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FLORAL BIOLOGY OF INDIGENOUS PUMMELO GENOTYPES

M. A. HOQUE[1]

Abstract

Flower morphology and bud development of pummelo accessions CG-1, CG-18 and CG-151 were studied at the Pummelo Orchard of Regional Agricultural Research Station, BARI, Akbarpur, Moulvibazar and the Horticulture Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University during 2008-2009. Pummelo flowers were bisexual, bore singly on leaf axils or in clusters with or without leaf on stem in all accessions, and colour were white. Calyx diameter varied from 0.94 in CG-1 to 1.02 in CG-18. Number of petals per flower ranged from 4.0 to 4.5. Anthers were yellow in colour and only CG-151 produced few rudimentary styles. Diameter of stigma varied from 0.39 mm to 0.49 mm. Number of locules per ovary was in between 14.6 to16.0 and number of ovules per locules varied from 4.0 to 9.0. Stages of floral bud development from initiation to anthesis were divided into 9 distinct stages. In pummelo, a total of 27.7 to 31.2 days were required from a bud initiation to reach its fully developed stage. Suitable time for emasculation of pummelo flowers was found within 26 days from flower bud initiation. Between 3:00am to 5:00am, about 76% flowers were found to be opened and between 4:00pm to 5:00pm in all the three accessions, dehiscence of pollens was recorded. Abscission of stamen, petal and style started after 50.8, 76.4 and 162.3 hrs and completed after 128.4, 137.9 and 228.3 hrs of anthesis, respectively.

Keywords: Floral morphology, pummelo, bud development.

Introduction

Pummelo is an important fruit among the citrus fruits grown in our country. It is very rich in vitamin-C and is a good source of vitamin A and B. Pummelo can be grown easily and can tolerate drought and pest infestation is comparatively lower (Rashid *et al*., 1987). Fruits are palatable; rinds possess essential oils that are used in cosmetic industry. Fresh ripe fruits are eaten directly and fruits can also be used in preparing various kinds of recipes such as jam, jelly, pickles, cakes and drinks (Azmatullah *et al.*, 1987). In Bangladesh, pummelo is cultivated in an area of around 7460 ha with total production of 59198 metric tons and average yield per fruit bearing tree is around 38.0kg (BBS, 2011). It seems to be ranking first among the citrus fruits grown in Bangladesh (Azmatullah *et al.*, 2006). Pummelo can be grown successfully in all areas of Bangladesh. But unfortunately there was no released pummelo variety before 1997 except some

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local cultivars. In 1997 and onwards, four varieties of pummelo have been developed through selection from collected indigenous germplasm with high yield potential and good bearing ability.

Pummelo production in Bangladesh is not remarkably increasing as in the recent years a lot of problems regarding pest and diseases are being faced by the growers. So, there is an urgent need to develop variety(s) with high yielding potentials and resistant/tolerant to pest and diseases. For obtaining variety (ies) with desired traits, hybridization programme is very much essential. But in Bangladesh, so far, no hybridization programme has been undertaken for the improvement of pummelo. But in India and other pummelo growing countries, hybridization programme have been successfully undertaken for the improvement of this crop. The pre-requisites of effective hybridization programme included knowledge on floral morphology, biology, anthesis, dehiscence, pollen viability, stigma receptivity etc. (Ahmad, 1996). As pummelo is a cross pollinated crop, so, there is a tremendous amount of variability within the species with which the breeder can work that provide even a wider selection of characters (Janick and Moore, 1996).

Flower biology is the study of the science of flowers, which includes anthesis, dehiscence of anthers, pollen fertility and stigma receptivity (Kalloo, 1988). Detailed information regarding the floral biology of pummelo is not available in our country. Therefore, the present investigation was undertaken with the following objectives:

1. To know the morphological characters of pummelo flower.
2. To determine and characterize different stages of flower bud development in pummelo.
3. To determine the time of emasculation in pummelo.

Materials and Method

The study was undertaken at the pummelo orchard of the Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Akbarpur, Moulvibazar during February 2008 to May 2009. Plant of the pummelo accessions CG-1, CG-18 and CG-151 was selected to study the different aspects of floral biology. Sapling of the accessions CG-1 and CG-18 were collected from Northern part of Bangladesh and then planted at RARS, Akbarpur, Moulvibazar in 1988, while CG-151 was collected from Sylhet region and planted at RARS, Akbarpur, Moulvibazar in 1998. The experiment was conducted following Randomized Complete Block Design (RCBD). Data were collected from three different plants of an accession where each plant was considered as a replication. During planting, fertilizer and manures were applied following the dose and method as described by Rashid *et al*. (1987). Irrigation, weeding, fertilizer

application and other crop management practices were followed as recommended by Ullah *et al*. (2006) to have a good healthy plant. Data on flowering habit of pummelo, chronology of bud development up to anthesis from the visible appearance of flower buds, time of anthesis and dehiscence of anthers, floral morphology and withering time of different floral parts were recorded.

Results and Discussion

Pedicel length, calyx diameter, number and characters of sepal, number of petals per flower and petal length and width in flowers of pummelo accessions are presented in Table 1. It is revealed from the table that pedicel length ranged from 1.38cm in CG-1 to 1.54cm in CG-151. Calyx diameter varied in the accessions from 0.98cm to 1.02cm. Number of petals per flower was 4.0 in the accessions CG-18 and CG-151, while in CG-1 it was 4.5. This implies that the accession CG-1 produced both tetramerous and pentamerous flowers. Petal length varied from 2.20-2.52cm; whereas, petal width varied from 0.88-1.20cm. Azmatullah (1987) found similar length (2.25cm) in petals while he was studying pummelo flowers. Number of sepal was 4 in the flowers of all accession and the four sepals were fused to one in the flowers. Azmatullah *et al.* (1987), Saha (2005) and Hossain (1983) recorded 4 to 5 petal and sepals in pummelo. This variation in number of petal and sepal might be attributed to genetic differences.

In the pummelo flowers, heterostyly was observed among the accessions (Table 2). It might be dis-adventitious for successful pollination and this condition favours cross pollination. All the accessions produced bisexual flowers that were white in colour and the anthers were yellow in colour. Schneider (1968) and Purseglove (1987) also reported the yellow colour of anthers in citrus. There was no rudimentary style observed in the flowers of CG-1 and CG-18 except some in the accession CG-151, which had a negative impact on successful fruit setting. Flowers were borne singly in the leaf axils or in clusters. This finding agreed with the findings of Webber and Batchelor (1948), Azmatullah (1987) and Hossain (1983).

Table 1. Pedicel length, calyx diameter, number of petal per flower, petal length and width and number of sepals per flower in pummel.

Accession	Pedicel length (cm)	Calyx diameter (cm)	Number of petal/ flower	Petal length (cm)	Petal width (cm)	Number of sepal/flower
CG-1	1.38	0.94	4.5	2.44	0.90	4.0
CG-18	1.42	1.02	4.0	2.20	0.88	4.0
CG-151	1.54	0.98	4.0	2.52	1.20	4.0
Mean	1.45	0.98	4.17	2.39	0.99	4.0
CV (%)	8.67	10.43	9.93	8.35	11.36	0.0
$LSD_{0.05}$	NS	NS	NS	NS	0.259	NS

Table 2. Length of anther related to stigma, flower type, colour of open flower, colour of anther, rudimentary style and flowers arrangement in pummel.

Accession	Length of anther related to stigma	Flower type	Colour of open flower	Colour of anther	Presence of rudimentary style	Arrangement of flower
CG-1	Shorter	Bisexual	White	Yellow	Nil	Single, cluster
CG-18	Shorter	Bisexual	White	Yellow	Nil	Single, Cluster
CG-151	Equal, longer	Bisexual	White	Yellow	Few	Single, cluster

Flowering time, number and length of stamen, and length and diameter of style in flowers of studied pummelo accessions are presented in Table 3. Flowering in the accessions varied from 2nd week of December (CG-151) to 2nd week of April (CG-1). Peak flowering time was observed in March, February and January for CG-1, CG-18 and CG-151, respectively. The starting of flowering in December indicated that the accession might be medium early, while the accession in which the flowering started in February might be late. This observation agreed with the findings of Hossain (1983) but varied slightly with the findings of Azmatullah *et al*. (1987), who found the flowering period from January to February. This variation in flowering time may be attributed climatic conditions that prevail during different years. Number and length of stamens in the flowers varied from 29.6 to 32.8 and 1.26-1.80cm, respectively. Schneider (1968) reported to have 20-40 stamens in citrus. The length and diameter of style in the accessions ranged from 0.84 to 0.87cm and 0.22 to 0.29cm, respectively. Hoque and Hossain (2012) reported a slightly varied result about stamen and style length; where they found a range of 0.85cm to 1.80cm length in stamen and a range of 1.02cm to 1.85cm length in style. The difference might be attributed to variations in genotype of the accessions.

Table 3. Flowering time, flowering month, number and length of stamen and style length and diameter in flowers of pummel.

Accession	Flowering time		Stamen		Style	
	Start	End	Number	Length (cm)	Length (cm)	Diameter (cm)
CG-1	1st week of February	2nd week of April	29.6	1.36	0.84	0.25
CG-18	1st week of January	4th week of March	30.4	1.26	0.86	0.22
CG-151	2nd week of December	4th week of February	32.8	1.80	0.87	0.29
Mean	-	-	30.9	1.47	0.86	0.25
CV (%)	-	-	8.26	15.67	11.63	9.93
$LSD_{0.05}$	-	-	NS	NS	NS	NS

Diameter of stigma in the flowers of studied accessions ranged from 0.39mm in CG-1 to 0.49mm in CG-18. Length of ovary ranged from 0.44cm to 0.47cm while, diameter of ovary ranged from 0.43cm to 0.54cm (Table 4). The similar length (0.44cm) and diameter (0.43cm) of ovary in CG-18 indicated that the fruit of the accession might be obloid; while, fruits of CG-151 and CG-1 might be semi-obloid and spheroid, respectively. Number of locules per ovary was 16.0 in CG-1 and CG-18, which indicated that the accessions had 16 segments while, CG-15 had 14 to 15 segments. This result partially agreed with the findings of Janick and Moore (1996), Purseglove (1987), Azmatullah (1987) and Ullah *et al*. (2001), who found 11-16 segments. Number of ovules per locules ranged from 4.0 to 9.0 in the accessions. As the ovules are the future seeds, therefore, it indicated the number of seeds in each segments.

The stages of floral bud development was divided into nine distinct stages (Fig.1) starting from the initiation of the detectable floral buds.

Table 4. Diameter of stigma, length and diameter of ovary, number of locules/ovary and number of ovules/ovary in flowers of pummel.

Accession	Diameter of stigma (mm)	Ovary		Number of locules/ ovary	Number of ovules/locules
		length (cm)	diameter (cm)		
CG-1	0.39	0.47	0.54	16.0	9.0
CG-18	0.49	0.44	0.43	16.0	4.0
CG-151	0.45	0.47	0.50	14.6	7.6
Mean	0.44	0.46	0.49	15.5	6.87
CV (%)	9.89	8.09	10.04	11.97	17.8
$LSD_{0.05}$	0.072	NS	0.02	0.691	2.77

The pedicel of buds at the first stage was deep green in colour with presence of hairs. At this stage the shape of bud was globose; colour of calyx and petal was deep green. Calyx length and diameter was very close to each other. Bud length was 12.19mm. Petals were about to enclosed with calyx. Among the accessions, bud took 6.3 to 7.5 days to reach the second stage (Table 5).

The colour of pedicel and petal turned to green and light green in the second stage. Shape of bud and colour of calyx remained same as observed in the first stage. Bud length was 15.99mm. On an average, 3.0-3.5 days required to reach in the third stage. Length of pedicel was about thrice to the length of petals.

At the third stage, the colour of calyx turned to light green and light separation line of splitting was observed in the petals. Bud length was 17.73mm. On an average, 3.4-3.7 days required to reach in the next stage (Table 5).

The colour of pedicel and calyx at the fourth stage were observed as green and light green respectively. Shape of buds were ovate and the petals were cream

coloured with some green spots on them (Fig. 1). Bud length was 20.18mm. Among the accessions, bud took 3.7 to 4.0 days to reach the next stage.

At the fifth stage of floral bud development in pummelo, no qualitative change observed in comparison to fourth stage except some quantitative changes. Length of buds increased to 27.46mm and the bud took 4.0-4.8 days to reach the sixth stage.

Colour of pedicel changed to light green from green at this stage. The shape of bud changed to obovate. Length of pedicel was about twice to the length of petals. Petal length in this stage was greater than width, which implies that the shape of corolla was changing to obovate from ovate. Buds were 30.40mm long that took 3.0-3.2 days to reach in the next stage (Table 5 and Fig 1).

At the seventh stage, the colour of pedicel and calyx were same as observed in Stage-VI. Bud shape was obovate and cream coloured petals were without any spot. A prominent constriction of splitting was observed in the petals. Length of bud was 36.74mm and the bud took 2.0-3.0 days to reach the next stage.

Qualitative characters at Stage-VIII were similar to Stage-VII. Length of pedicel and petals were about equal. Buds were 38.51mm long that took 1.8-2.0 days to reach the next stage (Table 5 and Fig. 1).

At ninth stage, all the qualitative characters were same as observed in Stage-VII and Stage-VIII, except one or two petals were observed to be splitted in Stage-IX (Fig. 1). The buds reached to its fully developed stage with an average length of 43.56mm (Table 5).

Table 5. Days required for flower bud development up to anthesis in pummelo and description of stages.

Accession	Days required for passing from one stage to another								
	I-II	II-III	III-IV	IV-V	V-VI	VI-VII	VII-VIII	VIII-IX	Total time required from I-IX
CG-1	7.5	3.5	3.5	4.0	4.5	3.2	3.0	2.0	31.2
CG-18	6.3	3.3	3.4	3.9	4.8	3.2	2.1	1.9	28.9
CG-151	6.5	3.0	3.7	3.7	4.0	3.0	2.0	1.8	27.7
Mean	6.8	3.3	3.5	3.9	4.4	3.1	2.4	1.9	29.3
CV (%)	9.5	10.7	14.3	13.4	11.1	13.7	13.2	12.3	12.1
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS
Stage-I	= Hairy and deep green pedicel; calyx and petals are also deep green; buds are globose shaped and 12.19mm long. Petals are about to enclosed with calyx.								

Stage-II	= Hairy, green pedicel; deep green calyx and light green petals, buds are globose, 15.99mm long. Length of pedicel is about thrice than the length of petals.
Stage-III	= Green and hairy pedicel, light green calyx and petals, buds are globose and 17.73mm long with light separation line on petals. Length of pedicel is about thrice than the length of petals.
Stage-IV	= Green, hairy pedicel; light green calyx, creamy petals with green spots, buds are ovate, 20.18mm long with light separation line on petals.
Stage-V	= Green, hairy pedicel, light green calyx, creamy petals with green spots, buds are ovate, 27.46mm long with light separation line on petals.
Stage-VI	= Light green and hairy pedicel, buds are creamy, obovate and 30.40mm long. Petal length becomes greater than diameter. Length of pedicel is about twice than the length of petals.
Stage-VII	= Light green, hairy pedicel; light green calyx, creamy petals with no spots, buds are obovate, 36.74mm long with prominent constriction of splitting on petals. Length of pedicel and petals are about equal.
Stage-VIII	= Light green pedicel, buds are cream coloured, obovate shaped and 38.51mm long with prominent constriction of splitting on petals. Length of pedicel and petals are about equal.
Stage-IX	= Cream coloured petals, buds are obovate shaped and 43.56mm long with one or two splitting petals.

Cumulative time required from a bud initiation to reach at its successive stages among the accessions are presented in Fig. 2. It is revealed from the table that the accession CG-1 took more time to reach in the next stages than other two accessions. To reach in the last stage of floral bud development, the accession CG-1 took 31.2 days followed by CG-18 (28.9 days) and CG-151 (27.7 days). Therefore, it can be said that in pummelo, a total of 27.7-31.2 days are required from a bud initiation to reach its fully developed stage (Fig. 2).

