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C O N T E N T S

PHYSIOLOGICAL RESPONSES OF MUNGBEAN (*Vigna radiata*) VARIETIES TO DROUGHT STRESS

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Abstract

A pot experiment under polyshed condition was carried out at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during the period from 27 March 2017 to 5 May 2017 to study the physiological responses of mungbean varieties to drought stress under varying water regimes. The treatments consisted of four mungbean varieties, namely BARI Mung-5, BARI Mung-6, BUmug 2, BUmug 4 and three water regimes viz., 50 to 60% field capacity (FC), 70 to 80% FC and 90 to100% FC which were considered as severe drought stress, moderate drought stress and non-stress, respectively. The experiment was laid out in a completely randomized design with factorial arrangement having four replications. Results indicated that BARI Mung-6 maintained significantly the highest relative water content, leaf water potential, proline content, shoot dry matter and lower rate of electrolyte leakage at 50 to 60% FC (severe drought stress). BUmug 2 showed the lowest performance in terms of all the water relation and physiological characters which indicates its higher sensitivity to severe drought stress. Variety BARI Mung-6 was relatively water stress tolerant than others in respect of physiological adaptations. So, BARI Mung-6 can be a potential variety for cultivation under drought condition where irrigation facility is limited.

Keywords: Mungbean, water potential, relative water content, proline and drought stress.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek), a popular pulse crop with good test and important source of plant protein (19.5 to 28.5% proteins), has been widely cultivated throughout the world especially in Asian sub-continent including Bangladesh (Lambrides and Godwin, 2006). In Bangladesh the present area under mungbean cultivation is 101 thousand acres with a total production of 37 thousand ton and an average yield of 351 kg acre^{-1} (BBS, 2016). The crop is cultivated either during early *kharif* or late *rabi* season (March to June). Several biotic and abiotic stresses either singly or collectively caused adverse effect on mungbean plant resulting poor growth and development. Abiotic stresses including drought, have been reported as major constraints to the mungbean

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production projecting more than 50% of yield loss (Gaur *et al.,* 2012). Soil water deficit or drought stress is considered as a severe threat to sustainable agriculture and food security (Foley *et al.,* 2011). The concern is very much alarming to the country like Bangladesh where it is more likely to face the consequences of different anthropogenic activities that might increase the severity of drought stress at near future. It has become a great need for the understanding of drought tolerance mechanisms prior to development of major drought tolerant varieties to achieve sustainable production goal of crop. Plants follow several strategies including morpho-physiological and molecular changes for the acclimation in drought stress. Drought induced several developments of plants seemingly adjust the water crisis either by the alteration of morphological, physiological or both to overcome the soil moisture stress. Physiological adaptation increases the accumulation of osmolytes and adjusted osmotic potential by reducing cellular dehydration (Omprakash *et al.,* 2017). Increased accumulation of proline has been reported in mungbean during drought (Bharadwaj *et al.,* 2018), nevertheless detail understanding of morphological and physiological alteration for screening of mungbean varieties based on the tolerance characteristics mentioned above should be very essential to adjust and mitigate the upcoming challenges. The problem is widespread in the northwestern part of the country where mungbean production is hampered to a great extent by the existing water limiting condition.

Therefore, the present study was carried out to investigate the physiological alterations regarding to the dry matter accumulation in popularly cultivated mungbean varieties during early stages of growth in response to drought stress and thus to identify a suitable variety by observing relative performance of drought tolerance physiological attributes.

Materials and Method

A pot experiment under polyshed condition was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the period from 27 March to 5 May 2017. Four mungbean varieties namely, namely BARI Mung-5, BARI Mung-6, BUmug 2, BUmug 4 and three soil moisture levels viz., 50 to 60% FC, 70 to 80% FC and 90 to100% FC were used as treatment variables. The trial was set up in a Completely Randomized Design with factorial arrangement having four replications. The soil of the plastic pot (20 cm internal diameter and 25 cm height) was filled up with mixture of soil and cowdung at a ratio of 4:1. Pot contained 9.5 kg soil. Soil used in the pot was silty clay loam and was fertilized uniformly with urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid containing 0.11 g N, 0.08 g P, 0.10 g K, 0.05 g S, 0.002 g Zn, and 0.001 g B, respectively. Total amount of all fertilizers and cowdung were well mixed with the soil before pouring into the pots. Ten seeds of mungbean were sown in each pot on 27 March 2017. Seedlings were emerged after 5 days of sowing and finally six healthy plants

pot^{-1} were allowed to grow. Weeding and spraying of insecticides were done as normal management practices.

Drought treatment was imposed at 12 DAS (when the first trifoliate leaf was fully expanded), on the basis of soil moisture status in each treatment. Irrigation water was applied to bring the soil moisture at the higher range of each treatment (60, 80, and 100% FC). Next irrigation was given when the soil moisture came down to the lower levels (50, 70, and 90% FC) of those treatments, respectively. Irrigation water was applied by measuring cylinder. Irrigation requirement was calculated by using the following formula (Giriappa, 1988):

IR= {(M_{FC} - M_{BI}) ÷ 100} × A× D. Where, IR= irrigation requirement (cm), M_{FC}= Soil moisture (%) at field capacity, M_{BI}= Soil moisture (%) before irrigation monitored by using soil moisture meter, A= Soil bulk density in gcm^{-3}, D= Rooting depth (cm). Soil bulk density and soil moisture (%) at field capacity were computed using the method described by Karim *et al.,* (1988).

Relative water content (RWC) was determined using 30 leaf disks (2.0 mm thick and 4.5 mm wide) from fully expanded uppermost leaves. Fresh weights of the leaf disks were recorded and soaked in 100 ml of distilled water and kept in the dark for 24 hour. The turgid leaves were quickly blotted dry prior to the turgid weight measurement. Dry weights of leaf disks were determined after oven-drying at 70°C for 72 hours. All the weight of the samples was recorded by using analytical balance. Relative water content (RWC) was determined using following formula (Schonfeld *et al.,* 1988):

RWC (%) = [(FW - DW) / (TW - DW)] × 100. Where, FW = Fresh weight of the leaf disks, DW = Dry weight of the leaf disks and TW = Turgid weight of the leaf disks.

Leaf water potential of a fully expanded leaf was measured using pressure chamber as described by Scholander *et al.,* (1965). The balancing pressure was regarded as the tension originally existing in the xylem sap and approximately equal to water potential of the cells. Sampling was done between 7.00 and 9.00 a.m. to avoid evaporation losses.

Leaf membrane damage was determined by recording of electrolyte leakage (EL) as described by Valentovic *et al.,* (2006) with a few modifications from 30 leaf disks of fully expanded uppermost leaves. The EL was defined as follows:

EL (%) = (L_1/L_2) × 100. Where, L_1 = Electrical conductivity before autoclave, L_2 = Electrical conductivity after autoclave.

Fully expanded uppermost leaf samples were collected and proline extractions were made using the method outlined by Bates *et al.* (1973). The proline concentration was determined from the standard curve and calculated on a fresh weight basis as follows:

Proline content (µmole g^{-1} fresh wt.) = {µg proline ml^{-1} × vol. of extr. sol. (ml) × toluene used (ml)} / {115.13 µg mole^{-1} × g sample}

Sampling for plant dry weights was done 10 days after appearance of visual symptom (at 40 DAS). Stem and leaf were separated and dried for 72 hours at 70°C in drying oven. Shoot dry weight was calculated by summing up the dry weight of stem and leaf of the plants. The relative performance was calculated using the following formula (Asana and Williams 1965):

Relative performance = Variable measured under stressed condition / Variable measured under normal condition

The data regarding to the physiological factors were recorded at 18 days after imposing of drought treatment (30 DAS), when visual symptom of drought stress appeared. Plant were harvested at 40 days after sowing maintain a drought period of 10 days.

Data thus collected were analyzed with Statisticx 10 program. The differences between the treatment means were compared by Least Significant Difference (LSD) at 5% level of significance.

Results and Discussion

Soil moisture variation: Soil moisture status under three different treatments involving ranges of field capacity (FC) was monitored at 4 days interval from 12 to 37 days after sowing (DAS). Soil moisture was directly influenced by the treatments that is, the treatment maintaining higher ranges of FC exhibited higher soil moisture status throughout the studies (Fig. 1).The treatment subjected to the highest range of FC (90 to 100% FC) maintained the maximum soil moisture (close to FC) throughout the growing season of the crop. The subsequent soil moisture curves followed the declining orders with the decrease of FC range. The bottom curve under the lowest range of FC (50 to 60% FC) showed the minimum soil moisture level (18.40 to 15.34%), sometimes went down to the permanent wilting point condition.

Relative water content (RWC): Relative leaf water content has been considered a measure of plant water status, reflecting the metabolic activity in tissues and used as a most meaningful index for dehydration tolerance (Anjum *et al.,* 2011). Field capacity with different soil water status caused significant differences in leaf RWC of all mungbean varieties (Table 1). RWC ranged from 75.14 to 80.91% at 90 to 100% field capacity, 67.72 to 74.42% at 70 to 80% field capacity and 55.21 to 66.14% at 50 to 60% field capacity. Such results apparently indicates that under decreasing soil moisture conditions, plants became unable to uptake sufficient water through the root system leading to decrease in relative water content. The finding is quite similar to the results supported by Hayatu *et al.* (2014). In the present experiment the treatment with the lowest field capacity

(50 to 60% FC), BARI Mung-6 was found to maintain the maximum RWC (66.14%) while BUmug 2 had the minimum RWC (55.21%). The minimum reduction in RWC recorded in BARI Mung-6 at water deficit condition indicates that the variety was able to uptake water most efficiently among mungbean varieties. Genotypic differences for RWC were also reported by Bharadwaj *et al.,* 2018 in cowpea and other pulses.
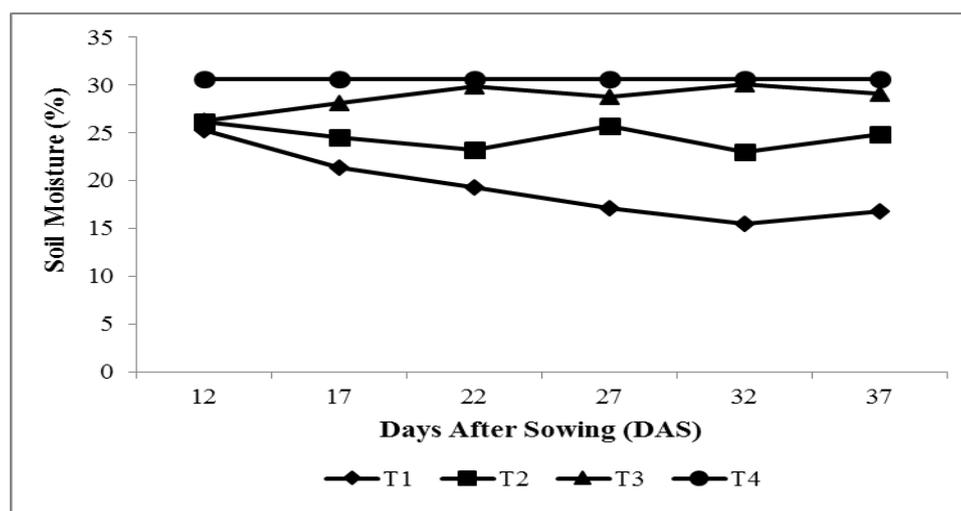
Fig 1: Soil moisture status (%) at regular interval of four days from 12 to 37 DAS. (T$_1$= 15.34 to 18.40% at 50 to 60%FC, T$_2$= 21.48 to 24.54% at 70 to 80% FC, T$_3$= 27.61 to 30.68% at 90 to 100% FC, T$_4$= Moisture at field capacity = 30.68%.

Table 1. Relative water content (RWC) of four mungbean varieties under three field capacity levels

Variety	Relative Water Content (%)		
	FC of 90 to 100%	FC of 70 to 80%	FC of 50 to 60%
BARI Mung-5	78.74 b	72.92 d	63.80 g
BARI Mung-6	80.91 a	74.42 cd	66.14 f
BUmug 2	75.14 c	67.72 f	55.21 i
BUmug 4	77.36 b	70.29 e	60.67 h
CV%	1.91		

Means along both rows and columns followed by the same letter (s) did not differ significantly at 5% level of probability.

Leaf water potential (Ψ$_w$): As adjustment of leaf water potential is a very important indication of drought stress tolerance of crop plants (Siddique *et al.,* 2000), the comparison of leaf water potential in the mungbean varieties should be necessary for screening suitable one. Leaf water potential of mungbean varieties was significantly affected by water stress treatments (fig. 2). The Ψ$_w$ of all mungbean varieties was reduced significantly due to reducing field capacity levels. The highest Ψ$_w$ ranging from -0.67 to -0.55 MPa was reported at 90 to 100% field capacity and it was gradually decreased at 70 to 80% field capacity (-0.87 to -0.70 MPa) and became the lowest (-1.64 to -1.13 MPa) at 60-50% field capacity. The results reflect the facts that plants exposed to low field capacity endured drought stress by low level of cellular water for their survival. The result is very consistent to that where lower amount of water content during drought stress acclimation of pulses were observed (Shrestha *et al.,* 2006). At low field capacity (50 to 60% FC), BARI Mung-6 was found to maintain the maximum Ψ$_w$ (-1.13 MPa). It could be due to better capacity of the variety BARI Mung-6 to adjust Ψ$_w$ even at very low moisture level of soil. Lentil genotype with varying leaf water potential during drought stress was also reported by Gangwar and Kumar (2018).
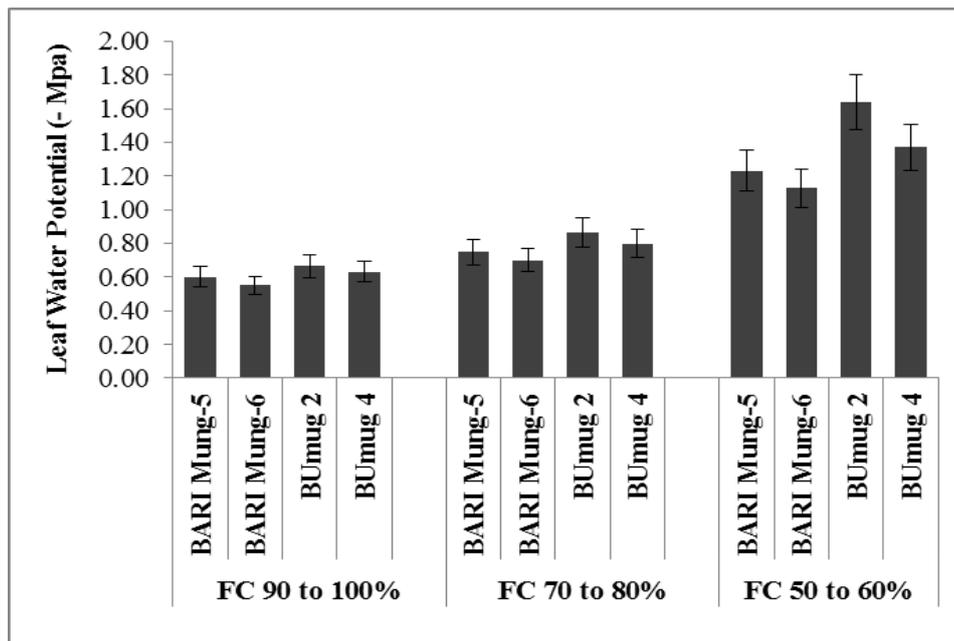
Fig. 2. Leaf water potential (-MPa) of four mungbean varieties at different levels of field capacity (FC). Bars represent mean ±SE.

Electrolyte leakage: Higher electrolyte leakage during drought stress of crop plants indicates higher amount of tissue damage (Tas and Tas, 2007). Significant differences in electrolyte leakage were observed among mungbean varieties

under water stress (Table 2). Electrolyte leakage of mungbean leaves was found to be increased with decreasing field capacity of soil in all varieties. It was found maximum at 50 to 60% field capacity and ranged from 64.22 to 75.11%, which at 70 to 80% field capacity, was found to be decreased within a range from 61.39 to 65.25%. Finally electrolyte leakage was recorded lowest (23.91 to 35.15%) at 90 to 100% field capacity. The results indicate that water deficit stress (50% to 60% field capacity) reduced membrane stability by altering the arrangement of phospholipid bilayer and resulted in reduced ability of plants to retain water and solutes causing increased leakage. Increased tissue damaged by enhanced electrolyte leakage was reported by Sairum and Saxena (2000) which is consistent to our results. In the present study, a comparison of electrolyte leakage among mungbean varieties indicates that, BARI Mung-6 had the minimum electrolyte leakage (64.22%) when grown at severe water stress (field capacity 50 to 60%), while BUmug 2 had the maximum electrolyte leakage (75.11%). The results suggest that BARI Mung-6 is able to maintain cell membrane integrity during drought by maintaining higher cell water status. Baroowa and Gogoi (2012) recorded decreased membrane stability in both black gram and green gram when exposed to drought stress.

Table 2. Electrolyte leakage of four mungbean varieties under three field capacity levels

Variety	Electrolyte Leakage (%)		
	FC of 90 to 100%	FC of 70 to 80%	FC of 50 to 60%
BARI Mung-5	30.46 i	62.17 ef	70.82 b
BARI Mung-6	23.91 j	61.39 f	64.22 cd
BUmug 2	35.15 g	65.25 c	75.11 a
BUmug 4	32.04 h	63.04 de	72.14 b
CV%		1.78	

Means along both rows and columns followed by the same letter (s) did not differ significantly at 5% level of probability.

Proline accumulation: Accumulation of proline is a common phenomenon during drought stress acclimation of crop plants and it was examined and compared in mungbean varieties. A profound effect of soil water crisis was observed on proline content of mungbean varieties (Fig. 3a). The mungbean plants maintained higher proline content (3.38 to 6.12 μmol/g FW) at 50 to 60% field capacity. As field capacity was increased, proline content was found to be

decreased to 1.61 to 3.98 µmol/g FW at (70 to 80% FC) and finally proline content was recorded at the lowest in all four mungbean varieties (1.19 to 1.65 µmol/g FW) at 90 to 100% field capacity. This result indicates that water deficit stress triggered the proline accumulation. This is a common physiological response of plants to drought stress (Mafakheri *et al.,* 2010).

Proline accumulation was recorded higher in BARI Mung-6 (6.12 µmol/g FW) at the lowest field capacity (50 to 60% FC), while BUmug 2 had the lower proline content (3.38 µmol/g FW). The relative proline content was also recorded higher in BARI Mung-6 at both 50 to 60% field capacity (3.71) and 70 to 80% field capacity (2.41), while BUmug 2 had the lower relative proline content of 2.84 and 1.35 at 60 to 50% and 70 to 80% field capacity, respectively (Fig. 3b). Thus higher proline content of BARI Mung-6 helped in lowering water potentials and involved in osmoregulation that allowed additional water to be taken up from the soil, thus buffering the immediate effect of water shortages. This drought tolerance mechanisms induced by proline accumulation was reported by Bharadwaj *et al.* (2018). Vendruscolo *et al.,* (2007) also reported that proline is isolated in tolerance mechanisms against oxidative stress and this was the main strategy of plant to avoid detrimental effects of water stress.
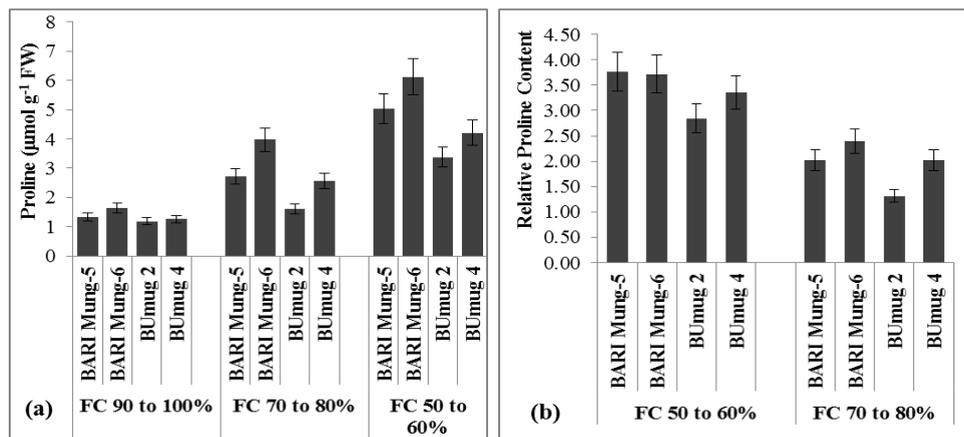
Fig 3. Proline content (µmol/g FW) (a) at three different levels of water regime and relative proline content (b) at 50-60% and 70-80% field capacity compared to 100-90% field capacity of four mungbean varieties. Bars represent mean ±SE.

Shoot dry weight: Field capacity with different soil water status had a profound effect on shoot dry weight (Fig 4a). Shoot weight in all four mungbean varieties was recorded higher at 90 to 100% field capacity with a range from 6.80 to 12.48 g plant[-1]. Shoot dry weight was decreased to 4.27 to 9.70 g plant[-1] at 70 to 80% FC and finally at 50 to 60% field capacity, shoot dry weight was lowest (1.93 to 4.88 g plant[-1]) (Fig 4a). Among the four mungbean varieties BARI Mung-6 recorded with the highest shoot dry weight (4.88 g

plant^{-1}) under drought stress condition (50 to 60% FC), while BUmug 2 recorded the lowest (1.93 g/plant) shoot dry weight (Fig 4a). Relative shoot dry weight was also higher in BARI Mung-6 at both 50 to 60% field capacity (0.39) and 70 to 80% field capacity (0.78) compared to that of BUmug 2 which had relative shoot dry weight 0.29 and 0.63 at 50 to 60% FC and 70 to 80% FC, respectively (Fig 4b). This result indicates that BARI Mung-6 is able to gain higher dry matter among all the four mungbean varieties and the results of that is very consistent to the appearance of better physiological attributes such as higher water content and leaf water potential, and increased accumulation of proline content of this variety.
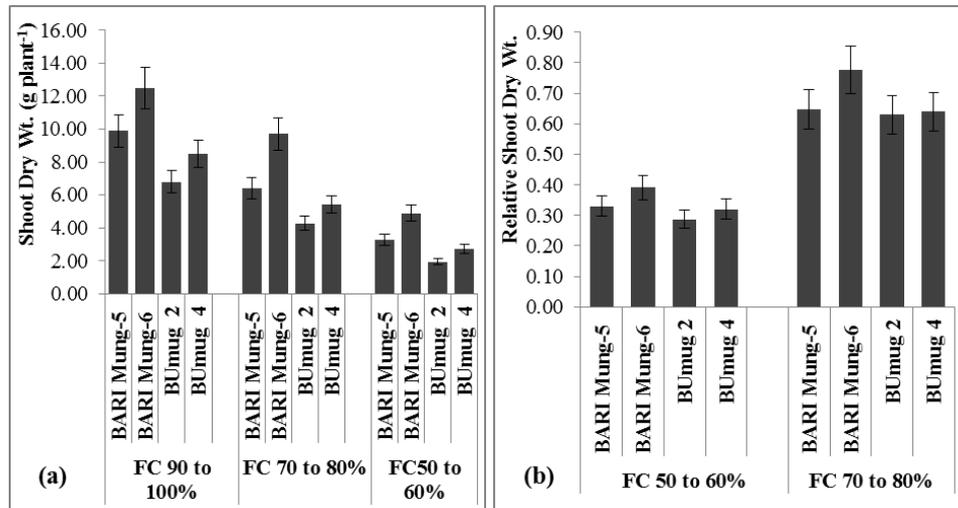
Fig 4. Shoot dry weight (g/plant) (a) at three different levels of water regime and relative shoot dry weight (b) at 50-60% and 70%-80% field capacity compared to 100-90% FC of four mungbean varieties. Bars represent mean ±SE.

Conclusion

Results of the study indicated that the variety BARI Mung-6 is more capable in tolerating water stress. So, BARI Mung-6 is considered as drought tolerant due to its high relative water content, leaf water potential, proline content, shoot dry matter and lower rate of electrolyte leakage.

Acknowledgement

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INTEGRATED NUTRIENT MANAGEMENT FOR GROWTH, YIELD AND PROFITABILITY OF BROCCOLI

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Abstract

A field experiment on broccoli taking the hybrid variety 'Green Magic' was conducted with seven treatments [T_1 = 100% recommended dose of inorganic fertilizer(100-35-60-18-2-1.2 kg/ha of N-P-K-S-Zn-B+Cowdung (CD) @5 t/ha), T_2 = 50% inorganic fertilizer recommended dose + Mustard Oil Cake(MOC) @ 1.5 t/ha, T_3 = 50% inorganic fertilizer of recommended dose + CD @ 10 t/ha, T_4 = 50% inorganic fertilizer of recommended dose + Poultry Manure (PM) @ 6 t/ha, T_5 = 25% inorganic fertilizer of recommended dose + MOC @ 3 t/ha, T_6 = 25% inorganic fertilizer of recommended dose + CD @ 15 t/ha, T_7 = 25% inorganic fertilizer of recommended dose + PM @ 12 t/ha] at the Horticultural Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during the period from September 2015 to February 2016. The aim of the study was to standardize the organic manure and inorganic fertilizers of broccoli for proper growth and yield. The experiment was laid out in a Randomized Complete Block Deign with three replications. All the parameters studied were significantly influenced by different treatments. The maximum plant height (62.20 cm) and canopy spread (64.67 cm), maximum number of leaves/plant (30.23) and average size of leaves (738.1 cm^2) and length of terminal head (15.57 cm) were found in T_5 which was statistically similar with T_7. The diameter of stems (3.87 cm), terminal head diameter (16.17 cm), terminal head weight/plant (424.6 g), number of lateral heads/plant (4.86), weight of lateral heads/plant (155.5 g), yield/plot (11.60 kg/6m^2), yield (19.34 t/ha) were found the highest in T_7 which was statistically similar with T_5. Gross return and net return were the highest in $T_7$and benefit cost ratio (BCR) was also maximum (3.64) in T_7.

Keywords: Organic fertilizer, Inorganic fertilizer, Growth, Yield and Broccoli.

Introduction

Broccoli (*Brassica oleracea*var. *italica* L.) is one of the non-traditional and relatively new cole crops in Bangladesh, belonging to the family Brassicaceae and it is grown in cool winter season in Bangladesh as an annual crop (Swarup, 2012).

Broccoli responds greatly to major essential elements like N, P, and K in respect of its growth and yield (Mital *et al.,* 1975; Singh *et al.,* 1976; Thompson and

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Kelly, 1988) and storage life. Nutrients may be applied through two sources *viz.,* organic and inorganic. Increased use of chemical fertilizers in crop field causes health hazards, and create problem to the environment by polluting water, air and soil. The continuous use of chemical fertilizers also badly affects the soil texture and structure. Decreased organic matter content of soil hampers soil microbial activity. Soils of Bangladesh contain 0.056 to1.638% organic matter (Akter *et al*., 2012). Now a days gradual decrease of soil organic matter and reduced yield of crop are alarming issues to the farmers. Organic manure plays direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization and improves physical and chemical properties of soils (Chaterjee *et al*., 2005, Kumar*et al.,* 2013, Attigah *et al.,* 2013).

Cow dung, poultry manure and mustard oil cake are available in the country, which are the good source of all the essential nutrients. Use of these manures also improves the organic matter status of soil. A judicious application of organic and inorganic fertilizers might be helpful to obtain a good economic return from a crop, as well as from the subsequent crop, and to maintain good soil health (Abou El- Magd *et al.,* 2006).

The production technology of broccoli has not yet been standardized in Bangladesh. Available information is scanty regarding the effect of organic manure with inorganic fertilizers on the growth and yield of broccoli. The present study was undertaken to investigate vegetative growth and yield performance of broccoli under different doses of organic manure and inorganic fertilizer and to find out the best combinations of them for sustainable crop productivity.

Materials and Methods

An experiment on integrated nutrient management of broccoli was conducted at the Horticultural Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the period from September 2015 to February 2016. The variety of broccoli used in this experiment was Green Magic, a hybrid, which was produced by Sakata Co. Ltd., Japan. The seeds were collected from Siddique Bazar of Dhaka. The experiment comprised of seven treatments [T_1 = 100% Recommended Dose of Fertilizer (RDF) (100-35-60-18-2-1.2 kg/ha of N-P-K-S-Zn-B+Cowdung (CD) @ 5 t/ha), T_2 = 50% RDF + Mustard Oil Cake (MOC) @ 1.5 t/ha, T_3 = 50% RDF + CD @ 10 t/ha, T_4 = 50% RDF + Poultry Manure (PM) @ 6 t/ha, T_5 = 25% RDF + MOC @ 3 t/ha, T_6 = 25% RDF + CD @ 15 t/ha, T_7 = 25% RDF + PM @ 12 t/ha]. As per treatment of the experiment, organic manures *viz.,* cowdung, mustard oil cake and poultry manure and inorganic fertilizers viz., N in the form of urea, P in the form of triple super phosphate (TSP), K in the form of muriate of potash (MoP), S in the form of gypsum, Zn in the form of zinc sulphate and B in the form of boric acid were applied to the field. Well decomposed CD, MOC & PM and TSP were incorporated in the soil during final land preparation. Gypsum, Ziinc

sulphate and Boric acid were incorporate in the soil during bed preparation. Urea and MoP were applied in three instalments; the first instalment was applied 15 days after transplanting (DAT), second and third instalments were top dressed at 30 and 45 DAT. The average monthly maximum and minimum temperature, relative humidity and monthly total rainfall during the crop growing period were collected from the meteorological station of BSMRAU and are presented in Appendix-3.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Unit plot size was 2.4 m × 2.5 m and 55 days old seedlings were transplanted on 22 November 2015 maintaining plant spacing of 50 cm × 60 cm. Intercultural operations such as weeding, mulching with straw and irrigation were done as per requirement. Data were recorded from 10 randomly selected plants of each plot on plant height (cm), number of leaves/plant, canopy spread (cm), stem diameter (mm), head initiation (days), leaf size (cm^2), terminal head length (cm), terminal head diameter (cm), terminal head weight/plant (g), number of lateral heads/plant, lateral head weight/plant (g), yield per plot (kg/ha) and yield (t/ha). The data were statistically analyzed using MSTATC software program. Means were separated using Least Significant Difference (LSD) test at 5% level of probability (Gomes and Gomes, 1984). Economic analysis was done in order to compare the profitability of the treatment combination and BCR was calculated using the following formula.

$$BCR = \frac{Gross\,return\,(Tk/ha)}{Total\,cost\,of\,production}$$

Results and Discussion

Plant height

Plant height was recorded at 15, 30, and 45 DAT and at harvest. The plant height at different DAT was significantly influenced by different treatments (Table 1). At 15 DAT the tallest plant (31.30 cm) was recorded in T_7 which was identical with T_5 (31.03 cm) and T_6 (30.33 cm). The plants of T_2 showed the lowest plant height (22.13 cm). At 30 DAT, maximum plant height was recorded from T_5 (52.33cm) closely followed by T_7 (52.10 cm) and the lowest was recorded from T_2 (37.70cm). At 45 DAT, T_5 produced the highest plant height (59.40cm) which was statistically similar with T_7 (58.87cm) and T_6 (56.67cm) and T_2 gave the lowest plant height. At harvest, the tallest plant was recorded in T_5 (62.20 cm) which was identical with T_7 (62.07 cm), T_6 (60.87 cm), T_1 (58.93 cm) and T_3 (58.20 cm). The plants of T_2 gave the lowest plant height (53.07 cm). The increased plant height might be due to nitrogen both in inorganic and organic form which enhanced the plant height up to 92% over the control. These results are in complete agreement with those obtained by Rakesh *et al.* (2006) who

showed that organic manure along with mineral fertilizers increased vegetative growth including plant height of broccoli.

Table 1. Effect of organic manure and inorganic fertilizerson plant height and number of leaves/plant of broccoli at different growth stage

Treatment combination	Plant height (cm) at DAT				Leaves per plant at DAT			
	15	30	45	At harvest	15	30	45	60
T_1	27.77	43.97	53.87	58.93	11.57	16.37	21.33	27.40
T_2	22.13	37.70	49.00	53.07	10.53	13.53	18.70	22.00
T_3	27.03	41.03	52.53	58.20	11.30	15.50	20.73	27.57
T_4	22.87	38.90	51.20	54.27	10.60	14.27	19.53	23.87
T_5	31.03	52.33	59.40	62.20	13.07	18.70	25.07	30.23
T_6	30.33	48.10	56.67	60.87	11.73	17.27	23.47	28.87
T_7	31.30	52.10	58.87	62.07	12.63	18.00	24.87	29.73
$LSD_{0.05}$	2.80	3.70	4.74	5.22	0.979	2.51	2.94	2.34
Level of significance	**	**	**	**	**	**	**	**
CV (%)	5.75	4.65	4.90	5.01	4.73	8.72	7.54	4.86

** Significant at 1% level of probability, DAT= Days after transplanting.

T_1 = 100% RDF @5 t/ha, T_2 = 50% RDF + MOC @ 1.5 t/ha, T_3 = 50% RDF + CD @ 10 t/ha, T_4 = 50% RDF + PM @ 6 t/ha, T_5 = 25% RDF + MOC @ 3 t/ha, T_6 = 25% RDF + CD @ 15 t/ha, T_7 = 25% RDF + PM @ 12 t/ha.

Number of leaves/plant

The number of leaves per plant at different growth stages was significantly influenced by different treatments (Table 1). Number of leaves per plant was recorded at 15, 30, 45 and 60 DAT. At 15 DAT, the highest number of leaves per plant(13.07) was recorded in T_5which was identical with T_7 (12.63). The plants of T_2gave the lowest number of leaves per plant(10.53). At 30 DAT, the highest number of leaves per plant(18.70) was recorded in T_5closely followed by T_7 (18.00) and T_6 (17.27)and the lowest was obtained from T_2 (13.53). Number of leaves/plant at 45 DAT showed similar trend of 30 DAT. At 60 DAT, maximum number of leaves per plant(30.23) was recorded in T_5 which was identical with T_7 (29.73) and T_6 (28.87). The plants of T_2produced the lowest number of leaves(22.00). Rakesh *et al.* (2006) reported that organic manure plus mineral fertilizer enhanced the vegetative growth of broccoli plants.

Stem diameter

The diameter of stem was measured at the point where the terminal head was cut off. The diameter of stem was significantly influenced by different treatments

(Table 2). Stem diameter was recorded at60 DAT. The maximum diameter (3.87 cm) was recorded in T_7 which was statistically similar with T_5 (3.86 cm) and T_6 (3.72 cm). The minimum stem diameter (3.26 cm) was noted in T_2. The diameter of stem was found maximum might be due to enjoying optimum nutrients at early stage (Rabby, 2008).

Table 2. Effect of organic manure and inorganic fertilizer on canopy spread, stem diameter and head initiationof broccoli

Treatment combination	Stem diameter (cm)	Head initiation (Days)		
		1st	50%	100%
T_1	3.55	37.67	45.00	52.33
T_2	3.26	35.33	41.00	50.00
T_3	3.49	38.33	45.00	52.33
T_4	3.30	35.33	43.00	51.00
T_5	3.86	42.33	46.33	54.33
T_6	3.72	41.00	46.00	53.00
T_7	3.87	41.67	46.33	53.67
$LSD_{0.05}$	0.333	4.89	3.54	2.63
Level of significance	**	*	*	*
CV (%)	5.21	7.10	4.46	2.83

** Significant at 1% level of probability, DAT=Days after transplanting.

T_1 = 100% RDF @5 t/ha, T_2 = 50% RDF + MOC @ 1.5 t/ha , T_3 = 50% RDF + CD @ 10 t/ha, T_4 = 50% RDF + PM @ 6 t/ha, T_5 = 25% RDF + MOC @ 3 t/ha, T_6 = 25% RDF + CD @ 15 t/ha, T_7 = 25% RDF + PM @ 12 t/ha.

Head initiation

Significant influence of different treatments on head initiation of broccoli was observed (Table 2). The plants under T_5 took the longest time (42.33 days) for first head initiation which was statistically similar with T_7 (41.67 days), T_6 (41.00 days), T_3 and T_1, while the plants of $T_2$and T_4required minimum time (35.33 days). The plants under T_5 and T_7 took the maximum time (46.33 days) for 50% head initiation which was statistically similar with T_6, T_1, T_3 and T_4. On the other hand T_2 took the lowest time (41.00 days) for 50% head initiation. Again T_5 took the maximum time (54.33 days) for 100% head initiation which was statistically similar with T_7 (53.67 days), T_6 (53.00 days), T_1 and T_3 and T_2 took the lowest time (50.00 days) for 100% head initiation. This finding was supported by the results of Thakur *et al.* (1991) and Balyan *et al.* (1988).

Leaf size (cm^2)

Leaves size was recorded at 60 DAT. The size of leaves varied significantly due to the influence of different treatments (Table 3). The maximum leaf size (738.10 cm^2) was found in T_5which was identical with T_6 (732.90 cm^2) and T_7 (729.40 cm^2) whereas the minimum (660.70 cm^2) was in T_2.

Table 3. Effect of organic manure and inorganic fertilizer on leaf size, head diameter, head length and number of lateral headsof broccoli

Treatment combination	Leaf size (cm^2)	Terminal head diameter (cm)	Terminal head length(cm)	Number of lateral heads/plant
T_1	692.20	14.13	14.33	4.13
T_2	660.70	12.87	13.47	3.07
T_3	681.10	14.20	13.83	3.60
T_4	667.50	13.40	13.67	3.33
T_5	738.10	16.17	15.57	4.46
T_6	732.90	15.60	14.90	4.46
T_7	729.40	16.17	15.40	4.86
$LSD_{0.05}$	41.78	1.66	1.50	0.318
Level of significance	**	**	*	**
CV (%)	3.35	6.37	5.85	4.45

** Significant at 1% level of probability, DAT=Days after transplanting.

T_1 = 100% RDF @5 t/ha, T_2 = 50% RDF + MOC @ 1.5 t/ha , T_3 = 50% RDF + CD @ 10 t/ha, T_4 = 50% RDF + PM @ 6 t/ha, T_5 = 25% RDF + MOC @ 3 t/ha, T_6 = 25% RDF + CD @ 15 t/ha, T_7 = 25% RDF + PM @ 12 t/ha.

Days required for terminal head harvest

Days required for terminal head harvest varied significantly due to the influence of different treatments (Fig 1). T_7 took the highest time (38 days) followed by T_6 (37 days) for 1st harvest and the lowest time was required in T_3 (33.33 days). For 50% head harvest, T_6 took the maximum time (50.00 days) closely followed by T_7 (49.67 days) and the minimum time was T_1 (44.00 days). On the other hand, for final harvest T_7 took the maximum time (57.33 days) while T_1 took the lowest time (49.67 days). This finding was supported by the results of Thakur *et al.* (1991) for cauliflower who reported that the increasing rate of N delayed head maturity. Balyan *et al.* (1988) also reported similar results in cauliflower.

Diameter and length of terminal head

Diameter and length of terminal head were significantly influenced by different treatments (Table 3). Maximum diameter was recorded in T_5 and T_7 (16.17 cm) which was identical with T_6(15.60 cm) and the minimum diameter (12.87 cm)

was in T_2. The maximum length (15.57 cm) of terminal head was recorded in T_5 which was statistically similar to T_7 (15.40 cm), T_6(14.90 cm) and T_1(14.33 cm).On the contrary minimum length (13.47 cm) was found in T_2.

Number of lateral heads/plant

There was a significant variation in number of lateral heads produced by the plants under different treatments (Tables 3). The maximum number of lateral heads (4.86) was recorded in T_7 with the minimum (3.071) of lateral heads was recorded in T_2.Similar trend has also been reported by Bankder and Mukhopadhyay (1980).

Weight of terminal head

Weight of terminal head varied significantly due to the influence of different organic manures and inorganic fertilizers (Table 4). The plants of T_7 produced the maximum terminal head weight (424.60g) which was statistically similar to T_5 (422.30 g) and T_6 (413.50 g) while T_2produced the lowest (328.90 g). This result is in agreement with Kandil and Gad (2009) who concluded that using organic manure along with inorganic fertilizers gave a significant promotive effect on plant growth, head yield, chemical constituents and mineral composition of broccoli. Similar results were also reported by Chaterjee *et al.* (2005), Mellgren (2008) and Yoldas and Esiyok (2004) in broccoli.

Table 4.Effect of organic manure and inorganic fertilizer on terminal headweight, lateral headweight, head weight per plant, yield per plot and yieldof broccoli

Treatment combination	Terminal head weight (g)	Lateral head weight (g)	Head weight per plant (g)	Yield per plot(kg)	Yield(t/ha)
T_1	374.4	137.5	511.93	10.58	17.64
T_2	328.9	120.2	449.10	8.98	14.97
T_3	372.7	134.5	507.27	10.14	16.91
T_4	339.8	125.8	452.27	9.31	15.51
T_5	422.3	155.1	577.43	11.55	19.19
T_6	413.5	153.9	567.47	11.35	18.92
T_7	424.6	155.5	579.40	11.60	19.34
$LSD_{0.05}$	34.78	13.83	9.85	1.04	1.96
Level of significance	**	**	**		
CV%	5.11	5.54	5.21	5.57	6.29

** Significant at 1% level of probability, DAT=Days after transplanting.

T_1 = 100% RDF @5 t/ha, T_2 = 50% RDF + MOC @ 1.5 t/ha , T_3 = 50% RDF + CD @ 10 t/ha, T_4 = 50% RDF + PM @ 6 t/ha, T_5 = 25% RDF + MOC @ 3 t/ha, T_6 = 25% RDF + CD @ 15 t/ha, T_7 = 25% RDF + PM @ 12 t/ha.

Lateral head weight

Significant variation was revealed regarding lateral head weight due to the influence of different treatments (Table 4). The highest lateral head weight was found in T_7 (155.50 g) which was identical with T_5 (155.10 g) and T_6 (153.90 g). The lowest lateral head weight (120.20 g) was obtained from T_2. This phenomenon might be due to continuous release of essential nutrient elements from different manures and fertilizers used. Treatment that nourished the plants properly gave the highest weight of lateral head/plant (Rabby, 2008).

Head weight per plant

The head weight/plant of broccoli varied significantly due to different treatments (Table 4). The head yield ranged from 449.10 to 579.40 g/plant. The highest head weight/plant (579.40 g) wasrecorded in T_7 which was identical with T_5 (577.43 g). The lowest head weight/plant (449.10 g) was found in T_2.

Yield per plot

The head yield/plot of broccoli were significantly influenced by different treatments (Table 4). The maximum head yield per plot was recorded in T_7 (11.60 kg) which was statistically similar to T_5 (11.55 kg) and T_6 (11.35 kg). On the other hand, the lowest head yield per plot (8.98 kg) was obtained from T_2. These results indicated that yields per plot can be enhanced with the application of organic manure and inorganic fertilization. This result is in agreement with Kandil and Gad (2009).

Table 5. Economic analysis of production as influenced by different organic manure and inorganic fertilizers

Treatment combination	Marketable Yield/ha (t/ha)	Total cost of production/ha (Tk)	Gross return/ha (Tk)	Net return/ha (Tk)	Benefit Cost Ratio (BCR)
T_1	17.64	125297	441000.00	315703.00	3.52
T_2	14.97	158919	374250.00	215331.00	2.35
T_3	16.91	130053	422750.00	292697.00	3.25
T_4	15.51	115553	387750.00	272197.00	3.35
T_5	19.19	223160	479750.00	256590.00	2.15
T_6	18.92	146630	473000.00	326370.00	3.23
T_7	19.34	132924	483500.00	350576.00	3.64

T_1 = 100% RDF @5 t/ha, T_2 = 50% RDF + MOC @ 1.5 t/ha , T_3 = 50% RDF + CD @ 10 t/ha, T_4 = 50% RDF + PM @ 6 t/ha, T_5 = 25% RDF + MOC @ 3 t/ha, T_6 = 25% RDF + CD @ 15 t/ha, T_7 = 25% RDF + PM @ 12 t/ha.
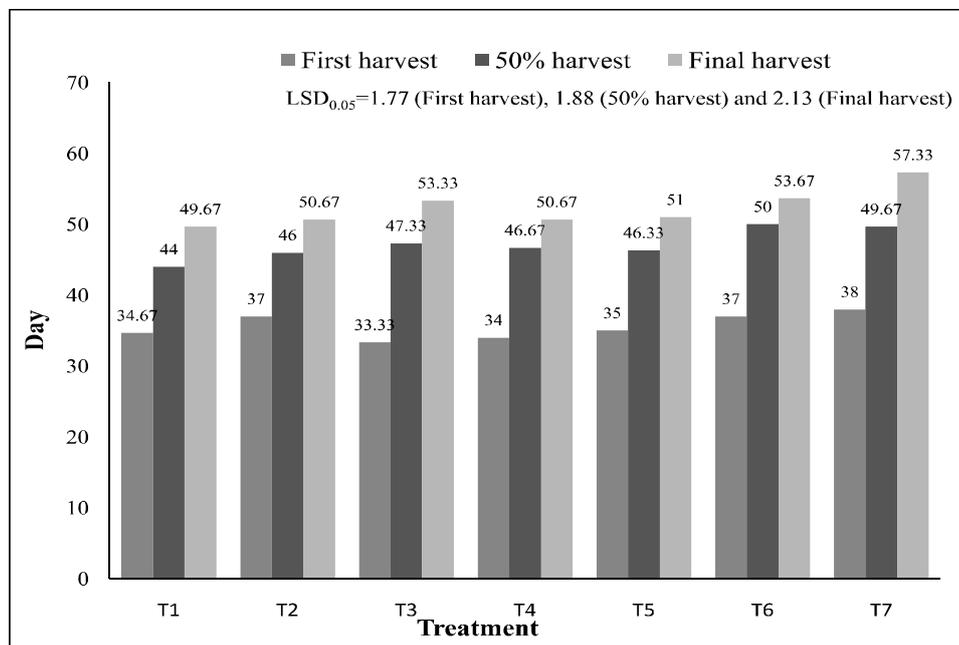
Fig. 1. Effect of organic manure and inorganic fertilizers on days required for head harvest.

T_1 = 100% RDF @5 t/ha, T_2 = 50% RDF + MOC @ 1.5 t/ha , T_3 = 50% RDF + CD @ 10 t/ha, T_4 = 50% RDF + PM @ 6 t/ha, T_5 = 25% RDF + MOC @ 3 t/ha, T_6 = 25% RDF + CD @ 15 t/ha, T_7 = 25% RDF + PM @ 12 t/ha

Yield per hectare

Yield per hectare was also significantly influenced by different treatment combination (Table 4). The highest head yield per hectare (19.34 t/ha) was recorded from T_7 which was identical with T_5 (19.19 t/ha), T_6 (18.92 t/ha) and T_1 (17.64 t/ha) while the lowest head yield of 14.97 t/ha was recorded in T_2.Similar results were reported by Chaterjee *et al.* (2005).

Economic analysis

The production cost of broccoli varied due to different organic manure and inorganic fertilizers (Table 5). Cost of production was higher in other approaches compared to recommended approach. Production cost was the highest (Tk. 223160/ha) in T_5followed by T_2 (Tk. 158919/ha) and it was the lowest (Tk. 115553/ha) in T_4. The maximum gross return (Tk. 483500.00/ha) and net return (Tk. 350576.00/ha) were found in T_7 while the minimum in T_2 (Tk. 374250.00/ha and 215331.00/ha, respectively). The highest benefit cost ratio (3.64) was found in T_7 followed by T_1 (3.52) while it was the lowest in T_5 (2.15).

Conclusion

Based on the results of the present study,it can be concluded that the treatment T_7= (25% RDF + PM@12 t/ha) performed the best regarding diameter of stem, terminal headdiameter, length of terminal head, terminal headweight per plant, no. of lateral heads per plant, weight of lateral heads per plant, yield per plot and yield per hectare (t/ha). Thistreatment was statistically similar to T_5 (25% RDF + MOC @ 3 t/ha).Gross return and net return was the highest in T_7 and benefit cost ratio was also the maximum (3.64) in the same treatment. Hence, 25% RDF + PM @ 12 t/ha may be the recommended for sustainable broccoli production.

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Appendix 1a. Physical properties of soil of the experimental field (0-15 cm)

Physical Properties	Content
Sand(%)	21.2
Silt (%)	51.4
Clay(%)	27.4
Bulk density(g/cm^3)	1.36
Particle density(g/cm^3)	2.65
Soil porosity (%)	51.32
Textural class	Silt loam

Appendix 1b. Chemical properties of soil of the experimental field (0-15 cm)

Chemical Properties	Analytical value	Critical value	Optimum value
P^H	6.1	-	-
Organic Carbon (%)	0.82	-	-
Total N (%)	0.118	0.075	3.0
Available phosphorus (ppm)	14.185	14.0	60.0
Exchangeable Potassium (meq/100g)	0.475	0.2	1.5
Exchangeable Calcium (meq/100g)	8.5	2.0	18.0
Exchangeable Magnesium (meq/100g)	2.035	0.8	9.0
Available Sulphur (ppm)	15.23	14.0	60.0

CEC (meq/100g) =20.55

Appendix 2. Nutrient content (%) of cowdung, mustard oil cake and poultry manure

Organic manure	Nutrient content (%)		
	N	P	K
Cowdung	0.45	0.15	0.45
Mustard oil cake	4.8	1.6	1.2
Poultry manure	1.89	0.55	0.73

Appendix 3. Monthly record of temperature, relative humidity and rainfall during the period from September, 2015 to February, 2016

Year	Month	**Air temperature (^{o}C)			**Relative humidity (%)	*Rainfall (mm)
		Maximum	Minimum	Average		
2015	September	33.03	26.56	29.80	86.60	253.18
	October	32.91	23.38	28.15	85.74	22.05
	November	30.45	18.31	24.38	85.33	0.00
	December	25.96	13.93	19.95	88.61	0.00
2016	January	24.24	12.82	18.53	85.03	12.98
	February	27.14	14.92	21.03	75.96	3.89

* Monthly total

** Monthly average

Source: Weather Records of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.

