Latitude and $90^0 26^/$ East Longitude with an elevation of 8.2 m from mean sea level. A description of soil physical and chemical properties of the experimental field is presented in Table 1.

Table 1. Soil properties of the experimental field

Texture	pH	OC (%)	Ca	Mg	K	Total N	P	S	B	Zn	Cu	Mn	Mo
			(meq 100g^{-1} soil)			%	(µg g^{-1} soil)						
Silty clay loam	6.2	0.86	1.6	0.71	6.0	0.09	10.2	12	0.28	0.9	0.7	8.0	0.05

The experiment was set up in a randomized complete block design (RCBD) with seven treatment combinations having three replications. The treatments were T_1 = 100% RDCF ($N_{80}P_{45}K_{50}S_{20}Zn_5B_2$ kg ha^{-1}), T_2 = 75% RDCF + 25% N from cowdung, T_3 = 50% RDCF + 50% N from Cowdung, T_4 = 150% RDCF, T_5 = 125% RDCF, T_6 = 75% RDCF and T_7 = 50% RDCF; RDCF means recommended dose of chemical fertilizers. The whole amount of cowdung, TSP, MoP, gypsum, zinc oxide and boric acid was applied as basal and 1/3rd urea was applied in three equal at 5th, 9th and 11th week after sowing. The seeds of black cumin cv. BARI Kalozira-1 were sown on 22 November 2016 in 2.5 m x 2.0 m plot at line to line distance 20 cm. Seeds were soaked in water for 24 hours to facilitate germination, then the seeds dried and treated with Bavistin (carbendazim) @ 2g kg^{-1} seeds to minimize the primary seed-borne disease. The seeds were mixed with some loose soil to allow uniform sowing in rows @ 10 kg ha^{-1} at a depth of about one cm. The seeds were covered with loose soil properly just after sowing and gently pressed by hands with slight watering to enhance proper germination. Continuous sowing was done to maintain plant to plant distance of 10 cm by thinning after 25 DAS. Intercultural operations (four irrigations, three weeding and three times' spray of Bavistin @ 2g L^{-1} of water spray for controlling damping off disease) were done in the whole cropping period. Observations were done on the growth parameters like plant height and number of branches at 100 DAS. The crops were harvested on 20 March 2017, when as around 50 - 60% of the capsules turned into straw color from green. Ten plants were selected randomly from each plot for counting some growth and yield parameters. The harvested plants were sun dried for four days and threshing was done by beating with sticks. The seeds were winnowed and cleaned for recording data. The seed yield per plot was recorded from $1m^2$ area and then converted to yield per hectare. The data were subjected to statistical analysis by using MSTAT software to find out the significance of variation between treatments. The difference between treatment means were judged by Duncan's Multiple Range Test (DMRT) according to Gomez and Gomez (1984).

Results and Discussion

Plant height

Fertilizer treatments significantly affected the plant height (Table 2). The tallest plant (65 cm) was recorded in treatment T_2 (75% RDCF + 25% N from cowdung) and the smallest plant (23.4 cm) was noted in treatment T_7 (50% RDCF). Similar results were reported by (Ali *et al*., 2015a, b).

Number of branches per plant

As shown in the Table 2, there was significant difference in number of branches per plant between the treatments, the maximum number of branches per plant (6.7) in treatment T_2 (75% RDCF + 25% N from cowdung) followed by treatment T_1, T_5. The minimum number of branches per plant (4.07) was found in the treatment T_7 (50% RDCF). Additional amount of nutrient applications increased the number of branches which ultimately contributed to the formation of additional number of capsules per plant. Thus, these parameters could be used as good indicators of improving yield potential in black cumin. These results are in agreement with the research findings of Tuncturk *et al*. (2013) and Bhutia *et al.* (2015).

Days to capsule setting

Table 2 shows that the maximum days (70.7) to capsule setting was required in treatment T_2 (75% RDCF + 25% N from cowdung) and the minimum days (63.3) in the treatment T_7 (50% RDCF). These results indicated that early capsule setting occurred in the plants which were inadequately supplied with nutrients.

Number of umbellets per plant

The number of umbellets per plant (Table 2) differed significantly due to variation in application of nutrient treatments. The maximum number of umbellets per plant (67.7) was found with application of 75% RDCF + 25% N from cowdung, while the minimum number of umbellets per plant (31.7) in application of 50% RDCF. The number of umbellets per plant directly influenced the number of capsules per plant. This was probably due to adequate nutrient uptake by plant by resulting in production of more branches as well as more number of umbellets per plant. Rana *et al*. (2012) and Ali *et al.* (2015b) reported similar results.

Table 2. Effects of nutrient management on the growth of black cumin

Treatment	Plant height (cm)	No. of branches per plant	Days to capsule setting	No. of umbellets per plant	No. of capsules per plant
T_1	58.8b	6.20ab	66.3cd	62.9b	55.5b
T_2	65.0a	6.70a	70.7a	67.7a	58.9a
T_3	53.6c	5.40b	68.0b	58.9c	56.9ab
T_4	45.5e	5.30bc	67.3bc	53.7d	38.8c
T_5	47.7d	6.17ab	68.0b	61.7bc	54.6b
T_6	37.1f	4.40cd	65.7d	39.9e	34.2d
T_7	23.4g	4.07d	63.3e	31.7f	26.2e
CV (%)	2.33	9.84	0.93	3.54	3.20

Legend: T_1 = 100% RDCF ($N_{80}P_{45}K_{50}S_{20}Zn_5B_2$ kg/ha), T_2 = 75% RDCF + 25% N from Cowdung, T_3 = 50% RDCF + 50% N from Cowdung, T_4 = 150% RDCF, T_5 = 125% RDCF, T_6 = 75% RDCF and T_7 = 50% RDCF

Number of capsules per plant

Table 2 exhibits that the maximum number of capsules (58.9) per plant was produced by treatment T_2 where nutrients were applied as 75% RDCF + 25% N from cowdung and the minimum results (26.2 capsules per plant) in T_7 representing 50% RDCF. Total number of capsules per plant appeared to be the most important component since it is closely related with seed yield. Increase in number of capsules per plant indicates production of more number of flowers per umbel, higher percentage of capsule set and reduced shedding of flowers and capsules which resulted in increased yield. Tuncturk *et al*. (2013) and Rana *et al.* (2012) also recorded similar results.

Capsule size

Capsule size is represented by the length and diameter of the capsule (Table 3). The mean maximum length (1.43 cm) and diameter (1.67 cm) of single capsule was observed in treatment T_2, while the minimum length (0.63 cm) and diameter (0.67 cm) of capsule was found in treatment T_7. Capsule size directly affects the number of seeds per capsule which in turn impacted yield. Bigger size capsule had higher number of seeds.

Number of seeds per capsule

The Table 3 shows that number of seeds per capsule was affected by the fertilizer treatments. The highest number of seeds per capsule (111.9) was obtained when nutrient elements were applied as 75% RDCF + 25% N from cowdung and the lowest number of seeds per capsule (70.2) was observed with 50% RDCF. The results are in agreement with the research findings of Ghanepasand *et al.* (2014) and Bhutia *et al.* (2015).

Table 3. Effects of nutrient management on the yield and yield components of black cumin

Treatment	Capsule size		No. of seeds per capsule	1000-seed weight (g)	Seed yield (kg ha^{-1})
	Capsule length (cm)	Capsule diameter (cm)			
T_1	1.23a	0.97b	96.33b	2.47b	1150.0b
T_2	1.43a	1.67a	111.9a	2.67a	1277.0a
T_3	1.27a	0.97b	94.53b	2.40bc	1043.0c
T_4	1.27a	0.87bc	75.47d	1.97d	593.7e
T_5	1.03b	0.80c	84.07c	2.27c	656.7d
T_6	0.90b	0.77cd	70.87d	1.77e	500.2f
T_7	0.63c	0.67d	70.20d	1.43f	420.3g
CV (%)	9.29	7.98	3.90	4.55	4.02

Legend: T_1 = 100% RDCF ($N_{80}P_{45}K_{50}S_{20}Zn_5B_2$ kg/ha), T_2 = 75% RDCF + 25% N from Cowdung, T_3 = 50% RDCF + 50% N from Cowdung, T_4 = 150% RDCF, T_5 = 125% RDCF, T_6 = 75% RDCF and T_7 = 50% RDCF

1000-seed weight

The weight of 1000-seed was significantly affected by the fertilizer treatments (Table 3). The maximum 1000-seed weight (2.67 g) was recorded in treatment T_2 and the minimum 1000-seed weight (1.43 g) was noted in treatment T_7. The 1000-seed weight can be affected by several factors such as variety, growing condition, climatic factors, soil properties and cultural and nutrient management. Similar results were obtained by Ghanepasand *et al.* (2014) and Ali *et al*. (2015b).

Seed yield

The data presented in Table 3 revealed that fertilizer treatments affected the seed yield of black cumin. The maximum seed yield (1277 kg ha^{-1}) was obtained when nutrients were applied as 75% RDCF + 25% N from cowdung and the minimum seed yield (420 kg ha^{-1}) in application of 50% RDCF. Similar results were recorded by Ali *et al.* (2015a, b) and Yousuf *et al.* (2014).

Conclusion

Fertilizer application played an important role on the growth and seed yield of black cumin. The fertilizer treatment T_2 (75% RDCF + 25% N from cowdung) was observed as the best nutrient package for black cumin cultivation in Shallow Red-Brown Terrace Soil of Salna series under AEZ-28 (Madhupur Tract).

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NITROGEN, PHOSPHORUS AND POTASSIUM STATUS OF RICE CO-PLANTED WITH A NOVEL PHYTOREMEDIATOR, *MARSILEA MINUTA* L.

U. HASSI[1], M. T. HOSSAIN[2] AND S. M. I. HUQ[3]

Abstract

A pot experiment was carried out to assess the effects of arsenic and aquatic fern (*Marsilea minuta* L.), when applied as a phytoremediator, on the nutrient content (nitrogen, phosphorus, and potassium) of rice. Two sets of pot experiments were conducted in the net house on rice (*Oryza sativa* L.) together with aquatic fern (*M. minuta*) and on aquatic fern (*M. minuta*) alone where soils were treated with 1 mg/L As-solution at 80% arsenite and 20% arsenate. No significant difference was found in the nitrogen, phosphorus, and potassium concentrations of rice, in the absence of arsenic, whether grown in the presence of *M. minuta* or not. The uptake of total nitrogen, phosphorus, and potassium was found to be 36%, 23%, and 22% more, respectively in rice plants treated with *M. minuta* and arsenic over the control treatment, although the results were statistically insignificant. However, a significant negative relationship was found between arsenic and root nitrogen (P-value of 0.0017) when grown together with arsenic and *M. minuta*. A significant positive relationship was found between arsenic and shoot phosphorus (P-value of 0.0025) as well as arsenic and shoot and root potassium (P-values were 0.0045 and 0.0115, respectively). The results indicate that *Marsilea minuta* might be used as a phytoremediator of As together with rice plants.

Keywords: Rice, Arsenic, *Marsilea minuta*, Nitrogen, Phosphorus, Potassium

Introduction

The plants of wetland ecosystems have been playing a crucial role in the lives of human beings for thousands of years, serving as food, fodder, and medicine. The medicinal value of pteridophytes has been known to man for more than 2000 years (Chandra, 2000). *Marsilea minutia* L. (Marsileaceae), is a common species of water fern widely found in wet and humid places and is considered a medicinal plant (Tiwari *et al*., 2010). Recently, aquatic plants have received more attention for their phytoremediation qualities. *Marsilea minuta* can be used as a phytoremediator for chromium, copper, and nickel (Kumar *et al*., 2012). The bioaccumulation factor of As in *M. minuta* was found to be 2.88-3.88 (Tripathi *et al*., 2012), demonstrating its potential to be a good phytoremediator for As. Phytoremediation is considered as a low-cost, but efficient method for As reduction (Pilon-Smits, 2005) and could be used to mitigate the wide-spread As

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[1&2]Department of Soil, Water & Environment, Faculty of Biological Sciences, University of Dhaka, Dhaka 1000, [2]University of Barisal, Kornokathi, Barisal 8200, Bangladesh.

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contamination in paddy fields (Han *et al*., 2007). Irrigation of agricultural soils with As-contaminated groundwater in Bangladesh, India, China, and other countries in Southeast Asia has caused the accumulation of As in both soils and plants, and elevated the transfer of As in the food chain, which poses long-term risks to human health (Imamul Huq *et al*., 2006).

Recent studies have shown the accumulation of As in *M. minuta* about 60 mg/kg (Tripathi *et al*., 2012) and 82.06 mg/kg (Hassi *et al*., 2017). One of our previous studies have further proved the phytoremediation capacity of *M. minuta*, finding that the bioaccumulation factor of As in *M. minuta* was found to be >5.34 while growing together with rice plants (Hassi *et al*., 2017). When a plant is used as a phytoremediator for any metal, the main concern is then how much metal could be remediated by the phytoremediators. It is also necessary to assess the nutrient competition between the host plants and the phytoremediator, especially when it is applied in a grain field. However, there is no report on the nutrient status of rice when *M. minuta* is applied as a phytoremediator of As. In the present study, two pot experiments were conducted to investigate the effects of As on nitrogen, phosphorus and potassium concentrations in rice and *M. minuta.*

Materials and Methods

A pot experiment was conducted in the net house of Department of Soil, Water and Environment, University of Dhaka. The experiment was conducted in As-contaminated soils (non-calcareous alluvium) collected from Manikganj district, Bangladesh (23°52’60” N and 90°02’12” E). Soils were collected from a depth of 0 – 15 cm, as recommended by the Soil Survey Staff of the USDA (1951). Rice seeds of BRRI dhan 28 were collected from authorized seed market, and *M. minuta* was collected from the Botanical Garden of the University of Dhaka. *Marsilea minuta* was allowed to grow in the water medium for seven days before transplantation. For optimum growth of plants, recommended doses of N, P, and K (N = 230.8 kg urea/ha, P = 78.05 kg TSP/ha, and K = 128 kg MoP/ha soil) was applied following a fertilizer recommendation guide (BARC, 2012). In the first phase, *M. minuta* was cultivated into 1.5 kg of soil, in the presence and absence of As, representing as MX and MA. In the next phase, *M. minuta* was allowed to grow together with rice in the presence and absence of As into 5 kg of soil which are represented as RAM (rice with *M. minuta* and As), RXM (rice with *M. minuta* and without As), RAX (rice with As and without *M. minuta)*, and RXX (rice without As and *M. minuta*). Three replications were conducted for each treatment. Throughout the growth period, 100 mL and 250 mL of As-treated water (1 mg/L As) was applied to the plants grown in 1.5 kg and 5 kg of soil, respectively. Arsenic stock solution was made from 80% arsenite ($NaAsO_2$) combined with 20% arsenate ($Na_2HAsO_4.H_2O$) (Ali *et al*., 2016). Three replications were conducted for each treatment. Rice plants were harvested at 90 days after transplantation, and *M. minuta* plants were harvested at 70 days after transplantation. After harvesting and washing, the whole rice plants were separated into roots, shoots, and unhusked grain and *M. minuta* were separated into roots and shoots. Plant samples were first air-dried, then oven dried at 85° ± 5°C for 48 hours, then ground with mortar and pestle for chemical analysis.

Soil samples were sieved through a 0.5 mm sieve for chemical analysis. Particle size analysis of soil was conducted following the USDA (1951) methods. Total organic C was determined following the methods of Walkley and Black (1949), and available N (%) and P (%) were estimated following the procedures described in Carter and Gregorich (2007). Moisture content was determined by using the gravimetric method. Total N of the plant samples was determined by Kjeldahl's method following concentrated sulphuric acid (H_2SO_4) digestion as described by Imamul Huq and Alam (2005). Total P of the plant samples was determined by Vanadomolybdophosphoric Yellow Color method using a spectrophotometer wavelength ranging from 400 to 490 nm (according to the sensitivity needed) (Imamul Huq and Alam, 2005). The amount of potassium was estimated using flame emission spectrophotometer, wavelength settings at 766.5 (Imamul Huq and Alam, 2005). Total soil arsenic (As) was extracted by aqua-regia (concentrated HCl: concentrated HNO_3 = 3:1) digestion, and As from plant samples was extracted by concentrated HNO_3 digestion with a 24-hour pre-digestion, determined by a Hydride Vapor Generator (HVG) with 20 % KI in acid medium. The hydride was generated using 5M HCl, 0.4% $NaBH_4$, and 0.5% NaOH in deionized water (Hassi *et al*., 2017; Ganje and Rains, 1982).

Data were analyzed by one-way Analysis of Variance (ANOVA), with significance values calculated using the least-significant-difference (LSD) test, using MINITAB-18.

Results and Discussion

The collected soil samples and fern (*M. minuta*) were analyzed before setting up the experiment to observe the nutrient status as well as the concentration of As (Tables 1 and 2).

Table 1. Background analysis of soil

pH	Moisture (%)	Sand (%)	Silt (%)	Clay (%)	Textural Class	Org. C (%)	Total N (%)	Available P (%)	Available K (%)	Total As (mg/kg)
6.52	21.45	13.4	74.6	12.0	Silt loam	0.87	0.09	0.0033	0.0023	15.52

Table 2. Background analysis of *M. minuta*

N (%)		P (%)		K (%)		As (mg/kg dry wt.)	
Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
2.06	3.63	0.91	1.37	BDL	2.00	0.23	1.70

The mean concentration of nitrogen, phosphorus, potassium, and arsenic in the shoots and roots of *M. minuta*, grown without rice and with rice, are shown in Table 3 and Table 4, respectively. There was an increase of nitrogen concentration in shoots of *M. minuta*, whereas the nitrogen concentration was decreased in roots for all treatments. The nitrogen concentrations of shoots and roots represented a significant difference between the control and As-treated ferns when grown alone (the value of P was 0.005 and 0.00, respectively), but the difference is not significant when grown together with rice (the value of P was >0.05). Phosphorus concentration also decreased for all treatments, although it was statistically insignificant with a P-value of >0.05 for shoots and roots. The potassium concentration increased in shoots of *M. minuta* when grown with rice compared to ferns grown alone. The ANOVA test shows a P-value of 0.017 indicating a significant difference among treatments. The mean uptake values (Table 4) of nitrogen, phosphorus, and potassium in *M. minuta* growing with rice plants showed that different parts of *M. minuta* uptake less nutrients compared to those plants (Table 3) grown without rice. These results imply that nutrient competition occurred between rice plants and *M. minuta* and most of the nutrients were uptaken by rice plants rather than the ferns.

Table 3. Concentration and uptake of N, P, and K in *M. minuta* grown without rice

Treatment	N (%)		P (%)		K (%)		N uptake (mg/kg soil)		P uptake (mg/kg soil)		K uptake (mg/kg soil)	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
MX	2.06	1.40	0.45	0.41	2.46	1.68	52.68	30.05	11.49	8.80	62.81	36.06
MA	3.13	3.15	0.41	0.62	1.41	0.32	75.54	103.74	9.89	20.42	34.03	10.54

Table 4. Concentration and uptake of N, P, and K in *M. minuta* grown with rice

Treatment	N (%)		P (%)		K (%)		N uptake (mg/kg soil)		P uptake (mg/kg soil)		K uptake (mg/kg soil)	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
RXM	2.94	3.13	0.72	0.96	4.81	BDL	11.94	5.57	2.92	1.71	19.53	BDL
RAM	3.06	1.49	0.71	0.72	3.13	BDL	16.22	3.96	3.76	1.92	16.59	BDL

Effect of As and *M. minuta* on Nitrogen Status of Rice

The total concentration of nitrogen, phosphorus, potassium and their uptake in rice plants were calculated, in the presence and absence of As, showing in Fig. 1. It has also been reported that the nitrogen concentrations in grain and straw increased with increasing addition of As (Begum *et al*., 2008). In this experiment, the nitrogen concentration was increased with As treatments and the highest concentrations of nitrogen in grain and shoot were observed in rice plants treated with As and *M. minuta,* which indicates that the presence of *M. minuta* did not affect the uptake of nitrogen in rice plants. However, the relationship between arsenic and nitrogen in the roots of rice was found to be negative, but significant with a P-value of 0.0017. In the case of unhusked grain and shoots, a positive correlation was observed although ANOVA tests resulted in P-values of >0.05 for unhusked grain and shoots. The highest uptake of nitrogen for unhusked grain and shoots was found for rice plants growing with *M. minuta* and As (113.6553 mg/kg soil and 124.6548 mg/kg soil, respectively). Total nitrogen uptake was found to be 36% more in *M. minuta* and As-treated rice plants than the control plants, however it is not statistically significant.

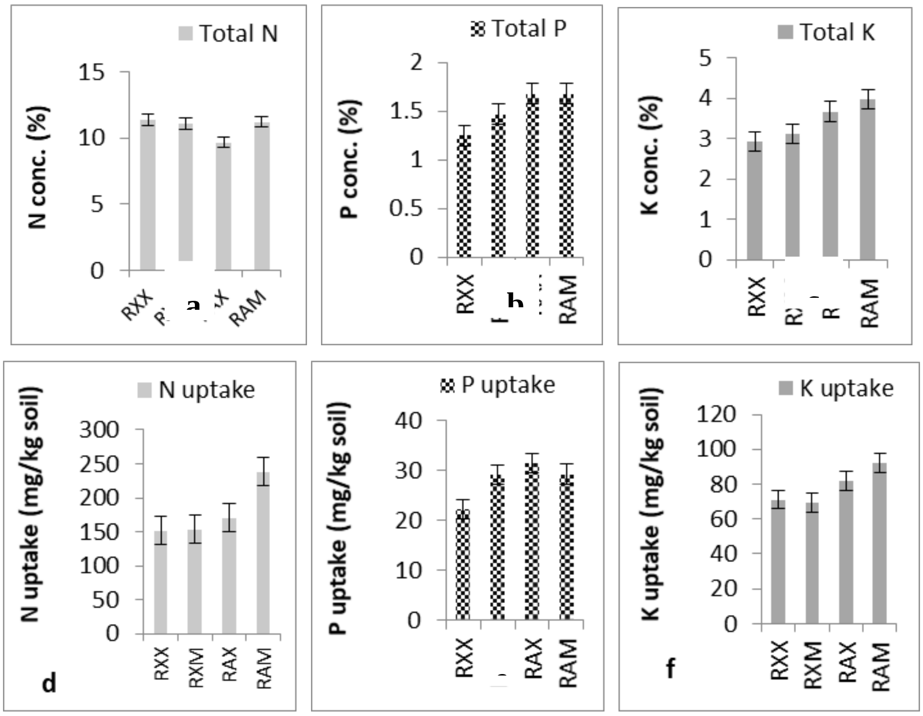

Fig. 1. Total concentration and uptake of N, P and K in rice plant.

Effect of As and *M. minuta* on Phosphorus Status of Rice

The competition between phosphorus and As under flooded conditions is more complicated. It has been found that the addition of phosphorus fertilizer to flooded paddy soil increased arsenic accumulation in rice (Hossain *et al*., 2009). In this experiment, the highest concentration of phosphorus was found in roots of rice grown together with As and *M. minuta* (the value is 0.85 %). Nevertheless, the highest uptake of phosphorus in unhusked grain was found for rice plants growing with *M. minuta* without As (17.12 mg/kg soil) followed by plants growing with As alone (16.87 mg/kg soil). In case of shoots and roots of rice, the highest uptake value was also found for As treatments alone (the value was 12.51 mg/kg soil and 2.11 mg/kg soil, respectively). ANOVA tests resulted in P-values of 0.0025 for shoots indicating a significant difference in phosphorus of shoots but >0.05 for grain and root indicating a non-significant difference in shoots and roots among the experiments. In this experiment, 23% greater phosphorus uptake was found in *M. minuta* and As-treated rice plants than the control plants, although the result is statistically insignficant. A positive correlation was observed between phosphorus and As which is evidenced by the report of Islam and Jahiruddin (2010) that the phosphorus concentration of rice grain increased with As doses, although in the present experiment, the application rate of As was only 1 mg As/L.

Effect of As and *M. Minuta* on Potassium Status of Rice

A wide variation of potassium concentrations in unhusked grain was observed and the presence of husks may have caused this. The highest concentration and uptake of potassium were found in the shoots of rice growing together with As and *M. minuta*, the values were 2.96% and 86.43 mg/kg soil, respectively. On the other hand, in unhusked grain and roots of rice, the highest uptake value was found for plants growing with As alone (4.74 mg/kg soil and 2.66mg/kg soil). About 22% more potassium uptake occurred in *M. minuta* and As-treated rice plants than the control treatments. A positive relationship was found for shoot and root phosphorus and As concentrations and ANOVA tests resulted in P-values of 0.0045 and 0.0115 for shoots and roots indicating a significant difference in potassium concentration in shoots and roots among the experiments.

Abedin *et al*., (2002) reported that As accumulation in rice follows the order of root> stem>grain. However, the application of *M. minuta* as a phytoremediator could reduce the uptake of As up to 58.67% for roots and 21.72% for shoots of rice (Hassi *et al*., 2017). It has also been observed that the nutrient necessities and distributions within the *Pteris* species were altered distinctly when the plants were exposed to As (Srivastava *et al*., 2006). Arsenic significantly decreases nitrogen, phosphorus, and potassium concentrations in both shoots and roots of winter wheat (Lui *et al*., 2008).

Conclusion

It could be concluded from the present study that nitrogen, phosphorus, and potassium concentrations of rice was not affected due to the application of *M. minuta* in rice cultivation. Moreover, the concentration of these three nutrients in different parts of *M. minuta* was not affected due to the application of As. Additional studies are needed before introducing *M. minuta* to an As-contaminated rice field.

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PROFITABILITY OF WINTER MAIZE CULTIVATION IN DROUGHT PRONE AREAS OF BANGLADESH

S. KHANDOKER[1], M. A. MONAYEM MIAH[2], M. A. RASHID[3]
M. KHATUN[4] AND M. Z. A. TALUKDER[5]

Abstract

The study was conducted in four districts namely Rajshahi, Chuadanga, Comilla and Rangpur during 2015-2016 to estimate the effect of drought in maize production, technical efficiency and adaptation strategy of maize farmers, and explore related problems of maize cultivation in the study areas.Rajshahi and Chuadanga were selected as drought prone areas whereas Rangpur and Comilla were selected as favorable environment. A total of 200 farmers taking 50 from each district were selected randomly for the study. Per hectare total cost of maize cultivation in drought prone areas was found Tk. 92,582, whereas in normal environment it was Tk. 79,594. Per hectare average yield in drought prone and normal areas were 7576 kg and 8729kg, respectively. Per hectare net return of maize in drought prone and normal areas were Tk. 28,062 and Tk. 59, 871, respectively.On full cost basis benefit cost ratio (BCR) in drought prone and normal areas were 1.31 and 1.75, respectively. Result of semi-logarithmic regression model indicated that maize production was decreased by 22.4 percent in drought prone areas than normal environment. Loss of yield (70%), loss of plant growth (55%) and problem in flowering stage (43%) were reported to be the major effects of drought.The major adaptation strategies in the drought prone areas were increase number of irrigation (77%), increase amount of fertilizer (42%) and seed (31%) and change of planting date (30%). Higher price of irrigation (70%), lack of drought tolerant variety (48%) and lack of quality seed (31%) were the major problem in drought prone areas. Again,disease infestation (64%), lack of quality seed (41%) and high price of seed (36%) were the major problem in normal environment. Scientists should take attempt to develop drought tolerant maize variety.

Keywords: Consequence, drought, maize, net return and adaptation strategy.

1. Introduction

Bangladesh is an agriculture based country. It is recognized as one of the most vulnerable areas to the impacts of global warming and climate change. This is due to its unique geographic location, dominance of floodplains, low elevation, high population density, and overwhelming dependence on nature for its resources and services. Many of the anticipated adverse effect of climate change, such as sea level rise, higher temperature, enhanced monsoon precipitation and an increase in drought intensity, will aggravate the existing

[1&4]Scientific Officer and [2&3]Principal Scientific Officer, Agricultural Economics Division, BARI, Joydebpur, Gazipur, [5]Senior Scientific Officer, Plant Breeding Division, BARI, Joydebpur, Gazipur.

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stresses that already impede the development of Bangladesh, particularly by reducing food security (Quazi and Quddus,2010). For ensuring food security, production of maize can play a vital role. The importance of maize crop cannot be over-emphasized. Maize is the third most important cereal crop in Bangladesh. It is much better than rice in terms of nutrients like protein, fat, minerals, phosphorus, carotene and thiamine (INFS, 2003). More than 90% of maize is used as poultry feed and the remaining in fish sector and as human food products (Hasan, 2008). The area under maize cultivation during 2013-2014 was about 3.07 lakh hectares with a total production of about 2.12 million metric tons and yield of 6.60 ton/ha (BBS, 2014). The area, production and yield of maize are increasing day by day (Table 1). If optimal irrigation and other inputs are given in appropriate way then it may be possible to obtain an average yield of 8 to 10 tons per hectare.

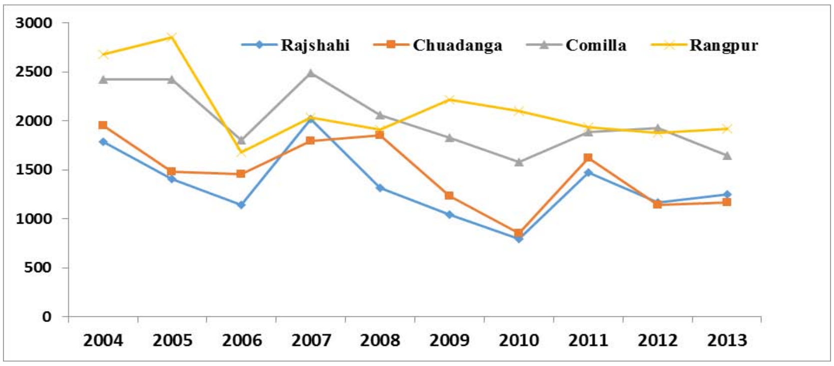
Drought is one of the crucial problems for many countries and the severity of such issue goes gigantic when it comes as obstacle to ensure an optimum agricultural production for a country like Bangladesh. Droughts are becoming more frequent, more intense, more spatially extensive, and of longer duration (IPCC, 2010). It is one of the major abiotic stresses which adversely affect crop growth and yield and thus a constraint for productivity worldwide (Jaleel *et al.*, 2009). This problem occupied an extreme position in the northwest region of Bangladesh. In the northwest region, drought can have devastating impacts on maize production. Further, every year farmers in this areas incurred high cost as well as a huge crop loss due to drought. The impact of drought not only leads to the shortage of water and food but also have a long-term environmental, socio-economic and health impact on the population (Sheffield *et al.*, 2009; WHO, 2011). At present, the phenomenon is causing enormous difficulties towards maintaining livelihoods and has become a severe problem in the northwestern parts of Bangladesh. Keeping this in mind, the present attempt has been made to focus the effect of drought on maize production and adaptation strategy of the farmers in Bangladesh.

Table 1. Area, production and yield of maize in Bangladesh

Year	Area	Production	Yield
2009-10	1.52	0.89	5.84
2010-11	1.66	1.02	6.15
2011-12	1.97	1.30	6.59
2012-13	2.35	1.55	6.59
2013-14	3.07	2.12	6.91

Source: BBS, 2014.

Figure 1. Average annual rainfall in selected areas



Source: BBS, 2013.

Fig. 1 reveals the average annual rainfall of four districts from 2004 to 2013. In 2004, average annual rainfall was found higher in Rangpur district and lowest in Rajshahi district. In Rajshahi district, highest rainfall was found in 2007 which was 2018 millimeter and lowest in 2010 which was 792millimeter. Similarly, in Chuadanga district, highest rainfall was found in 2004 which was 1951 millimeter and lowest in 2010 which was 852millimeter. Among four districts highest rainfall was found in Rangpur in 2005 and lowest in Rajshahi in 2010.During the period (from 2004 to 2013), annual rainfall of Rangpur and Comilla was found higher than Rajshahi and Chuadanga district.

1.1 Objectives

i. To estimate the cost and return of maize in drought prone and normal environment;

ii. To assess the effect of drought in maize production and adaptation strategies of the farmers in drought prone areas;

iii. To identify problems of cultivating maize in the study areas.

2. Methodology

2.1 Sampling Procedure and Sample Size

Purposive sampling and multistage stratified random sampling technique were followed to collect sample farmers for this study. The study was conducted in four districts of Bangladesh. At first stage, two production environments namely drought prone and normal environment were purposively selected in consultation with the scientists of Plant Breeding Division of BARI. In order to capture two production environments, two districts under each environment were selected in this study. Rajshahi and Chuadanga were selected as drought prone areas, whereas Rangpur and Comilla were selected as favorable areas. Then one upazila from each four districts and two blocks from each upazila were purposively selected in consultation with DAE personnel and maize scientists. Godagari upazila from Rajshahi district, Sadar upazila from Chuadanga, Daudkandi from Comilla and Mithapukur upazila from Rangpur district were selected for administering questionnaire survey. Finally, a total of 200 farmers taking 50 from each district were randomly selected for the study.

2.2 Data Collection

The study was mainly based on primary data collected through face to face interview during the month of January to April 2016. Field investigators under the direct supervision of the researcher collected field level cross-sectional data using pre-tested interview schedule. Necessary information regarding this study was collected based on input costs, price, yields etc.

2.3 Analytical Techniques

Collected data were edited, summarized, tabulated and analyzed to fulfill the objectives of the study. Descriptive statistics using different statistical tools like averages, percentages and ratios were used in presenting the results of the study. The profitability of maize production was examined on the basis of gross return, gross margin and benefit cost ratio analysis. Besides, the opportunity cost of family supplied labour was taken into consideration in estimating total cost. Land use cost was calculated on the basis of per year lease value of land.Semi-logarithmic regression model with dummy variable was used. A z- test for the two sample mean with known variance was conducted to test the mean difference between two groups of farmers i.e. drought prone and normal environment.

2.3.1 Profitability analysis

Profitability of maize was analyzed to compare the return received by the farmers.

Measurement on profitability of crop cultivation

Equations for cost analysis are as follows

$$\text{Variable Cost} = VC_i = \sum (X_i P_i)$$

$$TVC_i = VC_i + 10C_i$$

$$TC_i = TVC_i + TFC_i$$

Where, TC_i= Total cost for i^{th} farmer (Tk/ha)

TVC_i = Total variable cost (Tk/ha)

TFC_i = Total fixed cost (Tk/ha)

VC_i = Variable cost (Tk/ha)

IOC_i = Interest of operating capital (Tk/ha)

X_i = Quantity of inputs (kg)

P_i = Price of inputs (Tk/kg)
i = Number of farmers (1.2.3……..n)

Equations for profitability analysis
Gross return = $GR_i = Y_iP_i$
Net return = $GR_i - TC_i$
Gross margin = $GR_i = VC_i$

Where,

GR_i = Gross return (Tk/ha)
P_i = Price (Tk/ha) received by i^{th} farmer
Y_i = Quantity (kg/ha) produced

2.3.2 Functional analysis

Production variability analysis

Semi-logarithmic regression model with dummy variable was used to estimate production variability of maize between drought prone and normal environment. In this regression model, production was considered as the dependent variable and the drought considered as independent variable. Production of maize varied extremely due to drought. To estimate the production variability of maize the following semi-logarithmic regression model was employed:

$\ln Y = \beta 0 + \beta_1 D_1 + U$

Where, ln = Natural logarithm;

Y = Output of maize (kg/ha);

D_1 = Dummy for drought (1 = drought; 0 = otherwise);

β_1 = Slope coefficient of dummy for drought;

U = Random error term.

3.1 Technology Used in Maize Cultivation

Land preparation: Land preparation for maize production included ploughing, laddering and other activities needed to make the soil suitable for sowing seeds (Karim *et al.*, 2010). The number of ploughing varies from location to locations (Table 2). In the study areas cent percent farmers used Power tiller for land preparation which is mostly done on hire basis. Majority of farmers (35%) of drought prone areas ploughed their maize plot four times whereas in normal areas highest percentage of farmers (40%) ploughed two times.

Variety used by maize farmers: A total of 13 hybrid maize varieties were found in the study areas (Table 3). Among the varieties, Elite was the highly adopted variety (30%) in drought prone areas. On the other hand, innormal areas NK-40 was the mostly adopted varieties (53%). In normal areas the second and third positions were secured by Miracle (26%)and Pioneer-3396 (12%). Responded farmers of Comilla district cultivated NK-40 and Miracle. Farmers of drought prone areas cultivated more varieties. Farmers in this areas also cultivated, Nk-40,981 and Super-999, CP-383 etc. BARI has developed some improved maize varieties, but these varieties could not found in the study areas. The main reason for non-adoption of BARI varieties mightbe the non-availability of seeds. The extent of using maize variety depends on the availability of seed at local level.

Table 2. Number of ploughing done by maize farmers

Number of ploughing	% farmers responded					
	Drought prone area			Normal area		
	Rajshahi	Chuadanga	All areas	Comilla	Rangpur	All areas
1	-	2	1	10	16	13
2	10	22	16	34	46	40
3	30	10	20	40	32	36
4	44	26	35	14	6	10
5	16	38	27	-	-	-
6	-	2	1	2	-	1
Total	100	100	100	100	100	100

Source: Field survey, 2016

Table 3.Variety used by maize farmers

Varieties	% farmers responded					
	Drought prone area			Normal area		
	Rajshahi	Chuadanga	All areas	Comilla	Rangpur	All areas
NK-40	18	4	11	54	52	53
Miracle	12	14	13	46	6	26
Elite	6	54	30	-	2	1
Pioneer-3396	32	-	16	-	24	12
981	2	20	11	-	4	2
Pacific Super-999	12	-	6	-	6	3
CP-838	10	-	5	-	-	-
Uttaran	-	8	4	-	-	-
740	-	-	-	-	4	2
Kissanvutta	4	-	2	-	-	-
962	2	-	1	-	-	-
Vision agro	2	-	1	-	-	-
Kanok	-	-	-	-	2	1
Total	100	100	100	100	100	100

Source: Field survey, 2016

Irrigation: For maize cultivation, four irrigations are recommended by BARI. Variations were found among the responded farmers in irrigation application

(Table 4). In normal environment, highest percent of farmers (49%) irrigated two times followed by three times (33%). About 14% farmers in Comilla district irrigated their crop once a season. In Rangpur district, 26% farmer irrigated 3 times. However, farmers of drought prone areas irrigated 4-7 times. The highest percent of farmers (38%) irrigated 5 times followed by 6 times (36%). Sixteen percent farmers irrigated 7 times and 10% irrigated 4 times. Farmers of Rajshahi district provided more irrigation.

Table 4. Percent responses on the number of irrigation given to maize

Number of Irrigation	% farmers responded					
	Drought prone area			Normal area		
	Rajshahi	Chuadanga	All areas	Comilla	Rangpur	All areas
1	-	-	-	14	-	7
2	-	-	-	56	42	49
3	-	-	-	30	36	33
4	-	20	10	-	26	13
5	22	54	38	-	-	-
6	52	20	36	-	-	-
7	26	6	16	-	-	-
Total	100	100	100	100	100	100

Source: Field survey, 2016

Level of input use in Maize Cultivation

The account of input use by the farmers in different areas is presented in Table 5. Human labour was required for plantation of seed, application of manures and fertilizers, spraying, weeding, irrigation, and harvesting. Farmers of drought prone areas used 163 man-days of human labour per hectare of which 36% were family supplied and 64% were hired. On the other hand, in normal environment farmers used 144 man-days of human labour out of which 40% were family supplied and 60% were hired. Farmers of drought prone areas used more seed which was 20 kg per hectare than normal areas (18 kg). Per hectare manures used in maize cultivation was 2906 kg in drought prone areas whereas in normal areas it was 2450 kg. Farmers of drought prone areas used 335 kg urea, 188 kg TSP, 114 kg MoP etc. per hectare which was higher than normal environment. Farmers of drought prone areas also used slightly higher dose of other chemical fertilizers than normal environment.

3.2 Cost of Maize Cultivation

The cost of production included different variable cost items like land preparation, human labour, seed, manures, fertilizer, irrigation, insecticides etc. Both cash expenditure and imputed value of family supplied inputs were included in the analysis. Besides, interest on operating capital was also considered for the estimation of cost of maize cultivation.

Table 5. Per hectare input use pattern for maize cultivation

Inputs	Drought prone area	Normal area	t- test values	Results
Human labour (man-day)				
Family labour	58 (36)	57 (40)	0.1881	No difference
Hired labour	103 (64)	87 (60)	0.0000	Difference
Total human labour	161 (100)	144 (100)	0.0000	Difference
Seed (kg)	20.48	18.47	0.0000	Difference
Manures (kg)	2906	2450	0.0000	Difference
Chemical fertilizers(Kg)				
Urea	335	276	0.0000	Difference
TSP	188	158	0.0000	Difference
MoP	114	88	0.0000	Difference
Zipsum	4	0.84	0.0000	Difference
Zinc	98	77	0.0000	Difference
DAP	76	41	0.0000	Difference
Boron	8	2	0.0000	Difference

Source: Field survey, 2016

Note: Figures in the parenthesis indicate percentage

Table 6 represents the cost of maize cultivation in the study areas. Per hectare total cost of maize cultivation in drought prone areas was found Tk. 92,582 of which 70% were variable cost and the rest 30% were fixed cost. On the other hand, average total cost of maize cultivation in favourable environments was Tk. 79,594 per hectare of which 64% were variable cost and the rest 36% were fixed cost. Human labour was the major cost items incurred in both areas, which covered about 37% of the total cost in drought prone area and 39% in normal environment. Among the variable cost items, the second important cost item in drought prone areas was irrigation which occupied 9% of the total cost. Farmers of drought prone areas incurred Tk. 7,932 for irrigation whereas in normal environment it was Tk. 4,112 per hectare. The cost of seed and land preparation were 8% and 6% of the total cost, respectively. Land use cost occupied about 16% and 21% of the total cost in drought prone and normal environment. The cost of chemical fertilizers shared more than 15% of the total cost. Farmers of drought prone and favorable areas spent Tk. 3,331 and Tk. 2,652 per hectare, respectively for manures. The cost of insecticides occupied 2% of the total cost in the study areas.