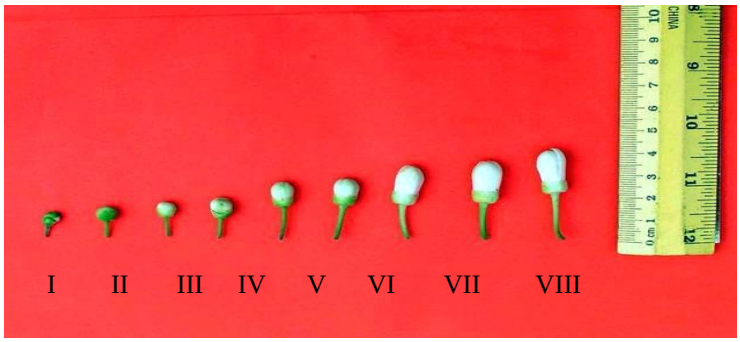

Fig. 1. Different stages of flower bud development in pummelo.

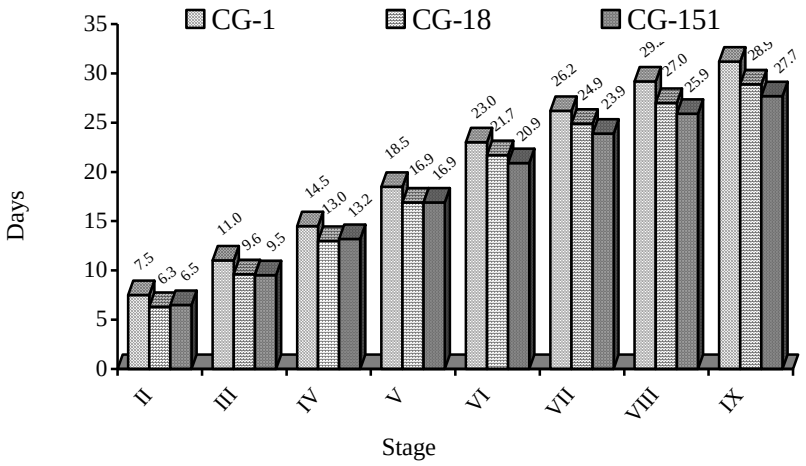

Fig. 2. Cumulative days required for passing from stage-I to another during flower bud development in pummelo.

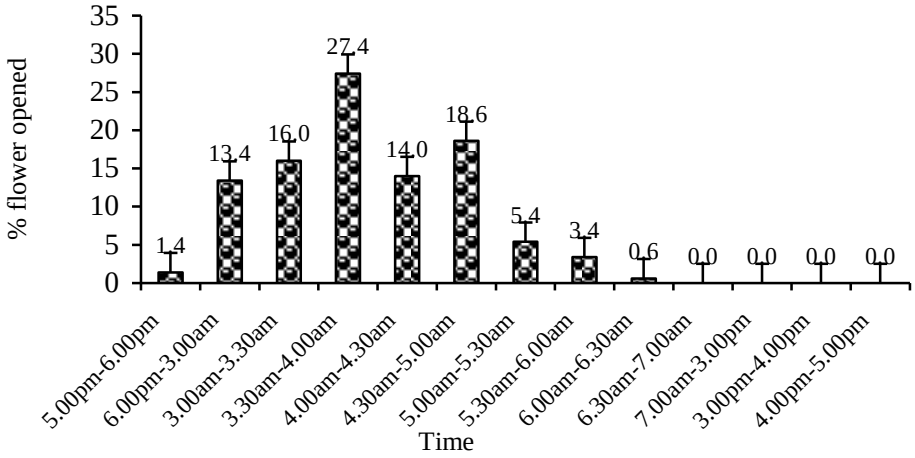

Fig. 3. Percentage of flower opening at different time of the day in pummelo.

Time of anthesis and dehiscence of anthers in flowers of studied pummelo accessions were observed and are presented in Table 6. Time of anthesis is very much important to a breeder, as selfing must be done before anthesis. On the other hand, bagging and emasculation for crossing must be done before anthesis and starting of receptivity of stigma. It was observed in the accessions that opening of pummelo flowers started between 5:00pm to 6:00pm and continued up to 6:30am. The maximum flowers were opened between 3:30am to 4:00am in

Table 6. Time of anthesis and dehiscence of anther in pummelo

Accession	Number of flower opening at different hours											
	5:00pm to 6:00pm	6:00pm to 3:00am	3:00am to 3:30am	3:30am to 4:00am	4:00am to 4:30am	4:30am to 5:00am	5:00am to 5:30am	5:30am to 6:00am	6:00am to 6:30am	6:30am to 7:00am	7:00am to 4:00pm	4:00pm to 5:00pm
CG-1	0	5	9	13	8	10	3	2	0	0	0	0+
CG-18	0+	7	8	13	5	9	5	2	1	0	0	0+
CG-151	2	8	7	15	8	9	0	1	0	0	0	0+
Total	2	20	24	41	21	28	8	5	1	0	0	0
Mean	0.667	6.67	8.00	13.7	7.00	9.33	2.67	1.67	0.33	-	-	-
CV (%)	25.0	18.4	8.84	8.45	20.2	25.9	18.4	14.8	20.0	-	-	-
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-

+ = dehiscence of pollen

Table 7. Abscission time (h) of different floral parts in pummelo after anthesis.

Accession	Stamen		Petal		Pistil	
	Start	Complete	Start	Complete	Start	Complete
CG-1	54.8	123.6	80.1	131.8	172.8	228.3
CG-18	54.9	128.4	77.2	137.9	167.3	224.4
CG-151	50.8	119.2	76.4	128.3	162.3	226.2
Mean	53.5	123.7	77.9	132.7	167.5	226.3
CV (%)	12.40	11.83	12.21	11.24	10.86	10.6
$LSD_{0.05}$	2.912	5.15	NS	3.73	3.26	3.052

all the accessions. A total of 41 flowers among 150 flowers were opened within this time in the accessions, which is about 27.3% of total flower. Between 3:00am to 5:00am, a total of 114 out of 150 flowers, which is about 76% of total flower were found to be opened in three observed accessions. There was no flower observed to be opened from 6:30am to 5:00pm (Table 6 and Fig. 3). This was in agreement with the findings of Shinde and Dhuria (1960). Like anthesis, it is also important to know the time of dehiscence of anthers for successful breeding work. In flowers of studied pummelo accessions, dehiscence of pollens was observed between 4:00pm to 6:00pm. Between 4:00pm to 5:00pm in all the three accessions, dehiscence of pollens were recorded which indicated that pollen dehisced in pummelo flowers mainly in this time (Table 6), which is about 10 hours after anthesis. Practically, it was observed that in a flower cluster some flowers were in bud stage, some other at anthesis and some other in a stage when floral parts were withering or already withered.

Among the floral parts, stamen withered and abscised first followed by petal and pistil. Abscission of stamen started after 50.8 hrs of anthesis and completed after 128.4 hrs of anthesis. Petals started to be abscised after 76.4 hrs of anthesis and completed after 137.9 hrs of anthesis (Table 7). Practically, it was observed that when petals started to wither and abscise, some stamens were still attached with the flowers. It was also seen in some flowers that petals abscised after completion of stamen withering. Pistil took a long time to start abscission and it was 162.3 hrs after anthesis. Abscission of pistil completed after 228.3 hrs of anthesis (Table 7). This result of abscission of different floral parts differed slightly with the findings reported by Frost and Soost (1968) in *C. lemon*. They reported the abscission time of petals and stamens after six days of pollination and abscission of style occurs after 10-15 days of anthesis. This variation might be attributed to genetic and environmental differences, because environmental factors such as, temperature, light, humidity, wind speed etc. are important for abscission of floral parts. Eti and Stosser (1992) reported the abscission time of style in mandarin was after 12 days of anthesis.

Conclusion

Pummelo flowers are bisexual, white coloured, borne singly or in clusters, having 4 sepals and petals, 27 to 34 stamens with 1.0 to 2.0cm long. Stages of floral bud development from initiation to anthesis may be divided into 9 distinct stages. In pummelo, a total of 27.7 to 31.2 days are required from a bud initiation to reach its fully developed stage. Emasculation of pummelo flowers should be done within 26 days from flower bud initiation. Starting from initiation, a floral bud of pummelo took 28 to 32 days up to anthesis. About 76% pummelo flower were found

to be opened between 3:00am to 5:00am, while dehiscence of anthers occurred between 4:00pm to 5:00pm. Therefore, selfing should be done in pummelo in the early morning and preferably before 3:00am to avoid cross pollination.

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DETERMINATION OF OPTIMUM MATURITY STAGE OF BANANA

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Abstract

Time of harvest based on maturity indices is very important for fruit quality. Fruits harvested before optimum maturity may not ripe adequately and may not develop adequate flavor, while fruits harvested late (over-matured) have a shorter postharvest life and deteriorate rapidly. Climacteric fruits can be harvested after reaching full maturation, and before reaching the ripening stage. The tissue culture suckers of BARI Kola1 and Sabri Kola varieties were used for the study. The experiment was conducted at the Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur in 2009-10. Optimum maturity stage of banana fruits reduced the postharvest losses and extended the storage life of fruits. BARI Kola 1 and Sabri Kola reached to flowering stages 10 and 15 months after planting, respectively. The optimum maturity stages of BARI Kola 1 and Sabri Kola were found to 120 and 100 days after emergence of flowering (DAEF) in summer and 130 and 110 DAEF in winter seasons, respectively. Higher pulp to peel ratio and yield of both the varieties was found in summer than those of winter season. The pre-harvest loss of banana fruits started at the point when it just exceeded the optimum maturity stage. Decreasing trend of shelf-life and firmness of fruits for both the varieties were observed with the advancement of maturity. On the other hand, dry matter content, angularity, pulp to peel ratio, and yield of banana fruits increased with the advancement of harvesting days. Degree days of these varieties were found to be 1750 and 1620, respectively.

Keywords: BARI Kola 1, Sabri Kola**,** optimum maturity stage, shelf-life, degree days and physico-chemical properties.

Introduction

Fruit maturation is an important postharvest criterion for banana. The stage of maturation at which the fruit is harvested greatly influences the green-life or storage lo5ngevity and eating quality. Every fruit attains its full characteristics e.g. flavour, taste and colour during storage if it is picked at optimum time. Fruits, harvested at an advanced stage of maturity, is not suitable for fruits intended for long distance transportation due to their shorter storage life (Harman, 1981; Kader, 1994).

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Most of the banana plants produce the flower buds within 10 to 15 months of emergence as a new sucker, depending mostly on variety and extent of cool weather. Banana production systems are perennial. Flower development is initiated from the true stem portion of the plant 9-12 months after planting. The inflorescence grows up through the center of the pseudostem. Depending on season and cultivar, bananas become matured at 90-120 days after appearing of first flower (Knowledge Master, 2003).

According to Morton (1987), banana bunches are harvested when the fruits are fully developed, that is, 75% matured, the angles are becoming less prominent and the fruits on the upper hands are changing to light green; and the flower remnants (styles) are easily rubbed off the tips. Generally, this stage reached 75 to 80 days after the opening of the first hand.

Harvesting of banana is done 12 to 15 months after planting in dwarf and 15 to 18 months after planting in tall varieties. Signs of maturity of banana fruits are: fruit becomes plumpy and angles are filled in completely; gives metallic sound when tapped, drying up of top leaves and change in colour of fruits from deep green to light green (Mpyshameem, 2010). Ara *et al.* (2009) reported that crop durations of Sabri and BARI Kola 1 was 412 days and 435 days, respectively.

Fruit characteristics at harvest may be important in the design of packaging for the fruit which would enhance efficient handling and transportation. Postharvest quality attributes (such as peel and pulp colour, pulp firmness, total soluble solids, moisture and dry matter content) are important to assess the maturity indices (Dadzie and Orchard, 1997). Optimum maturity stage of banana is important for attaining good quality fruits and optimum storage life of fruits. No information on maturity stages of varieties of BARI Kola 1 and Sabri Kola is available in the country. Therefore, this study was undertaken to determine the optimum maturity stages of BARI Kola 1 and Sabri Kola on the basis of different physico-chemical properties.

Materials and Method

Variety Selection

Two varieties of BARI Kola 1 and Sabri Kola were selected which were available in the local market in Bangladesh. One hundred fifty tissue culture suckers of BARI Kola 1 and same numbers of Sabri Kola were collected from Proshika, Manikgonj.

Cultivation of Selected Variety

Land preparation was done by disc ploughing and harrowing, the pits were dug for planting. Each pit size was 60 × 60 × 60 cm. Organic manures and fertilizers were applied in pit as well as top-dressing as per recommendation of Haque

(1988). Entire quantity of cow dung, TSP, gypsum, zinc oxide, boric acid and half of muriate of potash were applied in each pit one week after digging. Cowdung was mixed well with the pit soil while fertilizers were incorporated into top 10 cm soil by light spading.

Planting

The pits were filled with manures and fertilizers after one week. Selected sucker of uniform size of BARI Kola 1 and Sabri Kola were planted in the pits on 9 March 2008. The plot size was 3×3 m and 4 suckers were planted per plot maintaining a distance 2 × 2 m in the field.

Matured bunches of BARI Kola 1 and Sabri Kola were harvested in summer in 2009-10 at six maturity stages at 10 days interval such as 100,110,120,130,140, and 150 and 80, 90, 100, 110, 120, and 130 days after emergence of shooting, respectively. They were also harvested in winter 2009-10 at same maturity stages. To reduce variation and to obtain consistent data, all measurements were limited to (or taken on) the fingers of the second hand of freshly harvested physiologically matured bunches (with green fruit). However, if there were not enough samples, fruits from the third and fourth hand were included. Matured and uniform fingers of these selected hands were taken and washed them in fresh water. Fifteen fingers of banana were randomly separated for each treatment and taken five fingers for each replication. Three replications were used to carry out the each treatment.

Shelf-life

Shelf life (days) of banana fruit of each treatment was recorded during the period of storage. It was calculated from the date of harvesting to last edible stage.

Determination of angularity or degree of roundness

Fruit angles were determined at 3 points on the outer surface by measuring individual fruit with a stainless steel protractor. Angularity of fruit was expressed as degree.

Measurement of moisture and dry matter content

Empty container (aluminum dish) was weighed on electronic micro balance and recorded it (A). Chopped fresh pulp samples were put into the container and weighed it (B). The samples were placed in an air ventilated electric oven at 100 °C for 24 hours (Kushman *et al*., 1966). The samples were transferred with the container from oven into desiccators and cooled at room temperature and weighed to obtain the dry samples (C).

Percentage moisture and dry matter content of the samples were calculated by using the following formula.

Wet weight of sample (D) = B-A (1)

Dry weight sample (E) = C-A (2)

Moisture content, (%) (db) $= \frac{D-E}{E} \times 100$ (3)

Pulp to peel ratio

Pulp and peel were separated, weighed individually and expressed as pulp to peel ratio (i.e. pulp weight divided by the peel weight).

Determination of total soluble solids (TSS)

The total soluble solids of banana pulp were determined by using a refractometer. Thirty g of pulp tissue was homogenized with 90 ml of distilled water using a kitchen blender for two minutes and filtered through a filter paper 12.5 cm qualitative. Before measurement, the refractometer was calibrated with distilled water to give a 0 (zero) reading. A single drop of the filtrate was placed on the prism to obtain the TSS reading. The recorded value was multiplied by three (because the initial pulp sample was diluted three times with distilled water).Temperature corrections were made by using the methods described by manufacturer manual.

Determination of firmness

Fruit firmness was measured using digital firmness tester equipped with a 8 mm and 5 mm diameter cylindrical stainless probes. Tester was checked each day before use. The plunger was made to work in and out (about ten times) to ensure that it was running smoothly. Fruit firmness was expressed in kilogram force (kg_f cm^{-2}). Three readings were taken at three places on the surface of each banana and the mean value was calculated.

Degree days

The degree days were obtained by multiplying the daily mean temperature above 10 °C by number of days starting from full bloom to harvest (Jindal, 1985).

Statistical analysis

Data were statistically analyzed using MSTATEC software by analysis of variance and significant differences among the treatments were determined using Duncan's Multiple Range Test at $P \leq 0.05$.

Results and Discussion

Degree of roundness/angularity of banana fruit

The effect of harvesting days on degree of roundness and firmness of BARI Kola1 during summer and winter seasons is shown in Figure 1. Angularity of fruit surface sharply increased up to 120 and 130 days of harvesting for summer and winter, respectively. Later they increased slowly and towards steady state with the increase of harvesting days. The highest and the lowest degree of roundness of BARI Kola 1 in summer and winter were 147.94, 146.66 and 134.06, 132.13° for 100 and 150 DAEF, respectively.