Appendix 4. Date of head initiation and head harvest of broccoli

Treatment	Date of head initiation			Date of head harvest		
	1st head initiation	50% head initiation	100% head initiation	1st head initiation	50% head initiation	100% head initiation
T_1	30/12/2015	07/01/2016	14/01/2016	03/02/2016	13/02/2016	18/02/2016
T_2	28/12/2015	03/01/2016	18/01/2016	03/02/2016	16/02/2016	20/02/2016
T_3	31/12/2015	07/01/2016	14/01/2016	02/02/2016	16/02/2016	22/02/2016
T_4	28/12/2015	05/01/2016	13/01/2016	01/02/2016	13/02/2016	19/02/2016
T_5	04/01/2016	08/01/2016	16/01/2016	02/02 2016	13/02/2016	20/02/2016
T_6	03/01/2016	08/01/2016	15/01/2016	09/02/2016	28/01/2016	02/03/2016
T_7	03/01/2016	08/01/2016	15/01/2016	09/02/2016	20/02/2016	28/02/2016

Appendix 5. Analysis of Cost of production Input cost (Tk/ha)

Treatment Combination	Labour cost	Ploughing Cost	Seed cost	Bamboo and chati	Irrigation cost	Metallic substance	Insecticides and fungicides	CD	MOC cost	PM cost	Urea cost	TSP cost	MoP cost	Gypsum cost	ZnSO$_4$ cost	Boric acid cost	Total cost
T$_1$	45000	10000	3500	10000	9000	1000	3500	7500	0	0	3488	2100	1500	2500	296	96	99480
T$_2$	45000	10000	3500	10000	9000	1000	3500	0	51000	0	1744	1050	750	1250	148	48	127990
T$_3$	46400	10000	3500	10000	9000	1000	3500	15000	0	0	1744	1050	750	1250	148	48	103390
T$_4$	41600	10000	3500	10000	9000	1000	3500	0	0	7200	1744	1050	750	1250	148	48	90790
T$_5$	42400	10000	3500	10000	9000	1000	3500	0	102000	0	872	525	325	625	74	24	183845
T$_6$	56400	10000	3500	10000	9000	1000	3500	22500	0	0	872	525	325	625	74	24	118345
T$_7$	52400	10000	3500	10000	9000	1000	3500	0	0	14400	872	525	325	625	74	24	106245

Overhead cost (Tk/ha)

Treatment Combination	Cost of lease of land for 6 months (11% of value of land Tk.200000/year)	Miscellaneous cost (Tk.5% of the input cost)	Interest on running capital for 6 months (Tk.11% of cost/year)	Total of overhead cost	Total cost of production [Input cost +Overhead cost]
T$_1$	11000	4974	9843	25817	125297
T$_2$	11000	6400	13529	30929	158919
T$_3$	11000	5170	10493	26663	130053
T$_4$	11000	4546	9217	24763	115553
T$_5$	11000	9192	19123	39315	223160
T$_6$	11000	5917	11368	28285	146630
T$_7$	11000	5312	10367	26679	132924

T$_1$ = 100% RDF @5 t/ha, T$_2$ = 50% RDF + MOC @ 1.5 t/ha, T$_3$ = 50% RDF + CD @ 10 t/ha, T$_4$ = 50% RDF + PM @ 6 t/ha, T$_5$ = 25% RDF + MOC @ 3 t/ha, T$_6$ = 25% RDF + CD @ 15 t/ha, T$_7$ = 25% RDF + PM @ 12 t/ha.

EFFECT OF PLANT GROWTH REGULATORS ON PLANT REGENERATION OF HYACINTH BEAN (*LABLAB PURPUREUS* (L.) SWEET) THROUGH NODAL EXPLANTS

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Abstract

Nodal explants of three accessions namely BD-101, BD-122 and BD-8001 of hyacinth bean (*Lablab purpureus* (L.) Sweet) were cultured for four weeks on MS medium supplemented with different concentrations and combinations of NAA (0, 0.1 mgl^{-1}) and BAP (0.5, 1.0 and 2.5 mgl^{-1}) for plant regeneration. The highest shoot initiation was observed in 0.5 mgl^{-1} BAP while the lowest shoot initiation was found in 2.5 mgl^{-1} BAP with 0.1 mgl^{-1} NAA. Earlier shoot initiation was exhibited in 0.5 mgl^{-1} BAP with 0.1 mgl^{-1} NAA. The highest number of leaflets and higher shoot lengths were observed in MS medium. Comparatively higher number of shoots was found in BAP (0.5-2.5 mgl^{-1}). The highest percentage of callus was initiated in medium supplemented with 1.0 mgl^{-1} BAP. Earlier callus initiation and larger callus size were found in combination of BAP (0.5-2.5 mgl^{-1}) with 0.1 mgl^{-1} NAA. BD-122 cultured in MS medium was found superior for shoot regeneration through node culture. Four different concentrations of IBA (0.1-1.5 mgl^{-1}) were used for rooting. The highest percentage (86.67 %) of rooting was found in MS medium containing 0.1 mgl^{-1} IBA at four weeks. Rooting frequency decreased with the increasing concentration of IBA. The accession BD-8001 had 99.60 % rooting in 0.5 mgl^{-1} IBA. The highest number of longest roots was exhibited in 0.1 mgl^{-1} IBA. The regeneration protocol developed from nodal explants has applicability in improvement of hyacinth bean.

Keywords: *Lablab purpureus*, nodal explant, growth regulators, regeneration.

Introduction

Hyacinth bean is a popular vegetable in Bangladesh and South East Asia. The crop is mainly grown for its young pods and green, immature seeds for vegetable purpose. The dry seeds are used as pulse for human consumption in South and Southeast Asia, and East Africa (Magness *et al.*, 1971; Yawalkar and Ram, 2004). It is used as fodder, hay, silage, green manure and cover crop. Lablab leaves and seeds contain 20-28 % protein (Schaafhausen, 1963). It is grown on

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approximately 20,212 ha of land in Bangladesh during the winter season, yielding an average of 6.37 t of fresh pods per ha for a total yield of about 1,28,676 t (BBS, 2017). Because of its high adaptability, hyacinth bean may help to overcomes some critical seasonal effects in the vegetable production of Bangladesh. Bangladesh Agricultural Research Institute released seven varieties including one photo-insensitive variety of hyacinth bean. However, new varieties with even wider adaptability in stressed environment and resistance to insects and diseases are needed in near future. Systematic research, such as collection, conservation, morpho-molecular characterization, diversity studies, experiments on in vitro regeneration and utilization of hyacinth bean, has been done at PGRC of BARI (Islam *et al.,* 2002; Islam, 2008, 2012; Islam and Haque, 2009, Islam *et al.,* 2010). At present, PGRC conserves 661 accessions of hyacinth bean in the genebank. The availability of an *in vitro* regeneration system is a pre-requisite for the application of most biotechnological techniques such as production of synthetic seeds, use of somaclones and transgenic plants. *In vitro* techniques can be used for obtaining virus free materials, clonal propagation, germplasm collection and conservation. Callus initiation and plantlet regeneration by cotyledon, stem and leaf explants of hyacinth bean were reported earlier (Thiruvengadam and Jayabalan, 2000; Kale, 2005). Plant regeneration from immature embryo was also reported (Islam *et al.,* 2010). However, plant regeneration from nodal explant has not been reported in hyacinth bean. Nodal explants are easily available, inexpensive and easy to culture compared to other explants. Therefore, the present investigation was undertaken to develop a reproducible protocol on plant regeneration using nodal explants of hyacinth bean.

Materials and Methods

Two experiments were conducted with three accessions viz. BD-101, BD-122 and BD-8001 of hyacinth bean at the In Vitro Conservation Laboratory of PGRC, BARI, Joydebpur Gazipur. The accessions are the landraces and are collected from different regions (districts) viz. Naogoan, Hobiganj and Rangamati in Bangladesh in the first experiment. The edible pod shape is elongate and green in BD-101, flat and light purple in BD-122, and flat and light green in BD-8001. The seed colors of the three accessions are yellow, mosaic and black. Plantlets developed through embryo culture were used as source materials. Four weeks aged plantlets were taken on sterilized Petri dishes. Stem segments with 1-2 nodes having axillary buds were aseptically excised from the apical portion without shoot tip under laminar flow and the nodal segments were used as explants. MS salts with vitamins (Murashige and Skoog, 1962) were supplemented with BAP (0.5, 1.0 and 2.5 mgl^{-1}) alone or in combination with NAA (0, 0.1 and 0.5 mgl^{-1}) in 7 treatments (Table 1). The pH of the medium was adjusted to 5.8 before autoclaving and the media were solidified with agar 8 gl^{-1}. Ten ml media was poured in each culture tube (25 x 150 mm). The medium was

autoclaved at 1.06 kg/cm^{-2} pressure and 121°C for 15 min. The nodal explants were placed vertically on the medium keeping the tips upside and gently pressed into the culture medium. The explants were incubated for four weeks in a culture room at 22 ± 1°C under about 2000 lux light provided by cool-white fluorescent tubes maintaining a 16/8 h alternate light/dark cycle and 60-70 % relative humidity. The culture tubes were checked daily to note the morphogenic development and the data were recorded on eight parameters (Table 1). The experimental set up was a 7 x 3 factorial in a completely randomized design with five replications each replication consisting of 10 explants. Data were subjected to ANOVA using the General Linear Model procedure. Significant interactions were analyzed. Mean separations were carried out by DMRT at 1 % using the MSTAT program. The percentage data were subjected to square root transformation method (Steel and Torrie, 1960; Gomez and Gomez, 1984). In the second experiment, *in vitro* raised shoots were transferred to rooting medium for plantlet formation. Shoots were carefully removed from the culture tubes. Each shoot was cut from the basal end and was transferred to MS medium supplemented with 0.1, 0.5, 1.0 or 1.5 mgl^{-1} IBA One shoot was placed on the rooting medium and were incubated for four weeks. The experimental set up was 4 x 3 factorial CRD with three replications and each replication consisted of 10 explants. Similar methods were followed as of experiment-1 for data analysis in rooting and plantlets development.

Results and Discussion

Experiment-1

Percentage of callus initiation: The highest percentage of callus (99.60 %) was initiated in 1.0 mgl^{-1} BAP, followed by 98.07 % callus in 2.5 mgl^{-1} BAP and then 96.65 % callus in 2.5 mgl^{-1} BAP with 0.1 mgl^{-1} NAA which were statistically similar. The minimum of 85 % callus was obtained from 0.5 mgl^{-1} BAP with 0.1 mgl^{-1} NAA (Table 1). However, growth regulator free MS did not initiate any callus in node culture. BD-122 and BD-101 produced 93.20 to 94.09 % callus, respectively (Table 2). The treatment combination of 2.5 mgl^{-1} BAP and 0.1 mgl^{-1} NAA with BD-101 produced the maximum callus (99.96 %). On the other hand, the lowest callus was exhibited in 0.5 mgl^{-1} BAP and 0.1 mgl^{-1} NAA with BD-122 (80 %) (Table 3). Kale (2004) noted that the hyacinth bean genotype Konkan Wal 1, explant stem and growth regulator combination of 2.5 mgl^{-1} IAA + 5.0 mgl^{-1} BA recorded maximum callus induction (91.87%).

Days to callus initiation: Earlier callus initiation was found in case of 2.5 mgl^{-1} BAP with 0.1 mgl^{-1} NAA (6.0 days) followed by 1.0 mgl^{-1} BAP with 0.1 mgl^{-1} NAA (6.67 days) which were statistically identical (Table 1). However, the callus initiation was most delayed (11.33 days) at the lowest concentration of BAP used (0.5 mgl^{-1}) and followed by 1.0 mgl^{-1} BAP (10.67 days). BD-101 and BD-122 produced callus in 7.5 to 9.17 days, respectively (Table 2). The treatment

Table 1. Effect of BAP and NAA on *in vitro* shoot proliferation of hyacinth bean through node culture

BAP (mg/l)	NAA (mg/l)	% Callus initiation	Days to callus initiation	Size of callus (mm)	% Shoot initiation	Days to shoot initiation	Number of leaflet	Number of shoot	Length of shoot (cm)
0	0	-	-	-	78.33 (8.84 ±0.11) cd	7.33 ±0.21 c	5.33 ±0.30 a	1.07 ±0.07 b	0.97 ±0.06 a
0.5	0	91.67 (9.57) ±0.08 b	11.33 ±0.30 a	10.00 ±0.28 e	90.00 (9.48 ±0.07) a	8.33 ±0.27 b	2.67 ±0.30 c	1.60 ±0.16 a	0.63 ±0.04 c
1.0	0	99.60 (9.98) ±0.09 a	10.67 ±0.29 a	13.00 ±0.59 d	83.33 (9.12 ±0.06) b	8.67 ±0.23 b	3.67 ±0.28 b	1.73 ±0.16 a	0.77 ±0.06 b
2.5	0	98.07 (9.90) ±0.03 a	8.33 ±0.23 b	13.67 ±0.37 d	78.33 (8.85 ±0.08) cd	9.67 ±0.41 a	1.47 ±0.17 d	1.60 ±0.16 a	0.50 ±0.03 d
0.5	0.1	85.00 (9.21) ±0.09 c	7.00 ±0.32 c	15.33 ±0.60 c	81.67 (9.03 ±0.05) bc	6.00 ±0.28 e	2.53 ±0.27 c	1.06 ±0.07 b	0.57 ±0.02 cd
1.0	0.1	91.67 (9.57) ±0.06 b	6.67 ±0.30 cd	17.27 ±0.59 b	76.67 (8.75 ±0.06) d	6.33 ±0.27 de	1.67 ±0.27 d	1.07 ±0.07 b	0.47 ±0.02 d
2.5	0.1	96.65 (9.83) ±0.04 a	6.00 ±0.32 d	21.00 ±0.62 a	73.00 (8.54 ±0.05) e	7.00 ±0.28 cd	1.32 ±0.19 d	1.07 ±0.07 b	0.63 ±0.04 c

In a column, means with standard error followed by common letters are not significantly different from each other at 1% level of probability by DMRT, Figures in parenthesis are square root transformed values.

Table 2. Effect of different accessions on *in vitro* shoot proliferation of hyacinth bean through node culture

Accession	% Callus initiation	Days to callus initiation	Size of callus (mm)	% Shoot initiation	Days to shoot initiation	Number of leaflet	Number of shoot	Length of shoot (cm)
BD-101	94.09 (9.70) ±0.06 a	7.50 ±0.40 c	14.13 ±0.51 b	78.57 (8.86 ±0.06) b	7.57 ±0.35 b	2.94 ±0.19 a	1.34 ±0.09 a	0.59 ±0.03 b
BD-122	93.20 (9.65) ±0.07 a	9.17 ±0.36 a	14.50 ±0.80 b	79.43 (8.90 ±0.06) b	7.14 ±0.19 b	2.74 ±0.37 a	1.57 ±0.14 a	0.66 ±0.03 a
BD-8001	94.03 (9.69) ±0.06 a	8.33 ±0.46 b	16.50 ±0.75 a	82.57 (9.08 ±0.07) a	8.14 ±0.23 a	2.31 ±0.30 b	1.03 ±0.03 b	0.70 ±0.05 a

In a column, means with standard error followed by common letters are not significantly different from each other at 1% level of probability by DMRT, Figures in parenthesis are square root transformed values.

Table 3. Combined effect of BAP, NAA and accessions on *in vitro* shoot proliferation of hyacinth bean through node culture

BAP (mg/l)	NAA (mg/l)	Accession	% Callus initiation	Days to callus initiation	Size of callus (mm)	% Shoot initiation	Days to shoot initiation	Number of leaflet	Number of shoot	Length of shoot (cm)
0	0	BD-101	-	-	-	70 (8.36 ± 0.09) e	8 ± 0.32 cd	4.0 ± 0.32 b	1.0 ± 0.03 d	0.8 ± 0.09 b
0	0	BD-122	-	-	-	85 (9.22 ± 0.09) bc	7 ± 0.32 de	6.0 ± 0.32 a	1.2 ± 0.20 cd	1.0 ± 0.09 a
0	0	BD-8001	-	-	-	80 (8.94 ± 0.09) cd	7 ± 0.32 de	6.0 ± 0.32 a	1.0 ± 0.03 d	1.1 ± 0.09 a
0.5	0	BD-101	85 (9.22) ± 0.09 cd	10 ± 0.32 bc	11 ± 0.32 gh	85 (9.22 ± 0.09) bc	8 ± 0.45 cd	4.0 ± 0.32 b	1.8 ± 0.20 bc	0.5 ± 0.03 cd
0.5	0	BD-122	95 (9.75) ± 0.08 ab	12 ± 0.32 a	9 ± 0.32 i	90 (9.49 ± 0.08) ab	8 ± 0.45 cd	2.0 ± 0.32 cd	2.0 ± 0.32 b	0.6 ± 0.03 cd
0.5	0	BD-8001	95 (9.75) ± 0.08 ab	12 ± 0.32 a	10 ± 0.32 hi	95 (9.75 ± 0.07) a	9 ± 0.45 bc	2.0 ± 0.32 cd	1.0 ± 0.03 d	0.8 ± 0.03 b
1.0	0	BD-101	99.6 (9.98) ± 0.01 a	10 ± 0.45 bc	12 ± 0.45 fg	80 (8.94 ± 0.13) cd	9 ± 0.32 bc	2.0 ± 0.32 cd	1.0 ± 0.03 d	0.6 ± 0.03 cd
1.0	0	BD-122	99.6 (9.98) ± 0.01 a	11 ± 0.32 ab	13 ± 0.45 ef	80 (8.94 ± 0.13) cd	8 ± 0.32 cd	6.0 ± 0.32 a	3.0 ± 0.32 a	0.7 ± 0.03 bc
1.0	0	BD-8001	99.6 (9.98) ± 0.01 a	11 ± 0.45 ab	14 ± 0.45 de	90 (9.48 ± 0.12) ab	9 ± 0.32 bc	3.0 ± 0.32 bc	1.2 ± 0.20 cd	1.0 ± 0.03 a
2.5	0	BD-101	95 (9.75) ± 0.05 ab	8 ± 0.45 de	12 ± 0.32 fg	75 (8.66 ± 0.09) de	11 ± 0.45 a	2.0 ± 0.32 cd	2.0 ± 0.32 b	0.4 ± 0.03 d
2.5	0	BD-122	99.6 (9.98) ± 0.01 a	9 ± 0.32 cd	14 ± 0.32 de	75 (8.66 ± 0.09) de	8 ± 0.45 cd	1.2 ± 0.20 d	1.8 ± 0.20 bc	0.6 ± 0.03 cd
2.5	0	BD-8001	99.6 (9.98) ± 0.01 a	8 ± 0.32 de	15 ± 0.32 d	85 (9.22 ± 0.03) bc	10 ± 0.45 ab	1.2 ± 0.20 d	1.0 ± 0.03 d	0.5 ± 0.03 cd
0.5	0.1	BD-101	90 (9.48) ± 0.12 bc	6 ± 0.45 fg	15 ± 0.45 d	85 (9.22 ± 0.09) bc	5 ± 0.32 f	3.6 ± 0.40 b	1.18 ± 0.21 cd	0.5 ± 0.03 cd
0.5	0.1	BD-122	80 (8.94) ± 0.13 d	8 ± 0.45 de	13 ± 0.45 ef	80 (8.94 ± 0.07) cd	6 ± 0.32 ef	2.0 ± 0.32 cd	1.0 ± 0.03 d	0.6 ± 0.03 bcd
0.5	0.1	BD-8001	85 (9.22) ± 0.12 cd	7 ± 0.45 ef	18 ± 0.45 c	80 (8.94 ± 0.05) cd	7 ± 0.32 de	2.0 ± 0.32 cd	1.0 ± 0.03 d	0.6 ± 0.03 bcd
1.0	0.1	BD-101	95 (9.75) ± 0.05 ab	6 ± 0.32 fg	16.8 ± 0.49 c	80 (8.94 ± 0.09) cd	6 ± 0.45 ef	3.0 ± 0.32 bc	1.2 ± 0.20 cd	0.5 ± 0.03 cd
1.0	0.1	BD-122	90 (9.49) ± 0.07 bc	8 ± 0.32 de	15 ± 0.32 d	75 (8.66 ± 0.09) de	6 ± 0.45 ef	1.0 ± 0.06 d	1.0 ± 0.03 d	0.5 ± 0.03 d
1.0	0.1	BD-8001	90 (9.48) ± 0.12 bc	6 ± 0.32 fg	20 ± 0.32 b	75 (8.66 ± 0.09) de	7 ± 0.45 de	1.0 ± 0.06 d	1.0 ± 0.03 d	0.4 ± 0.03 d
2.5	0.1	BD-101	99.96 (10.00) ± 0.001 a	5 ± 0.45 g	18 ± 0.45 c	75 (8.66 ± 0.13) de	6 ± 0.32 ef	2.0 ± 0.45 cd	1.2 ± 0.20 cd	0.8 ± 0.04 b
2.5	0.1	BD-122	95 (9.75) ± 0.08 ab	7 ± 0.45 ef	23 ± 0.45 a	71 (8.43 ± 0.03) e	7 ± 0.32 de	0.96 ± 0.04 d	1.0 ± 0.03 d	0.6 ± 0.04 cd
2.5	0.1	BD-8001	95 (9.75) ± 0.05 ab	6 ± 0.45 fg	22 ± 0.45 a	73 (8.54 ± 0.05) e	8 ± 0.32 cd	1.0 ± 0.06 d	1.0 ± 0.03 d	0.5 ± 0.04 cd

In a column, means with standard error followed by common letters are not significantly different from each other at 1% level of probability by DMRT, Figures in parenthesis are square root transformed values.

Table 4. Effect of different concentrations of IBA on root and shoot development of hyacinth bean

IBA (mg/l)	% Root initiation	Days to root initiation	Number of leaflet	Number of shoot	Length of shoot (cm)	Number of root	Root length (cm)	Fresh wt. of plantlet (g)	Fresh wt. of root (g)	Dry wt. of shoot (g)
0.1	86.67 (69.24) ± 1.62 a	6.31 ± 0.30 b	17.58 ± 1.18 a	2.00 ± 0.17 a	4.03 ± 0.52 a	4.73 ± 0.55 a	4.86 ± 0.53 a	0.68 ± 0.05 a	0.093 ± 0.01 a	0.045 ± 0.005 a
0.5	83.87 (70.48) ± 4.05 a	6.55 ± 0.31 b	16.07 ± 1.34 ab	1.87 ± 0.17 ab	3.23 ± 0.54 ab	3.86 ± 0.54 a	4.79 ± 0.62 a	0.44 ± 0.06 ab	0.100 ± 0.01 a	0.029 ± 0.004 ab
1.0	74.00 (59.80) ± 1.96 b	6.75 ± 0.33 ab	16.74 ± 1.19 a	1.93 ± 0.18 ab	3.87 ± 0.61 ab	2.60 ± 0.36 b	3.35 ± 0.41 b	0.43 ± 0.07 ab	0.094 ± 0.01 a	0.025 ± 0.004 ab
1.5	70.93 (57.6) ± 1.42 c	7.75 ± 0.43 a	13.22 ± 1.10 b	1.47 ± 0.17 b	2.78 ± 0.41 b	2.06 ± 0.30 b	3.03 ± 0.34 b	0.41 ± 0.09 ab	0.085 ± 0.01 a	0.022 ± 0.003 ab

In a column, means with standard error followed by common letters are not significantly different from each other at 1% level of probability by DMRT, Figures in parenthesis are square root transformed values.

Table 5. Combined effect of different concentration of IBA and accessions on root development of hyacinth bean

IBA (mg/l)	Acce.	% Root initiation	Days to root initiation	Number of leaflet	Number of shoot	Length of shoot (cm)	Number of root	Root length (cm)	Fresh wt. of plantlet (g)	Fresh wt. of root (g)	Dry wt. of shoot (g)
0.1	BD-101	77.00 (61.35) ± 0.9 d	7.18 ± 0.36 a-e	12.98 ± 1.28 bc	1.40 ± 0.24 bc	1.56 ± 0.21 cd	2.22 ± 0.37 de	2.82 ± 0.42 de	0.11 ± 0.01 d	0.05 ± 0.01 c	0.0078 ± 0.0006 c
	BD-122	92.00 (73.65) ± 1.02 b	5.18 ± 0.38 e	17.38 ± 0.60 ab	2.20 ± 0.20 ab	4.78 ± 0.46 ab	5.38 ± 0.51 ab	4.78 ± 0.52 bc	0.66 ± 0.14 ab	0.07 ± 0.01 c	0.0416 ± 0.0101 ab
	BD-8001	91.00 (72.73) ± 1.45 b	6.58 ± 0.40 b-e	22.38 ± 1.28 a	2.40 ± 0.24 a	5.74 ± 0.44 a	6.60 ± 0.51 a	6.98 ± 0.53 a	0.73 ± 0.08 a	0.15 ± 0.02 ab	0.0606 ± 0.0045 a
0.5	BD-101	60.00 (50.77) ± 1.31 f	6.62 ± 0.50 b-e	10.22 ± 0.57 c	1.20 ± 0.20 c	1.12 ± 0.06 cd	1.62 ± 0.39 e	2.12 ± 0.34 e	0.11 ± 0.01 d	0.06 ± 0.01 c	0.0086 ± 0.0005 c
	BD-122	92.00 (73.77) ± 1.44 b	5.62 ± 0.23 de	19.78 ± 1.21 a	2.20 ± 0.20 ab	4.68 ± 0.61 a	5.58 ± 0.51 ab	4.76 ± 0.30 bc	0.60 ± 0.05 abc	0.08 ± 0.01 bc	0.0318 ± 0.0037 ab
	BD-8001	99.60 (86.90) ± 1.09 a	7.42 ± 0.52 a-d	18.22 ± 1.97 ab	2.20 ± 0.20 ab	2.88 ± 0.30 bcd	4.38 ± 0.73 bc	7.48 ± 0.44 a	0.54 ± 0.08 abc	0.16 ± 0.03 a	0.0352 ± 0.0035 ab
1.0	BD-101	58.00 (49.59) ± 0.66 f	6.60 ± 0.51 b-e	13.42 ± 1.36 bc	1.20 ± 0.20 c	1.72 ± 0.14 cd	1.60 ± 0.40 de	1.82 ± 0.24 e	0.13 ± 0.01 d	0.07 ± 0.01 c	0.0092 ± 0.0009 c
	BD-122	83.00 (65.65) ± 0.68 c	5.82 ± 0.21 cde	20.38 ± 1.47 a	2.20 ± 0.20 ab	4.16 ± 1.05 a	3.78 ± 0.59 bcd	3.14 ± 0.27 cde	0.54 ± 0.06 abc	0.10 ± 0.03 abc	0.035 ± 0.0033 ab
	BD-8001	81.00 (64.15) ± 0.52 cd	7.82 ± 0.59 abc	19.42 ± 1.93 a	2.20 ± 0.24 ab	3.72 ± 0.57 b	2.42 ± 0.50 cde	5.08 ± 0.50 b	0.42 ± 0.03 bc	0.12 ± 0.02 abc	0.032 ± 0.0025 ab
1.5	BD-101	64.00 (53.11) ± 0.42 ef	8.82 ± 0.38 a	8.82 ± 0.67 c	1.20 ± 0.20 c	1.0 ± 0.07 d	1.42 ± 0.40 e	1.72 ± 0.20 e	0.12 ± 0.02 d	0.06 ± 0.01 c	0.0114 ± 0.0005 c
	BD-122	67.00 (54.93) ± 0.69 e	6.22 ± 0.37 b-e	13.42 ± 1.36 bc	1.20 ± 0.20 c	4.28 ± 0.47 ab	2.38 ± 0.60 cde	3.28 ± 0.55 cde	0.35 ± 0.04 cd	0.09 ± 0.01 bc	0.0246 ± 0.0043 bc
	BD-8001	81.80 (64.76) ± 0.86 cd	8.22 ± 0.86 ab	17.42 ± 1.11 ab	2.00 ± 0.32 abc	3.08 ± 0.41 abc	2.38 ± 0.51 cde	4.08 ± 0.38 bcd	0.53 ± 0.13 abc	0.11 ± 0.02 abc	0.0296 ± 0.0059 ab

In a column, means with standard error followed by common letters are not significantly different from each other at 1% level of probability by DMRT, Figures in parenthesis are square root transformed values.

combination of 2.5 mg/l BAP and 0.1 mgl^{-1} NAA with BD-101 took minimum number of days (5 days) for callus initiation. However, it was delayed (12 days) under 0.5 mgl^{-1} BAP with BD-122 or BD-8001 (Table 3). The highest percentage (95%) of callus formation was observed in chickpea on MS+3.0 mgl^{-1} 2,4-D + 3.0 mgl^{-1} BAP on 8-10 days (Huda *et al.* , 2003).

Size of callus (mm):   The size of callus varied significantly among the treatments. The largest (21.00 mm) callus was evident in 2.5 mgl^{-1} BAP with 0.1 mgl^{-1} NAA. However, the smaller callus (10.0 mm) was obtained from 0.5 mgl^{-1} BAP (Table 1). BD-8001 produced significantly larger callus (16.50 mm) and smaller callus (14.13 mm) was found in BD-101 (Table 2). The combined effect of 2.5 mgl^{-1} BAP and 0.1 mgl^{-1} NAA with BD-122 produced the largest callus (23.0 mm) followed by the same combinations with BD-8001 (22.0 mm). The smallest callus was found in 0.5 mgl^{-1} BAP with BD-122 (9.0 mm). MS medium without BAP and NAA did not produce any callus from three accessions of hyacinth bean (Table 1, Plate 1).
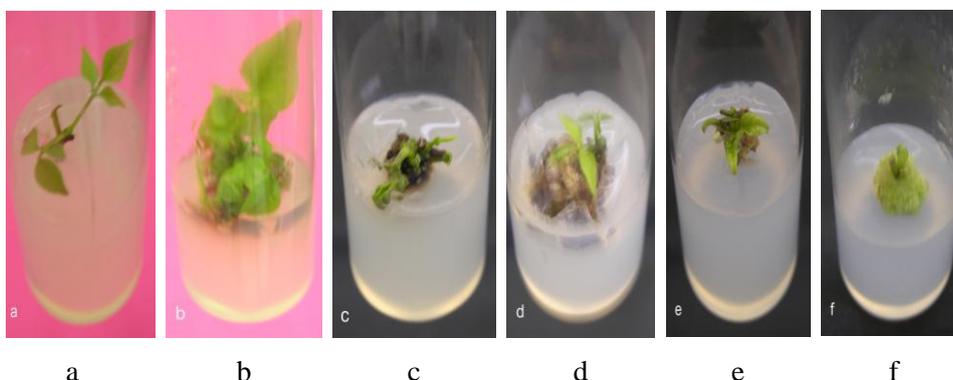

| a | b | c | d | e | f |

Plate 1. Shoot and callus developed from node culture at four weeks of hyacinth bean. The treatments represented by (a) MS + BD-8001, (b) MS+1.0 mgl^{-1} BAP + BD-122, (c) MS + 2.5 mgl^{-1} BAP + BD-101, (d) MS+ 0.5 mgl^{-1} BAP +0.1 mgl^{-1} NAA + BD-101. (e) MS+ 1.0 mgl^{-1} BAP + 0.1 mgl^{-1} NAA + BD-101. (f) MS+ 2.5 mgl^{-1} BAP +0.1 mgl^{-1} NAA + BD-8001.

Percentage of shoot initiation: The highest percentage (90 %) of shoot initiation was observed in 0.5 mg/l BAP followed by 83.33 % shoots in 1.0 mgl^{-1} BAP while the lowest (73 %) was found in 2.5 mgl^{-1} BAP with 0.1 mgl^{-1} NAA (Table1). Among the varieties, BD-8001 exhibited the highest shoot initiation (82.57 %), however, the lowest was obtained from BD-101 (78.57 %). BD-122 had 79.43 % shoot regeneration which was statistically identical to BD-101 (Table 2). The combined effect of 0.5 mgl^{-1} BAP with BD-8001 produced the highest shoot initiation (95 %) followed by 0.5 mgl^{-1} BAP with BD-122, and 1.0 mgl^{-1} BAP with BD-8001 (both 90 %) which were statistically similar (Table 3). The lowest percentage was exhibited in MS (without growth regulators) with BD-101 (70 %). Tzitzikas *et al.* (2004) found that 0.55 mgl^{-1} BAP and 1.1 mgl^{-1}

BAP in MS exhibited 100 % single shoot regeneration using nodal segment in pea varieties 'Puget' and 'Solara'. Sarker *et al.* (2003) reported that 0.5 mgl^{-1} BAP, 0.5 mgl^{-1} Kn, 0.1 mgl^{-1} NAA, 0.1 mgl^{-1} GA$_3$ in MS medium initiated 63 % shoot regeneration while 0.5 mgl^{-1} BAP, 0.5 mgl^{-1} Kn, 0.1 mgl^{-1} NAA, 0.1 mgl^{-1} GA$_3$, 5.5 mgl^{-1} tyrosine produced 78 % shoot using nodal segments in lentil.

Days to shoot initiation: Significant variations in development of shoots were observed among the hormonal supplements given to explants. MS medium containing 0.5 mgl^{-1} BAP and 0.1 mgl^{-1} NAA took minimum number of days to shoot initiation (6 days) followed by 1.0 mgl^{-1} BAP with 0.1 mgl^{-1} NAA (6.33 days) which were statistically at par (Table 1). On the other hand, 2.5 mgl^{-1} BAP required the highest number of days (9.67 days). BD-122 took the lowest number of days to shoot initiation (7.14 days) followed by BD-101 (7.57 days) which were statistically identical. The highest number of days was taken by BD-8001 (8.14 days) for shoot initiation (Table 2). The combined effect of 0.5 mgl^{-1} BAP and 0.1 mgl^{-1} NAA with BD-101 required the lowest number of days to shoot initiation (5 days) while 2.5 mgl^{-1} BAP with BD-101 took the highest number of days (11 days) for shoot initiation (Table 3). Sarker and Awal (1999) reported that 0.25 mgl^{-1} BAP, 0.1 mgl^{-1} Kn in MS medium produced shoot at 2-15 days in chickpea 'Binasola' but in the same treatment combination, chickpea 'Hyprosola' produced shoots at 3-15 days using nodal segments.

Number of leaflet: Significantly the highest number of leaflets was found in growth regulator free MS medium (8.27). On the contrary, the lowest number of leaflets was obtained from 2.5 mg/l BAP with 0.1 mgl^{-1} NAA (1.32) (Table 1). BD-101 and BD-122 produced significantly higher number of leaflets (2.74 to 2.94) than BD-8001 (2.31). The maximum number of leaflets (6) was found from MS with BD-122 and BD-8001, and 1.0 mgl^{-1} BAP with BD-122. The remaining treatment combinations produced 1.0 to 4.0 leaflets per explant (Table 3; Plate 1).

Number of shoot: BAP (0.5 to 2.50 mgl^{-1}) produced significantly higher number of shoots (1.60 to 1.73) than the remaining treatments (1.06 to 1.07 shoot) (Table 1). The highest number of shoots was exhibited from BD-122 (1.57) followed by BD-101 (1.34). The lowest number of shoots was found in BD-8001 (1.03) (Table 2). The combined effect of 1.0 mgl^{-1} BAP with BD-122 produced significantly higher number of shoots (3.0). The remaining treatments produced significantly lower number of shoots (1.0 to 2.0) (Table 3). Sarker *et al.* (2003) found that 1.0 mgl^{-1} BAP, 0.1 mgl^{-1} GA$_3$ in MS medium produced 1-2 shoots per explant while 0.5 mgl^{-1} BAP, 0.5 mgl^{-1} Kn, 0.1 mgl^{-1} NAA, 0.1 mgl^{-1} GA3, 5.5 mgl^{-1} tyrosine produced 4-5 shoots using nodal segments in lentil regeneration. Combination of 0.25 mgl^{-1} BAP, 0.1 mgl^{-1} Kn in MS produced 7-18 shoots in chickpea 'Binasola' while in the same treatment combination with chickpea 'Hyprosola' produced 6-21 shoots from nodal segments (Sarker and Awal, 1999).

Length of shoot (cm): The highest shoot length was found in MS medium (0.97 cm) followed by 1.0 mgl^{-1} BAP (0.77 cm) while the lowest was obtained from 1.0 mgl^{-1} BAP with 1.0 mgl^{-1} NAA (0.47 cm) (Table 1). The accessions produced 0.59 to 0.70 cm shoot from BD-101 and BD-8001, respectively. (Table 2). MS with BD-8001 and BD-122 produced relatively higher shoot lengths (1.1 and 1.0 cm) than the remaining treatments (Plate 1 and Fig. 1). Sarker and Awal (1999) observed that 0.25 mgl^{-1} BAP, 0.1 mgl^{-1} Kn in MS medium produced 2.65 cm shoot in chickpea 'Binasola' but in the same treatment combination with chickpea 'Hyprosola' produced 2.90 cm shoot from nodal segments.
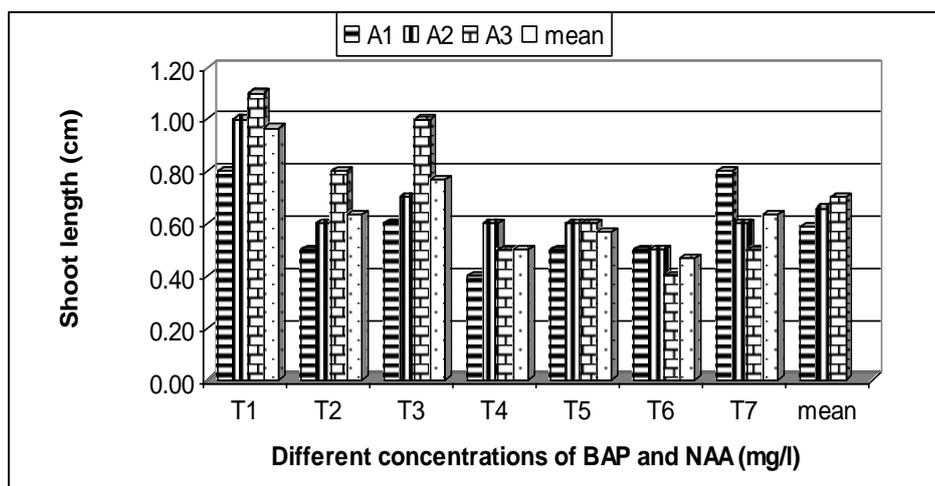

Fig.1. Combined effect of different media composition and accessions on *in vitro* shoot development in hyacinth bean from node culture. The seven treatments represented by T$_1$-MS (control), T$_2$-0.5 mgl^{-1} BAP, T$_3$-1.0 mgl^{-1} BAP, T$_4$- 2.5 mgl^{-1} BAP, T$_5$- 0.5 mgl^{-1} BAP + 0.1 mgl^{-1} NAA, T$_6$-1.0 mgl^{-1} BAP + 0.1 mgl^{-1} NAA, T$_7$- 2.5 mgl^{-1} BAP + 0.1 mgl^{-1} NAA, Three accessions represented by A1-BD-101, A2-BD-122 and A3-BD-8001.

The direct regeneration through induction of adventitious shoots using meristematic tissues and complete regeneration other hand became popular as there are no reports of genetic variation in progeny (Maheshwaran and Williams, 1984). Almost all reports of regeneration in legumes have been confined to members of the papilionoidae, the sub family of great economical important plants had been regenerated via organogenesis from 54 different legume species while only 39 species has been shown regeneration from somatic embryos (Parrot, 1992). Recalcitrance of crop is attributed to genetic differences that block the regeneration process in tissue culture. Morphogenic response of many legumes have been shown to be under genetic background (Malik and Saxena, 1992). So in several crops different cultural conditions were found to be necessary for regeneration of different genotypes. Similarly plant regeneration from different tissues is of great importance in obtaining transgenic individual.

The explants also had highly significant effect on per cent plantlet regeneration. The shoot-tip explant recorded higher regeneration response than cotyledonary node explants in hyacinth bean (Kale, 2004).The regeneration of shoot buds from various explants of pigeon pea such as leaves (Geetha, 1998) has been reported. Similarly, media combination is also greatly influenced on regeneration ability of explants. Naz *et al*. (2007) reported that the regeneration frequency increased with increase in concentration of cytokinins. Nine genotypes of lablab bean and one popular genotype of dolichos bean *Cv*. Konkan bhushan were employed for the regeneration studies. The frequency of shoot formation was influenced by the type of explants. Mature embryo axis with single cotyledon showed maximum frequency of shoot induction followed by mature embryo axis and shoot tip. Cytokinin like BAP was found to be much effective at lower concentration (MS + 0.5 mg/l BAP) and gave 100% shoot elongation response. But, at high concentration the response to shoot elongation was reduced. Lower level of IAA (MS + 0.5 mg/l BAP) also favoured elongation of shoots (13.33%) (Kshirsagar *et al.,* 2018). Kale (2004) revealed that shoot tip had grater regeneration potential than cotyledonary explant in field bean. He recorded 92% regeneration response in Konkan Wal. It indicates that regeneration response depends upon endogenous level of cytokynin in different genotypes. The genotypic variation in shoot induction studies in many pulses confirmed these results. Organogenic differentiation in cell and tissue cultures is due to hormonal manipulation in culture medium. The role of exogenous cytokinin during induction phase is difficult to assess. More commonly used cytokinins are BAP, kinetin, TDZ and Zeantin.

Experiment-2

Each shoot of experiment-1 was cut from the basal end and was transferred to MS medium supplemented with 0.1, 0.5, 1.0 or 1.5 mgl^{-1} IBA in the second experiment.

Percentage of root initiation: Significantly the highest percentage (86.67 %) of root initiation was observed in MS medium containing 0.1 mgl^{-1} IBA followed by 83.87 % in 0.5 mgl^{-1} IBA which were statistically similar (Table 4). Rooting frequency decreased with the increase of the IBA concentration. The lowest percentage (70.93 %) of root initiation was found in 1.5 mgl^{-1} IBA. The combined effect of 0.5 mgl^{-1} IBA with BD-8001 produced the highest (99.60 %) frequency of roots followed by 92.00 % in 0.1 to 0.5 mgl^{-1} IBA with BD-122. However, the lowest (58 %) was exhibited in 1.0 mgl^{-1} IBA with BD-101 (Table 5).Thiruvengadam and Jayabalam (2000) reported that 1.5 mgl^{-1} IBA in MS medium produced 72 % root in callus developed shoot in lablab bean. Huda *et al.* (2003) found that 1.0 mgl^{-1} IBA in MS and half MS initiated 66 % and 77 % roots, respectively from callus derived shoot in chickpea. On the other hand, MS medium supplemented with 0.05 mgl^{-1} IBA was found to be the best in producing roots in chickpea varieties 'Binasola' and 'Hyprosola' (Sarker and Awal, 1999).

Prem *et al.* (2003) reported that 4.9 µM IBA in half MS medium initiated 90 to 99 % root in guar. Khalafalla and Hattori (2000) found that 0.5 mgl^{-1} IAA in half MS medium initiated 42% root from *in vitro* developed shoots in faba bean.

Days to root initiation: The lower number of 6.31 days to root initiation was found in 0.1 mgl^{-1} IBA followed by 6.55 days in 0.5 mgl^{-1} BAP and it was increased with the increase of the concentration of IBA (Table 4). The higher number of 7.75 days to root initiation was observed in 1.5 mgl^{-1} IBA. The treatment combination of 0.1 mgl^{-1} IBA with BD-122 took relatively lower number of 5.18 days for shoot initiation. On the contrary, rooting was delayed in case of 1.5 mgl^{-1} IBA with BD-101 and BD-8001 (8.22 days) (Table 5). Huda *et al.* (2003) observed that 1.0 mgl^{-1} IBA in MS and half MS produced roots at 7-12 days and 9-11 days, respectively from callus derived shoots in chickpea. Hoque *et al.* (2007) found that 0.5 mgl^{-1} IBA in half strength MS was effective for root induction in mungbean. Tzitzikas *et al.* (2004) reported that 0.5 mgl^{-1} IBA in B5 media produced roots after 3 subculturing the plantlet in B5 media containing 1 mgl^{-1} GA$_3$ in the regeneration of pea. Khalafalla and Hattori (2000) found that 0.5 mgl^{-1} IAA in half MS produced roots in 12-13 days from *in vitro* developed shoot in faba bean.

Root length (cm): The longest (4.86 cm) roots were found in 0.1 mgl^{-1} IBA followed by 4.79 cm root in 0.5 mgl^{-1} IBA which were statistically at par (Table 4). On the contrary, the shortest 3.03 cm root was obtained from 1.5 mg/l IBA. The combined effect of 0.5 mgl^{-1} IBA with BD-8001 exhibited the highest 7.48 cm roots followed by the 6.98 cm roots in 0.1 mgl^{-1} IBA with BD-8001. On the other hand, 1.5 mgl^{-1} IBA with BD-101 exhibited the shortest 1.72 cm root in hyacinth bean (Plate 2). Huda *et al.* (2003) reported that 1.0 mgl^{-1} IBA in MS and half MS produced 5.50 cm and 5.00 cm roots, respectively in chickpea. Khalafalla and Hattori (2000) found that 0.5 mgl^{-1} IAA in half MS produced 4.83 cm longest root in faba bean.

Number of roots: The highest number of 4.73 roots was produced in 0.1 mgl^{-1} IBA followed by 3.86 roots in 0.5 mgl^{-1} IBA which were statistically identical (Table 4). The lowest number of roots was obtained from 1.5 mgl^{-1} IBA (2.06). The combination of 0.1 mgl^{-1} IBA with BD-8001 produced the highest number of 6.6 roots followed by the same concentration of IBA with BD-122 (5.38) which were statistically identical while the lowest number of 1.42 roots was exhibited in 1.5 mgl^{-1} IBA with BD-101 (Table 5). Huda *et al.* (2003) observed that 1.0 mgl^{-1} IBA in MS and half MS produced 6.59 and 6.94 roots, respectively in chickpea. Khalafalla and Hattori (2000) noted that 0.5 mgl^{-1} IAA in half MS produced 3.3 roots per explant in faba bean.

Fresh weight of roots (g): MS containing 0.5 mgl^{-1} IBA noticed the highest 0.10 g fresh roots while the lowest 0.08 g fresh roots were obtained from 1.5 mgl^{-1} IBA which were statistically insignificant (Table 4). MS containing 0.5 mgl^{-1} IBA exhibited the highest 0.10 g fresh roots while the lowest 0.09 g fresh root

weight was obtained from 1.5 mgl⁻¹ IBA (Table 4). The treatment combination of 0.5 mgl⁻¹ IBA with BD-8001 produced the highest 0.16 g roots followed by 0.15 g roots in 0.1 mgl⁻¹ IBA with BD-101 which were statistically at par. On the other hand, the lowest fresh weight (0.05 g) of roots was found in 0.1 mgl⁻¹ IBA with BD-101 (Table 5).
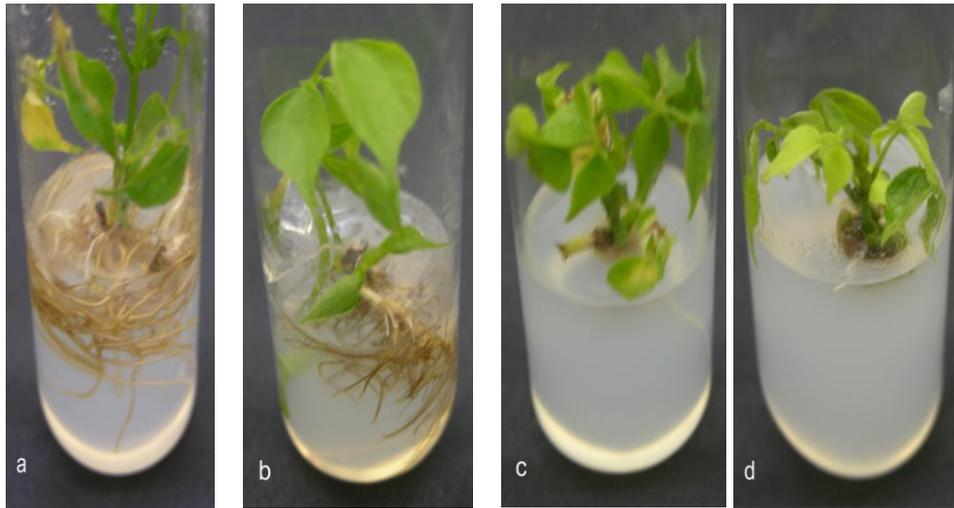
Plate 2. Root developed from shoots of hyacinth bean after four weeks of culture. The treatments are (a) MS + 0.1 mgl⁻¹ IBA + BD-8001, (b) MS + 0.5 mgl⁻¹ IBA + BD-8001, (c) MS + 1.0 mgl⁻¹ IBA + BD-8001, (d) MS + 1.5 mgl⁻¹ IBA + BD-8001.
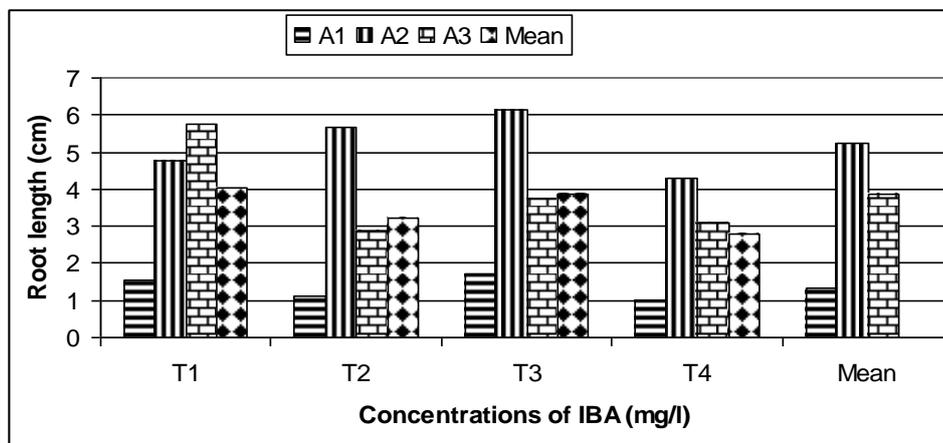
Fig.2 Combined effect of different media and accessions on *in vitro* development of root length in hyacinth bean from shoot culture at four weeks. The four treatments represented by T₁-0.1 mgl⁻¹ IBA, T₂-0.5 mgl⁻¹ IBA, T₃-1.0 mgl⁻¹ IBA and T₄-1.5 mgl⁻¹ IBA in MS. Three accessions represented by A1-BD-101, A2-BD-122 and A3-BD-8001.

Number of leaflet: The highest number of (17.58) leaflets was produced in 0.1 mgl^{-1} IBA followed by 16.74 leaflets in 0.5 mgl^{-1} IBA (Table 4). On the contrary, the lowest number of (13.22) leaflet was obtained from 1.5 mgl^{-1} BAP.

Number of shoot: The highest number of (2.0) shoots was obtained from 0.1 mgl^{-1} IBA followed by 1.93 shoots in 1.0 mgl^{-1} IBA while the minimum 1.47 shoots were produced from 1.5 mgl^{-1} IBA.

Length of shoot (cm): Further development of shoots during rooting was observed. It was found that the longest (4.03 cm) shoot was found in 0.1 mgl^{-1} IBA followed by 3.87 cm and 3.23 cm shoot from 1.0 mgl^{-1} and 0.5 mgl^{-1} IBA, respectively which were statistically at par. The shortest (2.78 cm) shoots were produced from 1.5 mgl^{-1} IBA. The highest fresh weight of plantlet (0.68 g) was produced in 0.1 mgl^{-1} IBA while the lowest (0.41 g) was obtained in 1.5 mgl^{-1} IBA.

Fresh weight of plantlet (g): The combined effect of 0.1 mgl^{-1} IBA with BD-8001 produced the highest fresh weight (0.73 g) of plantlet followed by the 0.66 g in 0.1 mgl^{-1} IBA with BD-122. The remaining treatments produced 0.11 to 60 g fresh weight per plantlet (Table 5).

Dry matter weight (g): The highest (0.029 g) dry matter of plantlet was found in 0.1 mgl^{-1} IBA while the lowest dry matter was noted in 1.5 mgl^{-1} IBA (Table 4). The combined effect of 0.1 mgl^{-1} IBA with BD-8001 exhibited the highest (0.060 g) dry matter production while the lowest was found in 1.0 mgl^{-1} IBA with BD-101 (Table 5)

As the survivability of plantlets depends mainly on number and type of roots produced from shoots, it was necessary to find out proper auxins and its concentration for inducing roots. Auxins such as IAA, IBA and NAA are most commonly used to induce rooting both in *in vitro* and *ex vitro* conditions. *In vitro* formed roots are obtained which were thin and lack roots hairs. These roots are frequently died or collapsed after the plantlets are removed from culture. There is a need to develop efficient rooting and establishment system, so that the recovery of the maximum *in vitro* plants will possible. Kshirsagar *et al*. (2018) reported the highest root induction frequency (79.51%) was observed on medium MS+ 1.0 mg/l IBA+ 2% sucrose in hyacinth bean. Comparing capability of IBA, NAA, BAP, maximum number of roots (7.67) were developed in media combination MS + 1 mg/l NAA + 2% sucrose and MS + 0.5 mg/l NAA.