Table 6. Cost of maize cultivation in the study areas*(in Tk./ha)*

Cost items	Drought prone area	Normal area	Z-test (p-values)	Results
A. Variable cost				
Cost of land preparation	5288 (5)	5732 (7)	0.0327	No difference
Hired labour	22064 (23)	18621 (23)	0.0251	No difference
Cost of seed	7904 (8)	6987 (9)	0.0000	Difference
Manures	3331 (3)	2652 (3)	0.0000	Difference
Chemical fertilizers				
Urea	5442 (6)	4550 (6)	0.0000	Difference
TSP	4281 (4)	3554 (4)	0.0000	Difference
MoP	1913 (2)	1417 (2)	0.0000	Difference
Zinc	612 (0.65)	126 (0.15)	0.0000	Difference
Zipsum	626 (0.67)	474 (0.60)	0.0000	Difference
DAP	1659 (2)	1091 (1)	0.0000	Difference
Boron	1362 (1)	282 (0.35)	0.0000	Difference
Cost of irrigation	7932 (9)	4112 (5)	0.0000	Difference
Cost of insecticides	2001 (2)	1539 (2)	0.0286	No difference
IOC@ 6% for 4 months	692 (0.74)	537 (0.67)		
Total variable cost	65107 (70)	50874 (64)		
B. Fixed cost				
Family labour	12450 (14)	12793 (16)	0.1085	No difference
Land use cost	15025 (16)	16427 (20)	0.0582	No difference
Total fixed cost	27475 (30)	28719 (36)		
C. Total cost (A+B)	92582 (100)	79594(100)		

Source: Field survey, 2016

Note: Figures in the parenthesis indicate percentage

3.3 Profitability of Maize Cultivation

The return from maize cultivation in different district is presented in Table 7. Farmers in the drought prone areas obtained an average yield of7576 kg per hectare. In the favorable areas, per hectare average yield was found 8729 kg. The higher gross return of maize was found in favourable environment (Tk. 1, 39,465/ha) and lower in drought prone environment (Tk.1, 20,644/ha). Similarly,higher net return of maize was found in favourable environment (Tk. 59,871/ha) and lower in drought prone environment (Tk.280, 62/ha). Benefit cost ratio (BCR) on full cost basis in drought prone and normal areas were 1.31 and 1.75, respectively. In drought prone areas, farmers spent on an average Tk. 12 for producing 1 kg of maize whereas farmers of normal areas spent Tk. 9. Finally, it was revealed that the farmers of drought prone areas used more inputs but received less output from maize cultivation compared to the farmers of normal area which might be the consequences of drought.

3.4 Effect of Drought in Maize Plant

Farmers of drought prone areas were asked what type of effect they found in maize plant due to drought. About 79% farmers reported that serious problem occurred in maize plant and the remaining 21% mentioned that problem was not significant (Table 8).Reduction of yield was the major effect of drought.Fifty five percent farmers said that due to drought plant growth hampered (Table 9). Problem in flowering stage (43%), dryness of cob (42%), leaf rolling (37%) and loss of grain (29%) were reported to be the major effect of drought in maize cultivation.

Table 7. Profitability of maize cultivation

Particulars	Drought prone area	Normal area	Z-test (p-values)	Results
A. Total cost (Tk./ha)	92582	79594		
Total variable cost (Tk./ha)	65107	50874		
Total fixed cost (Tk./ha)	27475	29719		
B. Yield (kg/ha)	7576	8729	0.0000	Difference
C. Price (kg)	16	16	0.1250	No difference
D. Gross return (Tk./ha)	120644	139465	0.0000	Difference
E. Gross Margin (Tk./ha)	55537	88590	0.0000	Difference
F. Net Return (Tk./ha)	28062	59871	0.0000	Difference
G. Benefit cost ratio (BCR)				
BCR on full cost basis	1.31	1.75	0.0000	Difference
BCR on cash cost basis	1.85	2.74	0.0000	Difference
H. Production cost (Tk./kg)	12	9		

Source: Field survey, 2016

Table 8. Severity of the effects of drought in maize plant

Items	Rajshahi	Chuadanga	All areas
Serious problem	82	76	79
Problem was not significant	18	24	21

Source: Field survey, 2016

3.5 Production Variability of Maize

In order to estimate the production variability of maize due to drought occurrence, semi-logarithmic regression model with dummy variable was employed. Drought greatly affects maize production in some areas of

Bangladesh. Maize is grown during the dry season (November to March), usually after the Aman harvest when drought occurs in some areas. Drought negatively affects the growth of maize in all stages, but the reproductive stage is the most sensitive to drought stress (Grant *et al.*, 1989). Drought stress occurred during this period result in a significant reduction of grain yield (Bolanos et al., 1993).

Table 9. Types of effects of drought in the study areas

Types of effects	Rajshahi	Chuadanga	All areas
Reduced yield	76	64	70
Stagnant of plant growth	52	58	55
Problem in flowering stage	62	24	43
Dryness of cob	34	50	42
Leaf rolling	42	32	37
Loss of grain	36	22	29
Plant die	6	14	10

Source: Field survey, 2016

Table 10 revealed that maize production decreased by 22.4 percent in the drought prone area compared to normal environment. In normal environment maize production increased due to favourable climate. This reduction of yield is consistent with (Miah, 2010).Miah found that in Bangladesh due to drought yield of maize decreased from 30% to 60%.

Table 10. Effect of drought on maize production

Variable	Coefficient	Standard error	t-value	Significant
Constant	9.104	0.007	1379.417	0.000
Drought dummy	-0.224	0.009	-23.958	0.000

3.6 Farmer's Perceptions about the Effect of Drought on Maize Yield

The study examined farmer's perception about the effect of drought on maize yield which is presented in Table 11. Highest percent of farmers (61%) in drought prone areas mentioned that due to drought their maize production decreased to a large extent and 25% said that the reduction of yield was moderate. Some farmers also mentioned that yield reduced slightly and some did not find any effect.

3.7 Farmer's Opinion about the Effect of Drought on Cost of Maize Cultivation

Hundred percent farmers in drought prone areas reported that due to drought their production cost increased to a large extent. Among them 41% farmers mentioned that cost increased highly and 26% reported that cost increased moderately (Table 12). About 33% farmers said that cost increased slightly.

Table 11. Farmer's perceptions about the effect of drought on maize yield

Acuteness of the effect	% farmers responded		
	Rajshahi	Chuadanga	All areas
Highly	64	58	61
Moderately	22	28	25
Slightly	10	8	9
Don't know	4	2	3
No effect	-	4	2
Total	100	100	100

Source: Field survey, 2016

Table 12. Farmer's perception about effect of drought on cost of maize

Acuteness of the effect	% farmers responded		
	Rajshahi	Chuadanga	All areas
Highly	54	28	41
Moderately	20	32	26
Slightly	26	40	33
Total	100	100	100

Source: Field survey, 2016

3.8 Adaptation Strategy of the Farmers

Farmers of the drought prone areas follow some strategies to cope up with the environment for cultivating maize which is presented in Tables 13 and 14. About 84% farmers reported that they took some strategiesin maize cultivation for mitigating drought. The main reasons for not taking strategy were lack of knowledge about strategy, unavailability of strategies and unwillingness.

Majority of the farmers (77%) reported that they increased number of irrigation for cultivating maize in drought prone areas. The highest 7 number of irrigation was found in those areas. About 42% farmers mentioned that they use more doses of fertilizer which was highest in Rajshahi district. Increasing amount of seed (31%) was also important strategy in both areas. About 30% farmers opined that they changed the date of planting for mitigating drought problem. Farmers of drought prone areas planted seed in 2nd week of October which they thought as vital strategy.

Table 13. Percent of drought affected farmers adopted adaptation strategy in maize cultivation

Items	Rajshahi	Chuadanga	All areas
Taking adaptation strategy	86	82	84
No strategy	14	18	16
Total	100	100	100

Source: Field survey, 2016

Table 14. Different adaptation strategies adopted by the farmers in drought prone areas

Strategies	% farmers responded		
	Rajshahi	Chuadanga	All areas
1. Increase in the number of irrigation	76	78	77
2. Use more fertilizer	58	36	42
3. Increase of seed rate	24	38	31
4. Change sowing date	38	22	30
5. Cultivate maize near water bodies	18	-	9
6. Set up shallow tube well in pond	10	-	5

Source: Field survey, 2016

Table 15. Problems of maize cultivation in the study areas

Type of problems	% farmers responded					
	Drought prone area			Normal area		
	Rajshahi	Chuadanga	All areas	Comilla	Rangpur	All areas
High price of irrigation	76	64	70	-	-	-
Lack of quality seed	12	50	31	60	68	64
Disease infestation	20	38	29	50	32	41
High price of seed	16	48	32	34	38	36
Non availability of quality insecticides	12	28	20	8	26	17
High price of fertilizers	-	6	6	2	36	19
Lack of drought tolerant variety	54	42	48	-	-	-
Bird cause disturbance	16	34	25	20	14	17
Dominance of intermediaries	-	8	4	-	28	14
Weighted loss	-	-		-	46	23
Water logging	-	-	-	20	6	13
High price of land preparation	-	12	12	4	18	11
Lack of training facility	18	2	10	4	10	7
Lack of credit		8	4		6	3
Lack of irrigation facility	4	-	2	-	-	-

Source: Field survey, 2016

3.9 Problems of Maize Cultivation

Although maize is a profitable crop in the study areas, there are some constraints to its higher production. The first and foremost constraint of maize cultivation in drought prone areas was high price of irrigation (70%). Due to low water aquifers, low discharge of water and high price of labour irrigation cost was high. Lack of quality seed (64%) was the main constraint of maize cultivation in normal areas. About 31% farmers of drought prone areas also reported this problem. Farmers of all areas said that the price of seed was also very high. Infestation of diseases was the important problem for farmers of all districts which hampered higher yield of maize. Non availability of pure insecticides, high price of fertilizers, lack of training facility and facing disturbance for bird were opined to be the important constraints for farmers of all areas. About 48% farmers of drought prone areas reported that lack of drought tolerant variety was one of the major problems. Dominance of intermediaries and weighted loss were major problem for the farmers of Rangpur district (Table 15).

Table 16. Facility demanded by the maize farmers

Facilities	% farmers responded				
	Rajshahi	Chuadanga	Comilla	Rangpur	All areas
Timely supply of quality seed	22	36	58	52	42
Reasonable price of seed	28	46	32	36	35
Provide drought tolerant variety	78	54	-	-	33
Provide irrigation facility at low price	46	32	-	4	20
Timely supply of quality insecticides	4	26	12	22	16
Reduce dominance of intermediaries	-	4	-	36	10
Monitoring system for quality seed	-	12	14	26	13
Arrange training facility	18	4	6	12	10
Provide credit facility	8	16	2	10	9
Improve irrigation system	16	4	-	-	5
Increase market demand	-	2	6	2	3

Source: Field survey, 2016

3.10 Facility Demanded by the Maize Farmers

Respondent farmers in the study areas wanted some facilities for cultivating maize. All of their demands are presented in Table 16. Majority (42%) of the farmers wanted quality seed because good quality seed is a pre-requisite for higher yield. Some farmers reported that they were cheated by seed dealers and experienced with low seed germination resulting in decline of production. Therefore, farmers wanted monitoring system for quality seed (13%) and also reasonable price (36%). In the study areas, farmers were very much enthusiastic to cultivate BARI hybrid maize. About 16% farmers wanted timely supply of pure insecticides. Reducing dominance of intermediaries was demanded by 13% farmers which was higher in Rangpur district (36%). A good number of farmers of drought prone areas wanted drought tolerant variety and low price of irrigation. Arranging training facility (10%), providing credit facility (9%), improving irrigation system (5%), and increasing market demand (3%) were also required for increasing maize production in the study area.

4. Conclusions and Recommendations

4.1. Conclusions

The study assessed the effect of drought in maize cultivation. Profitability indicators clearly indicate that maize is a remunerative crop both in drought prone and normal environment. The production of maize in drought prone areas was lower than normal areas. But the cost of production in drought prone areas was found higher than normal areas due to higher cost of irrigation and more use of inputs. The farmers in drought prone areas received less produce but incurred higher costs compared to normal environment which may be due to drought. Loss of yield, loss of plant growth and dryness of cob were the major effects of drought. About 100% farmers have taken some strategy to cope up with drought. Although maize is a profitable crop, due to some setbacks few farmers showed negative attitudes toward its production. High price of irrigation, lack of quality seed, disease infestation and high price of seed were the major problem in the study areas. Farmers also wanted some facilities for increasing maize production and improving livelihood status of maize farmers in study areas.

4.2 Recommendations

- Quality seed should be made available to the farmers at reasonable price. For this, Government should encourage BADC and private seed companies to produce quality maize seed.
- Scientists should take attempt to developdrought tolerant maize variety.
- High price of fertilizers affected the yield of maize. In this regard, government should take necessary step for supplying fertilizers to the farmers at reasonable price.

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Appendix Table

Table 1. Average annual rainfall in selected areas

Year	Rajshahi	Chuadanga	Comilla	Rangpur
2004	1786	1951	2424	2680
2005	1405	1482	2424	2853
2006	1145	1452	1803	1682
2007	2018	1797	2491	2037
2008	1315	1851	2057	1907
2009	1043	1234	1824	2217
2010	792	852	1578	2102
2011	1475	1622	1884	1932
2012	1164	1138	1929	1877
2013	1248	1165	1643	1916

Source: BBS, 2013

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ADOPTION OF BARI MANGO VARIETIES IN SELECTED SITES OF CHITTAGONG DISTRICT

M. J. UDDIN[1], M. E. A. BEGUM[2], S. M. K. H. CHOWDHURY[3] AND K. S. RAHMAN[4]

Abstract

The study was carried out in 28 villages covering131 mango growers of three Upazilas in Chittagong District with view to examine the adoption status of BARI mango varieties at farmer's level. The adoption status of improved mango varieties was unknown to the region. Results revealed that out of 11 varieties of BARI mango, the highest 77% farmers adopted BARI Aam-3 followed by BARI Aam- 4 (22.1%) and BARI Aam-8 15.9%. But the rate of adoption of other varieties of BARI Aam was found to be lower irrespective of all locations due to unavailability of sapling and unknown to the variety. The rate of adoption of individual production technologies of BARI mango varieties was found unsatisfactory. Majority of the farmers did not adopt recommended practices as stated in BARI Krishi Projokti Hathboi such as pit size, planting distance, application of manure and fertilizers, plant growth regulator, insects and diseases management. Farmers maintained pit size for mango sapling (1.4 ft × 1.4 ft× 1.3 ft) compared to recommended size of (3ft×3ft×3ft). Similarly, planting distance was 12.0 x11.7ft as against the recommended distance of 25ft×30ft. About 67.7% farmers adopted the improved practice such as breaking inflorescence of mango trees and 65.0% of farmers used mulching. But majority (52%) of farmers did not receive training and practice pruning for mango trees. Probit regression analysis revealed that yield of mango variety, training, extension contact, risk taking behavior and willingness to take loan has indeed helped in contributing to adopt BARI mango varieties significantly. Therefore, promoting training on BARI mango production technologies; ensuring the availability of BARI mango saplings, and campaigning about the varieties in mass media could help to increase the rate of adoption of BARI mango varieties in the region.

Keywords: Adoption, BARI mango varieties, Technologies, Factors affecting, Chittagong region.

1. Introduction

Mango (*Mangifera indica L.)* is the most important commercially grown fruit crop of the country. The position of mango is 1st in terms of area and 2nd in

[1]Senior Scientific Officer, Regional Agricultural Research Station (RARS), Hathazari, Chittagong, [2]Senior Scientific Officer, Agricultural Economics Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, [3]Scientific Officer, On-Farm Research Division, RARS, Hathazari, Chittagong-4330, [4]Scientific Officer, ASICT Division, BARI, Gazipur, Bangladesh.

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production among the fruits grown in Bangladesh. Mango shares 31.22% of the area and 24.38% production fruit crops in Bangladesh (Hamjah, 2014). Mangoes are considered ‘high volume’ food, low on calorie but quite high in natural sugar. A single, small size mango can provide a quarter of the recommended daily dose of vitamin A, along with a generous amount of vitamin E and fiber. It is also considered a rich source of vitamin K, phosphorus, magnesium and iron (the dailysar.net). Mango production can play a vital role for Bangladesh economy. But it needs better adoption of improved varieties of mango at farm level. Bangladesh Agricultural Research Institute (BARI) has released 11 mango varieties so far. But the status of adoption of improved variety of mangos waslow in the Chittagong district.

On the other hand, agricultural development is accelerated through adoption* of improved agricultural technologies and formulating policies favouring appropriate institutional and infrastructural changes (Rajni *et al.,* 2009). Adoption of improved mango varieties is the key to higher production of fruits and higher incomes to farmers (Singh *et al.,* 2010). The technical knowledge of farmers appears to be the key link to higher level of adoption. While shifting focus has opened up greatly in the north site of the country, the opportunity waiting to be exploited in the horticulture sector in this region, but the ground realities present a grave picture of low yields of fruits, wide gaps in adoption of improved fruit cultivation practices, inadequate technical guidance and for value addition and enterprise development in the Chittagong region. Uddin *et al.* (2016) reported that the percentage change in area of mango is 7.15% over the period of 1993/94 to 2009/10, while annual growth rate in area of mango was estimated by 94.9%.

According to BBS 2016, the area and production of mango in Chittagong region are stated as: area under garden 284 acres, average yield per fruit bearing tree 52 kg, production of inside garden 967m.tons, production of outside garden 19143m.tons and total production of inside and outside garden was 20110 m. tones in 2013-14 which was 2.02% of the total production in Bangladesh. Out of 11 BARI mango varieties, four varieties such as BARI Aam-1, BARI Aam-2, BARI Aam-3 and BARI Aam-8 were further evaluated by Barua *et al.* (2013) as suitability judgment for the Chittagong region where BARI Aam-8 and BARI Aam-4 gave higher yield per plant. The name of BARI released mango varieties and their key features are shown in Appendix1.

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*Oladele (2005), Pannell *et al.* (2006), and Parminter (2011) stated that the term ‘adoption’ could be described as conscious decision to implement a new practice or apply a new technology on a continuous basis. It described the process of decision making and behavior change. They agreed that during this decision-making process the intended beneficiaries could reject a change and seek to re-establish the previous practice or technology. Williams *et al*., (1984) described the stages of adoption as:
Awareness $\rightarrow$ Interest $\rightarrow$ Evaluation $\rightarrow$ Trial $\rightarrow$ Adoption.

According to BBS report, the productivity of mango was found to be low in Chittagong region. This might be happened due to the absence of improved varieties. The district has traditional mango orchard with a great promise for productivity of fruits. Once farmers acquire knowledge, they begin to use and apply new techniques and improved practices in their orchards. Even among farmers, there is a great variation in their levels of knowledge, as well as their readiness to accept, try new methods and adopt improved production practices. The variation in rate and extent of adoption of improved practices in mango production and reasons thereof, need to be thoroughly understood. The specific following objectives of the study are:

i. To document socioeconomic and contextual information of the mango growers;

ii. To assess the actual status of adoption of BARI mango varieties at farmers level; and

iii. To know the farmers production technologies of mango growers, and

iv. To identify the factors responsible for adoption and non-adoption of BARI mango varieties.

Description of the area: The study was carried out in 28 villages under three Upazilas namely Hathazari, Fatikchari and Sitakundoin Chittagong District with view to examine the adoption status of BARI released mango varieties and their production technologies by mango growers in the locations. Multi-stage sampling techniques were followed to select the study area. Based on the availability of mango growers, specific locations were selected (Appendix-2) in consultation with Upazila Agriculture Officer (UAO) and Sub-Assistant Agriculture Officer (SAAO) in the respective Upazilas.

Selection of sampling technique adopted: The purposive and stratified random sampling technique was followed for selecting the sample in each Upazila. In total 131 mango growers were selected randomly as sample where in Hathazari (70), Fatikchari (30) and Sitakundo (31). But the sample number of each village varied due to the availability of mango growers.

Data collection procedure: Both primary and secondary data were used in the study. The primary data were collected by pre-tested semi-structured survey questionnaire. The secondary data were collected from published reports, internet and BBS sources. Face to face interview with mango growers was done by Scientific Assistants and Researcher himself. Moreover, the respective SAAO facilitated for selecting the respondents (mango growers) in all locations. In each Upazila, 3-5 SAAOs were engaged for collecting the necessary data.

Period of study: The data collection period was August 2016 to April 2017.

Analytical technique: In tabular technique, mean, percentages and mean comparison were used in the study. In statistical technique, the Probit regression analysis was used for estimating the contribution of factors responsible for adopting BARI mango varieties in the region. In that case, the independent variables were chosen as: age, education, occupation, family size, family type, land under mango orchards, risk taking behavior, innovativeness, economic aspiration, scientific orientation and credit orientation. Two communication variables are included in the study: extension contact and mass media exposure. Suitable scales were used to measure the variables. As an important indicator of adoption of BARI mango varieties, The collected data were analyzed using appropriate statistical techniques. One-way ANOVA was used for analyzing the mean difference of the selected variables in locations. The mathematical expression of the Probit model is given below:

Probit Model:

In order to ascertain the probability of adoption of improved mango varieties, the following empirical Probit model was employed. Since the dependent variable is dichotomous, Ordinary Least Square (OLS) method is not suitable. Therefore, MLE method was followed to run the Probit model using STATA software. The empirical probit model was as follows:

$$Ai = \alpha + \beta iXi + \ldots\ldots.. + Ui$$

Where,

Ai = Farmers adopting BARI mango variety (If adopted = 1; Otherwise= 0),

α = Intercept,

Xi = Explanatory variables,

βi = Coefficients of respective variables, and

Ui = Error term

The adoption of improved mango variety is likely to be influenced by different explanatory variables.

The variables are

X^1 = Ln Yield(t/ha)

X^2 = Ln Cultivable land(ha)

X^3 = Family size (no.)

X^4 = Family type (score)

X^5 = Training (score)

X^6 =Risk taking behavior (score)

X^7 = Innovativeness (score)

X^8 = Willingness to take loan (score)

X^9 = Having modern knowledge on mango production (score)

X^{10} = Economic aspiration (score)

X^{11} = Mass media exposure (score)

X^{12} = Research contact of the farmers (score)

X^{13} =Extension contact of the farmers (score).

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

3. Results and Discussion

3.1 Socioeconomic profile of the respondents

It can be shown in Table1 that average age of the respondents was found to be 44.8 years irrespective of locations implied that all the respondents were able to adopt new technologies for agricultural development due to belongs young age. The mean differences of the age of respondents varied insignificantly ($F=1.43$; $p \leq 0.243$) among the locations. In the case of education of the respondents, the average year of schooling was found to be 7.1 years in all locations which was varied significantly among the locations ($F=4.47$; $p \leq 0.013$). The major occupation of the respondents was agriculture (83.5%) irrespective of locations which was the highest in Hathazari (97.1%) followed by Sitakundo (93.5%). Occupation of the respondents may influence in adopting new technologies. The secondary occupation was reported to be business (37.1%) and private job (15.2%) in all locations. The average household size was 6.2 persons per family which was higher than that of national average of 5.0 (BBS, 2016). The mean difference of the household size was varied insignificantly among the locations ($F= 1.59$; $p \leq 0.206$). The family type may be influenced the decision making for adopting new technologies which was shown in the probit analysis. But in this study, more than 76%respondentsbelonged to single family and the rest with joint family. The difference of family structure was varied insignificantly ($F= 0.692$; $p \leq 0.503$).

3.2 Contextual information of mango growers

It can be seen from Table 2that 77.1% farmers owned mango orchard either in homestead areas or in other places irrespective of locations. Of them, the highest percentage was found in Sitakundo area followed by Fatikchari and Hathazari. The average area of mango orchard was reported to be 0.81 ha in all locations which was the highest in Sitakundo areas (1.40 ha) followed by Fatikchari (0.90 ha) and Hathazari (0.14 ha). The mean difference of the area of mango orchard was found highly significant at 1% level of probability (F= 23.283; $p \leq 0.000$) among the locations. The year of 1st establishment of mango orchard was in 1985 at Fatikchari areas followed by Sitakundo (1993) and Hathazari (1994).

Table 1. Socioeconomic profile of the respondents by locations

Sl. No.	Particulars	Locations			
		Hathazari	Fatikchari	Sitakundo	All
1	Age of the respondent	47.52	43.2	43.8	44.8
2	Education: (average year of schooling)	7.02	8.7	5.7	7.1
3	Main occupation (%):				
	Agriculture	97.1	60.0	93.5	83.5
	Business	35.7	50.0	25.8	37.1
	Private job	22.8	6.7	16.1	15.2
4	Household size (Person/family):	6.4	6.5	5.9	6.2
	Male	3.4	3.6	3.2	3.4
	Female	3.0	2.9	2.7	2.8
5	Family types (%):				
	Single	80.0	70.0	80.6	76.8
	Joint	20.0	30.0	19.3	23.1

Source: Field survey, 2016

Irrespective of locations, the highest 29.5% mango orchard was established in the high land, 25.1% in medium high land and 22.7% in slope land. The highest 36.7% of the respondents reported that the soil type of mango orchard was sandy-loam. It was observed that on an average 8.1 to 13.3 mango trees were plantedin the homestead areas where the average area of homestead area was 0.08 ha to 0.1 ha. The average cultivable land was estimated to be 0.80 ha to 1.6 ha by locations. The mean differences of cultivable land was found to be significant at 5% level of probability (F = 4.36; $p \leq 0.015$). On the other hand, the average current fallow land per household was 0.08 ha irrespective of locations. This might be due to lack of capital. Table 3 shows that 74.2% farmers were found to be adopter of BARI Aam while 25.7 % were non-adopter. The respondent farmers were aware about the BARI mango from different sources such as BARI, DAE, Nursery, Media and NGOs. The highest percentages of the respondents gathered information about BARI variety from research station of BARI followed by DAE and nursery owner (Table 4).

Table 2. Contextual information of mango growers in the selected areas of Chittagong district

Sl. No.	Particulars	Locations			
		Hathazari	Fatikchari	Sitakundo	All
1	Having owned mango orchard (%)	41.42	90.0	100.0	77.1
2	Per household average area of mango orchard (ha)	0.14	0.90	1.40	0.81
3	Year of 1st establishment of mango orchard	1994	1985	1993	-
4	Types of land in mango orchard (%):				
	High land	17.1	23.3	48.3	29.5
	Medium high land	12.8	43.3	19.3	25.1
	Medium low land	5.71	3.3	9.6	6.2
	Slope land	12.8	23.3	32.2	22.7
5	Types of soil in mango orchard (%):				
	Loam	15.7	16.6	16.1	16.1
	Sandy-loam	11.4	40.0	58.8	36.7
	Clay-loam	18.5	30.0	38.7	29.0
6	Having mango tree (no.) in the homestead areas per household	12.4	13.3	8.1	11.2
7	Average area of homestead per household (ha)	0.09	0.1	0.05	0.08
8	Average cultivable land per household (ha)	0.45	1.6	0.80	0.90
9	Having current fallow land (ha) per household	0.05	0.1	0.1	0.08

Source: Field survey, 2016

Table 3. Respondents' awareness about BARI mango varieties

Sl. No.	Locations	Adopter (%)	Non-adopter (%)
1	Hathazari	88.5	11.5
2	Fatikchari	66.6	33.4
3	Sitakundo	67.7	32.3
	All	74.3	25.7

Source: Field survey, 2016

Table 4. Respondents' acquired the information about BARI mango varieties

Sl. No.	Locations	In % of respondents by source				
		BARI	DAE	NGO	Media	Nursery
1	Hathazari	72.8	22.8	-	-	4.28
2	Fatikchari	33.3	46.6	-	6.6	-
3	Sitakundo	19.3	58.8	3.2	3.2	9.6
	All	48.8	42.7	3.2	4.9	6.9

3.3 Extent of Adoption of BARI Mango Varieties: Out of 11 varieties of BARI Aam, the highest 77% farmers adopted BARI Aam-3 due to its sweetness, flavour and high market demand in Chittagong market followed by BARI Aam-4 (22.1%) due to late variety and higher market price and BARI Aam-8 15.9% due to its attractive colour and market demand (Table 5). But the rate of adoption of other varieties of BARI Aam was found to be lower irrespective of locations due to unavailability of sapling and unknown to the variety. The adoption of BARI Aam-3 was found as higher in Fatikchari areas (93.3%) might be due to receive more training and raised awareness about the variety followed by Sitakundo (80.6%) and Hathazari (57.1%).

Table 5. Rate of adoption of BARI Mango varieties in the Chittagong region, 2016

Sl. No.	BARI mango varieties	% of respondents (Rate of adoption)			
		Hathazari	Fatikchari	Sitakundo	All
1	BARI Aam-1 (Mohananda)	5.7	10.0	3.2	6.3
2	BARI Aam-2	3.0	-	3.2	3.1
3	BARI Aam-3	57.1	93.3	80.6	77.0
4	BARI Aam-4 (Hybrid)	28.5	21.6	16.3	22.1
5	BARI Aam-5	-	-	3.2	3.2
6	BARI Aam-6	1.4	-	3.2	2.3
7	BARI Aam-7	1.4	-	3.2	2.3
8	BARI Aam-8	12.0	16.6	19.3	15.9
9	BARI Aam-9 (Kachamitha)	-	2.0	2.5	2.4
10	BARI Aam-10	2.8	-	3.2	3.0
11	BARI Aam-11 (Baromasi)	-	10.0	6.4	8.2

Source: Field survey, 2016

Knowledge of modern technology for mango production: Table 6 shows that about 56.2 % of the mango farmers claimed that they had ideas on modern technologies of mango where the highest percentages 67.1% in Hathazari areas, 53.3% in Fatikchari and 48.3% in Sitakundo. The differences of the knowledge obtained by the farmers varied insignificant among the locations ($F = 1.891$; $p \leq 0.155$).

Training received: About 28.8% farmers received training on mango production in the last three years irrespective of locations. By location, the highest 57.1% farmers received training in Hathazari areas might be due to the activities of BARI and DAE offices. The differences of training received by the farmers was found to be highly significant at 1% level of probability ($F=15.174$; $p \leq 0.000$) among the locations (Table 6). *Source of sapling:* The highest 60.3% of the farmers collected BARI mango sapling from local nursery, 29.0% in research station and 16.9% in horticulture center. About 49.1 % of the farmers had owned spray machine irrespective of all locations. More than 60% farmers consulted with DAE personnel for spraying insecticide in mango trees, 21.6% for owner of dealer shop and 20.7% for research personnel (Table 6).

Table 6. Some basic questions and responses regarding BARI mango production

Sl. No.	Particulars	In % of respondents who answered 'Yes'			
		Hathazari	Fatikchari	Sitakundo	All
1	Known to modern technology of mango cultivation	67.1	53.3	48.3	56.2
2	Received training on mango production	57.1	16.6	12.9	28.8
3	Source of sapling of BARI Aam:				
	Owned	15.7	10.0	-	12.8
	Local nursery	20.0	93.3	67.7	60.3
	Research station	51.4	6.6	-	29.0
	Horticulture center	5.14	20.0	25.8	16.9
	BADC	-	3.3	-	3.3
	Local market	14.2	13.3	3.2	10.2
	Relatives	25.7	3.3	3.2	10.7
4	Having spray machine	27.1	56.6	64.5	49.1
5	Consult for spraying in mango tree:				
	Owner of dealer shop	35.7	10.0	19.3	21.6
	Extension personnel	34.2	83.3	64.5	60.6
	Research personnel	55.7	3.3	3.2	20.7
	NGO worker	1.4	-	-	1.4

Source: Field survey, 2016

Rate of Adoption of Individual Production Technologies: The rate of adoption of individual mango production technologies varied significantly among the locations and farmers. None of the individual practices were adopted in fully. Most of them adopted partially or slightly might be due to unawareness or ignorance. The rate of adoption of individual production technologies is shown in Table 7. In case of *land preparation*12.3% farmers used tractor or power tiller in mango orchard irrespective of locations. The average ***pit size*** maintained by mango farmers was 1.4ft×1.4ft×1.3ft as against the recommended size of 3.2 ft×3.2 ft×3.2ft (*BARI Krishi Projokti Hathboi*, 2016). One hundred percent of farmers didn't use recommended doses of *manures and fertilizers*. On an average,manure was used 6.1 kg per pitas against the recommended dose of 20-30 kg/pit. In the case of *chemical fertilizer*, farmers used 262gTSP, 119gMoP and 27g Zypsum per pit. The amount of aforesaid fertilizers used in pit preparation was found to be lower than that of recommended dose of 550 gm, 250gm, 215gm, respectively (*BARI Krishi Projokti Hathboi*, 2016). The average *planting distance*was12ftx11.7 ft which was lower than that of recommended distance of 24ft×30ft (BARI Krishi Projokti Hathboi, 2016). Majority of farmers 57.5% adopted the right *time of planting* (June-July) of sapling, while 57.7 % of farmer partially adopted the recommended *planting method* (square design) in mango orchard. More than 67.7% of farmers adopted the improved practice of *breaking the inflorescence of mango* trees in the study areas. Besides, 48.3% of farmers practiced *inter-cultural operation* in their mango orchard where leafy vegetables, ginger, banana and papaya were the intercrops into the mango orchard. *Fertilizer used per year per tree* is important for raising productivity. In the study area, cent percent farmers did not use the recommended dose of fertilizer per year per tree. A very negligible amount of fertilizer used in the mango tree per year (Table 7). *Irrigation in dry season* is also an important factor for higher yield of mango. More than 60% farmers provided irrigation into their mango orchard through pump or carrying bucket. But they did not know the exact time of irrigation for mango orchard.

Insect pest and disease management is inevitable for producing quality mango and for getting higher market price. Hoppers, fruit flies, mealy bugs, anthracnose, black spot on mango, and cracking of immature mango were the major problems reported by the respondents. More than 56% of farmers used pesticides in consultation with DAE people or pesticides dealer for controlling insect-pest and diseases. But they didn’t follow the recommended dose for pest and disease management due to unawareness and lack of training in this regard. About 65% of farmers used *mulching in their mango orchards* as an alternative to irrigation in dry season. The mulching materials were dry leaves and dry grass. *Training and pruning* of a mango tree are also crucial for improved management mango orchard which could lead to enhance productivity of mango. Generally, training and pruning of a mango tree is done just after harvesting of mango. In the study area, no farmer was to adopt the improved practice like training in mango tree, but 48% of farmers did pruning in their mango orchard partially. *Use of plant growth regulators (Hormone)* are recommended for getting bigger fruits and uniform ripening of fruits. Only 12.2% of farmer used hormone in their mango orchards in this regard. *Method of harvesting* is an important issue for reducing postharvest loss of mango. BARI has developed a mango harvesting tool, namely BARI mango harvester. In the study areas, only 3.2 % of farmers used the harvester and rest of others harvested mango by hand, bamboo, stick and through shacking. Only12.7% of farmers took partial care in *packing* using bamboo basket and *handling* of mango and only 24.7% of farmers partially graded mango during marketing. There was no warehouse for storing mango. But they stored mango in a traditional way for a short time. In addition, it was not found to use any medicine or malpractice for artificial repining of mango in the study areas (Table 7).

Table 7. Extent of individual production technology adopted by the mango growers

Sl. No.	Individual technology	Study location			
		Hathazari	Fatikchari	Sitakundo	All
1	Land preparation through ploughing (In % of respondents)	21.42	3.3	-	12.3
2	Average size of pit (sq. feet)	1.3x1.3x1.2	1.8x1.8x1.6	1.3x1.2x1.2	1.4x1.4x1.3
3	Manure used per pit before planting (kg)	5.41	9.7	3.4	6.1
4	Fertilizer used (gm) per pit before				
	planting	80.71	53	64.5	66
	Urea	289.28	277.3	220.9	262.4
	TSP	135.85	125	97.4	119.4
	MoP	20.14	51.6	10.3	27.3
	Zypsum				
5	Maintained plant distance (feet)				
	Plant to plant	9.74	13.4	13.0	12.0
	Line to line	7.43	14.3	13.4	11.7
6	Planting time (In % of respondents):				
	June	51.42	56.6	64.5	57.5
	July	27.14	10	25.8	21
	August	11.42	3.3	-	7.3
7	Orchard designed (In % of				
	respondents):	80	43.3	48.3	57.2
	Square	1.4	-	9.6	5.5
	Triangular	2.8	20	32.2	18.3
	Rectangular	10	20	12.9	14.3
	Hapazard				
8	Breaking the mango inflorescence (%)	62.85	63.3	77.04	67.7
9	Cultivated intercrop in mango orchard	27.42	50	67.7	48.3
10	Average fertilizer applied (kg) per mango tree per year:				
	Urea	0.13	0.12	0.16	0.1
	TSP	0.16	0.12	0.2	0.1
	MoP	0.07	0.06	0.11	0.08
	Zypsum	0.0007	0.02	0.01	0.01
11	Irrigation in dry season (In % of respondents)	62.85	53.3	64.5	60.2
12	Pesticide use (In % of respondents)	42.85	43.3	83.8	56.6
13	Mulching in dry season (In % of respondents)	52.85	53.3	90.3	65.4
14	Pruning after mango harvest (In % of respondents)	52.85	40	51.6	48.1

Sl. No.	Individual technology	Study location			
		Hathazari	Fatikchari	Sitakundo	All
15	Hormone used for quality mango(In % of respondents)	4.28	6.6	25.8	12.2
16	Followed appropriate harvesting time (% of respondents)	85.71	56.6	80.6	74.3
17	Harvesting methods(In % of respondents):				
	By hand	68.57	50	77.4	65.3
	By bamboo	42.85	13.3	6.4	20.8
	By shaking	45.71	10	16.1	24
	By harvester	-	-	3.2	3.2
18	Storing mango after harvest (In % of respondents)	10.0	10.0	12.9	10.9
19	Grading after harvest (In % of respondents)	17.14	40	29	24.7
20	Packaging of mango (In % of respondents)	15.71	3.3	19.3	12.7
21	Medicine used for ripening the mango (In % of respondents)	-	-	-	-

Source: Field survey, 2016.

Causes of non-adoption of BARI mango varieties: The highest 83.6% farmers claimed that the sapling of BARI mango variety was not available in the local nursery. Even 77% farmers reported that they did not get sufficient sapling of BARI mango varieties from the research center situated in the region. The other causes for non-adoption of BARI mango varieties are mentioned in the Table 8.

Table 8. Causes of non-adoption of BARI mango varieties in the selected locations

Sl. No.	Causes	In % of respondents			
		Hathazari n=70	Fatikchari n=30	Sitakundo n=31	All n=171
1	Unavailability of sapling of BARI Aam	75.7	70.0	67.7	72.5
2	Not met the demand by the research center	87.4	60.0	83.8	80.3
3	BARI mango variety was not confirm in the local nursery	87.4	80.0	83.8	83.6
4	Unknown to the right planting method	42.5	70.0	67.7	60.1
5	Unknown to the of pest and diseases management	67.4	76.6	67.7	70.4
6	Unknown to the right harvesting time	78.7	63.3	64.5	68.7

Source: Field survey, 2016

Farmer's responses to the support need from BARI and DAE*:* The highest 67.9% of the respondents demanded for high quality sapling of BARI mango varieties. The other need of the farmers was training on modern technology of specific BARI mango varieties. Providing power spray machine, proper treatment of the pest and diseases particularly of BARI Aam, judicious use of fertilizer in different BARI mango varieties and credit facilities were the important need of the respondent farmers (Table 9).

Table 9. Farmers responses to the support need from BARI and DAE

Sl. No.	Problem/Constraints	In % of farmers			
		Hathazari n=70	Fatikchari n=30	Sitakundo n=31	All n=171
1	Supply of high quality sapling	82.8	53.3	67.7	56.96
2	Training on modern technology	72.8	46.6	64.5	64.84
3	Provide power spray machine	-	20.0	64.5	42.25
4	Proper treatment for pest and disease	40.0	30.0	48.3	26.10
5	Judicious use of fertilizer & pesticide	54.2	23.3	45.1	40.86
6	Provide credit facilities	12.8	10.0	32.2	18.3

Source: Field survey, 2016

Farmer’s reaction for expansion of BARI mango varieties at farm level

Ensure quality sapling, conducting farmer meeting at village level, broadcasting in mass media, providing modern training and monitoring the mango orchard could help to extent of adoption of BARI mango varieties at farm level as reported by the respondent farmers in the study areas (Table 10).

Table 10. Farmer’s reaction to expand of BARI mango varieties at farm level

Sl. No.	Farmers reactions	In % of farmers			
		Hathazari n=70	Fatikchari n=30	Sitakundo n=31	All n=171
1	Ensure quality saplingsat farm level	72.8	30.0	67.7	61.79
2	Conduct farmer meeting at village level	11.4	26.6	54.8	30.93
3	Broadcast BARI Aam in mass media	7.14	53.3	16.1	25.51
4	Provide modern training on BARI Aam	57.4	53.3	25.8	45.50
5	Need regular orchard visit & monitoring	-	13.3	16.1	14.70

Source: Field survey, 2016

Factors Influencing BARI mango varieties adoption: In order to assess the contribution of various factors to the variation in the extent of adoption of BARI mango varieties at farm level. A regression equation was fitted with the dependent variable (0 and 1) of the extent of adoption of BARI mango varieties and fourteen independent variables such as yield, cultivable land, age of respondents, family size, family type, training, risk taking behaviour, innovativeness, willingness to take loan, having modern knowledge on mango production, economic aspiration, mass media exposure, research and extension contact. The results of the analysis are presented in Table 12 and Table 13.

The yield of BARI mango variety is a significant determinant of decision to grow BARI mango. Per household the highest yield was recorded from BARI Aam-3 followed by BARI Aam-4 and BARI Aam-8 (Table 11). The marginal effect of the relevant variable of training, extension contact and risk taking behavior are estimated at 0.29, 0.38 and 0.17 implying that a one per cent increase in the training, extension contact and risk taking behavour will increase the adoption of BARI mango variety significantly by 0.29, 0.38 and 0.17% respectively. On the other hand, the marginal effect of the variable willingness to take loan is estimated at - 0.14 implying that a one per cent increases in the loan will decrease the adoption of BARI mango variety. This might be due to the use the loan in other purposes (Table 13).

The results of regression analysis revealed that the yield of mango variety, training, extension contact, risk taking behavior and willingness to take loan has indeed helped in contributing to adopt BARI mango varieties at farm level. Out of these, family size, family type, innovativeness and mass media exposure can be seen as insignificant but positive indicator for formulating for adopting the BARI mango varieties in the region.