Effect of harvesting days on degree of roundness and firmness of fruit of Sabri Kola in summer and winter seasons is shown in Figure 2. The degree of roundness of fruits of Sabri Kola increased sharply with the advancement of days of harvesting in both the seasons. The maximum and minimum values were found to be 150.48 and 144.24 degree for summer and 146.78 and 138.11 degree for winter, respectively. The differences in values of degree of roundness in two seasons were from climatic effects. The stages of harvesting showed significant variation in respect of angularity.

In respect of seasons, angularity of BARI Kola 1 and Sabri Kola was significant (Table 1). Result indicated that summer was superior to winter in respect of angularity. Irrespective of seasons, harvesting stages of both the varieties exhibited significant effect on angularity (Table 2). Treatment combinations also did not have any significant effect in respect of angularity for both the varieties.

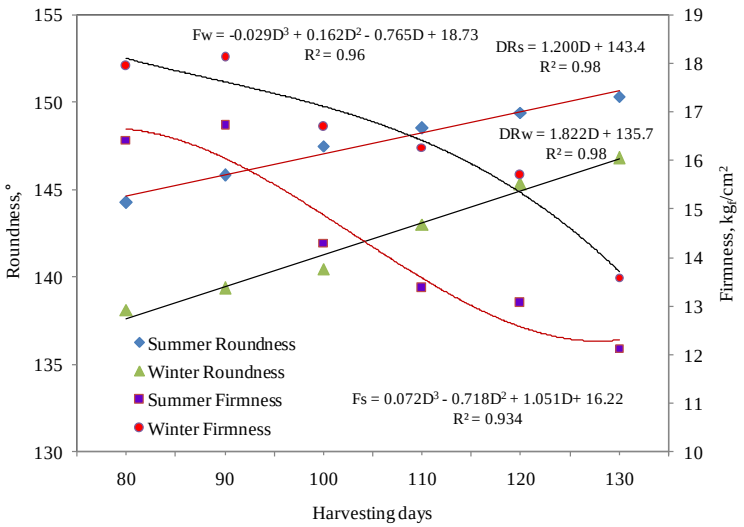

Fig.1. Effect of harvesting days on roundness and firmness of BARI Kola1.

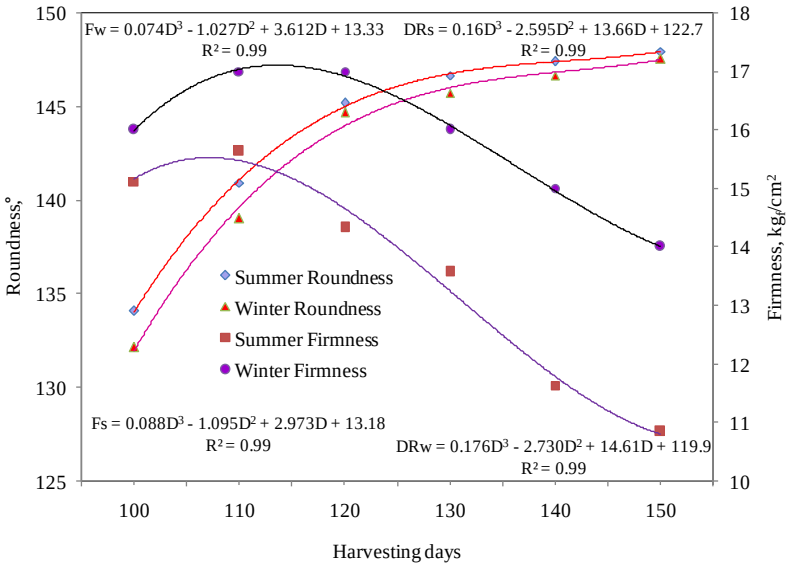

Fig. 2. Effect of harvesting days on roundness and firmness of Sabri Kola.

Firmness

Firmness of fruit of BARI Kola 1 and Sabri Kola gradually increased and then decreased with the advancement of harvesting days (Figure 1 and 2). It was also observed that firmness of BARI Kola 1 in summer and winter seasons increased towards maturity from 100 to 110 and 100 to 120 days after emergence of flowering (DAEF), respectively, and thereafter gradually declined up to 150 DAEF. It means fruits were tender initially and progressed towards the hardness with morphological advancement. It became soft at maturity stages. Optimum maturity stages of BARI Kola 1 might be laid between 110 to 130 DAEF for summer and 120 to 140 DAEF for winter. In summer, firmness under harvesting stages of 100, 110, 120 and 130 were statistically identical, but harvesting stages of 140 and 150 showed significant decrease in firmness.

In winter, significant variation was observed among the harvesting stages in respect of firmness. In respect of seasons, firmness of BARI Kola 1 varied significantly (Table 1). The finding indicated that firmness of BARI Kola 1 in winter was higher than that in summer. It might be due to the reason that fruit peel tissue got harder due to cold weather. At the stage of harvesting significant variations in firmness of fruits were found for both the seasons (Table 2).

Table 1. Effect of season on angularity and firmness of BARI Kola 1 and Sabri Kola.

Season	BARI Kola 1		Sabri Kola	
	Angularity (degree)	Firmness ($kg_f cm^{-2}$)	Angularity (degree)	Firmness ($kg_f cm^{-2}$)
Summer	143.70a	13.52b	147.70a	14.33b
Winter	142.67b	15.93a	142.16b	16.49a

Table 2. Effect of harvesting days on angularity and firmness of BARI Kola 1 and Sabri Kola.

Harvesting days	BARI Kola 1		Harvesting days	Sabri Kola	
	Angularity (degree)	Firmness ($kg_f cm^{-2}$)		Angularity (degree)	Firmness ($kg_f cm^{-2}$)
100	133.10c	15.76ab	80	141.20d	17.30a
110	140.00b	16.52a	90	142.60cd	17.47a
120	145.10a	15.46ab	100	144.00c	15.56b
130	146.20a	14.68bc	110	146.00b	14.66b
140	147.00a	13.42cd	120	147.20ab	14.54b
150	147.70a	12.52d	130	148.60a	12.93c
CV(%)	1.18	7.47	CV(%)	1.18	7.47

* Similar letter(s) in a column do not differ significantly by at 5% lebel of probability DMRT

Total soluble solids

Pulp to peel ratio (Pp) and total soluble solids (TSS) of BARI Kola 1 in summer and winter seasons were changed with the harvesting stage (Figure 3). It was observed that TSS increased initially but became almost constant in advanced stages of maturity. At immature stage, TSS value was lower than that of maturity stage while it was in similar state from maturity stage of 120 DAEF in both seasons. It was found that the fruits attained maturity condition from 120 to 130 DAEF. Optimum maturity stage ranged between 120 and 130 DAEF in summer and 130 and 140 DAEF in winter season. In summer, TSS was similar at 120, 130, 140 and 150 days of the harvesting but they significantly differed at 100 and 110 days of harvesting. In winter, TSS at 110, 120, 130, 140 and 150 days of harvesting was observed similar but they differed significantly at 100 days of harvesting (Table 3).

TSS content of *Sabri Kola* increased gradually as the harvesting days advanced towards optimum maturity (Figure 4). Harvesting days had no significant effect on TSS content in summer but had significant effect on the TSS content in winter (Table 3). In winter, harvesting days of 100, 110, 120 and 130 were similar but differed in harvesting days of 80 and 90. Significant difference was observed between the seasons in respect of TSS (Table 3). TSS was higher in winter than that of summer. For both seasons, significant variation among the harvesting days was found in respect of TSS (Table 4).

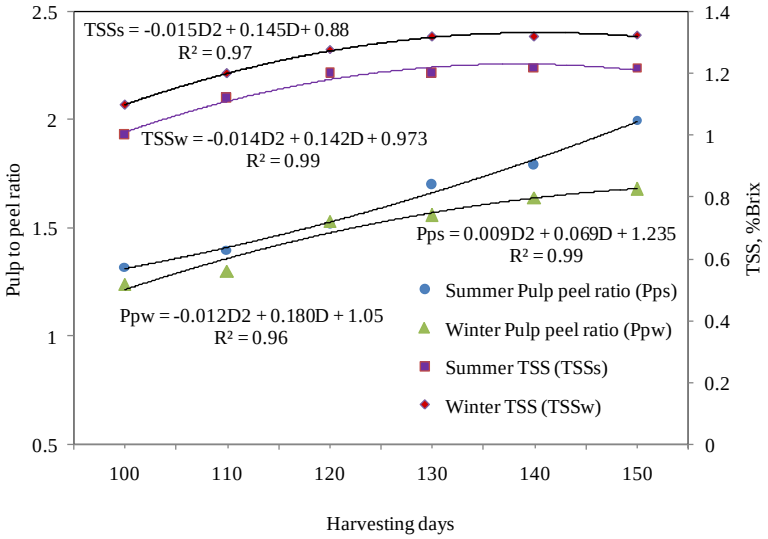

Fig.3. Effect of harvesting days on pulp to peel ratio and TSS of BARI Kola 1.

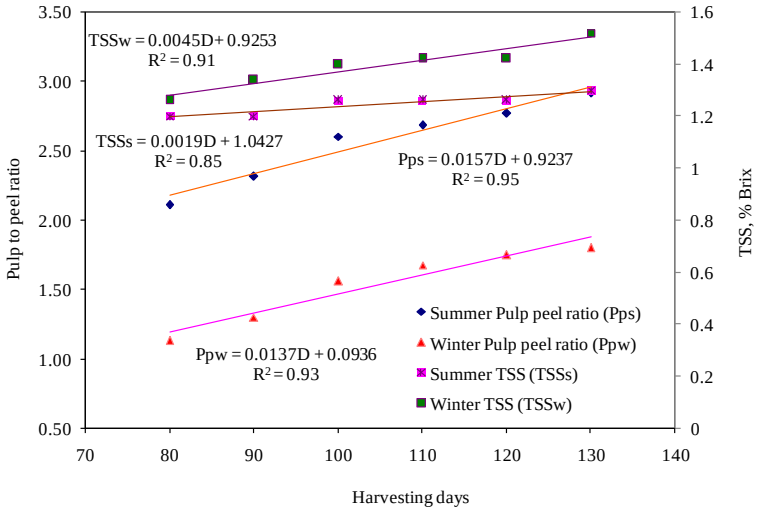

Fig.4. Effect of harvesting days on pulp to peel ratio and TSS of Sabri Kola.

Pulp to peel ratio

From Figure 3, it was observed that pulp to peel ratio of fruits of BARI Kola 1 increased rapidly in summer season but it increased slowly in winter season with the increase of harvesting days. The maximum pulp to peel ratio was noted at harvesting days of 150 and the minimum at harvesting days of 100. Maximum ratio indicates the end of maturity having maximum yield and shortest shelf-life.

From Figure 4, it was observed that pulp to peel ratio of *Sabri Kola* increased sharply in summer and winter seasons with the increase in harvesting days. The highest and the lowest values of pulp to peel ratios were found at matured and immature stages, respectively as the pulp thickness developed rapidly and the peel thickness reduced sharply with the physiological advancement of fruits. A linear relationship was found between harvesting days and pulp peel ratio. In summer, the highest and the lowest pulp to peel ratios were found 2.92 and 2.11 whereas in winter these were 1.84 and 1.13, respectively. Pulp to peel ratio was also influenced significantly by seasons (Table 3). The highest pulp to peel ratio was observed in summer compared to that in winter. It might be due to temperature effect on fruit growth. It was also observed for both varieties that there was significant variation among the harvesting days (Table 4). The increasing trend of pulp to peel ratios with the increase of harvesting days was reported by Dadzie (1993, 1994a, b) and Robinson (1996).

Table 3. Effect of season on pulp to peel ratio and TSS of BARI Kola 1 and Sabri Kola.

Season	BARI Kola 1		Sabri Kola	
	Pulp to peel ratio	TSS (% Brix)	Pulp to peel ratio	TSS (%Brix)
Summer	1.62a	1.16b	2.57a	1.25b
Winter	1.49b	1.26a	1.54b	1.40a

Table 4. Effect of harvesting days on pulp to peel ratio and TSS of BARI Kola 1 and Sabri Kola.

BARI Kola 1			Sabri Kola		
Harvesting days	Pulp to peel ratio	TSS (%Brix)	Harvesting days	Pulp to peel ratio	TSS (%Brix)
100	1.28d	1.05c	80	1.62e	1.23b
110	1.35d	1.16b	90	1.81d	1.27b
120	1.53c	1.24a	100	2.08c	1.33ab
130	1.63b	1.26a	110	2.18bc	1.34ab
140	1.75b	1.27a	120	2.26ab	1.34ab
150	1.84a	1.27a	130	2.36a	1.41a
CV(%)	5.62	6.04	CV(%)	7.56	6.95

Dry matter content

Changes of dry matter content of fruits of BARI Kola 1 at different maturity stages in summer and winter seasons are shown in Figure 5. It was observed that DMC increased initially with the progress of maturity up to 120 and 130 DAEF, respectively and after that time, it declined. Furthermore, it revealed that DMC gradually increased while the moisture content decreased with the development of physiological maturity of the fruits. Later, the DMC decreased as the moisture content increased for starting the ripening process. This finding corroborate with Hassan (2010) who reported decreasing trend of DMC (from 32.89 to 27.11%) of banana with the increase of ripening period (from 2 to 8 days).

It was also observed that the DMC of fruits of *Sabri Kola* for summer and winter increased gradually up to 100 and 110 DAEF, respectively and later, they were reduced gradually (Fig. 6). The maximum DMC was found in 100 and 110 DAEF while the lowest values obtained in treatment 80 DAEF for both the seasons. The results further indicated that the fruit ripening started from the optimum stage.

Harvesting days of BARI Kola 1 and Sabri Kola caused significant differences in dry matter content for both the seasons (Table 5 and 6). Depending on seasons, dry matter contents of BARI Kola and Sabri Kola were found to vary significantly (Table 5). Results indicated that summer season was superior to winter season in respect of dry matter content. Harvesting stages exhibited insignificant effect on dry matter content in BARI Kola 1 but significant effect on Sabri Kola (Table 6).

Shelf-life

Data on shelf-life of fruits for summer and winter seasons of BARI Kola 1 and *Sabri Kola* are presented in Figure 5 and 6. From these Figures, the shelf-life was found to decrease sharply with the increase in harvesting days. For BARI Kola 1, the shelf-life ranged between 6.83 and 11.17 days having the longest shelf-life of 11.17 days in 100 DAEF and the shortest shelf-life of 6.83 days in 150 DAEF in summer. In winter, the highest and the lowest values were 22.33 and 12.5 days in 100 and 150 DAEF, respectively. The variation of shelf-life of the fruits in both the seasons was due to climatic effect.

It was also observed that shelf-life of *Sabri Kola* ranged between 7.35 and 11.65 days with the longest shelf-life, 11.65 days in 80 DAEF and the shortest, 7.35 days in 130 DAES for summer while for winter the highest and lowest values were 24.6 and 12.35 days in the same DAES, respectively.

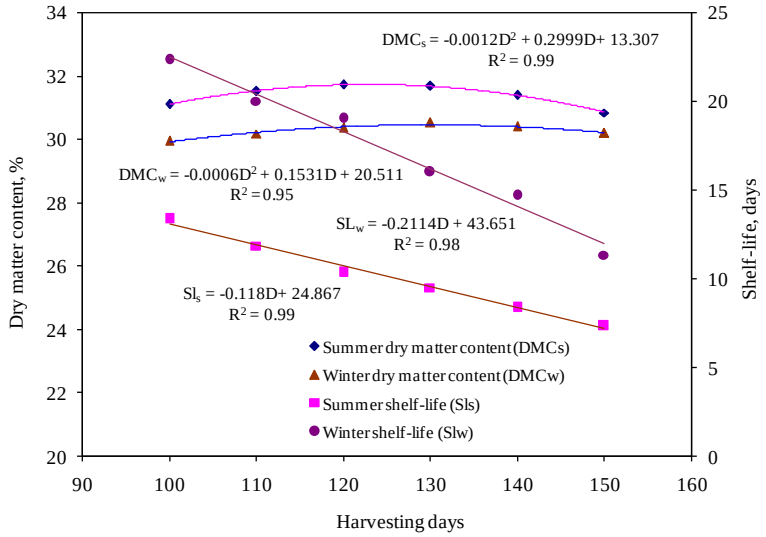

Fig.5. Effect of harvesting days on dry matter content and shelf-life of BARI Kola 1.