Conclusion

It may be concluded that MS medium without any growth regulators is the superior for shoot proliferation through node culture. Percentages of callus initiation increased with the increase in the concentration of growth regulators. The high concentration of IBA suppressed root development. MS medium containing 0.1 mgl^{-1} IBA emerged as the superior treatment for rooting of *in vitro*

shoots in hyacinth bean. A protocol for *in vitro* regeneration from nodal explants of hyacinth bean has been developed in this study. This protocol is reproducible for *in vitro* culture and, short term preservation of hyacinth bean.

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ECONOMIC ANALYSIS OF TURMERIC CULTIVATION: EVIDENCE FROM KHAGRACHARI DISTRICT

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Abstract

Turmeric is a good source of income for hilly people of Bangladesh. The study estimated the profitability and technical efficiency of turmeric cultivation in Khagrachhari district. In total 150 turmeric farms located in Khagrachari Sadar, Panchari and Matiranga Upazilas of Khagrachari district, were surveyed. Data were collected, using a pre-tested questionnaire during January, 2015. The study revealed that turmeric farming is a profitable farming with some dominating variable costs like seed (rhizome) and sowing, harvesting and carrying. As the net return was Tk. 112139 per hectare and the BCR of sampled farmers was 2.20, this indicates that turmeric farms with a BCR greater than 1 have greater benefits than costs as well as positive net benefits. Seed (rhizome) and fertilizer showed significant positive effects on the turmeric production in the stochastic frontier production model. Turmeric farming displayed a mean technical efficiency of 82%, which suggested a substantial 18% of potential output of turmeric can be recovered by removing inefficiency. Besides improving technical efficiency, potential also exists for raising turmeric production through higher education and extension services. For a land scarce country like Bangladesh this gain could help increase income and ensure better livelihood for the hilly farmers. The policy implication of the analysis is that investment in education and extension service would greatly improve technical efficiency that contribute to income of the hilly people.

Keywords: Turmeric cultivation, cost and return, profitability, technical efficiency.

Introduction

Turmeric (*Curcuma longa L.*) is a spice made from the roots of Turmeric plant referred as "Queen of Spices". It has been listed as one of the top five major spices in Bangladesh which shares about 6% of total spices production (BBS, 2018). It has diversified uses. The people of Bangladesh usually use turmeric in all curry preparation like meat, fish, vegetables, pulses etc. for its typical color and flavor. Besides, it is used in medicine and cosmetics and as dye in textile

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industries from the time immemorial. It contents about 69.43% carbohydrate, 6.30% protein, 5.10% oil and 3.50% mineral and other important element in dry turmeric (BBS, 2013$_a$).With increased awareness on the benefits of turmeric among the users and its use in a number of processed products, the demand of turmeric is increasing.

Turmeric can be regarded as a good cash crop for hilly regions of Bangladesh as its production requires low technology, less capital investment, and it can be grown with comparatively less use of fertilizer. The sloppy topography of hilly region and the nature of soil are optimal for turmeric cultivation as it allows no accumulation of water. Usually, turmeric is grown in those lands where other horticulture crops and grains do not grow properly. Regarding the production of turmeric in the hill areas, it has greater scope of expansion in terms of area and production as the current production is mostly for domestic consumption. The production area can be extended by the farmers having marginal land, which will be beneficial for them in terms of earning extra income from the sales of the crop. Turmeric has also import substitution potential as the country is importing various turmeric products from India and other neighboring countries.

In 2003-04, the total area under turmeric farming was estimated to be around 45 thousand acres (with production of 70 thousand tons), while in 2011-12 it was 60 thousand acres (with production of 149 thousand tons), which indicates an average increase of area of 33% per annum (BBS, 2013$_b$). This level of expansion reflects the government's priorities as turmeric farming is recognized as an essential component of economic development for the country. In spite of the spectacular expansion of turmeric farming during the last decades, still the average yield (2.5 ton/ha as dry matter) is low compared to other Asian countries (BBS, 2013). The reasons behind such low yield due to lack of high yielding varieties and inadequate adoption of improved technologies followed by the local growers.

Developing economy of Bangladesh can benefit a great deal from inefficiency studies, which shows that it is still possible to raise productivity by improving efficiency. Estimates on the extent of inefficiency can also help to decide whether to improve efficiency or to develop new technology. Moreover, efficiency of a farm refers to its performance in the utilization of resources at its disposal. Thus, it is important to know how well the resources are being utilized and what possibilities exist for improving the production using the existing resources and technology (Ahluwalia, 1996). Therefore, the main objective in this study was to evaluate profitability and technical efficiency in an attempt to modify the management strategy and increase turmeric farming productivity in Khagrachari district of Bangladesh. In the context of Bangladesh agriculture, a number of studies emerged to estimate the efficiency of agricultural production at the farm level. Almost all these estimates are related to the efficiency of rice, fish, and spices farms indifferent seasons (Backman *et al.*, 2011, Alam *et al.*,

2011, and Islam *et al*. 2011).No attempt has been made to measure the efficiency of the crop like turmeric. It is with this backdrop, that a stochastic production frontier with a technical inefficiency model is applied to investigate profitability and the technical efficiency and the factors affecting production inefficiency of turmeric farming in Khagrachari district. This study is expected to generate information that will be useful for farmers in choosing better production techniques, for identifying and eliminating inefficiencies, and for attaining the highest possible efficiency within the resource endowments. Keeping mind this study aims to: i) to find out the productivity and profitability of turmeric cultivation in the hill areas; ii) to estimate the technical efficiency of the turmeric growers; iii) to identify the factors causing technical inefficiency of turmeric growers; iv) to identify the constraints to turmeric cultivation and v) to suggest some policy implications for its further improvement.

Methodology

Selection of the study area and sampling procedure

The study was carried out in Khagrachari district which is one of the major turmeric growing districts in Bangladesh. It accounted for 8.9% of the total turmeric area. A stratified random sample was constructed by dividing the district into Upazila and village. Khagrachari district consists of eight Upazilas: Dighinala, Khagrachari Sadar, Laxshmichhari, Mahalchhari, Manikchhari, Matiranga, Panchhari and Ramgarh. Among these eight Upazilas Khagrachari Sadar, Matiranga and Panchhari were purposively selected for the study. These Upazilas were identified as the most important areas for turmeric farming. In 2010-11, a total of 2039 acres of land was cultivated for turmeric in these Upazilas which is around 41% of cultivated area of turmeric in Khagrachari district (BBS, 2013). Within each of these three Upazilas, two villages were randomly selected based on a complete list of villages. Within each village 20-33 households were randomly selected from the list provided by Sub Assistant Agriculture Officer, Department of Agriculture Extension office. This procedure gave a total sample of 150 households involved in turmeric cultivation in Khagrachari district.

Data collection

The data for this study were collected both from primary and secondary sources. The primary data were collected from the selected farmers for the whole year of 2014. The formal data, however, were collected during January 2015 by using face to face interview technique with the help of a pre-designed and pre-tested questionnaire. The main information gathered includes general household information like household size, age and education level, farming activities, experience with turmeric cultivation, use of inputs including land, labour (both

family and hired labour), seeds, fertilizers and pesticides, yields and prices of turmeric, perceptions on constraints to increased turmeric productivity etc. The secondary data were collected from different published and unpublished sources, internet browsing, BBS, Agricultural Statistical Yearbooks, etc.

Data analysis

Gross return: Gross return was calculated by multiplying the total volume of production of an enterprise by the average farmgate prices of that product in the harvesting period (Dillon and Hardaker, 1993). The following equation was used to calculate gross return:

$$GR = \sum Q_m \times P_m + \sum Q_j \times P_j$$

Where, GR = Gross return (Tk/ha), Qm = Quantity of turmeric (kg/ha), Pm = Per unit price (Tk/kg) of turmeric, Qj = Quantity of other Jhum crops (kg/ha), Pj = Per unit price (Tk/kg) of other Jhum crops.

Total cost: Total cost (TC) included all types of variable and fixed cost items involved in the production process. The total cost was estimated as: TC = $\Sigma Px_i \times X_i$ + TFC where, TC = Total cost (Tk/ha), X_i = Quantity (kg/ha) of the ith variable input, Pxi = Per unit price (Tk/kg) of the ith variable input, TFC = Total fixed cost, which included land use cost.

Computation of farmers' profit: Farmers' profits were calculated in two ways by (a) gross margin (GM) analysis and (b) net return (NR) estimation with the following two equations:

a) $$GR = \sum Q_m \times P_m + \sum Q_j \times P_j - \sum Px_i \times X_i$$

b) $$NR = \sum Q_m \times P_m + \sum Q_j \times P_j - \sum Px_i \times X_i - TFC$$

Econometric analysis

Farrell (1957) defined technical efficiency as the ratio between inputs per unit of output at the production frontier and inputs per unit of output in the observed case. Aigner *et al.,* (1977) and Meeusen and Van den Broeck (1977) independently proposed a stochastic frontier production function model with the following structure:

$$LnY = f(X_i; \beta) + \varepsilon_i \qquad\qquad (1)$$

$$\varepsilon_i = V_i - U_i, \ i = 1, ... , N_i \qquad\qquad (2)$$

Where, *Y* denotes production level, X_i is input level and β is a vector of unknown parameters to be estimated. ε_i is the composed error term and *f* is the Cobb–Douglas function form. V_i are independently and identically distributed random

errors, having N $(0, \delta v^2)$ distribution while $\underline{U_i}$ are non-negative stochastic variables, called technical inefficiency effect, associated with the technical inefficiency of production of farmers involved. According to Battese and Coelli (1995), technical inefficiency effects are defined by

$$U_i = Z_i\delta + W_i, i = 1, ... N \qquad (3)$$

where Z_i is a vector of explanatory variables associated with technical inefficiency effects, δ is a vector of unknown parameters to be estimated, W_i are unobservable random variables, which are assumed to be identically distributed, obtained by truncation of the normal distribution with mean zero and unknown variance σ^2, such that U_i are non-negative. In this study the ML was applied, using the FRONTIER 4.1.1 computer program developed by Coelli (1994). The following model specifications were used in the analysis

$$InY_i = \beta + \beta_1 InX_{1i,} + \beta_2InX_{2i,} + \beta_3InX_{3i,} + \beta_4InX_{4i} + V_i - U_i \qquad (4)$$

Where, $\ln$ represents the natural logarithm (i.e., to the base e) and i refers to the ith farm in the sample; Y_i represents geometric mean based on revenue share of multi-output (such as turmeric production, other crops and vegetable production) which is an ideal output variable in the production frontier analysis as suggested by Iinuma *et al.*,(1999);

X_{1i} represents the total area of land/farm size in hectares; X_{2i} represents the total quantity of labour employed in man-days per hectare per year; X_{3i} represents total number of turmeric seed used (rhizome) per hectare per year; X_{4i} represents quantity of fertilizer used in kg per hectare per year; V_i represents the random variations in output due to factors outside the control of the farm operator such as: natural disaster, disease of turmeric etc. and β_1 - β_4 are parameters to be estimated;

Following Battese and Coelli (1995), it is further assumed that the technical inefficiency distribution parameter, Ui is a function of various operational and farm specific variables hypothesized to influence technical inefficiencies as:

$$U_i = \beta_0 + \beta_1 Z_{1i,} + \beta_2Z_{2i,} + \beta_3Z_{3i,} + \beta_4Z_{4i,} + \delta_5Z_{5i} + W_i \qquad (5)$$

Where, Z_1 denotes the age of the ith farmer (in year); Z_{2i} denotes the education (year of schooling) of the ith farmer; Z_{3i} denotes experience in turmeric farming of the ith farmer (in years); Z_{4i} denotes the training received by the ith farmer (1 if received, 0 otherwise); Z_{5i} denotes farm visits by extension officers (1 if yes, 0 otherwise); δ_1, δ_2, δ_3, δ_4, and δ_5 are unknown parameters to be estimated.

Results and Discussion

Cost of turmeric cultivation

The cost of turmeric production relates to the level of inputs, the price of inputs, the cultivation systems and the institutional factors such as costs of credit and marketing (Shang and Tisdell, 1997). For this study, data on yield, costs and returns of turmeric were collected to clarify production costs and to assess the profitability. Production costs have been grouped into variable costs and fixed costs.

Variable costs are directly related to the scale of farm operations at any given time. Variable costs in turmeric farm are cost of seed (rhizome), labour, fertilizer, plant protection chemical and interest on working capital. The average annual variable costs of turmeric farming was Tk. 77351 per ha (Table 1).

Table 1. Average variable cost (Tk/ha) of turmeric cultivation in Khagrachari district

S/No	Particulars	Material input (Qty/ha)	Material input (Tk./ha)	Human labour (Tk./ha)	Total cost (Tk./ha)	Percentage
1	Slash and Burn			8383.44	8383.44	10.84
2	Trench			5489.85	5489.85	7.10
3	Seed (Rhizome) and sowing	652.87	15756.71	8967.61	24724.32	31.96
5	Fertilizer (Kg/ha)	362.50	5747.34	1026.84	6774.18	8.76
6	Intercultural operation (hoeing, weeding)	--	--	13686.58	13686.58	17.69
7	Plant protection chemical	--	330.99	159.71	490.70	0.63
8	Harvesting and carrying	--	--	15618.07	15618.07	20.19
10	Interest on working capital	--	--	--	2183.61	2.82
	Total variable cost	--	--	--	77350.74	100

Source: Calculated from field survey (2015)

Seed (rhizome) is the most important cost item for turmeric farming. The average annual cost of rhizome in turmeric farming was calculated to be Tk. 15757 per ha. In turmeric farming the highest operation cost was for seed and sowing (31.96%to the total variable cost) which is consistent with the BBS report on *The Productivity Survey of Turmeric Crop (BBS, 2013)*. Human labour was one of the most important and widely used inputs in the production process of turmeric farming. The sources of human labour were (1) family labour, for which no

payment was made, and (2) hired labour, for which farmers had to pay in cash. To determine the cost of unpaid family labour, the opportunity cost principle was adopted. In this study, a man-day was considered to be 8 hour of work. The labour wage ranges with respect to nature of work, location, number of labourers required, and season. The average wage rate for turmeric farming was found to be Tk. 280 per day ranged from Tk. 250 to Tk.300 per day. Human labour is required in all the stages of operations. In this study, the average cost for human labour was calculated at Tk. 53332 per ha. The cost of intercultural operations and harvesting were calculated at Tk .13687per ha and Tk.15618 per ha respectively. Interest rate for agricultural loans was considered at the rate of seven percent.

Table 1 shows the share of variable costs of different costs items which reflects that, seed and seed sowing, intercultural operations and harvesting constitute around 70% of variable costs in turmeric farming which is consistent with the study of Karthik and Amarnath (2014) and BBS (2013$_a$).

Rental value of land was considered as fixed cost of turmeric production. The average annual fixed cost for turmeric farming was Tk.15081per ha which accounted for16.32% of total cost of production (Table 2).

As Table 2 shows, total costs of turmeric farming of all sampled farmers averaged Tk. 92431 per ha. The average shares of variable and fixed costs were calculated as 83.68% and 16.32% of the total cost of cultivation respectively.

Table 2. Total cost (Tk/ha) of turmeric cultivation in the study areas

Particulars	Amount (Tk/ha)
Total variable cost	77351 (83.68%)
Total fixed cost	15081 (16.32%)
Total cost	92432 (100)

Note: Figures in the parentheses are percent of total cost

Farm Productivity

Turmeric and other crop productivity

It was revealed that the annual average yield of turmeric was estimated at 6354.71 kg/ha ranged from864.20 to 17119.34 kg/ha (Table 3).As turmeric in the study areas is grown in *Jhum* land and most of the farmers follow traditional methods of cultivation where they use less capital investment, comparatively little or no fertilizer application which in turn in lower yield. These levels of yields also suggest that the average productivity of turmeric has increased in the study areas over recent years as Karna *et al.* (2010) found turmeric productivity as 5.928 tons per hectare indicating lower productivity.

Table 3. Average yields (kg/ha) of turmeric and other crops grown in Jhum lands

Items/Crops	Average yield (t/ha)
Turmeric	6.35
Rice	1.27
Okra	0.11
Cucumber	0.29
Long yard bean	0.16
Red amaranth	0.03
Bottle gourd	0.53
Pulse	0.08
Pumpkin	0.53
Ginger	0.17
Banana	2.69
Chili	0.26
Others	0.19

Source: Field survey (2015)

Responses concerning the reasons for increased turmeric productivity included an increased supply of quality seed/ knowledge on appropriate seed selection including improved varieties, technical support in turmeric cultivation, introducing training facilities, experience of farming, and low cost of seed, etc.

Rice and other crops productivity

Besides turmeric, hill farmers generally cultivate different types of crops on *Jhum* lands as mixed crops which are rice, spices and vegetables such as okra, cucumber, long yard bean, red amaranth, bottle gourd, pumpkin, ginger, chili and others. Table 3 further revealed that the average rice productivity was estimated at 1.3 ton/ha. The rice productivity of the turmeric farmers (1.27 t/ha) are comparatively lower than the national average productivity of rice (6.22 t/ha) (BBS, 2010) which indicate that farmers have the great opportunity to improve rice productivity in the study areas by following better management practices and adopting HYVs of rice which are suitable in the hill area.

The average productivity of other crops were 0.11t/ha, 0.29 t/ha,0.16t/ha, 0.31t/ha, 0.53t/ha, 0.08 t/ha, 0.53 t/ha, 0.17 t/ha, 2.69t/ha, 0.26 t/ha and 0.19 t/ha for okra, cucumber, long yard bean, red amaranth, bottle gourd, pulse, pumpkin, ginger, banana, chili and others respectively.

Profitability of turmeric cultivation

Gross revenue is affected by the level of production and its market price. Increasing farm productivity is one way to increase gross return. Gross return

was calculated by multiplying the total amount [(seed, sold (fresh and dry) and consumed)] of production (kg) by its market price (Tk./kg).

The annual gross return of turmeric farming averaged at Tk. 205973 per hectare. Almost all the respondent farmers stated that their gross revenue had decreased as costs of turmeric farming had increased significantly, while the price of turmeric has not increased to a similar degree (Table 4).

At the farm level, net return is affected by the level of production, farm price and operating cost. Increase in farm productivity, reduction in production costs and increasing in average farm revenue are major measures to increase net return (Shang and Tisdell, 1997). Net return is calculated by deduction of total costs from gross return. As Table 4 shows, the annual net return per hectare of turmeric farms averaged Tk. 112139.

Table 4. Profitability of turmeric cultivation in the hill areas

Items	Amount
Gross return (Tk/ha)	205973
Total cost (Tk/ha)	93834
Variable cost (Tk/ha)	78753
Gross margin (Tk/ha)	127219
Net return (Tk/ha)	112139
Rate of income (%)	54.44
Benefit cost ratio (BCR)	
Over total cost	2.20
Over variable cost	2.62

Source: Calculated from field survey (2015)

Once the fixed investments have been made, farmers' production decision should be based on the expected returns or income above variable costs. The gross margin was calculated to be Tk. 127219 per ha in turmeric farming. It was observed that turmeric farms were able to generate positive returns to variable costs. This indicates that farmers are willing to pursue turmeric farming as the returns to variable costs are positive.

The rate of farm income is defined as net return divided by gross revenue multiplied by 100. The rate of farm income averaged 54.44% in turmeric farming (Table 4).

Benefit cost ratio (BCR) or profitability index is defined as gross revenue divided by total costs of turmeric farming, which implies that a ratio of 1 means that the operation is a break even position. Table 4 shows that the BCR of sampled farmers averaged 2.20. This indicates that the turmeric farmers are able to

recover Tk. 2.20 per Tk. 1 of investment. Turmeric farms with a BCR greater than 1 have greater benefits than costs as well as positive net benefits. It is observed that about 69% gross revenue came from turmeric in jhum cultivation (Table 5).

Table 5. Share of turmeric, other crops, vegetables and spices in gross revenue

Revenue items	Amount (Tk/ha)
Turmeric	205973 (68.70)
Vegetables and other crops	93834 (31.30)

Figures in the parenthesis indicate percent of total

Summary statistics of the variables included in the TE analysis

Summary statistics of the sample data from the survey for the different variables in the stochastic frontier and inefficiency model, defined by Equations (4) and (5), is presented in Table 6. The table shows that considerable variation exists among the farmers in terms of production practices and the socioeconomic attainments. The average farm size was 0.33 ha ranging from 0.08 ha to 2.03ha.

Seed (rhizome) has a major impact on production and the profitability of turmeric farm. In the study area, farmers are cultivating mostly the Pabna variety of turmeric as the demand for it is very high in the market and improved seed varieties like BARI Holud-1 (Dimla), BARI Holud-2 (Sinduri) and BARI Holud-3 are not locally available. Farmers hand-pick the best turmeric and preserve it as seeds for the next season. They also purchase from other farmers if they need additional seeds to available own stocks. Since farmers produce turmeric as a mixed crop in Jhum lands they do not take into account the exact size of the land to determine the volume of seeds required. The average annual application of seed of turmeric was 634.08 kg/ha which has considerable variation of turmeric farmers used. This finding is in line with the findings by Karna *at el.*(2010).

Fertilizer application (both organic and inorganic) is not based on the need of the soil, but rather on common practice. Except for some commercial production, most of the turmeric is produced by traditional farming practices where the farming knowledge derived from forefathers is used with no or less application of chemical fertilizer. On average, annual fertilization rate (organic and inorganic fertilizer) was 299.40 kg/ha ranging from nil kg/ha to 7135.80 kg/ha in turmeric farm.

The average labour use is 156.76 man-days/ha ranging from 26.67 man-days/ha to 475.31 man-days/ha. For the land preparation male labour were used. Mostly female labours were working for hoeing and weeding.

The average age of farmers is 40 years ranging from 20 years to 83 years in turmeric farming. Average general education level is seemed to be level of primary ranging from illiterate to fourteen years of schooling. The average

experience of farmers is 11 years ranging from 1 year to 42 years in turmeric farming.

Table 6. Summary statistics for variables in the stochastic frontier production functions for turmeric farming

Variables	Sample mean	Standard deviation	Minimum value	Maximum value
Geometric mean of total return (Tk/ha)	155958	51451	43519	372840
Land (Ha)	0.33	0.24	0.08	2.03
Labour (Person-days/ha)	156.76	63.31	26.67	475.31
Seed (rhizome) (kg/ha)	634.08	311.38	102.88	1975.31
Fertilizer (kg/ha)	299.40	759.48	0.00	7135.80
Education (years of schooling)	3.47	3.95	0	14
Age (years)	39.99	12.07	20	83
Experience (years)	11	6.87	1	42

Maximum Likelihood Estimates of Turmeric Cultivation

The estimates of the stochastic frontier which shows the best practice performance, i.e., efficient use of the available technology, is presented in Table 7. The empirical results indicate that the elasticity of frontier (best practice) production with respect to farm size in turmeric farming was estimated to be -0.169 and is significant at 1% level. This indicates that, if the farm size is increased by one percent, then per hectare return from turmeric is estimated to decrease by -0.169 %. In the turmeric farming, the elasticity of output with respect to labor, seed and fertilizer estimated to be positive and significant values of 0.004, 0.187, and 0.006, respectively.

Farm size may have some influence on production of output, but the study encountered a negative sings for farm size in turmeric farming which are significant. Whether small lands are more productive or not is still dilemma. No definite answer is established as yet. Rahman (2005) found medium sized farm having the highest yield. The small farm get intensively input fed since additional of a small quantity of inputs adds very little to the overall cost that is not usually felt burdened. However, this small addition of inputs might get proportionately higher than the farm requires. It is likely that this might have happened beyond the knowledge of the farmers. On the contrary, larger land owners also seldom add inputs proportionately with the farm size because costs associated with the inputs application for bigger farm are high. Therefore, they are likely to add proportionately less than the farm requires. This feeling often results in proportionately higher input feeding for small farm and lower for larger farm. This is general scenario in particularly the turmeric farming system in hill under

the existing economic conditions of the farmers. Appearance of a negative signs for the coefficient of farm size is therefore not surprising.

The value of the elasticity of seed implies that, if seed is increased by one percent, the turmeric return is estimated to increase by 0.187%. The increase in the use of seed (rhizome) is expected to have a positive effect on turmeric production. The value of elasticity of fertilizer implies that if the use of fertilizer is increased by one percent, the turmeric return will be increased by 0.006. The highest elasticity coefficient (0.187) was estimated for seed (rhizome).

Factors explaining inefficiency

The results indicate that the farm specific variables included in the technical inefficiency model contribute significantly to the explanation of the technical inefficiencies (Table 7). In turmeric farming, education of the farmers, age and farm visit have positive significant impact on technical efficiency (negative impact on technical inefficiency).Results indicate that education significantly improves technical efficiency of turmeric farming, consistent with Karthick *et al.*, (2013) for turmeric farms. The educated farmers are expected to follow the turmeric management practices properly, which might have led to higher efficiency for them.

The age coefficient is positive and significant with technical efficiency in turmeric farming which indicates that older farmers are more capable to take proper decisions regarding farm management practices as they have many years of practical experience. This confirms to the results obtained by Islam (2011).

The coefficient for number of farm visits by extension officers have positive impact on technical efficiency (negative impact on technical inefficiency) which indicates that an increase in the number of farm visits by extension officers decreases the inefficiency level of farmers in the study area. Thus, with the increase in farm visits their efficiency increases. This could be due to the fact that farmers that actively communicate with extension officer usually get information and benefits regarding input use and market prices of inputs and outputs.

It is evident from Table 7 that the estimate of γ and σ^2 are large and significantly different from zero, indicating a good fit and the correctness of the specified distributional assumption. Moreover, the estimate of γ, which is the ratio of the variance of farm-specific technical efficiency to the total variance of output, is 0.81; and significant at 10% level. This suggests that the technical inefficiency effect is significant component of the total variability of turmeric output.

Technical Efficiency Distribution

The mean technical efficiency of turmeric farmers in Khagrachari is 82% ranging from 44% to 95% (Table 8). Unfortunately, not a single farm appears as fully technical

efficient. The implication is that, on average, turmeric farming could generate 18% of the potential return by eliminating technical inefficiency, which is substantial.

Table7. Maximum likelihood estimates of the stochastic frontier production function of turmeric cultivation in Khagrachari district

Variables	Parameters	Coefficients	Standard error	t-ratio
Production frontier				
Constant	β_0	10.667***	0.263	40.409
Land (x_1)	β_1	-0.169***	0.038	-4.447
Labour (x_2)	β_2	0.004	0.017	0.232
Seed (rhizome) (x_3)	β_3	0.187***	0.041	4.599
Fertilizer (x_4)	β_4	0.006*	0.003	1.987
Inefficiency function				
Constant	δ_0	-0.159	0.897	-0.178
Age	δ_1	-0.005***	0.011	5.121
Education	δ_2	-0.019*	0.031	-1.639
Experience	δ_3	0.008	0.016	0.496
Training	δ_4	0.719	0.763	0.943
Farm visit	δ_6	-0.240*	0.274	-1.876
Variance parameters				
Sigma-squared	σ^2	0.208	0.191	1.088
Gamma	γ	0.808***	0.176	4.588
Log likelihood		-14.333		
Mean TE index		81.98		

Note: *** Significant at 1%, ** Significant at 5% and * Significant at 10%

The indices of TE indicate that if the average turmeric farmers of the sample could achieve the TE level of its most efficient counterpart, then average turmeric farmers could increase their return by 14% [1-(82/95)]. Similarly, the most technically inefficient turmeric farmers could increase the return by 46% [1-(44/95)], if he/she could increase the level of TE to his/her most efficient counterpart. These gains in return will increase their overall income and ensure better livelihood for the farmers.

About 4.67%, of the turmeric farmers are producing at an efficiency level of less than 60% while 70.66% of the turmeric farmers are producing at an efficiency level of 80% and above, which are encouraging. The mean technical efficiency of turmeric farms is 81.98%, which is quite similar to the estimates of average spices farms in Bangladesh and/or elsewhere in the world (Islam *et al*., 2011; Huq and Arshad, 2010).

Table 8. Distribution of technical efficiency scores

Efficiency levels	Percentage
≤ 50	1.34
$50 \leq 60$	3.33
$60 \leq 70$	6.67
$70 \leq 80$	18.00
$80 \leq 90$	53.33
$90 \leq 100$	17.33
Mean efficiency level	81.98
Minimum	44.20
Maximum	95.19
Standard deviation	0.102
Number of observations	150

Constraints of Turmeric Cultivation

A number of constraints were reported by respondents for turmeric farming, including lack of capital, insect, pest and disease attack, non-availability of modern verities, difficult to cultivate in slop of the land and problem of transportation, (Table 9). According to the survey, 61% of respondents identified inadequate finance as their single most important constraint. Costs of turmeric cultivation were reported to have increased significantly in recent years as a result of increased seed, fertilizer and labor costs. The prices of turmeric have decreased dramatically due to bumper yield has turned into a burden for farmers. Inadequate finance can therefore be a significant constraint. The proportion of respondents identifying pest and disease attack on turmeric and non-availability of improved seed varieties was 51%and 13%respectively. Only 9% and 7% of farmers reported problem of transport and cultivate in slop of the land to be the most important constraint, respectively.

Table 9. Constraints faced by turmeric growers

Key constraint	Grower($n = 150$)
Inadequate finance	92 (61%)
Insect, pest and disease attack	76 (51%)
Non-availability of improved/modern varieties	19 (13%)
Non-availability of transport	9 (6%)
Constraints to cultivate in slop of the land	7 (5%)

n sample size of turmeric farmers

Conclusions and Policy Recommendations

The profitability and technical efficiency of turmeric farming have been estimated by applying descriptive and Cobb-Douglas stochastic frontier

production function analyses. Production of turmeric was profitable as farmers earned higher level of net returns from turmeric they produced. The gross margin was calculated to be Tk. 127219 per ha in turmeric farming. It is observed that turmeric farms were able to generate positive returns to variable costs. This indicates that farms are willing to pursue turmeric farming as the returns to variable costs are positive. The BCR of sampled farmers was 2.20. This indicates that the turmeric farmers are able to recover Tk. 2.20 per Tk. 1 of investment.

According to a stochastic frontier production function, seed (rhizome) and fertilizer showed significant positive effects on the turmeric production. From the factors that were assumed to affect technical efficiency, age, education and higher number of farm visits of extension officers increased the efficiency level of farms in the study areas. All these observations were significantly contribute the efficiency level.

According to the result obtained from Stochastic Frontier estimation, technical efficiency levels of turmeric farmers ranged from 44.20 to 95.19%. Thus, there was a vast difference between technical efficiency levels of farmers even if they used the same level of inputs, though majority of the farmers were within the higher part of the range. The mean technical efficiency level of turmeric was 82% implying that a substantial 18% of the potential output from the farming system can be recovered by eliminating inefficiency with the present technology (technique) itself. Reductions in technical inefficiencies are unlikely to bring about large productivity gains. The estimates suggest that these efficiency gains could mainly come from production intensity and the improvement in the adoption of management practices and making better use of their inputs. Policies leading to the improvement of farm education would be favourable for improving the technical efficiency of farmers. While it is essential that farmers rotate their land for turmeric production every 3 years, this is rarely practiced leading to depletion of soil fertility, increasing soil erosion and reduced crop yields.

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SEED HEALTH OF STORED LENTIL COLLECTED FROM MAJOR LENTIL GROWING AREAS OF BANGLADESH

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Abstract

An experiment was conducted in the Plant Pathology Laboratory, Regional Agricultural Research Station, BARI, Jashore using 126 lentil seed samples collected from farmer's store of different lentil growing areas of Bangladesh to determine physical status and fungal association with lentil seeds. The collected seeds contained different varieties and locations. The seeds were grouped into four grades according to physical status. Among the varieties the maximum apparently healthy seed i. e. grade-1 was found in BARI Masur-7 (90.92 %) and the minimum was in local (59.34 %) varieties. In respect of location the maximum grade-1 seed was recorded from Madaripur (90.75 %) and minimum in Kushtia (47.67 %) district. Germination percentage was the highest in BARI Masur-7 (94.00 %) and the lowest in BARI Masur-3 (75.42 %) variety. Among districts, the highest germination was found in seeds of Meherpur (89.83 %) and the lowest in Narail (62.97 %). A linear positive relation was found between percent germination and apparently healthy seed in case of both varieties and locations. Six fungal genera were associated with lentil seed samples *viz. Fusarium* sp., *Alternaria* sp., *Stemphylium* sp., *Curvularia* sp., *Penicillium* sp. and *Aspergillus* spp. *Aspergillus niger* caused highest infection (17.58 %) followed by *Fusarium oxysporum, Alternaria tennuis, Stemphylium botryosum, Curvularia lunata, Penecillium* sp., *Aspergillus flavus, Aspergillus paraciticus* and *Aspergillus candidus* and the lowest (4.67 %) by *Aspergillus ocraceous*. Average association of fungi was the highest in local variety (3.27 %) and it was the lowest in BARI Masur-7 (0.50 %).

Keywords: Lentil seed, fungal association, germination, Bangladesh.

Introduction

Lentil is the oldest and most popular pulse crop in the world as it is grown since 8000 years ago. It has high protein content and special capacity for fixing atmospheric nitrogen. In Bangladesh pulses constitute an integral part of the daily diet as a direct source of protein for human beings (Sattar *et al.,* 1996). It is cultivated allover Bangladesh but intensively in Mid-Western region namely Jashore, Jhenidah, Magura, Faridpur, Rajbari, Kushtia, Chuadanga, Meherpur and Pabna district (Afzal *et al.,* 1999). The yield of lentil in Bangladesh is low compared to other countries like Syria, Turkey, Canada, USA and Ethiopia. In 2016-2017 the crop covered an area of 2,49,000 hector with a total production of

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2,69,000 metric tons in Bangladesh (Azad *et al,.* 2017). There are various factors responsible for low yield of lentil and low quality seed. Pulse seeds are rapidly deteriorated by high temperature and relative humidity during storage. In most of the cases farmers' stored seeds are badly infested with stored grain pests and moulds those resulted very poor germination. Although seeds can be affected by or can harbour seed-borne pathogens and can be contaminated with foreign materials such as crop debris, soil particles, weed seeds, seeds with other crops and of other varieties (Khokon *et al.,* 2005). Out of 16% annual crop losses due to plant diseases, at least 10% loss is incurred due to seed-borne diseases (Fakir, 2004). Lentil suffer from the attack of a number of seed-borne diseases such as vascular wilt, collar rot, root rot, stem rot, rust, powdery mildew and downy mildew which are caused by *Fusarium oxysporum f.sp. lentis, Sclerotium rolfsii, Rhizoctonia solani, Botrytis cinerea, Uromycis fabae, Erysiphe polygoni* and *Peronospora lentis,* respectively (Singh and Dwivedi, 1980 and Khare, 1981).

The supply of quality seeds of pulses is very limited in Bangladesh where Bangladesh Agricultural Development Corporation supplies only 1.15% seeds of total requirement. Remaining 98.85% seeds of pulses are produced by the farmers. In 2011-12 BADC supplied only 1092 metric ton pulse seeds all over the country. As such, the quality of farmers' stored seed is very poor (Fakir *et al.,* 2007). Pulses have inherently low yield potential and susceptibility to diseases and insect pests and sensitivity to microclimate changes (Fakir and Rahman, 1989). More than 60 pathogenic fungi including 20 major ones can infect seeds and transmit different diseases in the field causing considerable yield loss (Bakr and Rashid, 2007).

The aim of the research work was to determine health status and fungal incidence in farmers' stored lentil seed from major lentil growing regions of Bangladesh.

Materials and Methods

The experiment was carried out in the Plant Pathology laboratory, Regional Agricultural Research Station, BARI, Jashore.

Collection of seed samples

Seed samples were collected from the farmers of Mid-Western region covering intensively lentil growing districts of Bangladesh. Collection of seed samples was done from 1 March to 30 April 2012 directly from the store of the farmer. Lentil seeds were collected from 63 upazillas under 12 districts of Bangladesh such as Jashore, Jhenidah, Magura, Narail, Rajbari, Faridpur, Gopalgonj, Madaripur, Shariatpur, Chuadanga, Meherpur and Kushtia. Two samples from each upazila i.e., 126 working seed sample were collected from the farmers who had about one acre of lentil field and used own stored seed for sowing. The samples were collected directly from the storage of the farmers according to ISTA (1999) rules. Each sample was 250-300 g and the samples were enclosed in polythene bags with proper labeling and kept in the refrigerator at 5 ± 1^0C.

Dry inspection test

Dry inspection test was carried out according to ISTA (2001). A working seed sample of 400 seeds was drawn from each of the 126 samples. The seed samples were inspected visually under magnified hand lens and under steriobinocular microscope. The seeds were checked and grouped into four different grades following a standard grading scale such as Grade-1= Apparently healthy seed, Grade-2= Shriveled seed, Grade-3= Discolored seed and Grade-4= Broken seed. The graded seeds were separated using hand lens and stereo-binocular microscope and the data were expressed in percentage.

Germination test and blotter incubation test

The germination test was conducted during 11 August to 22 December 1013. The germination of the seeds was determined following blotter incubation test. Four hundred seeds were taken randomly from all the seed samples. The seeds were placed on three-layered moistened blotting paper in sterilized glass petridish (9 cm) using sterilized forceps and each petridish contained 25 seeds. The petridish were kept at room temperature under natural light and darkness for seven days. The germination were counted after seven days of incubation.

The associations of different fungi in lentil seed were also detected by blotter incubation method (ISTA, 2001). At that time, petridishes were observed under stereo-binocular microscope for observing the seed-borne mycoflora and also observed under compound microscope for confirmation. For the confirmation of identification, pure culture were prepared and studied under compound microscope. Pathogenicity test was also done of major fungi found from blotter incubation method (Ramanath *et. al.,* 1970, Neergaard, 1974). The association of fungi were counted and expressed in percentage.

Results and Discussion

Prevalence of seeds under different grades

Among 126 seed samples, the prevalence of grade-1, grade-2, grade-3 and grade-4 seeds ranged 59.34-90.92, 2.42-22.89, 1.67-20.45 and 3.01-4.83% with means 74.85, 13.27, 8.23 and 4.36%, respectively. The highest prevalence of grade-1, grade-2, grade-3 and grade-4 seeds were found in varieties BARI Masur-3, BARI Masur-5, Local and BARI Masur-3 and the lowest in Local variety, BARI Masur-7, BARI Masur-3 and BARI Masur-3, respectively (Table 1).

The prevalence of grade-1, grade-2, grade-3 and grade-4 seeds collected from different districts ranged 47.63-90.75, 6.63-20.52, 1.60-42.03 and 0.22-10.00% with mean 69.12, 4.34, 15.49 and 3.82%, respectively. The maximum prevalence of grade-1 seeds was recorded from samples collected from the district of Madaripur and the lowest samples from Kushtia. The highest prevalence of grade-2 seeds were found in samples from Jhenidah and the lowest in samples from Madaripur. The lowest prevalence of grade-3 seeds were found in samples

from Gopalganj and the highest in Kushtia. Under grade-4, the lowest and highest prevalence of seeds were observed in samples from Madaripur and Shariatpur (Table 2).

Table 1. Prevalence (%) of lentil seeds of different varieties and grades into four grades

Varieties	Grade-1 (%)	Grade-2 (%)	Grade-3 (%)	Grade-4 (%)	Germination (%)
BARI Masur-3	78.83	14.67	1.67	4.83	75.42
BARI Masur -5	63.06	22.89	9.50	4.65	76.98
BARI Masur -6	82.10	11.02	4.34	3.01	89.59
BARI Masur -7	90.92	2.42	5.17	4.50	94.00
Local variety	59.34	15.13	20.45	4.81	75.65
Range	59.34-90.92	2.42-22.89	1.67-20.45	3.01-4.83	75.42-94.00
Mean	74.85	13.27	8.23	4.36	82.33
SD	13.29	7.43	7.39	0.77	8.80

N.B. Grade-1: Apparently healthy seed, Grade-2: Shriveled seed, Grade-3: Discolored seed, Grade-4: broken seed,

Germination= Averages of four grades

Table 2. Germination of lentil seeds collected from different districts under four grades

District	Grade-1 (%)	Grade-2 (%)	Grade-3 (%)	Grade-4 (%)	Germination (%)
Jashore	71.55	13.27	11.20	3.98	82.03
Jhenidah	70.58	20.52	2.94	4.29	80.83
Magura	71.84	15.69	8.25	4.22	84.16
Narail	53.88	8.10	35.63	2.41	62.97
Rajbari	49.66	19.47	37.92	2.44	71.28
Faridpur	59.61	17.38	20.14	2.81	79.77
Gopalganj	77.08	18.15	1.60	3.20	86.93
Madaripur	90.75	6.63	2.38	0.22	85.00
Shariatpur	73.28	11.25	5.84	10.00	84.18
Chuadanga	82.19	13.19	1.88	5.09	87.66
Meherpur	81.33	14.04	3.42	1.21	89.83
Kushtia	47.67	11.58	42.03	5.67	73.94
Range	47.67-90.75	6.63-20.52	1.60-42.03	0.22-10.00	71.28-89.83
Mean	69.12	14.11	14.44	3.80	80.72
St. Dev.	13.64	4.34	15.49	2.50	7.77

N.B. Grade-1: Apparently healthy seed, Grade-2: Shriveled seed, Grade-3: Discolored seed, Grade-4: broken seed.

Germination= Averages of four grades.

Germination

The maximum average germination of seeds was found in BARI Masur-7 (94.00%) followed by BARI Masur-6 (89.59%). The lowest germination was recorded in samples of variety BARI Masur-3 followed by BARI Masur-3, Local and BARI Masur-5. These three varieties showed 75.42, 75.65 and 76.95% germination, respectively (Table 1).

The germination of seeds collected from the districts of Jashore, Jhenidah, Magura, Narail, Faridpur, Magura, Gopalganj, Madaripur, Shariatpur, Chuadanga and Kushtia were respectively 82.03, 80.83, 84.16, 62.97, 79.77, 86.93, 85.00, 84.18, 87.66, 89.83 and 73.94%. The maximum germination of 89.83% was recorded in seed samples collected from Meherpur and the lowest of 71.28% in the seeds from Rajbari (Table 2).

The percentage of germination was positively and linearly correlated with percentage of apparently healthy seeds collected from different districts. Their relationship could be explained by the regression equation Y=42.12 + 0.537X, where Y= estimated germination and X= regression coefficient. The correlation coefficient was r=0.811 (Fig. 1).
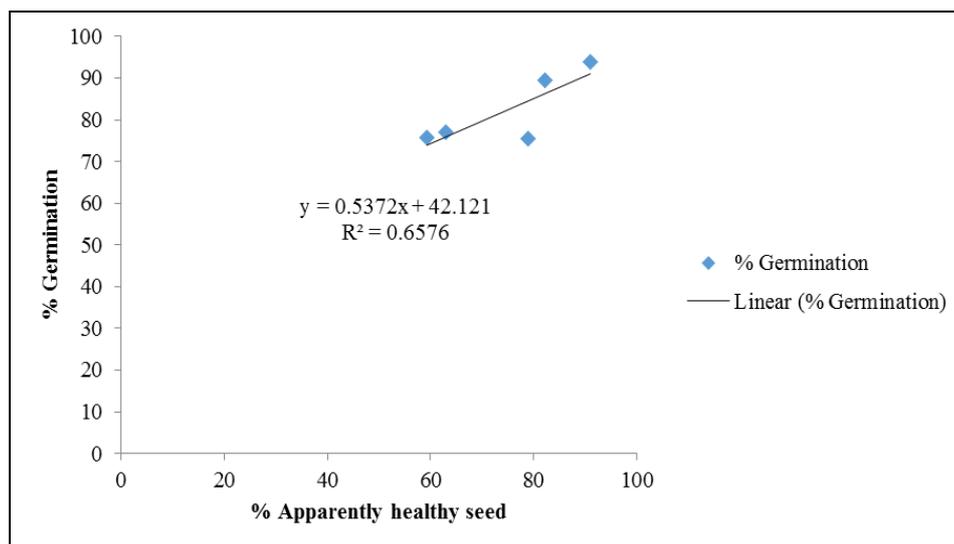
Fig. 1. Relationship between percent of germination and apparently healthy seed.

Association of fungi with seeds samples of five varieties

Six fungal genera were found to be associated seeds of five masur varieties. Those were alphabetically *Alternaria, Aspergillus, Curvularia, Fusarium*, *Penicillium* and *Stemphylium* (Table 3). Five species of *Aspergillus* (*A. candidus, A. flavus, A. niger, A. ocraceous, A. paraciticus*), one species of *Alternaria* (*A. tennuis*), one species of *Curvularia* (*C. lunata*), one species of *Fusarium* (*F.*

oxysporum) and one species of *Stemphylium* (*S. botryosum*) were identified. Prevalence of different species of fungi in BARI Masur-3, BARI Masur-5, BARI Masur-6, BARI Masur-7 and Local variety ranged respectively 0.50-7.17, 1.44-5.71, 0.74-3.09, 0.00-1.08 and 1.65-6.10% with mean 3.03, 2.98, 1.54, 0.05, 3.27 and 2.17%. The average prevalence of *A. tennuis, A. candidus, A. flavus, A. niger, A. ocraceous, A. paraciticus, C. lunata, F. oxysporum, Penicillium* sp. and *S. botryosum* under five lentil varieties were 0.58-3.24, 0.00-5.17, 0.17-4.25, 0.58-7.17, 0.00-1.81, 0.50-2.83, 0.67-2.36, 1.00-4.00, 0.75-5.05 and 0.58-3.13 % with mean 1.78, 1.99, 2.38, 4.49, 0.94, 1.49, 1.55, 2.40, 3.49 and 2.10%, respectively. The maximum prevalence of different varieties was found in *A. niger* and the lowest in *A. ocraceous.* The mean was 2.17% (Table 3).

Table 3. Prevalence (%) of fungi associated with lentil seeds of five varieties collected from different districts

Fungi (Alphabetically listed)	Prevalence (%) of fungi on five varieties					
	BARI Masur-3	BARI Masur-5	BARI Masur-6	BARI Masur-7	Local variety	Mean
Alternaria tennuis	1.17	2.46	1.44	0.58	3.24	1.78
Aspergillus candidus	5.17	1.44	1.06	0.00	2.31	1.99
Aspergillus flavus	4.25	3.58	0.84	0.17	3.08	2.38
Aspergillus niger	7.17	5.71	2.89	0.58	6.10	4.49
Aspergillus ocraceous	0.50	1.81	0.74	0.00	1.65	0.94
Aspergillus paraciticus	2.83	1.78	0.84	0.25	1.75	1.49
Curvularia lunata	0.67	2.35	1.30	1.08	2.36	1.55
Fusarium oxysporum	2.00	3.00	2.00	1.00	4.00	2.40
Penecillium sp.	3.83	4.73	3.09	0.75	5.05	3.49
Stemphylium botryosum	2.67	2.94	1.18	0.58	3.13	2.10
Mean	3.03	2.98	1.54	.050	3.27	2.17
SD	2.12	1.36	0.85	0.39	1.43	1.23

Association of fungi with seeds samples of twelve districts

Among 12 districts, the highest seed infection was caused by *F. oxysporum* recorded from the seeds of Narail (6.81%) followed by Kushtia (6.17%) and Rajbari (4.50%) district while the lowest seed infection was found in the seeds of Meherpur (1.71%) district (Table 4). The highest seed infection caused by *Alternaria tennuis* was recorded from local varieties (3.24%) followed by BARI Masur-5 (2.46%), BARI Masur-6 (1.44%) and BARI Masur-3 (1.17%). Only 0.58% seed infection was recorded in BARI Masur-7 (Table 3). Similarly, the highest infection of *Alternaria tennuis* was recorded from the seeds of Kushtia (5.05%) followed by Narail (3.94%) and Rajbari (3.10%) district and the lowest

seed infection was found in the seeds of Chuadanga (1.44%) district (Table 4). In case of lentil varieties the highest seed infection caused by *Stemphylium botryosum* was recorded from local varieties (3.13%) followed by BARI Masur-5 (2.94%), BARI Masur-3 (2.67%), BARI Masur-6 (1.18%) and BARI Masur-7 (0.58%) variety (Table 3). Highest seed infection due to *S. botryosum* was recorded from the seeds of Kushtia (7.30%) followed by Gopalganj (4.30%) and Narail (3.10%) district and the lowest infection was found in Meherpur (1.00%) district (Table 4). Highest seed infection caused by *C. lunata* was recorded from local variety (2.36%) followed by BARI Masur-5 (2.35%), BARI Masur-6 (1.30%), BARI Masur-7 (1.08%) and BARI Masur-3 (0.67%) variety (Table 3). Infection of *Curvularia lunata* was higher in Madaripur (8.00%) followed by Meherpur (7.00%) and Kushtia (4.80%) district and the lowest seed infection of *C. lunata* was found in Jashore (1.10%) district (Table 4). In case of *Penicillium* sp. the highest infection was recorded from local varieties (5.05%) followed by BARI Masur-5 (4.73%), BARI Masur-3 (3.83%), BARI Masur-6 (3.09%) and BARI Masur-7 (0.75%) variety (Table 3). Among 12 districts the highest infection of *Penicillium* sp. was recorded from the seeds of Kushtia (22.75%) followed by Faridpur (17.00%), Shariatpur (15.75%) and lowest in both Narail (6.50%) and Gopalganj (6.50%) district (Table 4). Higher infection of *Aspergillus niger* was recorded from BARI Masur-3 (7.17%) followed by local varieties (6.10%), BARI Masur-5 (5.71%), BARI Masur-6 (2.89%) and BARI Masur-7 (0.58%) variety (Table 3). *Aspergillus niger* was higher in Kushtia (19.50%) followed by Faridpur (18.75%) and Shariatpur (17.50%) and lower in Meherpur (5.00%) district (Table 4). *Aspergillus flavus* was maximum in BARI Masur-3 (4.25%) followed by BARI Masur-5 (3.58%), local varieties (3.08%), BARI Masur-6 (0.84%) and BARI Masur-7 (0.17%) (Table 3). Similarly, *A. flavus* was more in Faridpur (12.50%) followed by Jhenidah (9.50%) and Kushtia (9.50%) district. It was less in Madaripur (1.00%) and Meherpur (1.00%) district (Table 4). On the other hand, the highest *Aspergillus ochraceus* was recorded from BARI Masur-5 (1.81%) followed by local varieties (1.65%), BARI Masur-6 (0.74%) and BARI Masur-3 (0.50%) and no infection of this fungus was found in BARI Masur-7 (Table 3). The species *A. ochraceus* was highest in the seeds of Faridpur (7.25%) followed by Kushtia (6.50%) and Jhenidah (5.00%) and lowest in Gopalganj (1.25%) district (Table 4). The seed infection caused *A. paraciticus* was the highest in BARI Masur-3 (2.83%) followed by BARI Masur-5 (1.78%), local variety (1.65%), BARI Masur-6 (0.84%) and BARI Masur-7 (0.25%) (Table 3). Among 12 districts, highest seed of *A. paraciticus* was recorded from Chuadanga (7.50%) followed by Kushtia (7.00%) and Faridpur (5.00%), and the lowest was found in Shariatpur (0.50%) district (Table 4). *A. candidus* was highest in BARI Masur-3 (5.17%) followed by local variety (2.31%), BARI Masur-5 (1.44%) and BARI Masur-6 (1.06%), while no infection was found in BARI Masur-7 (Table 3). Among 12 districts, the highest seed infection by *A. candidus* was recorded from Kushtia (10.25%) followed by Jhenidah (7.00%), Faridpur (6.00%) and the lowest was in Chuadanga (1.50%) (Table 4).