Table 11. Yield of BARI mango varieties per household in locations, 2016

Sl. No.	BARI mango varieties	Average yield (kg/hh)			
		Hathazari	Fatikchari	Sitakundo	All
1	BARI Aam-1 (Mohananda)	30.0	600.0	-	315.0
2	BARI Aam-2	20.3	-	-	20.3
3	BARI Aam-3	84.3	291.5	1221.9	532.5
4	BARI Aam-4 (Hybrid)	85.0	100.0	1000.0	395.o
5	BARI Aam-5	-	-	-	-
6	BARI Aam-6	-	-	-	-
7	BARI Aam-7	-	-	-	-
8	BARI Aam-8	40.0	-	845.0	442.5
9	BARI Aam-9 (Kachamitha)	-	310.0	442.0	376.0
10	BARI Aam-10	-	-	-	-
11	BARI Aam-11 (Baromasi)	-	-	-	-

Table 12. Probit regression coefficient of extent of adoption of BARI mango varieties

Independent variables	Probit Coefficient	Std. Err.	Z	P-value
Constant	-1.2444	1.2604	-0.99	0.323
Ln Yield	0.2372***	0.0680	3.49	0.000
Ln Cultivable land	-0.0414ns	0.0628	-0.66	0.509
Age	-0.0270ns	0.0378	-0.72	0.475
Family size	0.0246ns	0.0379	0.65	0.515
Family type	0.1070ns	0.3757	0.28	0.776
Training	1.1823***	0.4184	2.83	0.005
Risk taking behaviour	0.6126**	0.2625	2.33	0.020
Innovativeness	0.1620ns	0.2481	0.65	0.514
Willingness to take loan	-0.5041**	0.2236	-2.25	0.024
Having modern knowledge on mango production	-0.3319ns	0.2738	-1.21	0.225
Economic aspiration	-0.1748ns	0.2992	-0.58	0.559
Mass media exposure	0.2158ns	0.2447	0.88	0.378
Research contact	-0.2294ns	0.3386	-0.68	0.498
Extension contact	1.1788***	0.3352	3.52	0.000
Model diagnosis:				
Log likelihood	-50.2441	-	-	-
Pseudo R^2	0.3767	-	-	-
LR chi-squared	60.73***	-	-	0.000
Accuracy of prediction (%)	79.0%			
Number of observations	131			

Note: The variable of education dropped because of multi colinearity problem

*** Significant at 1% level (P≤ 0.01); ** Significant at 5% level ((P≤ 0.05); * Significant at 10% level (P≤ 0.10).

Table13. Marginal effects after probit analysis

Independent variables	dy/dx	Std. Err.	z	P-value	X
Ln Yield	0.0682***	0.0179	3.80	0.000	2.513
Ln Cultivable land	-0.0119	0.0180	-0.66	0.510	3.269
Age	-0.0077	0.0108	-0.72	0.472	45.671
Family size	0.0070	0.0108	0.65	0.513	52.786
Family type	0.0307	0.1078	0.29	0.775	1.778
Training	0.2960***	0.0902	3.28	0.001	0.374
Risk taking behaviour	0.1761**	0.0742	2.37	0.018	1.923
Innovativeness	0.0465	0.0715	0.65	0.515	2.618
Willingness to take loan	-0.1449**	0.06431	-2.25	0.024	1.786
Having modern knowledge on mango production	-0.0954	0.0777	-1.23	0.219	1.801
Economic aspiration	-0.0502	0.0863	-0.58	0.561	2.664
Mass media exposure	0.0620	0.0699	0.89	0.375	2.564
Research contact	-0.0662	0.0986	0..67	0.502	0.473
Extension contact	0.3808***	0.1122	3.39	0.001	0.687

Marginal effect after probit **y** = 0.7909 (*) dy/dx is for discrete change of dummy variable from 0 to 1

Note: The marginal effect is the average change probability when x increases by one unit. Since a probit is a non-linear model, that effect will differ from individual to individual.

4. Summery, Conclusion and Recommendations

Adoption of BARI mango varieties is an important for raising farm income in the region. But the rate of adoption was found to be low except BARI Aam-3. Unavailability of the saplings of BARI mango varieties and lack of its campaign were the major bottlenecks for wider adoption of BARI mango varieties in the region. The yield of BARI mango variety, training, extension contact, risk taking behavior and willingness to take loan influence farmers to adopt BARI mango varieties to a greater extent. In the case of individual production technologies, most of the farmers' respondent adopted partially or slightly might be due to unawareness or ignorance. However, the following recommendations have been made based on the findings of the study:

- Proper and necessary actions should be taken for ensuring the availability of BARI mango varieties at local nursery, research and horticulture center in the region by the concerned departments such as BARI and DAE.
- Provide hand-on training by BARI and DAE on BARI mango varieties and its individual production technologies to the farmers and private nursery owner at field level;

- BARI (OFRD) and DAE could be motivate the private nursery owners for planting mother tree of BARI mango varieties in their nursery for supplying quality sapling;
- Formulating policy for campaign about the BARI mango varieties in both electronic and print media and responsibility can be taken by the AIS under the Department of Agriculture Extension and ICT section of BARI.
- Build a strong monitoring committee for evaluating the adoption of BARI mango varieties at field level in the region in collaborating with BARI and DAE. The committee will encourage to establish BARI mango orchard in each Upazilla and monitoring these orchards at least twice in a year.

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Appendix-1.The major characteristics of BARI mango varieties

Sl. No.	Name of Variety	Year of released	Production Season	Yield (Ton/ ha)	Major Features
1.	BARI Aam-1 (Mohananda)	1996	May	15	Regular bearing, average fruit wt. 190-210gm, TSS-19%, early variety
2.	BARI Aam-2	1996	June	20-22	Regular bearing, average fruit wt. 240-260gm, TSS-17.5%,
3.	BARI Aam-3	1996	June-July	18-20	Regular bearing, average fruit wt. 210-220gm, TSS-23.4%
4.	BARI Aam-4 (Hybrid)	2002	July-Aug.	18-20	Regular bearing, average fruit wt. 600gm, TSS-24%, late variety
5.	BARI Aam-5	2009	May	15-20	Regular bearing, average fruit wt. 230gm, TSS-19%.
6.	BARI Aam-6	2009	June	15-16	Regular bearing, average fruit wt. 280 gm, TSS-18%
7.	BARI Aam-7	2009	June	20-25	Regular bearing, average fruit wt. 285 gm, TSS-18%
8.	BARI Aam-8	2009	July	20-25	Regular bearing, average fruit wt. 270gm, TSS-22%
9.	BARI Aam-9 (Kachamitha)	2011	May	1.35 (7 yrs tree)	Regular bearing, average fruit wt. 166gm, TSS-11%, early variety
10.	BARI Aam-10	2012	June	15-20	Regular bearing, average fruit wt. 200gm, TSS- 20%
11.	BARI Aam-11 (Baromasi)	2015	Rabi &Kharif	2.2 (6 yrs tree)	Three times bearing per year (November, February & May) average fruit wt. 317gm, TSS-18.5%.

Source: *Krishi Projokti Hathboi, 2016.*

Appendix-2. The name of study areas (villages) under three selected Upazilas in Chittagong district

Sl. No.	Name of Upazila	No. of villages	Name of villages where the survey was conducted
1	Hathazari	8	Charia, Fakirkil, Dakkin Pahartali, Tandachari, Fateyabad, Dewan Nagor, Alipur and Alampur
2	Fatikchari	13	Nanopur, Kepayetnagor, Gamaritola, Jushkhula, Purbo Hasnabad Bhuiyapara, Purbo Hasnabad Ajolapara, Gopalghata, Maijvandar, Masterpara, Barmaniya para, Pacchim Soabil, Dakkin Rangamatia and Dakkin Baghmara
3	Sitakundo	7	Khadempara, Kesobpur, Vatiari, Jahanabad, Samobetorpara, Dakkin Bashbariya and KadomRasul

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GENETIC DIVERSITY IN AUS RICE (*Oryza sativa* L.) GENOTYPES OF BANGLADESH

N. AKTER[1], H. BEGUM, M. Z. ISLAM, M. A. SIDDIQUE
AND M. KHALEQUZZAMAN

Abstract

Genetic diversity in 31 traditional Bangladeshi Aus rice genotypes were studied under transplanted condition through Mahalanobis D^2 statistic for grain yield and yield contributing characters. The genotypes were grouped into five clusters. The inter-cluster distances were higher than intra-cluster distances indicating wider genetic diversity among the genotypes of different clusters. The intra-cluster distances were lower in all the cases reflecting homogeneity of the genotypes within the clusters. The cluster II contained the highest number of genotypes (08) and the cluster I and III contained the lowest (05). The highest intra-cluster distance was noticed for the cluster II and the lowest for cluster IV. The highest inter-cluster distance was observed between cluster II and V followed by cluster III and V, cluster I and V and the lowest between cluster I and III. Regarding inter-cluster distance, the genotypes of cluster V showed high genetic distance from all other clusters. The genotypes from cluster V could be hybridized with the genotypes of other characters of other clusters for producing transgressive segregants. The highest cluster means for yield, effective tiller number and grain length, were obtained from cluster I; whereas the lowest mean value for yield, culm length, plant height and grain breadth were found in cluster II. Therefore, genotypes under cluster I, cluster II and cluster V might be selected for future breeding program as parents for crossing to produce new recombinants with desired traits.

Keywords: Genetic diversity, D^2 analysis, cluster analysis, rice (*Oryza sativa* L).

Introduction

Rice (*Oryza sativa* L.) is a self-pollinated cereal crop of Poaceae family under the order Cyperales. It is considered as a major crop in Bangladesh as it constitutes 90.56% of the total food grain (rice, wheat & maize) production (Anon., 2015). Although Bangladesh is now on the verge of attaining self sufficiency in cereal production, there is still a large gap between the production and demand. Achieving self-sufficiency in rice production and maintaining price stability are important in countries where rice provides food security and generates employment and income for people (Hossain, 1995). Rice area coverage includes 13% upland ecosystem, 11% deepwater ecosystem and 25% rainfed lowland ecosystem of the total rice area (Fukai and Cooper, 1995). Upland rice (Aus) is in

[1]Genetic Resources and Seed Division, Bangladesh Rice Research Institute (BRRI), Gazipur-1701, Bangladesh.

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extreme emphasis for its short duration because, crop with less growth duration is good for accommodating more than three to four crops a year.

Bangladesh has a good source of indigenous rice cultivars with two million hectares coverage, while the HYV and hybrids occupy eight million hectares and one million hectares, respectively (Talukder, 2011). Knowledge of genetic diversity among existing cultivars of any crop is essential for long term success of breeding programme and maximizes the exploitation of the genetic resources (Belaj *et al.*, 2002). Hybridization is one of the major tools for the improvement of a crop that needs the analysis of genetic diversity for the selection of parents (Singh, 1983). Moreover, evaluation of genetic diversity is important for the source genes of particular traits within the available germplasm (Roy and Panwar,1993).

With the development of advanced biometrical techniques such as multivariate analysis based on the Mahalanobis (1936) statistics, quantification of divergence among the biological population and assessing the relative contribution of different components to the total divergence at intra and inter-cluster levels have now become possible. Such study also selects the genetically diverse parents to obtain the desirable recombinant in the segregating generations. Hybridization is a common practice for combining the desirable characters of two or more lines or varieties into a single variety. In several cases, the progenies become far superior to the parents in vigor *i.e.* hybrid vigor or heterosis. In addition, crossing in moderately diverse parents also showed the maximum heterosis (Chauhan and Singh, 1982). The necessity of principal component analysis (PCA), principal coordinate analysis (PCoA), non-hierarchical clustering and canonical vector analysis (CVA) for measuring the degree of divergence has been established by several investigators in rice and other crops (Selvakumar *et al.*, 1989; De *et al.*, 1988; Pathan *et al.*, 1993).

More than 8000 rice germplasm have been registered in BRRI genebank (BRRI, 2015). But information on grain yield and yield contributing characters in traditional rice is scanty. Keeping this in view, the present study was focused to assess the extent of genetic diversity in 31 traditional aus rice varieties. This will help classify those into clusters to select varieties as prospective parents to develop transgressive segregants.

Materials and Methods

A total of thirty one rice genotypes collected from the genebank of Bangladesh Rice Research Institute (BRRI), Gazipur were grown in transplanted condition (Aus) in 2015 (Table 1). The trial was conducted in a randomized complete block design with three replications. Twenty days-old seedlings from each entry were transplanted using single seedling per hill in 2.4 m^2 plot following 25 cm and 20 cm space between rows and plants, respectively. Fertilizers were applied @ 60:20:40: 12 kg N, P, K and S per hectare (BRRI, 2015). All the fertilizers except

N were applied at final land preparation. Nitrogen was applied in three equal splits, at 15 days after transplanting (DAT), at 35 DAT and just before flowering. Intercultural operations and pest control measures were done as and when necessary. At maturity, grain yield (g/hill) was taken and adjusted at 14% moisture level. Ten plants from each entry were randomly selected for recording data on Flag leaf length (cm), Flag leaf width (cm), Plant height (cm), Days to flowering, Days to maturity, Panicle length (cm), Effective tiller (no.), Filled grains per panicle (no.), Unfilled grains per panicle (no.), Grain length (mm), Grain breadth (mm), Length-breath ratio, 1000 grain weight (g) and Yield/hill (g). The data were analyzed following principal component analysis (PCA) and Mahalanobis's (1936) generalized distance (D^2) extended by Rao (1952). Intra and inter cluster distances were calculated by the methods of Singh and Chaudhury (1985). All statistical analyses were carried out using Genstat 5.5.

Table 1: Information on place of collection and local name of the aus rice landraces

Sl. No.	Genotypes	District of Collection	Sl. No.	Genotypes	District of Collection
1	Begun bichi	Kushtia	17	Raitul	Barguna
2	Hashikalmi	Kushtia	18	Kuchmuch	Barguna
3	Kalo dhan	Kushtia	19	Puitra Aijang	Barguna
4	Aus dhan	Kushtia	20	Boula	Barguna
5	Digha Bawalia	Kushtia	21	Chaina	Barguna
6	Hanuman jata	Kushtia	22	Saith shail	Barguna
7	Itcrie	Meherpur	23	Sadey Aus	Barguna
8	V-2	Meherpur	24	Mallika	Barguna
9	V-3	Meherpur	25	Adub alli	Barguna
10	V-4	Meherpur	26	Bar dhan Aus	Barguna
11	Parangi	Rajbari	27	Kalo Aus	Barguna
12	Sanda mioni	Rajbari	28	Bardhan Aus M-741	Barguna
13	Jaymori	Rajbari	29	H-171	Barguna
14	Kalo hizli	Rajbari	30	H-12	Barguna
15	Minikit	Barguna	31	Kadidet	Barguna
16	Parangi	Barguna			

All the genotypeses are new collection (NC) having same origin i.e. Bangladesh.

Results and Discussion

Qualitative traits characterization

One of the aims of the present study was to identify distinct qualitative traits variation among the tested aus rice landraces. Variation was found in 19 of the 22 qualitative traits under studied except ligule shape, collar colour and auricle colour (Table 2).

Table 2. Classification of aus rice landraces based on 22 qualitative characters

Sl. No.	Characters	Classification	Frequency	Genotype (Serial number in Table 1)	Frequency%
1	Blade pubescence	01.Glabrous	02	29,30	6.45
		02.Intermediate	29	1,2,3,5,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22, 23, 24,25,26,27,28,31	93.55
2	Blade colour	01. Pale green	02	6,12,	6.45
		02. Green	29	1,2,3,4,5,7,8,9,10,11,13,14,15,16,17,18,19,20, 21,22,23,24,25,26,27,28,29,30,31	93.55
3	Leaf sheath: anthocyanin colour	01. Absent	29	1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19, 20,21,22,23,24,25,26,28,29,30,31	93.55
		09. Present	02	9,27	6.45
4	Basal leaf sheath color	01. Green	28	1,2,3,4,5,6,7,8,10,11,12,13,15,16,17,18,19,20, 21,22,23,24,25,26, 28,29,30,31	90.32
		03. Light purple	02	14,27	6.45
		04. Purple	01	9	3.22
5	Flag leaf angle	01. Erect(<30^0)	13	3,4,6,7,10,12,16,17,18,20,22,25,27,	41.94
		03. Intermediate or Semi erect(<30-45^0)	14	2,8,9,11,13,1415,19,21,24,26,28,29,31	45.16
		05.Horizaontal (<46-90^0)	04	1,5,23,30,	12.90
6	Ligule color	01. White	30	1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19, 20,21,22,23,24,25,26,27,28,29,30,31	96.77
		02. Purple lines	01	9	3.22
7	Ligule shape	02. 2-cleft	31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22, 23,24,25,26,27,28,29,30,31	100
8	Auricle color	01. Pale green	31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22, 23,24,25,26,27,28,29,30,31	100

9	Collar color	01.Pale green	31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22, 23,24,25,26,27,28,29,30,31	100
10	Culm anthocyanin colour	01. Absent	30	1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19, 20,21,22,23,24,25,26,27,28,29,30,31	96.77
		09.Present	01	9	3.22
11	Culm Angle	01. Erect(<30^0)	06	7,8,9,10,30,31	19.35
		03. Intermediate	14	3,5,6,11,12,13,15,17,19,22,24,26,28,29,	45.16
		05.Open	11	1,2,4,14,16,18,20,21,23,25,27,	35.48
12	Internode colour	02.Light gold	30	1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19, 20,21,22,23,24,25,26,27,28,29,30,31	96.77
		03.Purple lines	01	9	3.22
13	Culm strength (lodging resistance)	01. Strong	16	4,7,8,9,10,13,18,19,20,21,22,25,27,29,30,31	51.61
		03.Moderately strong	14	1,2,3,6,11,12,14,15,16,17,23,24,26,28,	45.16
		07.Weak	01	5	3.22
14	Panicle Type	01.Compact	02	3,11,	6.45
		05.Intermediate	15	1,6,7,8,9,12,23,15,16,18,19,26,27,28,29,	48.39
		09. Open	13	2,4,10,14,17,20,21,22,23,24,25,30,31	41.94
Sl. No.	Characters	Classification	Frequency	Genotype (Serial number in Table 1)	Frequency%
15	Panicle exsertion	01. Well exerted	20	1,5,9,10,11,12,13,14,15,17,18,19,20,23,24,25, 26,27,28,29,	64.51
		03. Moderately well exerted	08	2,3,4,6,7,8,22,31	25.81
		05. Just exerted	03	16,21,30,	9.68

16	Awns in the spikelet	01. Absent	18	2,3,5,7,8,9,10,12,14,16,19,24,25,26,28,29,30, 31	58.06
		09. present	13	1,4,6,11,13,15,17,18,20,21,22,23,27,	41.94
17	Distribution of awning	01.Tip only	08	4,6,11,13,15,20,21,22,	25.81
		03.Upper half only	02	1,17	6.45
		05.Whole length	03	18,23,27	9.68
18	Awn colour	01.Straw	12	1,4,6,13,15,17,18,20,21,22,23,27	38.71
		06.black	01	11	35.48
19	Stigma colour	01.White	27	1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,19,20, 21,22,24,25,26,28,29,30,31	87.09
		02.Light green	01	18,	3.22
		05.Purple	03	9,23,27,	9.68
20	Lemma and palea colour	0. Straw	15	2,7,8,9,13,15,18,20,21,22,23,26,28,29,30,	48.39
		01. Gold	08	1,10,12,17,19,24,25,31	25.81
		02. Brown spots on straw	02	4,6	6.45
		09.Black	05	3,11,14,16,27,	16.13
21	Seed coat (bran) colour	01.White	10	7,8,10,15,19,21,22,26,28,30,	32.26
		02. Light brown	01	2	3.22
		04. brown	06	3,5,11,14,16,27,	19.35
		05.Red	14	1,4,6,9,12,13,17,18,20,23,24,25,29,31	45.16
22	Leaf senescence	01.Late and slow	03	27,30,31	9.68
		05. Intermediate	28	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22, 23,24,25,26,28,29,	90.32

Most of the characterized landraces (93.55%) exhibited intermediate leaf blade while the rest of the landraces exhibited glabrous (6.45%) leaf blade pubescence. About 93.55% of the evaluated aus rice landraces exhibited a blade colour green while the remaining landraces (6.45%) were pale green. Data in Table 2 also demonstrated variation in flag leaf angle where the percentage of aus rice landraces with erect, semi erect and horizontal flag leaf were 41.94%, 45.16% and 12.90%, respectively. The qualitative characters showing higher variability were culm angle (19.35% erect, 45.16% intermediate and 35.48% open), internode color (96.77% light gold and 3.22% purple lines), culm strength (51.61 % strong, 45.16% moderately strong and 3.22% weak), panicle type (6.45% compact, 48.39% intermediate and 41.94% open), panicle exsertion (64.51% well exserted, 25.81% moderately well exserted and 9.68% just exserted), awns in the spikelet (58.06% absent and 41.94% present), distribution of awning (25.81% tip only, 6.45% upper half and 9.68% whole length), awn color (38.71% straw and 35.48% black).

Most of the tested landraces possessed straw lemma and palea colour (48.39%), red seed coat colour (45.16%), intermediate type leaf senescence (90.32%). The present study exhibited high variability in most of the observed qualitative traits of aus rice landraces. Similar types of work was also reported by other authors (Bisne and Sarawgi, 2008; Moukoumbi *et al.,* 2011; Ahmed *et al*., 2016; Mau *et al.,* 2017; Akter *et al*., 2017).

Quantitative traits characterization

Eigen values (latent roots) and percentage of total variation accounted for them obtained from principle component analysis are presented in Table 3. The result exposed that the first five components in the PCA with eigen values >1, contributed 80.37 % of the total variations among the genotypes for 14 morphological characters.

Islam *et al.* (2016) observed that the first nine axes accounted about 90% of the total variations by PCA in 113 aromatic and fine grain rice landraces. On the other hand, Sohrabi *et al.* (2012) and Chakravorty *et al.* (2013) observed the contribution of 76.7 and 75.9% of the first six and four components, respectively to the total variation in rice. On the basis of principal component axes I (PCA score 1) and II (PCA score II), a two dimension chart (Z_1-Z_2) of the 31 genotypes was constructed where the genotypes are presented in Fig.1. As per the scattered diagram the genotypes were apparently distributed into five clusters. Similar findings also reported by Habib *et al.* (2005) for traditional Biroin rice germplasm.

Table 3. Latent roots (Eigen Values) and their variation in 14 quantitative characters in 31 aus landraces

Principal component axes	Latent roots	Variation (%)	Cumulative % of variation
PC 1	4.28	30.57	30.57
PC 2	2.64	18.88	49.45
PC 3	1.79	12.79	62.24
PC 4	1.43	10.24	72.48
PC 5	1.10	7.89	80.37
PC 6	0.76	5.41	85.78
PC 7	0.61	4.36	90.14
PC 8	0.58	4.13	94.27
PC 9	0.34	2.44	96.71
PC 10	0.30	2.14	98.85
PC 11	0.13	0.93	99.78
PC 12	0.03	0.18	99.96
PC 13	0.01	0.04	100
PC 14	0.00	0.00	100

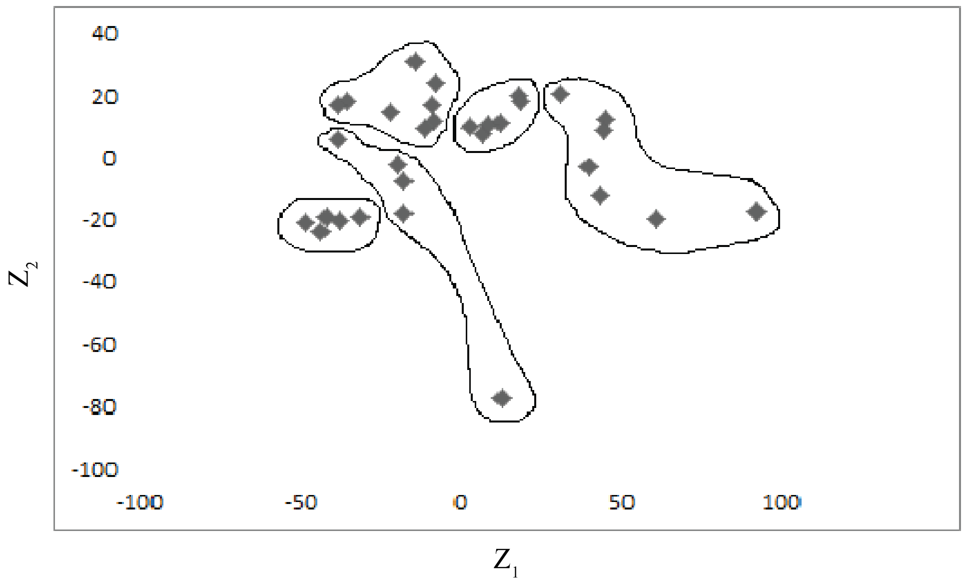

Fig. 1. Scatter diagram of 31 aus rice genotypes based on their principal component scores superimposed with clusters.

Based on the degree of divergence, 31 genotypes were grouped into five clusters on the basis of cluster analysis (Table 4). Islam *et al*. (2016) reported ten clusters, Ahmed *et al*. (2010) and Islam *et al*. (2014) reported six clusters each and Siddique *et al*. (2013) reported five clusters in their experiment with rice genotypes. The distribution pattern of the genotypes indicated that the maximum eight entries were grouped into the cluster II followed by seven in cluster IV, six in cluster V. Among five clusters, cluster I and III contained the lowest (5) number of genotypes

Table 4. Distribution of 31 aus rice genotypes into five clusters

Cluster	No. of genotypes	% Total	Name of genotypes
I	05	16.13	Bagunbichi, Aus dhan, V-3, Jaymori, Kalo Aus
II	08	25.81	Jteric, V-2, V-4, Minikit, Chaina, Saith shail, H-12, Kadidet
III	05	16.13	Hashikalmi, Kalo dhan, Porangi, Kalo hizli, Porangi
IV	07	22.58	Digha bawalia, Hanuman jata, Sondamoni, Raitul, Kuchmuch, Puitra aijang, Adub Alli
V	06	19.35	Boula, Sadey Aus, Mallika, Bar dhan Aus, Bar dhan Aus, H-171

Intra and inter-cluster distance are presented in Table 5. The inter-cluster distances in almost all of the cases was higher than the intra-cluster distance indicating that wider diversity was present among genotypes of distant groups. The germplasm were traditional and they showed high variability between them which was revealed from the results of intra and inter-cluster distance values. Here the highest intra-cluster value was 0.637 and the highest inter-cluster value was 10.168, which clearly indicated variability's in the germplasm of different clusters. However, lower values in clusters III (0.580) and IV (0.525) was observed due to lower variation in all morpho-agronomic data within these groups. The intra-cluster distances were low for all the six clusters with the range of 0.525 in cluster IV to 0.637 in cluster II which indicated apparently homogeneous nature of the genotypes within the clusters. The results were supported by the findings of Siddique *et al.* (2010 and 2011) in rice. The inter-cluster distances ranged from 3.352 to 10.168 and PCoA scores also indicated a high degree of genetic diversity among the genotypes. Regarding inter-cluster distance, cluster II showed the maximum genetic distance (10.168) from cluster V followed by cluster III (9.077) from cluster V, Cluster I (8.495) from cluster V and so on. Cluster V produced the highest inter-cluster distances (D^2 values) with all other clusters except IV suggesting wide diversity between the genotypes and the genotypes in these clusters could be used as parents in hybridization program for getting transgressive segregants (Saini and Kaiker, 1987). Moderate inter-cluster distance was observed between cluster II and III (6.123), followed by cluster III and IV (4.774), cluster I and IV (4.463). The minimum inter-cluster diversity was observed between cluster I and III (3.352), indicating that the genotypes of these clusters were genetically closed. The results were supported by the findings of Islam *et al*. (2014) in Sada jira rice germplasm.

Table 5. Intra (bold) and inter-cluster distances (D^2) for 31 Aus rice genotypes

Clusters	I	II	III	IV	V
I	**0.620**	7.785	3.352	4.463	8.495
II		**0.637**	6.123	7.727	10.168
III			**0.580**	4.774	9.077
IV				**0.525**	4.979
V					**0.605**

The highest cluster means for yield, effective tiller number and grain length, were obtained from cluster I (Table 6). The highest plant height, flag leaf length, culm length, days to flowering, days to maturity, filled grains per panicle and panicle length were found in cluster V. Moreover, the highest mean values for length-breadth ratio and 1000 grain weight were observed in cluster II and III, respectively. None of the 14 characters had the highest mean value under cluster IV. On the other hand, the lowest mean value for yield, culm length, plant height and grain breadth were found in cluster II, cluster III for flag leaf length, flag leaf width, days to flowering, days to maturity, panicle length and filled grains per panicle, cluster IV for grain length and length-breadth ratio. Again, the lowest cluster mean for 1000 grain weight and effective tiller number were observed in cluster I and V, respectively.

Mean performance of different clusters for the characters studied revealed that the maximum good characters were accumulated in cluster I and as a result higher grain yield (10.17g/ hill) was obtained in this cluster. Moreover, it was interesting that in most of the cases cluster V produced the highest inter cluster-value with all other clusters. Therefore, the genotypes of cluster I and V can be used in hybridization programme to produce higher yielding genotypes.

Table 6. Cluster means for fourteen characters in Aus rice genotypes

Characters	I	II	III	IV	V
Flag Leaf Length (cm)	47.12	43.88	40.76	48.17	53.37
Flag Leaf Width (cm)	1.25	1.15	0.96	1.15	1.19
Days to flowering	88.80	91.62	82.40	91.43	98.17
Days to maturity	119.6	122.12	112.6	121.71	129.50
Culm length(cm)	101.96	68.60	90.48	107.97	110.18
Panicle length (cm)	24.20	24.48	22.36	24.86	27.23
Plant height (cm)	126.16	93.07	112.84	132.83	137.42
Effective tiller (no.)	10.80	9.63	10.20	9.14	8.67
Filled grains per panicle (no.)	66.40	74.25	56.32	89.29	132.33
Grain length (mm)	9.07	8.50	8.56	8.34	8.48
Grain breadth (mm)	3.17	2.72	3.03	2.82	2.83
1000 grain weight (g)	22.40	23.93	25.06	24.53	24.43
Length-breadth ratio	2.43	2.69	2.44	2.41	2.63
Yield/hill (g)	10.17	7.10	8.64	8.17	7.69

Joshi and Dhawan (1966) reported that inclusion of more diverse parents (within a limit) is believed to increase the changes for obtaining stronger heterosis and give broad spectrum of variability in segregating generations. Therefore, more emphasis should be given on cluster I and V for selecting genotypes as parents for crossing with the genotypes of cluster II, which may produce new recombinants with desired traits. While, cluster II had the lowest cluster mean value for culm length, plant height, grain breadth and yield.

Contributions of the characters towards divergence are presented in Table 7. The canonical vector analysis revealed that the both vectors (vector 1 and 2) were not found positive for any of the 14 characters. Negative values for the two vectors for flag leaf length, culm length, panicle length, plant height and filled grains per panicle indicated the least responsibility of both the primary and secondary differentiation. However, positive absolute values of vector 1 and negative values for vector 2 for the traits effective tiller, grain breadth and yield indicated the responsibility of primary differentiation. On the contrary, negative absolute values for vector 1 and positive values for vector 2 for the traits of flag leaf width, days to flowering, days to maturity, grain length, 1000 grain weight and length-breath ratio indicated the responsibility of secondary differentiation. From the above result, it is assumed that Vector 1 obtained from PCA expressed that effective tiller, grain breadth and yield were those characters had some contribution to genetic divergence whereas in Vector 2, flag leaf width, days to flowering, days to maturity, grain length, 1000 grain weight and length-breath ratio played their role in genetic divergence.

Table 7. Relative contributions of the fourteen characters to the total divergence in Aus rice

Traits	Vector 1	Vector 2
Flag Leaf Length (cm)	-0.3302	-0.2150
Flag Leaf Width (cm)	-0.2078	0.0492
Days to flowering	-0.4240	0.0794
Days to maturity	-0.4222	0.0678
Culm length(cm)	-0.2402	-0.3695
Panicle length (cm)	-0.3222	-0.0250
Plant height (cm)	-0.2679	-0.3560
Effective tiller no.	0.0768	-0.0530
Filled grains per panicle (no.)	-0.3696	-0.1969
Grain length (mm)	-0.1107	0.3411
Grain breadth (mm)	0.2366	-0.4140
1000 grain weight (g)	-0.0356	0.1135
Length-breadth ratio	-0.2004	0.5013
Yield/hill (g)	0.0661	-0.2883

It is assumed that, the maximum amount of heterosis will be exhibited in cross combinations involving the parents that belong to most divergent clusters. However, for a practical plant breeder, the objective is not only high heterosis but also to achieve high level of yield and reducing the life duration. In the present study the maximum distances existed between cluster II and V. However, considering the cluster means and inter-cluster distances crosses between the genotypes of cluster I and cluster II, cluster I and cluster V would exhibit high heterosis as well as higher level of yield potential. So, based on this result, the genotypes under cluster I, cluster II and cluster V might be selected for future breeding programme.

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GROWTH ANALYSIS AND YIELD PERFORMANCE OF FOUR POTATO (*Solanum tuberosum* L.) VARIETIES

O. HOWLADER[1] AND M. A. HOQUE[2]

Abstract

An experiment with four potato varieties, namely Asterix, Cardinal, Diamant and Granola was conducted at the Horticulture Research Field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during November 2013 to February 2014 to observe the behaviour of growth parameters and yield potentiality of potato. Final harvest of tuber was done at 90 DAP. LAI, CGR, RGR and NAR were not significantly influenced by the varieties. Irrespective of varieties, LAI increased progressively with time reaching a peak at 60 DAP and thereafter declined. Granola maintained the lower LAI throughout all growth stages. Numerically, the maximum CGR (19.99 g m^{-2} day^{-1}) was found in Asterix at 50-60 DAP and the highest RGR (107.33 mg g^{-1} day^{-1}) as well as NAR (9.54 g m^{-2} day^{-1}) was recorded in Cardinal at 30-40 DAP. At 60-70 DAP, Cardinal recorded the highest TBR (84.35 g m^{-2} day^{-1}) while Asterix, the highest TGR (18.54 g m^{-2} day^{-1}) but Granola gave the lowest values of TBR (65.21 g m^{-2} day^{-1}) and TGR (14.92 g m^{-2} day^{-1}) at this growth stage. At all growth stages except 30 and 40 DAP, Diamant showed the best performance in SLA while Granola showed the lowest. The maximum yield was produced by Asterix (31.46 t/ha) closely followed by Diamant (29.91 t/ha) and Cardinal (27.27 t/ha) while the lowest yield was produced by Granola (24.82 t/ha). Granola showed the capacity of producing 95% or more of its final yield within 60 to 70 DAP. Therefore, Granola can be used as an early variety for potato cultivation.

Keywords: Potato, varieties, Leaf Area Index, Crop Growth Rate, Tuber Growth Rate. Tuber Bulking Rate and Yield.

Introduction

Potato (S*olanum tuberosum* L.) locally known as ‘Alu’ is a popular vegetables as well as cash crops in Bangladesh. It is the most important vegetable crop extensively grown all over the world and is called king of the vegetables (Mustafa, 1997). It is the second largest food crop in Bangladesh next to rice and has recently occupied an important place in the list of major food and cash crops of Bangladesh (Ali and Haque, 2011). The area and production of potatoes are increasing day by day due to its higher demand and profitability. Potato is grown more or less in all districts of Bangladesh but, better produced in the districts of Munsiganj, Bogra, Rangpur, Dinajpur and some parts of greater Comilla (Anon., 2014). More than 70 high yielding varieties (HYVs) of potato have been released for cultivation in our

[1&2] Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706, Bangladesh.

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country by the Tuber Crop Research Centre of BARI. Yield of these released varieties varies from 25-35 t/ha. Some of these varieties are late or some are early or medium late or medium early (Haque *et al*., 2012). Moreover, these varieties differ in various growth characters that largely influence the growing pattern, intercultural operations or yield of a particular variety.

Plant growth analysis, a collective technique used to quantify the components of growth such as crop growth rate, relative growth rate, net assimilation rate, specific leaf area etc. which regulate the crop yield that is a function of total dry matter production and its effective distribution on to economically important plant parts (Mbah and Eke-Okoro, 2015). These growth parameters allow describing the growth of the plant or plant organ and the relationship between the assimilatory apparatus and dry matter production (Olivera, 2000).

Research on potato cultivars is usually limited to analyzing differences in tuber yield, yet rarely do such analyses seek to account for the origins of such differences. For an optimum use of natural resources, an explanation for the production differences is important both for physiologists and agronomists (Borrego *et al*., 2000) to obtain useful information for the choice of genotype and the most appropriate agronomic practices to adopt. Indeed, potato cultivars show considerable diversity in terms of growth rates, due to their genetic make-up and their interaction with the environment. Therefore, a study of dry matter production and distribution in the various plant organs during development is important to determine a cultivar's growth rate and production. For this purpose, growth analysis has been widely used to study the factors that affect the plant's production and development as the accumulation of photosynthates in time (Ascione *et al.,* 2013). Proper growth analysis of a potato variety ensures the yield by timely performing the intercultural operations and other activities. But study on growth analysis in our climatic condition is very limited. The present study was therefore, undertaken to analyze the growth pattern and yield potentiality of four potato varieties.

Materials and Methods

The experiment was conducted at the Horticultural Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during November 2013 to Februry 2014. Single-factor experiment was laid out in Randomized Complete Block Design with three replications. Apparently disease free, uniform sized (28-55mm) and well sprouted seed tubers of four potato varieties *viz*., Asterix, Cardinal, Diamant and Granola were used as planting material for the experiment. Unit plot size was 4.8 m × 2.5 m and tubers were planted at a depth of 3-5 cm adopting a spacing of 60 cm x 25 cm. Seed tubers were planted on 24 November 2013 and final harvesting was done on 22 February 2014. Fertilizers were applied @ 150-44-125-22-3.2-1 kg/ha of N-P-K-S-Zn-B, respectively (Abdullah *et al*., 2010). Urea, Triple Super Phospahte (TSP), Muriate of Potash (MoP), Gypsum, $ZnSO_4$ and Boric acid were used as the sources of N, P, K. S. Zn and B, respectively. The land also received cowdung @ 10.0 t/ha. Half of urea and entire amount of cowdung, TSP, MoP, gupsum, $ZnSO_4$ and boric acid were applied during final land preparation and mixed in soil so that the tubers do not come in contact with fertilizers. The remaining half of N was top dressed at 30 days after planting (DAP). Irrigation, weeding, earthing up and other intercultural operations were done as and when necessary for raising a good crop. Furadan 5G @ 10 kg/ha was applied during the final land preparation to control cutworm and other soil borne insects. Malathion (0.2%) sprayed in two installments at 45 and 60 DAP to control insects. The crops were sprayed with Dithane-M 45 (0.2%) and Ridomil Gold (0.2%) alternately five times (at 30, 40, 50, 60 and 70 DAP) to prevent late blight infection and other diseases of potato.

Growth analysis was carried out by destructive sampling of plants with sequential harvesting at ten days interval. Five potato plants of each variety were randomly uprooted from the inner rows of the plots at 30, 40, 50, 60, 70 and 80 DAP. Total plant biomass was separated into leaves, stems, roots and tubers and fresh weight of each biomass group was taken with an electric balance. For dry matter estimation of each biomass group except tuber, the samples were kept in an oven. The temperature of the oven was set to 65°C and was dried until a constant weight was obtained. The final weight of the dried sample was taken by an electric balance. In case of tuber, about 100g of fresh tuber from each unit plot was measured and dry weight was taken at 30, 40, 50, 60, 70, 80 and 90 DAP following the procedure described above. This dry weight of 100 g tuber was used to calculate total dry weight per square meter. Leaf area per plant was measured with an automatic leaf area meter (Model AAM-8, HYYASHI, DENKOH, Japan) after harvest at different DAP. Growth parameters such as crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area index (LAI) and specific leaf area (SLA) were calculated by using the following formulae given by Gardner *et al.* (1985):

$$\text{CGR} = \frac{1}{\text{GA}} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2} \text{ day}^{-1}$$

Where, W_1 = dry weight (g) at time T_1, W_2 = dry weight (g) at time T_2 and GA = ground area or land area (m^2).

$$\text{RGR} = \frac{\text{Ln}W_2 - \text{Ln } W_1}{T_2 - T_1} \text{ mg g}^{-1} \text{ day}^{-1}$$

Where, W_1 = dry weight (g) of plant at time T_1, W_2 = dry weight (g) of plant at time T_2 and Ln = natural logarithm.

$$\text{NAR} = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\text{Ln}L_2 - \text{Ln}L_1}{L_2 - L_1} \text{ gm}^{-1}\text{day}^{-1}$$

Where, W_1= dry weight (g) of plant at time T_1, W_2= dry weight (g) of plant at time T_2, L_1= leaf area (m^2) at time T_1, L_2= leaf area (m^2) at time T_2 and Ln= natural logarithm.

$$\text{LAL} = \frac{\text{Surface area of green leaves (m}^2\text{)}}{\text{Land area from where the leaves were collected (m}^2\text{)}}$$

$$\text{SLA} = \frac{\text{Surface area of green leaves (cm}^2\text{)}}{\text{Leaf dry weight (g)}} \text{ cm2 g-1}$$

Whereas, tuber bulk rate (TBR) and tuber growth rate (TGR) were calculated by using following formulae given by Sen *et al.,* (2014).

$$\text{TBR} = \frac{1}{\text{GA}} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ gm}^{-1}\text{day}^{-1}$$

Where, W_1 = fresh weight (g) of tuber at time T_1, W_2 = fresh weight (g) of tuber at time T_2 and GA = ground area or land area (m^2)

$$\text{TGR} = \frac{1}{\text{GA}} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ gm}^{-1}\text{day}^{-1}$$

Where, W_1 = dry weight (g) of tuber at time T_1, W_2 = dry weight (g) of tuber at time T_2 and GA = ground area or land area (m^2)

Besides, data on fresh and dry weight of tuber per plant was also recorded at 90 DAP and dry matter (%) was calculated following the standard formula. The collected data on various parameters were analyzed using MSTAT-C program. The means were separated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Results obtained from the present study are presented below:

Leaf area index

Leaf area index (LAI) was measured for four potato varieties at 30 to 80 DAP (Fig. 1). The pattern of LAI at different stages was almost similar for all the varieties. Regardless of varieties, LAI increased sharply upto 40 DAP and afterwards LAI increased gradually reaching a peak at 60 DAP and declined thereafter. The sharp increase in LAI at 40 DAP might be due to production of more leaves per ground area and faster rate of leaf emergence and leaf expansion. At 50 DAP, Diamant recorded the maximum LAI closely followed by Asterix and Cardinal while Granola recorded the lowest LAI. Among the varieties, the maximum LAI was found in Cardinal (4.13) at 60 DAP, while in Granola it was found the lowest (3.19). The highest values of LAI at 60 DAP indicated full shooting of expanded leaves which increased the capacity factor for carbon assimilation. Higher LAI at 50 and 60 DAP was obtained which might be due to the higher number of leaves and branches per unit area. After 60 DAP, LAI for all the varieties showed declining trend but there was a marked variation among the values at 70 DAP stage. Significantly, the maximum LAI was found in Cardinal (3.37) closely followed by Diamant (3.21) and the lowest LAI was found in Granola (2.24) identical with Asterix (2.34). This might be due to the fact that Cardinal and Diamant had maximum number of leaves per ground area and less number senescent leaves compared to Asterix and Granola. These findings were in agreement with Ranjibar *et al.* (2012) and Sen *et al.* (2014), who reported the highest LAI at 60 DAP. According to findings of Ranjibar *et al.* (2012), LAI was the manifestation of the capacity factor of growth of the crop and it had a great effect on plant growth and the final yield of dried material.