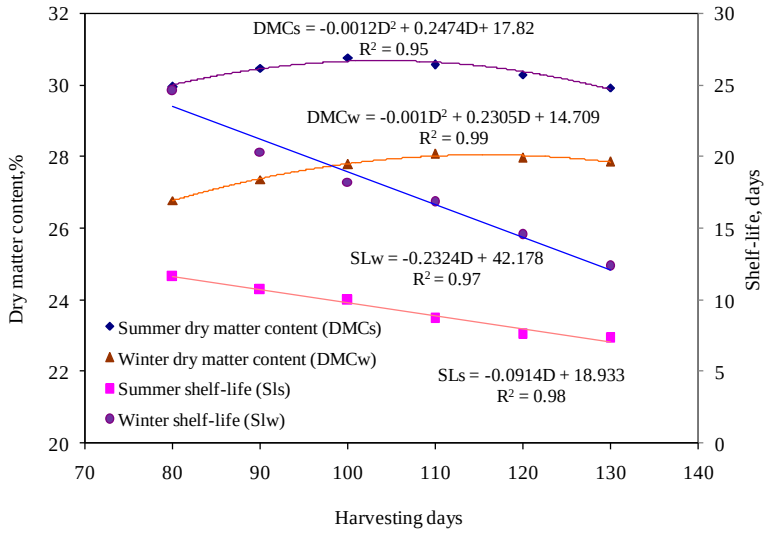

Fig.6. Effect of harvesting days on dry matter content and shelf-life of Sabri Kola.

In regards to seasons, shelf-life of BARI Kola and Sabri Kola varied significantly (Table 5). Results indicate that the longest shelf-life (17.25 days) was found in winter where as the shortest shelf-life (9.47 days) was observed in summer. Irrespective of seasons, harvesting stages exhibited significant effect on shelf-life for both the varieties (Table 6). Therefore, shelf-life of *Sabri Kola* was higher

than that of BARI Kola 1 in respect of harvesting days. Narayan and Mustaffa (2007) reported the similar results in shelf-life of banana.

Table 5. Effect of season on yield, dry matter content and shelf-life of BARI Kola 1 and Sabri Kola.

Season	BARI Kola 1			Sabri Kola		
	Yield t ha^{-1}	Dry matter content % (db)	Shelf-life days	Yield t ha^{-1}	Dry matter content % (db)	Shelf-life days
Summer	32.44a	31.30a	9.47b	24.74a	43.53a	9.33b
Winter	23.68b	30.60b	17.25a	17.79b	38.22b	17.82a

Determination of optimum maturity days of BARI Kola 1 and Sabri Kola

Scaling values of all the following physico-chemical parameters such as TSS, DMC, Firmness, angularity, shelf-life, yield, Pp for particular harvesting stage were summarized.

BARI Kola 1: Optimum maturity of banana was determined on the basis of physico-chemical parameters. Relation between sum of score of physico-chemical parameters and harvesting stages of BARI Kola 1 are shown in Figure 7. From this figure, it was found that scoring value gradually increased up to 120 harvesting days in summer and up to 130 harvesting days in winter and they gradually decreased with the increase of harvesting days. Optimum values were found near 120 harvesting days in summer and 130 harvesting days in winter, respectively.

Table 6. Effect of harvesting days on yield, dry matter content and shelf-life of BARI Kola 1and Sabri Kola.

BARI Kola 1				Sabri Kola			
Harvesting days	Yield t ha^{-1}	Dry matter content % (db)	Shelf-life days	Harvesting days	Yield t ha^{-1}	Dry matter content % (db)	Shelf-life days
100	21.75d	30.53	16.75a	80	14.23e	39.61d	18.13a
110	25.20c	30.85	15.33b	90	17.88d	40.71bc	15.52b
120	28.46b	31.04	14.17c	100	21.96c	41.40ab	14.13c
130	29.71ab	30.98	12.50d	110	23.73b	41.48a	12.75d
140	31.04ab	31.28	11.75d	120	24.45b	41.10abc	11.07e
150	32.17a	31.01	9.67e	130	25.33a	40.65c	9.85f
CV (%)	8.55	2.26	3.79	CV (%)	3.85	1.32	3.47

The variation in optimum maturity stage might be due to temperature and humidity at different seasons. BARI Kola 1 was harvested within 120-140 days after emergence of flowers. During this period, minimum postharvest losses occurred and got optimum storage life i.e shelf-life. When fruits were harvested before optimum maturity, postharvest losses and storage life increased but quality decreased while harvested after optimum maturity, postharvest losses of fruits increased but storage life and quality decreased. Best fitted two degree polynominal regression equations were attained for optimum harvesting maturity stage.

Sabri Kola: The scoring values of *Sabri Kola* for both the seasons were changed over the harvesting days (Figure 8). The values increased gradually up to 100 and 110 days of harvesting and later it declined. The maximum value of scoring was obtained at 100 and 110 DAEF in summer and winter, respectively and those were the optimum harvesting stages of the Sabri Kola. Best fitted three degree polynominal regression equations were attained for optimum harvesting maturity stage of Sabri Kola.

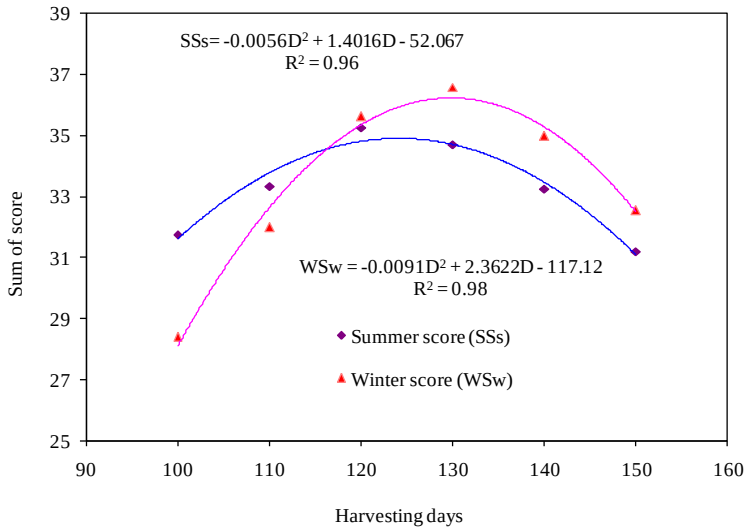

Fig.7. Effect of harvesting days on physico-chemical parameters of BARI Kola 1.

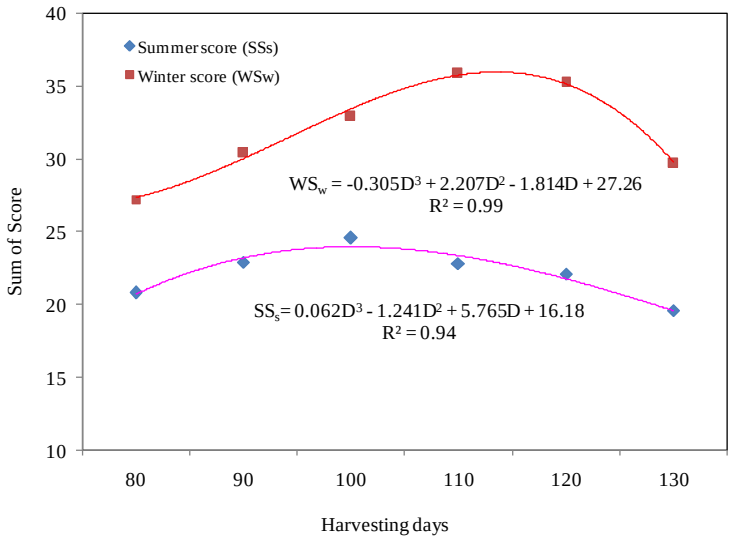

Fig. 8. Effect of harvesting days on physico-chemical parameters of Sabri Kola.

Degree days

Degree days of BARI Kola 1 and Sabri Kola are shown in Fig. 9.The degree days of BARI Kola 1 and Sabri Kola were found to be 1750 and 1620, respectively. Similar results of Williams banana bunch from emergence to harvest maturity ranged from 950 to 1050 was obtained in South Africa by Robinson *et al.* (1992).

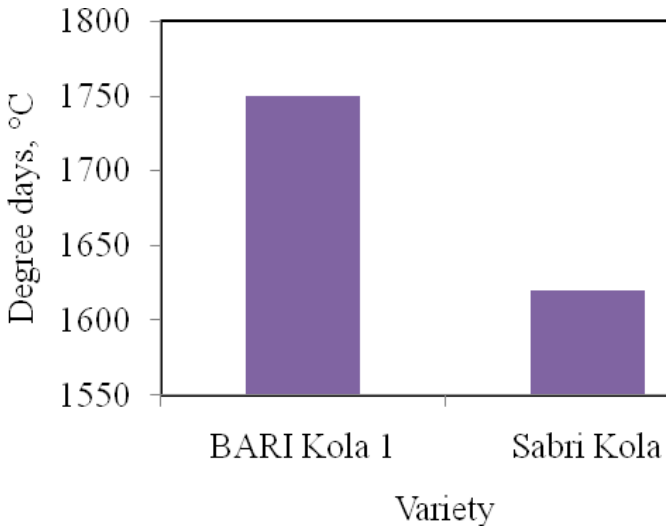

Fig.9. Degree days of BARI Kola 1 and Sabri Kola.

Conclusion

The study clearly showed that optimum harvesting days of BARI Kola 1 and *Sabri Kola* were found to be 120 and 130 days DAEF in summer, and 100 and 110 days DAEF in winter, respectively. Shelf-lives of BARI Kola 1 and Sabri Kola at optimum maturity stages obtained 10.33 and 15.50 days in summer and 10.00 and 16.80 days in winter, respectively. At optimum maturity, angularity of BARI Kola 1 and Sabri Kola was found at 145.20° and 145.73° and 145.48° and 142.99° in summer and winter seasons, respectively. BARI Kola 1 and Sabri Kola had 1750 and 1620 degree days, respectively. Farmers and traders should harvest banana at or before optimum harvesting days to store for long period and to attain good quality fruits.

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RESPONSE OF ELEVATED TEMPERATURE ON CARBOHYDRATE ACCUMULATION AND GRAIN YIELD IN DIFFERENT WHEAT CULTIVARS

SOYEMA KHATUN[1], AND JALAL UDDIN AHMED[2]

Abstract

In order to study the response of terminal heat stress on carbohydrate accumulation and grain yield of three wheat cultivars namely BARI Gom 25, BARI Gom 26 and Pavon 76 were sown on 18 November, 2011 in experimental field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur in Bangladesh and two temperature regimes viz. normal (23°C in open field) and elevated (6 ± 1°C higher compare to open field mean air temperature in polythene chamber) were created. Elevated temperature shortened the grain filling duration by 5-day in BARI Gom 25 and BARI Gom 26 and 10-day in Pavon 76. Under elevated temperature condition grain starch synthesis was found to be stopped at 25 days after anthesis (DAA) in Pavon 76 which in BARI Gom 26 appeared 5-day later (30 DAA) in spite of higher level of soluble sugar in grain. Results indicate that early failure of conversion of sugar to starch rather than supply of soluble sugar under elevated temperature condition were responsible for shortening of grain filling duration and smaller grain size in all wheat cultivars. Smaller reduction of grain size and grain number along with smaller reduction of grain weight per main stem under elevated temperature condition finally contributed to sustain negligible loss of grain yield, biological yield and harvest index in BARI Gom 25 and BARI Gom 26 compare to Pavon 76.

Keywords: Starch, soluble sugar, heat stress, wheat.

Introduction

In many wheat growing regions high temperature during post anthesis period are major factor limiting its productivity. Wheat is thermo sensitive crop. The optimum temperature for wheat growth ranged from 15ºC to 18ºC (Choudhury and Wardlaw 1978) but the temperature requirement of the crop during reproductive growth phases lies within 22°C for optimizing its grain yield (Campbell and Read 1968). In case of late sowing, temperature becomes stressful above 26°C, when a premature ripening of wheat is taken place (Aborl *et al*. 1991) and producing poorly develop grain in wheat (Hasan and Ahmed 2005). Because the crop can not complete the major portion of grain filling period

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before the temperature rises up to the critical level. High temperature during the reproductive stage and grain-filling is one of the main causes of yield loss in wheat in Bangladesh. Post-anthesis heat stress in wheat induces several physiological effect which eventually result in smaller grain weight due to reduced grain filling period and starch synthesis duration or the combined effect of both (Hasan and Ahmed 2005). Reduction of grain filling and starch synthesis duration is considered as one of the major environmental constraints that drastically reduce grain number per spike, grain size and grain weight per main stem and consequently significant reduction in wheat grain yield (Modhej *et al.* 2008, Gibson and Paulsen 1999).

Under Bangladesh condition a large number of findings are available regarding late planting induced heat stress effect on grain yield and yield attributes (Sikder and Paul 2010). In all of them, the temperature regimes were created by seeds sown on different sowing dates. There are fewer reports so far in which two temperature regimes were created by seeds sown on same day to study the response to terminal heat stress. This study was to investigate the response of elevated temperature on carbohydrate accumulation and grain yield in recently released wheat cultivars.

Materials and Method

The experiment was conducted at the research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during November, 2011 to April, 2012. In this experiment recently released two potential heat tolerant wheat cultivars namely BARI Gom 25, BARI Gom 26 along with a heat sensitive check wheat cultivar Pavon 76 were planted using split plot design with four replications under two growing condition viz. open field temperature and elevated temperature (Polythene Chamber). Seeds were sown on 18 November, 2011 in rows of 20 cm apart (at the rate of 120 kg ha^{-1}). The unit plot size was 3m x 3m having a plot to plot distance of 1.0 m. In each of this 3m x 3m plot, 1.5 m x 1.0 m area was covered by transparent polythene sheet. The chambers were constructed using bamboo frame of 1.5 m high keeping 30 cm open space near the ground surface. Light intensity during maximum grain filling was found 1280 µ mol $m^{-2}S^{-1}$ in open field and 950 µ mol $m^{-2}S^{-1}$ in polythene chamber which is higher than its normal light intensity. Normal light intensity requirement for wheat was 610 µ mol $m^{-2}S^{-1}$ reported by Gerbaud and Marcel 1980. Cow dung 8500 kg ha^{-1} and other fertilizers such as N 60 kg ha^{-1} (as Urea), P 140 kg ha^{-1} (as TSP), K 100 kg ha^{-1} (as MOP) and S 110 kg ha^{-1} (as Gypsum) were applied as per recommendation (FRG 2005). Irrigation was given to maintain more or less a

field capacity and to avoid the drought stress. Mean air temperature was recorded everyday at noon period (2 pm to 3 pm) using maximum-minimum thermometer from 5 days after anthesis (DAA) up to the maturity of each cultivar. Main shoot of 100 individual plants were tagged to confirm the equal exposure of elevated temperature starting the first appearance of anther emerged from the spike in each plant. Tagged ten spikes of main shoots were sampled at 5-day intervals starting from anthesis to 40 DAA and sampled spikes were oven dried at 70°C for 72 hours. After oven drying grains were sampled from the middle portion of the spike and their weight was taken with analytical balance (Model: AGN220C). The grain samples were used for sugar and starch analysis. Soluble sugar and starch content of grain was determined using the method of Yoshida *et al*. (1976).

Plants were hand-harvested by cutting them at ground level. Then grain 1000-grain weight, grain number per spike and grain dry weight per main stem was measured. The husk, straw and representative samples of grain were dried in sun properly to obtain grain yield and biological yield expressed in t/ha. Harvest index was calculated by the following formula-

$$Harvest\ index\ (\%) = \frac{Economical\ yield}{Biological\ yield} \times 100$$

The relative performance was calculated as Asana and Williams (1965) by the following formula-

$$Relative\ Performance\ (\%) = \frac{Variable\ measured\ under\ stress\ condition}{Variable\ measured\ under\ normal\ condition} \times 100$$

All statistical analyses were performed by MSTAT-C program. The treatment means were compared using Duncan's Multiple Range Test (DMRT) at 5% level of significance. Graphical representation and simple data were calculated by using Microsoft Excel.