Table 4. Prevalence (%) of fungi associated with lentil seeds collected from different districts

District	Prevalence (%) of fungi									
	Alternaria sp.	*A. candidus*	*A. flavus*	*A. niger*	*A. ocraceous*	*A. paraciticus*	*Curvularia* sp.	*Fusarium* sp.	*Penecillium* spp.	*Stemphylium botryosum*
Jessore	1.80	5.25	7.25	16.00	3.50	4.50	1.10	2.78	10.25	2.30
Jhenidah	1.69	7.00	9.50	16.75	5.00	5.00	1.20	2.63	12.50	2.50
Magura	2.10	2.50	3.50	9.50	3.25	1.75	1.80	2.91	10.00	1.40
Narail	3.94	5.25	5.75	11.50	2.25	3.75	1.50	6.81	6.50	3.10
Rajbari	3.10	6.50	7.75	15.50	3.50	4.00	1.90	4.50	10.50	2.40
Faridpur	2.30	6.50	12.40	18.75	7.25	6.25	3.80	2.98	17.00	2.40
Gopalganj	1.95	4.75	3.75	7.00	1.24	4.25	1.90	2.28	6.50	4.70
Madaripur	1.72	3.00	1.00	5.00	1.49	2.50	8.00	2.33	7.00	1.80
Shariatpur	2.63	2.50	9.25	17.50	4.00	0.50	3.10	2.55	15.75	1.30
Chuadanga	1.44	1.50	4.25	5.25	1.25	7.50	2.10	2.53	8.50	2.50
Meherpur	1.83	3.25	1.00	6.50	2.25	1.75	7.00	1.71	7.00	1.00
Kushtia	5.05	10.25	9.50	19.50	6.50	7.00	4.80	6.27	22.75	7.30
Total	29.55	58.25	74.9	148.75	41.48	48.75	38.2	40.28	134.25	32.7
Mean	2.46	4.85	6.24	12.40	3.46	4.06	3.18	3.36	11.19	2.73
St. dev.	1.08	2.48	3.62	5.54	1.98	2.18	2.30	1.63	5.04	1.73

The results of the present investigation reveal that variable associations of different fungi exist in various varieties of lentil seeds which is preserved by the farmers for next year sowing. BARI Masur-7 shows lower fungal association than other varieties and more associations were found in local and old varieties. It indicated that the seeds of latest varieties were more tolerant against fungal infection. In blotter incubation test six fungal genera were detected in lentil seeds such as *Fusarium* sp., *Alternaria* sp., *Stemphylium* sp., *Curvularia* sp., *Penicillium* sp. and *Aspergillus* sp. Five species of *Aspergillus* viz. *A. niger, A. flavus, A. ocraceous, A. paraciticus* and *A. candids* were detected in seeds of lentil. Six fungal pathogens from 16 lentil seed samples collected from farmer's store of Meherpur by other authors and found lower germination percentage in case of lower percentage of apparently healthy seeds (Hasan *et al.,* 2010). Sarkar *et al.* (2010) recorded eight fungal species under six genera in lentil seeds. Similarly, Dev *et al.* (2002), El-Nagerabi and Elshafie (2001) and Javed *et al.* (2000) also identified 6, 7 and 9 fungal genera from lentil seed. Based on findings of the present study, it may be concluded that prevalence of higher apparently healthy seed may give higher germination percentage and lower fungal infection.

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DEVELOPMENT OF ALTERNATE CROPPING PATTERN MUSTARD - BORO –T.AMAN AGAINST FALLOW - BORO- T. AMAN IN KUSHTIA REGION

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Abstract

The experiment was conducted at Kushtia Sadar, Bheramara and Gangni Multi Location Testing (MLT) sites under On-Farm Research Division (OFRD), BARI, Kushtia (AEZ 11) during the last week of July to second week of May for three consecutive years (2013- 14, 2014-15 and 2015-16) to develop alternate cropping pattern (Mustard-Boro -T.Aman) and to compare its productivity and profitability against farmer's existing cropping pattern (Fallow - Boro-T.Aman). The mustard (var: BARI Sarisha-14), Boro rice (var: BRRI dhan28) and T.Aman (var: Binadhan-7) were used in alternate cropping pattern, while BRRI dhan28 for Boro rice and BRRI dhan39/Sorna for T.Aman rice were used in the existing cropping pattern. Findings revealed that the mean crop duration of alternate cropping pattern ranged 269-287 days by inclusion of mustard. Rice equivalent yield of alternate cropping pattern was 13.98 t ha^{-1} year^{-1} which was 34% higher than that of existing pattern (10.47 t ha^{-1} year^{-1}). Land use efficiency (76.44%) and labour employment (441 mandays ha^{-1} year^{-1}) of alternate cropping pattern were 33 and 26%, higher, respectively than those of existing cropping pattern. The mean gross return (Tk. 2,53,960 ha^{-1}) and gross margin (Tk. 99,513/ha) of alternate cropping pattern were 29 and 32%, respectively higher compared to those of existing cropping pattern (Gross return: Tk. 1,97,346 ha^{-1} and Gross margin: Tk. 75,340 ha^{-1}) due to inclusion of high yielding variety of mustard. Therefore, farmers in Kushtia region of Bangladesh could follow alternate cropping pattern in their high and medium high land where lands remain fallow after harvesting of T. Aman rice for higher crop productivity and profitability.

Keywords: Grain yield, production efficiency, rice equvalent yield, profitability

Introduction

Bangladesh has achieved a remarkable progress in increasing food production. Agriculture sector contributes about 17% to the country`s Gross Domestic Product (GDP) and employs more than 45% of total labour force (BBS, 2018). At present total cultivable land of the country is 8.44 million hectares and it is shrinking day by day. There are some scopes of increasing cropping intensity (192%) by improving the existing cropping patterns by inclusion of short

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duration crops viz., mustard, potato, mungbean and T.Aus rice in the rice based cropping system (Mondal *et al.,* 2015).

Kushtia and Meherpur district is located under Agro Ecological Zone (AEZ) 11. The soil is calcareous under High Ganges River Floodplain. The cropping intensity of this area is 263% and about 93% lands are under irrigation (DAE, 2016). About 76% lands are under high and medium high land in which 20% lands remains fallow after harvesting of T.Aman rice.

Bangladesh Rice Research Institute (BRRI) has recommended the T.Aman-Mustard-Boro cropping pattern for the irrigated ecosystem (BARC, 2001; Khan *et al*., 2004) with the inclusion of 70-75 days local mustard (var. Tori-7) in between T. Aman and Boro rice. But the farmers harvest poor yield from local var. Tori7 that can be increased by introducing high yielding varieties (Alam and Rahman, 2006; Basak *et al.,* 2007). Bangladesh Agricultural Research Institute (BARI) has developed high yielding mustard varieties, BARI Sarisha-14 and BARI Sarisha-15, respectively and has been recommended for T. Aman-Mustard-Boro cropping sequence (Mondal *et al.,* 2011). Crop duration of BARI developed short duration mustard varieties is 75-85 days, whereas BRRI and BINA has developed short/medium duration rice varieties. With this view, the present study was, therefore, undertaken to develop Mustard-Boro -T.Aman rice cropping pattern and to compare its productivity and profitability against farmer's existing cropping pattern Fallow - Boro-T.Aman rice; and to determine the land use efficiency, production efficiency and labour employment generation of alternate and existing cropping pattern.

Materials and Methods

The experiment was conducted at Kushtia Sadar, Bheramara and Gangni Multi Location Testing (MLT) sites under On-Farm Research Division (OFRD), BARI, Kushtia (AEZ 11) during the last week of July, 2013 to second week of May, 2016 at farmers' field condition. The experiment was laid out in block approach where two blocks were used. Unit block size was one hectare per pattern. There were seven dispersed replications with two treatments i.e., alternate cropping pattern (Mustard-Boro-T.Aman) and farmer's existing cropping pattern (Fallow-Boro-T.Aman). In the alternate cropping pattern (ACP), the variety BARI Sarisha-14 for mustard, BRRI dhan28 for Boro rice and Binadhan-7 for T.Aman rice was cultivated. While, in the existing cropping pattern (ECP), the variety BRRI dhan28 for Boro rice was used in all sites but in T.Aman rice BRRI dhan39 and Sorna rice varieties were used at Bheramara, and Kushtia Sadar and Gangni, respectively. The trial was started by T.Aman rice cultivation. Because lands remain fallow after harvesting of Boro rice which help to plan three crops in a piece of land in a year. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to Mondal *et al.* (2011) and BRRI (2013). Transplanting was done with 27-28 days old seedling of rice var. Binadhan-7 for alternate cropping pattern and BRRI

dhan39 and Sorna for existing cropping pattern at a spacing 20 cm x 15 cm during 21-29 July for ACP and 05-10 August for ECP (Table 1). T.Aman rice was harvested during 27 October- 02 November for ACP and 16-22 November for ECP in three consecutive years. Mustard (var: BARI Sarisha-14) seed was sown in broadcasting method during 30 October - 6 November and harvested during 25 January -2 February in ACP. Mustard seed was sown in broadcasting method due to minimize labour cost of farmers. Boro rice seedling was transplanted with spacing 20 cm x 15 cm during 28 January – 7 February for ACP and 20 January -5 February for ECP. Seedling ages were 40-45 and 42-48 days old for ACP and ECP, respectively. Boro rice was harvested during 01-13 May in ACP and 06-20 May in ECP. In Boro and T.Aman rice, stem borer and sheath blight was observed in some plots. Folicur @ 0.5 ml/L was sprayed to control sheath blight and Virtako 40 WG @1.5g/10 L for stem borer. In Mustard, Rovral-50 wp @ 2 g/L was sprayed at early stage for controlling alternaria blight disease. All field operations and management practices of both alternate and existing cropping patterns were closely monitored and the data were recorded for observing agro-economic performance. The yield data of product and by-product were recorded. Grain/seed and straw yields of all rice and mustard as well as price data of inputs and outputs were taken timely.

Agronomic performance *viz.,* land use efficiency, production efficiency and rice equivalent yield of cropping patterns were calculated.

Land use efficiency: It is worked out by taking total duration of individual crop in a pattern divided by 365 days as Tomer and Tiwari (1990) as follows:

$$\text{Land use efficiency} = \frac{\sum di}{365} \times 100$$

Where,

di = duration of the ith crop   i = 1, 2, 3 and 4

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

$$\text{Production efficiency} = \frac{\sum Yi}{di}$$

Where,

Yi = Yield of the ith crop

di = duration of the ith crop   i = 1, 2, 3 and 4

Rice equivalent yield: For comparison between cropping patterns, the yield of all crops was converted into rice equivalent yield (REY) on the basis of prevailing market price of individual crop (Verma and Modgal, 1983).

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

Profitability analysis: The economic indices like total variable cost and gross return were also calculated on the basis of prevailing market price of the produces. For economic evaluation of two tested cropping patterns, average data of three crop cycles were used. Gross return was calculated on the basis of taka per hectare of product and by-product. Total variable cost of different crops was calculated on the basis of taka per hectare of different operations performed and materials used for raising the crops.

Results and Discussion

Crop management: Crop management practices include date of sowing/transplanting, date of harvesting, fertilizer dose used, irrigation, weeding and application of pesticides etc. of alternate and existing cropping pattern are shown in Table 1. The mean crop (field) duration of mustard, Boro and T.Aman rice under alternate cropping pattern (Mustard-Boro-T.Aman rice) were 78-88, 96-99 and 95-100 days, respectively while, in existing cropping pattern (Fallow-Boro-T.Aman rice) were 100-107 days for Boro and 102-108 days for T.Aman. Total crop duration of ACP and ECP were 269-287 and 202-215 days, respectively. The crop duration of T.Aman rice under ECP was higher (102-108 days) than that of ACP (95-102 days) due to use high crop durated Sorna variety in ECP. Mustard did not cultivate in ECP due to late transplanting of T.Aman rice which was harvested on 16-22 November. Late sowing of mustard yielded lower and it is not economically viable. But in ACP, short duration of T.Aman rice (Binadhan-7) was cultivated and it was harvested during 27 October – 02 November. After harvesting of T.Aman rice mustard was easily sown in optimum period. Turn around times for ACP and ECP were 77-96 and 143-176 days, respectively.

Seed/Grain yield: The mean seed/grain yield of mustard, Boro and T.Aman were 1.26, 5.30 and 4.79 t ha^{-1}, respectively in alternate cropping pattern while in existing cropping pattern Boro and T.Aman rice grain yields were 5.74 and 4.44 t ha^{-1}, respectively (Table 2). In alternate cropping pattern, mustard seed yield of Gangni was the highest (1.39 t ha^{-1}) and it followed by Kushtia (1.25 t ha^{-1}) and Bheramara (1.15 t ha^{-1}). The grain yields of Boro rice were 5.40, 5.49 and 5.60 t ha^{-1} for Kushtia, Bheramara and Gangni, respectively. T.Aman grain yield of Gangni was the highest (5.26 t ha^{-1}) and it followed by Bheramara (4.92 t ha^{-1}) and Kushtia (4.18 t ha^{-1}). The mean straw yield of mustard, Boro and T.Aman were 1.71, 5.43 and 5.00 t ha^{-1}, respectively in alternate cropping pattern while in existing cropping pattern Boro and T.Aman rice grain yields were 5.48 and 4.83 t ha^{-1}, respectively.

Table 1. Crop management practices of existing and alternate cropping pattern in different MLT sites under OFRD, Kushtia during 2013-2016

Parameters	Existing Cropping Pattern			Alternate Cropping Pattern		
Crop (variety)	T. Aman (BRRI dhan39/Sorna)	Fallow	Boro (BRRI dhan28)	T. Aman (Binadhan- 7)	Mustard (BARI Sarisha-14)	Boro (BRRI dhan28)
Kushtia						
Seedling age (days)	25-27	-	42-47	28-30	-	40-45
Sowing/Transplanting date	05-10 August	-	20-30 January	21-29 July	30 October-05 November	30 January- 07 February
Harvesting date	16-19November	-	06-10 May	27 October – 02 November	25-30 January	07-13 May
Field duration (day)	103-108	-	101-107	97-99	87-88	96-98
Turn around time (days)	64-70	-	90-92	02-04	04-06	74-76
Bheramara						
Seedling age (days)	27-28	-	47-48	27-28	-	42-45
Sowing/Transplanting date	07-10 August	-	01-05 February	21-24 July	02-04 November	28-30 January
Harvesting date	19-21 November	-	15-16 May	28 -30 October	25-26 January	01-07 May
Field duration (days)	102-107	-	100-105	99-100	84-85	94-98
Turn around time (days)	73-76	-	83-85	01-03	02-05	77-80

Table 1. Cont'ed

Parameters	Existing Cropping Pattern			Alternate Cropping Pattern		
Crop (variety)	T. Aman (BRRI dhan39/Sorna)	Fallow	Boro (BRRI dhan28)	T. Aman (Binadhan- 7)	Mustard (BARI Sarisha-14)	Boro (BRRI dhan28)
Gangni						
Seedling age (days)	27-30	-	44-48	27-30	-	40-44
Sowing/Transplanting date	05-08 August	-	30 January -05 February	25-28 July	04-06 November	30 January-05 February
Harvesting date	20-22 November	-	15-20 May	28-30 October	20-27 January	08-13 May
Field duration (days)	107-108	-	105-106	95-96	78-83	98-99
Turn around time (days)	83-84	-	79-81	05-07	08-09	76-77
Mean						
Seedling age (days)	25-30	-	42-48	27-30	-	40-45
Sowing/Transplanting date	05-10 August	-	20 January -05 February	21-29 July	30 October-06 November	30 January-07 February
Harvesting date	16-22 November	-	06-20 May	27 October – 02 November	25 January -02 February	01-13 May
Field duration (days)	102-108	-	100-107	95-100	78-88	96-99
Turn around time (days)	64-84	-	79-92	01-07	02-09	74-80

Table 2. Yield of alternate and existing cropping pattern in different MLT sites under OFRD, Kushtia during 2013-2016

Parameters	Existing Cropping Pattern			Alternate Cropping Pattern		
Crop (variety) \\\\ Location	T. Aman (var. BRRI dhan39/ Sorna)	Fallow	Boro (var. BRRI dhan28)	T. Aman (var. Binadhan- 7)	Mustard (var. BARI Sarisha-14)	Boro (var. BRRI dhan28)
Seed/grain yield (t ha^{-1})						
Kushtia	4.30	-	5.70	4.18	1.25	5.40
Bheramara	4.22	-	5.73	4.92	1.15	5.49
Gangni	4.80	-	5.80	5.26	1.39	5.60
Mean	4.44	-	5.74	4.79	1.26	5.50
Straw yield (t ha^{-1})						
Kushtia	4.40	-	5.40	4.85	1.86	5.30
Bheramara	5.10	-	5.50	5.00	1.62	5.48
Gangni	5.00	-	5.55	5.15	1.65	5.50
Mean	4.83	-	5.48	5.00	1.71	5.43

Rice equivalent yield: It is revealed from Table 3 that the mean rice equivalent yield (REY) of alternate cropping pattern was 13.98 tha^{-1}year^{-1} which was 34% higher over existing cropping pattern (10.47 tha^{-1}year^{-1}). REY of alternate cropping pattern for Kushtia (13.97), Bheramara (13.47) and Gangni (14.51) was 28, 38 and 35% higher against existing cropping pattern (10.88, 9.74 and 10.78 tha^{-1}year^{-1}). Higher rice equivalent yield was obtained in alternate cropping pattern due to inclusion of short duration mustard and high yielding varieties as well as improved management technologies. It is evident from the above findings that alternate cropping pattern gave higher yield compared to existing pattern. This finding was supported by Nazrul *et al.* (2017), Rahman et al. (2015), and Nazrul *et al.* (2013).

Land use efficiency: Land use efficiency is the effective use of land in a cropping year, which mostly depends on crop duration. The mean land-use efficiency of alternate cropping pattern was 33% higher (76.44%) than that of existing pattern (57.53%). Alternate cropping pattern utilized the land by 77.53, 76.44 and 75.34% for Kushtia, Bheramara and Gangni, respectively, whereas existing pattern utilized the land by 57.53, 56.71 and 58.36% for Kushtia, Bheramara and Gangni, respectively (Table 3). The land use efficiency was higher in alternate cropping pattern due to cultivation of mustard in the pattern. The similar trend of the findings was cited by Nazrul *et al.* (2017), Rahman et al. (2015), and Nazrul *et al.* (2013).

Production efficiency: The mean production efficiency of alternate cropping pattern was found to be 41.38 kg ha^{-1} day^{-1} which was 15% lower over existing

cropping pattern (48.48 kg ha^{-1} day^{-1}). Production efficiency of alternate cropping pattern was found to be 38.22, 41.42 and 44.50 kg ha^{-1} day^{-1} for Kushtia, Bheramara and Gangni, respectively, while in existing cropping pattern it was found to be 47.62, 48.05 and 49.77 kg ha^{-1} day^{-1} for Kushtia, Bheramara and Gangni, respectively (Table 3). The production efficiency was lower in alternate cropping pattern over existing cropping pattern due to lower mustard yield and its medium crop duration.

Labour employment generation: Human labour was employed for land preparation, sowing/transplanting, fertilizing, weeding, pesticide application, harvesting, carrying, threshing, cleaning and drying. It is observed that the mean total number of human labour used for crops cultivation under alternate cropping pattern was 441 man-daysha^{-1} year^{-1} which was generated 26% higher labour employment than that of existing cropping pattern (349 man-days ha^{-1} year^{-1}) due to inclusion of mustard in alternate cropping pattern (Table 3). Human labour employed to alternate cropping pattern in Kushtia, Bheramara and Gangni was 446, 436 and 442 man-daysha^{-1} year^{-1}, respectively while it was 354, 346 and 348 man-daysha^{-1} year^{-1}, for Kushtia, Bheramara and Gangni, respectively in existing cropping pattern.

Table 3. Rice equivalent yield, production efficiency, land use efficiency and labour employment of alternate and existing cropping pattern in different MLT sites under OFRD, Kushtia during 2013-2016

MLT sites	Cropping pattern	Rice equivalent yield (tha^{-1})	Land use efficiency (%)	Production efficiency (Kg ha^{-1}day^{-1})	Labour employment (man-days ha^{-1} year^{-1})
Kushtia	Alternate	13.97	77.53	38.22	446
	Existing	10.88	57.53	47.62	354
Bheramara	Alternate	13.47	76.44	41.42	436
	Existing	9.74	56.71	48.05	346
Gangni	Alternate	14.51	75.34	44.50	442
	Existing	10.78	58.36	49.77	348
Mean	Alternate	13.98	76.44	41.38	441
	Existing	10.47	57.53	48.48	349

Profitability analysis: The study revealed that the mean gross return of alternate and existing cropping pattern was Tk. 2,53,960 ha^{-1} and Tk. 1,97,346 ha^{-1}, respectively (Table 4). The mean gross return of alternate cropping pattern was 29% higher than that of existing cropping pattern and it might be due to inclusion of mustard and new high yielding varieties. The mean total variable cost of alternate and existing cropping pattern was Tk. 1,54,447 ha^{-1} and Tk. 1,22,006 ha^{-1}, respectively. About 32% higher (Tk. 99,513 ha^{-1}) gross margin was

calculated at alternate cropping pattern than that of existing cropping pattern (Tk. 75,340 ha^{-1}). Mean MBCR of alternate cropping pattern was found 1.75 which implied that alternate cropping pattern was 75% better against existing cropping pattern. The highest MBCR was found in Gangni (1.82) and it followed by Bheramara (1.78) and Kushtia (1.64). According to locations, the gross return of Gangni was slightly higher than other two locations due to higher yields and total variable cost was also higher compared to other two locations due to high labour wages. The gross margin of Kushtia was slightly lower than other two locations due to lower yield.

Table 4. Profitability of alternate and existing cropping pattern in different MLT sites under OFRD, Kushtia during 2013-2016

Parameters	Existing Cropping Pattern				Alternate Cropping Pattern			
	Kushtia	Bheramara	Gangni	Mean	Kushtia	Bheramara	Gangni	Mean
Gross return (Tk. ha^{-1})	196350	196537	199150	197346	251008	246961	263910	253960
Total variable cost (Tk. ha^{-1})	106650	126677	132691	122006	140017	154960	168363	154447
Gross margin (Tk. ha^{-1})	89700	69860	66459	75340	110991	92001	95547	99513
MBCR					1.64	1.78	1.82	1.75

Conclusion

The total crop productivity (in terms of REY), land use efficiency, labour employment, and profitability of alternate cropping pattern [Mustard (Var:BARISarisha-14) - Boro rice (Var:BRRIdhan28) - T.Aman rice (Var:Binadhan-7)] were much higher than that of existing cropping pattern [Fallow – Boro (Var:BRRIdhan28) - T.Aman rice (Var:BRRIdhan39)] due to inclusion of HYV short duration mustard. Thus, mustard can be successfully accommodated in the existing cropping pattern which increased cropping intensity and system productivity with reasonable profitability. This ACP could be demonstrated to exhibited areas in the high and medium high land of Kushtia region in Bangladesh with the collaboration of DAE and BARI.

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POPULATION ABUNDANCE OF LEAF-EATING CATERPILLARS OF CABBAGE

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Abstract

This study was conducted in the experimental field of Entomology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur during October 2014 to April 2015 to know the population abundance of leaf-eating caterpillars, namely prodania caterpillar, *Spodoptera litura* and diamondback moth (DBM), *Plutella xylostella* attacking cabbage in Bangladesh. The lowest population of both DBM and prodania larvae per plant was found during November and January whereas the highest population per plant was recorded during September and March 2014 and 2015, respectively. The same trend were observed in case of the adult population in the sex pheromone trap catch. The adult prodania caterpillar population was the highest during October-November and March. During December population declined totally in the month of January. The highest diamondback moth (*Plutella xylostella*) population was observed during November and March. During the last week of December population again declined entirely which continued until the last week of January. *S. litura* population was always higher than that of diamondback moth (DBM). There is a positive correlation between the rise of temperature with the population buildup of both *S. litura* and *P. xylostella* in cabbage. Especially when the mean temperature declined below 15˚C then the population of both the pest became nil.

Keywords: Cabbage, *Spodoptera litura*, *Plutella xylostella*, population abundance, pheromone trap, temperature

Introduction

Cabbage, *Brassica oleracea* L., is a popular vegetable in Bangladesh. Cabbage is growing throughout the year due to introduction of heat tolerant varieties. Cabbage is attacked by a group of insect pests. However, two leaf-eating caterpillars, prodenia caterpillar, *Spodoptera litura,* (F.) (Lepidoptera: Noctuidae) and diamondback moth (DBM), *Plutella xylostella*, (L.) (Lepidoptera: Plutellidae) are the most destructive pests of cabbage (Nyambo and Pekke, 1995). High population levels of diamondback moth can cause losses in yield up to 90% (Verkerk and Wright, 1996) worldwide and for many years been considered as the most important pest of cabbages and other brassica crops

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(Shelton, 2004; Furlong *et al*., 2013), costing up to 4-5 billion US$ per year due to damage and control costs (Zalucki *et al.*, 2012). In India, Krishnamoorthy (2003) reported 52% yield loss of cabbage due to diamondback moth.

Spodoptera litura infested all cruciferous vegetables including cabbage, cauliflower, broccoli, Chinese cabbage, mustard, radish, turnip etc. in Bangladesh and *P. xylostella* has now been reported and documented at least one hundred and twenty-eight countries or territories of the world and is believed to be the most universally distributed of all lepidopterous insect pests (Sarfraz *et al.*, 2006). Shelton (2004) reported that currently, this insect pest is present all over the world wherever the crucifers exist.

The importance of climatic factors in the population dynamics of *P. xylostella* and *S.litura* have been emphasized by Vickers *et al.*, 2004. Biology and development of leaf-eating caterpillars are highly dependent on temperature and humidity (Guo and Qin, 2010). Ansari *et al*., (2010) reported that temperature is a vital factor for the development of *P. xylostella* and *S.litura*. Life table and population studies showed that besides host plants, rainfall, temperature, humidity and natural enemies greatly influence the survival and reproduction of *P. xylostella* and *S. litura* (Haseeb *et al.,* 2001).

S. litura and *P. xylostella* are a key and destructive pest around the world, but still, little attention has been paid to forecast its population dynamics (Zaluci *et al*., 2011). Forecasting population dynamics of leaf-eating caterpillars are not easy as many factors influence its abundance and fluctuation (Schellhorn *et al*., 2008; Muthuthantri *et al*., 2010). To develop a proper planning for the management of this pest, prediction of the population abundance, it is proper timing of occurrence and level (pest pressure) is highly important (Maelzer *et al*., 1996). Therefore, the present research was conducted to observe the population dynamics of *S. litura* and *P. xylostella* on cabbage and to determine the effects of temperature, relative humidity on population trend of this pest.

Materials and Methods

Study site

The population dynamics of *S. litura* and *P. xylostella* was examined under the sub-tropical climatic zone, present at the experimental field of Entomology Division, BARI, Gazipur conducted during October 2014 to April 2015. The area was situated at 24.09° North latitude and 90.26° East longitude with an elevation of 8.4 meters from the sea level.

Parameters and design of the study

Experiments were laid down in a randomised complete block design (RCBD) having an experimental unit size of 10 meters in width and 10 meters in length transplanted with 40 days old 'Atlas-70'variety of cabbage. Each experimental

unit consisting of forty (40) cabbage plants, having five (5) rows and every row consisted of eight (8) plants. Plant to plant distance of cabbage was about 60 cm and row to row distance was 60 cm. For studying population dynamics of leaf-eating caterpillars, each experimental unit was replicated three times under the same experimental conditions. For documentation of population dynamics, standard agronomic practices, including normal weeding, irrigation practices, fertilisation and sanitation etc. except plant protection measures were followed as per recommended package of practices (Rashid, 1999) in the cabbage fields.

Data collections

The population of *S. litura* and *P. xylostella* larvae was recorded from two weeks after sowing at weekly intervals and continued until the harvest. The number of adult population of *S. litura* and *P. xylostella* recorded by sex pheromone traps. Bangladesh Agricultural Research Institute (BARI) developed water traps and Ispahani Agro Ltd. pheromone lures were used for adult population monitoring. On the other hand, mean number of larvae were examined and recorded in the field by visually counting at harvest cabbage plant. The collected data were pooled over the cropping season. The infested and healthy yield data were also recorded. Data regarding maximum and minimum temperature, relative humidity and rainfall were collected from Meteorological Department, BARI, Gazipur. Correlation of population fluctuation of prodania caterpillar and diamondback moth (DBM) was done with weather parameters.

Results and Discussion

A. Results

The mean population of both leaf-eating caterpillars varied in different months from September 2014 to March 2015. Pest appeared in the first-week after transplanting of 40 days old cabbage seedlings to the field in September. The lowest population of both *P. xylostella* and *S. litura* larvae per plant was found on November 2014 and January 2015, whereas the highest population per plant was recorded during September 2014 and March 2015, respectively (Table 1). This trend of the population increase continued during September 2014 and March 2015 and decline of population noticed during November to January, when the temperature was below 15˚C.

It is observed from the result of pheromone trap catches that *S. litura* adult population was the highest during October-November and March. During December the population declined and became nil during January (Fig. 1 & 2). The highest *P. xylostella* adult population was observed during November and March. During the last week of December the population became nil which continued till the last week of January (Fig. 1 & 2). Especially when the mean temperature declined beyond 15˚C then the population of both the pest became nil (Fig. 2). *S. litura* population was always higher than *P. xylostella* population in the study area.

Table 1. Population dynamics of both *P. xylostella* and *S. litura* larvae on cabbage plant during 2014-2015

Date (2014-2015)	Number of *P. xylostella* (Mean ±SE)	Number of *S. litura* (Mean ±SE)	Temperature ˚C (Max.)	Temperature ˚C (Min.)	RH%
28 Sep 2014	2.7±0.14	4.5±0.20	34.56	20.23	80
12 Oct 2014	2.2±0.10	3.1±0.23	34.23	24.25	75
26 Oct 2014	2.6±0.02	3.8±0.41	29.59	22.53	73
10 Nov 2014	0.6±0.02	2.7±0.13	30.45	22.24	72
24 Nov 2014	0.9±0.07	2.7±0.13	32.23	21.25	73
08 Dec 2014	1.4±0.11	2.3±0.12	30.25	19.20	80
22 Dec 2014	1.2±0.05	1.2±0.03	20.07	15.32	81
05 Jan 2015	0.7±0.05	1.3±0.17	29.22	19.23	83
19 Jan 2015	0.6±0.10	2.6±0.24	28.36	17.45	82
02 Feb 2015	1.2±0.08	2.2±0.06	29.51	15.45	78
16 Feb 2015	1.02±0.18	3.1±0.17	21.82	15.23	78
02 Mar 2015	2.2±0.09	4.3±0.29	25.98	16.24	70
16 Mar 2015	2.7±0.17	5.5±0.28	23.12	15.76	70
30 Mar 2015	2.0±0.15	4.8±0.66	26.45	16.23	65
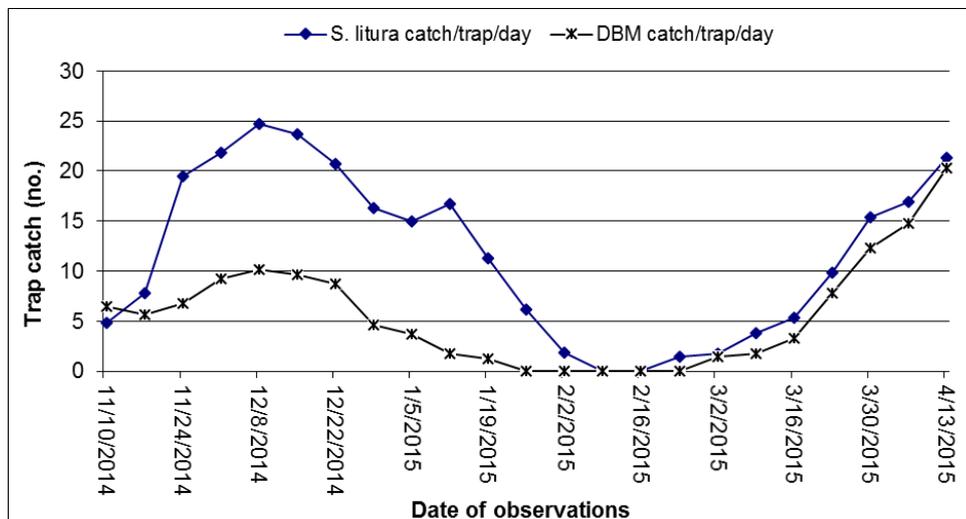
Fig. 1. Population fluctuation of *S. litura* and *P. xylostella* during the study period on the basis of pheromone trap catch.
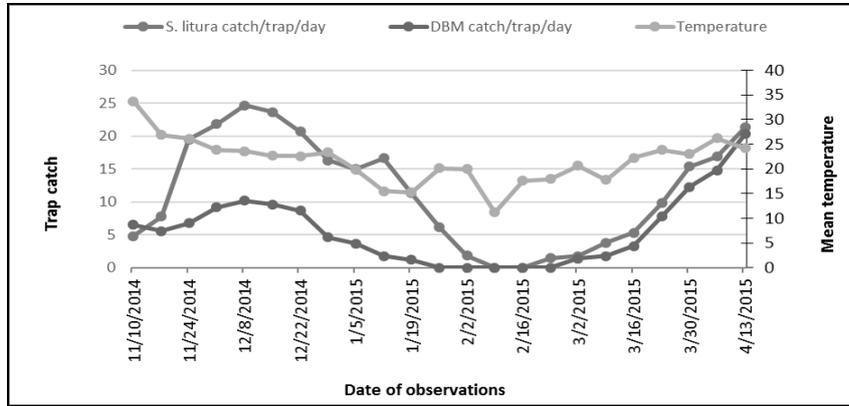
Fig. 2. Population fluctuation of *S. litura* and *P. xylostella* in relation to temperature as these leaf eating caterpillar adults caught by pheromone trap.

There is a positive correlation between temperature rise with the population buildup of both *S. litura* and *P. xylostella* in cabbage (Figure 3 & 4).
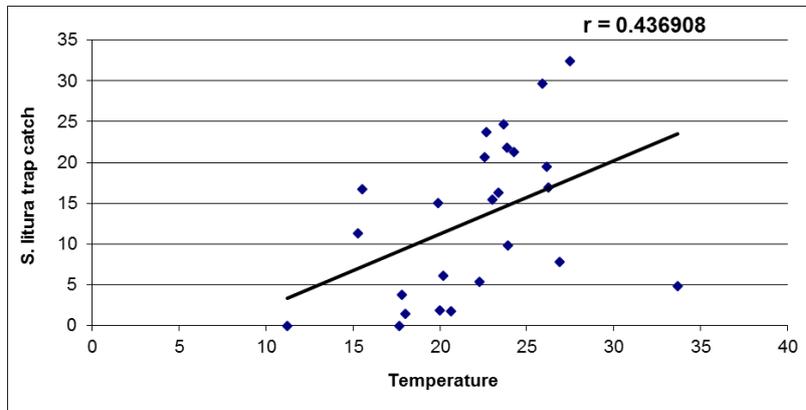

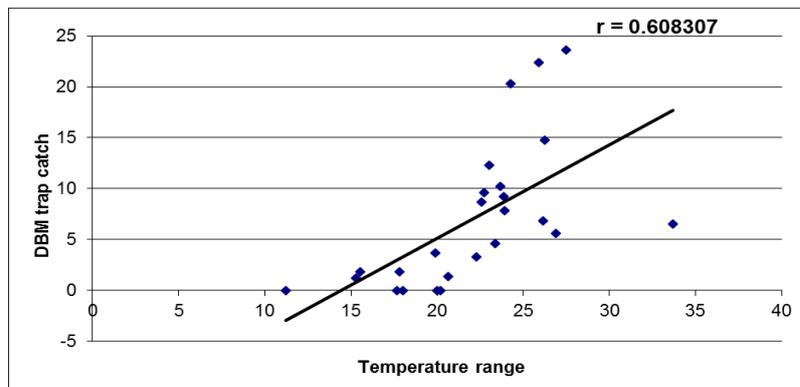**Fig. 3. Correlation between *S. litura* trap catch with the increase of temperature.**

Fig. 4. Correlation between *P. xylostella* trap catch with the increased temperature.

B. Discussion

Our studies showed that the incidence of leaf-eating caterpillar *Plutella* larvae was lowest in the month of November and January and the highest population was found in the month of September and March. Similarly, Ahmed *et al.* (2015) revealed that the highest population of larvae per cauliflower plant was recorded in September and the lowest was observed in July. The population of the *P. xylostella* showed flare up in the month of August and September (Ahmed and Ansari, 2010).

Our findings were in conformity with the reports of Hasanshahi *et al.* (2013) who reported that *P. xylostella* population appears at the beginning of the cauliflower season and shortly after transplantation of the seedlings in the field. Patra *et al.* (2013) stated that *P. xylostella* attacked the crop about one month after transplanting in the field. There was a gradual increase in the population density of *S. litura* after transplantation. It was found that *P. xylostella* was available in the field from July to November (cropping season) with a mean temperature range of 37˚C (max.) in July to 7˚C (mini.) in November, thus indicating that it can survive in a wide range of temperatures (Mohammed *et al.*, 2004). Liu *et al.* (2000) stated that *P. xylostella* remained active throughout the year in China at a daily minimum temperature in January below 2˚C to a daily maximum temperature in July rises above 35˚C. *P. xylostella* is distributed in the wide range of temperature from the tropics to cool regions all over the world (CAB International, 2000). Lower relative humidity, higher temperature and lower total rainfall, seem to favour *P. xylostella* population build up (Hemchandra and Singh, 2007). Thus, our result indicate that temperature showed positive correlation with population buildup of *S. litura* and *P. xylostella* in cabbage. Likewise, Venkateswarlu *et al.* (2011) reported that among different climatic tools, the maximum and minimum temperature had a significant positive correlation whereas percent relative humidity showed significant negative correlation with *P. xylostella* population.

Fund *et al.* (2015) revealed that the development rate as a function of temperature increased linearly for all the immature stages of *S. litura* until approximately 34–36°C, after which it became nonlinear. Seasonal abundance of diamondback moth recorded on cabbage in India revealed that the infestation of diamondback moth (larva) was first recorded on 31 January with an initial population of 0.20/plant. The population increased gradually in successive weekly counts and reached a peak of 12.05/plant on 27th March and thereafter (Goudegnon *et al.*, 1999). They also observed that diamondback moth population attained its peak during February and March. The maximum population of diamondback moth in the month of March was also reported by Kumar *et al.* (2007), Vanlaldiki *et al.* (2013) and Venkateswarlu *et al.* (2011) which are in agreement with the present findings. Temperature is recognized as the most important environmental factor influencing development and survival of insects. The relationship between

temperature and development of *P. xylostella* has also been studied in other countries (Shirai, 2000; Liu *et al*., 2002; Mohandass and Zalucki, 2004; Golizadeh *et al*., 2008). In our studies, we also found that temperature is one of the most important factor for development of both *S. litura* and *P. xylostella* populations. The highest population of both *S. litura* and *P. xylostella* per plant was recorded during September and March and the lowest was found November and January with a mean temperature range of 34°C in September to 15°C in December. In addition, pheromone trap results showed that the population of leaf-eating caterpillars increased when temperature was high moreover the population declined beyond temperature 15°C, consequently, indicates that it can persist in a wide range of temperature.

It can be concluded that the attack of both *S. litura* and *P. xylostella* in cabbage commenced during the first week after transplantation of cabbage seedling. The lowest population of both *P. xylostella* and *S. litura* larvae per plant was found on November to December whereas highest population per plant was recorded during October and March and the highest infestation was recorded from November and March. A positive correlation was observed between the populations of *P. xylostella* and *S. litura* and temperature. The influence of temperature on development and survival of the diamondback moth may affect the population dynamics of the pest.

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RESIDUAL BEHAVIOUR OF IMIDACLOPRID IN THE COUNTRY BEAN GROWING SOIL

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Abstract

The assessment of residual behavior of imidacloprid (Admire 20SL) in the soil of country bean agroecosystem and its risk assessment for consumption was studied. QuEChERS method was used for the extraction and clean-up of samples and the residues of imidacloprid was estimated using Gas Chromatography. The dissipation studies in the soil system were carried out by application of imidacloprid at five different dosages i.e. 100, 200, 300, 400, and 500 g a.i. ha^{-1}. Average initial deposits of imidacloprid were found to be 0.99, 1.33, 1.62, 1.83 and 2.20 mg.kg^{-1}. The residues reached below determination limit (BDL) of 0.01 mg kg^{-1} in 9 days for recommended dose and 12 days for remaining higher dosages. Half-life ($T_{1/2}$)) of imidacloprid in the soil was observed to be 1.88, 1.74, 1.73, 1.56 and 1.52 days for 100, 200, 300, 400, and 500 g a.i. ha^{-1}, respectively. The chemodynamics study of imidacloprid spray indicated that only 27.20 -28.40% sprays were deposited to the target site (plant canopy) and 71.60-72.80% were lost to non-target site such as soil and air. The drift of imidacloprid to soil (39.47-40.20%) was higher than the air (32.13-32.60%). Based on degradation pattern and maximum, the recommended preharvest interval (PHI) might be eight 9 days and a waiting period of two days might be suggested for reapplication of the imidacloprid in country bean agroecosystem.

Keywords: Imidacloprid, residue, soils, country bean agroecosystem.

Introduction

Safe food production depends on a number of factors, including the degradation of persistent chemicals applied in the agroecosystem. As pesticides are the most widespread agrochemicals, their frequent monitoring in agricultural produces and soils in which it was grown is essential (Durovic, 2011). It seems that soil contamination over a long period of time is the biggest problem in terms of food quality and food. The most frequent and harmful contamination of soil is caused by the use of pesticides and fertilizer. The pesticides penetrating the soil undergo chemical reactions and biochemical transformations (Borş et al., 2012). On the other hand, pesticides in the soil or subsoil are absorbed through complex processes such as: transfer of load, ionic exchange, and hydrophobic bonds. Soil particles, by means of clay-humic complex, represent an adequate support for

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both pesticides adsorption and for some of their degradation by products, the adsorptive capacity depending on soil texture (Bors *et al.*, 2012). Biological properties of soils, such as enzymatic activity and the total number of microorganisms in the soil, serve as a tool for assessment of soil quality change under the influence of various agrochemical processes, regarding the state of fertility for the diagnosis and certification of influence of the application of chemical fertilizers and pesticides on the global biological activity of soil (Liste, 2003).

Pesticide residues in agricultural produces are a fast-growing global problem with serious consequences on human health (Asmatullah & Shakoori, 1998). The indiscriminate use of pesticides in Bangladesh has contaminated agricultural produces, waters, aquifers, wildlife, foods and feeds all over the country (Shammi *et al.*, 2017)). Furthermore, irrational use of pesticides has created new pests that have never been a problem before (Haque *et al.,* 2010). In this experiment, the widely-used pesticides in agricultural protection, Imidacloprid was selected. Imidacloprid constitute a family of neonicotinoids pesticides which cover a wide range of uses in the treatment of seed, soil and crops (Nunes *et al.,* 1998). Imidacloprid is in toxicity class II - moderately toxic under the classification of EPA toxicity (Campbell *et al.*, 2004). Although it has low mammalian toxicity, but residue levels in foodstuffs are generally legislated to minimize the exposure of consumers to the harmful or unnecessary intake of pesticides (Zeljezic *et al.,* 2008).

Imidacloprid (I-[(6-chloro-3-pyridinyl)-methyl]-N-nitro-2-imidazolidinimine), is a systemic insecticide that acts as an insect neurotoxin and belongs to a class of chemicals called the neonicotinoids, which act on the central nervous system. Specifically, it causes a blockage of the nicotinergic neuronal pathway. By blocking nicotinic acetylcholine receptors, imidacloprid prevents acetylcholine from transmitting impulses between nerves, resulting in the insect's paralysis and eventual death. It is effective on contact and via stomach action. Because imidacloprid binds much more strongly to insect neuron receptors than to mammal neuron receptors, this insecticide is more toxic to insects than to mammals (Gervais *et al*., 2010). Other uses include application to foundations to prevent termite damage, pest control for gardens and turf, treatment of domestic pets to control fleas, protection of trees from boring insects and in preservative treatment of some types of lumber products (Herms *et al,* 2009).

Imidacloprid as a chloronicotinyl insecticide used to control biting and sucking insects. The insecticide is extremely potent against wide range of arthropods, including aphids, scale insects, whiteflies, pod borers, some heteroptera, coleoptera, and lepidoptera species (Decourtye *et al*., 2004). It is a soil or plant-applied insecticide used in a wide variety crops.

Recent research suggested the widespread agricultural use of imidacloprid may be contributing to honey bee colony collapse disorder, the decline of honey bee

colonies (Chensheng *et al*., 2012 and Whitehorn *et al*., 2012). As a result, many countries have restricted use of imidacloprid and other neonicotinoids (Carrington, 2012). The European Food Safety Authority reported imidacloprid as a neonicotinoid pose an unacceptably high risk to honeybees (EFSA, 2013) and impairs its memory and brain metabolism (Decourtye *et al*., 2004).

The synthetic organic pesticide begins to degrade as soon as they synthesized. Liu *et al.* (2006) reported that imidacloprid was stable in water at neutral and acidic pH and slowly degraded in alkaline conditions. Vegetation also increased the dissipation rate of imidacloprid as well as its half-lives (Anhalt *et al.*, 2007). The breakdown of principle component may be caused by harsh environmental condition, chemical interaction or photolytic reaction (Segura *et al.,* 2008). Therefore, dissipation studies imidacloprid for a given crop in open field conditions of each growing area are necessary to test.

Country bean (*Lablab purpureus* L.) is an important year-round vegetable in Bangladesh. It has wide adaptability among the farmers because of its fast growth, high production with good nutritional quality. It was estimated the cultivated area of country bean in Bangladesh around 48000 ha with yield ranging from 10-12 t/ha (Rashid *et al.*, 2007). The low production of the crop in the country could be attributed to several factors, the most important being the damage caused by the insect pests like Aphid (*Aphis spp.*), Pod borers (*Maruca testularis & Helicoverpa armigera*), Leaf eating caterpillar (*Plusia oricalchea*), Hairy caterpillar (*Spilarctia obliqua*), Green semilooper (*Plusia oricalchea*), Hooded hopper (*Leptocentrus Taurus*), Leaf beetle (*Madurasia obscurella*), Bean bug (*Coptosoma cribrarium*) and Coreid bug (*Leptoglossus* spp*).* Since, Imidacloprid has a wide range action against insect pests, majority of the farmers of Bangladesh use this insecticide indiscriminately. The studies on the behavior of imidacloprid on various commodities like cabbage and cauliflower (Gajbhiye *et al.*, 2004); eggplant (Mandal *et al.*, 2010); corn (Bonmatin *et al.*, 2005); sunflower (Laurent and Rathahao, 2003); soil and water (Liu *et al.*, 2006) have been carried out but no study has been reported on the fate of imidacloprid in the soils of any agroecosystem. Therefore, the present investigation has been planned and designed to carry out in depth study on degradation pattern and risk assessment of imidacloprid in the soils of country bean agroecosystem.

Materials and Methods

The study was conducted during November 2016 to October 2017. Field experiment was done in the Entomological farm and laboratory analysis was done in the pesticide and environmental toxicology laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur. The experimental site is located at Madhupur Tract (24°09' N latitude and 90°26' E longitude) having an elevation of 8.2 m from sea level.

Field experiment: Country bean crop was raised following recommended agronomic practices (Mondal, 2015). Imidacloprid (Admire 20 SL) was applied in the soil during flowering stage of the plant @ 100, 200, 300, 400 and 500 g a.i. ha^{-1} with a control. About 250g soil sample was collected randomly at 0 (1h), 1, 3, 6, 9 and 12 days after the application of the insecticide. The country bean grown soil samples were collected from each plot separately, packed in polyethylene bags and brought to the laboratory for processing. Samples were extracted and cleaned up immediately after sampling.

Chemodynamics study

Determination of Imidacloprid in soil: For determining insecticide application loss in soil, a polythene sheet (2.25 m^2) was initially placed randomly in the 1.5 m^2 plot. Then the foam sheet (1.25 cm thickness) of the same size (weighed) was placed on the polythene sheet to avoid loss of applied insecticide to the ground. Immediately after application of insecticide, the foam was weighed by electric balance. Insecticide application loss in soil was determined by subtracting the initial weight from the final weight of the foam sheet.

Determination of Imidacloprid loss in air: The plots (1.5 m^2) were housed by the polythene sheet. Underside of the roof of the house, 2.25 m^2 foam sheet (weighed) was placed randomly. Immediately after application of insecticide, final weight of the foam sheet was taken by electrical balance and loss of insecticide in the air was measured from the difference between final and initial weight of foam sheet.

Determination of quantity of imidacloprid retained on plant canopy: Quantity of imidacloprid on plant canopy = Total quantity of insecticide applied – (Quantity of Imidacloprid lost in the soil + Quantity Imidacloprid lost in the air).

Preparation of standard solution: A standard stock solution of imidacloprid (1 mg. L^{-1}) was prepared in GC grade acetonitrile. The standard solutions required for constructing a calibration curve (10, 20, 30 ngL^{-1}) were prepared from stock solution by serial dilutions with GC grade acetonitrile. All standard solutions were stored at 4 °C before use.

Instruments: The quantification of imidacloprid residues was done by using Gas Chromatograph (GC) equipped with Electron Capture Detector (ECD), The residues of imidacloprid were confirmed using the standard chromatogram and retention time. The Gas chromatographic conditions are presented in the Table 1.

Table 1. Details of gas chromatographic conditions using in this study

Parameter	: Condition			
Column	: Column name: Rtx-CL pesticide (Sl# 726625) Column Length: 30 m Inner Diameter: 0.32 mm Film thickness: 0.50μm Column Max Temp: 340 ºC			
Column temperature program	: Rate ºC/min	Temperature (ºC)	Hold time (min)	Total Program
	---	220	1.0	9 min
	5	235	5.0	
Oven temperature	: 280 ºC			
Injector temperature	: 280 ºC			
Detector temperature	: 300 ºC			
Gas flow rate	: Nitrogen as carrier, 30 mL min^{-1}			
Injection volume	: 2 μL			

An aliquot was injected into the GC with auto injector. Tentative identification of the suspected insecticide was carried out in relation to retention times of the pure analytical standard.

Sample preparation, extraction and cleanup: A standardized analytical method with slight modification was followed for extraction of imidacloprid residues as reported by Sharma (2013). The soil samples were prepared following QuEChERS method for the determination of imidacloprid residues.

The collected soil samples (250g) were dried under the sun. A sub sample of 10 g of soil was weighed into a 250-mL conical flask and then 20 mL acetonitrile was dispensed into it. The sample was homogenized using high speed homogenizer (Heidolph Silent Crusher-M$^®$) for 2-3 min at 1400-1500 rpm to homogenize soil sample. 4 g MgSO$_4$ and 1 g Sodium chloride (NaCI) was added to homogenize the sample for phase separation. Then the sample solution was covered with parafilm as acetonitrile is volatized in nature. The contents were centrifuged at 3300 rpm for 5 min. An aliquot of 20 ml acetonitrile layer was transferred in a vial and then stored in 4°C. The acetonitrile extract was then subjected to suspension mixture of primary secondary amine (PSA) + MgSO$_4$ to clean up the sample. An aliquot of acetonitrile was transferred into a separatory funnel and n-hexane was added to the aliquot and vigorously shaken for 1 minute. The layers

were allowed to separate. Then acetonitrile was drained out and n-hexane remained in the separatory funnel. Then sulfuric acid was added to hexane so that microorganisms were killed. After 1-1.5 minutes, sulfuric acid drained out of the separatory funnel and distilled water added to the hexane to remove sulfuric acid from the aliquot. The aliquot was drained out through the bed of anhydrous sodium sulphate with a filter paper.