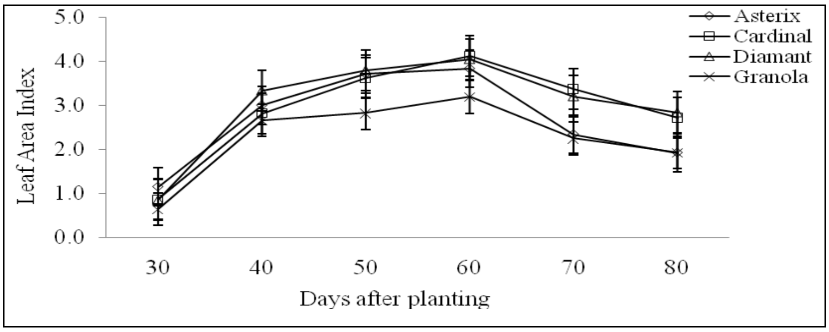

Fig. 1. Leaf area index of four potato varieties at different days after planting. Vertical bars indicate ±SE

Crop growth rate (g m^{-2} day^{-1})

The crop growth rate (CGR) of the four potato varieties were studied at different growth stages (Fig. 2). No significant variation in CGR value was observed among the varieties at all the growth stages. However, the CGR values increased progressively with time reaching peak at 50-60 DAP stage in Diamant, Cardinal and Asterix except Granola which recorded the maximum value of CGR at 40-50 DAP and thereafter declined till 70-80 DAP regardless of varieties. CGR values were found higher because of maximum leaf area index (LAI) between 50 and 60 DAP (Fig. 1). At 50-60 DAP stage the highest CGR was found in Asterix (19.99 g m^{-2} day^{-1}) followed by Diamant (18.45 g m^{-2} day^{-1}) and Granola (17.41 g m^{-2} day^{-1}), while the lowest was found in Cardinal (17.29 g m^{-2} day^{-1}). At 60-70 DAP and 70-80 DAP stages, Granola gave the lowest CGR values, 10.83 g m^{-2} day^{-1} and 8.98 g m^{-2} day^{-1}, respectively. At 70-80 DAP stage, the highest CGR was obtained in Asterix (11.28 g m^{-2} day^{-1}) followed by Cardinal (10.66 g m^{-2} day^{-1}) and Diamant (10.27 g m^{-2} day^{-1}). The decrease in CGR at the early of growing season indicates that the crop had an early maturing tendency. From this it may be interpreted that variety Granola had early maturing tendency, but the rest three varieties *viz*., Asterix, Cardinal and Diamant had late maturing tendency as they maintained higher CGR values till the last stage of sample harvest. Similar results were reported by Mahmud (2012) and Esfahai *et al*. (2012). At later stages, CGR value slowed down because of reduction in absorption of solar radiation and leaf falling (Borrego *et al.,* 2000). According to research findings of Esfahai *et al*. (2012), early maturing varieties reached maximum CGR during the early stage compared to the late maturing ones.

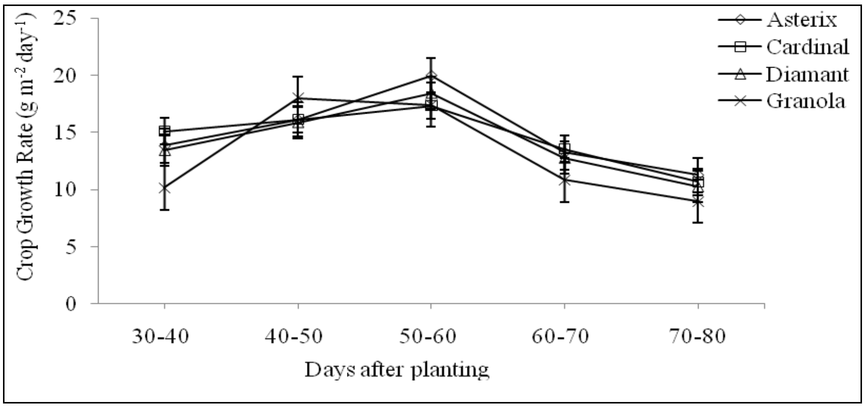

Fig. 2. Crop growth rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Relative growth rate (mg g^{-} day^{-1})

The relative growth rate (RGR) of four potato varieties were studied from 30 to 80 DAP growth stages (Fig. 3). No marked variation was observed in RGR value among the varieties at all the growth stages from 30-40 DAP to 70-80 DAP. Irrespective of varieties, the RGR values were earlier in the season and showed a decreasing trend as the crop advanced in age. The values of RGR were attained maximum at 30-40 DAP stage for each of the varieties. At this stage the highest RGR value was obtained from Cardinal (107.33 mg g^{-1} day^{-1}) followed by Asterix (93.18 mg g^{-1} day^{-1}) and Granola (91.73 mg g^{-1} day^{-1}), while the lowest from Diamant (89.37 mg g^{-1} day^{-1}). This may be interpreted as Cardinal is the most efficient variety in utilization of dry mass for further growth as relative growth rate expresses growth in terms of a rate of increase in size per unit of dry mass basis (Hunt, 2003). The greatest difference in RGR value among the varieties occurred at the time of tuber initiation (30 DAP) and development (40-50 DAP). For varieties Asterix, Cardinal and Diamant the RGR values declined very sharply after 30-40 DAP except Granola, which showed the highest RGR value (73.18mg g^{-1} day^{-1}) at 40-50 DAP stage. The RGR value decreased with plant age due to the fact that an increasing of the plant is structural rather than metabolically active tissue and as such does not contribute to growth. The decline in RGR value was also due to the decrease in net assimilation rate (NAR) (Fig. 4.). Our present findings were in agreement with Mahmud (2012) and Begum *et* *al*. (2011), who reported similar decreasing trend of RGR in potato varieties and the highest RGR value was calculated at 30-40 DAP. According to Abbas (2011), the variation in the RGR in the respective varieties might be due to difference in temperature or weather during the crop seasons.

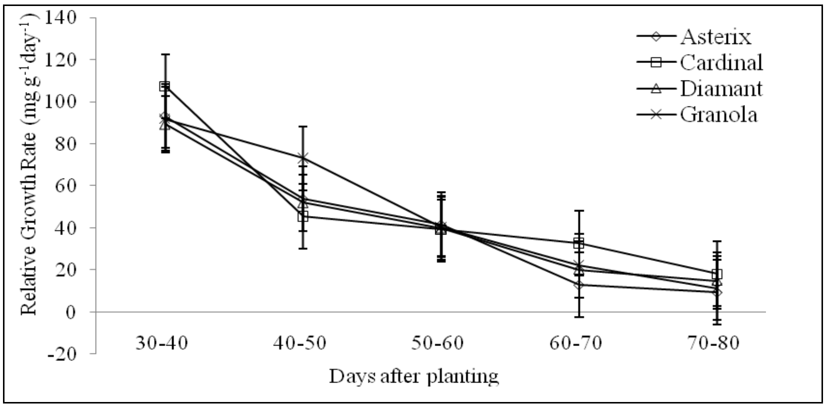

Fig. 3. Relative growth rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Net assimilation rate (g m^{-2} day^{-1})

Net assimilation rate (NAR) of four potato varieties were studied from 30-40 DAP to 70-80 DAP growth stages (Fig. 4). Among the varieties there were no significant variations found at these five growth stages. All the four varieties showed maximum level of NAR at the beginning of the growing season. The slight differences in NAR among the varieties were at the time of tuber initiation (30 DAP) and development (40 to 50 DAP). At 30-40 DAP, the highest NAR was found in Cardinal (9.54 g m^{-2} day^{-1}) followed by Diamant (7.74 g m^{-2} day^{-1}) and Granola (7.58 g m^{-2} day^{-1}), while the lowest in Asterix (7.52 g m^{-2} day^{-1}). NAR showed a decreasing trend with the advancement of crop upto maturity in case of four varieties. At the early of growing season, due to an underdeveloped canopy solar radiation can easily pass through the crop canopy. Thus underneath leaves can receive more solar radiation i.e. photosynthetic photon flux density (PPFD) for photosynthesis and consequently NAR was at the highest point at 30-40 DAP. As the crop develops, the underneath leaves receive lower amount of PPFD due to mutual shading of leaves and the aged leaves had lower photosynthetic efficiency. As a result, NAR was found lower compared to the preceding growth stage till 80 DAP. At 60-70 DAP and 70-80 DAP stages Granola maintained the highest NAR values of 4.83 g m^{-2} day^{-1} and 4.30 g m^{-2} day^{-1} and Asterix, the lowest NAR values of 3.79 g m^{-2} day^{-1} and 3.21 g m^{-2} day^{-1}, respectively. It might be interpreted as Granola had the capacity to manufacture higher photosynthates per unit leaf area and Asterix had the lowest capacity for this. The present findings were in agreement with Ranjibar *et al*. (2012) and Esfahai *et al*. (2012), who reported a decreasing pattern of NAR irrespective of potato genotypes. However, the differences of NAR in present findings might be due to genetical difference. According to Tekalign and Hammes (2005), the enhanced NAR might be attributed to the increased photosynthetic efficiency of leaves. Solar radiation, active photosynthesis increased the efficiency of net gain of assimilates (NAR) and eventually yield.

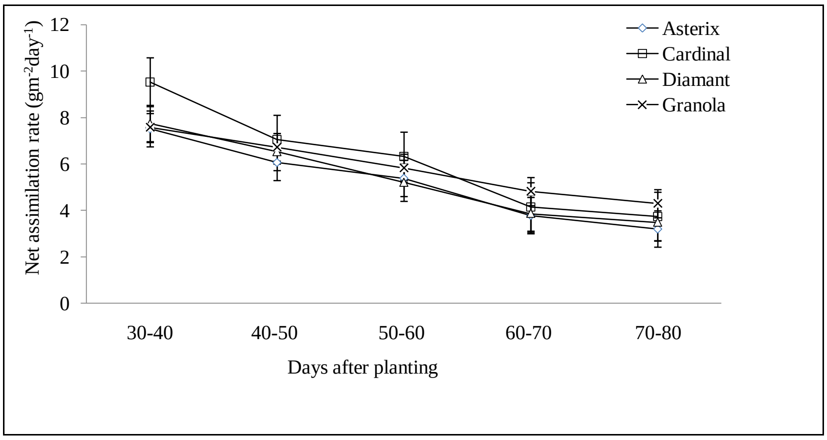

Fig. 4. Net assimilation rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Specific leaf area (cm^2 g^{-1})

Specific leaf area (SLA) of four potato varieties were measured at different growth stages (30 to 80 DAP) (Fig. 5). The pattern of SLA did not follow any definite pattern in this experiment. Marked variation was observed among the varieties at 30, 50 and 60 DAP. At 30 DAP the maximum SLA was observed in Cardinal (284.00 cm^2 g^{-1}) followed by Asterix (271.67 cm^2 g^{-1}) and Diamant (185.67 cm^2 g^{-1}), where the lowest was for Granola (154.33 cm^2 g^{-1}). At 40 DAP, SLA values did not show any significant variation, however it was highest in Granola (400.33cm^2 g^{-1}) and lowest in Cardinal (340.67 cm^2 g^{-1}). A different result was found at 50 DAP, when the highest SLA value was found in Diamant (370.67 cm^2 g^{-1}) followed by Asterix (320.00 cm^2 g^{-1}) and Cardinal (307.33 cm^2 g^{-1}). Granola showed the lowest value of SLA (281.00 cm^2 g^{-1}). Similar result was observed at 60 DAP, highest for Diamant (362.00 cm^2 g^{-1}) and lowest in Granola (294.67 cm^2 g^{-1}). Though at 70 and 80 DAP, no significant difference was found among the varieties with regard to SLA, Diamant showed the highest value, 320.67 cm^2 g^{-1} and 318.27 cm^2 g^{-1}, respectively and Granola had the lowest 279.67 cm^2 g^{-1} and 272.80 cm^2 g^{-1}, respectively. It is seen that after 40 DAP Diamant maintained the maximum SLA till 80 DAP compared to other varieties and Granola registered the lowest SLA till 80 DAP. So, Diamant had higher amount of leaf area available for light interception. Data revealed that all the varieties showed maximum specific leaf area at 40 DAP. It might be due to all the varieties had higher leaf area with lower leaf dry mass, as the plants were immature so ratio value was higher. Similar results were reported by Ranjibar *et al.* (2012), who obtained the higher specific leaf area were higher at the beginning of the growth (40 DAP). But during the growing period, the total leaf weight of plant was increased, and it caused the reduction of SLA.

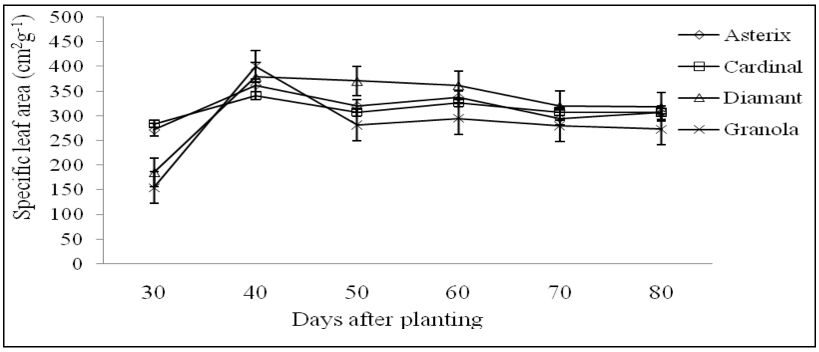

Fig. 5. Specific leaf area of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Tuber bulking rate (g m^{-2} day^{-1})

Tuber bulking rate of the four potato varieties were studied and data are represented in Fig. 6. Knowing the bulking profiles of varieties can be used to help determine when to harvest a crop for maximum yield. Knowing the bulking rate curves can also be useful in determining nutrient management practices, particularly nitrogen. Bulking profiles can be useful in determining when to apply nitrogen (Bohl and Love, 2004). Irrespective of varieties, tuber bulking rate (TBR) was found minimum at 30-40 DAP, where TBR values showed no significant variation among the varieties. But significant variation in TBR was found among the varieties at 40-50, 60-70 and 70-80 growth stages. After the initial stage (30-40 DAP), TBR in Diamant increased sharply upto 40-50 DAP and declined thereafter till 70-80 DAP. TBR in Asterix and Granola increased upto 50-60 DAP and then, in Granola TBR declined sharply while, in Asterix TBR decreased gradually till the sample harvest (70-80 DAP). From the initial stage (30-40 DAP), TBR in Cardinal increased progressively upto 70-80 DAP. At 50-60 DAP, the maximum TBR was found in Asterix (98.76 g m^{-2} day^{-1}) closely followed by Granola (98.67 g m^{-2} day^{-1}) and the lowest TBR was found in Cardinal (82.71 g m^{-2} day^{-1}). The highest bulking rate at 50-60 DAP was associated with greater leaf area index found between 50 and 60 DAP (Fig. 1). At 60-70 DAP, Cardinal showed the highest TBR (84.35 g m^{-2} day^{-1}) and Granola recorded the lowest value (65.21 g m^{-2} day^{-1}) and continued up to harvest. Almost similar pattern was found in the last stage (70-80 DAP), where, Cardinal had the highest TBR value (83.96 g m^{-2} day^{-1}), followed by Diamant (75.55 g m^{-2} day^{-1}) and Asterix (74.22 g m^{-2} day^{-1}), and Granola gave the lowest TBR (37.38 g m^{-2} day^{-1}). Sen *et al.* (2014) obtained peak tuber bulking rate at 45-60 DAP. The decrease in TBR value at earlier stages (after 50-60 DAP) may be due to the early bulking tendency of Granola. It may be concluded that Granola can be harvested slightly earlier than the other three varieties with an economic yield in our climatic condition, but Cradinal showed the highest TBR near harvest (70-80

DAP), it may take slightly more time to harvest and has potential to yield further in field followed by Diamant and Asterix. According to Kleinkopf *et al*. (2003), maximum bulking rates for any individual cultivar in the field can be determined by the physiological age of the seed and the environmental conditions during tuber initiation. To obtain adequate bulking rates for most commercial cultivars requires proper nutritional and production management. The growers have some control over the bulking rate through cultivar/seed lot selection and best management practices, but they have little control over annual environmental conditions during tuber initiation.

Tuber growth rate (g m^{-2} day^{-1})

The tuber growth (TGR) of the four potato varieties were studied from 30 to 80 DAP (Fig. 7). According to the results represented in the graph, the TGR in the plants followed a sigmoid pattern. In Asterix and Granola, TGR increased sharply upto 50-60 DAP beyond which it declined till 70-80 DAP. While in Diamant, TGR increased sharply upto 40-50 DAP, then increased gradually upto 50-60 DAP and thereafter declined. But TGR in Cardinal increased progressively upto 60-70 DAP and then decreased slightly.

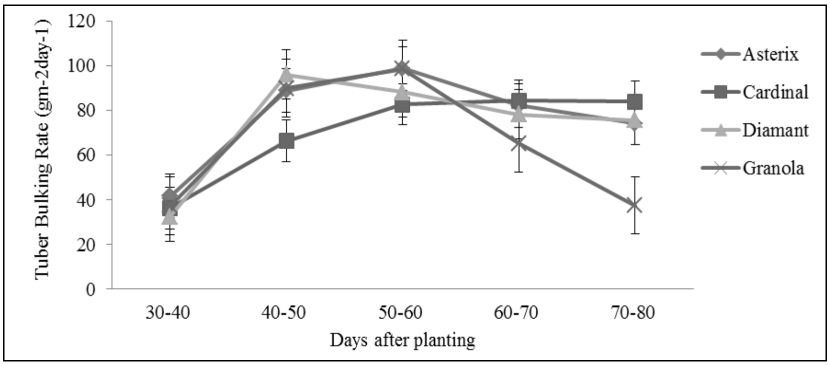

Fig. 6. Tuber bulking rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Minimum values of TGR were found at 30-40 DAP, where the varieties did not vary significantly. But marked variation was observed among the varieties at 40-50 DAP to 60-70 DAP stages. At 50-60 DAP, the highest TGR was attained by Asterix (20.72 g m^{-2} day^{-1}) followed by Granola (19.90 g m^{-2} day^{-1}), whereas, the lowest was for Cardinal (16.69 g m^{-2} day^{-1}) followed by Diamant (17.16 g m^{-2} day^{-1}). At 60-70 DAP a different scenario in TGR value was observed where Asterix (18.54 g m^{-2} day^{-1}) was the highest followed by Cardinal (18.18 g m^{-2} day^{-1}) and Diamant (16.59 g m^{-2} day^{-1}). At this stage Granola (14.92 g m^{-2} day^{-1}) showed the least TGR which indicates the earliness of this variety. On the other hand, Asterix and Diamant showed almost similar pattern of TGR at maturity (70-80 DAP). Though the TGR values at 70-80 DAP did not represent any marked variation, however, Cardinal showed the highest TGR (17.26 g m^{-2} day^{-1}) which might indicate that it required slightly more time to reach the maturity stage. Similar finding was reported by Sen *et al.* (2014), who obtained the highest TGR at 45-60 DAP whereas Mahmud (2012) recorded the highest TGR in Asterix at 50-60 DAP.

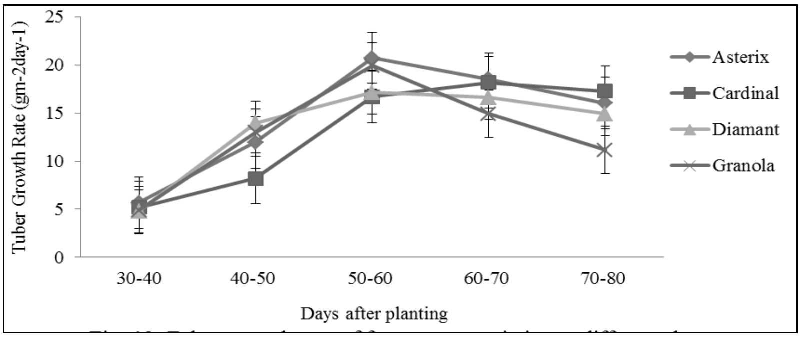

Fig. 7. Tuber growth rate of four potato varieties at different days after planting. Vertical bars indicate ±SE.

Fresh tuber yield (t/ha) from 30-80 DAP

Data revealed that fresh weight of tubers increased with the advancement of time. At 30 and 40 DAP, tuber fresh weight did not vary significantly among the varieties (Table 1). At 50 DAP, the highest fresh weight was produced by Asterix (13.23 t/ha) and the lowest by Cardinal (10.39 t/ha). Cardinal produced the lowest tuber fresh weight at 60 DAP, while Granola the highest (23.56 t/ha). At 70 and 80 DAP, Asterix produced the maximum fresh yield of 27.62 t/ha and 31.11 t/ha, respectively. On the other hand, Cardinal produced minimum yield at 70 DAP (21.89 t/ha) and Granola at 80 DAP (24.66 t/ha). But from the percentage values, it was clearly evident that in Granola, 95% of final yield was obtained at 60 DAP, whereas, in Asterix and Cardinal, more than 98% yield was obtained at 80 DAP, while in Diamant, more than 95% yield was obtained at this stage.

Table 1. Fresh yield of tubers of four potato varieties at different days after planting

Variety	Fresh yield of tuber (t/ha)					
	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	80 DAP
Asterix	0.17	4.35	13.23 a	23.11 a	27.62 a	31.11 a
	(0.55)	(13.81)	(42.07)	(73.46)	(87.80)	(98.89)
Cardinal	0.13	3.76	10.39 b	18.67 b	21.89 c	27.22 ab
	(0.48)	(13.79)	(38.12)	(68.45)	(80.27)	(99.82)
Diamant	0.11	3.35	12.97 a	21.78 a	23.11 bc	28.44 ab
	(0.37)	(11.21)	(43.35)	(72.81)	(77.27)	(95.10)
Granola	0.10	3.87	12.68 a	23.56 a	24.44 a	24.67 b
	(0.40)	(15.60)	(51.84)	(94.91)	(98.49)	(99.38)
Mean	0.13	3.83	12.36	21.78	24.27	27.86
CV%	14.26	10.61	7.80	7.00	3.33	8.9

In a column, means followed by same letter(s) are not significant at 5% level by DMRT. Figures in the parentheses indicate the percent of fresh yield compared to fresh yield at 90 DAP.

Fresh tuber yield at 90 DAP

Yield of four potato varieties showed statistically significant difference at different days after planting (Table 2). The highest fresh yield was found in Asterix (31.46 t/ha) and Granola showed the lowest (24.82 t/ha) (Table 2). Hoque *et al.* (2010) reported that, yield of Asterix, Cardinal, Diamant and Granola was 25-35 t/ha, 25-40 t/ha, 25-40 t/ha and 20-30 t/ha, respectively. The highest tuber yield per plant was obtained from Asterix (472.00 g) and the lowest from Granola (372.67 g). This was in agreement with the findings of Mahmud (2012), who recorded the highest yield per plant from Asterix (368.97 g). The variations in yield t/ha may be due to genetics, vegetative growth, crop duration/maturity and adaptability to prevailing environment. Yield was significantly influenced by variety and season of production (Sinha *et al.*, 1992). Patel *et al.* (2008) provided that higher tuber yield may be due to better plant growth, genotype, adaptability in wide range of environment and combined effect of all other growth and yield attributes.

Dry matter (%)

The highest dry matter content was found in Asterix during harvest (21.33%) and lowest in Granola (18.92%) (Table 2). According to Hoque *et al.* (2010), Asterix had 19% and Granola had 19.1% dry matter during harvest.

Dry yield of tubers (t/ha)

The highest tuber dry weight per plant was in Asterix (101.62 g) closely followed by Diamant and the lowest in Granola (70.51 g) (Table 2). Barghi *et al.* (2012) reported that Agria and Satina varieties obtained tuber dry weight of 95.0 g and 90.0 g per plant, respectively. From this table it is evident that, the highest dry tuber yield was found in Asterix (6.77 t/ha) and the lowest in Granola (4.70 t/ha). This finding was in agreement with the results of Harahagazwe *et al.* (2012), who reported to have 5.7-6.8 t/ha dry yield of tubers in eight CIP potato genotypes.

Table 2. Tuber yield and dry matter of four potato varieties at harvest (90 DAP)

Variety	Fresh yield of tuber		Dry matter (%)	Dry yield of tuber	
	g/plant	t/ha		g/plant	t/ha
Asterix	472.00 a	31.46 a	21.53	101.62 a	6.77 a
Cardinal	409.00 a	27.27 a	20.90	85.48 a	5.70 a
Diamant	448.67 a	29.91 a	21.40	96.02 a	6.40 a
Granola	372.67 b	24.82 b	18.92	70.51 b	4.70 b
Mean	425.58	28.37	20.56	88.17	5.88
CV%	20.85	20.84	14.32	13.66	13.64

In a column, means followed by same letter(s) are not significant at 5% level by DMRT.

Conclusions

Potato varieties did not vary significantly with each other with regard to Leaf Area lndex (LAl), Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR). Regardless of varieties, LAI increased progressively with time reaching a peak at 60 days after planting (DAP) and thereafter declined. In Asterix, Cardinal and Diamant the peak point in CGR was found at 60 DAP; while in Granola, the peak CGR found at 50 DAP. Tuber Bulking Rate (TBR) decreased sharply in Asterix, Cardinal and Granola up to 60 DAP and then decreased steadily in Cardinal but decreased in Asterix and Granola. While, in Diamant, TBR increased sharply up to 50 DAP and thereafter decreased steadily. On the other hand, in Asterix, Diamant and Granola Tuber Growth Rate (TGR) increased sharply up to 60 DAP beyond which it declined. But TGR increased up to 70 DAP in Cardinal. Granola produced tuber yield of 23.56 t/ha at 60 DAP and of 24.44 t/ha at 70 DAP, which were about 95% - 98.5% of final yield (24.82 t/ha obtained at 90 DAP). Therefore, Granola can be harvested within 60 to 70 DAP without significant yield reduction.

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RESPONSE OF HYBRID MAIZE TO BORON APPLICATION

M. S. RAHMAN[1], M. T. ISLAM[2], S. ISHTIAQUE[3]
M. J. U. SARKER[4] AND A. S. M. M. R. KHAN[5]

Abstract

An experiment was carried out at farmer's field of Kushtia district under High Ganges River Floodplain Soil (AEZ-11) during Rabi seasons of 2013-14, 2014-15 and 2015-16. The objectives of the study were to evaluate the effect of boron on the yield of hybrid maize (cv. BARI Hybrid Bhutta-9) and to find out the optimum dose of boron for higher yield and economic return. There were 6 treatments comprising 6 levels (0, 0.5, 1.0, 1.5, 2.0 and 2.5 kg B ha^{-1}) of boron along with a blanket dose of N_{256} P_{65} K_{45} S_{27} Zn_3 kg ha^{-1} and cowdung 5 tha^{-1}. Boron fertility of the initial soil was in medium level (0.33 µg g^{-1}). The experiment was conducted in RCB design with three compact replications. Results of three years study revealed that hybrid maize responded significantly to added boron for the first two years but for the third year the effect was statistically non significant. The highest grain yield was obtained with 2.5 kg B ha-1, which was marginally significant with boron control but statistically identical to rest of the boron levels. Although, the yield increased linearly up to 2.5 kg ha^{-1} but the effect was relatively better fitted with quadratic response function (R^2 = 0.943). The mean highest grain yield found to be 8.55 t ha^{-1} for 2.5 kg B ha^{-1} against 8.20 t ha^{-1} from 0.5 kg B ha^{-1} and 7.84 t ha^{-1} from boron control. Considering the boron fertilty of soil, response of maize to boron and economic return, the optimum dose of boron may be 0.5 kg ha^{-1} for the cultivation of hybrid maize for medium level boron fertile soil under AEZ-11 of Kushtia district or alike.

Keywords: Response, maize, boron, yield, return, MBCR.

Introduction

Maize (*Zea mays* L.) is the most important silage plants in the world because of its high yield, high energy forage produced with lower labor and machinery requirements than other forage crops (Roth *et al.*, 1995). Many environmental, cultural and genetic factors influence maize forage yield and quality. In Bangladesh, maize is cultivated mainly for grain; the agricultural area devoted annually to maize was 334975 hectare which was about 2.75% of cereal cultivating area and average grain production was 2445578 metric ton with an

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[1]Senior Scientific Officer, Agricultural Economics, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jessore; [2]Scientific Officer, Pomology Division, Horticulture Research Centre, BARI, Gazipur; [3]Scientific Officer, On-Farm Research Division (OFRD), BARI, Gazipur; [4]Former Director (T&C), BARI, Gazipur; [5]Chief Scientific Officer, On-Farm Research Division (OFRD), BARI, Gazipur, Bangladesh.

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average yield of 7.30 t ha^{-1} during the year 2015-16 (BBS, 2017). For its high yielding capacity and diversified uses, demand of maize is increasing day by day in the world as well as in Bangladesh. It is now widely used in the poultry farms as animal feed, as well as the people consume roasted and fried maize in Bangladesh. Maize has an immense potential to reduce shortage of food, poultry feed and malnutrition. Because, it is a high yielding and low- cost crop compared to rice and wheat (Rahman, 2011).

Bangladesh Agricultural Research Institute (BARI) has been conducting research activities for varietal development of maize since 1960. Initially, thrust was given for development of composite varieties. So far, BARI has developed seven open pollinated and fifteen hybrid maize varieties. The yield potentiality of the released composite varieties varied from 5.5 - 7.0 t/ha and the hybrid varieties ranged 7.4 – 12.0 t/ha (Rahman, 2011). In Bangladesh, maize farmers cultivate imported commercial hybrid seed (900M, 981, 987, NK 40, Pinnacle, 759, Pioneer-96, Elite, Miracle, Super Gold, Sunshine, Pioneer-V-92 etc.) which is imported by different private seed companies. The grain yield of BARI varieties was lower compared to imported commercial varieties (Khan, *et al.*, 2016; BARI, 2015). Due to tallness of the BARI maize varieties, farmers faced problems with top dressing and intercultural operation (Miah, *et al.,* 2013).

Boron plays an important role in cell-wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, regulation of plant hormone levels, and generative growth of plants (Marschner, 1995). Boron is taken up as a boric acid, which is translocated slowly within the plant. Deficiency symptoms can include a failure of root tips to elongate, inhibition of DNA and RNA synthesis and inhibition of cell division in the shoot apex of young leaves. Boron is also known to be critical in the elongation of the pollen tube (Salisbury and Ross, 1992). One of the challenges in corn production is its sensitivity to B deficiency (Salisbury and Ross, 1992; Soylu *et al.*, 2004). Boron, a micronutrient, is essential for pollen viability and seed production of crops as well as flowering and fruiting. It also plays vital role in nitrogen metabolism, hormonal action and cell division (BARI, 2006).

Maize has been previously considered to have a relatively low boron (B) requirement as compared to other cereals (Martens and Westermann, 1991). However, based on field responses to B application, its deficiency has been reported in maize across five continents (Bell and Dell, 2008; Shorrocks, 1997; Shorrocks and Blaza, 1973). For example, maize yield increase of 10% were reported in Rhodesia (now Zimbabwe), up to 26% in India (Shorrocks and Blaza, 1973), more than 10% in Switzerland (cited by Mozafar, 1987) and by 9% in China (Li and Liang, 1997). Deficiency of B in field grown maize was first observed in the 1960s in the United States (Shorrocks and Blaza, 1973), and yield increase of more than 10% were observed in response to B application (Woodruff *et al.*, 1987).

Limited studies on B deficiency of various crops including maize suggest a critical soil solution content ranging from 0.15 mg of B kg^{-1} to 1.0 mg of B kg^{-1} and 2.0 mg B kg^{-1} and a critical leaf B concentration of 30 mg kg^{-1} (FAO, 1990). However, additional studies are needed as soil chemical and physical properties and species selection influence B availability to and uptake by plants possibly resulting in large variability in optimum economic B rates for various crops and soils.

Sarkaut *et al.* (2013), Akhter and Mahmud (2009), BARI (2009), Akhter and Khan, 2007 and Singh, 1998 found significant response of hybrid maize to boron application. Akhter and Mahmud, 2009 reported that the yield of maize grain increased significantly due to added boron up to 2.0 kg B ha^{-1} and yield components like plant height, ear height and straw yield were influenced significantly due to application of boron. Singh (1998) found that Rabi maize gave the optimum yield at 1.5 kg ha^{-1} B application and Kharif maize produced the best yield at 2.0-2.5 kg B ha^{-1} rate. Boron application increased maize yield, indicating B deficiency (Gunes *et al.*, 2011).

In mustard, chickpea, mungbean, soybean, groundnut, cauliflower, tomato, papaya and wheat, positive response to boron fertilization were found (Rashid *et al.*, 2012; Hossain *et al.*, 1995; Islam, 2005; Saha *et al.*, 2003; Sinha *et al.*, 1991; Shen *et al.*, 1998). These studies revealed that boron is very important in cell division and in pod and seed formation. Rate of water absorption and carbohydrate transaction is restricted due to boron deficiency. Thus, boron fertilization is necessary for improvement of crop yield and nutritional quality. There is a good scope to introduce hybrid maize with proper management of fertilizer. This will help increase the present production and requirement. The response of hybrid maize to boron has not yet been tested under different agro-climatic conditions especially for calcareous soils under greater Kushtia region. Considering the above perspectives, the present experiment was undertaken to evaluate the effect of boron on the yield of hybrid maize and to findout the optimum dose of B application for the cultivation of hybrid maize with greater economic profitability.

Materials and Methods

The study was conducted at Multi Location Testing (MLT) site of Kushtia sadar (Latitude: 23.87736^0 N Longitude: 89.09126^0 E) during the periods (November to April) of 2013-14 to 2015-16 at farmers' field condition. Its altitude is 17m. The average high temperature is 37.8° C and the average low is 9.2° C. Annual rainfall averages 1,467 millimeters. The soil is calcareous in nature under High Ganges River Floodplain (AEZ-11). Before setting up of the experiment, soil samples were collected at depth of 0-15 cm to determine baseline its properties. Soil samples were air-dried, crushed, and sent to SRDI laboratory for analysis. The nutrient status of initial soil is presented in Table 1. The content of B in the initial soil was in medium level (0.33 µg g^{-1}). Based on the soil properties, the blanket dose of all nutrients except boron was estimated following FRG, 2012.

Table 1. Chemical properties of initial soil (0-15 cm depth) of the experimental field at Bottoil, Kushtia sadar, Kushtia during 2013-14.

Replication	pH	Organic matter (%)	K	Total N (%)	P	S	Zn	B
			meq/100 g soil		µg g^{-1}			
R_1	7.8	1.87	0.24	0.09	11.70	20.40	0.72	0.34
R_2	8.1	1.88	0.27	0.10	10.70	18.21	0.74	0.31
R_3	7.9	1.82	0.28	0.09	8.80	18.40	0.72	0.35
Mean/Range	7.8-8.1	1.86	0.26	0.09	10.40	19.00	0.73	0.33
Critical limit	-	-	0.12	0.12	10	10	0.60	0.20
Interpretation	Slightly Alkaline	Medium	Medium	Low	Low	Medium	Low	Medium

The experiment was laid out in randomized completely block design with three compact replications. There were 6 levels of B (0, 0.5, 1.0, 1.5, 2.0 and 2.5 kg ha^{-1}) applied in the form of boric acid. In addition, a blanket dose of N_{256} P_{65} K_{45} S_{27} Zn_3 kg ha^{-1} was applied in the forms of urea, TSP, MoP, gypsum and zinc oxide. Cowdung was applied @ 5 t ha^{-1}. As such, 6 treatments were used in this study. BARI hybrid butta-9 variety was used as the test crop. The unit plot size was 4 m x 5 m. Seeds were sown on 20 November, 2013, 07 November, 2014 and 16 November, 2015 with a spacing of 60 cm × 20 cm and the seed rate was 20 kg ha^{-1}. All P, K, S, Zn, B and one third of N were applied as basal dose at the time of final land preparation and the remaining two third of N was top dressed in two equal splits at 8-10 leaf stage and teaseling stage. Weeding was done two times at 31 days after sowing (DAS) and 51 DAS. The crop was irrigated 4 times at 31, 62, 77 and 103 DAS. Common cutworm was attacked in the maize filed in seedling stage. Dursban was applied in maize field @ 5 ml L^{-1} of water to control common cutworm. No disease was noticed in the maize field. The maize grain was harvested on 22 April, 2014, 10 April, 2015 and 18 April, 2016. The necessary data on different parameters were recorded from 1 m^2 in 3 areas from each treatment. Then it was computed and analyzed statistically using R package. The analyzed data was adjusted with Least Significant Difference (LSD) test at 5% level. Per hectare gross return, total variable cost, gross margin and marginal benefit cost ratio (MBCR) was calculated.

Results and Discussion

Yield components

There was no significant effect of boron on the yield components like plant height, ear height, number of grain per cob (2015-16) and 100 grain weight (except 2013-14) of hybrid maize although a positive trend of improvement was noticed (Table 2). The number of grain per cob increased significantly with the increased rate of boron application up to 2.5 kg B ha^{-1} during the year 2013-14 and 2014-15. Hundred grains weight increased significantly due to higher boron application during 2013-14. Numerically, the studied parameters showed the highest result with 2.5 kg B ha^{-1} and the lowest from boron control in most of the cases. The highest plant height was recorded in T_6 treatment in all the years except 2014-15 (Table 2). The ear height was the highest in T_6 treatment during 2013-14 and 2014-15. Numbers of grain per cob and 100 grain weight were maximum in T_6 treatment in all the year. Similar positive responses were found by Sarkaut, *et al.*, 2013; Gunes *et al.*, 2011; Akhter and Mahmud, 2009; Akhter and Khan, 2007 and Singh, 1998.

Grain yield

The yield of hybrid maize responded significantly to added boron for the first 2 years of the study but in the third year the effect was statistically non significant (Table 2). Residual effect of boron for a medium B fertile soil might have resulted in non-significant effect. However, the highest grain yield (8.40 and 8.77 t ha-1 for 2013-14 and 2014-15, respectively) was obtained with 2.5 kg B ha-1, which was narrowly ($p > 0.05$) significant with boron control but statistically identical to rest of the boron levels. The mean highest grain yield (8.55 tha^{-1}) was found in T_6 and the lowest yield (7.84 tha^{-1}) was in T_1. In fact, the yield of hybrid maize in T_6 was 9 percent higher than that of T_1. Boron fertility of initial soil was in medium level, which in presence of added cowdung might have resulted in relatively lower contribution of boron to the yield of hybrid maize. The yield was the highest in T_6 treatment due to its higher number of grain per cob and 100 grain weight. For straw yield, the effect of B showed similar trend although it was statistically non-significant. Similar findings of positive response were reported by Sarkaut *et al.* (2013), Gunes *et al.* (2011), Akhter and Mahmud (2009), Akhter and Khan (2007) and Singh (1998).

Cost and return of maize

The cost of maize cultivation for different treatments is shown in Table 3. The average highest gross return (Tk. 147249 ha^{-1}) was obtained from T_6 (2.5 kg B ha^{-1}). About 8.83 percent more return was found in T_6 treatment compared to T_1. The average highest total variable cost (Tk. 80942 ha^{-1}) was calculated on T_6. As a result, the average gross margin was also the highest in T_6 treatment (Tk. 66277 ha^{-1}). The marginal benefit cost ratios (MBCR) found to be positive and varied from 4.47 to 11.45. The highest MBCR (11.45) was obtained from T_2 treatment (0.5 kg B ha^{-1}) indicating that it was the most economically viable treatment among all other treatments.

Table 2. Yield and yield components of maize at different treatments of B application rates at MLT site, Kushtia during 2013-14 to 2015-16

Treatments	Plant height (cm)			Ear height (cm)			No. of grain cob^{-1}			100 grain wt (g)			Grain yield (tha^{-1})			Stover yield (tha^{-1})		
	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16	2013-14	2014-15	2015-16
T_1	224.10	215	220	118.33	114	118	488	500	441	31.67	33.00	32.00	7.83	7.89	7.85	9.60	10.34	9.10
T_2	225.27	214	220	120.00	115	121	519	516	440	32.00	33.33	33.50	8.07	8.33	8.20	9.73	10.50	9.20
T_3	224.83	217	219	119.33	117	119	524	519	442	32.00	34.00	32.00	8.07	8.40	8.27	9.70	10.47	9.08
T_4	225.80	217	222	118.67	118	119	523	522	452	32.67	34.67	33.67	8.20	8.53	8.29	9.73	10.43	9.22
T_5	224.80	219	223	120.00	114	121	535	537	450	33.67	35.00	34.00	8.30	8.67	8.37	9.70	10.53	9.07
T_6	227.50	218	224	120.00	119	120	541	538	452	33.33	35.33	34.50	8.40	8.77	8.49	9.80	10.50	9.13
CV (%)	6.75	3.95	6.99	5.41	4.61	5.18	4.53	3.17	7.39	3.35	6.78	7.76	3.82	5.47	5.67	5.83	7.18	5.14
LSD (0.05)	NS	NS	NS	NS	NS	NS	42.96	30.07	NS	1.98	NS	NS	0.57	0.84	NS	NS	NS	NS

T_1 = 0 kg ha^{-1} B, T_2 = 0.5 kg ha^{-1} B, T_3 = 1 kg ha^{-1} B, T_4 = 1.5 kg ha^{-1} B, T_5 = 2 kg ha^{-1} B and T_6 = 2.5 kg ha^{-1} B

Table 3. Mean yield, cost and return of maize at different treatments of B application rates at MLT site, Kushtia during 2013-14 to 2015-16

Treatments	Mean yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
T_1	7.84	135303	78267	57036	0
T_2	8.20	141428	78802	62626	11.45
T_3	8.25	142201	79337	62864	6.45
T_4	8.34	143681	79872	63809	5.22
T_5	8.45	145297	80407	64891	4.67
T_6	8.55	147249	80942	66277	4.47

T_1 = 0 kg ha^{-1} B, T_2 = 0.5 kg ha^{-1} B, T_3 = 1 kg ha^{-1} B, T_4 = 1.5 kg ha^{-1} B, T_5 = 2 kg ha^{-1} B and T_6 = 2.5 kg ha^{-1} B.