Results and Discussion

Wheat cultivars were grown in open field temperature condition where daily mean temperature during reproductive growth stage was recorded 23°C (ranging from 18.5 to 25.5°C) (Fig. 1). But under elevated temperature condition in polythene chamber the daily mean temperature was raised by 6 ± 1°C compare to open field mean air temperature. Generally optimum temperature for reproductive stages of wheat lies within a range of 22 - 26°C temperature (Campbell and Read 1968; Mullarkey and Jones 2000; Tewolde *et al*. 2006) and premature ripening of grain was occurred above 26°C (Aborl *et al*. 1991).

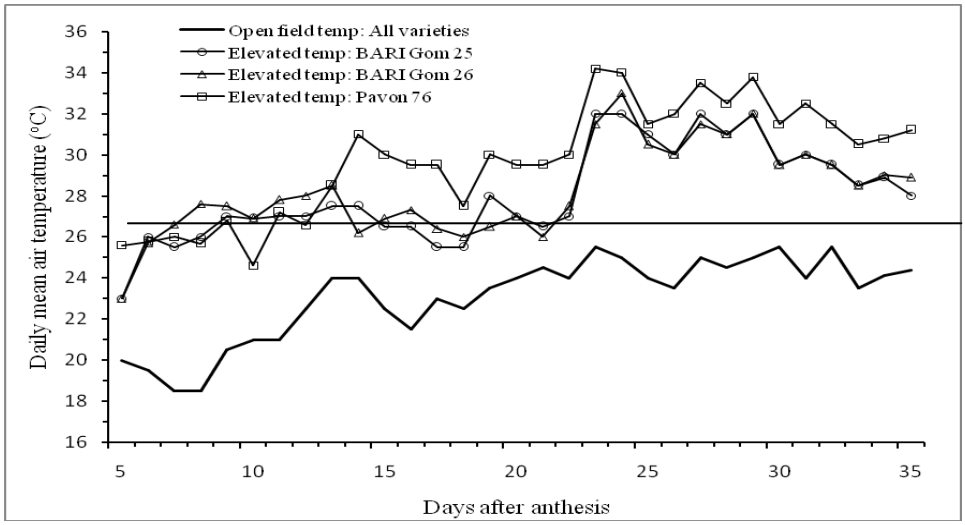

Fig. 1. Daily mean air temperature received by three wheat cultivars from 5 to 35 DAA under open field and elevated temperature conditions. Horizontal line indicates the critical level of temperature for grain growth of wheat.

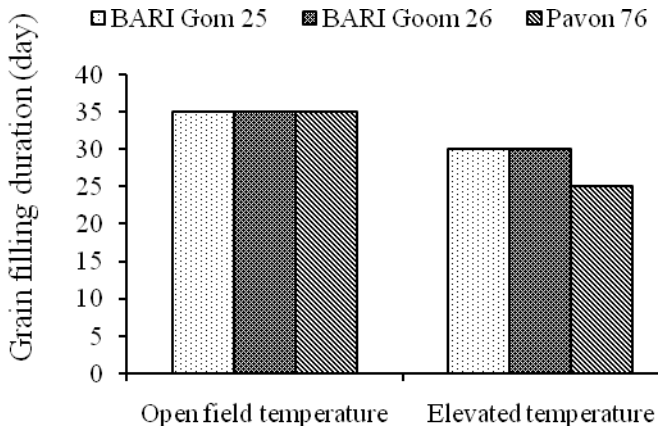

Fig. 2. Grain filling duration in three wheat cultivars under open field and elevated temperature condition.

Elevated temperature condition accelerated the physiological maturity of all wheat cultivars and hence reduced their grain filling duration. Under elevated temperature condition grain filling duration was 25-day in Pavon 76 and 30-day in BARI Gom 25 and BARI Gom 26 (Fig. 2). But under open field temperature condition grain filling duration in all wheat cultivars were 35-day. Therefore due to elevated temperature grain filling duration was reduced by 5-day in two BARI Gom cultivars and by 10-day in Pavon76. Reports are available on heat stress

about shortened grain filling period (Dias and Lidon 2009). Varietal difference in reduction of grain filling duration was also reported in wheat indicating a larger reduction in heat sensitive cultivars compared to heat tolerant cultivars (Hasan and Ahmed 2005).

Because of similar variation of grain filling duration out of two wheat cultivars BARI Gom 25 and BARI Gom 26, finally BARI Gom 26 was taken to compare with Pavon 76 for grain starch and soluble sugar analysis. Result indicate that percent of maximum starch content reached the highest level at 35 DAA in both of the wheat cultivars (BARI Gom 26 and Pavon 76) under open field temperature condition (Fig. 3.A). But under elevated temperature condition that reached the highest level at 30 DAA in BARI Gom 26 and at 25 DAA in pavon 76 (Fig. 3.A). Thus compared to BARI Gom 26, starch synthesis was stopped about 5-day earlier in Pavon 76 due to elevated temperature conditions. It was clearly indicate that heat stress effect was more pronounced in Pavon 76 and also appeared here that the end of grain filling duration and starch synthesis duration was almost equal in both of the wheat cultivars and growing temperature condition.

A higher level of grain soluble sugar was found up to 20 DAA in BARI Gom 26 under open field temperature condition compared to elevated temperature condition, which was found in Pavon 76 for 15-day (Fig. 4.B). Afterwards soluble sugar content was lower under open field temperature condition compare to elevated temperature condition in both cultivars.

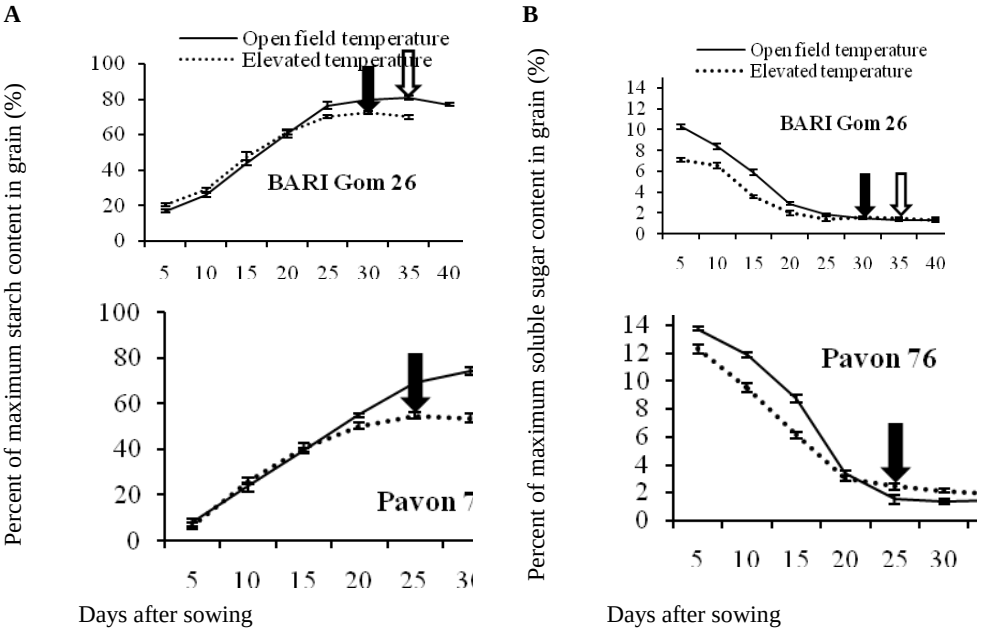

Fig. 3. (A) Percent of maximum starch and (B) soluble sugar content in grain of two wheat cultivars from 5 DAA to maturity under open field and

elevated temperature condition. Unfilled and filled arrows indicate physiological maturity of wheat cultivars under open field and elevated temperature conditions, respectively. Vertical lines are standard errors of selected data point.

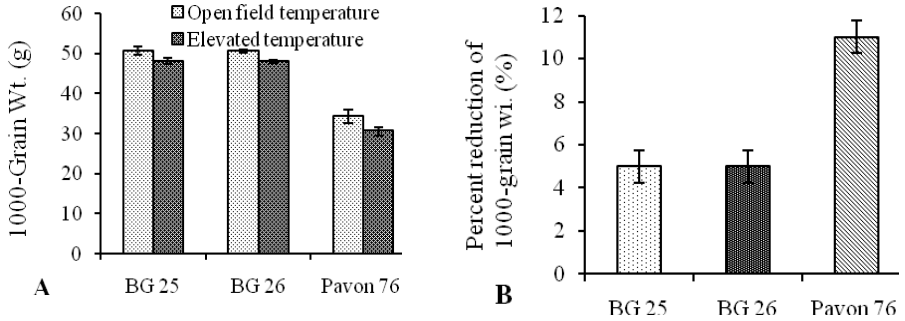

Fig. 4. (A) Weight of 1000-grain and (B) percent reduction of 1000-grain weight of three wheat cultivars under open field and elevated temperature condition. Vertical lines are standard errors of mean data point.

At physiological maturity, it is clearly noticed that the grain starch synthesis was terminated in presence of adequate amount of grain soluble sugar under elevated temperature condition due to some limiting factors in synthesis of starch from soluble sugar in grain. Premature of grain development under heat stress condition had been reported due to limited enzymatic function involving sugar to starch conversion (Denyer *et al.* 1994; Jenner 1994; MacLeod and Duffus 1988). It appeared here that elevated temperature restricted starch synthesis more prominent in heat sensitive cultivars compare to heat tolerant cultivars (Yang *et al*. 2002; Hasan and Ahmed 2005).

Under elevated temperature condition 1000-grain weight was reduced in all wheat cultivars. Such reduction was more pronounced through percent reduction of 1000-grain weight. Maximum reduction of 1000-grain weight was observed in Pavon 76 and minimum in BARI Gom cultivars due to high temperature (Fig. 4). Under elevated temperature condition poor grain development in Pavon 76 compared to the other genotypes was contributed by the heat sensitiveness of grain filling and starch synthesis duration. High temperature enhanced the reduction in grain filling duration which ultimately resulted in smaller grains (Rahman *et al.* 2005).

Under open field temperature condition, Pavon 76 had the maximum number of grain per spike (56.38/spike) but under elevated temperature condition the highest grain number was observed in BARI Gom 26 (47.65/spike) (Fig. 5.A). Pavon 76 showed the maximum reduction (25%) in number of grain per spike (Fig. 5.B) due to completely failure of grain development for poor cell division and cell enlargement in grain under high temperature condition. Result indicated that Pavon 76 affected more than BARI Gom 25 and BARI Gom 26 in producing grain number per spike at high temperature inside the polythene chamber. Exposure to high temperature above 30°C during 10 to 14 days after anthesis have been reported to contribute to the reduction of grain number in wheat by affecting primarily cell division and subsequently cell enlargement (Gibson and Paulsen 1999). Significant reduction in grain number in different wheat cultivars under elevated temperature was also found by Viswanathan and Khanna-Chopra 2001; Sail *et al*. 2005; Tahir and Nakata 2005 and Wollenweber *et al*. 2003.

The maximum percent reduction of grain dry weight per main stem ear was observed in Pavon 76 (22%) where as 11% in BARI Gom 25 and 8% in BARI Gom 26 (Fig. 6.B). The result prevailed that Pavon 76 affected more than other BARI Gom cultivars in producing grain dry weight per main stem ear under elevated temperature condition which was contributed to the maximum reduction of 1000-grain weight and grain number per spike in Pavon 76. Increasing temperature (from 30 to 38°C), during reproductive phase, reduced the main stem grain weight by 20 to 44% (Tahir and Nakata 2005). A significant reduction in main stem grain weight difference in five wheat cultivars had been reported by Fokar *et al.* 1998b. However in present experiment, the reduction of main stem grain weight was 8 to 22 % by raising daily mean temperature from 23°C to 29°C during post anthesis period.

Under elevated temperature maximum grain yield observed in BARI Gom 26 which was followed by BARI Gom 25 and the lowest grain yield observed in Pavon 76 which was statistically different from other cultivars (Table 1). The maximum percent reduction in grain yield and biological yield were observed in Pavon 76 than those in BARI Gom cultivars (Fig.7).

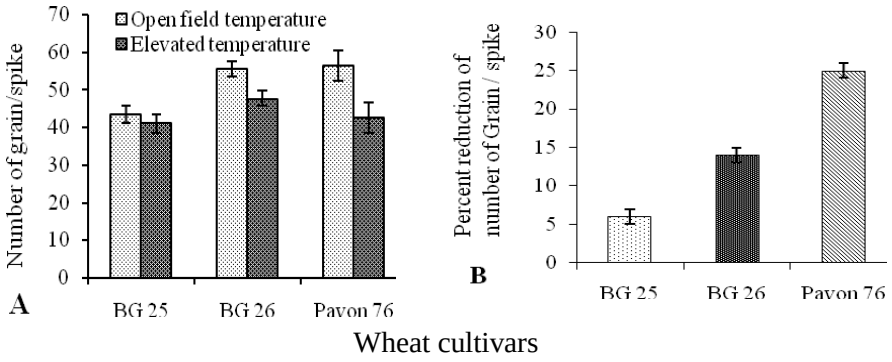

Fig. 5. (A) Number of grain per spike and (B) percent reduction of number of grain perspike of three wheat cultivars under open field and elevated temperature condition. Vertical lines are standard errors of mean data point.

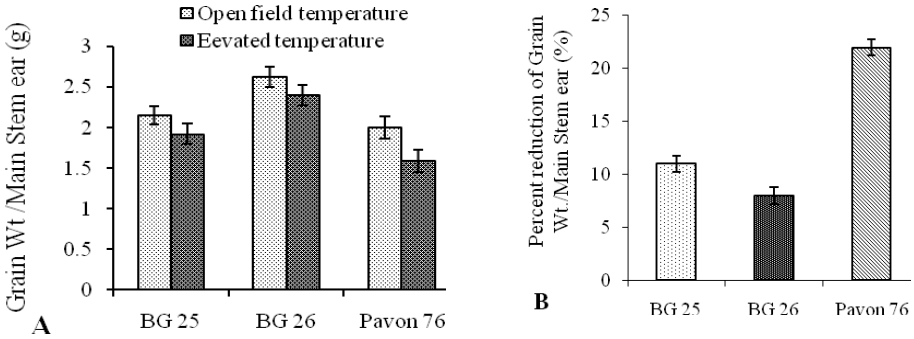

Fig. 6. (A) Grain dry weight per main stem ear and (B) percent reduction of grain dry weight per main stem ear of three wheat cultivars under open field and elevated temperature condition. Vertical lines are standard errors of mean data point.

Table 1. Grain yield, Biological yield and harvest index in three wheat cultivars under open field and elevated temperature condition

Cultivars	Grain yield (t/ha)		Biological yield (t/ha)		Harvest index (%)	
	Open field temp.	Elevated temp.	Open field temp.	Elevated temp.	Open field temp.	Elevated temp.
BARI Gom 25	4.59 ^{a}	4.15 ^{c}	10.30 ^{a}	9.42 ^{c}	48.15 ^{a}	44.09 ^{b}
BARI Gom 26	5.07 ^{a}	4.38 ^{b}	10.85 ^{a}	9.89 ^{bc}	46.77 ^{ab}	44.32 ^{b}
Pavon 76	4.38 ^{b}	3.39 ^{d}	9.92 ^{bc}	8.53 ^{d}	44.10 ^{b}	39.72 ^{c}

Values in a column with different letter are significantly different at P≤0.05 by DMRT.