Estimation by Gas Chromatograph

An injection volume of 2 µL was used in all the experiments. Residues of imidacloprid were quantified by comparison of peak height/peak area of standards with that of unknown or spiked samples run under identical conditions. Under these operating conditions the retention time of imidacloprid was found to be 8.295 min (Fig. 1).
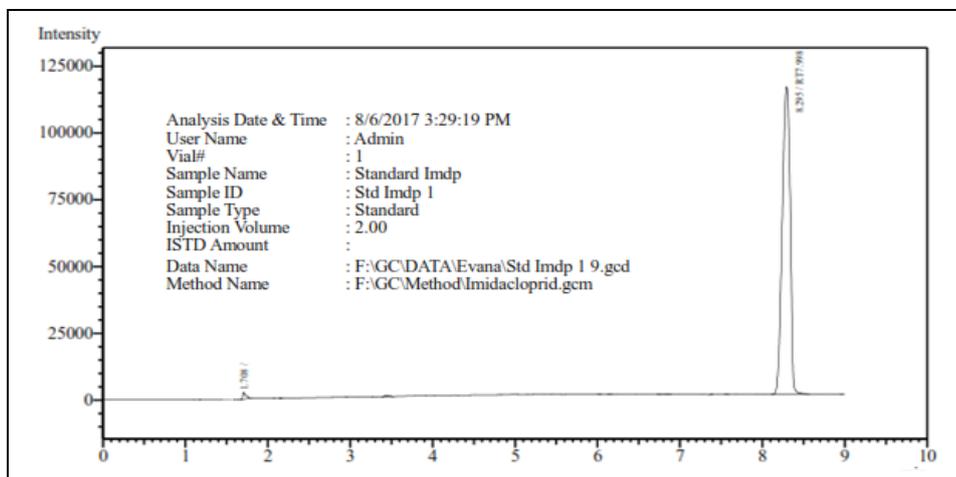

Fig. 1. Chromatogram of Imidacloprid insecticide standard.

Half-life of imidacloprid on country bean grown soil: The persistence of this insecticide is generally expressed in terms of half-life ($T_{1/2}$) or DT_{50} i.e. time for disappearance of pesticide to 50% of its initial concentration. The dissipation of imidacloprid on country bean soil follow first order kinetics. The Half-life value ($T_{1/2}$) is usually defined as the time required for half of the given quantity of material to dissipate (Gunther and Blinn, 1955). Half-life ($T_{1/2}$) of imidacloprid calculated by fitting first order kinetics as per Hoskins (1961) as

$$C = C_{0}.e^{-kt} \text{ ----------------------------- (1)}$$

$$T_{1/2} \text{ or } DT_{50} = ln\ 2.k^{-1} \text{ --------------(2)}$$

Where C is the chemical concentration (mg.kg^{-1}) at time t (days) and C_0 is the initial concentration (mg.kg^{-1}), K is the first order kinetic constant at (day^{-1}) independent of C and C_0. The Half-life value ($T_{1/2}$) was calculated using equation (2) with the obtained kinetics (K) from equation (1).

Results and Discussion

Method development and validation: The recovery studies were carried out at different levels to establish the reliability and validity of analytical method and to know the efficacy of the procedures. The average recoveries of the imidacloprid from country bean soil samples at fortification level 0.01 to 0.10 mg.kg^{-1} ranged from 85.27 to 90.57% (Table 2). The average recoveries values were found to be more than 85%. Therefore, the results have been presented as such without converting by any correction factor. The precision of the method was determined by repeatability studies of the method and expressed by RSD values (relative standard deviation).

Table 2. Recovery and repeatability (RSD) of imidacloprid on country bean grown soil at different levels

Insecticide	Level of fortification (mg.kg^{-1})	Mean[a] recovery (%)	SD	RSD
	0.10	90.57	1.57	1.63
Imidacloprid	0.05	85.27	1.48	1.72
	0.01	87.38	1.55	1.75

The RSD for repeatability, ranged from 1.63 % to 1.75 % different spiking levels as shown in Table 2. The quantification was accomplished by calibration curve prepared by diluting the stock solution. The assessment of linearity was done by statistical data obtained with correlation coefficient of 0.9989 (Fig. 2). Limit of quantification (LOQ) was found to be 0.01 mg kg^{-1} and limit of detection (LOD) being 0.003 mg.kg^{-1}. The cleaned-up procedure for this methodology was found to efficient since no significant matrix effect was observed.
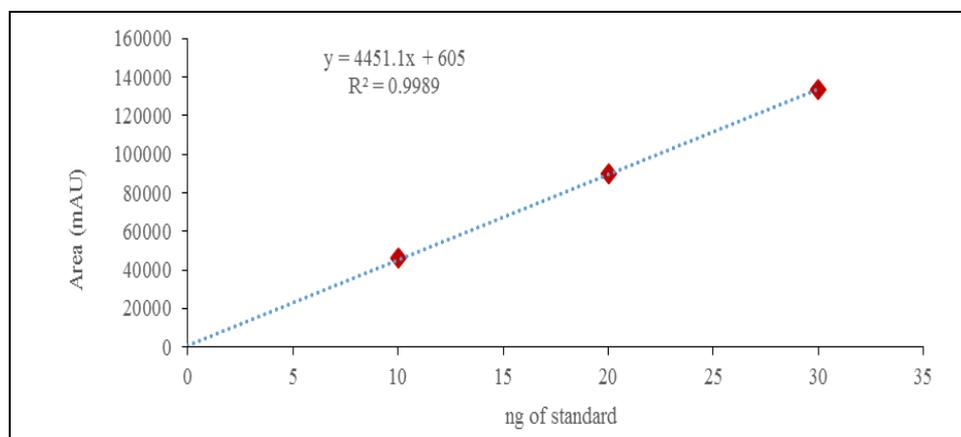

Fig. 2. Calibration curve of different concentrations of imidacloprid.

Persistence of imidacloprid in soils of country bean agroecosystem: Average initial deposit of imidacloprid were found to be 0.99, 1.33, 1.62, 1.83 and 2.20 mg.kg^{-1}, following application @ 100, 200, 300, 400 and 500 g a.i. ha^{-1}, respectively. The mean initial residues were reduced to more than 57% on one day. These residues were further reduced to more than 56% and 67% on 3rd day and 6th day, respectively.

Table 3. Residues of imidacloprid (mg. kg^{-1}) in soil at different intervals and doses

Days after treatment	100 g a.i. ha^{-1}	200 g a.i. ha^{-1}	300 g a.i. ha^{-1}	400 g a.i. ha^{-1}	500 g a.i. ha^{-1}
0 (1 hour after spray)	0.99±0.125	1.33±0.141	1.62±0.097	1.83±0.069	2.20±0.090
1	0.43±0.080 [a](57.15)	0.53±0.061 (60.03)	0.65±0.043 (61.03)	0.67±0.028 (64.00)	0.77±0.090 (65.05)
3	0.19±0.012 (56.06)	0.21±0.011 (60.70)	0.22±0.010 (65.35)	0.24±0.012 (63.95)	0.30±0.016 (61.31)
6	0.05±0.002 (72.47)	0.06±0.004 (69.75)	0.07±0.005 (69.22)	0.08±0.003 (67.42)	0.08±0.004 (72.50)
9	[b]BDL (100.00)	0.06±0.007 (90.15)	0.07±0.003 (60.28)	0.08±0.003 (60.40)	0.08±0.003 (56.31)
12	BDL (100.00)	BDL (100.00)	BDL (100.00)	BDL (100.00)	BDL (100.00)

[a] () Percentage dissipation after spraying, [b] BDL = Below determination limit (<0.03 mg kg^{-1})

The residues reached below determination limit of 0.03 mg kg^{-1} at 9 days following application of imidacloprid @ 100 g a.i. ha^{-1}. Imidacloprid residues were also found to be below the determination limit of 0.03 mg kg^{-1} in 12 days and thereby showing 100% loss following application of imidacloprid at all the dosages (Table 3).

The above findings revealed that higher rate of application of imidacloprid resulted in higher initial deposits. As with other insecticides, the residues of imidacloprid on country bean cultivated soil declined with time and fairly high rate of dissipation was observed. The results are in agreement with those of Zhang *et al.* (2012) who reported the fate of imidacloprid in rice field ecosystems after application @ 300 mL a.i. ha^{-1}. The residues of imidacloprid on rice straw were 3.16, 1.59 and 1.20 mg kg^{-1} after 2 h, 8 h and 1 day, respectively. In rice straw, 0.008 mg kg^{-1} imidacloprid was found even in 20 days after the application of pesticide.
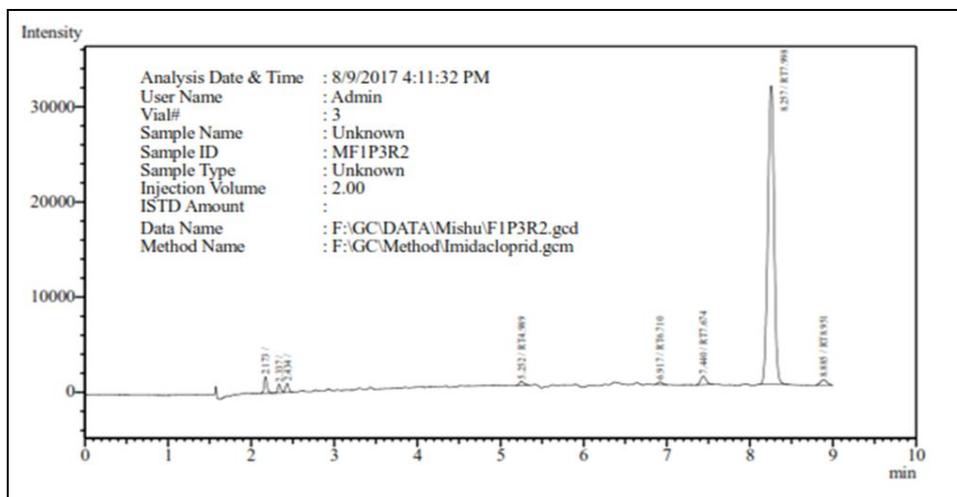
Fig. 3. Chromatogram of dissipation kinetics of imidacloprid in soil of country bean agroecosystem after 1 DAT.

Similarly, Malhat *et al.* (2012) reported the imidacloprid residues on tomato soil after application of imidacloprid 20% SC @ 60 ml. per feddan (1 feddan = 4200 m^2). The concentration of imidacloprid 2 h after treatment was 2.308 mg kg^{-1}. These residues were below determination limit of 0.03 mg kg^{-1} at 11 days after the application of pesticide. Malhat *et al.* (2012) also reported the residues of imidacloprid on grape soil after application of imidacloprid formulation at same dose. But, the initial deposit (1 h after application) of imidacloprid was found 2.829 mg. kg^{-1}. The residue of imidacloprid dissipated to 99.09% at 11 days after the application of pesticide. These residues were dissipated in grapes to undetectable limits in 12 days after last treatment. Kar *et al.* (2013) studied the environmental fate of imidacloprid residues on cauliflower curds following 3rd application of imidacloprid (Coragen 18.5 SC) @ 9.25 and 18.50 g a.i. ha^{-1}. The mean initial deposits of imidacloprid were 0.18 and 0.29 mg kg^{-1} on the curds at recommended and double the recommended dosages, respectively. These residues reached below the determination limit of 0.01 mg kg^{-1} in 3 and 5 days, respectively.

Degradation pattern & Half-life of imidacloprid on country bean grown soil: The degradation kinetics of the imidacloprid in the soils of country bean agroecosystem was determined by plotting residue concentration against time, and the maximum squares of correlation coefficients found were used to determine the equations of best fit curves (Fig. 4). The calculated Half-life value ($T_{1/2}$) were found 1.88, 1.74, 1.73, 1.56 and 1.52 days, respectively when applied @ 100, 200, 300, 400 and 500 g a.i. ha^{-1} (Table 4).
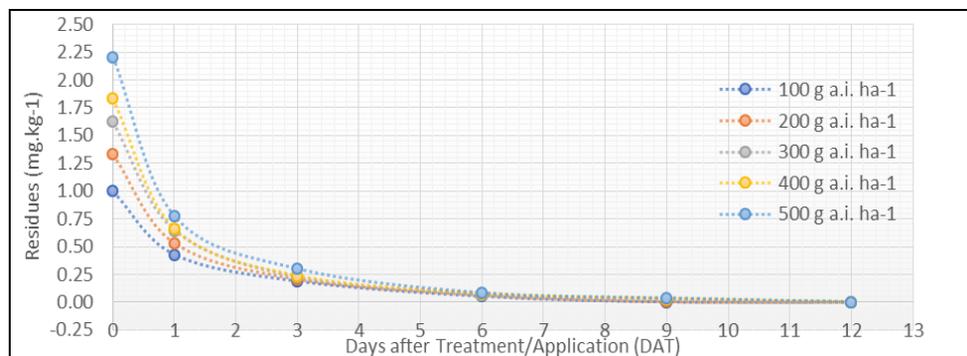
Fig. 4. Semi-logarithm graph showing dissipation kinetics of imidacloprid on country bean grown soil.

Half-life ($T_{I/2}$) of imidacloprid on cauliflower curds worked out to be 1.36 and 1.25 days, respectively when applied @ 9.25 and 18.50 g a.i. ha' (Kar *et al.*, 2013). The dissipation rate of imidacloprid on tomato soils followed first order kinetics.

Table 4. Regression analysis and half-life for the dissipation of imidacloprid

Dose (g a.i. ha^{-1})	Regression equation (Y)	Half-life (days)	Correlation coefficient (R^2)
100	-0.0659x + 0.6185	1.88	0.6375
200	-0.0855x + 0.7989	1.74	0.6048
300	-0.1029x + 0.9636	1.73	0.5895
400	-0.1132x + 1.0574	1.56	0.5652
500	-0.1357x + 1.2659	1.52	0.5617

The half-life of imidacloprid on tomato fruit was 3.30 days after application of imidacloprid 20% SC @ 60 mL per hm^{-2} and also reported half-life of imidacloprid in grapes (Malhat *et al.*, 2012). The half-life of imidacloprid in grapes was found to be 2.70 days. The half-life of imidacloprid in rice straw was 3.50 days following application of imidacloprid @ 300 mL a.i. hm^{-2}. The kinetics of imidacloprid was described by the equation $C=1.171e^{-0.198t}$ with R=0.902 (Zhang *et al.*, 2012).

Chemodynamics of Imidacloprid spray in country bean agro-ecosystem: Results revealed that deposition of imidacloprid spray volume on plants at different doses was not varied significantly (Table 5). During application

imidacloprid was not only received by the plants but also it was drifted to other non-target sites, mainly in the air and soil.

Table 5. Fate of Imidacloprid spray volume in country bean agroecosystem

Doses (mL/L/Plant)	Imidacloprid Deposited on plant (%)	Imidacloprid lost (%)	
		Air	Soil
1.00	27.20±1.21	32.60±0.95	40.20±0.36
2.00	28.40±2.03	32.13±1.03	39.47±1.15

The results also indicated that the rate of imidacloprid deposit, out of the target site varied differently. The percentage (%) loss of Imidacloprid in air was much lower than that of soil. But their loss was not greatly differed with different doses of application. Loss of applied imidacloprid through drifting to the air and soil at maximum mature stages of country bean was found as 32.13-32.60% and 39.47-40.20%, respectively. Loss of sprayed imidacloprid in soil through drifting was higher than the air and target site (plant canopy).

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ROLE OF INSECT POLLINATORS AND PESTS ON THE YIELD AND SEED QUALITY OF EGGPLANT (*Solanum melongena* L.)

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Abstract

The research work was conducted in the experimental field of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur to identify the insect pollinators abundant in eggplant field, and to know the effect of insect pollinators and pests on the yield and seed quality of the crop. Eggplants were cultivated in three conditions viz., open, enclosed in net without supplemented insect pollination, and enclosed in net with supplemented insect pollination. In total 8 species of insects belonged to 6 families in 3 orders were found as pollinator on eggplant and their abundance varied from 0.6±0.1 to 1.6±0.3 /30 sweeps. Among the pollinator insects, ant showed the highest abundance and longest foraging duration per flower. The plant infestation among the treatments varied from 2.6±2.6 to 12.8±1.6% and the highest and the lowest levels were observed in open condition and enclosed condition respectively. The fruit infestation ranged from 11.3±1.6 to 43.7±3.0% and the highest infestation was observed in open condition. Insect pollination produced the higher number of fruits per plant (14.4±0.4/plant) as well as larger fruits (length: 27.6±0.7 cm and breadth: 11.6±0.2 cm), and thus produced higher yield (11.6±0.4 tha^{-1}) and higher germination (82.0± 2.5%) of seeds.

Keywords: Eggplant fruit, insect species, foraging, infestation, germination.

Introduction

Eggplant (*Solanum melongena* L.), also called aubergine or brinjal is one of the top ten vegetables in the world. It grows throughout the year in Bangladesh and also adapted to high rainfall and high temperature (Hanson *et al*., 2006). The average yield of brinjal in Bangladesh is 9.1 tha^{-1} and the annual production area and amount of production are 49.4 thousand ha and 450.2 thousand tons, respectively (BBS, 2016). There are diversified insects present in eggplant field which are categorized as pest, predator, parasitoid and pollinator. In the tropics, eggplant production is severely hampered by several insect and mite pests. The major insect and mite pests include shoot and fruit borer, leafhopper, whitefly, thrips, aphid, spotted beetles, leaf roller, stem borer, blister beetle, mealy bug and mite which cause 20 to 60% yield loss (Roy and Pande, 1994).

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Insect pollinators help in transferring pollen from anther to stigma within a flower or between flowers of the same plant or different plants of the same species. Pollination is a key driver in the maintenance of biodiversity and ecosystem function. Insects pollinate about 80% of flowering plants, and assisted pollination is necessary when natural pollination is insufficient (Klein *et al*., 2007).

Eggplants bear flowers with abundant pollen that can only be dispersed through small orifices in the anthers. Eggplant flowers are hermaphroditic and are capable of some self-pollination (Free, 1993), but the process of expelling pollen from these flowers onto female flower parts requires shaking either by wind or by the action of insect visitors.

Honeybee *Apis mellifera* visitation has been shown to significantly increase fruit weight in eggplant (Levin, 1989). Some bee species can expel and efficiently harvest pollen from flowers with poricidal anthers by vibrating their bodies while in contact with the stamen, effecting a process termed ''buzz pollination'' (Buchmann, 1983). Honeybees are not able to effectively buzz pollinate, so it is likely that wild insect visitors that are capable of handling flowers in this way could be even more effective in accessing pollen from poricidal anthers and effectuating pollination (Kearns and Inouye, 1997). Moreover, eggplant flowers produce no floral nectar and bees that pollinate eggplant may be expected to depend on other sources of nectar nearby (Free, 1993).

Many horticultural crops are dependent on insect pollinators for optimal yields (Klein *et al.,* 2007). Anthropogenic disturbances including habitat modification and fragmentation cause declines in pollinator abundance and diversity. To operate the concept of ecosystem services in a practical sense, it is important to link research findings to the land-use decisions of the farming community. Therefore, this study was undertaken to identify the insect pollinators associated with eggplant using variety BARI Begun-8 and their impacts on yield and seed quality.

Materials and Method

The study was conducted during March to August, 2016 in the Field Laboratory of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh. The soil of the study site is silt clay in texture belonging to Salna series. The area represents the agro-ecological zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, cation exchange capacity of 25.6 and C:N ratio of 3:1 (Haider *et al.,* 1991).

Study location and climatic conditions: The study site (BSMRAU, Gazipur) is located at 25°25′ North latitude and 89°5′ East longitude, which is in the middle of Bangladesh.The study area has a subtropical *climate having* mean maximum and minimum temperaturesof 36.0 ℃ and 12.7 ℃, respectively, and relative humidity and average annual rainfall were 65.8% and 237.6 cm, respectively.

Collection of eggplant seeds and cultivation of crop: Seeds of eggplant varietyBARI Begun 8 were collected from the Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. Seeds of eggplant were sown on 2March, 2016 in polythene bags. For transplanting seedlings, plots having 3.0 m ×3.0 mfollowed by randomized complete block design were used. Eggplant seedlings were transplanted 60 cm apart on 21March2016, in rows. The distance fromrow to row was1.0 m. Each plot has three rows and each row contained 5 plants.Fertilizers were applied according to Fertilizer Recommendation Guide (FRG, 2012) (N- 80 kg, P- 24 kg, K- 60 kg, S- 10 kg per hectare). Intercultural operations such as irrigation and weeding were done whenever necessary.

Effect of pollinators on fruit set: To determine the effect of wind and insect pollinators on fruit set, three types of treatments were adopted on the experimental plots. The adopted treatments were (i) open plot (wind and wild insect pollination), (ii) enclosed plot (covered with mosquito net)having25supplemented insect pollinators (black ant, honeybee and house fly) per week, and (iii) covered plot (covered with mosquito net) without supplemented pollinators. Each treatment was replicated three times.

Collection of insect and identification of pollinators: Free-living insects were collected from flower initiation to fruit maturation stage using a 30 cm diameter sweep net having 1.5 mm mesh, and attached with a 2 m long rod. Every week sweeping was done in between 09:00 to 11:00 h of the day, and each sample was consisted of 30 sweeps. The collected insects werebrought to the Entomology Laboratory of BSMRAU for identification and counting. They were killed by storage in a freezer for a few hours, mounted on points, dried and morphotyped. Insect pollinators were identified to species following morphological characters and comparing with museum specimens.

Observation of insect abundance and foraging behavior of pollinators: Landing duration (length of foraging time on a flower) of the insect pollinators on eggplantflowerswere measured using a stop watch. Observations were donein between 10:00 to 13:00 h of the day and data were recorded 7 times for each pollinator species.

Observation of plant and fruit infestation: During the study, plants were regularly monitored to record their infestation level by different chewing and sucking insects. Infested plants were recorded by observing the symptoms on shoot and leaves and then percent infested plant was calculated. During fruiting, field inspection was done daily to observe the infestation of the fruits by shoot and fruit borer. The damaged and undamaged fruits were counted and percentage of fruit infestation was calculated on number basis.

Observation of the number of fruit per plant and quantifying yield: Systematic sampling was done to count the number of fruit per plant. In this

strategy, the plants in the third row of each plot were marked to collect data of the number of fruits produced per plant. Every harvesting date, number of fruits collected from the respective plants was recorded. Marketable and infested fruits of each plot were harvested and weighed using a digital balance (CANRY, China). The yield (kgunit area^{-1}) of each plot was converted to tha^{-1}.

Germination test: For this purpose, 5 mature fruits were randomly collected from each treatment and the seeds of the fruit were separated. Sixty seeds from each treatment were randomly selected and these were kept for germination test. Trays, each 30 cm × 30 cm × 5 cm (L × W × D), was used for this purpose. A single sheet of paper was placed in the bottom of each tray to cover drainage holes. Each tray was filled with clean and moist sandmixed soil and 20 seeds were sown in 5 rows of 4 seeds. Seeds were sown at the normal seeding depth of 3 cm and werewatered every alternate day. Only healthy seedlings were counted after 7 days when the majority of seedlings were emerged. Diseased, discolored, or malformed seedlings were excluded from counts. The total number of healthy seedlings for each treatment was used to determine germination percentage.

Statistical analysis: One way analysis of variance (ANOVA) followed by Tukey posthoc statisticwas employed for analyzing the data. All the analyses were performed using IBM SPSS 21.0. (IBM SPSS statistics 21, Georgia, USA).

Results and Discussion

The present study showed that8 species of insects belonged to 6 families under 3 orders (Hymenoptera,Lepidoptera and Diptera) were found as pollinators andtheir abundance varied from 0.6±0.1 to 1.6±0.3/30 sweeps (Table 1) and the results differed significantly ($F_{5, 160} = 4.2$, $p < 0.005$). Theblack ant showed the highest abundance (1.6±0.3)and syrphid fly, sulphur butterfly and wasp showed the lowest abundance (0.6±0.3 and 0.7±0.1, respectively) and they were statistically similar.

Vergara and Badano (2009) reported 12 species of insect pollinators in eggplant field and Sung *et al.* (2006) reported that the honey bees (*Apiscerana* and *A. mellifera*) were the major pollinators in the eggplant field followed by allodapine bee (*Braunsapishewitti*) and sweat bees (*Halictus*sp. and *Lassioglossumspp.*). The present findings differed with Sung *et al.* (2008) due to geographical location, climatic condition and surrounding cropping pattern.

Foraging duration of the major abundant pollinators, presented in Fig. 1, ranged from 10.7 ± 0.9 to 22.4 ± 1.7 seconds per flower and the results differed significantly ($F_{5, 42}$=5.1, $p< 0.05$). Ant spent the longest time per flower followed by wasp, honeybee, sulphur butter fly and house fly.The syrphid fly foraged for shortest duration. This study indicated that syrphid fly and ant are the most rapid and sluggish fliers,respectively. Saeed *et al.* (2008) observed the syrphid fly as a rapid visitor of loquat flowers. Amin *et al.* (2015) observed that the syrphid fly

and house fly were rapid fliers on mango flower compared to sulphur butterfly and wasp.

Table 1.Insect pollinators along with their relative abundance in eggplant field

Pollinator	Taxonomic profile	Abundance
Honey bee	*Apis mellifera* (Hymenoptera: Apidae)	0.9±0.2 ab
Wasp	*Vespa vulgaris* (Hymenoptera: Vespidae)	0.7±0.1 b
Sulphur butterfly	*Colias eurytheme* (Lepidoptera: Pieridae)	0.6±0.3 b
Black ant	*Formica rubra* (Hymenoptera: Formicidae)	1.6±0.3 a
	Camponotus compressus (Hymenoptera: Formicidae)	-
	Solenopsis geminate (Hymenoptera: Formicidae)	-
Syrphid fly	*Syrphus*sp. (Diptera : Syrphidae)	0.6±0.1 b
House fly	*Musca domestica* (Diptera: Muscidae)	1.0±0.2 ab

Data expressed as mean ± SE. Mean of each pest was taken from 30 sweeps per total collection. Means in the column followed by same letter(s) are not significantly different by Tukey HSD posthoc statistic at < 0.05.
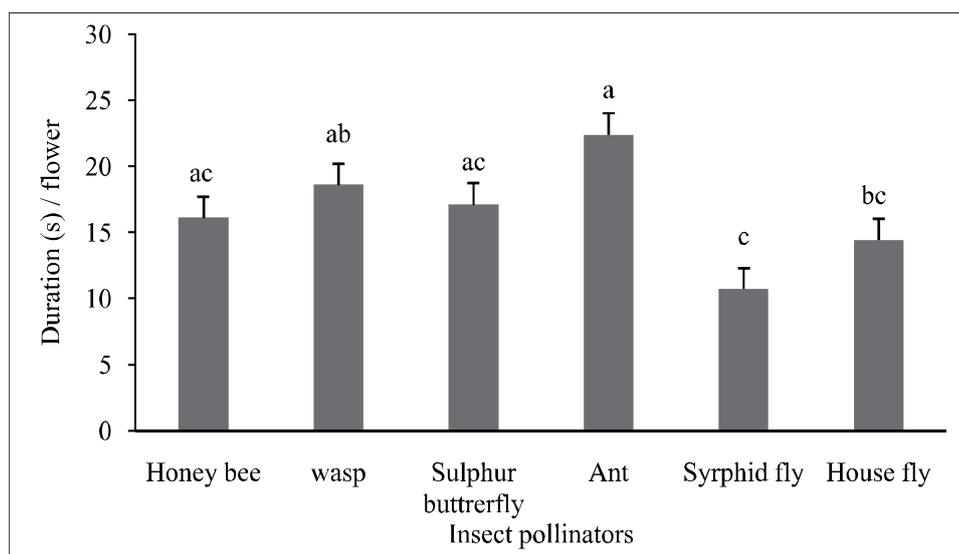
Fig. 1. Foraging duration (mean ± SE) of different insect pollinators visited eggplant flowers. Bars with common letter(s) are not significantly different by Tukey posthoc statistic at P < 0.05.

Significant differences were found in the level of plant infestation by insect pests when cultivated in enclosed and open conditions ($F_{2, 6}$ = 6.9, P < 0.05, Fig. 2). Plant infestation level varied from 2.6±2.6 to 12.8±1.6% and the highest and the lowest levels were observed in open condition and enclosed condition,

respectively. Percent fruit infestation ranged from 11.3±1.6 to 43.7±3.0 and the results differed significantly ($F_{2, 42}$ = 66.0, P < 0.001, Fig. 3). Percent fruit infestation was the highest in natural pollination condition. In enclosed condition, net hindered the entrance of shoot and fruit borer moth, red pumpkin beetle, epilachna beetle and other small to medium size insects thus resulted lowest level of plant and fruit infestation. In this condition, only minute insects like aphid, jassid and thrips entered and caused infestation. In insect pollination condition, pollinator insects (black ant, honeybee and house fly) were released 7 times when the minute insects as well as some medium size insects entered accidently and they caused infestation. In natural pollination condition, plants received benefit from insect pollinatiors but all the pests in the field were free to cause infestation in the suitable parts of the plant. El-Shafie (2001) recorded 28 species of insects were associated with damage on the reproductive parts (flower buds and fruits), 3 species were responsible for the damage of stem and roots, while 18 species were notorious for their occurrence as foliage pests of brinjal.

Fig. 2. Percent plant infestation by different chewing and sucking insects in different cultivation condition. Data expressed as % mean ± SE. Bars with common letter(s) are not significantly different by Tukey posthoc statistic at P < 0.05.

Insects, the biotic components of the environment are very potential interacting factors in the crop field. Their activity directly affects plant growth, productivity, and quality of the yields. Present study showed that pollination condition had significant effect on the number of fruit production of eggplant ($F_{2, 42}$ = 64.9, P < 0.001, Fig. 4). Fruit production in different pollination conditions varied from 7.2±0.4 to 14.4±0.4fruits plant[-1].Plants which were cultivated under enclosed with supplemented insect pollinators produced significantly the higher number of fruit compared to other two conditions (Fig. 4).
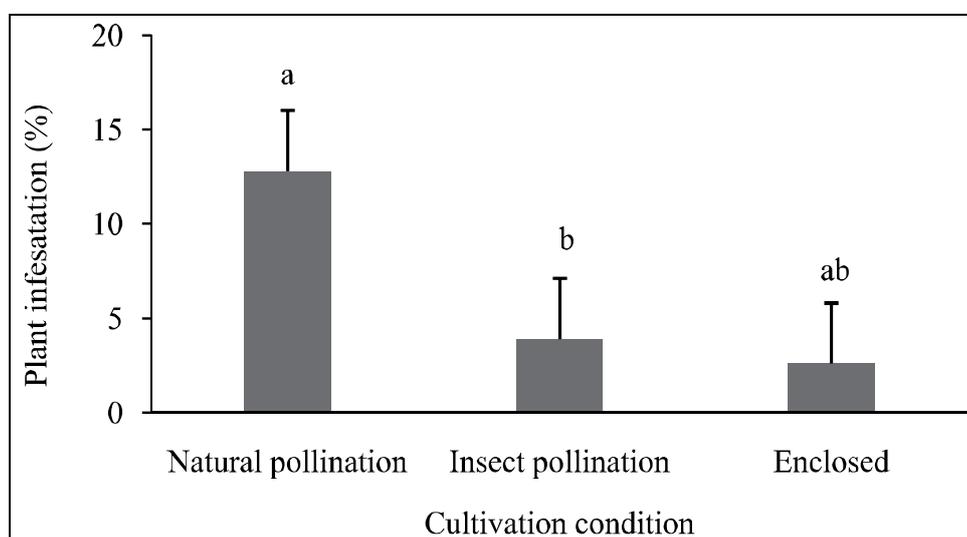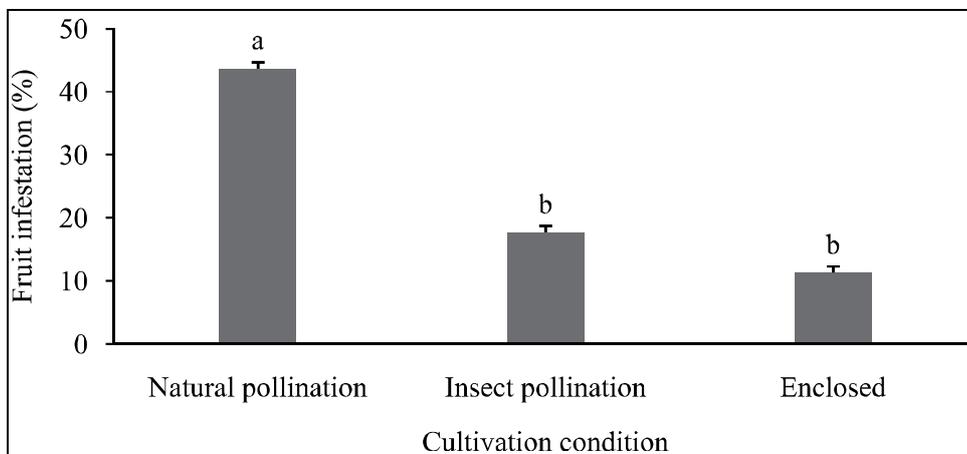
Fig. 3. Percent fruit infestation by different chewing and sucking insects in different cultivation condition. Data expressed as % mean ± SE. Bars with common letter(s) are not significantly different by Tukey posthoc statistic at P < 0.05.
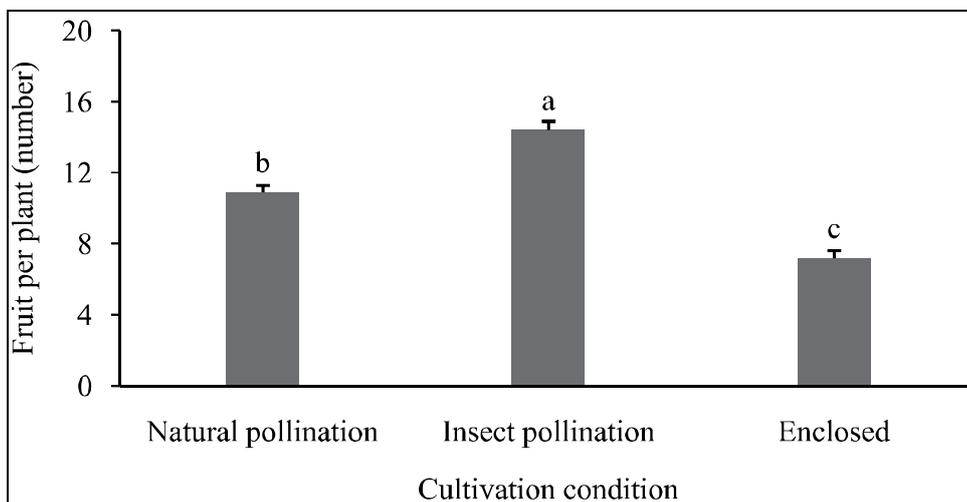
Fig. 4. Effect of pollination on the number of fruit production of eggplant. Data expressed as mean ± SE. Bars with common letter(s) are not significantly different by Tukey posthoc statistic at P < 0.05.

Significant different length and breadth of eggplant fruits were produced when cultivated natural pollination, insect pollination in enclosed condition (length: $F_{2, 27}$ = 9.3, P < 0.01; breadth: $F_{2, 27}$ = 4.6, P < 0.05; Fig. 5). Results showed that the fruit length and breadth ranged from 23.5±0.8 to 27.6±0.7 cm and 11.0±0.1 to 11.6± 0.2 cm, respectively.Fruit length and breadth were recorded the highest in insect pollinated condition. In enclosed with supplemented condition, there were sufficient insect pollinators and wind flew across the plot thus flowers received sufficient pollination. At the same time plants were protected from the attack of

insect infestation. In this condition, plants were healthy and vigorous and they produced higher number of fruits per plant as well as larger and heavier fruits. On the contrary, plants did not receive proper pollination in the enclosed condition devoid of insect pollinators and produced significantly lower number as well as smaller fruits. Farjado *et al.* (2008) reported that introduction of bee colonies in eggplant field significantly increase fruit setting and yield.

Fig. 5. Effect of pollination on the fruit size (length and breadth) of eggplant. Data expressed as mean ± SE. Bars with common letter(s) are not significantly different by Tukey posthoc statistic at P < 0.05

Fig. 6. Effect of pollination on the yield of eggplant. Data expressed as mean ± SE. Bars with common letter(s) are not significantly different by Tukey posthoc statistic at P < 0.05.

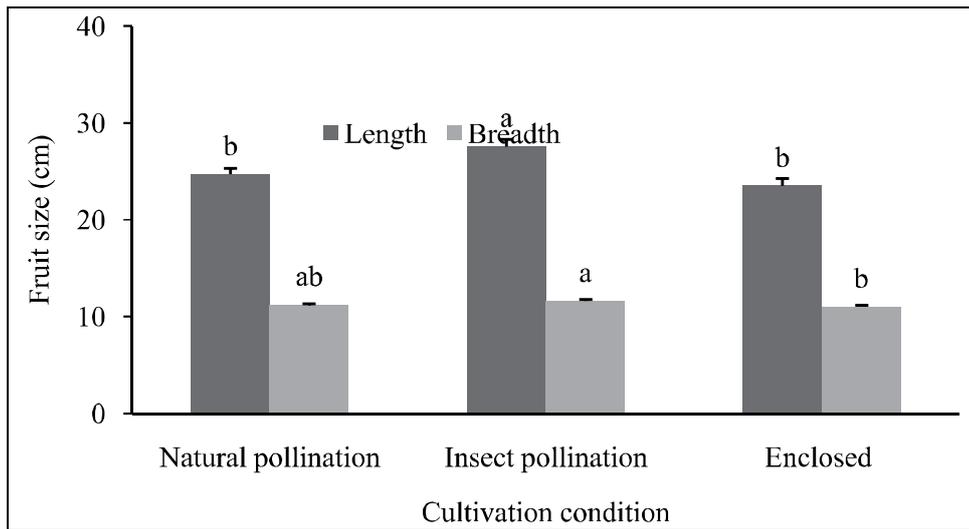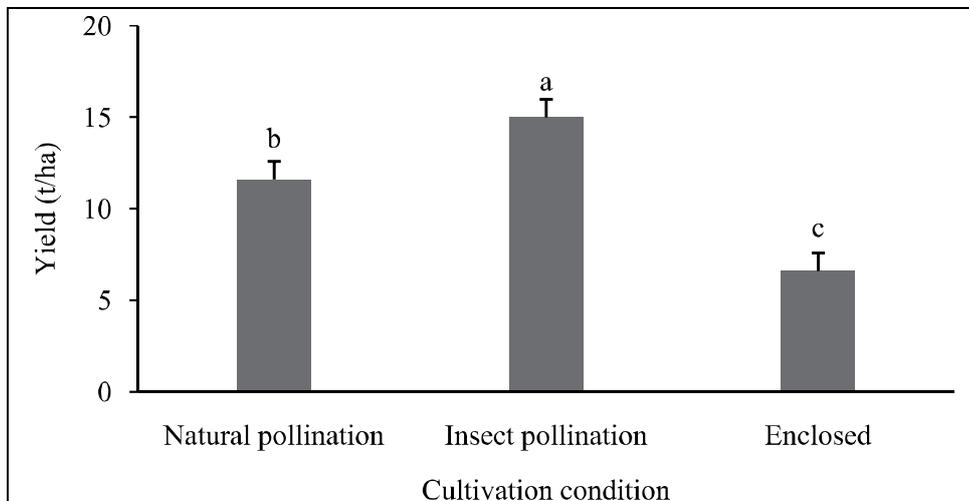The yield of eggplant in different treated pollination conditions varied from 6.6 ± 0.3 to 11.6 ± 0.4 tha^{-1} and the results differed significantly (Fig.6, $F_{2, 18} = 109.1$, $P < 0.001$). The highest and the lowest yields were obtained in insect pollination and enclosed condition, respectively. Fruit yield depends on fruit setting, fruit size and protection from pest attack. In this study, eggplants cultivated in insect pollinated condition were safe from pest attack and the flowers got sufficient pollinators due to frequent supplementation of insect as pollinators. In insect pollination condition, plants produced higher number of fruits per plant and the fruits were larger in size thus ensured higher yield. Farjado et al. (2008) reported that the eggplants cultivated in insect pollination produced 23.5% fruit setting while that of un-pollinated caged flowers was 1.8%. Amin et al. (2015) reported that insect pollination activity increased fruit setting in mango. Vergara and Badana (2009) reported that the pollinator diversity increases fruit production in Mexico.
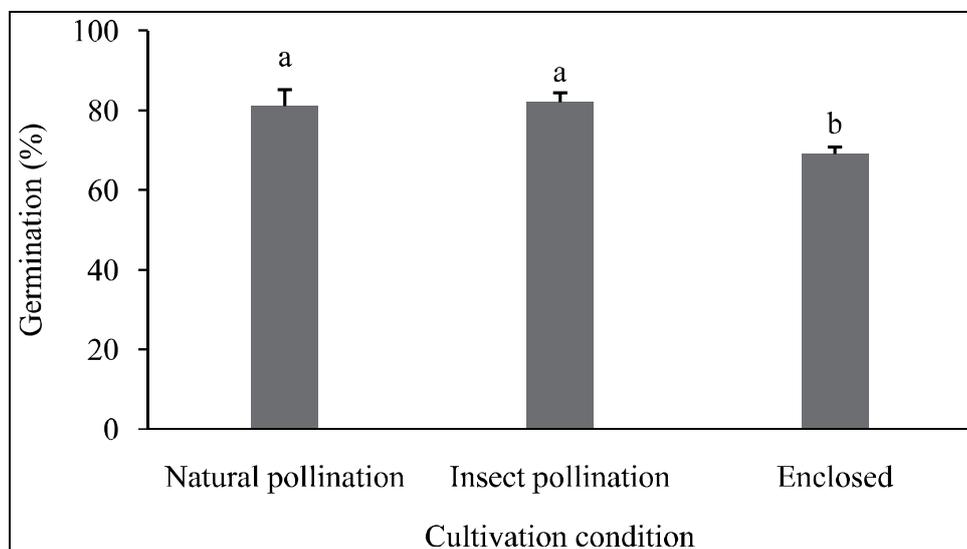
Fig.7. Effect of pollination condition on the germination of eggplant seed. Data expressed as mean ± SE. Bars with common letter(s) are not significantly different by Tukey posthoc statistic at P < 0.05.

Figure 7 shows the germination percentage of seeds in different treatments and the results differed significantly ($F_{2, 12} = 5.5$, $P < 0.05$). The germination percentage varied from 69.0 ± 1.9 to $82.0 \pm 2.5\%$ and the lowest results was found in enclosed condition devoid of insect pollinators. Germination percentage in natural (open) and insect supplemented pollination conditions showed statistically similar results. In natural and insect pollination conditions blooming eggplant flowers were very attractive to different groups of insects for pollination. On the contrary, the abnormal situation in the enclosed condition devoid of insect pollinators determined very weak seed setting.

Koltowski (2005) found that the plants freely visited by the pollinating insects, compared to those kept under gauze cover, were setting a similar number of fruits from 100 flowers and a higher number of seeds per pod. Plants freely available to the pollinating insects increased 16 to 50% yield compared to those under cover (Kamler, 1983; Manning and Boland, 2000). The findings of the present study showed that the foraging insects in eggplants are capable of producing higher yield and seed germination. Insect pest species caused significant level of infestation on plants and fruits, simultaneously pollinator insects contributed in producing higher yield and quality seed. Public awareness is necessary for implementation of IPM to control pest and conservation of native pollinators.

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PROFITABILITY ANALYSIS OF PAPAYA CULTIVATION IN SOME SELECTED AREAS OF BANGLADESH

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Abstract

The study was conducted to depict the overall economics of papaya cultivation in four districts namely Tangail, Jashore, Bandarban and Rajshahi. The objectives of the study were to examine the cost structure, resource use productivities, profitability and the problems of papaya production. A total of 152 farmers taking 38 from each district were selected randomly. Data were collected through a pre-tested interview schedule during January-March, 2017. The per hectare use of human labour, plant protection, manures and fertilizer were found to be maximum at Jashore whereas, the per hectare use of saplings was found to be maximum at Tangail district. The per hectare cost of cultivation of papaya was high at Jossere (365405) followed by Tangail (Tk.334261), Rajshahi (Tk.319754), and Bandarban (Tk. 272664). The average per hectare yield were maximum at Jossere (62MT) followed by Rajshahi (55MT), Tangail (54MT) and Bandarban (52MT). Per hectare gross margin was the highest at Tangail (Tk. 802797) followed by Bandarban (Tk. 658441), Jashore (Tk. 536346) and Rajshahi (Tk.471298). Per hectare net return was highest at Tangail (Tk.633738) followed by Bandarban (Tk.507335), Jossere (Tk.346594) and Rajshahi (Tk.302747). The overall benefit cost ratio was 2.39 which indicates papaya cultivation was profitable in Bangladesh. The yield of papaya would increase by 0.0407, 0.125, 00.0627, 0.0863 and 0.3785 % if papaya farmers apply 1% additional human labour, seedlings/saplings, fertilizer, improved variety, and dummy for loamy soil. Attacks on viral disease, adverse weather condition, non-availability of reliable seed, lack of irrigation facilities, lack of technical knowledge and problems in marketing of papaya were the major constraints of papaya cultivation in the study areas.

1. Introduction

Agriculture is the most dominant sector of the national economy of Bangladesh contributing nearly 17%of national income. On the other hand, about 45% of the population depends for their subsistence and livelihood on the agriculture sector (BBS, 2016). A number of crops are being cultivated in different parts of the country due to varying agro-climatic conditions. Among various fruits, papaya is

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one of the important fruits which is cultivated all over the country. The plants are of medium height (180-220 cm) and fruits are of medium to large size (1-2 kg) (BARI, 2014). The taste is superb with excellent quality. The ripe fresh fruits of papaya are eaten throughout the tropics, while unripe fruits are commonly used as vegetables for cooking. Every 100 gms of papaya contains 2020 I.U. vitamin A, 40 mg vitamin C, 10 mg calcium, 10 mgphosphorus, 9.5 gms of carbohydrates, and 0.5 gms of proteins (Sharma and Singh, 1990).

Papaya is a crop which has versatile uses. Raw papayas can be used for making salted pickles, while fully developed but somewhat raw fruits are used to make a perfect jelly, jam, candy, nectar, puree, concentrate, slab, powder, toffee, tutti-frutti, freeze dried chunks, dried rolls, dried slices are some other products that are made from papaya fruit (Garde, 1997). Now a days papain extraction from unripe fruits of papaya is one of the most important use. Papain is the dried latex from the fruit, containing a protein hydrolyzing enzyme which has a number of specific technological functions *viz.,* food and beverage preparations, pharmaceutical applications, textile industries and garment cleaning (Kumar and Saha, 1997).

Although climatic conditions of Bangladesh topapaya production. It is cultivated on large scale in Jashore, Rajshahi, Kustia, Tangail, Khulna and hill tracts. The national production of papaya is 332093 metric tons with an area of 14547 acres in 2015-2016 (BBS, 2016).

Table 1. Area and production of papaya at different years

year	Green papaya		Ripe papaya	
	Area(Acres)	Production(M. tons)	Area(Acres)	Production(M. tons)
2013-14	3973	207244	3021	130596
2014-15	5690	198724	3126	133370
2015-16	4786	201722	9761	130371

Source: Yearbook of Agricultural Statistics, 2016.

A good number of papaya varieties grown in Bangladesh such as Red lady, Top lady, Coorg honeydew, Washington, Ranchi, Shahi Papaya Kashimpur, and some exotic varieties. Papaya being a high value crop has got tremendous scope to increase the income of farmers with its high yield potential .Since no serious attempts have been found to know, a large number of farmers throughout the country are still unwilling to cultivate improved papaya varieties. It is important to know the farm level adoption of different varieties, their costs, returns, profitability, per hectare yield, per metric ton cost of production, and constraints faced by growers. Keeping all this points in mind the present study was under taken with following specific Objectives:

 ➢ To know the cultivation practices of papaya in different locations

 ➢ To estimate the profitability of papaya cultivation;

> ➢ To examine the resource use efficiency by using Cobb-Douglas production function;

> ➢ To identify constraints and problems of papaya production and to suggest appropriate policy measures.

2. Methodology

2.1 Sampling procedure and sample size

The study was conducted in four districts of Bangladesh namely Tangail, Jashore, Bandarban and Rajshahi. Then one upazila from each district and two blocks from each upazila were purposively selected in consultation with DAE personnel and papaya scientists. Finally, a total of 160 farmers, taking 40 from each district were randomly selected for the study (Table 2).

Table 2. Study areas and respondent farmers

Sl. No.	Name of district	Name of upazila	Name of agril. block	No. of farmer
1	Tangail	Madhupur	Magandinagar	20
			Orunkhula	20
2	Jossere	Jhikargacha	Godkhali	20
			Horinagar	20
3	Bandarban	Bandarbansadar	Tumcopara	20
			kuhalong	20
4	Rajshahi	Paba	Parila	20
			hargram	20
		Total		160

2.2 Data collection

The primary data like farm family, infrastructure, land utilization, cropping pattern, input use, farm production, papaya grading, packaging and transport in marketing cost, and problems of cultivation and marketing of papaya were collected by personal interview with the sample respondents. The data related to the year 2016-2017 were collected by survey method with the help of a pre specially designed comprehensive and pre-tested interview schedule.

2.3 Analytical techniques

Collected data were edited, summarized, tabulated and analyzed to fulfill the objectives of the study. Descriptive statistics using different statistical tolls like averages, percentages and ratios were used for presentation of the results of the study. The profitability of papaya production was examined on the basis of gross return, gross margin and benefit cost ratio analysis (Boardma, 1996). Besides, the

opportunity costs of family supplied labour were taken into consideration in estimating total cost. Land use cost was calculated on the basis of per year lease value of land.

2.3.1 Profitability analysis

The following equations were used to estimate the profitability of papaya cultivation at farm level.

Equations for cost analysis:

$$\text{Variable cost} = \sum_{I=1}^{n}(xijpij)$$

TVCij = VCij + IOCij

TCij = TVCij + TFCij

Where, TCij = Total cost of jth crop for ith farmer (Tk/ha)

TVCij = Total variable cost of jth crop for i^{th} farmer (Tk/ha).

TFCij = Total fixed cost of jth crop for i^{th} farmer (Tk/ha)

VCij = Variable cost of jth crop for i^{th} farmer (Tk/ha)

IOCij = Interest of operating capital of jth crop for i^{th} farmer (Tk/ha)

Xij = Quantity of inputs of jth crop for i^{th} farmer (kg)

Pij = Price of inputs of jth crop for i^{th} farmer (Tk/kg)

J = Number of crops

i = Number of farmers (1.2.3 ……..n)

Equations for profitability analysis

Gross return = GRij = YijPij

Net return = GRij – TCij

Gross margin = GRij – VCij

Where,

GRij = Gross return of jth crop for i^{th} farmer (Tk/ha)

Pij = Price (Tk/ha) of jth crops received by i^{th} farmer

Yij = Quantity (kg/ha) produced of jth crop for i^{th} farmer.