Conclusion

Considering the boron fertilty of soil, maize response to boron and economic return, it can be concluded that boron played significant role in augmenting the yield of hybrid maize and the optimum dose of boron may be 0.5 kg ha^{-1} for the study area. Therefore, for medium level boron fertile soil under AEZ-11 of Kushtia district or alike, application of 0.5 kg B ha^{-1} may be recommended for the cultivation of hybrid maize. Besides, a blanket dose of other nutrients (N_{256} P_{65} K_{45} S_{27} Zn_3 kg ha^{-1} and cowdung 5 t ha^{-1}) should also be applied on the basis of soil test following FRG -2012.

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YIELD LOSS ASSESSMENT AND MANAGEMENT OF FOOT ROT (*Sclerotium rolfsii)* OF BUSH BEAN

K. M. ALAM[1], M. M. ALAM[2], R. ISLAM[3], M. A. A. KHAN[4] AND M. N. ISLAM[5]

Abstract

The released three varieties of bush bean (BARI Jhar Shim-1, 2 and 3) were grown in both *Sclerotium rolfsii* inoculated and un-inoculated plots to assess the yield loss in the field of Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur during 2013. *Sclerotium rolfsii* infected the bush bean plant in every growth stage and reduced the germination capacity and lessened plant vigor. The yield loss ranged from 55.43 to 64.94%. A screening study was conducted to observe the resistant level of released varieties and local lines collected from On Farm Research Division (OFRD), BARI, Sylhet during 2013. B0124 and BARI Jhar Shim-3 showed susceptible and the others showed highly susceptible reaction. The antagonistic potential of the local isolates of *Trichoderma harzianum* against the phytopathogenic *S. rolfsii* was investigated in dual culture and bioassay on bean plants. Isolated *T. harzianum* showed antagonism effect against *S. rolfsii* and restricted around 80% mycelial growth in-vitro. A field experiment was carried out in Plant Pathology Division, BARI, Gazipur during 2014 to observe the efficacy of *T. harzianum* in controlling foot rot disease induced by *S.rolfsii* of bush bean in the field. Soil treated with *T. harzianum* mass plus seed treated with Provax 200 WP showed the lowest disease incidence (28.47%) and the highest germination (98.61%) and yield (873.33 kg/ha) in compared to other treatments with pathogen inoculated soil.

Keywords: Foot rot, *Sclerotıum rolfsıı*, *Trıchoderma harzıanum*, Yield loss and Bush bean

Introduction

Bush bean (*Phaseolus vulgaris*) is cultivated commercially in Chittagong, Sylhet, North Bengal, Hill tracts and also many other places of Bangladesh. The crop is considered to be the important exporting vegetables of Bangladesh. But cultivation area and production of bush bean are reducing day by day due to several biotic and abiotic factors. Foot and root rot caused by *Sclerotıum rolfsii*, *Fusarium oxysporum*, *Fusarium solani*, *Sclerotinia sclerotiorum* and *Rhizoctonia solani* are a common disease problem in bush bean (Ellil *et al*., 1998; Rashid and Singh, 2000 and Mozumder, 2004). The foot and root rot disease resulted 0 -

[1&5]Scientific Officer, Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, [2&3]Senior Scientific Officer, Plant Pathology Division, BARI, Gazipur-1701, [4]Scientific Officer, Regional Agricultural Research Station, BARI, Ishurdi, Pabna, Bangladesh.

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90% plant mortality of bush bean (Chunje and Zhibiao, 1996). In Bangladesh, foot rot disease caused by *S. rolfsii* is one of the important limiting factors in bush bean production. Among the major diseases, foot rot of bush bean caused by *S. rolfsii* is economically important one. The pathogen is a soil inhabitant, polyphagous and facultative fungal parasite. It is documented that the fungus has host range of 500 plant species (Punja, 1985). *S. rolfsii* is predominantly distributed in tropical and subtropical countries. It is common in rainy season, when warm temperature and high relative humidity exist. Garret (1956) reported that the fungus survived in the soil for many years by producing sclerotial bodies and causing the disease either in the form of stem rot or foot rot or root rot in addition to leaf blight on several of its hosts.

There is no clear estimation report on yield loss of bush mean due to *S. rolfsii* and also, lack of knowledge about pathogenesis of this disease. Using resistant line is the best way to control disease and reduce yield loss. Besides, *S. rolfsii* is soil borne pathogen, in most of the cases; this disease is difficult to control by any chemical means. Many approaches have been exploited for the management of this disease. Management of foot rot has been accomplished primarily by the application of chemical fungicides but not considered to be long-term solutions, due to its high cost, exposure risks, residual toxicity and other health and environmental hazards. In an attempt to overcome this problem, some alternative methods of control may be adopted.

Biological control of plant diseases has been the subject of extensive research in the last two decades. *Trichoderma* spp. is well documented as effective biological control agents of plant diseases (Sivan *et al.*, 1984 and Coley-Smith *et al.*, 1991). Control of soil borne plant pathogens including *S. rolfsii* can be achieved by different fungicides, soil fumigants (methyl bromide) and bioagents. Because of toxicity of these compounds, there is a general trend to reduce the amount of application in the soil. *S. rolfsii* is an economically important pathogen on numerous crops worldwide. It has an extensive host range; at least 500 species in 100 families are susceptible, the most common hosts are legumes, crucifers, and cucurbits, and commonly occurs in the tropics, subtropics, and other warm temperate regions (Punja, 1985).

Trichoderma harzianum was found to be an effective biological control agent for reducing yield loss due to disease induced by *S. rolfsii* under both greenhouse and field conditions (Elad *et al*., 1980 and Ciccarese *et al*., 1992).

Therefore, the present study was undertaken to estimate the actual yield loss caused by foot rot disease to commercial varieties of bush bean, to isolate the bio-agent, *Trichoderma* in agricultural fields and to evaluate its potential in controlling *S. rolfsii*, to develop sustainable management approach (es) against foot rot disease and to reduce yield loss of bush bean.

Materials and Methods

Collection of bush bean seed

Three varieties namely, BARI Bush bean 1, BARI Jhar Shim-2 and BARI Jhar Shim-3 were collected from Horticultural Research Center (HRC), BARI, Gazipur. Five local lines were collected from On Firm Research Division (OFRD), BARI, Sylhet.

Pathogen isolation

The pathogen was isolated from collar region of infected bush bean plant. At first, sample was washed thoroughly under running tap water to remove attached soil. Then sample was surface sterilized by using 20% Clorox for 2 min. Then Clorox was washed out twice by submerging in sterilized distiled water for 2 min. Sterilized pieces was placed on water agar plate and blotter plate and kept in growth chamber at 25^0C. After three days, mycelium growth on samples was isolated and put on PDA containing plate and kept in growth chamber at 25^0C. After purification, isolate of *S. rolfsii* was preserved in PDA containing slant at -20^0C.

Trichoderma isolation and identification

Soil samples were collected from bush bean disease infected field of OFRD, BARI, Sylhet. The collected rhizospheric soil samples were used for isolation of *Trichoderma* sp. through dilution plate method in PDA (Elad *et al*., 1983) and the morphologically different colonies from each medium were picked up and purified (Johnson and Elory, 1972). They were allowed to sporulate under temperature of 28 ± 2^0C; 12 hrs. dark and 12 hrs. light.

Mass preparation of inoculum

Inoculums of the *S. rolfsii* and *T. harzianum* isolates were prepared on autoclaved moist wheat bran in 1000 ml Erlenmeyer flask. Before using the wheat bran was soaked in water for 12 hours @ 2:1 (w/v). Then it was sterilized in autoclave at 121^0C under 1.1 kg/cm^2 pressures for 40 minutes. Five-millimeter diameter mycelial discs were cut from the edge of three days old PDA cultures in Petri dishes. Thirty to thirty five discs of *S. rolfsii* and *T. harzianum* were added to autoclaved wheat bran individually in the flasks and incubated at 25 ^{0}C for 14 days. It was shaken by hand at 2-3 days interval for proper colonization. The colonized wheat bran was air dried for 2 days and stored at 4 ^{0}C for further work.

Observation on yield loss of bush bean varieties due to infection of foot rot disease

This study was conducted in the field on Plant Pathology Division, BARI, during winter 2013. This study was carried out following RCBD with 3 replications.

Three BARI released varieties were grown on uninfected and disease infected plots. Inoculum mass of *S. rolfsii* was uniformly (20g / m^2) mixed with soil before 15 days of seed sowing in disease infected plots.

Observation of disease reaction of *S. rolfsii* against local lines of bush bean

The study was conducted in seed bed during winter 2013, on infected soil with *S. rolfsii* (20g/m^2). Five local lines and BARI Jhar Shim-3 were used in this study. Seven seeds in a line were sown in seed bed. This study was undertaken following RCBD with 3 replications where each replication contains three lines. Disease reaction of foot rot disease was graded at 0-4 scale as described by Chester (1950) where, 0 = no disease (I), 1 = 5% plants infected (R), 2 = 6-25% plants infected (MR), 3 = 26-50% plants infected (S) and 4 = 51-100% plants infected (HS). Germination of BARI Jhar Shim-3 and other lines were tested in laboratory of Plant Pathology Division, BARI during August, 2013. One hundred seeds of each variety and line were used in this test. Ten seeds were placed on a water soaked blotting paper in plate. Germination percentage was counted after 7 days of seed placing on blotting paper.

In vitro dual culture assay of *T. harzianum* against *S. rolfsii*

Three days young mycelial discs of *T. harzianum* isolate of 5 mm diameter were cut from the peripheries of expanding colonies grown on PDA with a cork borer. Three discs of *T. harzanum* were placed at the edges of each plate poured with 15ml PDA and one disc of *S. rolfsii* at the centre. All plates were incubated in the dark at for 28±2^0C until the mycelium of *S. rolfsii* fully covered the control.

Efficacy of *T. harzianum* against *S. rolfsii* in field

A field study was conducted in field of Plant Pathology Division, BARI, Gazipur during 2014. BARI Jhar Shim-3 was used in this study. Inoculum mass of *S. rolfsii* was uniformly (20 g/m^2) mixed with soil before 15 days of seed sowing. Five treatments with three replications were used following RCBD. Treatments were 1) control (without pathogen inoculation) (T_1), 2) control (with pathogen inoculation) (T_2), 3) soil treatment with Provax 200 WP (Carbixin+Thiram) @ 0.2% (T_3), 4) soil treated with *T. harzianum* mass (20 g/m^2) (T_4) and 5) Seed treatment with Provax 200 WP (Carbixin+Thiram) @ 0.2% + Soil treated with *T. harzianum* mass (20 g/m^2) (T_5). *S. rolfsii and T. harzianum* mass was uniformly mixed with soil before 15 and 3 days of seed sowing, respectively.

Observations and data analysis

The statistical analysis of data was carried out using standard analysis of variance-ANOVA by using MSTAT-C software (Russel and Eisensmith, 1993). To determine the significance of the difference between the means of two treatments, least significant difference (LSD) was computed at 5% probability level.

Results and Discussion

Yield loss of commercial Bush bean varieties due to infection foot rot disease

To observe the effect on yield of commercial bush bean varieties due to foot rot disease, three BARI released varieties were tested under inoculated condition. It was observed that *S. rolfsii* infected the bush bean in every stage of growth. *S. rolfsii* had effect on the germination of Bush bean. Germination percentage of BARI Bush bean 1, 2 and 3 were 91.66, 94.44 and 95.83% in uninfected plots whereas those were 63.89, 66.67 and 72.22% in infected plots, respectively (Table 1).

Table 1. Effect of *S. rolfsii* on germination and yield of three varieties of bush bean

Varieties	Treatment	Germination (%)	Yield (kg/ha)	Yield loss (%)
BARI Jhar Shim-1	Uninfected	91.66 a	1082 b	64.94
	Pathogen infected	63.89 c	379.33 d	
BARI Jhar Shim-2	Uninfected	94.44 a	1056 b	61.74
	Pathogen infected	66.67 bc	404 d	
BARI Jhar Shim-3	Uninfected	95.83 a	1139.66 a	55.43
	Pathogen infected	72.22 b	508 c	
LSD (0.5%)		5.81	41.83	
CV (%)		4.18	3.19	

*Values within a column with a common letter do not differ significantly (P= 0.05).

Table 2. Disease incidence in *S. rolfsii* infected and uninfected field on three varieties of bush bean released by BARI.

Varieties	Treatment	No. of Cotyledon infected plant	No. of twig or first leaf infected plant	No. of collar region infected plant	Total Disease incidence (%)
BARI Jhar Shim-1	Uninfected	0.33	0	3	15.27 c
	Pathogen infected	2.66	2.66	7.33	62.5 a
BARI Jhar Shim-2	Uninfected	0.33	0	3.33	13.19 c
	Pathogen infected	3.33	2.33	6.66	59.03 a
BARI Jhar Shim-3	Uninfected	0	0.33	2.33	9.72 c
	Pathogen infected	2.00	1.66	4.66	45.83 b
LSD 0.5%)					6.98
CV (%)					11.64

*Values within a column with a common letter do not differ significantly (P= 0.05)

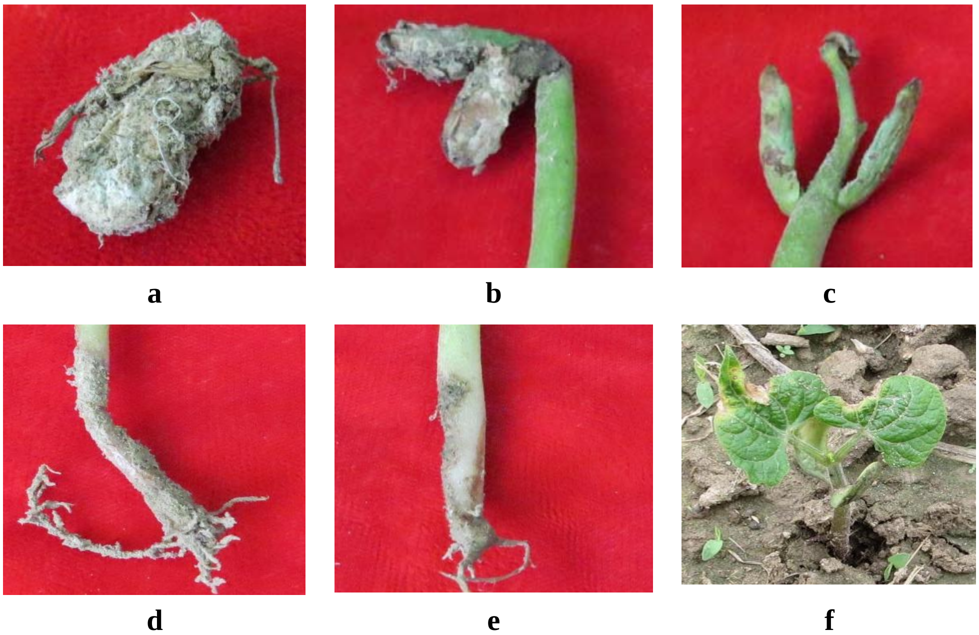

Fig. 1. a) Mycelial mass cover the seed under soil, b) Germinated seedling with cotyledon infection, c) Deformed twig, d,e) Infected collar region of established plant and f) First leaf infection.

It was also observed that plant infected at early stage (cotyledon infection and twig infection) reduced the vigor of plant producing fewer branches, flowers and pods than healthy one. The higher disease incidence (62.5%) was observed in disease infected plot of BARI Jhar Shim-1 followed by BARI Jhar Shim-2 (59.03%). BARI Jhar Shim-3 showed to some extent tolerant against *S. rolfsii* compared to other varieties (Table 2). BARI Jhar Shim-3 also showed lowest yield loss (55.43%) under inoculated condition which were 64.94 and 61.74% in variety 1 and 2, respectively (Table 1). It was observed that *S. rolfsii* infect seed under soil and form mycelial mass around seed (Fig 1 a). Some seed were germinated with cotyledon lesion (Fig 1 b), deformed twig infection (Fig 1c) and first leaf blight (Fig 1 f) and resulted poor vigor and yield. *S. rolfsii* infected the collar region of the established plant and produce black lesion (Fig 1d,e) and reduced the yield potentiality. The yield loss of groundnut caused by *S. rolfsii* was 25%, but sometimes it reached to 80- 90% (Grichar and Bosweel, 1987). Southern blight disease caused by *S. rolfsii* reduced 50-50.3% yield of different cultivars of cowpea (Fery and Dukes, 2002).

Disease reaction of *S. rolfsii* against local lines of Bush bean

To determine the reaction of local bush bean germplasm, five local and BARI Jhar Shim-3 varietie against *S. rofsii* were checked. It was found that the collected seeds were vigor and showed high germination capacity (96-100%) in blotting paper test. The lowest disease incidence (44.44%) was observed in B0124 followed by BARI Jhar Shim-3 (47.61%) and B0122 (55.55%). B0123 showed the highest disease incidence (79.36%) but was statistically similar to that of B0121 (69.84%) (Table 3). All accessions were highly prone to *S. rolfsii* and disease reaction was within susceptible to highly susceptible range. This may be due to seed cotyledon of bush bean contains high amount of starch along with its soft and succulent stem.

Table 3. Reaction of some Bush bean lines and varieties against *S. rolfsii*

Varieties/Lines	Germination (%)	Dissease incidence (%)	Disease reaction
B0121	97	69.84 a	HS
B0122	99	55.55 abc	HS
B0123	98	79.36 a	HS
B0124	100	44.44 c	S
B0125	96	57.14 b	HS
BARI Bush bean 3	100	47.61 bc	S
CV (%)		9.04	

*Values within a column with a common letter do not differ significantly (P= 0.05)

Trichoderma* sp. identification and *In vitro* dual culture assay of *T. harzianum* against *S. rolfsii

To find out potential *Trichoderma* sp., *Trichoderma* isolates were collected from soil. It was found that isolated *Trichoderma* produced white mycelium on PDA containing plate and after 3 days of growth, it gave huge sporulation and turned into light green. Hyphae was hyaline and conidiophores branched in a pyramidal fashion, with short branches near the tip and longer branches in the lower part; branching were more or less at 90^0 angles. Phialides were in whorls of 3-5, flask-shaped, abruptly attenuated near the ends (Fig 2 a). Conidia were round shaped, smooth-walled. This above character indicates that isolated *Trichodrerma* belongs to species *T. harzianum*.

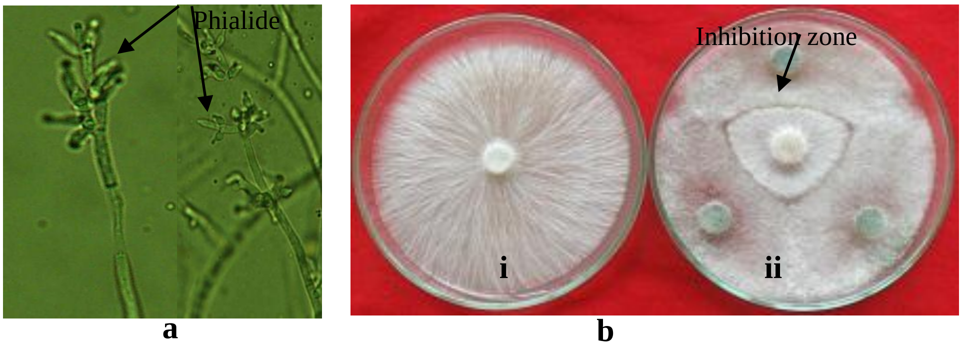

Fig. 2. a) Microscopic view of *T. harzianum*, b,i) *S. rolfsii* growth 72 hours after incubation at 25^0C and b,ii) Dual assay plate *S. rolfsii* and *T. harzianum*.

Similar identifying characters were reported by Rifai (1969). Mycelium of *S. rolfsii* covered full PDA plate after 72 hours of incubation at 25^0C (Fig 2 b,i). *T. harzianum* showed about 80% growth inhibition of *S. rolfsii* and produced clear inhibition zone (Fig 2 b,ii). Inhibition zone production indicated that *T. harzianum* may produce antibiotic or toxic substance against *S. rolfsii*. Major mechanisms involved in the biocontrol activity of *Trichoderma* spp. are competition for space and nutrients, production of diffusible and/or volatile antibiotics and hydrolytic enzymes like chitinase and β-1,3- glucanase. These hydrolytic enzymes partially degrade the pathogen cell wall and leads to its parasitization (Kubicek *et al.*, 2001). This process of mycoparasitism limits growth and activity of plant pathogenic fungi. In addition, several evidences have shown that the production of some lytic enzymes is induced during the parasitic interaction between *Trichoderma* spp. and some pathogenic fungi (Haran *et al*., 1996). The chitinolytic system of *T.harzianum* consists of five to seven distinct enzymes, depending on the strain (Haran *et al*., 1995). Adhikari *et.al*., (2014) also reported that *Trichoderma* sp can inhibit around 75% growth of *S. rolfsii* on PDA.

Efficacy of *T. harzianum* against *S. rolfsii* in field

The treatments had significant effect on plant height. The highest plant height (17.27 cm) was observed in T1 when the plots were kept without pathogen inoculation followed by T_5 (16.77 cm) where integration of seed treatment with Provax + soil treated with *T. harzianum*, and soil treated with *T. harzianum* (T_4) (15.27 cm). Soil treated with Provax (T_3) showed statistically similar plant height (10.13 cm) as compared to diseased plot (T_2) which gave the lowest plant height (9.50 cm). The treatments had significant influence on number of branch per plant. The highest 6.33 branches per plant was observed in T_1 (uninfected) followed by T_5 where integration of seed treatment with Provax + soil treated with *T. harzianum* (6.00 branches), and soil treated with *T. harzianum* (T_4) (5.67 branches). Both soil treated with Provax (T_3) and control infected plots (T_2) showed similar but the lowest (2.66) number of branches. Number of pod plant^{-1} varied significantly among the treatments. The highest (9.33) pods plant^{-1} was recorded in T_1 followed by T_5 (8.66 pods plant^{-1}) and (7.33 pods plant^{-1}). Soil treated with Provax (T_3) showed statistically similar result (2.66 pods/plant) as compared to that of control infected plot (T_2) (2.33 number of pods plant^{-1}) (Table 4).

The highest (113.06 g) 100 seeds weight was recorded in T_1 treated plot which was statistically similar to that of with T_5 (111.02 g), while the lowest (86.67g) 100 seeds was found in T_2 followed by T_3 (87.67g) (Table 4). Sothern blight disease of cowpea caused by *S. rolfsii* reduced pod numbers and dry-seed yields (Fery and Dukes, 2002).

Table 4. Effect of different treatments on plant height, number of branches and pods per plant and 100 seeds weight of bush bean

Treatments	Plant height (cm)	No. of branches/plant	No. of pod/plant	100 seeds weight (g)
T1 = Control (without pathogen inoculation)	17.27 a	6.33 a	9.33 a	113.06 a
T2 = Control (with pathogen inoculation)	9.50 b	2.66 b	2.33 c	86.67 c
T3 = Soil treatment with Provax 200 wp	10.13 b	2.66 b	2.66 c	87.67 c
T4 = Soil treated with *T. harzianum* mass	15.27 a	5.67 a	7.33 b	104.03 b
T5 =Seed treatment with Provax 200 wp + Soil treated with *T. harzianum* mass	16.77 a	6.00 a	8.66 ab	111.02 a
CV (%)	7.33	11.07	9.75	1.94

*Values within a column with a common letter do not differ significantly (P= 0.05)

The un-inoculated plot (T_1) showed the lowest disease incidence (10.06%) as well as highest 99.03% germination along with 1185.67 kg yield ha^{-1}. On the other hand, the highest disease incidence (45.83%) as well as lowest germination percentage (75.69%) and yield (524.67 kg/ha) was recorded in the inoculated plot (T_2). In disease inoculated condition, integrated approach (seed treatment with Provax 200 wp + Soil treated with *T. harzianum* mass) showed the lowest disease incidence (28.47%) as well as highest germination percentage (98.61%) and yield (873.33kg/ha) (Fig. 3).

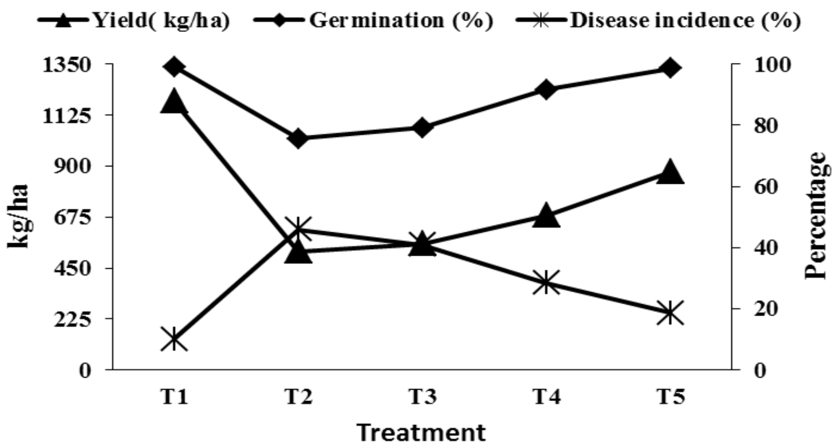

Fig. 3. Effect of treatment on germination, disease incidence and yield of Bush bean.

Different species of *Trichoderma* have the potential to control soil-borne plant pathogens more effectively than chemicals and they also exhibit plant-growth promoting activity (Harman and Bjorkman, 1998). *Trichoderma* spp. produce extracellular β-(1, 3) - glucanases, chitinases, lipases, and proteases when they are grown on cell walls of pathogenic fungi (Haran *et al.,* 1995). Elad *et al.* (1980) found that a wheat-bran preparation of *T. harzianum* applied to fields at rates of 500-1500 kg/ha, reduced the incidence of diseases caused by *S. rolfsii. T. harzianum* reduced 6.7-45.0% root rot infection of bean under field condition (Ellil *et al.,* 1998) and 66.8% collar rot of sunflower under greenhouse condition (Prasad and Rangeshwara, 1999) when soil was artificially inoculated by *S. rolfsii*.

Conclusion

It may be concluded that released varieties and collected local bush bean lines were highly prone to foot rot disease caused by *S. rolfsii*. It can be opined that *T. harzianum* was effective in controlling foot rot disease of bush bean both in-vitro and field conditions. Soil treatment by *T. harzianum* showed higher efficacy when seeds treated with Provax 200 WP.

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EVALUATION OF PROMISING MAIZE HYBRIDS IN DIFFERENT REGIONS OF BANGLADESH

A. N. M. S. KARIM[1], S. AHMED[2], A. H. AKHI[3]
M. Z. A. TALUKDER[4] AND T. A. MUJAHIDI[5]

Abstract

Nine single cross promising maize hybrids and three check varieties (NK40, BHM9 and 900 MGold) were assessed for genotype environment interaction (GEI) and stability for the selection of promising one(s) in seven different locations of Bangladesh. The AMMI (additive main effects and multiplicative interaction) model was used to analyze the genotype-environment interaction over seven locations to select desired hybrid having higher yield and other potential attributes. Regarding genotypes (G), significant variation was found in all the characters except yield while environment (E) was found significant for all the characters. The environment of Gazipur was poor; Jamalpur, Hathazari, Ishurdi, Rahmatpur, Burirhat, and Jessore were positive environments for tested maize hybrids. Considering the mean, bi and S^2di for all the parameters, it was evident that all the genotypes showed different response of adaptability under different environmental conditions. Among the hybrids E12 (900MG), E7(CML502 × CML491), E1(BIL95 × BIL28), E10 (NK40) and E2 (BIL95 × BIL31) were exhibited high yielder.Considering bi~1(regression co-efficient), S^2di ~ 0 (deviation from regression)and mean versace IPCA1 (fig1)indicated that hybrids E7and E1showed the higher yield as well as stable across locations.

Keywords: combing ability, maize hybrids, stability, different environments

Introduction

Multi-environment yield trials are used commonly to release superior genotypes for target sites in plant breeding programs. Genotype Environment Interaction (GEI) is universal phenomenon when different genotypes are tested in a number of environments. The large GEI variation usually impairs the accuracy of yield estimation and reduces the relationship between genotypic and phenotypic values (Nachit *et al.*, 1992). GEI due to different responses of genotypes in diverse environments makes choosing the superior genotypes difficult in plant breeding programs. Numerous methods for multi-environment trials data have been developed to expose patterns of G×E interaction (Yamada, 1962), joint regression (Finlay and Wilkinson, 1963; Eberhart and Russel, 1966) and currently AMMI (Gauch, 1992) and GGE biplot (genotype main effect plus genotype by environment interaction). AMMI model combines the analysis of

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[1,3&5]Scientific Officer, Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, [2]Principal Scientific Officer, Plant Breeding Division, BARI, Gazipur, [4]Senior Scientific Officer, Plant Breeding Division, BARI, Gazipur, Bangladesh.

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variance of genotypes and the environment main effects with principal component analysis of the GEI into a unified approach (Gauch and Zobel, 1996). Crossa *et al*. (1990) indicated that the AMMI model can be used to analyze the GEI and to identify the superior hybrid maize genotypes. Also, he pointed out that it can be used in the selection of the best test environments for hybrid maize genotype evaluation. Kaya *et al.* (2002) suggested that the interaction of the 20 genotypes with six environments was best predicted by the first two principal components of genotypes and environments. Also, they proposed that biplots generated using genotypic and environmental scores of the first two AMMI components can be used by breeders and have an overall picture of the behavior of the genotype, the environment and GEIs. More precise GEI estimates can be obtained with the AMMI model which makes to easier to interpret the results (Durate and Vencovsky, 1999).

Maize is one of the most important food grains in the world as well as in developing countries like Bangladesh. It is the highest yielding grain crop having various uses. A great combination of high market demand with relatively low production cost, ready market and high yield has generated great interest among the farmers in maize cultivation. Day by day it is gaining popularity in the country due to vast demand, particularly for poultry industry. In Bangladesh it is the third most important crop after rice and wheat and it accounts for 4.8% of the total cropped land area and 3.5% of the value of agricultural output (Ahmad *et al.,* 2011). In 2015-16, maize was cultivated in 3.5 lac hectare of land in Bangladesh and production was 25 lac mtons (Bidan, 2016). The objective of this study was to use the AMMI analysis model to assess the stability of some maize hybrids and verify the influence of a sample of environments at different locations of Bangladesh (Gazipur, Jamalpur, Hathazari, Ishurdi, Rahmatpur, Burirhat, and Jessore) in the productive performance of these hybrids.

Materials and Methods

The experiment was conducted at seven locations namely Gazipur, Jamalpur, Hathazari, Ishurdi, Rahmatpur, Burirhat, and Jessore during rabi 2014-15. Nine hybrids and three check varieties were evaluated in this study. The experiment was laid out in Randomized Complete Block Design with 3 replications. Seeds of each entry were sown in two rows, 4m long plots with 60 cm and 20 cm spacing between rows and hills, respectively. Seeds were sown at Gazipur on 14 December, Jamalpur on 27 November, Hathazari on 4 November, Ishuardi on 25 November, Rahmatpur on 24 November, Burirhat on 21 November and Jessore on 19 November. One healthy seedling per hill was kept after thinning. Fertilizers were applied @ 250, 55, 110 40, 5 and 1.5 kg/ha of N, P, K, S, Zn and B respectively. Standard agronomic practices were followed(Quayyum, 1993) and plant protection measures were taken as required. Two border rows at both end of each replication were used for minimize the border effect. Data on days to pollen shedding, days to silking was 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 and converted to t/ha.

The analysis of variance (ANOVA) was used and the GE interaction was estimated by the AMMI model (Zobel*et. al.,* 1988). In this procedure, the contribution of each genotype and each environment to the GE interaction is assessed by use of the biplot graph display in which yield means are plotted against the scores of the first principal component of the interaction (IPCA1). The computational program for AMMI analyses is supplied by Duarte and Vencovsky (1999).The stability parameters, regression coefficient (bi) and deviation from regression (S^2di) were estimated according to Eberhart and Russel (1966). Significance of differences among bi value and unity was tested by t-test while between S^2di and zero by F-test. All the data were processed and analyzed using Cropsatat 7.2 program.

Results and Discussion

Results of combined analysis of variance for five characters of twelve hybrids at seven environments are presented in Table 2. The mean sum of squares for the genotypes was highly significant for all the traits except yield which revealed the presence of genetic variability in the material under studied. Environments mean sum of squares were highly significant for all of the characters. The highly significant effects of environment indicate high differential genotypic response 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 GXE interaction. Environment relative magnitude was much higher than genotypic effect, suggesting that performance of each genotype is influenced more by environmental factors.

Table 1.Climatic scenario of seven locations in Bangladesh

Location	**Ecology**				
	Latitude	Longitude	Seasonal rainfall (mm)	Average annual temp. (°C)	AEZ
Gazipur	24° N	90.43° E	800-1200	25.8	18 (Madhupur Tract)
Rangpur	25.33° N	87.1° E	2169	24.9	2 (Tista Flood Plain)
Jamalpur	24.56⁰ N	89.55⁰ E	1,113.65	26.3	8 (Young Brahmaputra and Jamuna Floodplain)
Barisal	22.79˚N	90.29˚ E	1620-1900	25.9	13 (Ganges Tidal Floodplain)
Jessore	23.17˚ N	89.20˚ E	1460-1500	25.7	11(High Ganges RiverFloodplain)
Hathazari	22.5˚ N	91.80˚ E	2200	25.8	29 (Northern & Eastern Hills)
Ishurdi	26.12⁰ N	89.06⁰ E	1603	26.1	7(Active Brahmaputra–Jamuna Floodplain)

AEZ (Agro-Ecological Zones)

Table 2. Full joint analysis of variance including the partitioning of the G × E interaction of maize hybrids over 7 locations during 2014-15

Source of variation	df	Mean sum of squares				
		Days to pollen shedding	Days to silking	Plant height (cm)	Ear height (cm)	Grain yield (t/ha)
Genotypes (G)	11	15.80**	18.25**	507.61**	286.84**	1.94
Environment (E)	6	306.12**	260.81**	3768.01**	2134.69**	43.84**
Interaction G x E	66	4.89	5.04	85.98	47.40	0.81
AMMI Component 1	16	14.13**	15.50**	230.48**	99.50**	1.83
AMMI Component 2	14	4.24**	3.08**	75.55**	44.60**	0.78
GxE (Linear)	11	8.58	8.57	162.94	117.81	0.34
Pool deviation	55	4.15	4.34	70.59	33.32	0.91
Pooled error	144	1.95	2.93	149.55	63.60	1.32

*P<0.05, **P<0.01

Table 3. Stability analysis for yield and different traits on maize over 7 locations during 2014-15

Entry no.	Days to pollen shedding										
	Location							Mean	Pi	bi	S^2di
	Gaz	Jam	Hat	Ish	Rah	Bur	Jes				
E1	97.33	93.33	88.00	101.30	88.33	98.33	100	95.24	-0.03	0.98	5.75
E2	96.33	93.33	90.33	100.30	84.67	96.67	98.33	94.29	-0.98	1.03	1.87
E3	91.33	91.00	93.00	96.00	85.33	96.33	96.0	92.71	-2.55	0.64	6.03
E4	100.70	92.33	87.00	99.67	86.67	98.67	97.33	94.62	-0.65	1.11	4.28
E5	101.30	95.33	90.67	101.70	87.33	100.00	100.0	96.62	1.34	1.10	1.22
E6	98.33	91.00	92.67	96.00	85.00	95.00	96.67	93.52	-1.74	0.83	2.74
E7	103.70	95.67	90.67	103.70	85.33	101.30	97.67	96.86	1.48	1.33*	2.51
E8	104.00	96.33	88.00	104.30	87.00	102.70	98.33	97.24	1.96	1.35	7.00
E9	102.70	95.0	94.00	100.70	86.67	99.00	98.67	96.67	1.39	1.03	1.46
E10 (NK40)	96.00	90.33	97.33	97.00	86.33	95.67	95.67	94.05	-1.22	0.62	8.25
E11 (BHM9)	97.33	93.33	95.67	99.00	85.67	97.33	95.00	94.76	-0.50	0.79	4.13
E12 (900MG)	101.70	94.0	93.67	102.30	86.33	100.00	98.67	96.67	1.39	1.12	0.44
Mean	99.22	93.42	91.75	100.2	86.22	97.69	98.42	-	-	-	-
E. Index(Ij)	3.95	-1.85	-3.52	4.89	-9.04	2.42	3.14	-	-	-	-
LSD (0.05)	1.65	1.40	1.42	1.31	4.06	0.88	1.84	-	-	-	-

Pi= Phenotypic Indices, bi= regreaaion co-efficient and S^2di=deviation from regression

E1= BIL95 X BIL28, E2= BIL95 X BIL31, E3= BIL95 X BIL79, E4= CL02720 X CLQRCYQ17, E5= CML451 X CL02450, E6= CLQRCYQ59 X CML161, E7= CML502 X CML491, E8= CLQRCWQ24 X CML491, E9= CLQRCWQ10 X CML491, E10= NK40, E11= BHM9, E12=900 MGold

Table 2.Cont'd.

Entry	Days to silking										
	Location							Overall mean	Pi	bi	S^2di
	Gaz	Jam	Hat	Ish	Rah	Bur	Jes				
E1	99.33	98.0	91.67	105.0	91.33	103.0	100.0	98.33	0.38	1.02	1.67
E2	98.33	97.33	93.67	103.7	87.67	101.3	97.33	97.05	0.90	1.08	2.05
E3	96.0	94.0	96.0	97.33	88.0	99.67	97.67	95.52	-2.42	0.69	4.17
E4	102.3	96.0	91.33	102.3	90.0	101.0	100.0	97.57	-0.37	1.06	3.05
E5	102.7	99.33	93.67	105.0	90.33	103.0	101.3	99.33	1.38	1.13	1.19
E6	99.33	93.67	95.0	97.0	88.33	99.67	95.33	95.48	-2.47	0.74	3.44
E7	105.7	101.0	92.67	106.3	88.33	101.0	102.3	99.62	1.67	1.37	4.67
E8	105.3	100.3	90.67	107.7	89.67	101.7	103.0	99.76	1.81	1.39	7.73
E9	104.0	99.33	98.0	103.7	89.67	101.7	99.33	99.38	1.43	1.00	1.89
E10(NK40)	98.0	93.33	100.3	98.0	89.0	100.0	96.33	96.43	-1.52	0.59	10.33
E11(BHM9)	99.0	98.0	98.0	100.3	88.67	98.67	98.33	97.29	-0.66	0.75	3.27
E12 (900MG)	103.3	99.0	96.67	105.3	89.33	101.7	102.0	99.62	1.67	1.13	0.66
Mean	101.1	97.44	94.81	102.6	89.19	101	99.42	-	-	-	-
E. Index(Ij)	3.16	-0.50	-3.14	4.69	-8.75	3.07	1.46	-	-	-	-
LSD (0.05)	1.4.5	1.46	1.19	2.17	3.73	1.20	1.58	-	-	-	-

Table 2.Cont'd.

Entry	Grain yield (t/ha)										
	Location							Overall mean	Pi	bi	S^2di
	Gaz	Jam	Hat	Ish	Rah	Bur	Jes				
E1	8.15	12.24	13.25	11.58	12.93	13.13	12.45	11.96	0.40	0.89	0.17
E2	7.94	10.88	13.98	10.56	12.66	12.99	12.24	11.60	0.08	0.99	1.06
E3	7.93	10.72	13.84	10.03	12.36	12.38	11.95	11.32	-0.24	0.92	1.09
E4	7.24	11.95	13.91	11.17	12.65	10.66	10.38	11.14	-0.41	0.94	1.01
E5	6.75	12.23	12.57	12.07	12.46	12.2	11.08	11.34	-0.22	1.15	0.17
E6	5.99	10.67	13.96	10.79	12.02	10.64	9.65	10.53	-1.02	1.20	1.12
E7	7.59	12.9	12.63	12.86	13.07	13.96	12.56	12.22	0.66	1.05	0.63
E8	7.50	13.19	11.59	11.85	12.46	11.34	11.13	11.29	-0.26	0.88	1.01
E9	7.14	13.27	10.7	12.51	12.35	12.77	11.81	11.51	-0.5	0.86	1.65
E10(NK40)	7.72	11.49	13.95	11.46	13.03	12.98	11.98	11.80	0.33	0.97	0.62
E11(BHM9)	7.33	12.75	11.43	11.86	12.33	12.3	11.62	11.37	-0.18	0.89	1.02
E12(900MG)	7.27	12.56	13.65	13.34	13.36	13.85	12.64	12.50	0.93	1.20	0.51
Mean	7.38	12.07	13.25	11.67	12.64	12.50	11.62	-	-	-	-
E. Index(Ij)	-4.17	0.51	1.46	0.11	1.07	0.94	0.06	-	-	-	-
LSD (0.05)	1.09	1.55	1.95	1.53	2.31	1.46	1.65	-	-	-	-

The AMMI biplot provide a visual expression of the relationship between the first interaction principal component axis (AMMI component 1) and mean of genotypes and environment (Fig. 1) as well as relationship of IPCA1 and IPCA 2. From the figure 1 it was observed that hybrids E12 (900MG), E7, E1, E10 (NK40) and E2 were highest yielder but among them hybrids E12 (900MG), E7, E1 and E10 (NK40) were more stable because they have smaller IPCA1 score which is near about zero.

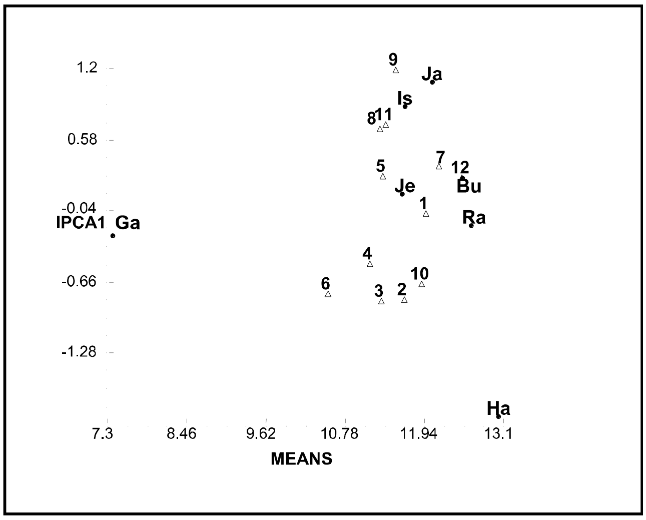

Fig.1. Biplot of the first AMMI interaction (IPCA1) score (Y –axis) plotted against mean yield (X- Axis) of twelve maize hybrids and seven environments.