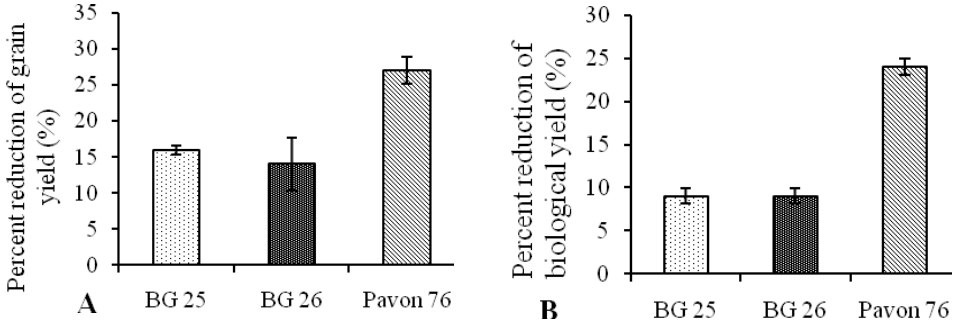

Fig. 7. (A) Percent reduction of grain yield and (B) biological yield of three wheat cultivars under open field and elevated temperature condition. Vertical lines are standard errors of mean data point.

Pavon 76 was affected more in grain yield and biological yield than BARI Gom 25 and BARI Gom 26 under elevated temperature condition due to maximum reduction in grain weight per main stem ear. Exposure to temperatures above 26°C this can significantly reduce grain yield (Mullarkey and Jones 2000; Sail *et al*. 2005; Tewolde *et al.* 2006). Significant variation in different wheat cultivars was also found by Hasan and Ahmed 2005.

Under elevated temperature the lowest harvest index was observed in Pavon 76 which was statistically lower than the other two wheat cultivars (Table 1). Harvest index decreased with an increase in mean temperature above 20°C applied 10 days after anthesis until ripeness (Gibson and Paulsen 1999).

Elevated temperature reduced grain filling and starch synthesis duration which contributed to the reduction of grain size and grain weight per main stem that finally contributed to the reduction of grain yield. The elevated temperature during post anthesis period had more effect in Pavon 76 in terms of grain filling and starch synthesis duration which contributed to sustained prominent loss of grain yield, biological yield and harvest index in Pavon 76. On the other hand the minimal effect of elevated temperature finally contributed to sustain negligible loss of grain yield, biological yield and harvest index in BARI Gom 25 and BARI Gom 26.

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EFFECT OF PHOSPHORUS IN REDUCING ARSENIC AVAILABILITY IN SOILS AND ARSENIC UPTAKE BY MAIZE

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SOHELA AKHTER[3] AND ROWSHAN ARA BEGUM[4]

Abstract

A pot experiment was carried out in the net house of Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur Gazipur on 16 March 2010 and 12 January 2011 with a view of study the effect of P addition to As-contaminated soils and the consequences on As uptake of maize (Zea mays L.) plants. Experiments were conducted in consecutive two years. Arsenic was added to the pots at the rates of 0, 20 and 30 mg kg^{-1}, and P at 0, 30 and 60 mg kg^{-1}. Thus there were seven treatment combinations, i.e., As_0P_0, $As_{20}P_0$, $As_{30}P_0$, $As_{20}P_{30}$, $As_{20}P_{60}$, $As_{30}P_{30}$, and $As_{30}P_{60}$. Phosphorus fertilization increased total As uptake, but the increase was restricted to the root. As concentration of root was much higher than that of shoot. As concentrations in shoot and root were positively correlated (r = 0.913, r = 0.975; P<0.01) in 2010 and 2011, respectively, and plant As was positively correlated to the plant P in shoot (r = 0.883 and 0.875; P<0.01) and in root (r = 0.829, P<0.05 and 0.917; P<0.01). The plants took up much greater amounts of P than As. Although it is well known that phosphate inhibits arsenate uptake (Wang et al., 2002), but it is highlighted the role of P fertilization to increase As uptake in maize plants. The results presented here indicate P supply may effect in higher As allocation to the plant parts, which has practical application in soil-crop systems. These findings could have important implications for human health and agricultural systems, since it may reduce As contamination through the consumption of crops (phytoextraction) grown on contaminated soils.

Keywords: Soil, arsenic, phosphorus, uptake, mize.

Introduction

There is increasing concern worldwide regarding the contamination of soil with arsenic (As), and the potential risk to human and environmental health arising from such contamination (Smith *et al*. 1998). Arsenic is a toxic and carcinogenic element that occurs widely in soil environments around the world. Soil contamination with As occurs through both natural and anthropogenic pathways. In recent years, As pollution has become a major public concern in many countries (Smith and Naidu, 1998). Remediation of As contaminated soil and

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water is necessary for protecting both human life and agricultural production. There are a variety of physical_chemical technologies for remediation of As-contaminated sites (U.S. Environmental Protection Agency, 1992.)

Arsenate, the dominant form of As in aerobic conditions, is taken up by plants via the phosphate transport systems because of the chemical similarity between arsenate and phosphate (Dixon, 1997). Phosphorus (P), that is a chemical analogue of As (Adriano, 2001) and competes with As in plant uptake (Meharg and Macnair, 1992). Thus, the relative plant As and P concentration and distribution determine the efficiency of As removal from the system (Santos *et al.* 2010). Since P and As are chemical analogues, it is important to examine both of them.

In fact, As is not an essential element for plants, but interferes with plant metabolism, inhibiting plant growth and crop yield (Abedin *et al*., 2002). The effect of P on the sorption/desorption of As in soil environments has received great attention, especially when P is used as a crop fertilizer (Peryea, 1998). Gultz *et al*. (2005) reported that P availability and P demand, which are plant specific, have to be taken in account to predict uptake of As by crop plants. Much of the research on As in grain crops have focused on rice (*Oryza sativa L*.) (Abedin *et al*., 2002; Williams *et al*. 2005; Rahman *et al*. 2007). The work that has been conducted on maize is less extensive, with limited information regarding As uptake and partitioning between different plant part. Therefore, it is important to evaluate the effects of P fertilizer applications on plant As accumulation; to quantify As concentration in root and shoot; and to evaluate the role of P and maize plant to mitigate As contamination.

Materials and Method

A pot experiment was carried out in the net house of Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur Gazipur on 16 March 2010 and 12 January 2011 with a view of study the effect of P addition to As-contaminated soils and the consequences on As uptake of maize plants. The sandy clay loam soil was used in pot. The physical and chemical properties of the initial soil which was used in pot are presented in Table-1.

Experiments were conducted in consecutive two years. The experiment consisted of a total of 21 plastic pots, each containing 10 kg soil. Maize (*Zea mays* var. BARI hybrid Maize-7) seeds were sown directly in pots at a density of 6 seeds per pot. Fourteen days after sowing the seedlings were thinned to 2 plants per pot. All the pots were fertilized two days before sowing with N: 90 mg kg^{-1} soil, K: 140 mg kg^{-1} soil, S: 30 mg kg^{-1} soil, Zn: 2 mg kg^{-1} soil, B: 1 mg kg^{-1} soil. Urea, MoP, gypsum, zinc sulphate monohydrate ($ZnSO_4$. H_2O) and boric acid were used as a source of N, K, S, Zn and B, respectively. Arsenic was added to the pots at the rates of 0, 20 and 30 mg kg^{-1}, and P at 0, 30 and 60 mg kg^{-1}. Thus

Table 1. Initial properties of the soil samples used in potting media

Soil Properties	Texture	pH	OM %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn	As
				meq $100g^{-1}$				mg kg^{-1}						
Result	Sandy clay loam	7.6	0.51	10.4	2.85	0.07	0.03	17.5	12	0.33	1.6	113	0.90	2.2
Critical level	-	-	-	2.0	0.8	0.20	-	14	14	0.20	1	10	2.0	20[§]

ASI method (Hunter,1984); [§]Maximum acceptable limit for agricultural soil (20.0 mg kg^{-1}) recommended by the European Union.

there were seven treatment combinations, i.e., As_0P_0, $As_{20}P_0$, $As_{30}P_0$, $As_{20}P_{30}$, $As_{20}P_{60}$, $As_{30}P_{30}$, and $As_{30}P_{60}$, in three replications. Arsenic and P were added as As_2O_3 and $Ca(H_2PO_4)_2$, respectively, in solutions. Doses of fertilizer elements were determined as per the Fertilizer Recommendation Guide (BARC 2005). All fertilizers were added as solutions and thoroughly mixed with the soil. Nitrogen was applied in two equal splits, the first split before sowing and the remaining splits at 8-10 leaf of plants after sowing. Soil moisture was maintained by periodically adding equal quantity of water in each plastic pot.

The crop was harvested at 60 and 80 days following seeding for 2010 and 2011, respectively, when it had attained reproductive maturity (before flowering). Soil was removed from the roots by careful and repeated washing in water. Shoots and roots were washed with tap water and then rinsed twice with deionized water. Arsenic and P concentrations were measured in the roots and shoots samples.

Preparation and preservation

After delivery to the laboratory, all samples were washed in fresh running water to eliminate dust, dirt, possible parasites or their eggs and then were again washed with deionized water. The clean samples were air-dried and placed in an electric oven at 65 °C for 72–96 h depending on the sample size. The dry samples were homogenized by grinding using a ceramic coated grinder. The final samples were kept in labeled polypropylene containers at ambient temperature before analysis.

Digestion and determination of phosphorus

One gram of dry matter was weighed into 50 ml beakers, followed by an addition of 10 ml mixture of analytical grade acids HNO_3: $HCIO_4$ in the ratio of 5:1. The digestion was performed at a temperature of about 190 ºC for 1.5 h. After cooling, the solution was made up to a final volume (30 ml) with distilled water in a volumetric flask. Phosphorus was measured calorimetrically by ascorbic acid method using a Varian spectrophotometer. Analysis of each sample (on a dry matter basis) was carried out three times to obtain representative results.

Digestion and determination of Arsenic

The total plant As concentration was determined digesting the plant sample (1 g) with concentrate HNO_3 and 2 hours after cooling 2 ml of H_2O_2 was added in the solution. Total As concentration of extract was determined by hydride generation- using a VARIAN model AA2407 Atomic Absorption Spectrophotometer (AAS). Analysis of each sample was carried out three times to obtain representative results and the data are reported in mg kg^{-1} (on a dry matter basis).

Statistical analysis

The experiment was designed in completely randomized (CRD) with 7 treatments and three replications. Treatment effects were determined by analysis of variance with the help of statistical package MSTAT-C and mean separation was tested by Duncan's Multiple Range Test (DMRT). Linear correlation coefficients were also computed for various parameters using Microsoft Excel.

Results and Discussion

Despite the effect of P the As concentrations of shoot and root of maize increased with increasing As addition to soil (Figures-1 and 2). In both the year 2010 and 2011, the lowest As concentration was observed with the As_0P_0 treatment and the highest As concentration with the $As_{30}P_{60}$ treatment which was identical with $As_{30}P_{30}$. Arsenic concentration of root was much higher than that of shoot.

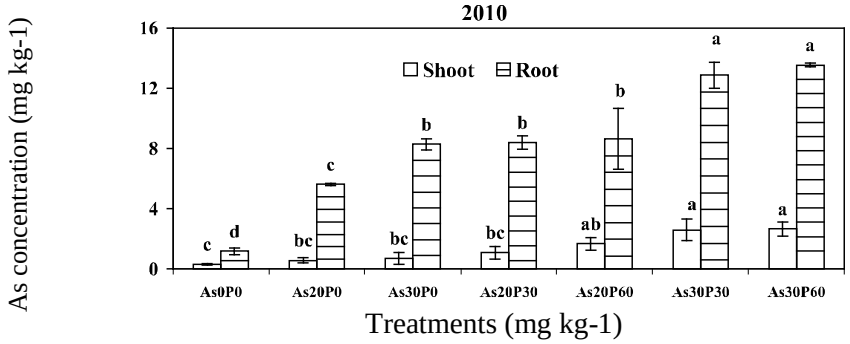

Fig. 1. Total As concentration in roots and shoots of maize under different As and P application in soil - 2010.

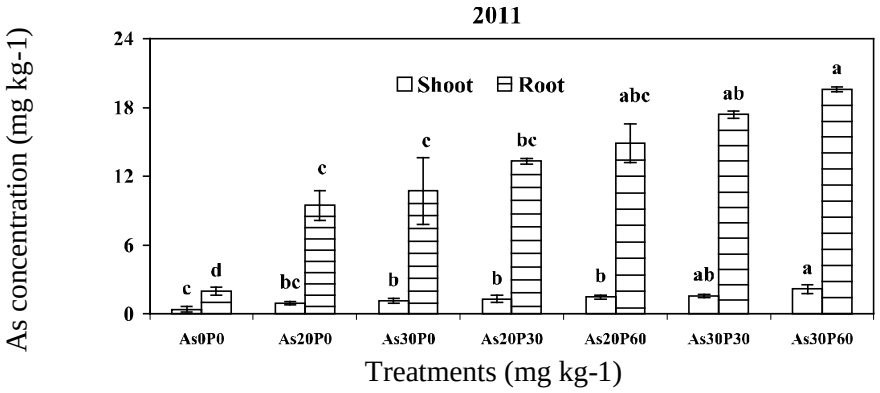

Fig. 2. Total As concentration in roots and shoots of maize under different As and P application in soil - 2011.

The treatment column in specific line item with the same letter is not significant different ($P<0.01$) by DMRT.

Comparatively P concentration of shoot was higher than that of root. Phosphorus containing treatments showed significantly higher P concentrations than that of without P in both shoots and roots (Figures-3 and 4). Contrary to normal understanding that increasing P supply could reduced As accumulation in plants, results from the present study showed that P fertilization did not inhibit the As uptake by plants (As accumulation in root and shoot). The effect of applied P was the opposite, the higher As concentrations in both shoot and root was observed in P treatments (AsP_{30} and AsP_{60}). Similar result was observed by Hossain *et al.* (2009). In contrast, the highest shoot As concentration (2.45 mg kg^{-1}) was measured in the plants grown in As contaminated soil in the absence of P fertilization reported by Pigna *et al.* (2010). To alleviate As toxicity, plants must take up sufficient amount of P to balance excessive As. Thus, as plant As increases, the plants react by increasing P accumulation (Burlo *et al.* 1999).

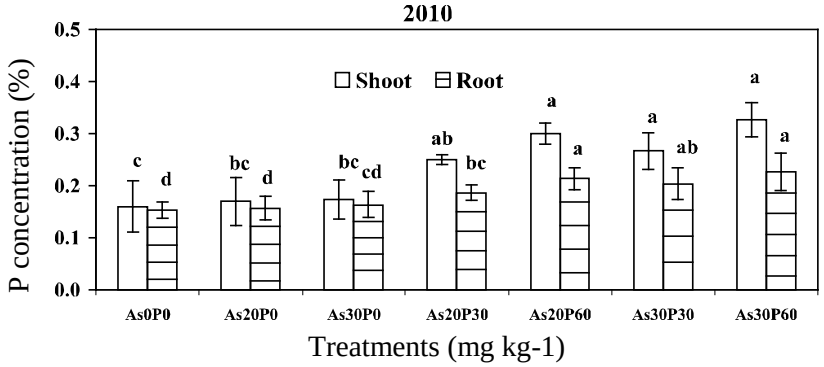

Fig. 3. Total P concentration in roots and shoots of maize under different As and P application in soil - 2010.

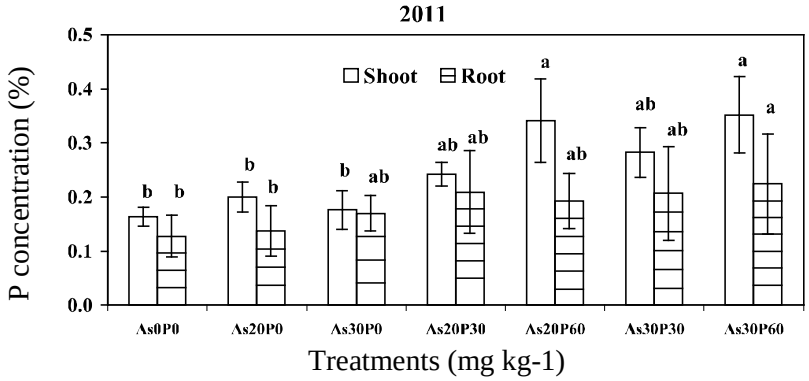

Fig. 4. Total P concentration in roots and shoots of maize under different As and P application in soil - 2011.

The treatment column in specific line item with the same letter is not significant different ($P<0.01$) by DMRT.