2.3.2 Choice of function

The empirical evidences form the previous studies suggested that to study the relationship between crop output and input variables, the following Cobb-Douglas production function was used.

$$Y = a\, X_1^{b1}.X_2^{b2}\ldots\ldots.X_n^{bn}.e^{\mu}$$

In the logarithmic transformation, the function becomes linear one. This function allows constant, increasing or decreasing return to scale. In this function 'b$_1$' is the elasticity of production of factor X_1, and can be used directly irrespective of units of measurement. The function in logarithmic form is expressed as follows.

$$\text{Log } Y = \text{Log } a + b_1 \text{ Log } X_1 + b_2 \text{ Log } X_2 + ... + b_n \text{ Log } X_n + \mu \text{ Log } e$$

2.3.4 Selection of variables

Nine independent variables were considered as important contributors to the production of papaya. The equation fitted was of the following form (Kapase, 1992).

$$Y = a.\ X_1^{b1}\ X_2^{b2}\ X_3^{b3}\ X_4^{b4}\ X_5^{b5}\ X_6^{b6}\ X_7^{b7} X_8^{b8}\ X_9^{b9}\ e^{\mu}$$

i.e. $\text{Log} Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_4 \log X_4 + b_3 \log X_3 + b_5 \log X_5 +$

$b_6 \log X_6 + b_7 \log X_7 + b_8 \log X_8 + b_9 \log X_9 + \mu \log e$

where,

i) Dependent variable

    Y = Yield of papaya (MT/ha)

ii) Independent variable

    X_1 = Land preparation cost (Tk./ha)
    X_2 = Quantity of fertilizer (kg)
    X_3 = Quantity of manures (kg)
    X_4 = Total human labour (in man days)
    X_5 = Seedlings/saplings cost (Tk/ha)
    X_6 = Expenditure on plant protection (Tk./ha)
    X_7 = Irrigation (No.)
    X_8 = Dummy for soil type(1= Loam, 0= otherwise
    X_9 = Dummy for papaya variety (1= improved, 0= otherwise)
    a   = Intercept term (constant)
    bi = Regression coefficient or elasticity of production (1 = 1, .. .9)
    e^{μ} = Error term
    The estimated production function was statistically tested with the help of 't' test and 'F' value.

3. Results and Discussion

3.1 Production practices of papaya at different location

Papaya farmers in the study areas used different types of varieties such shahi papaya, red lady, top lady, Indian and different local varieties. On an average 28% farmers used local variety. Among different locations 45% farmers in Tangail districts used local variety because farmers established their garden in pineapple orchard. The maximum (60%) gardens were established on plain land

in all areas which was 78% farmers choose sandy loamy soil for papaya cultivation. Planting was done during monsoon season in the study area. Papayas are planted in pits of 50 cm x 50 cm x 50 cm size in a square system with spacing of 2 m x 2m accommodating 10442 plants/ha. Before planting, the farmers filled pits with 10-15 kg decomposed farm yard manure that mixed with surface soil. In the study area the sample farmers irrigated 7-8 times in their papaya garden. The responded papaya growers mainly cultivated ginger, turmeric, pineapple, banana, chili and different leguminous crop as inter crops.

Table 3. Cultivation practices of papaya in farmers field at different locations

Production practice	Locations				
	Tangail	Jossere	Bandarban	Rajshahi	All areas
1.Varity used (% of farmers)					
Local variety	45	30	24	16	28
Shahi papaya	18	26	15	58	29
Red lady	10	18	30	12	18
Top lady	7	9	8	5	7
Others hybrid	20	17	23	7	17
2. Types of land: (%)High land					
Medium high land	50	20	60	30	40
Plain land	50	80	40	70	60
3. Types of soil: (%) Sandy soil					
Loamy soil	30	20		40	22
Sandy loamy soil	70	80	100	60	78
4. Sources of seedling: (%)					
Own garden	30	30		35	24
Market/neighbor	70	60	50	65	61
BADC/Others		10	50		15
5. Planting time	March-April	March-April	March-April	March-April	March-April
6. No. of saplings /ha	10560	10860	10000	10350	10442
7. Age of saplings (days)	40-60	40-60	40-60	40-60	40-60
8.Plant to plant distance(meters)	1.8	1.7	2.3	1.9	1.93
9.Depth of pit (c.m.)	45	45	45	45	45
10. Weeding (No./year)	10	12	8	10	10
11. Spraying (times)	2.5	3.6	1.8	3.4	2.8
12. Irrigation (No./year)	8	8.5	5.3	9.5	7.8
Intercrop and relay crop	Ginger, turmeric, pineapple, banana	Brinjal, chilli	Ginger, turmeric Banana, chilli	Chilli, brinjal, Banana pulse	Ginger, turmeric, pineapple, banana, chilli

Source: Field survey, 2017.

3.2 Input Utilization

Uses of various inputs directly affect the cost of cultivation. Papaya farmers use different inputs like human labour, machinery, seeds, saplings, manures, fertilizers, irrigation, plant protection etc. in their garden. The information regarding per hectare inputs utilization for papaya cultivation of selected farms of different size groups is presented in Table 4.

Table 4. Input use pattern per hectare for papaya cultivation.

Particulars	Units	Actual utilization level on different locations				
		Tangail	Jossere	Bandarban	Rajshahi	All areas
Human labour	man days	185	204	162	187	184
Family labour		105	120	100	80	101
Hired labour		80	84	62	107	83
Power tiller cost	Tk.	6000	6526	5580	6850	6239
Manures	kg	45000	65504	23309	57046	47714
Fertilizers						
Urea	kg	1470	1560	705	1091	1207
MoP	kg	980	780	650	830	810
TSP	kg	1210	1380	1210	1208	1252
Gypsum	kg	750	812	713	755	757
Boric acid	kg	96	105	92	85	94
Zinc sulfate	kg	74	82	86	88	83
Irrigation	No.	8	8.5	5.3	9.5	7.8
Plant protection cost	Tk.	6362	6820	6750	6138	6517

Source: Field survey, 2017.

Fertilizers should be applied in time to achieve good yield. The doses of fertilizers should be applied depending on the variety and initial soil fertility. Urea (450-500) gm and MP (450-500) gm per plant should be applied as split application. Urea (50gm) and MP (50gm) should be applied per plant one month interval commencing from one month after plant. The fertilizer doses should be double after flowering. The average quantity of manures applied by the farmers was worked out as 47714 kg per hectare. Human labour was required for land development, plantation of sapling, application of manures and fertilizers, spraying, weeding, irrigation and harvesting. On an average, 184 man-days of human labour was required for papaya cultivation of which 55% was family supplied and 45% was hired labour. The average application of fertilizers per hectare in terms of urea1207kg, MoP 810 kg, TSP 1252 kg, gypsum 757 kg, boric acid 94kg and zinc sulfate 83kg were applied. The average number of irrigation was 7.8 per hectare. The number of irrigation in case of Tangail, Jashore, Bandarban and Rajshahi were 8, 8.5, 5.3 and 9.5 in numbers, respectively. Plant protection in monetary terms was Tk.6517, while it was the highest at Jashore (Tk. 6820)and the lowest at Rajshahi (Tk. 6138).

3.3 Cost of cultivation

Planting materials, land preparation, input cost (FYM, fertilizers, plant growth regulators, plant protection chemicals etc.), labour cost, power cost, harvesting, packing and transportation charges were the cost components for papaya cultivation. Rental value of land was treated as fixed cost and interest on operating capital was also considered for the estimation of papaya cultivation cost. On average farmers spend Tk. 6239/ha for land preparation by using power tiller/tractor. The highest manures cost was observed Tk. 49128/ha at Jashore followed by Rajshahi (Tk. 42784/ha), Tangail (Tk. 33750/ha) and Bandarban (Tk. 23309/ha). Per hectare average saplings cost was Tk.31327 which was the highest in Jashore (Tk.32580) and lowest in Bandarban (Tk3000).Among variable costs human labour cost was the highest in all study areas. The highest human labour cost was observed (Tk. 57120/ha) at Jashore and lowest (Tk. 40500/ha) in Bandarban. The overall rental value of land was Tk.30374/ha. The interest on fixed cost and interest on operating cost was calculated @ of 8% basis. Among four locations the highest total cost was found Tk. 365405/ha at Jashore and lowest inBandarbanTk.272664/ha.

Table 5. Per hectare cost of cultivation of papaya in different locations

Cost heading	Tangail	Jossere	Bandarban	Rajshahi	All areas	% of total cost
Land preparation	6000	6526	5580	6850	6239	1.93
Manures	33750	49128	23309	42784	37242	11.53
Human labour[*]	51800	57120	40500	48620	49509	15.33
TSP	30250	34500	30250	30210	31302	9.69
Gypsum	9000	9744	8556	9060	9090	2.81
Saplings	31680	32580	30000	31050	31327	9.70
Urea	23520	24960	11280	17456	19304	5.98
Mop	16660	13260	11050	14110	13770	4.26
Boric acid	17280	18900	16560	15300	17010	5.27
Zinc sulfate	13320	14760	15480	15840	14850	4.59
Irrigation	10956	10620	8360	10311	10061	3.11
Plant protection cost	6362	6820	6750	6138	6517	2.02
Bamboo and fencing	20000	24000	14652	17920	19143	5.93
Transportation	2300	2420	2140	2360	2305	0.71
Miscellaneous expense	3623	3000	3000	3560	3295	1.02
Interest on operating capital	22120	24667	18197	21725	21677	6.72
Rental value of land	35639	32399	26999	26460	30374	9.40
Total cost	334261	365405	272664	319755	323018	100

*Human labour cost included expenditure on land development, farm layout, digging of pits, filling of pits and application of inputs.

3.4 Profitability of papaya cultivation

Input-output ratio indicates the rate at which the expenses on different inputs and factors are paid for. It also indicates the degree of profitability in relation to expenditure. The output input relationship worked out at the different cost concepts indicates the ratio between the gross income and cost showing the returns per taka invested. The output-input ratio in papaya cultivation in different locations is shown in the table 6. After 3-5 months of garden age, papaya production started and its continue up to twelve months. Farmers marked two categories of papaya such as green papaya as vegetables and ripe papaya as fruit. Prices of both categories depend on quality and seasonality of production. In the last year farmers got the average price of green papaya Tk. 8.87 per kg and ripe papaya tk. 19.5 per kg. Per hectare highest yield was found 60MT at Jossere followed by Rajshahi (55MT), Tangail (54MT) and Bandarban (52MT). The highest gross return was estimated at Tk. 968000 for Tangail followed by Bandarban (Tk. 780000), Jashore (Tk. 712000) and Rajshahi (Tk. 622500). Average gross margin was estimated Tk.622500. Net return was highest Tk. 633738 at Tangail followed by Bandarban (Tk.507335), Jashore (Tk.346594) and Rajshahi (Tk.302745). Average BCR was 2.39 which was than one meaning that papaya cultivation was a profitable farm business at farmers' level in the study areas (Table 6).

Table 6. Yield level, farm harvest price and gross income per hectare at different locations

Locations	Yield (green papaya) MT/ha	Yield (ripe papaya) MT/ha	Harvest price (green) Tk./MT	Harvest price (ripe) Tk/MT	Gross output (Tk./ha)
Tangail	20	34	11000	22000	968000
Jashore	35	27	8000	16000	712000
Bandarban	28	24	9000	22000	780000
Rajshahi	35	20	7500	18000	622500
All areas	29.5	26.25	8875	19500	773688.5

Source: Field survey, 2017.

3.5 Factors affecting papaya production

Papaya production at farm level is influenced by different variables. The estimates of the parameters of the Cobb-Douglas production function for papaya are presented in Table 7. The coefficients of the variables in the function are the elasticity of average output with respect to the different inputs used in papaya production.

Table 7. Profitability analysis of papaya cultivation at different locations

Items	Locations				
	Tangail	Jessore	Bandarban	Rajshahi	All areas
A. Total cost (TC)	334261	365405	272664	319754	323018
b. Total variable cost (TVC)	165202	175653	121558	151202	153401
Gross return(Tk./ha)	968000	712000	780000	622500	773687
Gross margin(Tk./ha)	802797	536346	658441	471298	620286
Net return(Tk./ha)	633738	346594	507335	302745	450668
BCR(cash cost basis)	5.86	4.05	6.42	4.12	5.04
BCR (Full cost basis)	2.89	1.95	2.86	1.94	2.39

Table 8. Regression coefficient and coefficient of multiple determinations for papaya

Variables	Locations				
	Tangail	Jossere	Bandarban	Rajshahi	All areas
Constant	3.43	4.34	5.68	3.23	3.36
Land preparation cost (Tk.)	0.0231	0.0265	0.0023	0.0365	0.0298
Fertilizer(kg)	0.0326^*	0.0112^{**}	0.0134^*	0.0637^{**}	0.0627^{**}
Manures (kg)	0.0365	0.0277	0.02568	0.0586	0.0624
Human labour (days)	0.0425^{**}	0.0301^{**}	0.02365^{**}	0.0389^{**}	0.0407^{**}
Seedlings/saplings cost (Tk)	0.0236^*	0.1861^*	0.0365^*	0.0129^*	0.125^*
Plant protection chemicals (Tk)	0.06325	0.0925	0.0864	0.0962	0.0913
Irrigation (No.)	0.0362	0.3730	0.7802^{**}	0.7562^{**}	0.0213
Dummy for soil type (1= Loam, 0= otherwise	0.0985^*	0.0785^*	0.0986^*	0.8752^*	0.0863^*
Dummy for papaya variety (1= improved, 0= otherwise)	0.8562^{***}	0.965^{***}	0.3562^{***}	0.3689^{***}	0.3785^{***}
R^2	75	84	82	79	82
F value	89	91	84	95	93

The empirical results indicated that the coefficients of human labour, seedlings, fertilizer, papaya variety, and soil type had positive and significant impacts on papaya production at farm level. The yield of papaya would increase by 0.0407, 0.125, 0.0627, 0.0863 and 0.3785% if papaya farmers use 1% additional human labour, seedlings/saplings, fertilizer, papaya variety, and loamy soil. More or less similar results regarding significant variables were found in the Cobb-Douglas production function models estimated of papaya production in the study areas.

Table 9. Constraints faced by farmers at different locations

Constraints	% farmers responded				
	Tangail	Jossere	Bandarban	Rajshahi	All areas
Do not protected crop from adverse weather	80	85	86	85	84.0
No proper control for viral disease	70	90	89	85	83.5
Do not know the name, proper method and doses of pesticides and insecticides	70	75	85	76	76.5
Problems in marketing of papaya	60	80	60	85	71.3
No direction and encouragement from local administration for papaya cultivation	60	63	72	50	61.3
Non availability of quality seedling	60	50	60	55	56.3
Lack of capital	50	45	80	50	56.3
Do not know the name and proper doses of manures and fertilizers	50	60	72	40	55.5
Non-availability of institutional loan	50	56	62	40	52.0
Lack of irrigation facilities	40	30	70	65	51.3
Lack of technical know-how for papaya cultivation	45	40	70	42	49.3
Problems of intercultural operations	30	35	26	28	29.8

Source: Field survey, 2017

3.6 Constraints to cultivation of papaya

The constraints relating to different resources reported by the sample farmers in the production of papaya are depicted in Table 8. It is observed that 56% sample farmers did not get reliable quality seedlings in time while, 83% of the sample farmers reported to non-availability of viral disease resistant seed to which was very dreadful to crop. Forty nine per cent of selected farmers complained about lack of knowledge about production technology. Non- availability of pesticides on time and lack of knowledge about its use were opined by 76% sample growers, while 55% stated that they did not know the name and proper doses of manures and fertilizers. Papaya growing is capital intensive enterprise that why 56% of sample farmers complained about inadequate capital. Eighty four per cent of the sample farmers reported that they could protect their garden from adverse weather condition and 71% farmers claimed that marketing of papaya was a serious problem. Farmers did not get proper price when peak period. Irrigation facilities were not adequate in the study areas mentioned by 51% farmers as a problem.

4. Conclusions and Recommendations

4.1 Conclusions

The study was conducted for understanding the present situation of papaya cultivation in Bangladesh. This study examined the production practices of papaya at different locations. It also gives clear picture of papaya cultivation in hill regions and plain land. Highest cost item was found human labour cost followed by fertilizer cost and saplings cost. Mostly family labour was used for papaya cultivation. The gross margin, net margin and benefit cost ratio indicated that farmers were benefited from cultivation of papaya in all areas. Human labour, seedlings, fertilizer, improved papaya variety, and loamy soil had positive and significant impacts on papaya production at farm level. In production of papaya, growers faced the problems of non-availability and high prices of quality seedlings, shortage of labour and no proper control over viral disease. While low price of papaya, fluctuating prices, higher transportation cost etc. were reported to be major problems of papaya cultivation in the study areas.

4.2 Recommendations

➢ Papaya growers cultivate exotic varieties which are much susceptible to virus diseases so farmers need suitable high yielding and virus resistant variety of papaya.

➢ Regular training should be arranged for the farmers to developing their knowledge about improved cultivation practices and adaptation of new technology.

➢ Fertilizers and plant protection chemicals price should be reduced.

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EFFICACY OF DIFFERENT SUBSTRATES TO FORMULATE
Trichoderma harzianum AGAINST SEEDLING
DISEASE OF CABBAGE

M. I. FARUK[1]

Abstract

Efficacy of three different substrates viz. rice bran, wheat bran, grass pea bran and their combination along with or without Mustard oilcake (MOC) were tested to formulate *Trichoderma harzianum* based bio-fungicides for the management of seedling disease (*Fusarium oxysporum*) of cabbage in seedbed. All combinations of substrates were equally suitable for mass culturing and preparing of *T. harzianum* bio-fungicides and all the substrates based *T. harzianum* bio-fungicides were effective in increasing seedling emergence and reducing pre-emergence and post-emergence mortality of cabbage seedling under *F. oxysporum* inoculated seedbed soils. The shoot length, shoot weight, root length and root weight of cabbage seedling were enhanced significantly by the application of different substrates based *T. harzianum* bio-fungicides under *F. oxysporum* inoculated soil under seedbed conditions. The individual (rice bran, wheat bran, grasspea bran) and combination of substrates (rice bran + wheat bran, rice bran + grasspea bran, rice bran + Mustard oilcake, rice bran + wheat bran + MOC and wheat bran + grass pea bran + MOC) were equally suitable to formulate effective *T. harzianum* based bio-fungicides for the management of foot and root rot disease of cabbage seedling in seed bed condition.

Keywords: Rice bran, wheat bran, grasspea bran, mustard oilcake, *Trichoderma harzianum*, *Fusarium oxysporum*, cabbage.

Introduction

Availability of quality food and nutrition are the major challenges to achieve healthy and prosperous Bangladesh like other developing countries of the world. Bangladesh is yet to be self-sufficient in quality food and nutrition. In the country vegetables play a vital role in everyday diet to a huge population in general. Among the vegetables, cabbage (*Brassica oleracea*) is one of the popular herbaceous annual or biennial vegetable that has achieved tremendous popularity over the last century. The crop attacked by several diseases mostly caused by fungi and bacteria leading to severe crop losses. Among the diseases germination failure, seedling mortality, foot and root-rot disease caused by the soil borne pathogen *Fusarium oxysporum*, is one of the major constraints for seedling

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production of vegetable crops in seedbed (Najar *et al.,* 2011). Control measures like host resistance is not yet become a viable measure. No resistant variety of cabbage has yet been developed and released against this soil borne pathogen *F. oxysporum* in Bangladesh. Soil solarization and organic soil amendment have been found less effective. On the other hand, application of chemical fungicides is expensive and also hazardous to health and environment (Brown and Hendrix, 1980; Punja *et. al.,* 1982). Biological methods, on the other hand can be economical, sustainable and free from residual effects and also consider as a potentially effective alternative method (Kulkarni *et al.,* 2007; Anand and Reddy, 2009). The beneficial microbes are used as biological agents that effectively control soil borne plant pathogens, and about 90% of such bio-control agents are different strains of *T. harzianum*, *T. virens*, *T. viride* (Elad *et al.,* 1983; Roy, 1989; Benítez *et al.,* 2004). The fungus *Trichoderma* possesses different mechanisms to combat the targeted pathogen such as mycoparasitism, competition for space and nutrients, secretion of antibiotics and fungal cell wall degrading enzymes for the inhibition of growth and reproduction of phytopathogens (Kubicek *et al.,* 2001; Howell, 2003; Benítez *et al.,* 2004; Harman *et al.,* 2004). In addition, *Trichoderma* has a stimulatory effect on plant growth (Naseby *et al.,* 2000) as a result of modification of soil conditions. The native bio-control agents usually remain in low population density in most of the agricultural soil, so up- scaling of their density to a higher stability level in soil through artificial inoculation with effective inoculum is necessary for successful management of soil borne pathogens in cabbage seedbed. The major limitation is the lack of appropriate mass culturing techniques and inadequate information on the suitable substrate materials of *T. harzianum* (Harman *et al.,* 1991). Several research report revealed that *T. harzianum* has been formulated as bio-fungicides in various substrates including wheat bran, rice bran, maize bran, sawdust (Das *et al.,* 1997); rice straw, chickpea bran, grasspea bran, rice course powder, black gram bran (Shamsuzzaman *et al.,* 2003); cow dung, poultry manure, groundnut shell, black ash, coir waste, spent straw from mushroom bed, talc, vermiculite (Rettinassababady and Ramadoss, 2000); and jaggery, groundnut cake, neem cake, niger cake, pongamia (Shamarao *et al.,* 1998). All these substrate materials are available in Bangladesh but their potentialities to use in the formulation of *T. harzianum* bio-fungicide have not yet been studied in the country. Therefore, the present study was undertaken to find out the effective local substrates to formulate the suitable medium for mass culturing of *T. harzianum* to be used as effective bio-fungicides against *F. oxysporum* causing seedling disease of cabbage under seedbed condition.

Materials and Methods

Efficacy of three organic substrates viz. rice bran, wheat bran, grasspea bran and their combinations mixed with or without Mustard oilcake (MOC) was

evaluated to formulate *T. harzianum* based bio-fungicides for the management of foot and root rot disease of cabbage caused by *F. oxysporum*. The experiment was conducted in seedbed of Plant Pathology Division, Bangladesh Agricultural Research Institute (BARl), Gazipur during three consecutive years from 2011-12 to 2013-14. The seedbed was inoculated with the fungal isolate *F. oxysporum* multiplied on the barley grains @ $100g/m^2$ soil. The pathogen was allowed to colonize the soil in seedbed for 10 days. A pure culture of *T. harzianum* (TM7) isolated from the native soil was grown in potato dextrose agar (PDA) medium which was used as inocula for preparation of bio-fungicides. The treatments substrate in the experiment were T_1= Rice bran, T_2= Wheat bran, T_3= Grasspea bran, T_4= Rice bran + Wheat bran (1:1), T_5=Rice bran + Grasspea bran (1:1), T_6= Rice bran + Mustard oilcake (1:1), T_7= Rice bran + Wheat bran + MOC (1:1:1), T_8= Rice bran + Grasspea bran + MOC (1:1:1), T_9= Wheat bran + Grasspea bran + MOC (1:1:1), T_{10}= Rice bran + Wheat bran + Grasspea bran+ MOC(1:1:1:1), T_{11}=Seed treatment with Provax and T_{12}= Control. According to the treatment combinations 600 g of individual or combination of substrate materials were taken separately in 1000 ml Erlenmeyer flask. The flask with substrate materials were sterilized in an autoclave at 121^0C for 15 minutes and cooled down to make it ready for inoculation. The sterilized substrate was inoculated individually with 5 mm diameter mycelia disc of five-day old culture of *T. harzianum* grown on PDA and then incubated at room temperature (25 ± 2 ^0C) for 15 days. After incubation the colonized substrates were removed from the flasks, air dried and finally preserved in refrigerator at 10 ^0C. The inoculum of *T. harzianum,* colonized on different substrates, were incorporated to the previously *F. oxysporum* inoculated seedbed soils @ 100 g/m^2 soil and kept for 7 days maintaining proper soil moisture to establish *T. harzianum* in the soils. The control bed did not receive any colonized substrate of *T. harzianum* except the inoculum of *F. oxysporum*. The seeds of cabbage variety Atlas were sown in the seedbed @ 200 seeds per treatment. The initial germination in blotter test of the seeds was 99%. The percent emergence of the seedling was calculated on the basis of initial germination status of the seeds. The experiment was laid out in completely randomized design (CRD) with four replications. Proper weeding, irrigation and intercultural operations were done to raise cabbage seedlings in the seedbed. Data were collected on seedling emergence after 15 days of seed sowing. Similarly seedling mortality was recorded at an interval of 7 days starting from seedling emergence and it was continued up to 35 days of seedling age. The height and weight of shoot and length and weight of root of tomato seedlings were recorded at 35 days of seedling age. The percent data were converted into arcsine transformation values before statistical analysis. Data were analyzed statistically by using the MSTATC program. The treatment effects were compared by applying the least significant different (LSD) test at P=0.05 level.

Results and Discussion

a) Seedling emergence and pre-emergence mortality

Every year, the seedling emergence of cabbage was significantly increased over control in the *F. oxysporum* inoculated seedbed due to *T harzianum* bio-fungicides. Under control treatment the emergence was 49.33, 64.00 and 66.00% in 1st, 2nd and 3rd year, respectively. The seedling emergence ranged from 58.00-67.00, 80.33-86.67 and 79.00-91.00% due to treatment of seedbed soil with the bio-fungicides in 1st, 2nd and 3rd year, respectively. Seedling emergence under various treatments with the bio-fungicides was statistically similar (Table 1).

On the contrary, the pre-emergence seedling mortality of cabbage under control was 50.67, 36.00 and 34.00% in 1st, 2nd and 3rd year, respectively. The corresponding mortality under treatment of seedbed soils with the bio-fungicides was 33.00-42.00% in first year, 13.33-19.67% in second year and 09.00-21.00% in third year. It was reduced to 17.11-34.87, 45.36-62.97 and 38.23-73.53% in first, second and third year, respectively due to treatments of seedbed soils with various bio-fungicides (Table 1). However, efficacy of all bio-fungicides was more or less similar.

b) Post-emergence mortality

Post-emergence mortality of cabbage in *F. oxysporum* inoculated seedbed soil was 21.33, 33.67 and 24.67% under treatment control in 1st, 2nd and 3rd year of study, respectively. The substrates based *T. harzianum* bio-fungicides reduced the disease incidence from 64.04-73.42, 60.41-66.35 and 60.80-72.96% in 1st, 2nd and 3rd year, respectively compared to untreated control. Efficacy of all bio-fungicides to reduce the disease incidence was statistically similar (Table 2).

c) Shoot growth

Shoot length and shoot weight of cabbage seedlings were increased significantly by different substrates based *T. harzianum* bio-fungicides over Provax and untreated control in the *F. oxysporum* inoculated seed bed soil (Table 3). Under control seedbed, shoot length was 13.03 cm in first year, 4.90 cm in second year and 10.87 cm in third year. Treatment of seedbed soils with *T harzianum* based bio-fungicides resulted increase in shoot length ranging by 17.07-18.13, 8.30-10.13 and 16.33-22.07 cm in 1st, 2nd and 3rd year, respectively. The shoot weight under control treatment was 3.75, 3.97 and 6.57 g plant^{-1} in first, second and third year, respectively. Treatments of seedbed soils by *T. harzianum* based bio-fungicides increased the shoot weight ranging 5.53- 5.81, 7.11-8.53 and 8.88-12.40 g plant^{-1} in 1st, 2nd and 3rd year, respectively. Effect of all bio-fungicides treatments on shoot growth was more or less similar (Table 3).

Table 1. Effect of substrate based *T. harzianum* bio-fungicides on the emergence and mortality of cabbage seedling in *F. oxysporum* inoculated soils in seedbed

Name of substrates	Emergence (%) of cabbage seedling in seedbed soil			Pre-emergence mortality (%) of cabbage seedling in seedbed		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
T_1=Rice bran	63.00	85.33	86.00	37.00 (26.98)	14.67 (59.25)	14.00 (58.82)
T_2=Wheat bran	62.67	82.33	85.00	37.33 (26.33)	17.67 (50.92)	15.00 (55.88)
T_3=Grasspea bran	61.67	83.33	90.00	38.33 (24.35)	16.67 (53.69)	10.00 (70.58)
T_4=Rice bran + Wheat bran	63.33	84.33	89.00	36.67 (27.63)	15.67 (56.47)	11.00 (67.65)
T_5=Rice bran + Grass pea bran	66.00	82.00	91.00	34.00 (32.89)	18.00 (50.00)	09.00 (73.53)
T_6=Rice bran + Mustard oilcake	59.67	82.00	83.00	40.33 (20.41)	18.00 (50.00)	17.00 (50.00)
T_7=Rice bran + Wheat bran + MOC	61.00	86.00	85.00	39.00 (23.03)	14.00 (61.11)	15.00 (55.88)
T_8=Rice bran + Grasspea bran + MOC	67.00	80.67	86.00	33.00 (34.87)	19.33 (46.30)	14.00 (58.82)
T_9=Wheat bran + Grass pea bran + MOC	59.33	80.33	88.00	40.67 (19.74)	19.67 (45.36)	12.00 (64.70)
T_{10}=Wheat bran + Grass pea bran+ Rice bran + MOC	58.00	86.67	79.00	42.00 (17.11)	13.33 (62.97)	21.00 (38.23)
T_{11}=Seed treatment with Provax	57.67	79.00	83.00	42.33 (16.46)	21.00 (41.67)	17.00 (50.00)
T_{12}=Control	49.33	64.00	66.00	50.67	36.00	34.00

Values with in the parenthesis are percentage of reduction in pre-emergence mortality due to treatments over control.

Table 2. Reduction of cabbage seedling mortality by different substrate based _T. harzianum_ bio-fungicides in _F. oxysporum_ inoculated soils in seedbed

Name of substrates	Post-emergence cabbage seedling mortality (%) in seedbed soil			Reduction of cabbage seedling mortality (%) over control in seedbed soil		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
T_1=Rice bran	7.33 b	13.33 b	7.67 b	65.64	60.41	68.91
T_2=Wheat bran	7.67 b	11.67 b	7.67 b	64.04	65.34	68.91
T_3=Grasspea bran	7.00 b	11.67 b	9.33 b	67.18	65.34	62.18
T_4=Rice bran + Wheat bran	5.67 b	12.00 b	6.67 b	73.42	64.36	72.96
T_5=Rice bran + Grass pea bran	7.00 b	12.00 b	7.67 b	67.18	64.36	68.91
T_6=Rice bran + Mustard oilcake	7.00 b	11.33 b	7.33 b	67.18	66.35	70.29
T_7=Rice bran + Wheat bran + MOC	7.00 b	11.67 b	8.33 b	67.18	65.34	66.23
T_8=Rice bran + Grasspea bran + MOC	7.67 b	11.67 b	7.67 b	64.04	65.34	68.91
T_9=Wheat bran + Grass pea bran + MOC	7.33 b	12.67 b	9.67 b	65.64	62.37	60.80
T_{10}=Wheat bran + Grass pea bran+ Rice bran + MOC	6.33 b	12.67 b	8.33 b	70.32	62.37	66.23
T_{11}=Seed treatment with Provax	5.67 b	13.00 b	9.67 b	73.42	61.39	60.80
T_{12}=Control	21.33 a	33.67 a	24.67 a	-	-	-

Table 3. Effect of different substrate based *T. harzianum* bio-fungicides on the shoot growth of cabbage seedling in *F. oxysporum* inoculated seedbed soil

Name of substrates	Shoot length in consecutive three years (cm)			Shoot weight in consecutive three years (gplant⁻¹)		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
T₁=Rice bran	17.07 b	8.53 cd	16.97 c	5.78 ab	7.18 b	8.88 cd
T₂=Wheat bran	17.70 ab	8.50 cd	16.33 cd	5.60 ab	7.40 b	9.58 bcd
T₃=Grasspea bran	17.60 ab	8.30 d	16.33 cd	5.67 ab	7.11 b	9.28 bcd
T₄=Rice bran + Wheat bran	18.17 ab	8.67 cd	20.00 ab	5.56 ab	8.57 a	10.88 abc
T₅=Rice bran + Grass pea bran	17.80 ab	8.93 bcd	22.07 a	5.73 ab	8.47 a	12.40 a
T₆=Rice bran + Mustard oilcake	18.13 ab	9.63 abc	20.67 ab	5.74 ab	8.85 a	11.08 ab
T₇=Rice bran + Wheat bran + MOC	17.83 ab	9.67 abc	20.73 ab	5.81 a	8.73 a	11.90 ab
T₈=Rice bran + Grasspea bran + MOC	18.13 ab	9.87 ab	20.13 ab	5.60 ab	8.73 a	10.77 abc
T₉=Wheat bran + Grass pea bran + MOC	17.13 b	10.07 ab	19.73 b	5.67 ab	7.45 b	10.38 abc
T₁₀=Wheat bran + Grass pea bran+ Rice bran + MOC	19.13 a	10.13 a	21.10 ab	5.53 b	7.57 b	10.50 abc
T₁₁=Seed treatment with Provax	14.97 c	5.83 e	14.27 d	4.74 c	4.88 c	7.70 de
T₁₂=Control	13.03 d	4.90 e	10.87 e	3.75 d	3.97 d	6.57 e

Values in a column having same letter did not differ significantly (p=0.05) by LSD.

Table 4. Effect of different substrate based *T. harzianum* bio-fungicides on the root growth of cabbage seedling in *F. oxysporum* inoculated seedbed soil

Name of substrates	Root length of cabbage seedling in consecutive three years (cm)			Root weight of cabbage seedling in consecutive three years (mgplant⁻¹)		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
T₁=Rice bran	7.13 a	7.33 ab	6.07 bcd	610 a	600 ab	660 b
T₂=Wheat bran	7.13 a	7.20 ab	5.67 d	620 a	540 ab	680 b
T₃=Grasspea bran	7.07 a	7.17 b	5.93 cd	590 ab	560 ab	650 b
T₄=Rice bran + Wheat bran	7.37 a	7.17 b	7.33 a	590 ab	610 a	830 a
T₅=Rice bran + Grass pea bran	7.76 a	7.60 ab	8.00 a	610 a	550 ab	870 a
T₆=Rice bran + Mustard oilcake	7.40 a	8.50 ab	7.07 abc	570 b	570 ab	860 a
T₇=Rice bran + Wheat bran + MOC	7.53 a	8.73 a	7.20 ab	610 a	580 ab	830 a
T₈=Rice bran + Grasspea bran + MOC	7.47 a	8.47 ab	7.53 a	580 ab	610 a	890 a
T₉=Wheat bran + Grass pea bran + MOC	7.87 a	8.27 ab	7.07 abc	610 a	600 ab	910 a
T₁₀=Wheat bran + Grass pea bran+ Rice bran + MOC	7.53 a	8.40 ab	7.33 a	610 a	520 b	830 a
T₁₁=Seed treatment with Provax	6.25 b	5.23 c	5.13 de	480 c	400 c	650 b
T₁₂=Control	5.46 b	4.47 c	4.27 e	430 d	320 d	600 b

Values in a column having same letter did not differ significantly (p=0.05) by LSD.

d) Root growth

Every year, the root length of cabbage seedling was significantly lower in non-treated
seedbed (control) compared to bio-fungicide and Provax treated beds. The root length of cabbage seedlings during consecutive three years ranged from 7.07-7.87, 7.17-8.37 and 5.67-8.00 cm under different treatments and 5.46, 4.47 and 4.27 cm in control seedbeds, respectively (Table 4).

The root weights were also higher having 0.58-0.62, 0.52-0.61 and 0.65-0.91 g plant^{-1}, in the 1st, 2nd and 3rd year respectively in the seedbed treated with *T. harzianum* based bio-fungicides and the lowest root weight 0.43, 0.32 and 0.60 g plant^{-1} in 1st, 2nd and 3rd year, respectively in the control seedbeds (Table 4). The root weight was significantly higher compared to seedbeds received neither bio-fungicide nor Provax. Effect of bio-fungicide treatments on root growth was more or less similar (Table 4).

Seed treatment with Provax was also effective to reduce the incidence of foot and root rot disease and to increase shoot and root growth of cabbage seedlings over control in seedbed soil infested with *F. oxysporum*. However, its efficacy was lower compared to all bio-fungicides (Tables 1- 4).

Results of the present experiment revealed that biological control agent *T. harzianum* multiplied on different substrates materials viz. rice bran, wheat bran, grasspea bran used alone or in different combinations mixed with or without MOC were effective against foot and root disease of cabbage caused by *F. oxysporum* under seedbed condition. The bio-fungicides achieved satisfactory increase in seed germination, decrease pre- and post-emergence seedling mortality and also enhance growth of cabbage seedling. Similar findings were reported by other researchers (Bentez *et al.,* 2004; Mausam *et al.,* 2007; Prasad and Anes, 2008; Mukhtar, 2008; John *et al.,* 2010). The well-known antagonistic fungus *Trichoderma* spp. could directly parasitize a diversity of fungi as they were capable of detecting other fungi in the soil and destroyed other plant pathogenic fungi through expression of cell wall degrading enzymes, mostly chitinases, glucanases and proteases (Harman *et al*., 2004). The fungus *T. harzianum* prevailing in the soil was being used in many crops, like lettuce, tomato, onion, cotton, grapes, peas, apples, sweet corn and carrots to control various diseases caused by *Phytophthora, Pythium, Sclerotinia, Botrytis, Rhizoctonia* and *Fusarium* (Benítez *et al*., 2004; Mausam *et al.,* 2007). These findings were in accordance with the observation of the present study where soil was treated with different substrates based *T. harzianum* bio-fungicides that enhanced the growth of cabbage seedling in *F. oxysporum* inoculated seedbed soils though the degree of shoot and root growth varied among the treatments. Harman (2006) and Manju and Mall (2008) also reported positive role of *Trichoderma* species in increasing plant growth and productivity. In present experiment there was significant increase in emergence, shoot and root length

and also shoot and root weights of tomato seedling due to *T. harzianum* bio-fungicides which was supported by the findings of many investigators (Prasad and Anes, 2008; Mishra and Sinha, 2000; Chaur-Tsuen and Chien-Yih, 2002). It was reported that *Trichoderma* isolates possesses the ability to compete for key exudates from seeds that stimulate germination of propagules of plant pathogenic fungi in the soil as they compete with microorganisms for nutrient and space. The three well known mechanisms associated with pathogen control by *Trichoderma* were competition for nutrients, antibiosis, and myco-parasitism (Chet, 1987). It was noticed by Tjamos *et al*. (1992) that *T. harzianum* controls *F. oxysporum* by competing for both rhizosphere colonization and nutrients. The study confirmrd the reports of other researchers regarding the role of *T. harzianum* to enhance seed germination and root and shoot growth of seedlings (Dubey *et al*., 2007) as well as increasing the frequency of healthy plants (Rojo *et al*., 2007). Shoresh *et al.* (2005) stated that *Trichoderma* spp. were effective bio-control agents for a number of soil borne plant pathogens and induced a potentate state in the plant enabling it to be more resistant to subsequent pathogen infection.

Acknowledgement

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PROFITABILITY ANALYSIS OF MANGO CULTIVATION AND ITS IMPACT ON FARMER'S LIVELIHOOD IN SOME AREAS OF BANGLADESH

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Abstract

The study was carried out to investigate profitability of mango farming and to assess the impact of BARI Aam-3 mango variety production on the farmer's livelihood in four mango growing districts namely Khagrachori, Bandorban, Naogaon, and Satkhira of Bangladesh during February to March, 2018. A total of 128 BARI Aam-3 growers were selected using multi-stage random sampling technique. Descriptive statistics and financial profitability analysis was used to analyze data. The net return for one hectare of mango orchard was Tk. 730233 for 6-7 years of BARI Aam-3 mango orchard. Net present value was estimated to Tk. 444397 for BARI Aam-3 which indicates that mango cultivation fetches higher returns. The estimated benefit cost ratio was 2.01 for BARI Aam-3 which ensures that investment in BARI Aam-3 is feasible for the mango farmers. The BARI Aam-3 mango cultivation was also found to be a profitable enterprise since internal rate of return was very high (83.075%). The results also reveal that human capital increased by 54.34%, 68% and 60.54%; physical capital increased by 48.17%, 58% and 50% as well as social capital increased by 28.50%, 43% and 45.95% of the small, medium and large farmers respectively due to cultivation of BARI Aam-3 mango variety. Therefore, it is highly recommended to spread the information of BARI Aam-3 cultivation as a profitable enterprise among the mango growers throughout the country.

Keywords: Mango, Profitability, Assets, livelihood, Bangladesh.

Introduction

Agriculture is the dominant economic activity in Bangladesh which comprises more than 15% of country's GDP and employs around 43% of labor force (BBS, 2017). Ensuring food and nutritional security and alleviating poverty is the prime concern of the present government. The Sustainable Development Goals (SDG) has reemphasized on the need of building more dependable food security system with increased productivity. Therefore, it is necessary to generate more diversified food with greater shares of fruit production. But production of fruits is still far behind the countries present requirement. About 78gm fruit is available

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per person in Bangladesh whereas 200gm is the daily requirement (BBS, 2017). Among the fruits in Bangladesh banana stands in the top position in terms of area coverage (32%) and production (17%) followed by mango (25% area and 24% production) and pineapple (9% area and 4% production) (BBS, 2016). Mango (*Mangifera indica L.*) is recognized as the one of the choicest and well accepted fruit all over the world due to its attractive color, marvelous flavor, delicious taste and high nutritive value. It is a nutritionally important fruit being a good source of vitamin A, B & C and minerals. Sugar constitutes main bulk of the carbohydrates and most of the soluble solids are found in ripe mango (Ravani and Joshi, 2013; Nigam *et al.,* 2007). Area under mango production is fluctuated over the last decades whereas total production has been increased in Bangladesh. In 2004-05, mango was cultivated in 25055 hectares of land and yield was 26.43 ton/ha (BBS, 2008). Still then area coverage is being increased continuously with an upward movement of total production. In 2015-16, mango acreage was 37823 hectares with the highest level of production (1161685 metric tons) throughout the last decade with average yield of 30.71ton/ha (BBS, 2017). It is grown in most of the districts of Bangladesh. Bangladesh is the world's eighth largest mango producing country as it produces about 1,047,850 tons of mangos every year which accounts for 3.9 percent of the world total mango production (Rahman and Khatun, 2018).

Area under mango production is fluctuated over the last decades whereas total production has been increased in Bangladesh. Figure 1 denotes that in 2004-05, mango was cultivated in 25055 hectares of land and yield was 26.43 ton/ha. Still then area coverage is being increased continuously with an upward movement of total production. In 2015-16, mango acreage was 37823 hectares with the highest level of production throughout the last decade i.e., 1161685 metric tons. The figure also shows that the yield of mango is increasing at an increasing rate during the year 2004-05 to 2014-15.
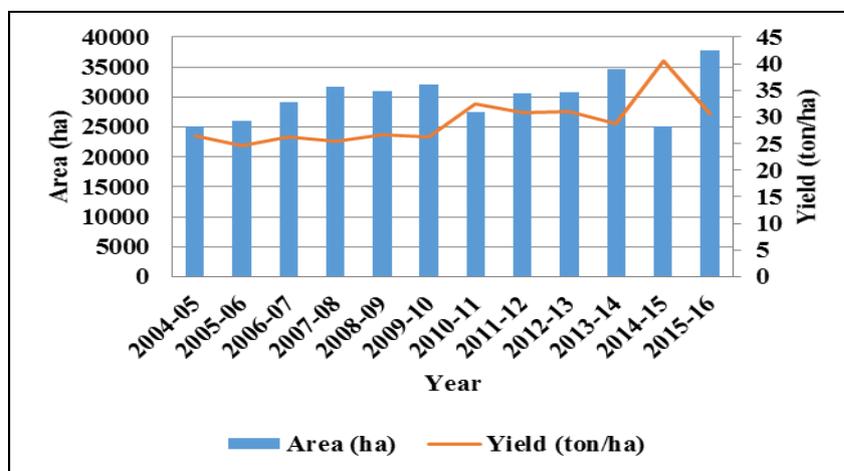

Fig. 1. Area and Yield of Mango Fruits in Bangladesh (Source: Various issues of BBS).

But due to climatic context and soil advantages most of the best variety mango cultivation was limited to north-western and south-western districts of Bangladesh. The main source of income of this region is mango cultivation. With the innovation of modern developed mango variety, it is now cultivated commercially in other districts of Bangladesh. Bangladesh Agricultural Research Institute (BARI) is the leading organization to develop mango variety in Bangladesh. Since 1996 to 2015, it has developed 11 types of improved high yielding mango varieties (Azad *et al.*, 2017).

Among the varieties BARI Aam-3 is an important innovation in Bangladesh. It is a hybrid mango variety, has been developed by crossing between Kiron (female) and Deshari (male) (Hossain *et. al.*, 2003). At field level this variety is well known as Amropali or Aam Rupali or Rupali. Mainly it was developed in the Indian Agriculture Research Institute at Pusa, Delhi in 1971 (Wikipedia). Since then this mango has been introduced in the farms and orchards across India. After justifying its suitability in Bangladesh, it was approved for cultivation in 1996 in the name BARI Aam-3. BARI Aam-3 has been demonstrated very rapidly during the last decade. Because the climate and soil of Bangladesh are suitable for high yielding BARI Aam-3 cultivation and farmers get yield within three years of plantation with relatively less efforts. Shiblee (2015) conducted a study on assessing BARI released mango varieties at field level where he concluded that BARI Aam-3 was the best in all the firms under investigation in terms of sale of stions (stock + scion). Its cultivation has brought solvency to many people in Satkhira, Khagrachori, Naogaon and Bandarban districts of Bangladesh. But there is no in depth study on finding out profitability of growing mango specially BARI Aam-3 and its impact on farmer's livelihood in Bangladesh. The farmers need information regarding investment and returns from mango production business. Keeping in view the importance of mango in terms of area and production the present study investigates in determining cost of production and profitability of growing mango orchard. So the specific objectives of the study are:

    i. To evaluate the economic profile of mango growers and

    ii. To assess the assets of livelihood strategies of mango growers

Methodology

Study area selection

A preliminary survey was conducted in Sadar Upazila of Khagrachori district for pre-testing the survey schedule. Based on the preliminary survey, four BARI Aam-3 growing districts namely Khagrachori, Satkhira, Bandarban, and Naogaon were selected and two major BARI Aam-3 growing Upazilas from each district were purposively selected for selecting sample orchards. All the mango growers were randomly stratified into small (≤40 trees), medium (41-≤79 trees) and large (≥80 trees).

Sampling technique adopted and way of sample selection

Multi-stage random sampling technique was used to select the required mango growers. A total of 128 mango orchards were randomly selected for the study. The distribution of sample orchards is presented in the following Table 1.

Table 1. Distribution of sample orchards

Location	BARI Aam-3 orchard (No.)				
	Up to 1 year	1-3 year	3-5 year	More than 5 year	Total
1.Khagrachori					
- Khagrachori Sadar Upazila	2	2	2	10	16
- Dighinala Upazila	2	2	2	10	16
2. Bandorbon					
- Bandorban Sadar Upazila	2	2	2	10	16
- Ali Kadam Upazila	2	2	2	10	16
3. Satkhira					
- Satkhira Sadar Upazila	2	2	2	10	16
- Kaliganj Upazila	2	2	2	10	16
4. Naogaon					
- Naogaon Sadar Upazila	2	2	2	10	16
- Sapahar Upazila	2	2	2	10	16
Total	16	16	16	80	128

Study period

Primary data were collected from the respondents by using interview schedule during the month of January to March, 2018.

Analytical Technique

Descriptive Statistics

Descriptive statistics were used to analyze the data by sum, average and percentages.

Statistical technique

Growing fruit trees represent long term investment. Production of mango can be considered as a function of various inputs employed in the process of production. The farmers had to incur cost for different inputs such as human labor, machinery, fertilizer, insecticides etc. for cultivating mango in the orchard. The profitability of mango production was measured on the basis of Gross Return, Gross Margin and Net Return. At the same time capital budgeting was also done

by calculating Net Present Value, Benefit Cost Ratio and Internal Rate of Return of the mango orchard. The discount rate was specified by assuming the opportunity cost of capital which is 12% for most of the developing countries (Gittinger, 1984).

Livelihood analytical technique

Livelihood pattern was measured by presenting the five types of capitals namely human capital, social capital, natural capital, physical capital and financial capital (DFID, 2000) which is known as assets pentagon. A sustainable livelihood is the outcome of inter and intra relationship between the components of these five livelihood assets/capitals. In this study, an attempt was made to measure the changes in assets position of the mango farmers for one year due to cultivation of BARI Aam-3 mango variety.

Results and Discussions

Profitability of BARI Aam-3 Mango Farming

Profit is a basic criterion for selecting an enterprise. The study found that farmer planted 100-120 trees per acre (100 decimal) of land in the sense that after 5-6 years they cut one of every three of the line in order to clear it for air and light. Farmers have the option to do intercrop with BARI Aam-3 mango orchard up to 3-4 years of age. Generally, after 4 years of mango tree farmers did not cultivate any kind of intercrop. The study also found that only 18% of the respondents do intercrop in one or two years in their orchard and they did it with different crops. Due to complexity in accounting costs and return of intercropping, the present study does not cover costs and return of intercropping in determining profitability of BARI Aam-3 mango farming.

It is evident from Table 3 that hired labor ranked the highest variable cost item of BARI Aam-3 mango orchard. The lowest used variable input was manures following by MoP among the chemical fertilizers. The per hectare total cost of BARI Aam-3 mango orchard from the establishment year to two years was estimated to Tk. 104211 where cost of saplings was the major cost item. Insecticides cost was not recorded during this period because there was no problem of insect. For the second section (2-3 years' trees) total cost was Tk. 82524 per hectare and the main component of variable cost was hired labor whereas the second most important one was insecticides. After that total cost was increased in ascending order. Fixed cost does not depend on the level of production. Only three items were considered as fixed cost for the mango orchard viz., family labour, interest on operating capital (IOC) and rental value of land in the study areas as indicating in Table 3. Considering all variable and fixed costs, total cost and net return was determined in the study areas.

Table 3. Average cost of BARI Aam-3 mango cultivation (Tk. /ha)

Items	Age of mango tree (year)						All years	% of total
	Up to 2	2-3	3-4	4-5	5-6	6-7		
A. Variable Cost (Tk.)	50717	28307	25324	32331	29455	36072	202205	34.8
Hired labor	13775	10940	11370	17896	16523	21326	91830	15.8
Saplings	30245	0	0	0	0	0	30245	5.2
Manures	630	371	891	704	693	655	3943	0.7
Fertilizers								
Urea	378	926	573	1853	1890	1853	7473	1.3
TSP	1638	1606	955	2470	2142	2161	10972	1.9
MoP	378	926	573	1853	1638	1766	7134	1.2
Insecticides	0	7904	7639	2737	2641	2594	23515	4.0
Irrigation	1079	1235	2546	2905	2352	3930	14046	2.4
Miscellaneous	2594	4399	777	1914	1575	1788	13047	2.2
B. Fixed cost (Tk.)	53494	54217	55887	63482	73128	79294	379503	65.2
Family labour	8451	7199	8138	12833	18154	20345	75120	12.9
Interest on operating capital (Tk.)	3876	5851	6582	9482	13807	17782	57381	9.9
Rental Value of land (Tk./year)	41167	41167	41167	41167	41167	41167	247002	42.5
C. Total Cost (A+B) (Tk.)	104211	82524	81212	95813	102583	115365	581708	100.0

Source: Field Survey, 2018.