Since IPCA2, scores also play a significant role in explaining the GEI; the IPCA1 scores were plotted against the IPCA2 score for further explanation of adaptation (Fig 2). The hybrids E4, E6, E8 and E9 were unstable due to their dispersed position. E1, E5 and E7 appeared to be more stable when plotting the IPCA1 and IPCA2 scores.

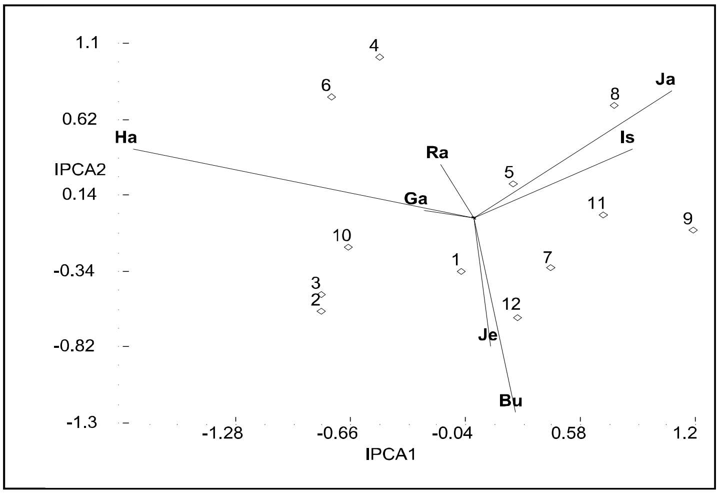

Fig.2 Biplot of the first AMMI interaction (IPCA2) score (Y –axis) plotted against AMMI interaction (IPCA1) (X-Axis) of twelve maize hybrids and seven environments.

Conclusion

Considering the yield potentially and stability parameters, two tested hybrids viz. E7 (CML502 × CML491) and E1 (BIL95 × BIL28) genotypes showed the highest yield as well as stable for over all environments and need to be further evaluated in large plots before release as commercial hybrids across ecological zones in Bangladesh.

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ADOPTION AND PROFITABILITY OF BARI RELEASED POTATO VARIETIES IN NORTHERN REGION OF BANGLADESH

Q. M. S. ISLAM[1], M. A. MATIN[2], M. S. H. SIDDIQUEE[3]
AND M. T. ISLAM[4]

Abstract

The study was conducted in three potato growing areas in nothern districts of Bangladesh namely Rajshahi, Rangpur and Thakurgaon. Data were collected during 2016-17 to assess the level of adoption, profitability, farmers attitude towards the cultivation of BARI released potato varieties and to explore the constraints to potato cultivation. The study revealed that 59% potato areas were covered by BARI Alu-7 variety. The varieties BARI Alu-13, BARI Alu-25 and BARI Alu-8 covered 14%, 14% and 12% of the potato areas respectively. The adoption level of seed rate, gypsum and boron were found high which adoption score were 95, 72 and 71. The level adoption of urea, TSP and MoP were over used which adoption score were 103,138 and 110. The adoption levels of cowdung and zinc sulphate were found medium which adoption score were 50 and 61. Only 37% farmers used potato seeds from their own source. Per hectare total cost of BARI released potato cultivation was Tk. 204003 and variable cost was Tk. 161033. The major share of cost was seed (31%) followed by fertilizer (13%) and land use (11%). Per hectare average yield of potato was 28 ton with gross return Tk. 249819 and gross margin Tk. 88786. The net return of potato cultivation was Tk. 45816 per hectare. The benefit cost ratio was 1.22. Infestation of insect and diseases, non-availability of quality seed, high price of seed and inadequate storage facilities were the major constraints to potato cultivation.

Keywords: Potato, Adoption, Profitability, Constraints.

Introduction

Potato (*Solanum tuberosum*) is a leading vegetable crop in the world and occupies top-most position after rice and wheat both in respect of production and consumption (Aktar *et al.*, 1998). It is the third largest food crop in Bangladesh and has recently occupied an important place in the list of major food and cash crops of Bangladesh (Ali and Haque, 2011). The crop ranks first among the vegetables in Bangladesh and its area and production are increasing day by day (BBS, 2016). The total potato area is 475709 ha and production is 9474000 M. tons in Bangladesh. The growth rate of area, production and yield were 6.4%, 9.5% and 3.1% respectively during the period from 1995 to 2016 (Table 1). Ensuring food security for all is one of the major challenges in Bangladesh today.

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[1]Principal Scientific Officer and [2]Chief Scientific Officer, Agricultural Economics Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, [3]Senior Assistant Director, National Agriculture Training Academy (NATA), Gazipur and [3]Scientific Officer, Promology Division, HRC, BARI, Gazipur, Bangladesh.

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So, to ensure adequate food supply, it is necessary to give thrust to increase food production using BARI released crop varieties and recommended production practices. Potato is a short duration and labour intensive crop. In fact, short cycle of potato frees the land for cultivating other crops. The Tuber Crop Research Centre of BARI released different HYV potato varieties which have good yield potential and tolerant to insect pests and diseases.

Table 1. Area, production and yield of potato in Bangladesh

Year	Acreage (ha)	Production (M. tons)	Yield (t/ha)
1995-96	132389	1492000	11.27
1996-97	134008	1508000	11.25
1997-98	136437	1553000	11.38
1998-99	244939	2762000	11.28
1999-00	243320	2933000	12.05
2000-01	248988	3216000	12.92
2001-02	237652	2994000	12.60
2002-03	245344	3386000	13.80
2003-04	270850	3908000	14.43
2004-05	326316	4856000	14.88
2005-06	301215	4161000	13.81
2006-07	345344	5167000	14.96
2007-08	402024	6648000	16.54
2008-09	395547	5268000	13.32
2009-10	434818	7930000	18.24
2010-11	460324	8326000	18.09
2011-12	430364	8205000	19.07
2012-13	444534	8603000	19.35
2013-14	462348	8950000	19.36
2014-15	471255	9254000	19.64
2015-16	475709	9474000	19.92
Mean	318401	50408000	14.89
Standard deviation	115151	2658452	3.01
Growth rate (%)	6.4	9.5	3.1

Most of the varieties are not cultivated by the farmers because of various unknown reasons that need to be identified. The adoption of recommended practices of potato production by the farmers could easily raise food production and net income of the users (Amin and Islam, 2009). Usually farmers follow different levels of production technologies depending upon their infrastructural facilities and socioeconomic conditions which ultimately resulted in variability in yields of potato (Elias *et al.*, 1992). Farmer's production performance depends on physical resources and technology available to them as well as existing farm management conditions. Efficient use of inputs and technologies could help farmers to get higher production from a given amount of resources. A very few studies were conducted (Begum *et. al*., 2017 and Haque *et al.*, 2011) regarding the adoption of potato varieties in Bangladesh.

In view of the above discussion, the study attempted to achieve the following specific objectives: (i) to know the level of adoption of BARI released potato varieties at farm level; (ii) to know the agronomic practices of potatoes cultivation; (iii) to estimate the profitability of BARI released potato varieties; (iv) to evaluate the farmers attitude towards the cultivation of BARI released potato varieties and (v) to identify the socio- economic constraints of BARI released potato varieties adoption at farm level.

Methodology

Study area selection:

Sampling technique: Three districts, namely Rajshahi, Rangpur and Thakurgaon were purposively selected considering the major potato growing areas in northern region of Bangladesh. Again from each district three upazilas were selected considering the concentration of potato growers and easy access. From each upazila one block was also selected in consultation with the Upazila Agriculture Officer. A list of potato growers from the selected block were collected with the help of DAE personnel. Thus a total of 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 for the period of 2016-2017. Both fixed cost and variable cost were taken into account in calculating cost of potato cultivation. Land use cost was calculated on the basis of per year existing lease value of land. The profitability of potato production was examined on the basis of gross margin, net return and benefit cost analysis.

Analytical technique: Farm level collected data were edited, summarized, tabulated and analyzed to fulfill the objectives of the study. In most cases, tabular method of analysis supported with appropriate statistical parameters such as average, ratio, percentages were used to present the results of the study. The adoptions of improved technologies were measured through three ways: variety adoption, acreage covered, and use of crop management technology (i.e. agronomic practices, time of operation, input use). For assessing the adoption of crop management technology, respondent farmers was grouped into three categories such as high adopter, medium adopter, and low adopter based on the mean index of the farmer with respect to each technology. A higher index was indicating a higher level of adoption, while a lower index was indicate a lower level of adoption of a technology. Adoption level were categorized for mean index >100 as over use; 70-100 as high, 50-69 as medium, and <50 as low.

Calculation of adoption index

Adoption index was calculated using the following formula (Gupta and Chowdhi, 2002**:**

$$\text{Adoption Index} = \frac{100}{\text{Recommended dose}} \times \text{Farmers dose}$$

Profitability analysis

Profitability of potato was analyzed to compare the return received by the farmers.

a. Measurement of cost and return from potato cultivation

Equations for cost analysis are as follows

$$\text{Variable Cost} = VC_i = \sum (X_i P_i)$$

$$TVC_i = VC_i + IOC_i$$

$$TC_i = TVC_i + TFC_i$$

Where, TC_i = Total cost (Tk/ha)

TVC_i = Total variable cost (Tk/ha)
TFC_i = Total fixed cost (Tk/ha)
VC_i = Variable cost (Tk/ha)
IOC_i = Interest of operating capital (Tk/ha)
X_i = Quantity of inputs (kg)
P_i = Price of inputs (Tk/kg)
i = Number of farmers (1.2.3……..n)

Equations for profitability analysis

$$\text{Gross return} = GR_i = Y_i P_i$$

$$\text{Net return} = GR_i - TC_i$$

$$\text{Gross margin} = GR_i - VC_i$$

Where,

GR_i = Gross return (Tk/ha)

P_i = Price (Tk/kg) received by *i*th farmer

Y_i = Quantity (kg/ha) produced

Results and Discussion

Adoption of potato varieties

Within the study areas, the sample farmers adopted BARI released potato varieties such as BARI Alu-7, BARI Alu-13, asterisk and BARI Alu-8. Within the sample farmers on an average, 59% area was covered by BARI Alu-7. Highest area coverage(92%) by BARI Alu-7 was found at Rajshahi followed by Rangpur and Thakurgaon. Area coverage of both BARI Alu-13 and BARI Alu-25 were 14% (Table 2). The farmers of Rangpur mostly cultivated BARI Alu-7 and BARI Alu-25 varieties as a result BARI Alu-8 variety adoption was low. The local variety potato were *Lalsheet*, *Sheet Bilatee*, *Lalpakri* etc. It was mentioned that farmers choice BARI Alu-7 variety due to high price, good test and high market demand. Farmer choose BARI Alu-13 for short duration, less disease infestation and low risk in cultivation. They cultivated BARI Alu-25 for high yield attractive colour and high demand in Rangpur. The farmers in the study areas also cultivated BARI Alu-8 variety for higher price and good test. It was observed that though BARI released more than 70 varieties, the farmers adopted only four varieties. Farmers of the study areas were not aware about the latest released varieties of potato.

Table 2. Adoption of area of BARI released potato varieties in northern region of Bangladesh

Variety	Adoption of area (%)			
	Rajshahi	Rangpur	Thakurgaon	All
BARI Alu-7	92	40	15	59
BARI Alu-13	-	15	37	14
BARI Alu-25	2	35	20	14
BARI Alu-8	5	9	25	12
Local*	1	1	3	1

* *Lalsheet, Sheet Bilatee, Lalpakri* etc.

On an average, 47% farmers adopted BARI Alu-7 variety followed by BARI Alu-13 (39%) BARI Alu-25 (31%) and BARI Alu-8 (30%) (Table 3). Among the locations BARI Alu-7 was popular at Rajshahi(73%), BARI Alu-25 at Rangpur and BARI Alu-13 at Thakurgaon.

Table 3. Farmers adopted different potato varieties in some selected areas of Bangladesh

Variety	% farmers responded			
	Rajshahi	Rangpur	Thakurgaon	All
BARI Alu-7	73	44	22	47
BARI Alu-13	-	40	78	39
BARI Alu-25	18	51	24	31
BARI Alu-8	31	13	44	30
Local	4	2	18	8

* *Lalsheet*, *Sheet Bilatee*, *Lalpakri* etc.

Technology used in potato production

The existing level of technology adoption in terms of agronomic practices, time of operation and input use are essential for achieving higher yield and return. The potato farmers in the study areas ploughed their lands with the help of power tiller and tractor.

Table 4. Adoption of crop management technologies in potato cultivation in the study areas

Technology	% Farmers responded and adoption score				Adoption level
	Rajshahi (n=45)	Rangpur (n=45)	Thakurgaon (n=45)	All (n=135)	
Ploughing:					
Recommended (4)	16(7)	55(25)	18 (8)	30 (40)	
Below recommendation > (4)	4(2)	8(18)	2(4)	12(9)	
Above recommendation <(4)	80(36)	27(12)	78(35)	61(83)	
Adoption index	*139*	*103*	*126*	*123*	*Over use*
Sowing date :					
Recommended (Nov.1-30)	78(35)	27(12)	93(42)	66(89)	
Below recommendation (Before Nov. 1)	-	-	-	-	
Above recommendation (After Nov.30)	22(10)	73(33)	7(3)	34(46)	
Adoption index	*89*	*101*	*71*	*87*	*High*

Note: Technology adoption was categorized for mean index>100 as overuse, 70-100 as high; 50-69 as medium and <50 as low.

Figures in the parentheses indicate number of farmer responded.

The number of ploughing varied from farm to farm and location to location. Four times ploughing is recommended for potato cultivation. Based on the mean index, land preparation secured the over ploughing level of adoption for cultivation. On an average, only 30% farmers ploughed their land 4 times. More than 4 times ploughig was done by 61% farmers. Sowing was started from the 1st week of November and continued up to the 3rd week of December. About 93% farmer of Thakurgaon and 78% farmers of Rajshahi district had plant their seed in optimum period (Table 4). Adoption level of ploughing and sowing date was found over use and high respectively. About 46% farmers followed recommended seed rate, whereas 43% farmer used above recommendation (Table 5). Only 8% farmers used recommended doses (Kamal *et al.*, 2012). of cowdung (1.5-2.0 t/ha) in their plots. About 48% of the farmers used more than recommended dose and 44% farmers used lower than recommended doses of cowdung.

Table 5. Adoption of recommended seed rate and fertilizer in potato cultivation in the study areas

Technology	% Farmers responded and adoption score				Adoption level
	Rajshahi (n=45)	Rangpur (n=45)	Thakurgaon (n=45)	All (n=135)	
Seed rate:					
Recommended (1.5-2.0 t/ha)	60(27)	40(18)	38(17)	46(62)	
Below Recommended	13(6)	13(6)	7(3)	11(15)	
Above Recommended	27(12)	47(21)	55(25)	43(58)	
Adoption index	*91*	*92*	*102*	*95*	*High*
Cowdung:					
Recommended (8-10 t/ha)	-	5(2)	15(6)	8(8)	
Below recommendation (<8t/ha	67(8)	54(22)	27(11)	44(4)	
Above recommendation (>10 t/ha)	33(4)	41(17)	58(24)	48(45)	
Adoption index	15	61	73	50	Medium
Urea:					
Recommended (220-250 kg/ha)	7(3)	18(8)	20(9)	15(20)	
Below recommendation (<220 kg/ha	22(10)	2(1)	7(3)	10(14)	
Above recommendation (>250 kg/ha)	71(32)	80(36)	73(33)	75(101)	
Adoption index	*96*	*120*	*93*	*103*	*Over use*
TSP:					
Recommended (120-150 kg/ha)	23(8)	19(4)	4(2)	14(14)	
Below recommendation (<120 kg/ha)	23(8)	-	2(1)	9(9)	
Above recommendation (>150 kg/ha)	54(19)	81(17)	94(42)	77(78)	
Adoption index	*112*	*93*	*208*	*138*	*Over use*
MoP:					
Recommended (220-250 kg/ha)	4(2)	18(8)	27(12)	16(22)	
Below recommendation (<220 kg/ha)	18(8)	-	24(11)	14(19)	
Above recommendation (>250 kg/ha)	78(35)	82(36)	49(22)	70(93)	
Adoption index	*119*	*124*	*86*	*110*	*Over use*
Gypsum:					
Recommended (100-120 kg/ha)	5(2)	12(5)	4(1)	8(8)	
Below Recommended (<100 kg/ha	49(19)	29(12)	43(12)	40(43)	
Above Recommended (>120 kg/ha)	46(18)	59(24)	53(15)	62(57)	
Adoption index	*69*	*87*	*61*	*72*	*High*
Zinc:					
Recommended (8-10 kg/ha)	8(3)	56(23)	27(8)	32(34)	
Below recommendation (<8 kg/ha	49(18)	12(5)	33(10)	30(33)	
Above recommendation (>10 t/ha)	43(16)	32(13)	40(12)	38(41)	
Adoption index	57	71	53	61	Medium
Boron:					
Recommended (8-10 kg/ha)	3(1)	40(17)	32(11)	25(29)	
Below recommendation (<8 kg/ha	38(15)	20(8)	32(11)	30(34)	
Above recommendation (>10 kg/ha)	59(23)	40(17)	35(12)	45(52)	
Adoption index	*67*	*83*	*63*	*71*	*High*

Note: Technology adoption was categorized for mean index>100 as overuse, 70-100 as high; 50-69 as medium and <50 as low. Figures in the parentheses indicate number of farmer responded.

Table 6. Agronomic practices of potato cultivation in the study areas

Practices	Farmer responded (%)			All
	Rajshahi	Rangpur	Thakurgaon	All
Ploughing method :				
Power tiller	60	42	7	36
Tractor	40	58	93	64
Seed source :				
Own	34	40	38	37
Market	2	27	18	15
Neibours	42	15	3	20
BADC	2	7	13	8
Others*	20	11	28	20
Earthing up (No.) :				
One	49	73	22	48
Two	51	20	75	49
Three	-	7	3	3
Pesticides application (No.):				
2-4	7	7	33	16
5-8	78	45	65	62
9-12	15	48	2	22
Irrigation (No.):				
1-4	22	95	93	70
5-7	78	5	7	30

- Others means BRAC, Supreme seed, Ispahani, Research agro etc.

About 75% of the farmers used urea more than recommended dose. Fifteen percent farmers used recommended doses of urea (220-250 kg/ha) in their plots and only 10% farmers used lower than recommended dose. Adoption level of urea was found slightly over use in the study areas with an adoption score 103. Most of the farmers (77%) used TSP above the recommended rate (120-150 kg/ha). Only 14% farmers used recommended doses of TSP while 9% farmers used below recommended dose. Overall adoption score of TSP application was found 138%, which indicates over use of TSP in the study areas. About 70% of the farmers used MoP above recommended dose. About 16% farmers used recommended doses of MoP (220-250 kg/ha) in their plots and only 14% farmers used lower than recommendation. As a result adoption level of MoP application found to be slightly over use in the study areas with an adoption score 110. About 8% farmers used recommended doses of gypsum (100-120 kg/ha) in their plots and 40% farmers used lower than recommended dose. Most of the farmers (62%) used gypsum above than recommendation. Adoption level was found high in gypsum. About 32% and 25% farmers used recommended doses (8-10 kg/ha) of Zinc and Boron in their plots. Adoption level was found 61 and 71% which indicates medium and high level of adoption respectively.

Agronomic practices

Farmers in the study areas prepared their potato plots using power tiller and tractor. Sixty four percent farmers used tractor for land preparation which was higher in Thakurgaon (93%) followed by Rangpur (58%) and Rajshahi (40%). Rest of the farmers (34%) used power tiller (Table 6). About 37% farmers used their home supplied seed and rest of the farmers used seeds from different sources like local market, neibouring farmers, BADC, BRAC and seed companies. Generally one earthing up (48%) which was more (73%) in Rangpur or two earthing up (49%) which was more (75%) in Thakurgaon, was practiced by the farmers in the study areas. Sixty two percent farmers applied insecticides 5-8 times, 22% applied 9-12 times and 16% applied 3-4 times. Most of the famers (70%) irrigated their field 1-4 times.

Input use pattern

The human labour used for producing potato was found to be 176 man days per hectare of which 41% were family supplied (Table 7). The use of human labor was highest in Rangpur (183 man-days/ha) followed by Rajshahi (179 man-days/ha) and Thakurgaon (166 man-days/ha). The average quantity of seed used by the farmers were 1904 kg/ha which was similar to recommended doses (1.5-2.0 t/ha) (Kabir *et al.*, 2012). On average, farmers used 8075 kg/ha of cowdung which was similar to recommended doses (8-10 t/ha). The farmers of Thakurgaon used cowdung slightly higher than recommended doses and Rajshahi farmers used very less amount of cowdung. It may be due to availability of cowdung to the farmers in those areas. They used chemical fertilizers like urea (371 kg/ha), TSP (219 kg/ha), MoP (400 kg/ha), DAP (177 kg/ha) and gypsum (114 kg/ha). They used higher doses of urea, TSP and MoP and lower dose of gypsum than the recommended dose.

Table 7. Level of input used in HYV and local variety of potato cultivation in the study areas

Inputs	Rajshahi	Rangpur	Thakurgaon	All
Human labour:				
Own	67	77	74	73
Hired	112	106	92	103
Total	179	183	166	176
Seed (kg/ha)	1825	1851	2036	1904
Cow dung (kg/ha)	2194	9994	12039	8075
Urea (kg/ha)	331	443	339	371
TSP(kg/ha)	177	150	331	219
MoP (kg/ha)	413	453	333	400
DAP	340	174	16	177
Gypsum	98	148	98	114
Others	35	23	369	142

Source: Field Survey (2016-17)

Table 8. Per hectare cost of cultivation of potato in the study areas

Input costs	Taka per hectare			
	Rajshahi	Rangpur	Thakurgaon	All
A. Variable cost:				
Land preparation	15032	11678	14070	13927(7)
Hired human labour	29277	26876	25819	27327(13)
Seed	67760	54658	68625	63681(31)
Manures	1109	7367	8248	5575(3)
Fertilizers:				
Urea	5303	5744	5375	5825(3)
TSP	3883	3589	8187	5220(2)
MoP	6206	6765	4815	5929(3)
DAP	8616	4654	389	4553(2)
Gypsum	1393	1404	1113	1303(1)
Others	3846	2906	4195	3649(2)
Total	27247	25062	23776	25362(13)
Insecticides	16957	22527	11737	17074(8)
Irrigation	6961	3952	3345	4753(2)
Int. on opt. capital	3835	3549	3631	3672(2)
Total variable cost	168178	155669	159251	161033(79)
B. Fixed cost				
Family labour	19220	22021	21860	21033(10)
Land use cost	22249	21407	22155	21937(11)
Total fixed cost	41469	43428	44015	42970(21)
Total cost (A+B)	209647	199097	203266	204003(100)

Source: Field Survey (2016-17), Parentheses indicates the percentage of total cost

Cost of cultivation

The cost of potato cultivation was estimated to be Tk. 204003 and Tk. 161033 per hectare on total cost and variable cost basis, respectively. The major share in total cost was seed (31%), followed by chemical fertilizers (13%) and land use cost (11%). The cost of potato

cultivation in Rajshahi was found higher (Tk. 209647/ha) than Thakurgaon (Tk. 203266/ha) and Rangpur (199097/ha). due to the higher cost of human labour, land preparation and more use of DAP (Table 8).

Profitability of potato cultivation

The average yield of potato was 28 ton per hectare which was higher than the national average of 20.91 t/ha (BBS, 2015). Comparatively higher yield was recorded in Rajshahi (30 t/ha) followed by Rangpur (28 t/ha) and Thakurgaon (26 t/ha) (Table 9). Higher yield was obtained in Rajshahi due to better management.

The gross return and gross margin of potato cultivation were Tk. 249819/ha and Tk.88786/ha respectively. Gross margin was found to be highest in Rajshahi (Tk. 126759) followed by Rangpur (Tk. 74302) and Thakurgaon (Tk. 65298). The net return of potato cultivation was Tk. 45816 per hectare. The benefit cost ratio was 1.22. Average cost of production of potato was found 7.39 Tk/kg and it was highest in Thakurgaon (7.82 Tk/kg) and lowest in Rajshahi (6.99 Tk/kg).

Table 9. Profitability of Potato cultivations in the study areas

Items	Rajshahi	Rangpur	Thakurgaon	All
Yield (t/ha)	30	28	26	28
A. Total cost:				
Variable cost (Tk./ha)	168178	155669	159251	163886
Fixed cost (Tk./ha)	41469	43428	44015	42970
B. Gross return (Tk./ha)	294937	229971	224549	249819
C. Gross margin (Tk./ha)	126759	74302	65298	88786
D. Net return (Tk./ha)	85290	30874	21283	45816
E. Benefit cost ratio	1.41	1.16	1.10	1.22
F. Cost (Tk/kg)	6.99	7.11	7.82	7.39

Farmers' attitude towards BARI released potato varieties

Table 10 revealed that about 66% farmers willing to increase the cultivation of BARI released potato varieties in the next year. Higher yield (83%) ranked first behind the reasons for increasing potato cultivation followed by profitability (70%), easy production technology (57%) and short duration (47%). On the other hand, 34% farmers were not interested to increase cultivation of BARI released potato varieties due to high infestation of insect and diseases (87%), high price of seed (73%), lack of capital (51%) and inadequate storage facilities (48%).

Table 10. Reasons for increasing BARI released potato varieties for the next year

Type of Facility	Farmers responded (%)			
	Rajshahi	Rangpur	Thakurgaon	All
A. Willingness to increase				
1. Yes	73	62	58	66
2. No	27	48	62	34
B Reasons for increasing				
1. Higher yield	91	82	76	83
2. Profitable crop	78	62	71	70
3. Easy production technology	53	69	49	57
4. Short duration crop	44	53	42	47
C. Reasons for not increasing				
1. High infestation of insect and diseases	84	98	78	87
2. High price of seed	76	73	69	73
3. Lack of capital	51	56	47	51
4. Inadequate storage facilities	56	47	42	48

Constraints of potato cultivation

The farmers in the study areas encountered different constraints during potato cultivation. The constraints were ranked based on their priority (Table 11). A brief discussion on various problems has been made in the following sections.

Insect and diseases infestation: Late blight (LB) disease is the aqute problem in potato cultivation. This was mentioned by 76% farmers. The yield of potato is seriously hampered by this disease. Although farmers have little knowledge about the harmful effects of disease incidence in potato. Generally farmers apply pesticide without recommendation in their field.

Non-availability of quality seed: Quality seed is the pre-requisite for higher yield of potato. Farmers in the study areas used potato seed from different sources like own source, BADC, market traders, etc. Market traders usually adulterate potato seed for receiving higher profit. Seed supplied by BADC is good but they supplied a small amount of seed, which do not meet the farmers' requirement and also the price of BADC seeds is very high. Nonetheless, own seed retained for their own use don't fulfill their requirements. Therefore, 70% respondent mentioned that non-availability of quality seed is a problem which hampered the potato yield.

Table 11. Constraints to potato cultivation in the study areas

Constraints	Farmer responded (%)			
	Rajshahi	Rangpur	Thakurgaon	All
Insect and disease	78	84	64	76
Non-availability of quality seed	76	64	71	70
High price of inputs	71	53	67	64
Impure fertilizer	56	53	62	57
Inadequate storage facilities	51	47	40	46
Lack of training/knowledge	29	22	33	28
Others*	27	16	20	21

*Others mean high price of insecticides, lack of capital, low price of product etc.

High price of input: Sixty four percent farmers opined that the cost of production of potato is high. Farmers have to spend a large amount of money in the form of seed, labour and fertilizer. Such a high cost prevents the farmers to expand the area under potato cultivation.

Impure fertilizer: About 57% farmers have identified the problem of adulteration and artificial scarcity of fertilizer. Farmers also informed that the dishonest traders try to create artificial scarcity through hoarding in the peak season for getting higher profit.

Lack of technical knowledge: Technical knowledge relating to crop cultivation is also crucial for getting higher yield. It optimize input use, save production cost and increase yield of crops as well as farmers' income. Respondent farmers (28%) in the study areas were suffering from lack of technical knowledge regarding potato cultivation since they used various inputs unwisely. Therefore, this problem was reported to be an important problem of potato cultivation.

Inadequate storage facility: Potato is a semi perishable vegetable which needs storage for using it throughout the year. The small and medium farmers have to sell most of their potatoes immediately after harvesting with lower price. Most of them have little access to the local cold storage because of their small volume. Therefore, inadequate storage facility (46%) reported to be a problem in the study areas.

Conclusions and Recommendations

The study shows that BARI Alu-7 is a highly adopted potato variety in the study areas followed by BARI Alu-13, BARI Alu-25 and BARI Alu-8. Adoption index in ploughing is over use and adoption level of sowing date is high. Adoption level of seed rate, gypsum and boron were found higher in the study areas. The adoption level of urea, TSP, MoP was over use and adoption levels of cowdung and zinc sulphate were found medium. Most of the farmers collected potato seeds from other sources. Mostly one and two times earthing up, 5-8 times insecticides application and 1-4 times irrigation was practiced by the farmers in the study areas. Yield of potato was found higher at Rajshahi followed by Rangpur and Thakurgaon. Gross return, gross margin and net return also found higher in Rajshahi than Rangpur and Thakurgaon. Farmers' attitudes towards BARI released potato varieties seem to be very positive because most of the farmers wanted to increase potato production in the next year. Although potato cultivation is profitable, it faces various constraints like unavailability of quality seed, high price of inputs, insect and diseases, inadequate storage facilities etc.

Based on the findings, the following recommendations are put forward for wider adoption of BARI released potato varieties at farm level:

- BARI released potato seed should be made available to the farmers. So it should be need to encourage private seed companies to come forward for producing quality seed of potatoes.
- Motivational campaign through providing training, booklets and other supporting materials to farmers and extension personnel about the latest improved potato varieties should be continued.
- More intensive research should be undertaken by the breeders to develop disease and insect-pest resistant potato varieties in the near future.

- Farmers level low cost storage facilities should be developed. Therefore, emphasis should also be given to increase the number of cold storage in the potato growing areas of the country.

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BIO-RATIONAL MANAGEMENT PACKAGES OF JASSID AND SHOOT AND FRUIT BORER OF OKRA

A. MOHAMMAD[1], S. N. ALAM[2], M. R. U. MIAH[3]
M. R. AMIN[4] AND H. B. SAIF[5]

Abstract

The study was conducted for bio-rational management of jassid (*Amrasca biguttula biguttula*), and shoot and fruit borer of okra (*Earias vittella*) at experimental field of Bangladesh Agricultural Research Institute (BARI) during April to July 2016. Management Packages used in this study were package 1: Hand picking+ pheromone mass trapping for *Earias vittella* + spraying of bio-neem plus 1 EC @ 1ml l^{-1} of water, package 2: Hand picking + pheromone mass trapping for *Earias vittella* + spraying of emamectin benzoate 5 SG @ 1g l^{-1} of water, package 3: Hand picking + pheromone mass trapping for *Earias vittella* + spraying of spinosad 45 SC @ 0.4ml l^{-1} of water, package 4: Farmers practice: Spraying of cypermethrin 10 EC@ 1ml l^{-1} of water at seven days interval, and an untreated control. Among the packages bio-neem based one (Package 1) was the best to control jassid population, emamectin benzoate based package (Package 2) was the best to control okra shoot and fruit borer infestation on shoot and spinosad based package (Package 3) was the best to control okra shoot and fruit borer infestation on fruit. Statistically similar yields were obtained from bio-rational package treated plots and their yields were significantly higher than farmer's practice (Package 4) and untreated control plot. Higher benefit cost ratio (4.57-9.18) was obtained from bio-rational management package treated plots compare to that of farmer's practice plot (4.50).

Keywords: Jassid, okra shoot and fruit borer, bio-rational management.

Introduction

Okra (*Abelmoschus esculentus* L.) is a popular vegetable in Bangladesh and grows at different parts in the world. Okra is an important summer vegetable in Bangladesh, which plays an important role to meet the demand of vegetables of the country when vegetables are scanty in the market (Rashid, 1999). Okra production in Bangladesh is affected by many factors, among them insect pest attack is major one. On okra, 72 species of insects have been recorded of which jassid, shoot and fruit borer, aphid, whitefly, mealybug, leaf roller cause significant damage (Ali *et al.*, 2005).

[1]Scientific Officer, Lac Research Station, Bangladesh Agricultural Research Institute (BARI), Chapainawabganj, [2]Chief Scientific Officer, Entomology Division, BARI, Gazipur, [3,4&5]Professor, Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, [5]Scientific Officer, Planning & Evaluation Wing, BARI, Gazipur, Bangladesh.

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Among the insect pests, jassid (*Amrasca biguttula biguttula* Ishida) and okra shoot and fruit borer (OSFB) (*Earias vittella* Fabricius) are the most serious pests and major limiting factors in okra cultivation. Jassids are very destructive pest of okra during seedling and vegetative stage. They suck sap from leaves, stems and developing fruits, transmit viral diseases and also inject toxic substance to plant which retards growth of the plant (Bi *et al.*, 2001). Okra shoot and fruit borer larvae cause damage by boring into the tender shoots and fruits of okra (Rahman et *al.*, 2013). Infested shoot wilt and dry, damage plant develop branches and produce smaller fruits. In case of infested fruit, feeding larvae and their excreta present inside the fruit which reduce marketable yield and attraction of the consumers.

Farmers frequently apply toxic insecticides to protect their crops but extensive use of insecticides leads to the problems of pest resistance, resurgence, pesticides residues, destruction of beneficial fauna and environmental pollution (Adilakshmi *et al.*, 2008). Therefore, it is urgent to develop alternative methods of pest management other than the use of insecticides.

Different sources of bio-insecticides are being used as safe alternatives to synthetic chemical insecticides to overcome the challenges of food contamination as they are supposed to be environment friendly, safe to human and other non-target organisms as well. Azadirachtin containing neem insecticides are well known for their safety and good performance (Schmutterer, 2002). Various findings have been published (Naqvi, 1996; Aslam and Naqvi, 2000) which endorsed their effectiveness in controlling numerous pests. Whereas spinosad, consisting spinosyns substances derived from naturally occurring soil bacterium *Saccharopolyspora spinosa* by aerobic fermentation of this actinomycete species, possesses both contact and stomach poisoning activity against a wide range of insect groups. Emamectin is a foliar insecticide derivative of abamectin, which is isolated from fermentation of *Streptomyces avermitilis*, a naturally occurring soil actinomycete. It has been registered for uses in many countries on fruits, vegetables, cereals, tree nuts, oilseeds, herbs and tea crops (Ishaaya *et al*., 2001).

Considering the hazardous impact of chemical insecticides, the utilization of bio-pesticide based management tactics are safe and hazards free and considered as environmental friendly management tactics for insects pests. So it is very much important to develop bio-rational based integrated management packages against jassid, and shoot and fruit borer of okra.

Materials and Methods

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in the field of Entomology Division, BARI. The whole experimental field was divided into three blocks. The unit plot size was 6m × 4m. The inter block distance was 2 m and inter plot distance was 1 m and a distance of 200 m was maintained between bio-rational management package treated plots and the farmer's practice and untreated control plots. The management package were package 1: Hand picking+ pheromone mass trapping for *Earias vittella* + spraying of bio-neem plus 1 EC (Azadirachtin) @ 1ml l^{-1} of water, package 2: Hand picking + pheromone mass trapping for *Earias vittella* + spraying of emamectin benzoate 5 SG (Proclaim) @ 1g l^{-1} of water, package 3: Hand picking + pheromone mass trapping for *Earias vittella* + spraying of spinosad 45 SC (Tracer) @ 0.4 ml l^{-1} of water, package 4: Farmers practice: Spraying of cypermethrin 10 EC (Ripcord) @ 1 ml l^{-1} of water at 7 days interval, Untreated control (Water spray). Management packages were applied at 12 days interval and in farmers practice plot, treatment was applied at 7 days interval. In case of management packages using hand picking of infested leaves, shoots, flower buds, fruits and destruction of insect eggs were done before spraying.

Data were collected on the basis of some pre-selected parameters, such as number of jassid leaf^{-1}, total number of shoot and okra shoot and fruit borer (OSFB) infested shoot plant^{-1}, total number of fruit and OSFB infested fruit plant^{-1}, weight of healthy fruit, weight of infested fruit and total yield of okra.

Number of jassid leaf^{-1} were counted and recorded 1 day before spray (pre-treated condition) and 48 hours after every spray (after treatment application) from 5 leaves of randomly selected 5 plants of each plot. Data were converted to mean jassid population leaf^{-1}.

Total number of shoot, and OSFB infested shoot were counted and recorded from randomly selected 5 plants of each plot starting from vegetative stage and continued till last harvesting at 7 days interval. Total number of fruit and OSFB infested fruit were also counted and recorded at 7 days interval from randomly selected 5 plants of each plot. It was started from fruit initiation stage and continued till last harvest. Healthy and infested yield data were recorded at the time of harvesting of fruits. Total 18 harvests were made at every 2 to 3 days intervals at different fruiting stages (5 early, 8 mid and 5 late) and the yield was converted in t ha^{-1}. Forty-sixty, 61-80 and greater than 80 days old crops were considered as early, mid and late fruiting stages, respectively.

Benefit cost analysis

For benefit cost analysis, records of the costs incurred for labour, pesticides, application of pesticide in each treatment and that of control without insecticide were considered. The untreated control did not require any pest management cost. The price of the harvested marketable healthy fruit of each treatment and that of control were calculated at market rate. The result of benefit cost-analysis was expressed in terms of benefit cost ratio (BCR).

$$\text{BCR} = \frac{\text{Adjustable net return}}{\text{Total management cost}}$$

Statistical analysis

Data were analysed by analysis of variance with the help of computer package STATISTIX 10 program. The mean differences of the treatments were observed by Least Significant Difference (LSD) test at 5% level of probability for the interpretation of results.

Results and discussion

The number of jassid after 48 h of treatment application varied from 1.72 to 5.14 leaf^{-1} (Table 1). Significantly lower jassid population was found among the bio-rational management package treated plot compared to farmer's practice and untreated control plot. The lowest jassid number 1.72 leaf^{-1} was found in package 1 consisting of Hand picking+ pheromone mass trapping of *E. vittella* + spraying of bio-neem plus 1 EC. Second lowest jassid population was found in package 3 (Hand picking+ Pheromone mass trapping for *E. vittella* + spraying of spinosad 45 SC) treated plot (2.36 leaf^{-1}) which was statistically similar to that of package 2 (Hand picking+ pheromone mass trapping for *E. vittella* + spraying of emamectin benzoate 5 SG) (2.52 leaf^{-1}). The highest number of jassid was found in untreated control plot (5.14 leaf^{-1}) followed by farmer's practice plot (3.19 leaf^{-1}). The population reduction over pre-treated population was 67%, 55.55%, 50.68%, 47.18% and 7.05% in package 1, package 3, package 2, farmer's practice and untreated control plot, respectively. Population reduction occurs in control plot may be due to water spray.

Table 1. Effect of different bio-rational management packages on jassid population abundance in okra field after 48 hours of treatment application

Treatments	Mean number of jassid/ leaf		% Reduction of jassid population over pre-treated population
	Before treatment application	After 48 hours of treatment application	
Package 1	5.22b	1.72d	67.04
Package 2	5.11b	2.52c	50.68
Package 3	5.31b	2.36c	55.55
Farmer's practice	6.04a	3.19b	47.18
Untreated control	5.53b	5.14a	7.05
CV %	4.43	4.10	

In a column, means having similar letter(s) are not significantly different at 5% level of significance by Least Significant Difference (LSD) test. The numerical figure within column indicates the mean of three replicates.

Effect of different management packages on shoot infestation by okra shoot and fruit borer (OSFB) at different growth stages of okra

At vegetative stage, numerically minimum shoot infestation was found in bio-rational management package 2 treated plot (2.56%) followed by package 3 (3.12%) and package 1 treated plot (3.33%) (Table 2). Infestation of OSFB in package 2 treated plot was not differ significantly from package 3 but from package 1. All management package treated plot showed significantly lower per cent shoot infestation than farmer's practice and untreated control plot (Table 2).

At early fruiting stage, numerically the lowest shoot infestation was found in package 2 (2.46%) treated plot followed by package 3 (2.80%) and package 1 (3.34%) (Table 2). Shoot infestation in package 2 treated plot was statistically similar to package 3 but statistically different from package 1. The highest per cent shoot infestation was found in untreated control plot (9.62%) followed by farmers practice plot (5.98%) and both were significantly different from all other packages (Table 2).

At mid fruiting stage, significantly lower infestation was found in three bio-rational management package treated plots compared to farmer's practice and untreated control plots (Table 2). Numerically the lowest shoot infestation was found in package 3 (2.34%) treated plot followed by package 2 (2.46%) and package 1 (3.20%). Management package 2 and 3 were statistically identical and other treatments were significantly different from each other (Table 2).

Among these crop stages, the lowest shoot infestation was found in late fruiting stage having a range of 1.79% to 5.66% (Table 2). Statistically similar but numerically lower shoot infestation was found in package 3 (1.43%) treated plot followed package 2 treated one (1.79%). Among the bio-rational management packages, higher shoot infestation was found in package 1 treated plot (2.39%) but it was significantly lower than farmer's practice (3.36%) and untreated control plot (5.66%) (Table2).

During the study, the mean OSFB shoot infestation was found 2.32% to 8.06%. The highest shoot infestation was found in control plot (8.06%) followed by farmer's practice plot (4.81%). Numerically the lowest shoot infestation was found in package 2 treated plot (2.32%) followed by package 3 (2.43%) and package 1 treated plot (3.16%). OSFB infestation in package 2 and package 3 treated plot was statistically similar but significantly different from package 1. All bio-rational package treated plots showed significantly lower shoot infestation than farmer's practice and untreated control plot (Table 2).