The As concentrations in shoot and root and P concentration in shoot and root were positively correlated (r = 0.913, P<0.01; r = 0.975, P<0.01) and (r = 0.994, P<0.01; r = 0.800, P<0.05) in 2010 and 2011, respectively (Figures-5 and 6). As expected, in this study both the year 2010 and 2011 plant As was positively correlated to the plant P in shoot (r = 0.883 and r = 0.875; P<0.01) and in root (r = 0.829, P<0.05 and r = 0.917; P<0.01) (Figure-7a, 7b and 8a, 8b) and the plants took up much greater amounts of P than As (P in % × 10000 = P in mg kg^{-1}). Our results are in agreement with those reported in previous studies (Cao and Ma, 2004).

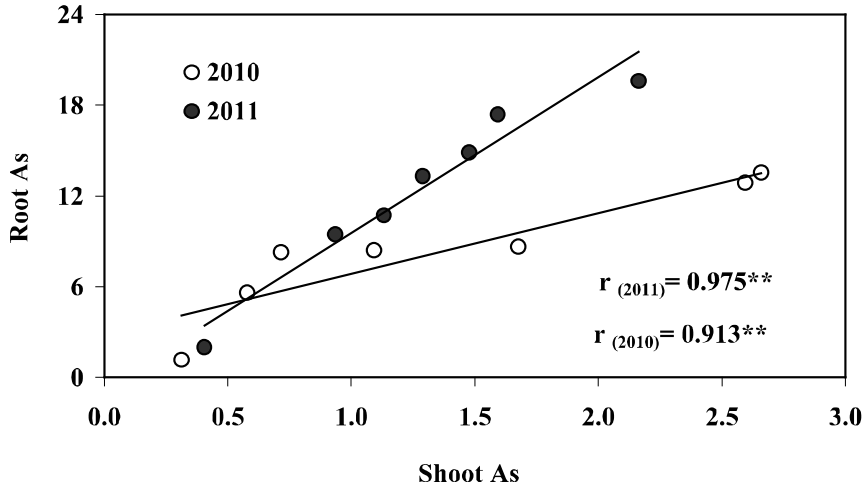

Fig. 5. Correlation of As concentration (mg kg-1) between roots and shoots of Maize.

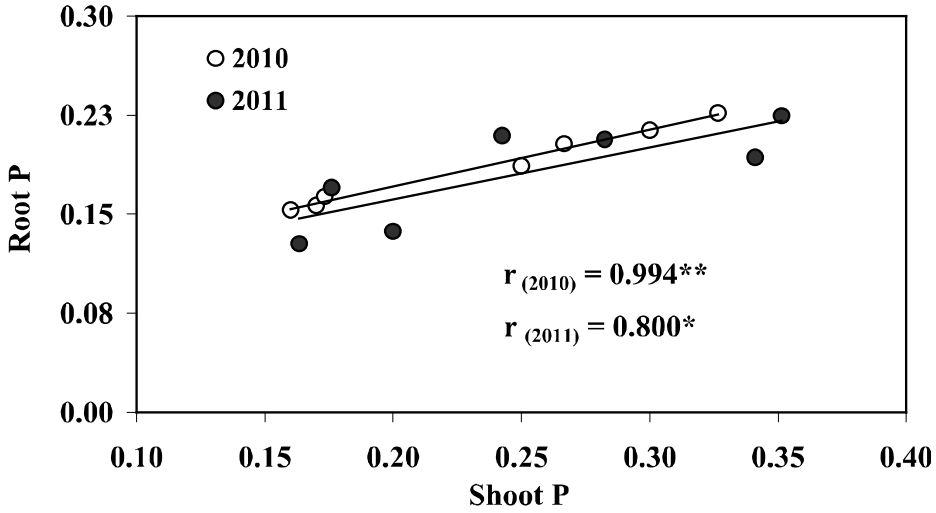

Fig. 6. Correlation of P concentration (%) between roots and shoots of Maize.

Phosphorus addition (P_{30}) to As concentration increased in maize plants was 40 - 54% and 29 - 37%, respectively in 2010 and 2011. Where as it was 50 – 55% and 37 – 47%, for phosphorus addition (P_{60}), respectively in 2010 and 2011. Cao and Ma (2004) reported that addition of P to soils increased As accumulation by 4.56-9.3 times for carrot and 2.45-10.1 for lettuce plant.

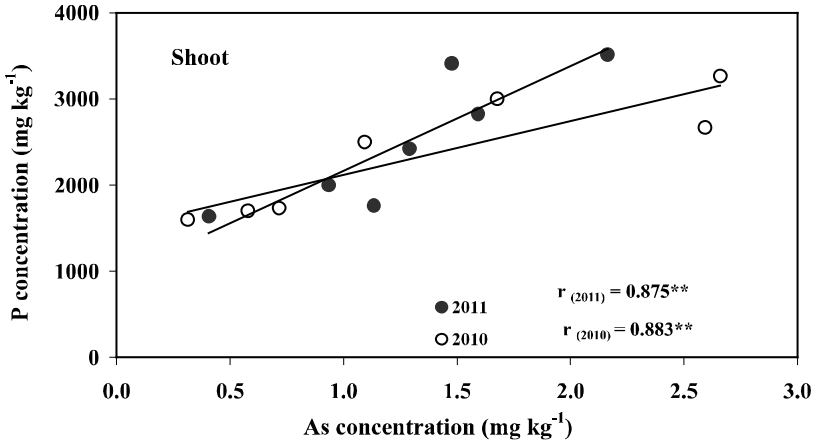

Fig. 7. Correlation between As and P concentration in shoot of maize.

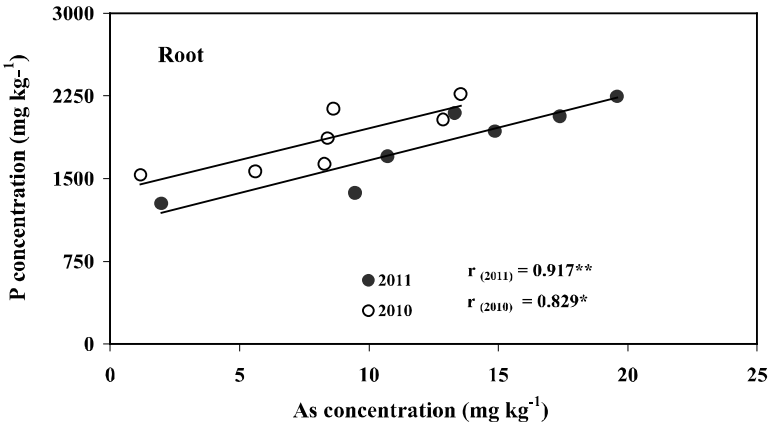

Fig. 8. Correlation between As and P concentration in root of maize.

Figures 1 and 2 show the As partitioning in maize plant tissues for 2010 and 2011. In –P plants for the highest As concentration in As_{30} treatment was found to be 92% in root and 8% in shoot; whereas in +P plants, at the same As concentration, 84% was in the root and 16% in shoot. For the year 2011 it was 90% and 10% in root and shoot, respectively both in –P and +P plants. Results indicate that regardless P treatment, most of As accumulated in maize plant tissues, remains in root and the smallest amount in the shoot. In fact, P fertilization increased total As uptake, but the increase was restricted to the root.

Similar result was observed by (Pigna *et al*. 2009). In wheat plants, Pigna *et al*. (2009) also observed that a very large amount of As (72%) retained in root compared to its content (28%) in shoot (straw and grain). Moreover, Abedin *et al*. (2002) also observed that a very large amount of As retained in root compared to its content in straw and grain. Other literature studies (Rahman *et al*. 2007) also reported similar results.

Arsenic exists in the environment in both inorganic and organic forms, and both arsenite (III) and arsenate (V) are often found in both anaerobic and aerobic soil environments (Liu *et al*., 2004). Although it is well known that phosphate inhibits arsenate uptake (Wang *et al.* 2002), this was not the case for this work. In the experiments showed, it is highlighted the role of P fertilization to increase As uptake in maize plants. Phosphate can decrease or increase the uptake of As by plants, depending on the speciation of As, the species of plant and the plant growth medium (Tsutsumi, 1980; Otte *et al*. 1990). Moreover, phosphate addition to arsenic-contaminated soils would enhance arsenic release from soil through competitive exchange (Smith *et al.* 2002), thereby increasing soil As availability (Peryea and Kammereck, 1997). Arsenic phytoavailability primarily depends on soil properties. Iron and aluminum oxides adsorb As species in acidic soils, whereas calcium oxides adsorb As species in alkaline soils (Wauchope and McDowell, 1984). However, the quantitative relationships between P nutrition, and As accumulation both arsenite and arsenate in maize plants remain unclear, and further investigation is warranted.

Conclusion

Phosphorus fertilization increased total As uptake in maize plant, but the increase was restricted to the root. The results presented here indicate P supply may effect in higher As allocation to the plant parts, which has practical application in soil-crop systems (Pigna *et al.*, 2010). These findings could have important implications for human health and agricultural systems, since it may reduce As contamination through the consumption of crops grown on contaminated soils. Maize (*Zea mays* L.) is a widely grown staple cereal with promising attributes of the potential for accumulating toxic heavy metals and metalloids like As. The potential use of this robust tropical crop in phytoextraction technology is advocated especially for environmental restoration.

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EFFICACY OF FUNGICIDES TO CONTROL *STEMPHYLIUM* BLIGHT (*STEMPHYLIUM BOTRYOSUM*) OF LENTIL

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Abstract

A field experiment was carried out during Rabi seasons of 2011-12 and 2012-13 to evaluate the efficacy of fungicides in controlling *Stemphylium* blight (*S. botryosum*) of lentil. Five fungicides were evaluated under higher disease pressure (10^6 ml^{-1}) of *Stemphylium* blight. Results revealed that Foliar spray (4 sequences) with Rovral 50WP (Iprodione) @ (0.2%) and Secure 600WG (Fenamidione+Mancozeb) @ (0.2%) at an interval of 7 days effectively controlled the disease and increased yield of lentil by 31.99% and 28.20%, respectively. The fungicides may be selected for control of the disease.

Keywords: Efficacy, *Stemphylium* Blight, Fungicide, Lentil.

Introduction

Lentil (*Lens culinaris* Medik) is the second most important pulse crop in terms of both area and production (Anon., 2014). The crop is vulnerable to many diseases. At least 15 pathogens causing 17 diseases of lentil have been recorded in Bangladesh (Ahmed, 1986). Among the diseases, *Stemphylium* blight (*S. botryosum* Wallroth) is a major one in Bangladesh (Bakr and Zahid, 1986). Generally, it appears at flowering stage of the crop. Relatively high temperature (around 21°C) and high humidity (90%) enhance the disease development. Control of plant diseases becomes successful and economical when management approach contains several methods including chemical means (Bakr and Ahmed, 1992), cultural practices (Howlider *et al.,* 1989, Rahman *et al.,* 1988) and use of resistant varieties (Ahmed, 1986). Use of fungicide is the most dependable method to control plant diseases. Therefore, the present experiment was conducted to test five fungicides to control *Stemphylium* blight of lentil.

Materials and Method

The fungicides tested in the present experiment were Rovral 50WP (Iprodione), Secure 600 WG (Fenamidione+Mancozeb), Companion, Indofil-45 (Mancozeb) and Nativo 75WG (Tebuconazole+Trifloxystobin). All fungicides were applied as foliar spray at 0.2% suspension in plain water. The experiment was laid out in randomized complete block design with three replications. The unit plot size was 3 m×4 m. Seeds of lentil variety BARI Masur-1 susceptible to *Stemphylium* blight were sown in continuous rows maintaining of 30 cm×5 cm row to row

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spacing on 23 November, 2011 and 19 November, 2012. Intercultural operations were done whenever necessary. The experiment was visited regularly to observe the onset of the disease. Spraying of fungicides was started when the disease appeared on the crop. Four sprays were applied on 8, 15, 22 and 27 January, 2012 and 3, 10, 17 and 24 January, 2013. Data on severity of *Stemphylium* blight disease were recorded on 18, 25 and 30 January in 2012 and 13, 20 and 27 January in 2013. The disease severity was indexed on a 0-10 disease scoring scale (Hashemi *et al.*, 2005) where, 0= Healthy plant; free of disease, 1= Dull leaves or few tiny tan spots, 2= A few small to large chlorotic spots, 3= Expanding lesions on leaves and leaf drop starting, 4=20% nodes on main stem showing chlorotic/necrotic symptoms and/or leaf drop, 5=40% nodes on main stem showing chlorotic/necrotic symptoms and/or leaf drop, 6= 60% nodes on main stem showing chlorotic/necrotic symptoms and/or leaf drop, 7= 80% nodes on main and lateral stems showing chlorotic/necrotic symptoms and leaf drop, 8= 100% leaves dried up/defoliated but small green tip recovering, 9= 100% leaves dried up/defoliated including tip but stem still green, and 10= Whole plant die and completely dried up. The crops were harvested at full matured stage. Data on yield and other characters were recorded from 10 randomly selected plants in each plot. The crop was harvested on 9-13 March in 2012 and 8-10 March in 2013. Grain yield were determined based on the whole plot and expressed in kilogram per hectare. The recorded data were analyzed statistically. Means of treatments were compared following Least Significance Difference (LSD) test.

Results and Discussion

In 2011-2012 crop season, ranges in severity of *Stemphylium* blight, plant height, number of pod per plant and yield were 2.16-3.83, 24.33-30.87 cm, 25.27-33.13 and 673.30-986.90 kg/ha, respectively under various treatments including control. The highest disease severity was recorded from control. Treatments with different fungicides reduced disease severity by 8.62-43.60%. The lowest reduction was obtained with Nativo followed by Companion and Indofil. The disease severity under Indofil and Secure was 26.11%. The maximum and significant reduction was achieved with only Rovral compared to control. The lowest plant height of 24.33 cm was recorded from control and the treatment with Companion, which was statistically similar to the plant height observed under Indofil. Two fungicides, Secure and Nativo gave the maximum plant height of 30.87 cm, which was statistically similar to the plant height recorded from Rovral treatment but significantly higher compared to other fungicides and the control. The lowest pod number was found under control which was statistically similar to the pod number recorded from Indofil and Companion. Other fungicides increased pod number significantly over control. The highest pod number was achieved with Secure followed by Nativo and Rovral. Effect of latter three fungicides on pod number was statistically similar. The lowest yield of lentil

grain was recorded from control. All treatments with fungicides increased the yield significantly over control. The highest increase was achieved with Secure followed by Rovral and Nativo. The effect of three fungicides on yield was significantly different (Table 1).

Table 1. Efficacy of fungicides in controlling *Stemphylium* blight (*S. botryosum*) of lentil during rabi, 2011-2012 at RPRS, Madaripur

Fungicides with concentration	*Stemphylium* blight severity (0-10 scale)	Plant height (cm)	No. of pod /plant	Yield (kg/ha)
Rovral 50WP(Iprodione) 2%	2.16 b (43.60)	28.20abc	30.27ab	986.90b (31.77)
Secure 600WG (Fenmidione+Mancozeb) 2%	2.83 ab (26.11)	30.87a	33.13a	1083.00a (37.83)
Companion 2%	3.16 ab (17.49)	24.33d	27.47b	823.30cd (18.21)
Indofil-45 (Mancozeb) 2%	2.83 ab (26.11)	26.33cd	26.00b	750.00d (11.40)
Nativo 75WG (Tebuconazole+Trifloxystobin) 2%	3.50 a (8.62)	30.87a	30.47ab	885.00c (23.92)
Control (Plain water)	3.83 a	24.33d	25.27b	673.30e

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

Values within the parentheses are percent decrease of disease over control and percent increase of yield over control.

During 2012-2013 lentil growing season, ranges in severity of *Stemphylium* blight, plant height, number of pod per plant and yield ranged 2.00-4.16, 22.84-28.17 cm, 26.04-40.06 and 968.00-1428.00 kg/ha, respectively under various treatments including control. The highest severity of *Stemphylium* blight was found under control, which was statistically similar to the treatments with Nativo and Companion. Other fungicides significantly reduce disease severity over control. The highest reduction was obtained with Rovral followed by Secure as well as Indofil. All fungicides increased plant height and pod yield per plant compared to control. However, significant increase in these parameters was achieved with only Nativo, Secure and Rovral. Effectiveness of three fungicides on plant height and pod number was statistically similar (Table 2).

Table 2. Efficacy of fungicides in controlling *Stemphylium* blight (*S. botryosum*) of lentil during rabi, 2012-2013 at RPRS, Madaripur.