Table 4. Profitability of mango variety BARI Aam-3 cultivation

Items	Age of mango tree (year)						All Year
	Up to 2	2-3	3-4	4-5	5-6	6-7	
A. Total cost (Tk./ha)	104211	82524	81212	95813	102583	115365	581708
Variable cost (Tk./ha)	50717	28307	25324	32331	29455	36072	202205
Fixed cost (Tk./ha)	53494	54217	55887	63482	73128	79294	379503
B. Average yield (kg)	--	1578	4889	5512	7080	9586	28645
C. Average price (Tk./kg)	--	45	44	45	45	50	45.8
C. Gross return (Tk./ha)	--	71010	215116	248040	318600	479300	1311941
F. Gross margin (Tk./ha)	-50717	42703	189792	215709	289145	443228	1109736
G. Net return (Tk./ha)	-63291	-11514	133904	152227	216017	363935	730233

Per hectare average return of BARI Aam-3 mango orchards in the study areas are depicted in Table 4. Farmers told that they got fruits just after 2-3 years of plantation and this is unique only for BARI Aam-3 variety. So, gross margin and net return became negative up to 2 years of plant age as total cost was high enough at that time. Then net return increased substantially. Farmer told that in case of BARI Aam-3, fruit yield started decreasing drastically after 15 years of plant age. Per hectare average mango yield was found 5729 kg and gross return and net return was Tk. 1311941 and Tk. 730233 respectively from 2-3 years to 6-7 years of mango orchard.

Capital Budgeting of BARI Aam-3 Mango Orchard

Net present value (NPV): It is evident from Table 5 that NPV of BARI Aam-3 mango orchard is positive and greater than zero. Therefore, the mango production is an acceptance practice and feasible from financial point of view. Further, it also implies that the owner became able to increase his wealth by Tk. 444397 per hectare of mango production at the end of 6-7 years of plants age.

Benefit cost ratio (BCR): BCR was emerged to be 3.03 (Table 5) showing that investment in mango cultivation can be considered substantial and economically justifiable. It indicates that the mango growers earned a gross income of Tk. 2.01 by investing Tk. 1 per one hectare of mango orchard.

Internal rate of return (IRR): IRR was determined by following 'trial and error' approach at different discount rates. By using the formula mentioned in the methodology, IRR was calculated and it was 83.075%. It is evident from Table 5 that IRR of BARI Aam-3 mango orchard stood at 83.075% which is sufficiently greater than existing bank interest rate. So, it assures that investing in BARI Aam-3 mango orchard was very much feasible and it ensured a reasonable profit for the investors.

Table 5. Per hectare rate of returns to investment on BARI Aam-3 mango orchard

Year	Gross cost (Tk)	Gross benefit (Tk)	Present worth of gross cost at 12%	Present worth of gross benefit at 12%
0	104211	0	104211	0
1	82524	71010	73682	63402
2	81212	215116	64741	171489
3	95813	248040	68198	176550
4	102583	318600	65193	202476
5	115365	479300	65461	271968
	Total		441487	885885
	NPV		444397	
	BCR		2.01	
	IRR		83.075%	

Impact of BARI Aam-3 mango cultivation on livelihood improvement

Livelihood improvement of a farmer depends on various socioeconomic activities of the farmer as well as society. However, an attempt was made to measure the changes in assets position of the respondent farmers for one year due to cultivation of BARI Aam-3 variety.

Human capital

Appendix Table 1 shows that the access to human capital of small orchard owners increased by 54.34% due to cultivation of BARI Aam-3 especially education and training increased by 72.7% and 81.8% respectively. Appendix Table 1 represents that involvement in medium type BARI Aam-3 mango orchard production increases their access to human capital by 68% of which health and sanitation was increased by 100%. At the same time education and nutrition status of the medium type BARI Aam-3 mango orchard owner increased by 80%. Access to human capital by the large type BARI Aam-3 orchard owner was increased by 60.54% which also represents a good range of improvement in health and sanitation (70.27%), education (72.97%) and nutrition (78.38%).

Social capital

Appendix Table 1 shows mostly a constant situation of the farmer's involvement in the social capital as they are mostly small mango orchard owner and their income may not support to build their strong social position. It shows only 28.8% of their access to social capital has increased. On the other hand, with the increase in the size of the BARI Aam-3 mango orchard farmers' access to social capital has increased slightly by 43.3% and 45.95% for the medium and large mango orchard owner respectively (Appendix Table 1). But in all the three types a positive movement was found in improvement of social respect and women empowerment.

 Natural capital

Own cultivable land, cultivable land in lease system, using water (pond) and safe drinking water were increased compare to the other natural capital assets which is represented in Appendix Table. Majority of respondents had constant access to different types of natural capital. Most often some natural capital   decrease for the respective respondents.

Physical Capital

The total access to physical capital was increased by 48.17% in case of small mango orchard owner while it was 58% (Appendix Table 1) for medium mango orchard owner and 50% for large mango orchard owner. It means that with the

investment in large size mango orchard brought out more positive output which tends to raise different kinds of physical assets. Number of brick built house was increased. These situations indicate the improvement of household condition of the respondent. The condition of other major components of housing as well as safe drinking water i.e., presence of tube well, electricity and sanitary toilet were also developed considerably. The number of using mobile phone increased tremendously for all the respondents. Some living assets like livestock such as cattle, goat, poultry and duck also were decreasing for the respective respondents. This happened because of lacking livestock grazing land in the study area.

Financial capital

In the case of small mango orchard owner, the status is more or less constant while in case of other two types it shows a gradual increase in all of the items of financial capital. The capital, cash in hand increased by 36.4%, 100% and 78.38% for the small, medium and large mango orchard owner respectively. Farmers' income was increased and they were able to save money and thereby donate more money than the past through raising their participation in mango production practices.

The shape of the pentagon (Figure 2) displayed schematically the variation in farmer's access to assets. It shows the change of livelihood status of BARI Aam-3 farmers. Medium farmers were able to change all types of capital moderately than the small farmer. It is evident from the figure that livelihood status of large farmers has changed tremendously through BARI Aam-3 mango cultivation.
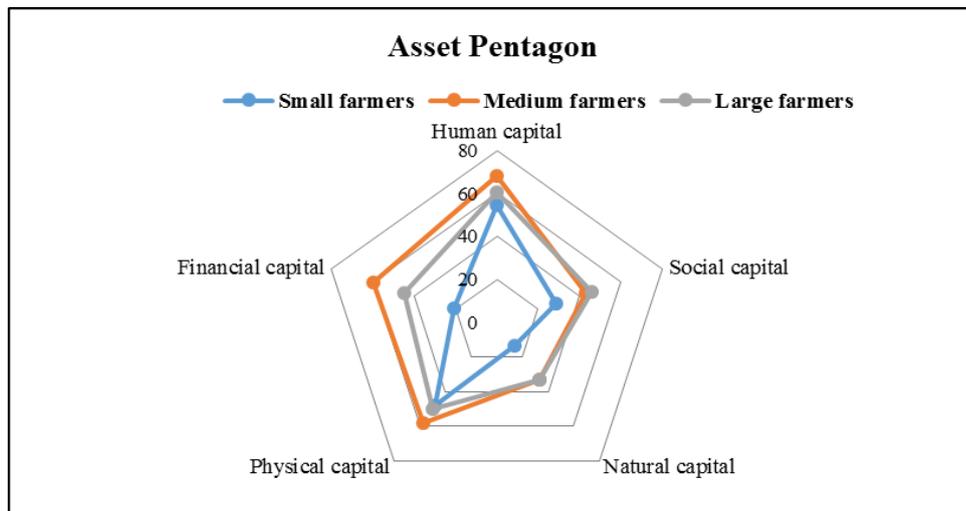

Fig. 2. Livelihood status of sample mango farm households

Table 10 shows that the significant improvement took place in farmer's livelihood due to the production of BARI Aam-3 variety in the study areas. Due

to the adoption of BARI Aam-3 variety, small farmers were able to improve their human and physical capital by 54.34% and 48.17% respectively. In the case of medium farmer's, human, financial and physical capital was increased by 68%, 60% and 58% respectively. But the adoption of BARI Aam-3 mango variety changed human capital and physical capital by 60.5% and 50% respectively for large farmer.

Table 10. Distribution of livelihood capital of BARI Aam-3 mango orchard owner

Asset category	Improvement of livelihoods (%)		
	Small farmers	Medium farmers	Large farmers
Human capital	54.34	68.00	60.54
Social capital	28.50	43.30	45.95
Natural capital	13.65	33.30	33.33
Physical capital	48.17	58.00	50.00
Financial capital	20.47	60.00	44.60

Source: Field Survey, 2018

Conclusion and Recommendation

Cultivation of BARI Aam-3 mango is profitable because it gives substantial higher gross return and net return. Human labor, cost of saplings, insecticides were the major cost items for mango production in the study areas. The rate of returns (i.e. BCR, NPV and IRR) indicated that BARI Aam-3 cultivation is profitable for the farmers. After adopting this variety all types of farmer are able to change their livelihood. They are able to increase their human, physical and social capital significantly. It signifies that, BARI Aam-3 mango production has a good potentiality in Bangladesh. So, to sustain the yield of BARI Aam-3, the combined efforts of concerned authorities are essential at the level of policy formulation. Besides, a proper initiative should be taken to record the information on cost and return and to disseminate this information throughout the country.

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Appendix

Table 1. Changes in livelihood status of BARI Aam-3 mango orchard owner

Livelihood Assets	Degree of change (Small orchard)			Degree of change (Medium orchard)			Degree of change (Large orchard)		
	Increased	Decreased	Constant	Increased	Decreased	Constant	Increased	Decreased	Constant
Human Capital									
Health & Sanitation	36.4	-	63.6	100	-	-	70.27	-	29.73
Education	72.7	-	27.3	80	-	20	72.97	-	27.03
Training	81.8	-	18.2	20	-	80	16.22	-	83.78
Knowledge	18.2	-	81.8	60	-	40	64.86	-	35.14
Nutrition	63.6	-	36.4	80	-	20	78.38	-	21.62
Average	54.34	-	45.46	68	-	32	60.54	-	39.46
Social capital									
Association	18.2	18.2	63.6	40	-	60	48.65	-	51.35
Politics	18.2	-	81.8	-	-	100	8.11	-	91.89
Management	27.3	-	72.7	40	-	60	35.14	21.62	43.24
Social Respect	54.5	18.2	27.3	80	20	-	70.27	13.51	16.22
Decision making	36.4	-	63.6	60	-	40	59.46	2.70	37.84
Women empowerment	18.2	-	81.8	40	-	60	54.05	-	45.95
Average	28.8	6.06	65.13	43.3	3.3	53.3	45.95	6.31	47.75
Natural capital									
Own cultivable land	27.3	-	72.7	20	-	80	43.24	-	56.76
Lease cultivable land	-	45.5	54.5	40	-	60	40.54	-	59.46
Pond	-	45.5	54.5	-	20	80	10.81	24.32	64.86

Livelihood Assets	Degree of change (Small orchard)			Degree of change (Medium orchard)			Degree of change (Large orchard)		
	Increased	Decreased	Constant	Increased	Decreased	Constant	Increased	Decreased	Constant
Water use	36.4	-	63.6	40	-	60	40.54	-	59.46
Safe drinking water	18.2	-	81.8	80	-	20	56.76	-	43.24
Forestry	-	63.6	36.4	20	20	60	8.11	40.54	51.35
Average	13.65	25.76	60.58	33.3	6.7	60	33.33	10.81	55.86
Physical capital									
Brick built house	72.7		27.3	60	-	40	54.05	-	45.95
Furniture	36.4		63.6	80	-	20	75.68	-	24.32
Ag. Tools	9.1	18.2	72.7	60	40	-	51.35	8.11	43.24
Vehicle	9		91	40	20	40	37.84	-	62.16
Tube well	91		9	20	-	80	8.11	24.32	67.57
Electricity	54.5		45.5	80	-	20	51.35	-	48.65
TV/radio/cable network	63.6		36.4	60	-	40	40.54	-	59.46
Mobile phone	81.8		18.2	100	-	-	89.19	-	10.81
Toilet	63.6		36.4	40	-	60	59.46	-	40.54
Livestock	-	81.8	18.2	40	40	20	32.43	24.32	43.24
Average	48.17	10	41.83	58	10	32	50.00	5.68	44.59
Financial capital									
Cash in hand	36.4	-	63.6	100	-	-	78.38	-	21.62
Bank/Savings	18.2	-	81.8	40	-	60	21.62	40.54	37.84
Jewels	-	18.2	81.8	40	-	60	8.11	37.84	54.05
Donation/grant/aid	27.3	-	72.7	60	-	40	70.27	18.92	10.81
Average	20.47	4.55	74.97	60	-	40	44.60	24.33	31.08

(-) indicates no change.

EFFECTS OF ARBUSCULAR MYCORRHIZAL FUNGI, *RHIZOBIUM* AND PHOSPHORUS ON MUNGBEAN (*Vigna radiata*) IN SALINE SOIL

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Abstract

A pot experiment was carried out in the nethouse of Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2017 and 2018 with an objective to evaluate the potentiality of AM fungi, *Rhizobium* and P in different best combinations on germination (%), growth, yield and yield contributing characters, nodulation, sporulation and nutrient concentration of mungbean under low salinity (4 dSm^{-1}) stress condition. The experiment was designed in CRD with 10 treatments and 4 replications. Mungbean variety BARI Mung-6 was used as a test crop. Peat based rhizobial inoculum (BARI RVr-403) was used in this experiment @ 50 g kg^{-1} seed and the population density of inoculum being above 10^8 cfu g^{-1} inoculant. Soil based AM inoculum containing 275 ± 20 spores and infected root pieces of the host plant was used in each pot. There were 10 treatments viz. T_1: Control (Not absolute control), T_2: Arbuscular mycorrhiza (AM) + 50% P, T_3: AM + 75% P, T_4: AM + 100% P, T_5: *Rhizobium* + 50% P, T_6: *Rhizobium* + 75% P, T_7: *Rhizobium* + 100% P, T_8: AM + *Rhizobium* + 50% P, T_9: AM + *Rhizobium* + 75% P and T_{10}: AM + *Rhizobium* + 100% P. The highest seed yield (2.28 g plant^{-1}, 46.2% higher over control in 2017 and 2.97 g plant^{-1}, 33.8% higher over control in 2018) and stover yield (5.23 g plant^{-1}, 30.8% higher over control in 2017 and 5.67 g plant^{-1}, 32.8% higher over control in 2018) were found in AM + *Rhizobium* + 75% P treatment. Dual inoculation significantly increased P, S, Mg, Fe, Mn and Zn concentration of mungbean plant compared to control. The results suggest that inoculation of AM fungi and *Rhizobium* along with 75% of recommended P rate can help increased mungbean yield under low salinity stress condition through influence on nodulation, colonization and nutrient uptake.

Keywords: Nodulation, salinity, seed yield and nutrient content

Introduction

Soil salinity globally results in the greater loss in agricultural productivity. Over 30% of the cultivable area of Bangladesh lies in the coastal and offshore zones. Out of 2.86 million hectares of coastal and offshore lands, about 1.05 million hectares are affected by varying degrees of salinity (SRDI, 2010). Furthermore, the salinized areas are increasing at a rate of 10% annually for various reasons,

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including low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water and poor cultural practices. It has been estimated that more than 50% of the arable land would be salinized by the year 2050 (Jamil *et al.*, 2011).

Microorganisms specially arbuscular mycorrhiza have the potential to reduce the sodium and chloride toxicity in crops and that could be a more cost effective long term environmental friendly option. Arbuscular mycorrhizal fungi are pervasive and they are found in 80% of vascular plant families in existence today and fungi belonging to the order glomeromycota. Plants inoculated with mycorrhiza have been reported to improve plant growth and yield under salinity or NaCl stress conditions such as *Ocimum basilicum* (Ashoori *et al.*, 2015) and *Lens culinaris* (Rahman *et al.*, 2017). *Rhizobium* biofertilizer is a significant technology for improving crop productivity and soil fertility. It improves nodulation and as well as nitrogen fixation even under adverse soil conditions. Some studies are available on the double inoculation of AM and rhizobium under salinity condition increased yield of plants (Soliman *et al.*, 2012). But there is no evidence of combined use of AM fungi and *Rhizobium* biofertilizer along with inorganic P fertilizer in the mitigation of soil salinity. It is known that very high and very low P levels may reduce mycorrhizal infection/colonization (Koide, 1991). It is also well established that infection by mycorrhizal fungi is significantly reduced at high soil P levels (Koide and Li, 1990). Thus, we made intention to use 50%, 75% and 100% P in the current experiment.

Mungbean (*Vigna radiata*) var. BARI Mung-6 is commonly used as an important pulse crop in Bangladesh. In 2016-2017, about 41,421 ha of land was under mungbean cultivation and the total production was about 34,783 metric tons (BBS, 2017). Mungbean may benefit from symbiotic association with mycorrhiza and rhizobium forming tripartite symbiosis. Keeping in view the above information, present investigation was undertaken to investigate the potential of AM fungi, *Rhizobium* and P on germination (%), growth, yield and yield contributing characters, nodulation and nutrient concentration of mungbean plant under low salinity stress condition.

Materials and Methods

Seed collection and soil preparation

The experiment was carried out during kharif season from March to May 2017 and March to June 2018 in the nethouse of Soil Science Division, BARI, Joydebpur, Gazipur. Seeds of mungbean (BARI Mung-6) were collected from Pulses Research Centre, BARI, Gazipur. Bulk soil was collected from the bank of Turag river at Kodda, Gazipur. Soil was mixed with cowdung (Soil: Cowdung = 5:1) for use in the pot experiment. Each pot (28 cm in diameter and 23 cm in height) was filled with 8-kg soil leaving upper 3 inches of pot vacant to facilitate watering.

Soil analysis

Soil pH was measured by a combined glass calomel electrode (Jackson, 1958), organic carbon was determined by Wet Oxidation Method (Walkley and Black, 1934), total N by modified Kjeldahl method (Jackson, 1962), and Ca, K & Mg by NH_4OAc extraction method (Black, 1965). Copper, Fe, Mn and Zn were determined by DTPA extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method, P by Modified Olsen method (Olsen *et al.*, 1954) and S by $CaH_4(PO_4)_2.H_2O$ extraction method (Chesnin and Yien, 1950).

Fertilizer application

Chemical fertilizers @ 23 kg N ha^{-1} from urea, 25 kg P (100%) ha^{-1} from TSP, 35 kg K ha^{-1} from MoP, 8 kg S ha^{-1} from gypsum, 2.25 kg Zn ha^{-1} from $ZnSO_4$, 0.81 kg B ha^{-1} from Boric acid and 0.34 kg Mo ha^{-1} from $Na_2MoO_4.2H_2O$ were applied (BARC, 2012). Half of urea-N and all other fertilizers were applied as basal and the remaining half was applied after 10 days of sowing. There were three P levels: 50%, 75% and 100% P. Peat based rhizobial inoculum (BARI RVr-403) was used in this experiment @ 50 g kg^{-1} seed and in that case N fertilizer was not used. The population density of used inoculum was above 10^8 cfu g^{-1} inoculant.

Preparation of salinity solution and mycorrhizal inoculum

Required concentrations of salinity were prepared according to New South Wales (NSW), Australia and applied three times during the experimentation period (Before seed sowing, 25 DAS and 35 DAS to maintain salinity level at 4 dSm^{-1}). The arbuscular mycorrhizal inoculum was prepared from the roots and rhizosphere soils of Sorghum. Mycorrhizal species was originally isolated from different AEZs using the wet sieving and decanting method (Gerdemann and Nicolson, 1963). The spores mixed soil were put in the bed of sorghum plants to multiply for 6 months in the nethouse of Soil Science Division, BARI. Plants were irrigated with tap water as needed. A mixture of infected sorghum root and soil which contained spores was used as mycorrhizal inoculum. Dominant mycorrhizal spores were from the genera *Glomus*, *Acaulospora*, *Gigaspora* and *Scutellospora*. The soil based AM fungal inoculum containing 150 g of rhizosphere soil (approximate 183 ± 20 spores/100 g soil) along with infected sorghum root fragments with a minimum infection level was inoculated to each mycorrhizal pot. Different mycorrhizal spores identified in the Soil Microbiology Laboratory, Soil Science Division, BARI and used for the experiment were shown in Figure 1. The mycorrhizal inoculum was placed in each pot at 3-5 cm depth and was covered with a thin soil layer of 1 cm immediately prior to the seed sowing of mungbean to facilitate AM colonization of plant roots.
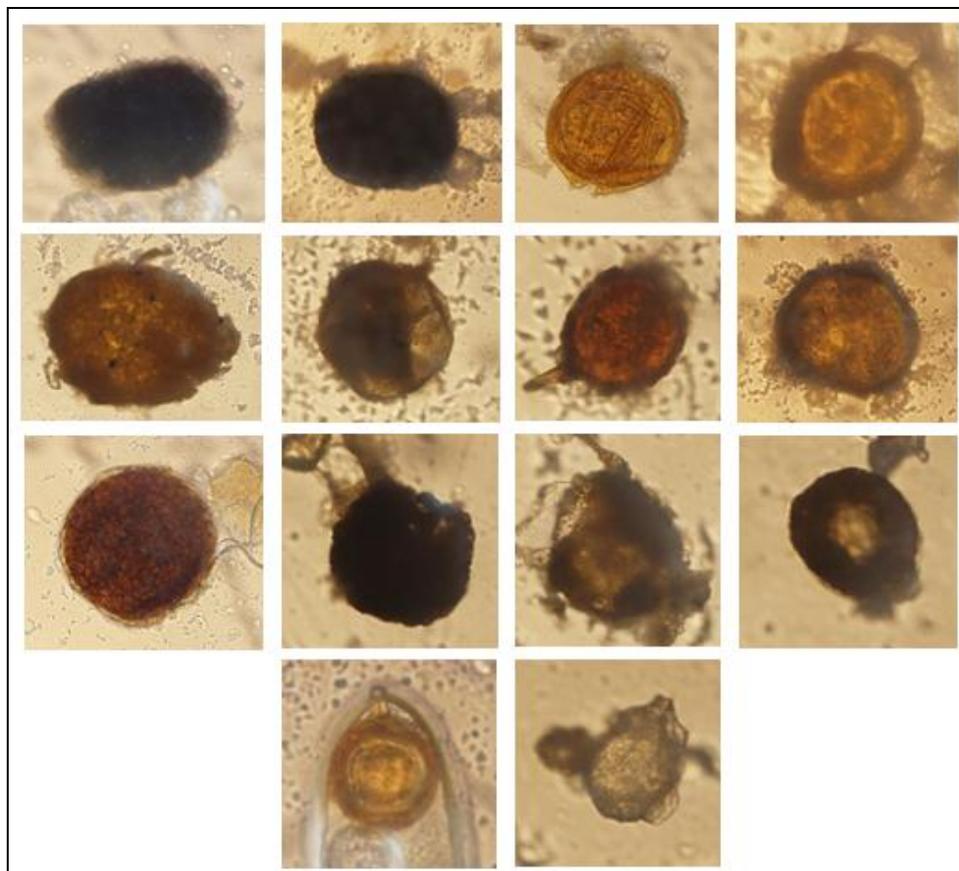
Figure 1. Different mycorrhizal spore (*Glomus*, *Acaulospora*, *Gigaspora* and *Scutellospora* spp) identified in the Soil Microbiology Laboratory, Soil Science Division, BARI and used for the experiment.

Identification of AM fungal spore

AM fungal spore, single spore or sporocarps were easily picked up from the Petridis by filter paper with the help of syringe or fine point camel brush and mounted on a glass slide with a drop of polyvinyl lactophenol (PVL) and a cover slip was placed. Subsequently, recovered spores were identified with the help of a Manual and different taxonomic keys proposed by different workers (Schwarzott *et al*., 2001). Spore morphology, size, shape and peridium of spore, sporocarps colour, wall ornamentation, subtending hyphae and mode of attachment are considered for identification of spore or sporocarps.

Design of experiment and treatments

The experiment was designed in CRD with 10 treatments and 4 replications. There were 10 treatments viz. T_1: Control (Not absolute control), T_2: Arbuscular

mycorrhiza (AM) + 50% P, T_3: AM + 75% P, T_4: AM + 100% P, T_5: *Rhizobium* + 50% P, T_6: *Rhizobium* + 75% P, T_7: *Rhizobium* + 100% P, T_8: AM + *Rhizobium* + 50% P, T_9: AM + *Rhizobium* + 75% P and T_{10}: AM + *Rhizobium* + 100% P. Ten seeds were sown in each pot beneath 1 cm soil depth. After collecting germination percentage data, 6 vigorous seedlings were kept in each treatment and other seedlings were removed from the pot. Three plants of each were collected for nodulation and colonization data and rest three plants were kept finally in each pot for yield and yield contributing measurements.

Determination of germination percentage

The germination test was carried out according to ISTA rules (ISTA, 1976). For each treatment, 25 seeds were put into Petri dishes. The Petri dishes were put on a laboratory table at room temperature ($28 \pm 2^{o}C$). After 3 days, normal, abnormal and diseased seeds were counted. Germination of mungbean seed in the laboratory table was 84%. Ten seeds were sown in each pot. After 4, 6, 8 and 10 days germinated seeds were observed and counted.

Crop harvest

Mungbean was harvested after 62 days of sowing. Different growth parameters like plant height, pods plant^{-1}, seeds pod^{-1}, 100-seed weight, seed yield and stover yield were recorded. Other parameters like nodule number, nodule weight and root infection (%) were measured at the time of 50% flowering stage of mungbean.

Assessment of root colonization infection

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

Table 1. Initial fertility status of soil and cowdung used in the experimental pot

Samples	Texture	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
				meq 100 g^{-1}				µg g^{-1}						
Soil	Sandy clay loam	7.1	0.51	7.2	2.5	0.11	0.026	9.9	21.1	0.22	1.8	15	1.1	0.38
Cowdung	-	6.7	14.1	1.55	0.82	0.88	0.84	1.26	0.62	0.02	0.01	0.25	0.11	0.02
Critical level	-	-	-	2.0	0.5	0.12	-	10	10	0.20	0.2	4.0	1.0	0.60

Statistical analysis

Data were statistically analyzed using Analysis of Variance (ANOVA) following CropStat package while the all pair comparisons were done by Statistix 10.

Results and Discussion

Effects of AM, *Rhizobium* and P on germination of mungbean

Effect of AM, *Rhizobium* and P on germination of mungbean have presented in Table 2 and Fig. 2. Significant differences were found in case of germination in 2017, not in 2018. The highest germination was found in the AM + *Rhi.* + 100% P treatment and the lowest germination in the control treatment.

Table 2. Effects of AM, *Rhizobium* and P on germination of mungbean in 4 dSm^{-1} saline soil

Treatments	Germination (%)					
	4 DAS		6 DAS		8 DAS	
	2017	2018	2017	2018	2017	2018
Control	52.5d	45.0	75.0bc	72.5	75.0a	72.5
AM + 50% P	65.0bcd	52.5	80.0abc	70.0	80.0abc	72.5
AM + 75% P	60.0cd	65.0	75.0bc	80.0	75.0c	82.5
AM + 100% P	60.0cd	55.0	70.0c	85.0	77.5bc	87.5
Rhi. + 50% P	82.5a	62.5	85.0ab	72.5	90.0a	75.0
Rhi. + 75% P	80.0ab	67.5	87.5a	77.5	90.0a	82.5
Rhz. + 100% P	75.0abc	65.0	77.5abc	77.5	82.5abc	80.0
AM + *Rhi.* + 50% P	80.0ab	60.0	87.5a	72.5	90.0a	77.5
AM + *Rhi.* + 75% P	70.0abc	57.5	85.0ab	75.0	85.0abc	75.0
AM + *Rhi.* + 100% P	80.0ab	57.5	87.5a	77.5	87.5ab	75.0
SE (±)	5.36	6.26	4.24	5.86	4.08	5.14
F-test	**	NS	*	NS	*	NS
CV (%)	15.2	21.3	10.5	15.4	9.80	13.2

AM: Arbuscular mycorrhiza, *Rhi.: Rhizobium*. Control is not absolute control. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. **Significant P≤0.01, *significant P≤0.05, NS not significant
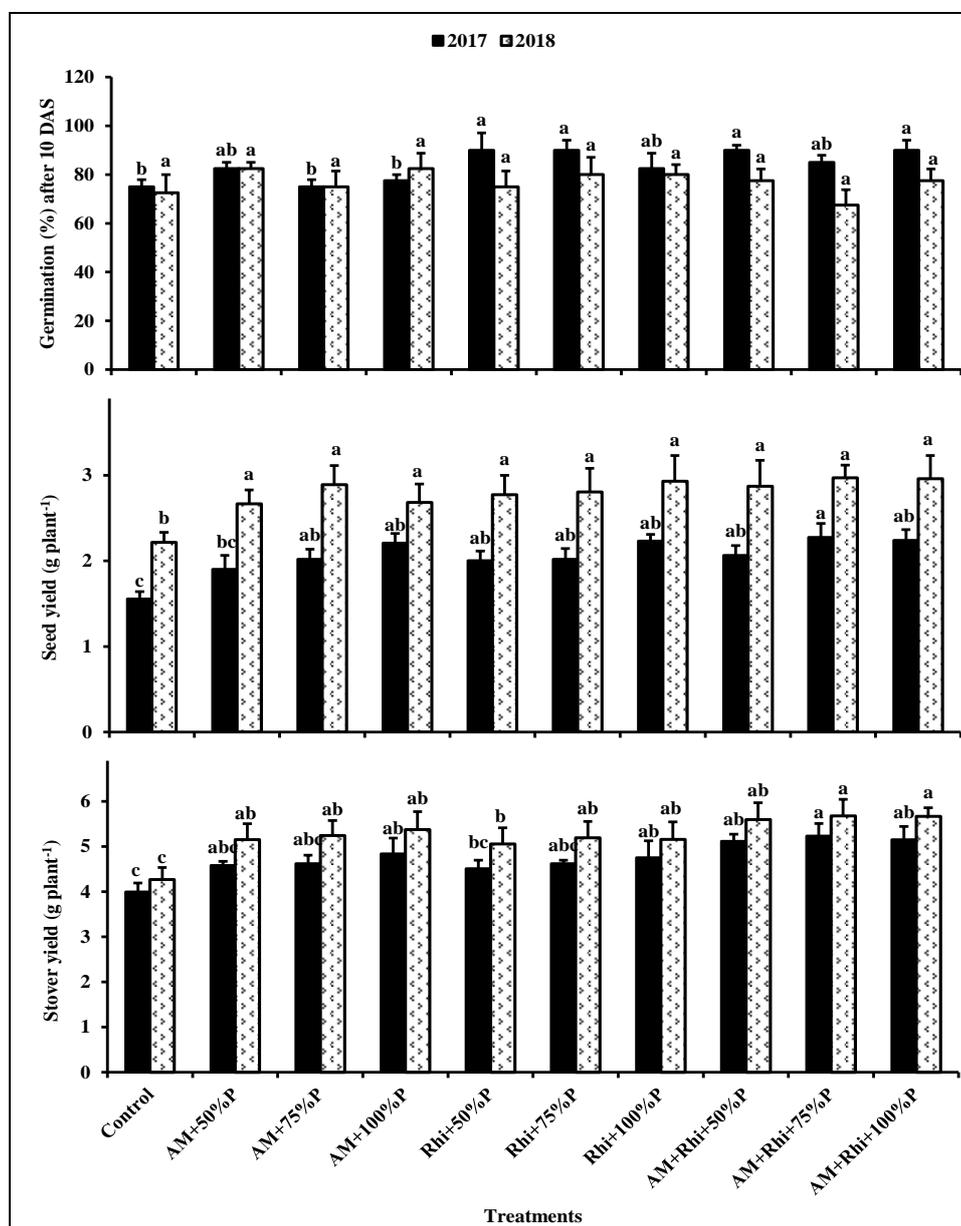
Fig. 2. Effects of AM, *Rhizobium* and P on germination (%), seed yield and stover yield of mungbean in slightly saline soil during 2017 and 2018.

High salt concentrations can reduce seed germination and initial seedling growth, as well as the growth of established plants (Zedler *et al*., 2003). Mendez *et al*. (2015) reported that salinity stress reduced both seed germination and seedlings growth of *Phaseolus vulgaris* at salt concentrations above 150 mM. Beneficial

effect of AM fungi and *Rhizobium* in soil would be due to creation of soil conditions suitable for the growth of hyphae and increased microbial activity.

Effects of AM, *Rhizobium* and P on plant height, yield and yield attributes of mungbean

Effects of AM, *Rhizobium* and P on plant height, yield and yield attributes of mungbean are shown in Table 3 and Fig. 2. Seed yield (g pot^{-1}) and stover yield (g pot^{-1}) was significant but statistically identical with rest of the treatments except control while the plant height, yield and yield attributes were not significant. The highest seed yield (2.28 g plant^{-1}, 46.2% higher over control in 2017 and 2.97 g plant^{-1}, 33.8% higher over control in 2018) and stover yield (5.23 g plant^{-1}, 30.8% higher over control in 2017 and 5.67 g plant^{-1}, 32.8% higher over control in 2018) were found in AM + *Rhizobium* + 75% P treatment. On the other hand, lowest seed yield (1.56 g plant^{-1} in 2017 and 2.22 g plant^{-1} in 2018) and stover yield (4.00 g plant^{-1} in 2017 and 4.27 g plant^{-1} in 2018) were found in control treatment.

Table 3. Effects of AM, *Rhizobium* and P on plant height, yield and yield attributes of mungbean in 4 dSm^{-1} saline soil

Treatments	Plant height (cm)		Pods plant^{-1}		Seeds pod^{-1}		100-seed weight (g)		Seed yield increase over control (%)		Stover yield increase over control (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Control	25.0	30.7	4.75	6.75	6.80	8.20	4.92	4.59	-	-	-	-
AM + 50% P	27.2	31.9	5.50	8.65	8.00	8.90	5.24	5.47	21.8	20.3	14.5	20.6
AM + 75% P	27.5	32.3	5.92	8.50	8.30	9.20	5.26	5.42	29.5	30.2	15.5	22.7
AM + 100% P	27.9	31.8	6.17	7.82	8.40	8.90	5.40	5.40	41.7	20.7	21.0	25.8
Rhi. + 50% P	27.5	31.8	5.83	6.90	7.50	9.30	5.36	4.62	28.9	24.8	12.8	18.5
Rhi. + 75% P	28.0	32.3	5.92	8.00	7.60	9.40	5.44	4.64	29.5	26.6	15.5	21.6
Rhiz. + 100% P	29.0	31.8	6.25	7.75	8.25	9.35	5.44	5.65	43.0	32.0	18.8	20.8
AM + *Rhi.* + 50% P	27.6	32.3	5.92	7.78	8.15	9.50	5.42	5.11	32.7	29.3	28.0	30.9
AM + *Rhi.* + 75% P	28.8	32.0	5.92	8.50	8.80	9.50	5.46	5.53	46.2	33.8	30.8	32.8
AM + *Rhi.* + 100% P	29.7	32.7	6.25	8.50	8.45	9.70	5.46	5.36	43.6	33.3	28.8	32.6
SE (±)	1.46	0.88	0.32	0.55	0.44	0.43	0.09	0.41	-	-	-	-
F-test	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	-
CV (%)	7.40	5.49	11.1	13.9	11.0	9.25	6.90	11.1	-	-	-	-

AM: Arbuscular mycorrhiza, *Rhi.: Rhizobium*. Control is not absolute control. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. NS not significant

Table 4. Effects of AM, *Rhizobium* and P on nutrient concentration of mungbean in 4 dSm^{-1} saline soil

Treatments	Nutrient concentration										
	N	P	K	S	Ca	Mg	B	Cu	Fe	Mn	Zn
	%						ppm				
Control	2.26	0.46c	1.55	0.27de	2.51	1.31b	0.38	6.09	894c	357.5c	34.7b
AM + 50% P	2.33	0.46c	1.58	0.32b	2.72	1.45a	0.46	6.66	950bc	379.8bc	38.6a
AM + 75% P	2.39	0.47bc	1.58	0.30b-e	2.67	1.42a	0.43	6.89	897c	358.7c	39.3a
AM + 100% P	2.36	0.50bc	1.59	0.30bc	2.76	1.47a	0.45	6.72	910c	364.1c	39.4a
Rhi. + 50% P	2.27	0.46c	1.56	0.27e	2.66	1.47a	0.44	6.57	1031ab	417.3ab	37.5a
Rhi. + 75% P	2.31	0.49bc	1.57	0.30b-d	2.75	1.46a	0.41	6.82	1022ab	408.8ab	38.4a
Rhiz. + 100% P	2.27	0.50b	1.58	0.29b-e	2.72	1.47a	0.46	6.54	1032ab	412.7ab	39.5a
AM + *Rhi.* + 50% P	2.38	0.56a	1.59	0.28c-e	2.75	1.46a	0.45	6.88	1070a	427.8a	39.5a
AM + *Rhi.* + 75% P	2.40	0.57a	1.59	0.30b-d	2.79	1.48a	0.43	6.78	1091a	436.4a	39.5a
AM + *Rhi.*+ 100% P	2.40	0.57a	1.59	0.36a	2.78	1.48a	0.45	6.96	1077a	430.5a	39.5a
SE (±)	0.08	0.01	0.02	0.02	0.06	0.03	0.02	0.29	38.5	15.1	1.17
F-test	NS	**	NS	**	NS	*	NS	NS	**	**	**
CV (%)	5.03	5.57	3.09	7.19	4.43	4.45	7.54	6.09	7.72	7.54	4.29

AM: Arbuscular mycorrhiza, *Rhi.: Rhizobium*. Control is not absolute control. The values represent means of 4 replicates. Different letters within each column indicate significant differences between treatments. Test CropStat and Statistix 10. **Significant P≤0.01, *significant P≤0.05, NS not significant.

The present results agree with Sharifi *et al*. (2007) who reported that the alfalfa specimens inoculated with both *Rhizobium* and *Glomus* produced the highest shoot yield and they concluded that *Rhizobium* may affect fungal metabolism. The results are also in line with other studies that have shown that inoculation of legumes with both rhizobium and AMF increases plant growth to a greater extent than either inoculum when added singly (Murakami *et al*., 1991). Soliman *et al*. (2012) observed that co-inoculation (AMF + R) enabled the plants (*Acacia saligna*) to maintain osmotic adjustments and enhanced the plants tolerance against salinity.

Effects of AM, *Rhizobium* and P on nodule number, nodule weight and root colonization of mungbean

Effect of AM, *Rhizobium* and P on nodule number, nodule weight and root colonization of mungbean are displayed in Fig. 3 and Fig. 4. Significant differences were found in case of nodule number plant^{-1}, nodule weight (mg plant^{-1}) and root infection (%) at 50% flowering stage. The highest nodule number (21.3 plant^{-1}), nodule weight (26.7 mg plant^{-1}) and root infection (33.3%) at 50% flowering stage was found in AM + *Rhizobium* + 100% P treatment. The

lowest nodule number (18.8 plant^{-1}), nodule weight (18.3 mg plant^{-1}) and root infection (13.3%) at 50% flowering stage was found in control treatment.
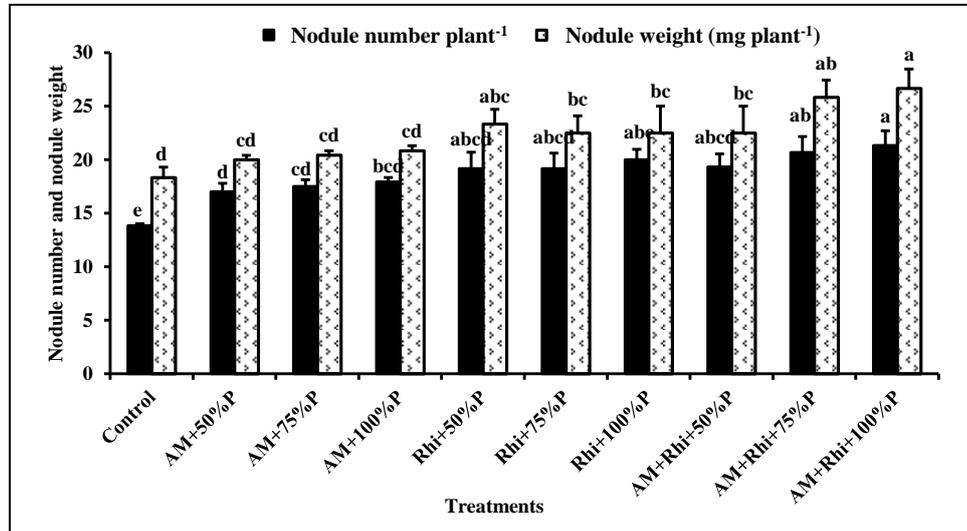

Fig. 3. Effects of AM, *Rhizobium* and P on nodule number and nodule weight of mungbean in slightly saline soil.
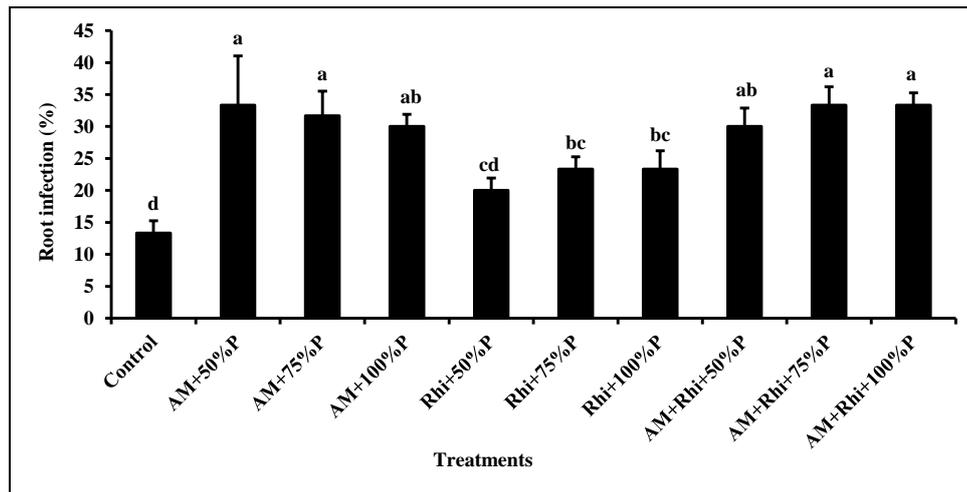

Fig. 4. Effects of AM, *Rhizobium* and P on root infection (%) of mungbean in slightly saline soil.

Soliman *et al*. (2012) reported that co-inoculated (AMF + *Rhizobium*) stressed plants enhanced nodulation parameters. Reduction in nodulation under salt stress could be due to a reduction in survival and multiplication of rhizobia cells (Elboutahiri *et al*., 2010). The reduction in the number and weight of nodules was less when the plants were double inoculated, compared to inoculation with

rhizobium or mycorrhiza alone. This depicted that the harmful effect of salinity could be reduced by dual inoculation. Salinity decreased the hyphae growth and/or viability of AMF and also decreased respiration, survival probability, inhibited enzyme function and multiplication of the rhizobia cells in the substrates, which affect the process of root colonization and nitrogenase activity (Mahmood *et al*., 2008). In this present study, co-inoculated (AMF + *Rhizobium*) test plants showed less toxic effects of salts on nodulation parameters and mycorrhizal infection compared with control plants. This can be attributed to improve root growth. In addition, root exudation is modified both qualitatively and quantitatively by arbuscular mycorrhizal symbiosis and this has led to increase in nodulation parameters and mycorrhizal infection (Garg and Manchanda, 2009).

Effect of AM, *Rhizobium* and P on nutrient concentration of mungbean

Effect of AM, *Rhizobium* and P on nutrient concentration of mungbean is exhibited in Table 4. Significant differences were found in case of P, S, Mg, Fe, Mn and Zn concentrations of mungbean but other nutrients not significant. The highest P concentration was found in AM + *Rhizobium* + 100% P treatment and the lowest P concentration in control treatment. The highest Mg, Fe, Mn and Zn concentrations were found in AM + *Rhizobium* + 75% P treatment and the lowest result in control treatment.

However, N, P, K, S, Zn and B concentrations of mungbean were higher in co-inoculated plants at all P levels compared to sole-inoculated plants. Increased N and P supply resulting in an increase in nitrogen fixation can be suggested for the benefits of the synergistic relationship (Giri *et al*., 2002). Under salinity condition, the greatest amount of mycorrhizal infection, nodulation, P concentration and the root Ca concentration of alfalfa plants were recorded when plants were double inoculated. (Ashrafi *et al*., 2014).

This report therefore confirms that mycorrhizal-inoculated plants have alternative mechanisms to satisfy their nutritive requirement in stress situations. There are indications that a beneficial effect of AM fungi and *Rhizobium* in soil are due to the creation of soil conditions suitable for the growth of hyphae, increased microbial activity and increased mineral nutrient uptake specially P by plant.

Conclusion

Results of the experiment revealed that the highest yield of mungbean was found in AM + *Rhizobium* + 75% P treatment. Mungbean yield considerably increased under low salinity stress condition by increasing nodulation, colonization and nutrient uptake. Maximum increment was noted where 100% of the recommended P along with dual inoculation (AM + *Rhizobium*) was applied, however, it was statistically at par with the results recorded by 75% of recommended P along with dual inoculation of mycorrhiza and *Rhizobium* inoculum.

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EVALUATION OF JACKFRUIT GERMPLASM FOR YIELD AND YIELD CONTRIBUTING CHARACTERS

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Abstract

Twenty germplasm of jackfruit grown in the Fruit Research Farm of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) were evaluated for growth, yield and yield parameter along with qualitative characters from July 2012 to June 2015. All the germplasm varied for most of the parameters evaluated. The tallest plant was recorded in AH Joy-079(6.75m) and shortest plant in AH Joy-075 (3.50 m) among the germplasm. Base girth ranged from 42.50 cm to 80.20 cm in AH Joy-075 and AH Joy-085, respectively. Maximum plant spreading with North-South and East-West canopy (5.50 m and 6.00 m, respectively) was recorded in AH Joy-079 and minimum (3.00 m and 3.50m) in both AH Joy-075 and AH Joy-090 germplasm. The fruit number varied from 02 to 11 among the germplasm. Individual fruit weight ranged from 2.27 kg to 11.33 kg where AH Joy-034 had the lowest and AH Joy-092 noted the highest fruit weight. Maximum bulb (184) was recorded in AH Joy-092 and minimum (45) in AH Joy-085. Maximum TSS (25.0) was recorded in AH Joy-029 and minimum (14.0) in AH Joy-067 and the edible portion was noted the highest in AH Joy-036 (48.60%) where it was lowest in AH Joy-078 (32.10%). Bulb texture was soft to hard. Maximum germplasm were juicy to medium juicy having yellow to light yellowPulp. Therefore, The germplasm AH Joy-089, AH Joy-017 and AH Joy-092 may be selected for higher yielder. The germplasm AH Joy-034,AH Joy-067, AH Joy-078,AH Joy-085 and AH Joy-098 should be selected for family size jackfruit as their individual fruit weight ranges between 2 to 4 kg including yellow bulb colourcontaining good juiciness and soft bulb texture.

Keywords: Jackfruit, qualitative characters, quantitative characters, family size fruit and yield.

Introduction

Jackfruit (*Artocarpus heterophyllus* L.) is a tree species of the family Moraceae which is native to Southeast Asia. It is the largest edible fruit in the world (Naik, 1949 and Sturrock, 1959). Jackfruit locally called "kathal" has gained the position of national fruit of Bangladesh due to its popularity and diversified use and other features. Every part of either the jackfruit tree or fruit has great economic importance. The poor people of jackfruit growing area used to eat this fruit instead of rice for one of their daily meals, in this regard it is commonly referred to as "the poor man's food" (Rahman *et al.*, 1994). It is a cross-

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pollinated fruit tree and is mainly propagated by seeds in Bangladesh. As a result, wide range of variation is exhibited in morpho-agronomic characteristics. Narasimham (1990) and Hossain (1996) reported different types of jackfruit, which vary widely in size, shape, bearing habit and quality. Azad (1999) noted the vast genetic diversity in jackfruit on the basis of morpho-agronomic traits and using isozyme marker.Jackfruit is identified as deserving priority attention in Bangladesh because of its importance and diversity (Azad *et al.,* 2007; Hossain, 1996; Saha *et al.,* 1996), and Bangladesh is considered as a secondary center of jackfruit diversity (Arora, 1998; Dhar, 1998 and Hossain, 1996). Jackfruit rips mostly in May-July and there is an abundance of fruit in the market in this period. Every year a lot of fruits get rotten at that time. If the farmers can produce jackfruit early, they can get more benefit. It is a large monoecious tree producing fruit up to 50×100 cm size and weighing 50 kg (Jagadeesh *et al.,* 2006). The development of jackfruit varieties through hybridization is cumbersome and more time consuming. Therefore, selection of superior chance seedling has been suggested for the varietal development of jackfruit. The field population of jackfruit is composed of a large number of variable genotypes providing ample scope of selecting the superior ones.Bangladesh Agricultural Research Institute has already released two jackfruit varieties, but still there are opportunities to develop jackfruit varieties that farmers can cultivate for better yield and quality. Keeping this view in mind, the study was therefore, carried out to find out suitable line(s) for the development of a variety.

Materials and Methods

The studywas conducted at the Fruit Research Farm of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) during June 2012–June 2015 at Gazipur (24°06´N; 90° 21´E), Bangladesh. Earlier a survey was carried out in the central region of Bangladesh using questionnaire developed as per descriptor of jackfruit published by International Plant Genetic Resources Institute (IPGRI, 2000). Fruits of20 germplasm were collected and five fruits from each accession were analyzed in the laboratory to study the fruit characteristics. Seedlings of each accession were planted following single row plantation in the Fruit Research Farm of HRC on 01 July 2001. The age of plants was 10 years at the time of study. Subsequently three fruiting years of each accession are included under this study. The climate of the experimental area was under subtropical zone which was characterized by high temperature and high rain during April to November and little or no rain during October to march. The soil of the experimental site was clay loam belonging to the Modhupur tract under Agro Ecological Zone 28 (Ahmed *et al.*, 2016). Planting distance was maintained 6 m x 3 m. A fertilizer dose of 300g Urea, 300g TSP, 250g MOP and 20 kg cowdung per plant and subsequent irrigation were applied on August 2012 after harvesting of fruits. The experimental plot was ploughed with power tiller just before applying fertilizer. Weeding was performed in the month March and April 2013. Unwanted branches were pruned off in September 2012. Data on

plant height, base girth, canopy spreading (north-south and east-west spread), number of fruits per plant, fruit length and diameter, spine number per 5 square cm, rind weight, rachis weight, bulb length and width, TSS, number of bulb and edible portion were recorded and analyzed statistically. Tree volume was calculated using the formula of Westwood *et al.* (1963), i.e., tree volume $(m^3) = 4/3\pi a^2 b$, where a= average of east-west and north-south spread, b=half of plant height and π (constant) =3.14.

Results and Discussion

Growth characteristics of jackfruit germplasm

Plant and fruit characteristics of 20 accessions of jackfruit are presented in Table 1. The highest plant height (6.75 m) was found in AH Joy-079 closely followed by AH Joy-086 (6.50 m) and AH Joy-059 (6.25 m), while it was noted the lowest (3.50 m) in AH Joy-075.