Result of the present study revealed that at vegetative and early fruiting stage, the lowest shoot infestation was found in bio-rational package 2 (Hand picking+ pheromone mass trapping + emamectin benzoate 5 SG) treated plot and at mid and late fruiting stage, the lowest shoot infestation was found in package 3 (Hand picking + pheromone mass trapping + spinosad 45 SC) treated plot. The lowest mean shoot infestation was found in package 2 (Hand picking+ pheromone mass trapping + emamectin benzoate 5 SG) treated plot. Patra *et al.* (2009) observed lower shoot infestation in emamectin benzoate treated plot compared to spinosad treated plot.

Table 2. Effect of different bio-rational management packages on the incidence of okra shoot and fruit borer infestation on shoot at different growth stages of okra during April-July, 2016

Treatments	Shoot infestation (%)				
	Vegetative stage	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean infestation
Package 1	3.33c	3.34c	3.20c	2.39c	3.16c
Package 2	2.56d	2.46d	2.46d	1.79d	2.32d
Package 3	3.12cd	2.80cd	2.34d	1.43d	2.43d
Farmer's practice	5.77b	5.98b	4.14b	3.36b	4.81b
Untreated control	10.37a	9.62a	6.59a	5.66a	8.06a
CV (%)	7.21	7.44	5.38	8.77	4.21

In a column, means having similar letter(s) are not significantly different at 5% level of significance by Least Significant Difference (LSD) test. The numerical figure within column indicates the mean of three replicates.

Effect of different packages on fruit infestation by okra shoot and fruit borer (OSFB) at different growth stages of okra

At early fruiting stage, numerically the lowest fruit infestation was found in the plots those received bio-rational management package 3 (2.10%) followed by package 2 (2.34%) and package 1 (2.99%) (Table 3). Fruit infestation due to OSFB in package 3 and 2 were statistically similar but both were significantly different from IPM package 1. Significantly the highest fruit infestation was found in untreated control plot (8.67%) followed by farmer's practice plot (4.59%) (Table 3).

At mid fruiting stage, the lowest fruit infestation by OSFB was found in package 3 treated plot (2.12%) which was statistically identical with that of package 2 treated plot (2.38%) (Table 3). Among the bio-rational management packages, significantly higher fruit infestation was found in package 1 treated plot (3.51%) but this was significantly lower than farmer's practice (5.43%) and control plot (10.49%) (Table 3).

Comparatively higher fruit infestation due to OSFB was found at late fruiting stage with a range of 2.61% to 11.97%. Significantly the lowest fruit infestation was found in the plots treated with bio-rational management package 3 (2.61%) followed by package 2 (3.37%) and package 1 treated plot (4.10%). Significantly the highest number of fruit infestation was found in untreated control plot (11.97%) followed by farmer's practiced treated plot (5.82%) (Table 3).

Mean fruit infestation range for all stage was 2.28% to 10. 38%. Significantly lower infestation was found in three bio-rational management packages treated plots compared to farmer's practice and untreated control plot. Numerically the lowest fruit infestation was found in package 3 (2.28%) treated plot followed by package 2 (2.69%) and package 1 treated plot (3.53%). The highest percent of fruit infestation was found in untreated control plot (10.38%) followed by farmer's practice (5.47%). Fruit infestation due to OSFB in package 2 and 3 were statistically identical (Table 3).

The results suggested that in all the stages, numerically the lowest fruit infestation was found in bio-rational management package 3 (Hand picking + pheromone mass trapping + spinosad 45 SC) treated plot followed by package 2 (Hand picking+ pheromone mass trapping + emamectin benzoate 5 SG) treated plot. The lowest mean fruit infestation (2.28) was also found in package 3 treated plot and followed by package 2 (2.69), although both of them were statistically identical. Patra *et al.* (2009) and Shinde *et al.* (2007) found the lowest fruit infestation in spinosad treated plot.

Table 3. Effect of different bio-rational management packages on the infestation of fruit by okra shoot and fruit borer at different growth stages of okra during April-July, 2016

Treatments	Infestation of fruit (%)			
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean infestation
IPM Package 1	2.99c	3.51c	4.1c	3.53c
IPM Package 2	2.34d	2.38d	3.37d	2.69d
IPM Package 3	2.10d	2.12d	2.61e	2.28d
Farmer's practice	4.59b	5.43b	5.82b	5.47b
Untreated control	8.67a	10.49a	11.97a	10.38a
CV (%)	7.90	7.85	5.36	4.68

In a column, means having similar letter(s) are not significantly different at 5% level of significance by Least Significant Difference (LSD) test. The numerical figure within column indicates the mean of three replicates.

The lowest yield of healthy fruit and the highest yield of infested fruit ha^{-1} were recorded in the untreated control plots. Three bio-rational packages resulted in significant increase of yield of healthy fruits and decrease of infested fruit yield over untreated control and farmers practice.

Numerically the highest marketable yield ha^{-1} were recorded from bio-rational management package 1 (Hand picking+ pheromone mass trapping + spraying of bio-neem plus 1EC) (11.56 t ha^{-1}) followed by package 3 (Hand picking + pheromone mass trapping + spraying of spinosad 45 SC)) (11.44 t ha^{-1}) and package 2 (Hand picking + pheromone mass trapping + spraying of emamectin benzoate 5 SG) (11.28 t ha^{-1}). However no significant difference was observed among them. The lowest marketable yield was found in untreated control (6.64 t ha^{-1}) plots and second lowest yield was found in farmer's practice plots (8.84 t ha^{-1}). Both were significantly lowewr and differed from the bio-rational management packages.

Significantly the highest yield of infested fruit was found in untreated control plots (0.96 t ha^{-1}) followed by farmer's practice plots (0.61 t ha^{-1}). The yield of the infested fruit was significantly reduced in all bio-rational management packages. The marketable yield increase over control was 74.10%, 69.88%, 72.29% under bio-rational management package 1, 2 and 3, respectively. Farmer's practice gave 33.13% marketable yield increase over control.

Table 4. Yield of okra under different bio-rational management practices against jassid and okra shoot and fruit borer infestation

Treatments	Yield (t/ha)		% Marketable yield increase over control
	Marketable	Infested	
Package 1	11.56a	0.34c	74.10
Package 2	11.28a	0.25d	69.88
Package 3	11.44a	0.23d	72.29
Farmer's practice	8.84b	0.61b	33.13
Untreated control	6.64c	0.96a	
CV (%)	3.29	8.34	

In a column, means having similar letter(s) are not significantly different at 5% level of significance by Least Significant Difference (LSD) test.

The highest benefit cost ratio (9.18) was obtained from the bio-rational management package 1 consisting of Hand picking + pheromone mass trapping for *Earias vittella* + spraying bio-neem plus 1EC. Second highest benefit cost ratio of 7.15 was recorded from the plot treated with package 2 (Hand picking + pheromone mass trapping for *Earias vittella* + spraying of emamectin benzoate 5 SG) followed by package 3 comprise of Hand picking + pheromone mass trapping for *Earias vittella* + spraying of spinosad 45 SC (4.57). The lowest benefit cost ratio 4.50 was found from the farmer's practice treated plot (Table 6).

Table 6. Benefit cost analysis of different bio-rational management packages for controlling jassid and shoot and fruit borer of okra

Treatments	Marketable yield t/ha	Gross return TK/ha	Cost of treatment TK/ha	Net return TK/ha	Adjusted net return	Marketable BCR
Package 1	11.56	404600	16920	387680	155280	9.18
Package 2	11.28	394800	19920	374880	142480	7.15
Package 3	11.44	400400	30120	370280	137880	4.57
Farmer's practice	8.84	309400	14000	295400	63000	4.50
Control	6.64	232400	00	232400	-	

Bio-rational management package 1 consisting of hand picking and spraying of bio-neem plus 1 EC was the most effective in controlling jassid population. Other two packages also gave significant result to control jassid population. All bio-rational management packages significantly controlled okra shoot and fruit borer infestation. However, package 2 consisted of Hand picking + pheromone mass trapping + spraying of emamectin benzoate 5 SG was the best to control shoot infestation and package 3 consist of Hand picking + pheromone mass trapping + spraying of spinosad 45 SC was the best to control fruit infestation, although both were statistically similar. Statistically identical yield was obtained from all bio-rational package treated plots and their yields were significantly higher than farmer's practice and untreated control plots. Higher benefit cost ratio was also obtained from bio-rational packages treated plots compared to farmer's practice plot.

Present study revealed that bio-neem based package was the best to control jassid population, emamectin benzoate based package was the best to control okra shoot and fruit borer infestation on shoot and spinosad based package was the best to control okra shoot and fruit borer infestation on fruit. Further studies are needed to know the effectiveness of the alternate and combined use of bio-neem, emamectin benzoate and spinoasd in the package against jassid, and okra shoot and fruit borer infestation.

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INCREASING CROPPING INTENSITY AND PRODUCTIVITY THROUGH MUNGBEAN INCLUSION IN WHEAT-FALLOW-T. *AMAN* RICE CROPPING PATTERN

M. A. H. KHAN[1], N. SULTANA[2], N. AKTER[3]
M. S. ZAMAN[4] AND A. K. CHOUDHURY[5]

Abstract

The experiment was conducted at the farmers' field of Bhaluka Upazilla under On-Farm Research division, Bangladesh Agricultural Research Institute, Mymensingh during 2014-15 and 2015-16 to evaluate the performance of Wheat-Mungbean-T.aman rice improved cropping pattern against a farmers cropping pattern of Wheat-Fallow-T.aman rice. The findings of the study indicated that three crops could be grown successfully in sequence in the tested site. The higher rice equivalent yield (15.33 t hd^{-1} $yr.^{-1}$), production efficiency (34.74 kg ha^{-1} day^{-1}) and land utilization index (70.69 %) were obtained from the improved cropping pattern than the farmer's one. Average gross return (Tk. 262750 ha^{-1}), gross margin (Tk 126204 ha^{-1}) and marginal benefit cost ratio (MBCR) 2.23 of the improved pattern indicate it's superiority over farmers' existing pattern. The fertility status of soil i.e. pH, organic matter, total N, available P, S, Zn and B content in soil were increased over the initial soil due to addition of mungbean biomass.Thus, inclusion of mungbean in the existing farmer's cropping pattern will improve soil health and the system productivity as a whole.

Keywords: Cropping intensity, cropping pattern, mungbean, productivity and gross return.

Introduction

Bangladesh is almost self-sufficient in rice production, other food production such as wheat, pulses, oil crops and vegetables etc. are still deficient to a large extent. Wheat is one of the major cereals in *rabi* season in the central and northwestern part of Bangladesh, though the largest area is still under transplanted aman rice cultivation during monsoon season. However, most of the aman rice area is covered with long duration T.*aman* varieties which cause a delay in wheat sowing, resulted reduce the yield. November 15 to 30 is the best time for wheat sowing, which can avoid drought and diseases at the terminal stage of growth of the crop. If short duration T.aman rice varieties mainly BRRI dhan56, BRRI dhan57 and Binadhan-16 can be transplanted instead of long duration ones then timely (November) sowing of wheat could be ensured. Most

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[1&2]Senior Scientific Officer, [3]Scientific Officer, [4&5]Principal Scientific Officer, On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Joudebpur, Gazipur, Bangladesh.

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of the farmers of Mymensingh area follow Wheat-Fallow-T.aman rice and Wheat-Jute-T.aman rice cropping pattern in 1 % of the cultivated land (Kabir and Islam, 2012). Many farmers are cultivating wheat followed by T.*aman* rice with keep their fallow land for at least 120-130 days. There is an ample scope of introducing a short duration crop like mungbean in *kharif 1* during fallow period after wheat. Mungbean is a short duration (60-70 days) leguminous high value pulse crop, which may easily be fitted in between wheat and T.*aman* rice in the existing cropping pattern. Mungbean contains 60 % carbohydrates, 25 % protein, 4 % mineral and 3 % vitamins (Kaul, 1982). Moreover, as a leguminous crop, it adds nitrogen in soil and improves soil health. Wheat-Mungbean-T.*aman* rice cropping pattern is presumably suitable for the Bhaluka soils, which requires relatively limited amount of irrigation water for wheat, mungbean and T.*aman* rice cultivation. However, incorporation of green manure and grain legume crops in the pattern might improve soil health (BARC, 2001). It is well known that biomass of legumes and arable crops improve soil fertility with little or no reduction in crop yields. Therefore, the experiment was undertaken to assess the feasibility of growing mungbean into Wheat-fallow-T.*aman* rice cropping pattern to improve soil fertility and the system productivity.

Materials Methods

The experiment was conducted at the farmers' field of Bhaluka, Mymensingh under On-Farm Research Division, Bangladesh Agricultural Research Institute, Mymensingh during 2014-15 and 2015-16.The geographical position of the area is between 24º38′N latitude and 90º33′E longitude. The meteorological data of the experimental site revealed that the highest temperature prevails in July and the lowest in December (Table 1). There is no precipitation in December. In June, the precipitation reaches its peak with an average of 436.45 mm. Maximum rainfall was received during the months of April to September. The precipitation varies 436.45 mm between the driest month and wettest month. In 2014-15, monthly mean maximum 32.93 (^{0}C) and minimum 17.51(^{0}C) air temperature and annual total rainfall 2110.70 (mm) and in 2015-16, monthly mean maximum 32.95 (^{0}C) and minimum 19.99 (^{0}C) air temperature and annual total rainfall 1895.00 (mm) were prevailing in the study area (Appendix I). However, a analysis of 10 years (2004-2013) daily climatic data indicates the average maximum temperature (0.35^{0}C), average minimum temperature (0.11^{0}C) and average temperature (0.24^{0}C) increase over 2004 (Appendix II).

The experimental site belongs to Madhupur Tracts Agro-ecological Zone (AEZ-28) of Mymensingh. The land type was medium high and general soil types exist in the area of which deep red brown terrace, shallow red brown terrace and acid basin clays. The top soil are mainly strongly acidic to slightly acidic with low to medium status of organic matter, low moisture holding capacity and low fertility level. A description of nutrient status of initial soil is presented in Table 1.

Table 1. Initial soil test values of the farmers' field at Bhaluka upazilla, Mymensingh

Sample	pH	OM (%)	Total N (%)	K (meq/100 g)	P (Bray)	S	Zn	B
					(μ/g)			
Initial	5.85	1.59	0.088	0.15	10.30	13.42	0.75	0.18
Critical level	-	-	0.12	0.12	7.00	10.00	0.60	0.20

The experiment was laid out in a randomized complete block design with six dispersed replications. Two cropping pattern *viz*., improved pattern and farmers' existing pattern were the treatments variables of the experiment. The unit plot size was 1000-1200 m^2. Fertilizer management was followed by FRG (2012) and intercultural operations like weeding, mulching, irrigation and pest management were done to support the normal growth of the crops. Wheat var. BARI Gom-26, mungbean var. BARI Mung-6 and rice var. BRRI dhan57 were used in improved pattern and wheat var. BARI Gom-26 and rice var. Horidhan were used in the farmers' pattern. Wheat was the first crop of the sequence. In improved pattern, BARI Gom-26 was seeded as broadcast at @ 120 kg ha^{-1} during 26-29 November, 2014 and 20-26 November 2015 and harvested during 15-17 March 2015 and 10-15 March 2016. In the farmers' pattern, BARI Gom-26 was seeded as broadcast at @ 120 kg ha^{-1} during 04-07 December 2014 and 24-27 November 2015, and harvested during 21-24 March 2015 and 14-18 March 2016. Mungbean was the second crop of the sequence which was seeded as broadcast @ 30 kg ha^{-1}during 5-10 April 2015 and 26-30 March 2016, and harvested during 15-20 June 2015 and 10-16 June 2016, respectively. After harvest of mungbean pods, the plants were incorporated into soil. The third crop was T.*aman* rice was transplanted, 25-30 days old seedlings with 20 cm × 15 cm spacing during 8-10 August, 2015 and 12-16 August 2016. The crop was harvested during 24-27 October, 2015 and 26-29 October 2016. In farmers'pattern, 30-35 days old seedlings of T.aman rice were transplanted with a 20 cm × 15 cm spacing during 10-15 August, 2015 and 08-13 August 2016, and harvested during 25-28 November, 2015 and 15-20 November 2016. In *T.aman* rice, fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). Yield data were collected from 4m × 3m area of each plot. Grains and straw were sun dried and weighed adjusting at 14, 12 and 10 % moisture content for T.*aman* rice, wheat and mungbean, respectively. Agronomic performance like field duration, rice equivalent yield (REY), production efficiency and land utilization index of cropping patterns were calculated as follows.

Rice Equivalent Yield (REY): For comparison between crop sequences, the yield of every crop was converted into rice equivalent yield. Rice equivalent yield (REY) was computed as yield of individual crop multiplied by market price of that crop divided by market price of rice (Verma and Modgal, 1983).

Rice equivalent yield ($t ha^{-1} yr^{-1}$) = $\frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{market price of rice}}$

Production efficiency: Production efficiency value in terms of $kg ha^{-1} day^{-1}$ was calculated by total main product in a cropping pattern divided by total duration of crops in that pattern (Tomar and Tiwari, 1990).

Production Efficiency ($kg ha^{-1} day^{-1}$) = $\frac{\sum Y_i}{\sum d_i}$

Where, Y_i= Yield (kg) of i^{th} crop, d_i= Duration (day) of i^{th} crop of the pattern and i= 1, 2, 3

Land utilization index (LUI): It was worked-out by taking total duration of crops in an individual cropping pattern divided by 365 days (Rahman *et. al.* 1989). It was calculated by the following formula:

Land Utilization Index (%) = $\frac{d_1 + d_2 + d_3}{365} \times 100$

Where d_1, d_2, and d_3 the duration of 1^{st}, 2^{nd} and 3^{rd} crop of the pattern

Economic analysis was done on the basis of prevailing market price of the commodities. The marginal benefit cost ratio (MBCR) of the farmer's prevalent pattern and any replacement for it can be computed as the marginal value product ((MVP) over the marginal value cost (MVC). The marginal of prevalent pattern (F) and any potential replacement (E) which was computed following CIMMYT (1988).

Marginal Benefit Cost Ratio (MBCR) $= \frac{\text{Gross return (E) - Gross Return (F)}}{\text{TVC (E) - TVC (F)}} = \frac{\text{MVP}}{\text{MVC}}$

Where TVC= Total Variable Cost

Results and Discussion

Results of the two years study of improved cropping pattern (Wheat-Mungbean-*T.aman* rice) and farmer's existing pattern (Wheat-Fallow-*T.aman* rice) are presented in Table 2-5.

Grain and By-Product Yield

Grain yields of wheat were 3.50 and 3.65 t ha^{-1} and straw yields were 3.65 and 3.90 t ha^{-1} in two consecutive years, respectively. Wheat grain yield decreased by 4 % in the 1^{st} year probably due to late sown (6 days) than that in the 2^{nd}year. Two years average grain and straw yields of wheat were 3.58 and 3.78 t ha^{-1}. Seed yield of mungbean was 1.16 t ha^{-1} in the 1^{st} year and 1.29 t ha^{-1} in the 2^{nd} year. Mean seed and biomass yields of mungbean were 1.23 and 2.31 t ha-^{1}, respectively. The yield of mungbean was also satisfactory in the 1st year but produced 10 % less yield than the 2nd year due to late sown mungbean (10 days earlier in the 2nd year). These results are in agreement with Sarker *et. al*. (2014) who reported that late sown mungbean produced lower yield than that of sown only 5-7 days earlier. Grain yields of T.*aman* rice were 4.10 and 4.23 t ha^{-1} in the two successive years. Mean grain and straw yields of *T.aman* rice were 4.17 and 4.48 t ha^{-1}. It was revealed that all the component crops under improved pattern (Wheat-Mungbean-*T.aman* rice) gave higher grain yield as well as by-product yield (Table 2). Average yield of wheat and *T.aman* rice in improved pattern increased by 9 and 15 % over farmers' practice (FP). The yield of improved pattern was higher presumably due to change of variety with improved production technologies and timely sowing of the component crops. Improved pattern produced higher by-product yield (10.56 t ha^{-1}) over farmers' practice (7.80 t ha^{-1}) which was 35 % higher due to change of variety with improved management practices and inclusion of mungbean. Farmers' pattern produced less yields than the improved one mostly due to use of imbalance fertilizers and poor management practices.

Farmers' cropping pattern Wheat-Fallow-*T.aman* needed 205 and 207 days field duration in the 1st and 2nd year. Contrary, total field duration of the improved pattern Wheat-Mungbean-*T.aman*was 256 and 260 days (excluding seedling age of rice) to complete the cycle in the 1st and 2nd year, respectively (Table 2). Thus, the turn-around period of 158-160 days was utilized in the farmers existing pattern. Result indicated that mungbean could be easily fitted in Wheat-Rice cropping pattern with an average of 108 days turn-around time in a year.

Table 2. Yield of different crops under improved cropping pattern (IP) and farmers' existing cropping pattern (FP) at Bhaluka upazilla, Mymensingh during 2014-15 and 2015-16

Parameters	Years	Improved Cropping Pattern (IP)			Farmers' Cropping Pattern (FP)	
		Wheat	Mungbean	T.aman	Wheat	T.aman
Grain yield (t ha^{-1})	2014-15	3.50	1.16	4.10	3.10	3.52
	2015-16	3.65	1.29	4.23	3.45	3.75
	Average	3.58	1.23	4.17	3.28	3.64
Straw yield (t ha^{-1})	2014-15	3.65	2.23	4.40	3.29	4.20
	2015-16	3.90	2.38	4.56	3.48	4.62
	Average	3.78	2.31	4.48	3.39	4.41
Duration (days)	2014-15	108	70	78	109	96
	2015-16	109	76	75	109	98
	Average	109	73	77	109	97
Turnaround time (days)	2014-15	32	22	55	20	140
	2015-16	25	17	63	17	141
	Average	29	20	59	19	141

Rice Equivalent Yield (REY)

Total productivity of improved and farmers' cropping patterns were evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of component crops. Improved cropping pattern produced higher mean rice equivalent yield (15.33 $tha^{-1}yr^{-1}$) over farmers' (8.75 $tha^{-1}yr^{-1}$) existing pattern (Table 3). Inclusion of mungbean in *kharif-1* season in improved cropping pattern increased REY of 75 % compared to farmers' one. These results are in agreement with that of Mondal *et al*. (2015) who reported that total productivity increased by 67 % over farmers, practice due to inclusion of a third crop (mungbean) in the pattern.

Production Efficiency (PE)

Maximum production efficiency (34.74) in terms of $kgha^{-1}day^{-1}$ was obtained from improved pattern and slightly lower (33.54) in the farmers' existing pattern (Table 3). Production efficiency in improved cropping pattern increased by 3.57 $kgha^{-1}day^{-1}$ over farmers' practice which might be due to inclusion of an additional mungbean crop with modern varieties and improved management practices.

Land Utilization Index (LUI)

Land utilization index is the effective use of land in a cropping year, which mostly depends on crop duration. Land utilization index (LUI) indicated that improved pattern used the land for 70.69 % period of the year, whereas farmers' pattern used the land for 56.44 % period of the year (Table 3). Land use efficiency was 25.25 % higher in improved pattern than farmers' practice, mostly because the improved pattern occupied the field for longer duration (259 days), than the farmers' pattern (206 days) in a year. As a result labour utilization could be more in the improved cropping pattern than existing one.

Table 3. Rice equivalent yield, production efficiency and land utilization index of improved pattern and farmers' existing pattern at Bhaluka, Mymensingh (average of 2014-15 and 2015-16)

Cropping Pattern	REY ($t\ ha^{-1}yr^{-1}$)	PE ($kg\ ha^{-1}day^{-1}$)	LUI (%)
Wheat-Mungbean-T.*aman* (IP)	15.33	34.74	70.69
Wheat –Fallow-T.*aman* (FP)	8.75	33.54	56.44
Increased (%)	75.20	3.57	25.25

Note: REY=Rice equivalent yield, PE=production efficiency and LUI= land utilization index

Soil fertility status

The status of soil pH, organic matter, total N, available P, K, S, Zn and B in initial soil as well as after completion of two cropping cycle of Wheat-Mungbean-T.*aman* cropping pattern is shown in Table 4. Initially the pH of the soil was 5.85 but after completion of two cropping cycle the soil pH slightly increased to near 5.88. It was also found that the fertility status of soil i.e. organic matter, total N, available P, S, Zn and B contents in soil were increased slightly over the initial soil due to addition of mungbean biomass. However, K in the improve pattern tended to be lower than the farmers one, which indicated to add more K to the soil to improve K content. Rao and Bhardwaj (1980) conclusively proved that pulses receiving optimum fertilizer, especially P, had more pronounced residual effect both in terms of N and P on the succeeding cereals.

Table 4. Effect of mungbean inclusion in Wheat-Fallow-T.*aman* rice cropping pattern on soil fertility status of the farmers' field of Bhaluka upazilla, Mymensingh during 2014-15 and 2015-16

Sample	Land type	Rainfed/ Irrigated	pH	OM (%)	Total N (%)	K (meq/ 100 g)	P (Bray)	S	Zn	B
							(μg/g)			
Initial	MHL	Irrigated	5.85	1.59	0.088 (VL)	0.15 (L)	10.30 (L)	13.42 (L)	0.75 (L)	0.18 (L)
Final	MHL	Irrigated	5.88	1.62	0.091 (L)	0.12 (L)	10.57 (M)	13.51 (L)	0.77 (L)	0.21 (L)

Note: MHL=Medium high land, VL= Very low and L= Low

Cost and return analysis

The economic analysis as shown in Table 5 indicated the higher return of the improved cropping pattern (Wheat-Mungbean-*T.aman*) than the farmers' pattern (Wheat-Fallow-*T.aman*). Average gross return of the improved pattern was Tk.262750 ha^{-1} which was 72 % higher over farmers' pattern. Mean variable cost was lower in farmers' pattern (Tk. 87420 ha^{-1}) than that in the improved pattern (Tk. 136546 ha^{-1}) which was probably due to inclusion of mungbean in the pattern as well as management practices. Average gross margin was substantially higher in the improved pattern (Tk. 1,26,204 ha^{-1}) than farmers' pattern (Tk. 65,780 ha^{-1}). The higher gross margin of the improved pattern was achieved mainly due to higher yield advantages of the component crops. Additional gross margin (92%) was achieved by adding 56 % extra cost in the improved pattern. These findings are supported by Sarker *et al*. (2014) who reported that among the six patterns, Wheat-Mungbean-*T.aman* rice produced the higher economic benefit in terms of BCR. Mean marginal benefit cost ratio (MBCR) was found 2.23 which further indicated the superiority of the improved pattern over the farmers' one. Thus, inclusion of mungbean in the existing pattern might be agronomically suitable and economically profitable for the farmers' in the study site.

Table 5. Cost and return analysis of improved cropping pattern and farmer's existing pattern at Bhaluka upazilla, Mymensingh (average of 2014-15 and 2015-16)

Cropping pattern	Gross return (Tk ha^{-1})	Total variable cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	MBCR
Wheat-Mungbean-T.aman (IP)	2,62,750	1,36,546	1,26,204	2.23
Wheat-Fallow-T.aman (FP)	1,53,200	87,420	65,780	--
Increased over FP (%)	71.50	56.19	91.86	1.23

Output Price: Wheat=Tk 25.00 kg^{-1}, T.aman=Tk.16 kg^{-1},Mungbean=Tk.70 kg^{-1}, and Straw= Tk.2 kg^{-1}.

Apparent soil nutrient balance

Total N, P, K and S uptake by different crops at the farmer's field are presented in Fig.1. The partial net balance of N was negative in both the patterns and ranged from -93 to -211 $kgha^{-1}$. Nitrogen replenishment through chemical fertilizer and organic matter addition either singly or in combination was not enough to balance N removal by crops presumably due to substantial loss of the applied N from the soil. The P balance was favourable as expected due to individual crop basis fertilization. Excess amount of P accumulated in the soil and positive effect of P was reflected in the improved pattern. In farmers' pattern, P balance was also positive. However, the partial net balance of K was negative and ranged from -65 to -96 $kgha^{-1}$. This may lead to K depletion in the long run. There was a positive balance of S in both the patterns and ranged from 6 to 33 $kgha^{-1}$. These results are supported by the reports of Khan *et al*. (2006).

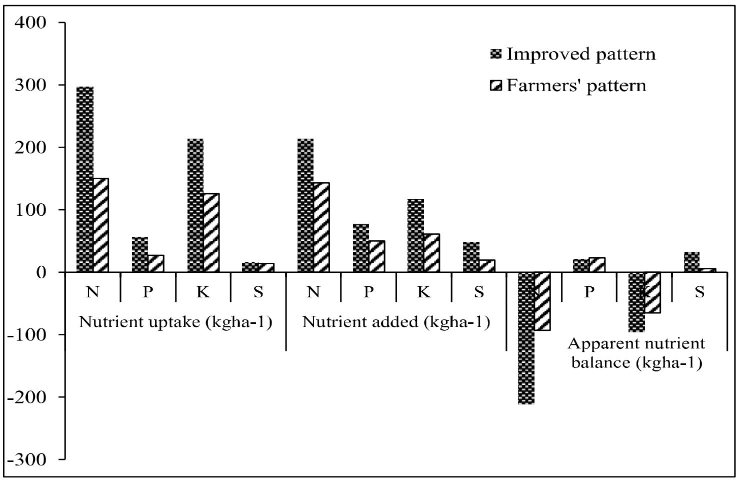

Fig 1. Effect of improved pattern and farmers' pattern on soil nutrient balance at Bhaluka, Mymensingh.

Conclusion

Results of the two years trial clearly indicated that Wheat (Var. BARI Gom-26)-Mungbean (Var. BARI Mung-6)-*T.aman* (Var. BRRI dhan57) cropping pattern was more productive and profitable than the farmers existing pattern Wheat (Var. BARI Gom-26)-Fallow-T.*aman* (Var. Haridhan). Thus, mungbean can be successfully accommodated in the existing farmers' pattern with total crop duration (259 days) in Bhaluka upazilla of Mymensingh district to increase cropping intensity and system productivity with profitability. Furthermore, through this cropping pattern the soil health may be improved and the farmers could cultivated year round crop successfully and creates employment opportunity of labour forces.

Acknowledgement

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Appendix I. Monthly maximum, minimum and mean air temperature (ºC) and monthly total rainfall (mm) of Mymensingh during September 2014 to August 2016

Month/ Year	2014-15			2015-16			Monthly total rainfall (mm)	
	Max.	Mini.	Mean	Max.	Mini.	Mean	2014-15	2015-16
September	35.00	23.00	29.00	35.00	24.00	30.40	394.50	287.50
October	35.00	18.50	26.80	34.00	19.00	27.00	15.30	78.00
November	33.40	13.70	23.60	33.69	15.00	23.60	0.00	4.30
December	28.70	9.80	19.30	28.50	9.00	18.80	0.00	0.00
January	24.70	10.00	18.90	24.90	12.02	17.99	15.20	18.20
February	27.20	11.00	20.60	27.84	16.84	22.34	19.60	8.40
March	35.00	13.50	24.30	34.09	20.16	26.39	0.70	104.80
April	34.70	18.60	26.70	34.69	24.30	28.40	206.50	53.20
May	35.50	20.50	28.00	35.40	22.15	27.90	203.60	331.10
June	35.60	22.50	29.10	35.74	23.94	28.50	484.10	388.80
July	35.70	24.40	30.10	36.70	26.53	29.14	387.90	523.10
August	34.60	24.60	29.60	34.90	26.88	30.04	383.30	97.60
Annual	**32.93**	**17.51**	**25.50**	**32.95**	**19.99**	**25.88**	**2110.70**	**1895.00**

Appendix II. Yearly maximum, minimum and average air temperature (ºC) rainfall (mm) of Mymensingh during 2004 to 2013

Year	Maximum (ºC)	Minimum (ºC)	Average (ºC)	Temperature change (ºC/year) over 2004	Yearly total rainfall (mm)
2004	29.54	20.97	25.25	0.00	2563.50
2005	29.63	21.16	25.39	0.23	2690.40
2006	30.12	21.28	25.70	0.45	2016.20
2007	29.57	20.89	25.23	-0.02	2779.40
2008	29.62	21.17	25.39	0.14	2202.90
2009	30.46	21.28	25.87	0.62	1658.30
2010	30.26	21.40	25.83	0.58	2059.70
2011	29.66	20.82	25.24	-0.01	2144.80
2012	29.94	20.94	25.44	0.19	1521.10
2013	30.10	20.90	25.60	0.35	1660.50
Average	**29.89**	**21.08**	**25.49**	**0.253**	**2129.68**

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IMPACTS OF WHEAT SEED STORAGE AT POOR HOUSEHOLD LEVEL IN BANGLADESH

M. A. MONAYEM MIAH[1], Q. M. S. ISLAM[2], M. E. BAKSH[3]
F. J. ROSSI[4] AND T. P. TIWARI[5]

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 successfully overcome this problem. With this aim CSISA-CIMMYT (Cereal Systems Initiative for South Asia) project in Bangladesh have been working since 2012. Therefore, the study assessed the impacts of wheat seed storage systems at HH level, with a particular emphasis on how the poor farmers are benefited by doing the seed storage business. The study analyzed data and information collected at random from 210 supported and 60 non-supported farmers spread over three wheat growing districts namely Mymensingh, Faridpur and Rangpur. Wheat farmers used different storage containers and showed the highest level of satisfaction towards plastic sac along with poly bags and plastic/metal drum due to cost effectiveness and seed quality maintenance. On an average, supported and non-supported farmers retained respectively 103 kg and 100 kg of seed at household level, and sold most of their seeds to neighbouring farmers, local markets, and dealers. Wheat seed storage at household level was a profitable business to most of the respondent farmers. They could earn a reasonable net income (Tk.1127-Tk.1210) from seed storage. The farmers who stored seed in plastic/metal drum received the highest net income due to higher storage capacity, less storage cost, and higher seed price. The wheat storage program has created significant impacts in the study areas. A substantial increase was recorded in wheat area, wheat productivity, and financial benefit of the wheat farmers as a whole. Nevertheless, improved wheat seed is now available at farm level and most farmers become enthusiastic towards improved wheat cultivation because of this program. Respondent farmers did not face any critical problem during seed storage.

Introduction

Wheat is one of the important cereal crops after rice in Bangladesh. It is highly nutritious and a good source of energy. 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 current production and

[1&2]Agricultural Economics Division, Bangladesh Agricultural Research Institute (BARI), Gazipur and [3,4&5]CIMMYT Bangladesh.

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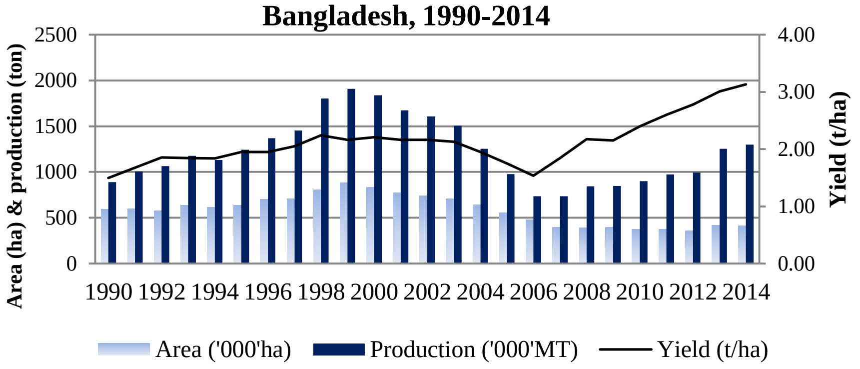
productivity of wheat must be raised for maintaining the country's food security without substantial and unaffordable imports.

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 positive and highly significant growth rates due to introduction of modern seed-water-fertilizer technologies (Miah *et al.,* 2015). Unfortunately, both area and production started decreasing at a faster rate from 2000 and continued up to 2007 (Fig.1). Many wheat growers started shifting their wheat lands to *Boro* rice during this period because of stable and higher yield, higher return and for food security (Hussain and Iqbal, 2011). Besides, a vast wheat area was also replaced by maize in this period (Miah *et al.,* 2013).

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



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

Considering these depressing situations, Bangladesh Government give 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 that can tolerate saline soils and temperature elevation at seed-setting, as well as resisting new diseases through on-going selections from diverse germplasm provided by CIMMYT. Generally, the seeds of these improved varieties are multiplied and distributed by the Bangladesh Agricultural Development Corporation (BADC). At present, BADC produces 27,208 tons of wheat seed which is 48.4% of the total seed requirement (Maswood, 2014; Nuruzzaman, 2015). Much of these seeds were sourced by 'better-off' farmers following their attendance at demonstrations that are regularly promoted by the extension services of DAE and research organization (especially WRC, BARI and under different research projects).

Seed security is the key to the attainment of household food security among resource poor farmers in developing countries (Wambugu *et al.,* 2009). Food insecure, marginal, and landless farmers have little access to these improved seed from BADC and are thus largely excluded from the benefits of any new variety (Page, 2007). The production and storage of improved varieties of seed at the household (HH) level has successfully overcome this problem. Over the past three years, CIMMYT under the Cereal Systems Initiative for South Asia in Bangladesh (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 after wheat cultivation with the aim of encouraging farmers to store seeds of these new varieties at their HH level for own use and earning income by selling surplus portion. This 'bottom-up' seed dissemination program has created a lot of socioeconomic impacts at farm level that need to be documented properly. Therefore, the present study was conducted with the following objectives:

1. To find out the project supports and catalog the systems used in storing wheat seed at the HH level.
2. To assess the overall impacts of CSISA-CIMMYT wheat seed storage and dissemination program in the study areas.

Methodology

Sampling procedure and sample size: The study was conducted at three wheat growing districts, namely Mymensingh, Faridpur and Dinajpur. The populations of this study were the wheat farmers who stored wheat seed at their homes with the purpose of own use as well as business. Before selecting sample respondents, a list of wheat seed storing farmers was prepared with the help of CSISA-CIMMYT project personnel working under respective district. Finally, a total of 210 small and marginal (having land size 0.50-2.49 acres) supported farmers[*] taking 70 farmers from each districts were selected randomly for interview. Again, 60 small and marginal non-supported farmers (20 from each district) were also selected randomly as control. Thus the total sample size of the present study was 270.

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-CIMMYT project personnel in respective district assisted researchers and enumerators in collecting primary level data. Secondary data were collected from different published sources, such as BBS, journal articles, and internet.

Analytical technique: The collected data were edited and tabulated for analysis. Descriptive statistics were mostly used in analysing collected data and

[*] Supported poor farmers were those wheat farmers who took supports like seed storage training and improved wheat seed from CSISA-CIMMYT project.

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 applying straight-line method for one year. In this study, the salvage value of storage container was reported to be zero. Therefore, the straight-line equation applied in this study was as follows:

$$\text{Depreciation cost} = \frac{\text{Original value of storage container}}{\text{Total life of storage container}}$$

Again, the gross income of storage was estimated by multiplying storage quantity (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

The Project Supports

Training: CSISA-CIMMYT project arranged training on wheat production and seed storage at household level for its collaborators before providing any sort of support from the project. The project continued its seed dissemination program for three years (2012-2014). However, 94.3% supported farmers received training on improved wheat seed storage technique from CSISA-CIMMYT project. The rest participants received training from the district level office of Department of Agricultural Extension (DAE). Majority of the farmers (55.3%) received training in 2013 followed by in 2014 (Table 1).

Table 1. Training organization and participating year of the supported wheat farmers

Particulars	% of responses			
	Mymensingh *(n= 70)*	Faridpur *(n= 70)*	Rangpur *(n= 70)*	All area *(n= 210)*
1. Providing organization				
▪ CSISA-CIMMYT project	100	82.9	100	94.3
▪ DAE	--	15.7	--	5.2
▪ IRRI	--	1.4	--	0.5
2. Participating year				
2012	8.6	5.7	2.9	5.7
2013	72.8	58.6	34.3	55.3
2014	17.2	31.4	62.8	37.1

The major training materials delivered among farmers included the improved techniques of wheat cultivation and seed storage. From the training, supported farmers learned many things regarding wheat production and storage. Majority of the farmers opined that they could learn how to produce quality seed; maintaining grain maturity, grain dryness, container's air tightness, and its placement. They could also know that dried grain should be kept in the container fully after proper cooling and it should be monitored several times for getting quality seed. The supported farmers mentioned that they could learn many things about wheat cultivation through participation of such a training programme. They could know the benefit of raised bed cultivation, germination test of seed, timely seed sowing, water and fertilizer management and the harmful effect of weeding wheat crop (Table 2).

Table 2. Knowledge learned by supported wheat farmers during storage training

Knowledge learned	% of responses			
	Mymensingh *(n=70)*	Faridpur *(n= 70)*	Rangpur *(n= 70)*	All area *(n= 210)*
A. Seed storage				
1. Matured grain should be retained for seed	32.9	38.6	5.7	25.7
2. Wheat grain should be dried properly for seed	87.1	72.9	51.4	70.5
3. Seed container should be tied properly	77.1	80.0	50.0	69.0
4. Seed container should be placed on upper place	57.1	58.6	47.1	54.3
5. Container should be filled in properly	7.1	7.1	18.6	11.0
6. Dried grain should be kept in the container after cooling properly	17.1	2.9	11.4	10.5
7. Seed should be dried separately from unwanted variety	2.9	5.7	--	2.9
8. Seed in container should be monitored frequently	1.4	4.3	1.4	2.4
B. Wheat production				
1. Wheat cultivation on raised bed is better compared to conventional practices	--	7.1	11.4	6.2
2. Seed should be sown after germination test	32.9	30.0	10.0	24.3
3. Seed should be sown timely	--	24.3	18.6	14.3
4. Appropriate quantity of inputs (fertilizers & irrigation) should be applied timely.	--	12.9	54.3	22.4
5. Weed should be controlled for better wheat yield	--	--	2.9	1.0
6. Harvested wheat plant should be threshed properly	--	--	5.7	1.9

Dissemination of improved wheat variety: After providing wheat production and seed storing training, CSISA-CIMMYT project disseminated a number of improved wheat varieties among supported resource poor farmers so that they could cultivate the latest released varieties of wheat. In the study areas, both supported and non-supported farmers used eight different improved wheat varieties. Among these varieties, BARI Gom-26 was reported to be the highest adopted variety both by supported (59%) and non-supported farmers (52%) farmers. Followed by BARI Gom-28, were adopted about 12% and 8% by SF and NSF, respectively. The other popular old varieties of wheat were Shatabdi and Prodip which were adopted by supported (17 &18%) and non-supported (15 & 12%) farmers respectively. However, supported farmers used latest variety more than non-supported farmers (Table 3).

Most of the supported farmers (59%) collected new and latest improved wheat varieties from CSISA-CIMMYT project, whereas about 72% non-supported farmers collected it from own source, neighbouring farmers and local market (Table 3). The findings clearly implied that most of the non-supported farmers in the study areas could cultivate new improved varieties only because of seed storage program at household level.