Table 1. Growth characteristics of 20 jackfruit germplasm (average of 3 years)

Acc. no.	Plant height (m)	Base girth (cm)	Canopy Spreading		Tree volume (m^3)
			N-S	E-W	
AH Joy-017	5.50	75.00	4.50	4.75	16.96
AH Joy-029	6.00	60.00	4.00	5.25	18.50
AH Joy-032	6.00	62.50	3.75	4.00	15.50
AH Joy-034	5.67	60.00	3.00	4.33	13.85
AH Joy-036	5.55	55.60	3.10	4.00	13.14
AH Joy-059	6.25	72.00	4.75	5.00	20.31
AH Joy-067	5.50	66.00	3.50	4.25	14.21
AH Joy-075	3.50	42.50	3.00	3.50	18.90
AH Joy-078	5.30	65.00	5.70	5.00	7.58
AH Joy-079	6.75	55.80	5.50	6.00	25.88
AH Joy-080	5.67	45.50	4.70	4.00	16.44
AH Joy-081	4.75	68.30	5.00	4.85	15.60
AH Joy-085	5.33	80.20	4.65	5.20	17.50
AH Joy-086	6.50	50.50	4.50	5.33	21.30
AH Joy-087	3.75	58.00	3.75	4.25	10.00
AH Joy-089	5.75	75.50	5.50	5.80	21.66
AH Joy-090	4.30	45.00	3.00	3.50	9.32
AH Joy-092	4.50	55.00	4.00	3.75	11.63
AH Joy-098	5.20	65.00	3.50	4.30	13.52
AH Joy-097	4.33	58.00	4.00	4.55	12.34
Mean	5.30	60.77	4.18	4.58	15.71
SD	0.87	10.43	0.85	0.72	4.23
CV (%)	16.51	17.16	20.30	15.63	12.43

Maximum base girth (80.20 cm) was obtained from AH Joy-085 followed by AH Joy-089 (75.50 cm) and AH Joy-017 (75.00 cm). Minimum base girth (42.50 cm) was found in AH Joy-075. North-South (5.50 m) and east-west (6.00 m) plant spreading were exhibited maximum in AH Joy-079 and those were demonstrated minimum (3.00 m and 3.50 m, respectively) in AH Joy-090. More or less similar physico-morphological variation has been reported in jackfruit by Reddy *et al.*, 2004; Shyamalamma *et al.*, 2008; Ullah and Haque, 2008. Maximum tree volume was yielded by the germplasm AH Joy-079 (25.88 m^3) where it was minimum (7.58m^3) in AH Joy-078.

Fruit characteristics of jackfruit germplasm

a.   Quantitative characteristics

A wide variation in physico-morphological fruit characteristics of jackfruit was observed among the 20 jackfruit germplasm (Table 2). The harvesting time showed that first harvesting was done in all the germplasm from mid-May to late May in three consecutive study years. The earliest first harvest (12-16 May) was recorded in AH Joy-098 which was late (26-31 May) in the germplasm AH Joy-017.Duration of harvest was carried out 24.67 to 48.67 days (in the germplasm AH Joy-087 and AH Joy-080 respectively) which is supported by the result of karim *et al*. (2008). Maximum coefficient of variation was observed for number of bulbs/fruit(50.41%) followed by number of fruits per plant (44.81%).Bulbis the economically important part of jackfruit as it comprises the edible part known as flake. Hence these characters can be considered for selection of elite type jackfruit. There are a few published reports which indicated variation for bulb characters in jackfruit clones (Muralidharan *et al.,* 1997; Mitra and Mani, 2000; Reddy *et al*., 2004 and Jagadeesh *et al*., 2010). Total soluble solids in the genotypes recorded comparatively low values for coefficient of variation (14.75%) signifying that this trait is conserved in nature. This result agreed with findings of Jagadeesh *et al*. (2010). However, a slight variation in this parameter can cause considerable impact on taste. Maximum number of fruits per plant (10.67) was produced by the accession AH Joy-067 followed by AH Joy-017 (8.33) and AH Joy-089 (7.67) whereas minimum number (02) was found in AH Joy-081 and AH Joy-087.The biggest fruit (11.33 kg) with maximum fruit length (39.00 cm) and diameter (25.20 cm) was harvested from the germplasm AH Joy-092 followed by AH Joy-090 (8.63 kg).

The smallest fruit (2.27 kg) having minimum fruit length (23.50 cm) and diameter (13.80 cm) was observed in AH Joy-034. Very dense spine (per five squire centimeter) was found in AH Joy-090 (151) followed by AH Joy-089 (134) and minimum in AH Joy-017 (38).

Table 2. Fruit characteristics of 20 jackfruit germplasm (average of 3 years)

Acc. no.	First harvesting time	Duration of harvest (days)	Fruit length (cm)	Fruit dia (cm)	Spine no/5sq. cm of fruit	No of bulbs/fruit	TSS (%)	Edible portion (%)
AH Joy-017	26-31 May	41.00	25.0	24.4	38	75	20.0	42.50
AH Joy-029	20-25 May	39.33	30.4	23.0	63	181	25.0	43.20
AH Joy-032	22-27 May	40.33	25.0	20.2	59	60	20.0	39.20
AH Joy-034	16-20 May	28.67	23.5	13.8	103	94	21.0	44.70
AH Joy-036	15-20 May	36.33	28.1	23.0	64	104	16.0	48.60
AH Joy-059	15-20 May	42.00	26.1	21.8	64	73	15.5	48.20
AH Joy-067	18-24 May	37.67	26.3	16.2	87	74	14.0	41.40
AH Joy-075	15-22 May	46.33	26.1	24.1	47	165	18.0	44.60
AH Joy-078	18-22 May	34.67	29.7	17.0	64	52	14.0	32.10
AH Joy-079	15-20 May	46.33	33.2	20.1	108	55	16.5	45.50
AH Joy-080	16-22 May	48.67	26.5	21.8	100	182	18.0	40.00
AH Joy-081	20-25 May	30.67	30.3	24.0	102	130	16.0	41.80
AH Joy-085	24-30 May	46.00	34.3	19.3	69	45	17.0	37.20
AH Joy-086	20-27 May	40.67	33.7	18.7	49	175	20.0	39.70
AH Joy-087	22-28 May	24.67	35.2	18.2	60	45	16.0	32.00
AH Joy-089	15-20 May	45.67	32.0	20.7	134	56	16.5	44.20
AH Joy-090	15-22 May	49.33	37.5	23.0	151	157	18.0	43.90
AH Joy-092	20-27 May	26.33	39.0	25.2	57	184	20.0	45.10
AH Joy-098	12-16 May	36.33	23.7	17.0	66	63	18.5	47.90
AH Joy-097	18-25 May	42.67	26.6	22.5	48	165	20.0	42.60
Mean	-	39.18	29.36	20.70	76.65	106.75	18.00	42.22
SD	-	7.29	4.24	3.13	31.51	53.81	2.66	4.60
CV (%)	-	18.59	14.44	15.11	41.10	50.41	14.75	10.90

TSS= Total Soluble Solid

Maximum TSS (25.0) was recorded in AH Joy-029 and minimum (14.0) in AH Joy-067 with a mean value of 18.0 which is agreed with the findings of Rahman *et al*. (1994). The edible portion was recorded the highest in AH Joy-036 (48.6%) followed by AH Joy-059 (48.2%) and the lowest in AH Joy-078 (32.1%). The findings of the study partially similar to the results of Ullah and Haque (2008) where the authors reported 37.3 to 52.8% edible portion in their studied germplasm. Maximum bulb was counted in AH Joy-092 (184) followed by AH Joy-080 (182) and minimum in AH Joy-085 (45).

Table 2. Continued

Acc. no.	Individual fruit wt (kg)				Fruits/ plant (no.)				Rind wt (kg)	Rachis wt (g)
	2012-13	2013-14	2014-15	Average	2012-13	2013-14	2014-15	Average		
AH Joy-017	4.60	5.50	5.90	5.33	7	10	8	8.33	3.40	225
AH Joy-029	6.65	7.40	8.60	7.55	4	4	5	4.33	4.00	260
AH Joy-032	4.40	5.80	5.00	5.07	6	5	7	6.00	2.80	240
AH Joy-034	2.20	2.20	2.40	2.27	4	6	5	5.00	1.10	150
AH Joy-036	7.00	7.10	7.00	7.03	3	4	5	4.00	3.10	500
AH Joy-059	5.30	5.00	6.25	5.52	7	6	6	6.33	2.60	200
AH Joy-067	3.00	2.60	3.20	2.93	11	11	10	10.67	1.40	300
AH Joy-075	6.45	6.50	6.70	6.55	3	4	3	3.33	3.30	300
AH Joy-078	3.00	3.30	3.10	3.13	6	7	7	6.67	1.90	185
AH Joy-079	6.40	7.30	8.00	7.23	3	2	4	3.00	3.80	165
AH Joy-080	6.00	6.50	6.50	6.33	3	5	4	4.00	3.50	280
AH Joy-081	6.00	6.30	6.20	6.17	2	2	3	2.33	3.20	350
AH Joy-085	4.00	4.50	4.20	4.23	7	7	8	7.33	2.50	170
AH Joy-086	4.90	5.40	5.20	5.17	4	6	6	5.33	2.80	250
AH Joy-087	4.50	5.00	5.00	4.83	3	2	2	2.33	3.00	300
AH Joy-089	5.40	6.10	6.00	5.83	8	8	7	7.67	3.00	275
AH Joy-090	8.50	8.80	8.60	8.63	4	3	5	4.00	4.20	550
AH Joy-092	11.00	11.50	11.50	11.33	3	3	4	3.33	5.80	500
AH Joy-098	3.50	3.85	3.55	3.63	6	5	7	6.00	1.60	250
AH Joy-097	6.50	7.00	7.00	6.83	4	6	5	5.00	3.70	200
Mean	5.465	5.882	5.995	5.78	4.9	5.3	5.55	5.25	3.04	282.50
SD	2.040	2.141	2.197	2.108	2.27	2.49	1.99	2.16	1.06	113.92
CV (%)	37.33	36.39	36.64	36.47	46.30	47.06	35.79	41.09	34.96	40.33

* Three years average data of rind weight and rachis weightare shown in the table.

The highest rind weight (5.8 kg) was recorded in AH Joy-092 followed by AH Joy-090 (4.2 kg). The lowest rind weight was noticed in AH Joy-034 (1.1 kg). Maximum rachis weight (550 g) was observed in AH Joy-090 followed by AH Joy-036 and AH Joy-092 (500 g) while it was recorded minimum in AH Joy-034 (150g).

Table 3. Yield performance of 20 jackfruit germplasm

Acc. no.	Yield/ plant (kg)			
	2012-13	2013-14	2014-15	Average
AH Joy-017	32.20	55.00	47.20	44.44
AH Joy-029	26.60	29.60	43.00	32.72
AH Joy-032	26.40	29.00	35.00	30.40
AH Joy-034	8.80	13.20	12.00	11.33
AH Joy-036	21.00	28.40	35.00	28.13
AH Joy-059	37.10	30.00	37.50	34.94
AH Joy-067	33.00	28.60	32.00	31.29
AH Joy-075	19.35	26.00	20.10	21.83
AH Joy-078	18.00	23.10	21.70	20.89
AH Joy-079	19.20	14.60	32.00	21.70
AH Joy-080	18.00	32.50	26.00	25.33
AH Joy-081	12.00	12.60	18.60	14.39
AH Joy-085	28.00	31.50	33.60	31.04
AH Joy-086	19.60	32.40	31.20	27.56
AH Joy-087	13.50	10.00	10.00	11.28
AH Joy-089	43.20	48.80	42.00	44.72
AH Joy-090	34.00	26.40	43.00	34.53
AH Joy-092	33.00	34.50	46.00	37.78
AH Joy-098	21.00	19.25	24.85	21.80
AH Joy-097	26.00	42.00	35.00	34.17
Mean	24.50	28.37	31.29	28.01
SD	8.99	11.53	10.80	9.57
CV (%)	36.71	40.62	34.53	34.15

Number of fruit (10.67) was highest in AH Joy-067 followed by AH Joy-017 (8.33) and AH Joy-089 (7.67) but the highest yield per plant was calculated in AH Joy-089 (44.72 kg/plant) followed by AH Joy-017 (44.45 kg/plant) and the lowest yield per plant was in AH Joy-034 and Ah Joy-087 (11.28 kg/plant).

b. Qualitative characteristics

Out of twenty germplasm, maximum (9) gave ellipsoid shaped fruit and others were clavate, spheroid and oblong in shaped(Table-4). Fruit colour varied from

yellow to greenish yellow. Fruit surface of maximum germplasm was spiny except three (AH Joy-032, AH Joy-089, AH Joy-097) which showed smooth fruit surface. Spine shape was Intermediate to pointed. Regarding attractiveness of fruit four germplasm (AH Joy-029, AH Joy-032, AH Joy-059 and AH Joy-097) produced good fruits and others produced intermediate to poor fruits. Pulps were yellow to light yellow in colour. Bulb of maximum germplasm were juicy to medium juicy except AH Joy-089 and AH Joy-092 which were less juicy. Bulb texture was soft to hard and only two germplasm (AH Joy-017 and AH Joy-086) showed high fibrousness and others were medium and low. Most of the studied characters like fruit colour, fruit shape and pulp colour are similar to the research results of Azad *et al.* (2001) and Roy *et al.* (2012).

Table 4. Qualitative characteristics of jackfruit germplasm

Acc. no.	Fruit Shape	Fruit colour	Fruit surface	Spine shape	Attractiveness
AH Joy-017	Clavate	Greenish yellow	Spiny	Intermediate	Intermediate
AH Joy-029	Ellipsoid	Yellow	Spiny	Intermediate	Good
AH Joy-032	Oblong	Yellow	Smooth	Intermediate	Good
AH Joy-034	Oblong	Greenish yellow	Spiny	Intermediate	Poor
AH Joy-036	Spheroid	Yellow	Spiny	Intermediate	Intermediate
AH Joy-059	Spheroid	Greenish yellow	Spiny	Intermediate	Good
AH Joy-067	Ellipsoid	Yellow	Spiny	Pointed	Poor
AH Joy-075	Spheroid	Yellow	Spiny	Intermediate	Intermediate
AH Joy-078	Ellipsoid	Yellow	Spiny	Pointed	Intermediate
AH Joy-079	Oblong	Yellow	Spiny	Intermediate	Intermediate
AH Joy-080	Ellipsoid	Yellow	Spiny	Intermediate	Intermediate
AH Joy-081	Clavate	Greenish yellow	Spiny	Pointed	Intermediate
AH Joy-085	Ellipsoid	Yellow	Spiny	Pointed	Intermediate
AH Joy-086	Oblong	Yellow	Spiny	Intermediate	Intermediate
AH Joy-087	Oblong	Greenish yellow	Spiny	Intermediate	Poor
AH Joy-089	Ellipsoid	Yellow	Smooth	Intermediate	Intermediate
AH Joy-090	Ellipsoid	Yellow	Spiny	Intermediate	Intermediate
AH Joy-092	Ellipsoid	Greenish yellow	Spiny	Intermediate	Intermediate
AH Joy-098	Ellipsoid	Yellow	Spiny	Intermediate	Intermediate
AH Joy-097	Spheroid	Greenish yellow	Smooth	Intermediate	Good

Table 4. Continued

Acc. no.	Bulb color	Bulb Juiciness	Bulb fibrousness	Bulb texture
AH Joy-017	Yellow	Juicy	High	Hard
AH Joy-029	Yellow	Juicy	Low	Soft
AH Joy-032	Yellow	Juicy	Low	Soft
AH Joy-034	Yellow	M juicy	Medium	Soft
AH Joy-036	Yellow	Juicy	Low	Soft
AH Joy-059	Yellow	M juicy	Low	Soft
AH Joy-067	yellow	Juicy	Low	Soft
AH Joy-075	yellow	Juicy	Medium	Hard
AH Joy-078	L yellow	Juicy	Low	Semi hard
AH Joy-079	Yellow	Juicy	Medium	Hard
AH Joy-080	Yellow	Juicy	Low	Soft
AH Joy-081	L yellow	Juicy	Low	Soft
AH Joy-085	Yellow	Juicy	Low	Soft
AH Joy-086	Yellow	Juicy	High	Soft
AH Joy-087	L yellow	Juicy	Low	Soft
AH Joy-089	L yellow	L juicy	Medium	Hard
AH Joy-090	Yellow	Juicy	Low	Semi hard
AH Joy-092	Yellow	L juicy	Low	Soft
AH Joy-098	L yellow	M juicy	Low	Semi hard
AH Joy-097	Yellow	M juicy	Medium	Soft

*L Yellow=Light yellow; L Juicy=Less Juicy; M Juicy=Medium Juicy

Conclusion

Evaluation of available jackfruit germplasm helps to developnew varieties. Keeping this view in mind, the evaluation can be concluded with the selection of AH Joy-089, AH Joy-017 and AH Joy-092 for top yielder but AH Joy-034,AH Joy-067, AH Joy-078,AH Joy-085 and AH Joy-098germplasmshould be selected for the family size fruits.

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EFFECT OF HARVESTING DATES ON THE YIELD AND TUBER QUALITY OF PROCESSING POTATOES

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Abstract

An experiment was conducted to study the effect of harvesting dates and variety on the yield and processing quality of potato tuber. Three processing potato varieties (BARI Alu-25, Asterix; BARI Alu-28, Lady Rosetta and BARI Alu-29, Courage) were used as test crops and they were harvested at different days after planting [80, 90, and 100 days after planting (DAP)]. The three processing potato varieties showed higher tuber yield of Grade A (9.12 t ha^{-1}) and B (13.64 t ha^{-1}). The highest tuber yield (Grade A+B) [29.62 t ha^{-1}] and total tuber yield (35.97 t ha^{-1}) was found in Courage at 90 and 100 DAP harvest, respectively. The variety Lady Rosetta attained the highest percent of processable tuber yield (86.8% of the total tuber yield), the maximum dry matter content (26.37%), specific gravity (1.102) at 90 DAP harvest and this variety also contained the highest mean starch content (111.75 mg g^{-1} FW) followed by Courage (111.17 mg g^{-1} FW) and Asterix (103.95 mg g^{-1} FW). Optimum dry matter content (24.07%), specific gravity (1.091), starch content (110.15 mg g^{-1} FW), processable tuber yield (26.62 t ha^{-1}) and total tuber yield (32.76 t ha^{-1}) was found at 90 DAP harvest and therefore, it could be mentioned as suitable harvesting date for processing purposes. Among the varieties, Lady Rosetta and Courage were found preferable potato varieties that could be used for processing of potato products.

Key words: Potato, processable yield, tuber yield, dry matter and starch.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crop and it is a part of daily food utilization of almost all the world population (Mathur, 2003). Bangladesh is the world's seventh largest producer of potatoes with a total production of about 10.21 million tons (BBS, 2017). It is consumed in different forms like boiled or fried and many different processed products such as chips, French fries, powder, potato papad etc. which are enjoyed across the generations and continents. Processing quality of potato tubers is determined by high dry matter and low reducing sugar and phenol contents (Kadam *et al.*, 1991). High

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dry matter content increases chip yield, crispy-consistency and reduces oil absorption during cooking (Pedreschi *et al.*, 2005; Rommens *et al.*, 2010).

Meeting the increasing demand and quality of the end products of potato processing industries depend mostly on production capacity of quality tubers. Moreover, a grading system, one popular approach for determining properties and minimizing the risk of marketing of the produce, can be easily utilized to ensure quality tubers for fresh dishes as well as processing industries. However, quality of these processed food products mainly depends on tuber inherent characteristics, growing conditions, maturity, dry matter, starch content, specific gravity, low fat and sugars etc. (Kumar *et al.*, 2011; Buono *et al.*, 2009).

Though dry matter and starch contents of potato affect mainly texture and nutritional value of the tubers, in addition to tuber chemical composition, texture of processed food products is affected also by the degree of tuber maturity (Murniece *et al.*, 2010). It has been revealed by many efforts that yield of potato tubers along with their external and internal characteristics are influenced by different factors such as soil type, fertilizers application, dates of planting and harvesting in addition to their genetic factor (Hamouz *et al.*, 2005; Herman *et al.*, 1996). According to Rytel (2004) and Lisińska (2006), delayed harvest results in increased starch and dry matter contents of potato but their accumulation depends on cultivar and growing conditions. Among the agricultural practices, total crop duration or harvesting time had the prominent effects on total yield and nutritional composition of crop plants so, it is necessary to collect the produce at its proper growth stage.

Considering above facts, the present study was initiated to determine appropriate harvesting date and processing variety of potatoes regarding yield and tuber quality.

Materials and Methods

The experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, which is located at the center of Madhupur Tract (24°05' N latitude and 90°25' E longitude) at an elevation of 8.4 m above the sea level. BARI Alu-25 (Asterix), BARI Alu-28 (Lady Rosetta) and BARI Alu-29 (Courage) were used as plant materials and they were harvested at different days after planting [80, 90, and 100 days after planting (DAP)]. Here, three processing potato varieties represent Factor A and harvesting dates of 80, 90, and 100 DAP represent Factor B. The experiment was laid out in a factorial RCBD design with 4 replications.

 The processing potato seed tubers were planted in 4m×3m plot using 60cm×25cm spacing at the end of November and sixteen seed tubers were placed in every row. The crop was raised as per the recommended cultural practices for the Modhupur Tract region. A fertilizer dose of N, P, K and S was applied as per

fertilizer recommendation guide in the form of Urea, Triple Supper Phosphate (TSP), Muriate of potash (MP), Gypsum, respectively along with cow dung. Full doses of cow dung (10 t ha^{-1}), TSP (150 kg ha^{-1}), MP (250 kg ha^{-1}), Gypsum (120 kg ha^{-1}), and half doses of Urea (125 kg ha^{-1}) were applied at final land preparation. The rest half doses of Urea were applied as top dressing at 30 DAP followed by earthing up and light irrigation. Irrigation was applied five times. First one was given just after planting while the rest irrigation was applied at 20, 30, 40, and 50 DAP. Earthing up was done in two times during growing period. First earthing up was done at 30 DAP when the plant attained a height of about 15-20 cm while the last one was done after 20 days of first earthing up. Ridomil Gold was sprayed at the rate of 5g L^{-1} once after rainfall to prevent the late blight disease of potato. The haulms were cut at 70, 80, and 90 DAP. Tubers were harvested 10 days after haulm cutting.

Data were recorded on the yield of different grades tuber, processable tuber yield, total tuber yield, dry matter content, specific gravity and starch content of the test varieties. The chemical analysis was done in the Crop Botany Laboratory of BSMRAU.

Grading of potato tubers

After harvesting potato tubers were classified into four grades according to Karim *et al.* (2010), estimating diameter at the middle of the potato tubers. The grades were i) Under grade (<28 mm), ii) Grade A (28-40mm), iii) Grade B (41-55 mm), and iv) Over grade (>55 mm). Among these grades, Grade A and Grade B together was considered as *processable grade tuber*.

Determination of tuber dry matter (%) and specific gravity

For dry matter content estimation, five tubers were chopped in thin pieces and about 50g fresh sample were oven dried at 80°C till constant weight was achieved. Then the moisture percentage was determined and this was deducted from the total 100% moisture to get the dry matter (%). Specific gravity was determined according to Schippers (1976).

Extraction and determination of starch

Following the procedure of Kang *et al.* (2009), potato flesh was extracted using 80% ethanol at 80°C for 30 min at first and then extracts were centrifuged at 5000g for 10 min. Same procedure was repeated for two times taking the supernatants. The remaining residue was washed several times with water to remove soluble sugars remaining in the residue. Then it was dried overnight, added with distilled water and heated in a boiling water bath for 30 min while stirring on the super mixture several times to gelatinize the starch released from the sample. Eventually, 52% (v/v) perchloric acid, 6 ml of distilled water was added, and after centrifugation at 4000g for 20 min, the supernatant was

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collected in a test tube. This acid hydrolysis was repeated once again and the volume of the supernatants was made up to 50 ml with distilled water into a volumetric flask.

One ml of aliquot was mixed with distilled water and anthrone reagent, and boiled for 15 min. After cooling for 10 min in the dark, the absorbance was read at 620 nm. Standard solutions of starch were tested in a same way to obtain a calibration curve. A series of standard solution (0, 62.5, 125, 250, 500, 1000 µg µl^{-1} starch) was made using starch for the preparation of standard curve.

Statistical analysis

The analysis of variance for various parameters of potato was performed following ANOVA Technique. When F was significant at the $p \leq 0.05$ level, treatment means were separated using DMRT. Data were reported as mean ± standard error (SE).

Results and Discussion

Data collected during the experiment were subjected to two factor analysis of variance (ANOVA). The ANOVA for yield data showed that the main effects of the varieties were insignificant except over grade yield, dry matter, specific gravity and starch content (Table 1).

But the main effect of days to harvest were significant for all the parameters except over grade yield. Two-way interaction between the varieties and days to harvest was significant for dry matter and starch content only and the rest others were found insignificant (Table 1).

Table 1. Source of variance and their effect on yield of different grades, processable tuber grades, total tubers, dry matter, specific gravity and starch content of the potatoes

Source of variation	Degrees of freedom	Mean Squares								
		Under grade	Grade A	Grade B	Over grade	Processable yield	Total yield	Dry matter (%)	Specific gravity	Starch content
Variety (V)	2	6.89	15.42	2.10	48.90*	8.80	17.51	72.27**	$1.16 \times 10^{-3**}$	226.45**
Harvest date (HD)	2	15.13*	66.48**	55.53**	12.10	241.08**	493.93**	18.28**	$5.72 \times 10^{-4**}$	128.76**
V×HD	4	0.84	7.79	9.52	3.19	33.02	43.58	5.26*	3.85×10^{-5}	193.91**
Error	24	3.03	9.38	18.50	11.18	29.09	60.63	1.92	3.50×10^{-5}	22.87

*indicates significant at $p \leq 0.05$; **indicates significant at $p \leq 0.01$

Yield of different grade tubers

Under grade (<28 mm) tuber yield increased with crop maturity in all varieties, but the increment was significant only in variety Lady Rosetta between 80 and 100 DAP harvest (Table 2). Lowest mean tuber yield (1.97 t ha^{-1}) was found in the variety Courage followed by Asterix (2.91 t ha^{-1}) and Lady Rosetta (3.24 t ha^{-1}) but their difference was not significant. 80 DAP harvest (1.73 t ha^{-1}) and 90 DAP harvest (2.49 t ha^{-1}) gave significantly lower under grade tuber yield than 100 (3.90 t ha^{-1}) DAP harvest. Here, Courage gave the lowest percent (5.40%) of under grade (<28 mm) tuber yield of total tuber yield at 90 DAP harvest (Fig. 1).

In Grade A (28-40 mm), the highest tuber yield (12.12 t ha^{-1}) was found in Courage and Lady Rosetta at 90 DAP harvest (Table 2). The lowest tuber yield (4.95 t ha^{-1}) was recorded in Asterix harvested at 80 DAP. The result of 90 DAP and 100 DAP harvest was statistically similar but their difference with 80 DAP harvest was significant in case of all varieties (Table 2). Among the varieties, the highest mean yield was achieved by Courage (10.05 t ha^{-1}) followed by Lady

Table 2. Yield of different grades of potato tuber as influenced by variety and different harvesting dates

Variety	Yield (t ha^{-1})			
	80 DAP	90 DAP	100 DAP	Mean
Under grade (<28mm)				
Asterix	1.97 ± 0.72^b	2.65 ± 0.72^b	4.12 ± 1.61^{ab}	$2.91 \pm 0.63^{A'}$
Courage	1.39 ± 0.49^b	1.83 ± 0.26^b	2.69 ± 0.6^{ab}	$1.97 \pm 0.38^{A'}$
Lady Rosetta	1.83 ± 0.35^b	2.99 ± 0.83^{ab}	4.89 ± 1.40^a	$3.24 \pm 0.89^{A'}$
Mean	1.73 ± 0.175^B	2.49 ± 0.343^B	3.90 ± 0.645^A	2.71
Grade A (28-40mm)				
Asterix	4.95 ± 1.24^d	$9.25 \pm 1.86^{a-d}$	$8.36 \pm 2.40^{a-d}$	$7.52 \pm 1.31^{A'}$
Courage	6.07 ± 0.69^{cd}	12.12 ± 1.61^a	11.95 ± 1.55^{ab}	$10.05 \pm 1.99^{A'}$
Lady Rosetta	7.01 ± 0.70^{bcd}	12.12 ± 1.37^a	10.20 ± 2.13^{abc}	$9.77 \pm 1.49^{A'}$
Mean	6.01 ± 0.594^B	11.16 ± 0.955^A	10.17 ± 1.036^A	9.12
Grade B (41-55mm)				
Asterix	11.63 ± 1.46^a	14.60 ± 2.81^a	13.69 ± 2.65^a	$13.31 \pm 0.88^{A'}$
Courage	10.76 ± 2.59^a	17.50 ± 2.11^a	16.79 ± 2.59^a	$15.02 \pm 2.14^{A'}$
Lady Rosetta	9.63 ± 2.23^a	14.27 ± 1.87^a	13.92 ± 1.86^a	$12.61 \pm 1.49^{A'}$
Mean	10.67 ± 0.579^B	15.46 ± 1.023^{AB}	14.80 ± 0.997^A	13.64
Over Grade (>55mm)				
Asterix	3.79 ± 0.77^{ab}	6.59 ± 3.19^a	6.09 ± 2.94^{ab}	$5.49 \pm 0.86^{A'}$
Courage	2.66 ± 0.52^{ab}	3.30 ± 0.70^{ab}	4.54 ± 1.43^{ab}	$3.50 \pm 0.55^{AB'}$
Lady Rosetta	0.65 ± 0.37^b	1.05 ± 0.41^{ab}	2.71 ± 0.87^{ab}	$1.47 \pm 0.63^{B'}$
Mean	2.37 ± 0.919^A	3.65 ± 1.609^A	4.44 ± 0.976^A	3.49

Mean (±SE) was calculated from four replicates for each treatment. Values in a column and rows with different small letter(s) are significantly different at P = 0.05 by DMRT. Different capital letters beside the mean values are significantly different at P = 0.05 by DMRT

Rosetta (9.77 t ha^{-1}) but the difference was not significant. Considering the harvest mean, 90 DAP (11.16 t ha^{-1}) and 100 DAP (10.17 t ha^{-1}) gave significantly higher Grade A tuber yield than 80 DAP harvest (6.01 t ha^{-1}) (Table 2). At 90 DAP harvest, the variety Lady Rosetta produced the highest percent (39.93%) of Grade A tuber (Fig. 1).

In Grade B (41-55 mm), the highest yield was obtained at 90 DAP harvest in all 3 varieties but there was no significant difference among their results (Table 2). Varietal means of grade B yield showed that Courage had the highest yield (15.02 t ha^{-1}) as compared to Asterix (13.31 t ha^{-1}) and Lady Rosetta (12.61 t ha^{-1}) (Table 2). The highest mean Grade B tuber yield of three harvesting dates reveals that 90 DAP harvest (15.46 t ha^{-1}) was the highest and it had no significant difference with 100 (14.80 t ha^{-1}) DAP harvest but significantly different from 80 DAP harvest (10.67 t ha^{-1}) (Table 2). Here Lady Rosetta (56.79%) gave the highest percent of Grade B tuber yield of total tuber yield at 100 DAP harvest (Fig. 1).

Over grade (>55 mm) tuber yield increased with crop maturity (Table 2). Lowest tuber yield (0.65 t ha^{-1}) was found in the Lady Rosetta followed by Courage (2.66 t ha^{-1}) and Asterix (3.79 t ha^{-1}) at 80 DAP harvest.
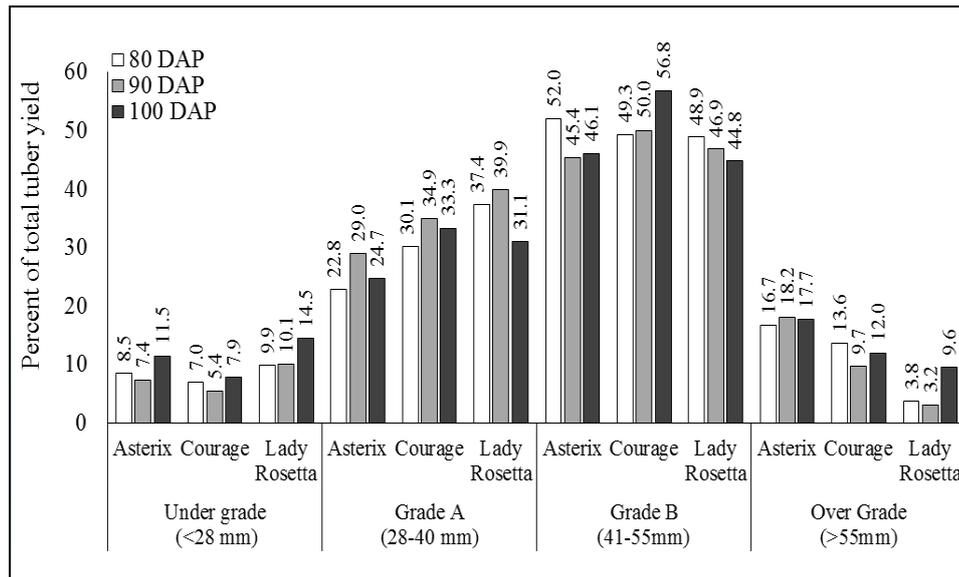
Fig. 1. Percent yield of different grades of potato processing varieties at respective harvesting dates. DAP- Days after planting.

Mean over grade (<55 mm) tuber yield also increased with crop maturity (Table 2). Lowest mean tuber yield (1.47 t ha^{-1}) was obtained in the Lady Rosetta followed by Asterix (5.49 t ha^{-1}) and Courage (3.50 t ha^{-1}) and the result of Courage and Lady Rosetta is statistically similar but Lady Rosetta had

significant difference with Asterix (Table 2). Lady Rosetta (3.15%) gave the lowest percent over grade tuber yield of total tuber yield at 90 DAP harvest (Fig. 1). Results of the study showed differences in tuber grading of three potato varieties. The effects of heredity were also found significant on potato grading by Muthuraj *et al.* (2005). Among the tuber grades medium and large tubers are the most prized in fresh tubers market due to peeling facilitation on both domestic and processing purposes. For chips and French frying process, round or oval round form of tuber is preferable besides larger size for commercial standards (Pádua *et al.*, 2012) that suits the present findings where medium to large tubers yielded significantly higher than under and over grade potatoes at 90 DAP harvest.

Processable tuber yield

Processable tuber (Grade A+B) yield was increased with the maturity up to 90 DAP afterwards it was decreased slightly at 100 DAP in all 3 varieties (Fig. 2). The increment was significant in case of variety Courage and Lady Rosetta. 90 DAP; harvest showed the highest processable tuber yield in all three varieties. The highest processable tuber yield was found in Courage (29.62 t ha^{-1}) at 90 DAP followed by Lady Rosetta (26.39 t ha^{-1}). At 90 DAP harvest, the highest processable tuber yield of Courage (29.62 t ha^{-1}) was found as 85.2% of total tuber yield of that variety followed by 26.39 t ha^{-1} in Lady Rosetta (86.7% of total tuber yield) and 23.86 t ha^{-1} in Asterix (72.1% of total tuber yield) at same harvesting date (Fig. 2).

Irrespective of harvesting time, the varietal mean values did not show any significant difference among them (Fig. 2). Courage had the highest processable tuber yield (25.07 t ha^{-1}) followed by Lady Rosetta (22.38 t ha^{-1}) and Asterix (20.83 t ha^{-1}).

Mean values of harvesting dates exhibited that 90 DAP gave higher processable tuber yield (81.3%) than 80 DAP (80.3%) and 100 DAP harvest (75.0%) (Fig. 2) but the processable tuber yield of 90 and 100 DAP harvest was statistically similar. Results of the processable tuber yield reveals that 90 DAP harvest is better than 80 and 100 DAP harvest for producing potato yield of suitable sizes. For chips production, round or oval tubers of 35 to 65 mm sizes having higher dry matter (21-25%) and starch content (16-20%) were emphasized by many research efforts (Lisinska, 2006; Zgorska and Frydecka-Mazurczyk, 2002) that justifies the result of present experiment yielding high amount of Grade A and Grade B (processable) potato tubers. It might be the impact of rapid plant emergence and better plant growth (Patel *et al.*, 2008).
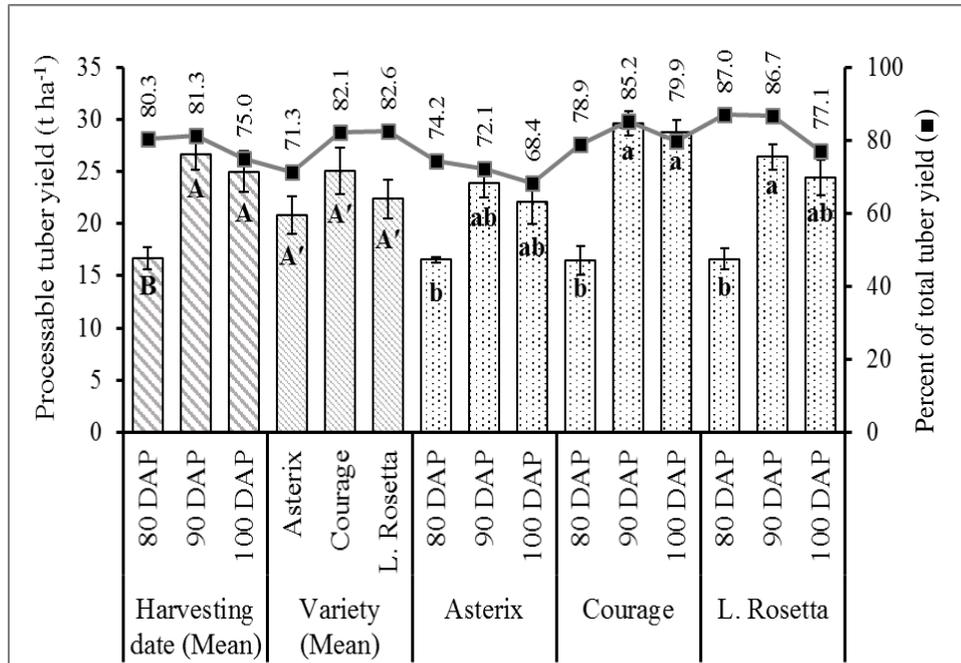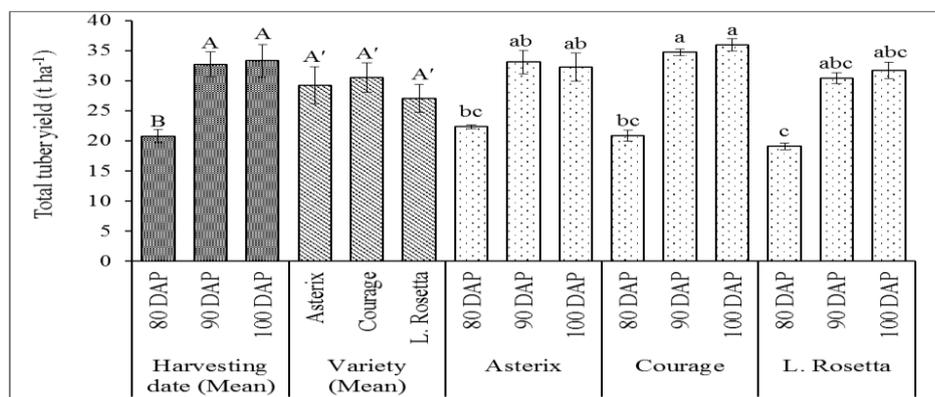
Fig. 2. Processable tuber yield of potatoes as influenced by varieties under different harvesting dates. Vertical bass represent standard error (±SE) of four replicates.

✢ Values in a column with different capital letter(s) are significantly different at P = 0.05 by DMRT.

✢ Values in a column with different prime-marked capital letter(s) are significantly different at P = 0.05 by DMRT.

‡ Values in a column with different small letters denote interaction effect and are significantly different at P = 0.05 by DMRT.

Total tuber yield

Harvesting time had significant effect on total tuber yield and increased with the crop maturity but the varieties did not show any statistical difference (Fig. 3, Table 1). The increment was significant from 80 to 90 DAP but in 100 DAP; it was insignificant. The interaction effect of Variety × Harvesting dates gave lowest tuber yield at 80 DAP harvest in all three processing potato varieties. The highest total tuber yield was recorded in variety Courage (35.97 t ha^{-1}) at 100 DAP (Fig. 3).

Among the varietal means, although yield didn't vary significantly, Courage showed the highest tuber yield (30.54 t ha^{-1}) followed by Asterix (29.23 t ha^{-1}) and Lady Rosetta (27.09 t ha^{-1}) (Fig. 3).
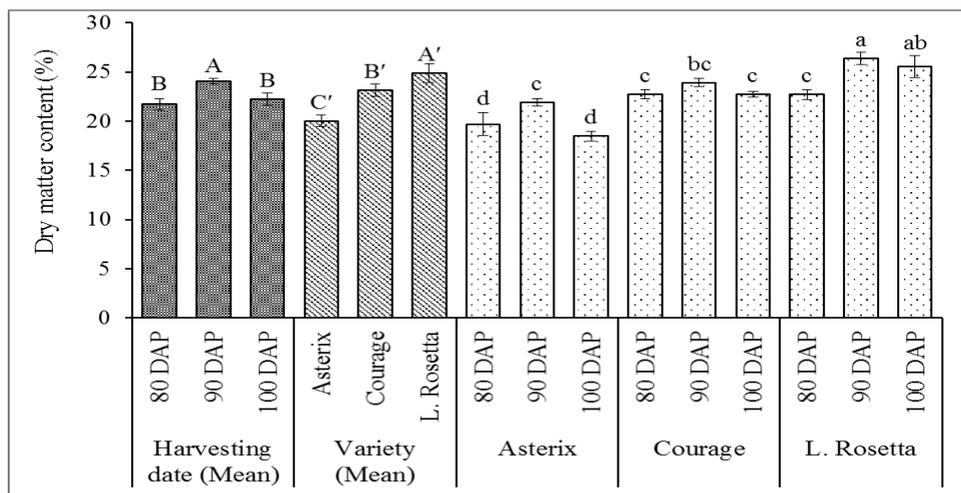
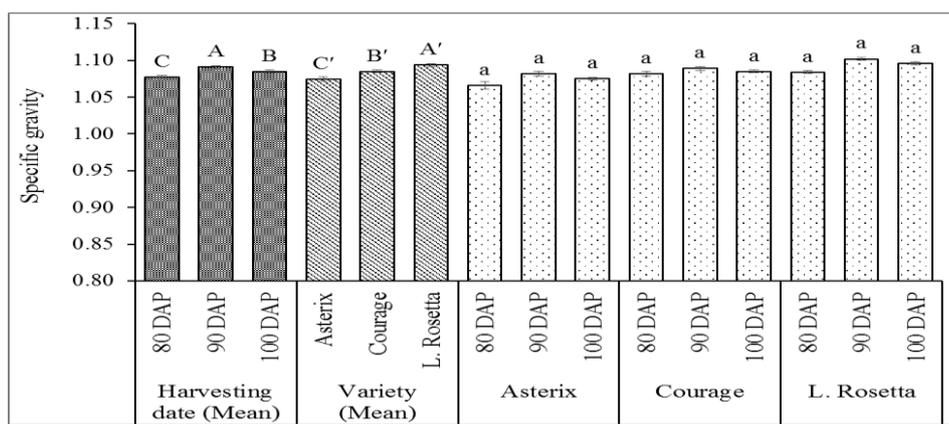**Fig. 3. Total tuber yield of potatoes as influenced by varieties under different harvesting dates. Vertical bass represent standard error (±SE) of four replicates.**

✢ Values in a column with different capital letter(s) are significantly different at P = 0.05 by DMRT.

✢ Values in a column with different prime-marked capital letter(s) are significantly different at P = 0.05 by DMRT.

ǂ Values in a column with different small letters denote interaction effect and are significantly different at P = 0.05 by DMRT

Considering the mean value of harvesting dates, 100 DAP harvest gave the highest tuber yield (33.31 t ha^{-1}) followed by 90 (32.76 t ha^{-1}) and 80 DAP harvest (20.78 t ha^{-1}) (Fig. 3). The higher yield at 100 DAP harvest compared to 80 DAP harvest might be result of considerable accumulation of dry matter in the tubers after the linear phase of bulking (Gregory, 1956). Because an early harvest, even at an advanced stage of the crop, leads to significant reductions in the percentage of large tubers and the tuber specific gravity (Silva, 2004). Although, many tubers may be initiated during the first four to six weeks of growth, only a fraction of these tubers actually achieves commercial size (greater than 30 mm diameter). The duration and rate of tuber bulking vary among varieties and depend on environmental condition. Here, 90 DAP harvest can be considered as good for total tuber production compared to 100 DAP since there are no significant differences in between them.

Dry matter content (%)

The dry matter content in potato tuber was significantly influenced by the variety and different harvesting dates. Dry matter (%) was increased up to 90 DAP harvest and thereafter decreased in all three potato varieties (Fig. 4). The highest dry matter content (26.37%) was found in Lady Rosetta at 90 DAP, which was statistically similar with 100 DAP harvest (25.55%) in the same variety, and it was significantly higher than Asterix (21.91%) and Courage (23.93%). In all 3 varieties, the highest dry matter content was attained at 90 DAP harvest

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compared to 80 and 100 DAP (Fig. 4). Moreover, the mean value of harvesting dates also showed that, 90 (24.07%) DAP harvest gained significantly higher dry matter (%) than 80 (21.71%) and 100 (22.27%) DAP harvest (Fig. 4).

Varietal means of dry matter content, irrespective of harvesting time, was found significantly higher in Lady Rosetta (24.87%) as compared to Asterix (20.02%) and Courage (23.14%) (Fig. 4). The results indicate that variety Lady Rosetta can be preferred as suitable variety and 90 DAP harvest can be optimum to get higher dry matter (%). Dry matter is an index of better processing quality, as it results into lesser oil absorption, less frying time (Pavlista and Ojala, 1997) and better textured products (Genet, 1992) associated with high fat absorption at frying (Araújo *et al.* 2016). And this biomass accumulation can be influenced by various factors, especially by the cultivar, date of harvest and location (Marwaha *et al.,* 2005). Though early harvesting of potato tuber gives economic support to the farmers but it affects the quality. Tuber harvested at increased maturity stage contain maximum dry matter than immature ones (Misra *et al.*, 1993). Solaiman *et al.* (2015) recorded higher (21.72%) dry matter at 110 DAP compared to 80 DAP (16.94%) while a slight decrease in dry matter accumulation at later stage of maturity was observed earlier (Wubr, 1978) that resembles the present findings.

Fig. 4. Dry matter content in potatoes as influenced by varieties under different harvesting dates. Vertical bass represent standard error (±SE) of four replicates.

⊕ Values in a column with different capital letter(s) are significantly different at P = 0.05 by DMRT.

⊕ Values in a column with different prime-marked capital letter(s) are significantly different at P = 0.05 by DMRT.

‡ Values in a column with different small letters denote interaction effect and are significantly different at P = 0.05 by DMRT.

Specific gravity

Specific gravity is an important factor for maintaining quality tuber and is directly associated with the dry matter content (Haase, 2003; Pedreschi and Moyano, 2005). Changes in specific gravity between harvesting dates is insignificant for all the varieties (interaction effect) in the present finding (Fig. 5). 90 DAP harvest gave higher specific gravity in case of all varieties.

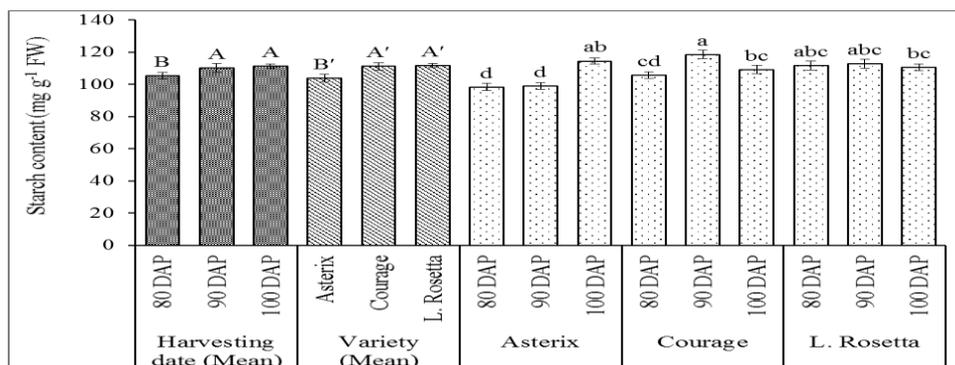**Fig. 5. Specific gravity of potatoes influenced by varieties under different harvesting dates. Vertical bass represent standard error (±SE) of four replicates.**

⊕ Values in a column with different capital letter(s) are significantly different at P = 0.05 by DMRT.

⊕ Values in a column with different prime-marked capital letter(s) are significantly different at P = 0.05 by DMRT.

‡ Values in a column with different small letters denote interaction effect and are significantly different at P = 0.05 by DMRT

Variety Lady Rosetta (1.102) gave the highest specific gravity at 90 DAP followed by Courage (1.089) and Asterix (1.082). The varietal mean values exhibited that Lady Rosetta (1.094) had significantly higher specific gravity (1.094) as compared to Courage (1.085) and Asterix (1.0741) (Fig. 5). Counting the harvest mean, 90 DAP harvest gave significantly higher specific gravity compared to 100 (1.094) and 80 (1.074) DAP harvest (Fig. 5).

With increasing harvesting time i.e from 80 to 110 DAP, significantly increased specific gravity (1.050 to 1.085) was also reported by Solaiman *et al.* (2015) and Marwaha (1998). But a slight decrease in specific gravity at 100 DAP harvest was found that could be the result of reduced dry matter accumulation at the later stage. From the above mentioned results it can be said that 90 DAP harvest can be most suitable harvest date to get higher specific gravity in potatoes. Because higher specific gravity is an indication of higher dry matter content and lower reducing sugar content in potato tubers (Schippers, 1976; Salamoni *et al.,* 2000)

so, investigation of specific gravity in tubers for processing purposes could play a vital role as a preliminary indication of good quality potatoes.

Starch content

The effect of variety × harvesting dates on starch content of the potatoes showed an increase up to 90 DAP in all the three varieties but this increment was significant in Courage and Asterix also (Fig. 6). Afterwards it significantly increased in variety Asterix and declined in Courage and Lady Rosetta. Variety Courage and Lady Rosetta gave the highest starch content at 90 DAP harvest but in Asterix, the highest starch content was attained at 100 DAP. The highest starch content was found in Courage (118.56 mg g^{-1} FW) at 90 DAP followed by Asterix (114.51 mg g^{-1} FW) at 100 DAP and Lady Rosetta (112.93 mg g^{-1} FW) at 90 DAP harvest (Fig. 6).

Among the varieties, the highest starch content was observed in Lady Rosetta (111.75 mg g^{-1} FW), which was closely followed by Courage (111.17 mg g^{-1} FW). The minimum starch content was recorded in Asterix (103.95 mg g^{-1} FW) (Fig. 6). Among the harvest means, 100 DAP gave the highest mean starch content (111.47 mg g^{-1} FW) followed by 90 DAP (110.15 mg g^{-1} FW) and 80 DAP (105.25 mg g^{-1} FW) harvest (Fig. 6). Noda *et al.* (2004) found a manifest increase (18-20%) in starch content at late maturity whereas a range of 82.90-101.0 mg starch g^{-1} fresh potato sample was recorded by Al-Meraj *et al.* (2017) that supports the finding of the study.

Fig. 6. Starch content of potatoes as influenced by varieties under different harvesting dates. Vertical bass represent standard error (±SE) of four replicates.

⊕ Values in a column with different capital letter(s) are significantly different at P = 80.05 by DMRT.

⊕ Values in a column with different prime-marked capital letter(s) are significantly different at P = 0.05 by DMRT.

‡ Values in a column with different small letters denote interaction effect and are significantly different at P = 0.05 by DMRT.

As we know, higher starch content is desired for quality product because starch comprises the largest part of dry matter, it has direct influence on technological quality, especially with regard to the texture of the processed products (Kadam *et al.,* 1991). So to obtain higher amount of starch content, 90 DAP harvest can be optimum harvesting date in case of variety Courage and Lady Rosetta.

Conclusion

The maximum dry matter content, specific gravity, starch content and processable tuber yield were recorded at 90 DAP harvest. Among the varieties, the highest yield and the maximum processing quality were noted in Lady Rosetta followed by Courage. Therefore, Lady Rosetta and Courage as processing variety and 90 DAP harvest can be recommended for processing purpose.

Acknowledgement

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