Table 3. Wheat variety use and sources of seeds of the sample farmers, 2013-2014

Seed type and source	Mymensingh		Faridpur		Rangpur		All area	
	SF	NSF	SF	NSF	SF	NSF	SF	NSF
1. Variety used (%)	*n=70*	*n=20*	*n=70*	*n=20*	*n=70*	*n=20*	*n=210*	*n=60*
BARI Gom-25	1.4	--	4.3	--	--	--	1.9	--
BARI Gom-26	75.7	80.0	28.6	20.0	71.4	55.0	58.6	51.7
BARI Gom-27	4.3	--	2.9	--	8.6	5.0	5.2	1.7
BARI Gom-28	22.9	20.0	1.4	--	12.9	5.0	12.4	8.3
Shatabdi	--	--	34.3	45.0	--	10.0	11.4	18.3
Prodip	2.9	5.0	40.0	40.0	2.9	5.0	15.2	16.7
Sonalika	1.4	5.0	--	5.0	10.0	25.0	3.8	11.7
Bijoy	--	--	2.9	--	--	--	1.0	--
2. Source of seed (%)								
Own	12.9	20.0	44.3	50.0	14.3	20.0	23.8	30.0
Neighbour/relatives	4.3	20.0	7.1	25.0	7.1	20.0	6.2	21.7
Local market	11.4	20.0	15.7	10.0	4.3	30.0	10.5	20.0
CSISA project	74.3	40.0	25.7	5.0	75.7	15.0	58.6	20.0
NGO	--	--	--	--	1.4	--	0.5	--
DAE	--	--	--	10.0	--	5.0	--	5.0
Dealer	--	--	22.9	10.0	1.4	10.0	8.1	6.7

Note: SF = Supported farmer, NSF = Non-supported farmer

***Storage container used*:** Quality characters of wheat seed, such as seed germination, moisture content, seed color and seed-borne fungal prevalence is influenced by various factors during storage (Malaker *et al.*, 2008). The type of storage container is one of the important factors that determine the quality of seed to a great extent. The supported farmers were provided training about the use of different types of container for seed storage. The 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, jute sac, plastic sac, along with poly bags and plastic/metal drum were highly used over the years by the respondent farmers.

Table 4. Average score on preference ranking for different storage devices

Type of farmer	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
A. Mymensingh								
Supported	1.3	2.7	3.6	5.3	5.6	7.1	7.5	2.8
Non-supported	1.2	2.8	3.8	5.3	5.6	7.2	7.7	2.7
B. Faridpur								
Supported	1.1	2.6	3.7	6.4	4.6	7.2	6.9	3.5
Non-supported	1.0	2.4	3.7	6.6	5.0	6.9	6.7	3.8
C. Rangpur								
Supported	1.1	2.6	3.7	6.1	5.3	7.3	6.8	3.0
Non-supported	1.1	2.7	3.7	6.1	5.6	7.4	7.0	2.7
D. All area								
Supported	1.1	2.6	3.7	6.0	5.2	7.2	7.1	3.1
Non-supported	1.1	2.6	3.7	6.0	5.4	7.1	7.1	3.0

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

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* (7.1-7.2) for both supported and non-supported farmers 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* (4.6-5.0). The lowest preference was reported to be on using jute sac alone for both categories of farmers. In Mymensingh hub, the average score on preference ranking was the highest for *metal/plastic drum+poly bag* (Table 4).

Protection measures adopted: The supported farmers were provided training about different protection measures which will be adopted in the time of insects-diseases attack. In the case of air tight container and appropriate moisture content of seed, no protection measure is needed for getting quality seed. However, more or less similar percentage of supported and non-supported farmers in the study areas took protection measures against insects. Among different protection measures, the dust/powder of *Neem* leaves was highly used as protection measure for both types of farmers. Usually, no cost was involved with these traditional measures. However, the average costs incurred for other less used protection measures ranged from Tk.15 to Tk. 72 (Table 5).

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

Type of protective measures	Mymensingh		Faridpur		Rangpur		All area		Average cost (Tk/year)
	SF	NSF	SF	NSF	SF	NSF	SF	NSF	
Sample size (n)	*n=70*	*n=20*	*n=70*	*n=20*	*n=70*	*n=20*	*n=210*	*n=60*	
Measure adopted (%)	47.1	45.0	34.3	35.0	60.0	60.0	47.1	46.7	--
1. *Neem* leaf powder	35.7	35.0	15.7	20.0	--	20.0	17.1	25.0	--
2. *Biskatali* leaf powder	4.3	5.0	--	--	--	35.0	1.4	13.3	--
3. White powder	4.3	5.0	1.4	--	--	--	1.9	1.7	57.9
4. Phostoxine	2.9	5.0	1.4	--	--	--	1.4	1.7	62.5
5. Naphthalene	--	--	7.1	--	--	10.0	2.4	3.3	15.3
6. Insecticides	2.9	--	--	--	--	--	1.0	--	16.7
7. Finish powder	--	--	--	10.0	--	--	--	3.3	72.1
8. Others*	2.9	--	18.5	5.0	--	5.0	7.2	1.7	--

Note: SF = Supported farmers, NSF = Non-supported farmer, *It included sand, ash, rice bran, tobacco powder

Production and Distribution of Wheat Grain and Seed

In 2013-2014, supported and non-supported farmers produced on an average 894 kg and 1056 kg of wheat of which 11.5% and 9.5% were retained for seed at household level respectively. It indicated that supported farmers produced less, but retained seed higher than that of non-supported farmers. Except Rangpur, this trend was observed at Mymensingh and Faridpur areas. The using pattern of wheat grain revealed that both supported and non-supported farmers sold more than 80% of grain and consumed the rest at household levels. Exceptions were found only in Faridpur, where household consumptions were much higher compared to other two areas.

Supported and non-supported farmers sold 64% and 52% of seed to others and used the rest amounts for their own cultivation, respectively. Farmers also reported that a small percentage (1-4%) of seed was consumed at household level in the case of unsold or time of need (Table 6).

'Delivering improved seeds to smallholder farmers in the developing world is an efficient and sustainable method of increasing crop yields and quality' (http://www.dryingbeads.org). Both supported and non-supported small holder farmers sold seed to neighbouring farmers or relatives, other farmers at local market and fertilizer/pesticides/seed dealers. Table 7 shows that 60-61% seeds were sold to neighbouring farmers and relatives; 28-31% to other farmers at local markets; and 9-11% to fertilizer & pesticides dealers.

However, Faridpur farmers were not found to sell any quantity to dealers. Both supported and non-supported farmers received higher price when they could sell seed to dealers and received the lowest price when they sold it to local markets. The local seed dealers in the study areas collected seed of improved variety wheat from known farmers and could sell them higher price. Again, most respondent farmers could sell their new variety seed to neighbouring farmers at higher price.

Table 6. Use of wheat grain and seed at farm level during *Rabi* season, 2013-2014

Disposal pattern	Mymensingh		Faridpur		Rangpur		All area	
	SF	NSF	SF	NSF	SF	NSF	SF	NSF
1. Total production (kg)	1007	1316	1028	1100	648	752	894	1056
2. Use of grain (kg)	891	1214	906	1000	577	656	791	956
a. Sale	763 (86)	1084 (89)	646 (71)	752 (75)	528 (92)	568 (87)	646 (82)	801 (84)
b. Consumption	128 (14)	130 (11)	260 (29)	248 (25)	49 (8)	88 (13)	145 (18)	155 (16)
3. Use of seed (kg)	116	102	122	100	71	96	103	100
a. Own use	44 (38)	56 (55)	33 (27)	50 (50)	21 (30)	29 (30)	33 (32)	45 (45)
b. Sale	68 (58)	45 (4)	83 (68)	47 (47)	48 (67)	63 (66)	66 (64)	52 (52)
c. Consumption	3 (3)	1 (1)	6 (5)	3 (3)	2 (3)	4 (4)	4 (4)	3 (3)
d. Gifted to others	1 (1)	--	--	--	--	--	--	--

Note: SF = Supported farmer, NSF = Non-supported farmer
Figures in the parentheses indicate the percent of total

Table 7. Distribution pattern of sold seed and price received in 2013-2014

Study area	Farmer/relatives		Local market		Dealer		Total quantity (kg)
	Quantity (kg)	Price (Tk/kg)	Quantity (kg)	Price (Tk/kg)	Quantity (kg)	Price (Tk/kg)	
1. Mymensingh							
Supported farmer	46.2 (68)	41.3	4.6 (7)	39.1	17.4 (25)	40.0	68.2
Non-supported farmer	24.8 (56)	37.8	3.5 (8)	37.0	16.0 (36)	35.0	44.3
2. Faridpur							
Supported farmer	40.9 (49)	28.4	41.9 (51)	27.6	--	--	82.8
Non-supported farmer	22.3 (47)	28.3	24.8 (53)	28.6	--	--	47.1
3. Rangpur							
Supported farmer	32.4 (68)	35.7	14.3 (30)	32.8	1.2 (2)	40.0	47.9
Non-supported farmer	47.4 (75)	33.4	15.8 (25)	37.5	--	--	63.1
4. All area							
Supported farmer	39.8 (60)	34.3	20.3 (31)	31.1	6.2 (9)	40.0	66.3
Non-supported farmer	31.5 (61)	35.1	14.7 (28)	31.6	5.3 (11)	35.0	51.5

Note: Figures in the parentheses indicate the percentages of total quantity

Storage Device and Quantity of Seed Storage

Table 8 revealed that supported farmers stored the highest amount of wheat seed using *jute sac+poly bag* in the years 2012 and 2013, although the number of users were very low. In 2014, the number of users of *jute sac+poly bag* increased to a great extent, but average storage quantity becomes low compared to the past two years. However, the uses of plastic/metal drum with poly bag showed an increasing trend among trained farmers over the years. In the case of non-supported farmers, the highest amount of wheat seed was stored through plastic/metal drum over the years, although the number of users was low compared to other devices. Again, the number of users of *jute sac + poly bag* showed an increasing trend during 2012-14 (Table 8).

Impacts of Wheat Seed Storage and Distribution Program

The training and dissemination of improved wheat seed programme among small and marginal farmers has created a lot of socioeconomic impacts in the study areas. The perceived impacts are briefly discussed below.

Table 8. Storage devices and quantities stored in different years by wheat farmers

Name of storage Device	Supported farmer				Non-supported farmer		
	% of users	Quantity stored (kg)	Storage duration (week)	Storage loss (kg)	% of users	Quantity stored (kg)	Storage duration (week)
Year: 2014	*N =210*				*N=60*		
1. Jute sac + poly bag	42 (89)	99.0	32.0	3 (3)	38 (23)	72.4	31.8
2. Plastic sac + poly bag	7 (15)	118.3	30.7	--	17 (10)	57.5	31.1
3. Plastic/metal drum+ poly bag	44 (92)	98.2	30.8	2 (1)	43 (26)	122.9	35.4
4. Plastic sac	0.5 (1)	80.0	28.0	--	--	--	--
5. Jute sac	0.5 (1)	40.0	28.0	5 (1)	--	--	--
6. Poly bag	0.5 (1)	35.0	31.0	--	--	--	--
7. Earthen pot	5 (10)	40.6	32.2	--	3 (2)	42.5	32.5
8. Other	2 (4)	50.0	31.8	--	--	--	--
Year: 2013							
1. Jute sac + poly bag	3 (7)	202.9	30.4	--	12 (7)	42.9	30.7
2. Plastic sac + poly bag	27 (57)	94.8	31.9	--	33 (20)	72.6	31.6
3. Plastic/metal drum+poly bag	17 (36)	87.9	31.3		15 (9)	186.7	31.2
4. Plastic sac	0.5 (1)	40.0	26.0	--	--	--	--
5. Poly bag	0.5 (1)	60.0	30.0	--	--	--	--
6. Earthen pot	3 (7)	19.3	32.6	--	2 (1)	40.0	33.0
7. Other	1.4 (3)	31.7	32.7	--	--	--	--
Year: 2012							
1. Jute sac + poly bag	2 (4)	142.5	32.3	--	10 (6)	50.0	31.0
2. Plastic sac + poly bag	22 (47)	94.8	31.8	--	30 (18)	73.6	31.7
3. Plastic/metal drum+poly bag	12 (25)	58.8	31.04	--	12 (7)	158.6	32.2
4. Plastic sac	0.5 (1)	30.0	28.0	--	--	--	--
5. Earthen pot	3 (7)	29.3	31.9	--	--	--	--
6. Others	2 (4)	35.0	33.3	--	2 (1)	120.0	32.0

Note: Other includes jar cane, biscuit tin, and soybean oil container
Figure in the parentheses indicates number of respondent farmer

***Increase in wheat area*:** CIMMYT-Bangladesh has been trying to disseminate different newly released high yielding wheat varieties along with production technologies among wheat farmers through CSISA project since 2012. Due to this effort, a substantial increase was occurred in the area under wheat cultivation in the study areas. A plenty of fallow and char lands are currently using for wheat cultivation. Again, a large group of farmers in Faridpur and Rangpur hubs become interested toward improved wheat cultivation due to the availability of improved variety seed, higher yield, less cultivation cost and financial benefit. More than 80% farmers mentioned that the seed storage program of CSISA had a positive impact on the expansion of wheat area in the study areas (Table 9). However, their statement is highly supported by the data on wheat area expansion in different CSISA-CIMMYT project Hub areas (Table 10).

Table 9. Overall impacts of wheat seed storage program in the study areas

Overall impact	% responses			
	Mymensingh	Faridpur	Rangpur	All area
Sample size (n)	*n=90*	*n=90*	*n=90*	*n=270*
1. Wheat area is increasing	75.6	77.8	90.0	81.1
2. Farmers become financially benefited	65.6	51.1	61.1	59.3
3. Improved wheat seed is now locally available	48.9	56.7	52.2	52.6
4. Farmers become enthusiastic towards wheat cultivation	57.8	23.3	18.9	33.3
5. Grain yield increased	1.1	31.1	34.4	22.2
6. Possibility of crop damage reduced and timely sowing increased	4.4	2.2	7.8	4.8
7. Household food security increased	11.1	1.1	--	4.1
8. Farmers can meet up cultivation cost through seed income	1.1	8.9	1.1	3.7

Table 10. Time series data on wheat area (ha) and their growth rates

Year	Mymensingh	Faridpur	Rangpur
2011-12	1322	51290	106072
2012-13	1537	64085	125130
2013-14	1960	62879	124971
2014-15	2006	68841	154478
Growth rate (%)	14.9**	8.6	11.3*

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

Source: District level DAE offices, 2015

Increase in financial benefit: Wheat is a profitable crop in the study areas. Besides, wheat seed storage at household level is also a profitable venture to the wheat growing farmers. Therefore, a majority of the respondent farmers (59.3%) mentioned that they become financially benefited to cultivate and storage improved variety wheat (Table 9).

Table 11 revealed that supported and non-supported farmers stored on an average 96 kg and 91 kg of seed per season respectively. The range of increased seed prices due to storage was found to be Tk.10.90 to Tk. 22.0 for supported farmers, whereas it was Tk. 9.4 to Tk. 15.8 for non-supported farmers. The higher increased price received by supported farmers might be due to improved variety and reliability. The average net returns received by supported and non-supported farmers were Tk.1210 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 11. Profitability of wheat seed storage under different storage devices in 2014

Storage device	N	Quantity stored (kg/farm)	Increased price due to storage (Tk/kg)	Gross income (Tk/farm)	Cost of storage device		Net income (Tk/farm)
					Tk/year	Tk/kg	
A. Supported farmer	***212***	***95.9***	***12.92***	***1239***	***29.01***	0.30	***1210***
1. Plastic sac + poly bag	15	118.3	12.7	1502	31.1	0.26	1471
2. Jute sac + poly bag	89	99.0	11.1	1099	32.9	0.33	1066
3. Plastic/metal drum	92	98.18	14.6	1429	26.3	0.27	1402
4. Plastic sac	1	80.0	15.0	1200	25.0	0.31	1175
5. Poly bag	1	35.0	22.0	770	25.6	0.73	744
6. Earthen pot	10	40.6	10.9	443	23.0	0.57	420
7. Others	4	50.0	18.9	945	14.4	0.29	931
A. Non-supported farmer	***61***	***90.5***	***12.78***	***1157***	***29.6***	0.33	***1127***
1. Plastic sac + poly bag	10	57.5	13.9	799	31.1	0.54	768
2. Jute sac + poly bag	23	72.4	9.4	681	32.9	0.45	648
3. Plastic/metal drum	26	122.9	15.0	1843	26.5	0.22	1817
4. Earthen pot	2	42.5	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

***Availability of improved variety seed*:** The profitability of a crop mostly depends on its productivity. Among many other factors overall wheat cultivation has been decreasing over the years due to lack of seeds of improved wheat varieties. More than half of the respondent farmers opined that the seeds of improved wheat varieties are now locally available only because of launching wheat seed storage and dissemination program through CSISA project (Table 9). Due to availability of new variety seeds, areas under new varieties have been increasing.

***Enthusiasm toward wheat cultivation*:** It was mentioned earlier that wheat cultivation has been decreasing over the years due to various socioeconomic factors. A good section of the sampled farmers (33.3%) in the study areas opined that they become enthusiastic towards wheat cultivation because of seed storage and dissemination program (Table 9). Some supported farmers argued that the disseminated wheat varieties had a strong demonstration effect on non-supported farmers to adopt improved wheat varieties.

***Increase in productivity*:** The overall productivity of wheat is increased to a great extent in the study areas which was due to adoption of improved varieties and more areas were planted to improved wheat varieties. More than 22% farmers received higher yield compared to the recent past (Table 9).

***Ensure timely seed sowing*:** In the past, wheat crop was damaged due to lack of quality seed. Besides, the sowing time also delayed because of non-availability of improved seed. Ahmed and Meisner (1996) showed that late seeding reduced the yield at the rate of 1.3% per day of delay after November 30. Due to the seed storage and dissemination program, improved variety seeds are now locally available to the farmers. Therefore, the possibility of crop damage or late sowing of seed reduced to a great extent as mentioned by 4.8% of the sampled farmers in the study areas (Table 9).

Table 12. Income from seed storage spent on different items in 2014

Expenditure head	Average amount spent (Tk./HH)			
	Mymensingh	Faridpur	Rangpur	All area
Sample size (n)	*n= 64*	*n=72*	*n= 68*	*n= 204*
Average income (Tk./HH)	3437 (100)	2467 (100)	2235 (100)	2694 (100)
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

***Increase household food security*:** Household food security is a vast issue. However, the respondent farmers could produce higher amount of wheat through adopting improved varieties which brought food security at household level to some extent. That's why 4.1% wheat farmers claimed that their household food security increased to some extent due to improved wheat production (Table 9).

Met up cultivation cost: The income earned from seed storage was spent for different purposes. The increased income mostly spent for land preparation and buying inputs (e.g. fertilizer and irrigation) of wheat cultivation. Table 12 showed that the net income was mostly spent for land preparation and buying inputs for wheat cultivation (56%) followed by purchase of food items (16%), other expenses (14%), spent for education (7%), and buying agricultural instruments.

***Other impacts*:** Most supported and non-supported farmers knew the method of cultivation and storage of wheat from long or near past. Their methods might be traditional to some extent. That's why the study did not find significant difference among two categories of farmers. However, a good demonstration effect of the CSISA-CIMMYT program was also found in the study areas and because of this effect many non-supported farmers could know the improved techniques of wheat cultivation and seed storage.

Problems of Seed Storage

Both supported and non-supported farmers did not face any critical problem during seed storage. During seed drying, some respondent farmers faced problem with scavenging poultry and birds. However, some of the supported farmers were found to use old variety, not rouging their wheat plot, use traditional device in seed storage, and placing seed container on ground.

Conclusions and Recommendations

Conclusions

The study has been conducted to assess the wheat seed storage systems at HH level, with a particular emphasis on how the poor farmers as well as the community as whole are benefited by doing the seed storage business. The wheat farmers in the study areas use eight types of storage containers and show the highest level of satisfaction towards plastic sac and plastic/metal drum along with poly bags due to cost effectiveness and better quality seed. Respondent farmers retain wheat seed at household level mainly for getting quality seed for own use, higher price, timely sowing, and higher grain yield. 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 respondent farmers. They can earn a reasonable income from seed storage. The farmers who store seed in plastic/metal drum receive the highest net income due to higher storage capacity, less storage cost, and higher seed price. The net income is mostly spent for the next year wheat cultivation followed by food purchase, and educational expenses.

Due to the seed storage program, a good number of new wheat varieties have been adopted in the study areas. Most supported farmers collect new varieties from CSISA-CIMMYT project and non-supported farmers collected it from neighbouring farmers and local market. Finally, the wheat seed storage program has created a lot of socioeconomic impacts in the study areas. A substantial increase has been recorded in wheat area, wheat productivity, and financial benefit of the wheat farmers as a whole. Nevertheless, new variety wheat seed is now available in the study areas and most farmers become enthusiastic towards wheat cultivation because of this program. Respondent farmers did not face any critical problem during seed storage.

Recommendations

Respondent farmers showed the highest level of satisfaction towards plastic/metal drum due to seed quality maintenance, longevity, and cost effectiveness. But most small and marginal farmers do not have capability to buy drum. Therefore, interested small and marginal wheat farmers should be provided a plastic/metal drum with subsidized price. Finally, the study strongly recommends that the existing training and dissemination program should be extended to other new and promising areas for fostering wheat cultivation as well as improving farmers' income in Bangladesh.

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INFLUENCE OF MORPHOLOGICAL AND REPRODUCTIVE CHARACTERS ON THE YIELD OF MUSTARD/RAPESEED

M. M. A. MONDAL[1] AND M. A. MALEK[2]

An understanding of some morpho-physiological characters in mustard is necessary to make progress in genotypic improvement and for the management of the crop to increase yield and quality (Malek *et al*., 2012). The incorporation of morphological characters which have been shown to give a physiological advantage into an ideotype, or model crop plant, has been shown to be of value in many crops (Mondal *et al*., 2016). Two of the most important characters of an ideotype are plant canopy structure and magnitude and degree of sink (flower and siliqua) production. In mustard, rate of siliqua setting from flowers is only 55 to 80 % (Islam and Fakir, 2012).

Seed yield is a complex character that can be determined by several components reflecting positive or negative effects upon this character, whereas it is important to examine the contribution of each of the various components in order to give more attention to those having greatest influence on seed yield. Therefore, information on the association of plant characters with seed yield is of great importance to a physiologist in selecting a desirable genotype.

To increase productivity in mustard/rapeseed, it is necessary to create variability and select desirable type with stable yield. The yield potential of mustard/rapeseed is lower due to its unfavourable canopy structure. If improvement can be achieved through the manipulation of morphological and architectural parameters like plant height, number of branches, leaf area with its orientation and siliqua architecture, there might be a good prospect for yield increase in mustard. The present research work was designed to assess the performance of ten promising mustard/rapeseed mutants along with ten existing varieties on the basis of morpho-physiological, reproductive efficiency and yield attributes.

The experiment was carried out at the Field Laboratory, Bangladesh Institute Of Nuclear Agriculture (BINA), Mymensingh, during the period from 14 November 2014 to 10 March 2015. Ten advanced lines along with 10 mustard/rapeseed varieties under three species of *Brassica napus (*MM 49-3-98, MM 25-11-98rb, MM 48-19, MM 02-02rb, MM 06-02rb, MM 09-02rb, MM 011-02rb, BARI Sarisha-8 and *Binasarisha*-4), *B. juncea* (MM 03-05, MM 05-05, MM 04-04, NAP-3, RAI-5 and BARI Sarisha-10) and *B. campestris* (*Binasarisha*-6, Agrani, Safal and Sonali) were used as plant material. The experiment was laid

[1]Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture, BAU Campus, 2Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, BAU Campus, Mymensingh-2202, Bangladesh.

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out in a Randomized Complete Block Design with 3 replications. The size of the unit plot was 2 m × 2 m. The mutants who were near unicum (MM 03-05 and MM 05-05) maintained spacing of 6 cm × 20 cm and others spacing were maintained 8 cm × 30 cm according to the breeder's suggestion of BINA. Fertilizers were applied at the rate of 115-31-40-32-1 kg ha^{-1}, respectively in the form of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and borux. Total amount of TSP, MoP, gypsum, Borax and half urea were applied as basal during final land preparation. The rest half urea was applied as top dress at 21 days after sowing (DAS). Intercultural operations such as thinning, weeding, irrigation and pesticide were done according to standard procedure. At harvest, 10 plants were randomly selected from each plot for collecting morphological, total dry matter, reproductive and yield contributing characters. Reproductive efficiency was calculated by dividing total reproductive unit to siliqua number of plant multiplying with 100 and expressed in percentage. The plot yield was converted into t ha^{-1}. Phenotypic correlation coefficient for different quantitative characters was calculated following the formulae given by Miller *et al.* (1958). The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjusted with Duncan's New Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C.

Significant variation in morphological characters such as plant height, primary and secondary branches $plant^{-1}$ existed (Table 1). The highest plant height was observed in *B. campestris* (139.1 cm) while the lowest was recorded in *B. napus* (91.0 cm). Considering genotypes basis, the highest plant height was recorded in Safal (152.0 cm) and the shortest in MM 49-3-98 (72.2 cm). Even within a species there had significant different in plant height. *B. campestris* produced greater number of branches $plant^{-1}$ (4.79) than the *B. juncea* and *B. napus*. The highest number of branches $plant^{-1}$ was observed in Sonali (6.17) that was statistically significant different from the others. In contrast, MM 49-3-98, MM 06-02rb, MM 03-05 and MM 05-05 produced the lower number of branches $plant^{-1}$ (range 1.50-1.83) with being the lowest in MM 05-05 (1.50). The mean number of secondary branches $plant^{-1}$ was higher in *B. napus* (3.65) followed by *B. juncea* (1.83). On the other hand, the secondary branch was fully absent in *B. campestris*. The highest number of secondary branches $plant^{-1}$ was observed in MM 25-11-98rb (7.17) that was statistically significant different from the others. Mentionable that although the varieties of *B. campestris* did not produced secondary branch but produced higher number of primary branches $plant^{-1}$ (average 4.79) which mitigate the contributory effect of secondary branches. These results are in agreement with the result of Hasan *et al.* (2014) who stated that plant height and number of branches $plant^{-1}$ differed significantly among the studied genotypes in rapeseed and mustard.

Table 1. Days to maturity, morphological, physiological and reproductive characters in 20 mustard/rapeseed genotypes

Mutants/ varieties	Morphological characters			Physiological characters		Reproductive characters		
	Plant height (cm)	1^0 branches plant^{-1} (no.)	2^0 branches plant^{-1} (no.)	Total dry matter plant^{-1} (g)	Harvest index (%)	Total repro-ductive unit plant^{-1} (no.)	Aborted siliqua plant^{-1} (no.)	Repro-ductive efficiency (%)
B.napus								
MM 49-3-98	72.2 j	1.66 k	6.50 b	10.1 gh	32.9 b	105 f	38.0 e	63.8 e-h
MM 25-11-98rb MM	76.0 ij	2.83 efg	7.17 a	12.4 ef	36.5 a	113 def	32.8 g	70.8 b-e
48-19	82.5 hi	3.00 ef	0.50 j	7.28 ij	28.7 cd	55 k	26.7 h	51.5 k
MM 02-02rb	105.2 ef	4.33 c	0	6.16 jk	23.3 g	82 hi	48.7 bc	48.8 k
MM 06-02rb	85.5 gh	1.66 k	5.33 d	12.1 ef	34.4 ab	143 b	48.7 bc	54.6 jk
MM 09-02rb	100.2 f	3.17 e	5.83 c	17.0 c	32.6 b	194 a	50.7 b	73.9 bcd
MM 011-02rb	81.8 hi	2.16 ij	4.00 e	12.5 ef	33.5 b	109 ef	33.8 fg	68.9 c-f
BARI Sarisha-8	91.5 g	2.83 efg	2.50 f	13.6 e	26.4 def	129 c	62.7 a	55.9 ijk
Binasarisha-4	103.5 f	3.66 d	2.50 f	13.8 de	29.9 c	111 ef	44.3 cd	59.9 g-j
Binasarisha-5	111.7 de	2.66 fgh	2.17 fg	13.8 de	28.5 cde	109 ef	47.8 bc	56.3 h-k
Mean	91.0	2.80	3.65	11.9	30.7	115	43.4	60.4
B. juncea								
MM 03-05	90.2 g	1.83 jk	0	4.34 l	25.8 efg	64 jk	16.7 j	73.9 bcd
MM 05-05	100.8 f	1.50 k	0.16 jk	5.47 kl	29.0 cd	73 ij	16.8 j	77.0 ab
MM 04-04	112.2 de	2.33 hi	1.00 i	7.65 ij	29.2 cd	86 h	21.3 i	75.3 abc
NAP3	102.2 f	5.33 b	2.00 gh	8.77 hi	26.7 de	93 gh	32.5 g	74.9 a-d
RAI-5	91.5 g	2.50 ghi	1.66 h	4.12 l	28.7 cd	101 fg	37.3 ef	62.9 f-i
BARI Sarisha- 10	117.3 d	3.16 e	6.16 bc	11.5 fg	27.0 de	123 cd	46.5 cd	60.5 g-j
Mean	102.4	2.78	1.83	6.97	27.8	90	28.5	70.8
B. campestris								
Binasarisha-6	141.3 b	5.33 b	0	18.9 b	28.2 cde	140 b	45.7 cd	67.4 d-g
Agrani	132.5 c	3.83 d	0	16.0 c	26.5 def	82 hi	15.0 j	81.6 a
Safal	152.0 a	3.83 d	0	15.5 cd	25.8 efg	108 ef	31.2 g	71.1 b-e
Sonali	130.5 c	6.17 a	0	25.9 a	24.0 fg	119 cde	43.0 d	62.3 f-i
Mean	139.1	4.79	0	19.1	26.1	112	33.7	70.6
Range	72.2 -152.0	1.50 -6.17	0.00 –7.17	4.12 -25.9	23.3 -36.5	15.0 -62.7	48.8 -81.6	1.11 -6.22
CV (%)	3.99	7.02	9.43	8.77	5.81	6.02	6.38	6.30

In a column, means followed by same letter (s) do not differ significantly at 5% level.

Table 2. Variations in yield attributes and seed yield in 20 mustard/ rapeseed genotypes

Mutants/ varieties	Days to maturity	Siliqua plant^{-1} (no.)	Siliqua length (cm)	Seeds siliqua^{-1} (no.)	1000- seed weight	Seed yield (t ha^{-1})
B. napus						
MM 49-3-98	91 de	66.8 d	5.73 c	17.2 i	3.72 cde	2.23 abc
MM 25-11-98rb	86 hi	79.7 c	6.90 ab	27.6 a	4.04 b	1.97 de
MM 48-19	87 ghi	28.3 j	4.81 d	28.3 a	3.84 c	0.80 jk
MM 02-02rb	85 i	38.0 i	4.97 d	20.8 fgh	4.19 b	0.92 ij
MM 06-02rb	89 efg	77.5 c	6.20 bc	20.0 h	3.53 efg	2.00 cde
MM 09-02rb	90 ef	143.2 a	7.20 a	25.5 bc	3.71 cde	2.45 a
MM 011-02rb	91 de	75.0 c	6.85 ab	25.1 bc	3.46 fg	1.80 ef
BARI Sarisha-8	90 ef	65.8 d	6.90 ab	22.7 def	4.07 b	1.53 g
Binasarisha-4	90 ef	66.3 d	7.40 a	26.4 ab	3.43 g	1.89 def
Binasarisha-5	88 fgh	64.5 de	7.38 a	22.3 ef	3.63 def	1.70 fg
Mean	89	70.5	6.43	23.6	3.76	1.73
B. juncea						
MM 03-05	102 a	47.2 h	3.51 ef	8.20 k	3.63 def	0.54 l
MM 05-05	102 a	56.3 fg	3.72 ef	8.70 jk	4.58 a	0.96 ij
MM 04-04	102 a	65.0 de	3.73 ef	9.70 jk	4.03 b	0.99 ij
NAP3	98 b	60.2 ef	4.23 de	15.4 ij	2.60 i	1.10 hi
RAI-5	100 ab	53.3 g	3.25 f	10.4 j	2.39 j	0.59 kl
BARI Sarisha- 10	93 cd	79.8 c	4.76 d	15.3 ij	2.84 h	1.29 h
Mean	100	60.3	3.87	11.3	3.34	0.91
B. campestris						
Binasarisha-6	94 c	94.3 b	5.93 c	22.1 efg	3.81 cd	2.13 bcd
Agrani	95 c	66.5 d	7.65 a	22.8 def	4.05 b	1.28 h
Safal	95 c	76.7 c	6.14 bc	20.2 gh	3.83 c	1.56 c
Sonali	100 ab	80.0 c	6.34 bc	24.1 cde	4.45 a	2.29 ab
Mean	96	79.4	6.52	22.3	4.04	1.82
Range	85 -102	28.3-143.2	3.25-7.65	8.20-28.33	2.39-4.58	0.54-2.45
CV (%)	1.60	4.08	7.86	5.57	2.89	9.09

In a column, means followed by same letter (s) do not differ significantly at 5% level.

Total dry matter (TDM) plant^{-1} varied significantly and ranging from 4.12 to 25.9 g plant^{-1} (Table 1). The highest mean TDM plant^{-1} was recorded in *B. campestris* (19.1 g) followed by *B. napus* (11.9 g). The lowest mean TDM plant^{-1} was recorded in *B. juncea* (6.97 g). The TDM was higher in *B. campestris* due to production of greater number of primary branches and taller plant than the other species (Table 1). In contrast, *B. juncea* produced lower TDM plant^{-1} due to fewer number of branches plant^{-1}. *B. napus* produced moderate TDM plant^{-1}. Although there was significant variations in harvest index (HI) but not highly different among the studied species (Table 1). The highest HI was recorded in MM 25-11-98rb (36.5%) and MM 02-02 rb showed the lowest HI (23.3%). Yadava *et al*. (2011) evaluated 30 genotypes for growth pattern and dry matter production and reported that there had significant genotypic variability in TDM and HI.

Significant variation in total reproductive unit (TRU) number plant^{-1} was observed in 20 mustard/rapeseed genotypes and varied from 55 to 194 (Table 1). The mean TRU plant^{-1} was higher in *B. napus* (115) followed by *B. campestris* (112). The lowest mean TRU plant^{-1} was observed in *B. juncea* (90). Results indicated that the genotypes which produced increase number of branches plant^{-1} also showed higher number of TRU plant^{-1}. In general, low yielding genotypes produced fewer number of TRU plant^{-1} indicating for increase seed yield in mustard, there should have higher number of TRU. The highest number of TRU plant^{-1} was observed in MM 09-02rb (194) and the lowest in MM 48-19 (55). The mean aborted siliqua plant^{-1} was the highest in *B. napus* (43.4) followed by *B. campestris* (33.7). The lowest number of aborted siliqua plant^{-1} was recorded in *B. juncea* (28.5). Low yielding genotypes produced fewer number of aborted siliqua plant^{-1} indicating greater number of aborted siliqua production do not hampering seed yield in mustard. The variation in per cent siliqua to TRU (reproductive efficiency, RE) was significant and ranged from 48.8 to 81.6% (Table 1). In general, RE was greater in *B. juncea* (70.8%) and B. *campestris* (70.6%) than in *B. napus* (60.4%). The RE was lower in *B. napus* due to production of greater number of aborted siliqua (Table 1). Agrani had the highest RE value (81.6%) and the lowest in MM 02-02rb (48.8%). Genotypic variability in TRU and RE was also observed by Khaton (2004) in mustard/rapeseed.

Days to maturity varied between 85 and 102 days (Table 2). In general, genotypes belong to *B. napus* matured earlier (average 89 days) than the genotypes of *B. juncea* (average 100 days) and *B. campestris* (average 96 days). Of all the genotypes, mutant MM 02-02rb matured earliest (85 days) followed by MM 25-11-98rb (86 days) and MM 48-19 (87 days) with same statistical rank. In contrast, three mutants MM 03-05, MM 05-05 and MM 04-04 required significantly maximum days to maturity (102 days) followed by RAI-5 and Sonali (100 days). The other genotypes matured between 88 and 98 DAS. The large variation in days required to maturity might be due to differential in genetic makeup and their differential interactions with the prevailing climatic factors where they grew could be the most probable ones.

Table 3. Simple correlation coefficient among different quantitative characters in three *Brassica* genous themselves.

Characters	***B. napus*** (n = 30)				***B. juncea*** (n = 18)				***B. campestris*** (n = 12)			
	Seed yield	Siliqua number	Seed No./ siliqua	1000-seed weight	Seed yield	Siliqua number	Seed No./ siliqua	1000-seed weight	Seed yield	Siliqua number	Seed No./ siliqua	1000-seed weight
Plant height	0.06	0.06	0.03	-0.02	0.90**	0.87**	0.38	0.11	0.23	0.23	-0.69**	-0.70**
1^0 branch	0.37*	0.17	0.35*	0.43*	0.52*	0.30	0.92**	-0.65**	0.98**	0.60*	0.50	0.55*
2^0 branch	0.75**	0.70**	-0.14	-0.22	0.79**	0.85**	0.63**	-0.53*	0.07	-0.02	0.23	-0.17
Siliqua number	0.86**	---	0.08	-0.48**	0.93**	---	0.52*	-0.16	0.78**	---	-0.12	-0.26
Siliqua length	0.79**	0.59**	0.16	-0.41*	0.84**	0.75**	0.70**	-0.22	0.48	-0.65*	0.46	0.19
Number of seeds/siliqua	0.14	0.08	---	-0.001	0.69**	0.52*	---	-0.62**	0.41	-0.12	---	0.39
1000-seed weight	-0.48**	- 0.23	-0.001	---	-0.17	-0.16	-0.62**	---	0.48	-0.26	0.39	---
Total dry mass	0.87**	0.81**	0.14	-0.37*	0.96**	0.90**	0.74**	-0.24	0.82**	0.57*	0.60*	0.44
Total reproductive unit	0.79**	0.92**	-0.09	-0.24	0.67**	0.78**	0.59**	-0.65**	0.71**	0.90**	0.05	-0.12
Reproductive efficiency	0.80**	0.75**	0.23	-0.23	-0.18	-0.33	-0.18	0.56**	-0.92**	-0.71**	-0.10	-0.34
Harvest index	0.67**	0.48**	0.09	-0.35*	0.01	0.16	-0.30	0.24	-0.26	0.23	-0.15	-0.62*
Days to maturity	0.50**	0.40*	-0.14	0.60**	0.18	-0.12	0.71**	0.57**	0.53*	-0.07	0.33	0.88**

*, ** significant at 5 and 1% level of probability, respectively.

Siliqua number, one of the most important yield attributes varied between 28.3 and 143.2 plant^{-1} (Table 2). The mean siliqua number plant^{-1} was the highest in *B. campestris* (79.4) which was significantly greater than in *B. napus* (70.5) and *B. juncea* (60.3). The lowest siliqua plant^{-1} was observed in *B. juncea* (60.3) due to production of fewest number of TRU plant^{-1} (Table 1). Among the genotypes, MM 09-02rb produced the highest number of siliqua plant^{-1} (143.2) which was almost double than the other genotypes. In contrast, MM 48-19 produced the lowest number of siliqua plant^{-1} (28.3). In between *B. napus* and *B. campestris,* there was a lower level of siliqua length variability with ranged 6.43-6.52 cm (Table 2). But within the group, there had a wide variability except *B. juncea*. The lowest siliqua length was observed in *B. juncea* ranging from 3.25 to 4.76 cm. The mean number of seeds siliqua^{-1} was statistically identical in both *B. napus* and *B. campestris* (range 22.3-23.6) and the lowest mean number of seeds siliqua^{-1} was observed in *B. juncea* (11.3). The number of seeds siliqua^{-1} was lower in *B. juncea* due to shorter siliqua length. The seeds of *B. campestris* were bolder than *B. napus* and *B. Juncea* (Table 2). The higher 1000-seed weight was recorded in MM 05-05 (4.58 g) and Sonali (4.45 g) and the lowest in RAI-5 (2.39 g). The highest seed yield ha^{-1} was recorded of the mutant, MM 09-02rb (2.45 t ha^{-1}) due to production of higher number of siliqua plant^{-1}. The second highest seed yield was observed in Sonali (2.29 t ha^{-1}). The lowest seed yield was recorded in MM 03-05 and RAI-5 might be due to production of fewer numbers of siliqua and seeds siliqua^{-1} (Table 2). Genotypic variability in siliqua number, siliqua length, number of seeds siliqua^{-1}, 100- seed weight and seed yield was also obserbed by many workers (Mondal *et al*., 2003; Malek *et at*., 2012; Zare *et al*. 2012; Hasan *et al*., 2014).

Phenotypic correlation coefficients among different quantitative characters are presented separately for the three species of *Brassica* (Table 3). Seed yield plant^{-1} was positively and significantly correlated with the number of secondary branches plant^{-1} in *B. napus* (r = 0.75 **) and *B. juncea* (r = 0.79 **) but not in *B. campestris*. On the other hand, seed yield plant^{-1} was highly correlated with primary branches plant^{-1} (r = 0.98 **) in *B. campestris* while moderately correlation was observed in *B. napus* (r = 0.37 *) and *B. juncea* (r = 0.52 *). In *B. campestris*, secondary branch was absent (Table 1). So primary branches contributed maximum to the seed yield in *B. campestris*. Seed yield plant^{-1} was highly and positively correlated with TDM, TRU and siliqua number plant^{-1} in all three species in mustard. This result indicates that the improvement of siliqua number plant^{-1} could be achieved by selecting increased number of TRU plant^{-1}. Thousand-seed weight was negatively associated with seed yield and siliqua number in *B. napus* and *B. juncea* and non-significant positive association with seed yield and negative association with siliqua number was observed in *B. campestris*. Reproductive efficiency (RE) was only positively associated with seed yield and siliqua number in *B. napus.* The above results are supported by many workers (Yadava *et al*., 2011; Hasan *et al.,* 2014; Synrem *et al*., 2014).

It may be concluded that high yielding genotypes have higher number of primary branches plant^{-1}, total dry matter plant^{-1} and total reproductive unit plant^{-1}, which resulted increase number of siliqua plant^{-1} than low yielding ones. The mutant MM 09-02rb and the variety Sonali maintained superiority in most of the morpho-physiological parameters and produced higher seed yield. This information may be useful in future plant breeding programme.

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