Fungicides with concentration	*Stemphylium* Blight severity (0-10 scale)	Plant height (cm)	No. of pods/plant	Yield (kg/ha)
Rovral 50WP(Iprodione) 2%	2.00 d (51.92)	28.17 a	40.06 a	1428.00 a (32.21)
Secure 600WG (Fenmidione+Mancozeb) 2%	3.00 d (27.88)	26.21 b	33.02 ac	1189.00 b (18.58)
Companion 2%	4.00 a (3.85)	25.34 ab	31.55 bc	1097.00 bc (11.75)
Indofil-45 (Mancozeb) 2%	3.00 b (27.88)	27.45 a	35.09 ab	1254.00 ab (22.71)
Nativo 75WG (Tebuconazole+Trifloxystobin) 2%	3.83 ab (7.93)	28.13 a	38.88 ab	1259.00ab (23.11)
Control (Plain water)	4.16 a	22.84 b	26.04 c	968.00 c

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

Values within the parentheses are percent decrease of disease and percent increase of yield over control.

Results of the present investigation revealed that foliar spray with 0.20% suspension of all the tested fungicides reduced the disease severity and increased plant growth parameters and yield of lentil compared to control. Among five fungicides, Rovral, Indofil and Nativo showed better performance than other three in both test seasons. Similar findings had been recorded by many researchers. Bakr and Ahmed (1992) reported that disease score was the lowest whereas yield was the highest in plots treated with Rovral 50WP @ 0.2%. Sardar (2005) also reported that the lowest disease severity was obtained from the Rovral 50WP and Tilt 250EC treated plots. So, the findings of the present investigation are comparable with the findings of the previous researchers.

Conclusion

Based on findings of the present study, it may be concluded that four times foliar spray with Rovral 50WP (Iprodione) or Secure 600WG (Fenamidione + Mancozeb) at an interval of 7 days may be recommended to control of *Stemphylium* blight of lentil.

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STATUS OF CONSERVATION AGRICULTURE BASED TILLAGE TECHNOLOGY FOR CROP PRODUCTION IN BANGLADESH

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Abstract

Conservation agriculture (CA) based tillage technology permits direct seeding through the moderate level of crop residue. CIMMYT introduced this technology in the farmers' field of Bangladesh for wheat crop in collaboration with Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI). Farmers accept CA based tillage technologies considering the advantages of higher yields, reduced cost of tillage operation, and minimum turn around time between the crops. Up land crops are more suitable under these tillage technologies. Weed management in rice cultivation is not yet in a good shape. Most of the tillage implements are operated by imported Chinese two wheel tractor (power tiller). There are few four wheel tractor CA implement using in research farm. Local manufacturers are being fabricated these cost effective small minimum tillage seed drill, raised bed planter, zero till drill, and strip till drills efficiently in different districts of Bangladesh. Farmers accept CA technologies in their field, especially raised bed planting and minimum tillage technology. There are about 425 numbers of raised bed planters and 865 minimum tillage seed drill in the country. Area coverage under bed planting and minimum tillage system are 5764 ha and 21850 ha, respectively. There are 20125 numbers of farmers involved in raised bed farming. There is a big prospect accelerating the CA based tillage technology in the farmers' field as irrigation water availability becoming limited or more costly. Mind set up is the big issue for adopting CA tillage technology. Training and multi disciplinary approaches can push forward these tillage technologies ahead.

Keywords: Conservation agriculture, zero tillage, minimum tillage, strip tillage, bed planting

Introduction

Conservation agriculture (CA) based tillage technology permits direct seeding in untilled soil with moderate level of crop residue. It is defined as the combination of three major farming principles for successful crop production with the latest technologies -less soil disturbance, crop residue management, and following beneficial crops rotation (Hobbs *et al*., 2008). Conservation agriculture is a win-win approach that reduces operational costs, including machinery, labour, fuel while increasing yields and better utilize natural resources (Roy *et al*., 2009). In

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greater sense, resources are time, energy, money, soil, water etc. CA aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource efficient or resource effective agriculture (FAO web site).

Generally farmers grow rice in puddled land by manual transplanting and wheat is cultivated after *T. aman* with 3-4 numbers of ploughing and hand broadcasting seeds. This system is time consuming and costly operation. There are about 70% wheat area planted late due to lack of adoption of advanced technologies and awareness (Hossain *et al*., 2012). Research reports available in Bangladesh (Barma *et al*., 2014) revealed that wheat, maize, pulses, oilseeds, jute, rice can be established and grown successfully through CA technology. There are about 700,000 two wheel tractor (power tiller) in the country (Satter Mondal, 2013). Two wheel tractor operated CA based tillage technology has been developed by different organizations and promotional activities are being conducted in the farmer's field of Bangladesh for yield gap minimization, water saving, efficient input utilization, soil health improvement and sustainable crop production and crops diversification (Hossain *et al*., 2014). The Government organization, non government organizations, agricultural research institutes, donar funded agencies are trying to increase more area coverage and involve more number of farmers in CA system. CA technologies especially zero tillage and strip tillage technologies are more viable in drought stress areas where seeding operation and initial plants establishment can be done utilizing the residual soil moisture available immediate after monsoon rice harvest (Bell and Johansen, 2009). Similarly, raised bed technology with crop residue management can mitigate soil salinity some extend for better crop establishment in Southern saline problem area of Bangladesh. Machinery manufacturers are fabricating tillage implements in different locations of the country. Local machinery service providers are making business in the farmers' field as custom hire basis but the numbers of these service providers are not adequate (Hossain *et al*., 2014). There are huge demands of these services. Agri business started among the farming community. But, there are lacks of information related to CA implements availability, technology adoption, constraints, crop and crop production under CA system. Therefore, this study has been under taken to summarize the status of CA based tillage technology available for crops production within the country.

Objectives: The main objectives of this study are

i. to summarize the present status of conservation agriculture based tillage technologies available in Bangladesh
ii. to find out the adoption status of these technologies for crops production

Materials and Method

The study was conducted in those areas where the CA based tillage technology of crop production was dominant such as Dinajpur, Jamalpur, Jessore, Pabna, Faridpur and Rajshahi regions. Conservation agriculture based tillage implements are available in Bangladesh and these are mostly operated by two wheel tractor imported from China. There are few imported four wheel tractor driven CA implements which are mainly used in research purposes in limited areas. There are considerable numbers of machinery manufacturers now making CA based tillage implements and spare parts in different locations of the country. The CA related information was collected from machinery manufacturers, local service providers, lead farmers, agricultural department, and machinery traders from different corners of Bangladesh. There is no established section or department with the name of conservation agriculture in the country. Personal communication was applied most of the cases for collecting the data especially number of implement, number of CA adopted farmers, area coverage.

CA implements are being used in the farmers' field of North West part, central part and Southern part of Bangladesh. Priority crops are wheat, maize and pulses. Cornell University, CIMMYT, ACIAR-SRFSI, CSISA (Cereal System Initiative in South Asia) project, DAE are now promoting CA tillage technology. NGOs (RDRS, IDE, PROVA, CARITAS, farmers field school, farmer club) are also involved expanding these works in the farmers field.

Followings are the common CA based tillage equipments which are now using in the farmers field. 1. Minimum tillage seed drill 2. Strip tillage seed drill 3. Zero tillage seed drill and 4. Raised bed planter.

Fig. 1. Two wheel tractor operated seeder.

1. Minimum tillage seed drill

The minimum tillage seed drill is operated by two wheel tractor (9 kW) and it is commonly known as power tiller operated seeder (PTOS) among the farming community. The seeding part of this drill needs to hitch with power tiller drawbar point through nuts and bolts replacing the tilling part. In the standard commercially available arrangement this seed drill is set up for one pass seeding with full rotary tillage. The seed box is set up above the tillage unit, and the seed delivered by tubes and lightweight soil openers to the

soil immediately behind the tilled zone. A steel made long press roller then lightly firms the soil behind the seed drill. There is no fertilizer box in the original seeder unit. But, recently inclined plate seed meter was introduced and make a separate seed box with it. Now, seed and fertilizer can be applied with separate delivery tubes as per requirement. Improved furrow opener has been introduced which is capable placing seeds and fertilizer side by side, not in a mixing form. Before start seeding operation, mixed basal doses fertilizers are broadcasted over the soil surface. The minimum tillage seed drill comprises four operations – shallow tilling with high speed (450-500 rpm) of tilling blades, seeding in lines, seed covering with minimal press and land leveling (Fig.1). Most of the seeds (wheat, lentil, mungbean, maize, rice, chickpea, groundnut, jute) can be sown by the same seed drill with small changes such as for jute seeding mix rice husk with seed 4:1 proportion. The effective field capacity of the drill is 0.15 ha/h (Hossain *et al*., 2009a). Limitations of this technology are high price of the seeder and trained operator needed for effectively using the seeder.

2. Strip tillage seed drill

Strip tillage seed drill is one step ahead of minimum tillage seed drill in terms of soil disturbance and crop residue management. It is also operated by two wheel tractor and hitched similarly as a minimum tillage drill. Strip tillage seed drill performs as- strip tilling with high speed rotating blades, seed and fertilizer placed side by side and soil compaction over seeds with press wheel. The space between the tilled rows remains untilled. Fertilizer application is done by a separate operation, and fertilizer positioned besides the seed rows. Improved "T" type furrow opener has been introduced which is capable placing seeds and fertilizer side by side, not in a mixing form. The depth of seeding is adjustable according to the status of soil behavior and moisture condition.

Fig. 2. Two wheel tractor operated strip till seeder

Fig. 2 shows the rotary strip till drill. Strip till perform works through crop residue without plugging. Fot strip- tillage, generally four blades are used on the rotor shaft per line furrow making by the strip till equipment for minimizing the torque requirement and torque variation on the rotor shaft (Lee et al.,2003). The left bent and right bent blades are set facing towards the furrow centre. The average speeds of rotating blades are 400-450 rpm.

The high speed rotation of the blades cut the previous crop residue and create the strip for seed and fertilizer placement. The average width of the furrow strip is 40-60 mm which is sufficient for placement of seed and fertilizers. The width of strip also depends on the specific requirement of the crops. Effective field capacity of the drill increased by 19% and fuel consumption reduced by 21% compared to traditional ploughing and manual broadcasting system (Hossain et al., 2012). Limitations of this technology are trained operator needed for effectively using the seeder. Recently operator's seat introduced with the strip till drill which facilitates long distance travel and more comfortably use.

3. Zero till drill

This is a pull type seeding implement and works as seeding and fertilizing at a time. Generally, granular type fertilizer like- Triple Super Phospate (TSP), DAP (Di Amonium Phosphate) are used in this system. This no till drill capable seeding operation through moderately dense (0.2-0.4 t/ha) crop residue field. A set of press wheel was attached with toolbar frame for closing the seeding furrow. The planter was capable to apply seed and fertilizer in a narrow (30-35 mm) opening slit at one operation. The planting depth and seed rate can be adjusted depending on crop standard. The inclined plate seed meter is used for metering seeds and flute type meter is used for metering fertilizers. The furrow opener of zero till drill is made with the used car leaf spring which is more strong, lighter in weight and more durable. Before seeding, round up herbicide applied for killing existing weeds. Fertilizer management and weed control was the key issue for adopting this new technology. Wheat, mungbean and maize were planted by the zero till drill in Rice-Wheat cropping system. Zero till wheat was less lodge compare to conventional planted wheat. The zero till drill can pull 4 tynes in soft and medium soil but 3 tynes for hard soil. Round up herbicide was applied to kill the weeds before seeding operation. Loose crop residue some times create problem but generally it does not happened in manually harvested fields. Zero-till farmers saved plant establishment cost 40-65% minimizing the average turn around time 9-10 days between the two crops. The effective field capacity of the no till drill was 0.15 ha/h (Hossain *et al*., 2009b). This drill enables farmers to sow seeds

Fig. 3. Two wheel tractor operated zero till drill.

when soil moisture and optimum planting time is critical. This drill is structurally improved, lighter in weight and more versatile for different adjustment. Herbicide use and additional learning is more in this technology compare to conventional method.

4. Raised bed planter

Fig. 4. Two wheel tractor operated bed planter.

Bed planter is a seeding implement which works as a formation of bed, fertilizing and seeding on the top of the bed at a time (Fig.4) maintaining the recommended agronomic practices. It is a pull type unit which attached with a power tiller replacing the rotary part of the tiller. The functional part of the bed planter are (i) toolbar frame (ii) furrow opener (iii) seed box with metering unit (iv) bed shaper (v) chain and sprocket for power transmission. It is required pre tilled soil for bed formation. Wheat, maize, mungeban, lentil, rice can be grown successfully on bed. Cornell University, Food for progress project (Hossain *et al*., 2014) finds out the following advantages- (i) Easy irrigation water application and less amount of water requirement (ii) Keeping bed permanent, crop grown without ploughing (iii) Higher yield compare to conventional system (iv) Minimum rat damage of crop (v) Easy intercultural operation. (vi) Less amount fertilizer requirement (vii) Less arsenic contamination in cereal gain.

The inclined plate seed meter is used for metering seeds and flute type meter is used for metering fertilizers. WRC and FMPE Division, BARI also developed rotary blade type bed planter which can form bed in untilled soil. It is also further improved introducing with fertilizer attachment and replacing seed metering mechanism. Bed planting systems are more popular in Rajshahi area. Farmers accept this technology and service providers started commercial business with this implement. Crop establishment difference between CA system and conventional system are shown in Table 1.

Table 1. Crop establishment differences between conservation agriculture system and conventional method.

Sl No.	Performance parameter	CA tillage system	Conventional system
1	Crop establishment	One pass direct seeding	Land prepared by 3-4 passes. Manual broadcasting
2	Seed rate	Optimum	More than recommended
3	Depth of planting	Uniform	Uneven
4	Irrigation water	Less water	Comparatively more
5	weeding	Comparatively easy	Difficult to control
6	Fertilizer application	During seeding operation	During land preparation and top dress application (2/3 split)
7	Turn around time	Minimum	7-9 days required from first ploughing to seeding

Results and Discussion

Conservation agriculture based tillage works progress

In Bangladesh, conservation agriculture based tillage technology was first introduced by CIMMYT-Bangladesh in the farmers field with wheat crops late 90's with minimum tillage technology by two wheel tractor (power tiller) operated seeder (Amin *et al*., 2002). CIMMYT-Bangladesh also conducted limited number of strip tillage technology trials during that period through Wheat Research Centre, BARI in Northern Bangladesh. In the mean time, toolbar attached raised bed planter was developed in WRC- BARI (2002) and it was successfully demonstrated for wheat, maize, mungbean, and rice cultivation. Food and Agriculture Organization (FAO, Rawson *et al.*, 2007) formed a two years project (2003-04) for intensification of wheat and wheat based cropping system through CA based tillage technology in four greater districts of Bangladesh (Dinajpur, Rajshahi, Jessore and Jamalpur) through WRC-BARI collaboration. Under FAO project two wheel tractor attached pull type zero till drill was first developed in WRC Dinajpur. CA promotional activities had been continuing in the farmers' field through FAO, CIMMYT supported activities. IRRI-ADB took over (2005-07) the CA works with direct seeding rice and wheat in Northern Bangladesh. Farmers start showing interest on CA technology considering the advantages of crops yield, cost and resources saves. Agricultural officials, researchers, extension personnel, machinery manufacturers are now involved in this system. ACIAR (2006-2009)

implemented a project on legume crop sustainability in North-West part with a major component of tillage technology. Under this project, zero till drill, strip till drill has been much improved with a very acceptable limit by the farmers. Farm machinery Division, BARI further developed rotary type bed planter in 2006 with a single seed box. Considering the easiness of bed formation, WRC-BARI -Cornell University (2010-14) Food for Progress project further improved the rotary type bed planter with the introduction of inclined plate seed meter, separate seed & fertilizer box, split power transmission chain and set up operator's seat for easy movement and more adoption in the farmer's field of Rajshahi region and Faridpur areas. CSISA and CIMMYT are now expanding these tillage technology in Southern and central part of Bangladesh. ACIAR-SRFSI project is now actively involved for sustaining resilient farming through these tillage options in North-West part of Bangladesh. Moreover, leading NGOs like RDRS, IDE, CARITAS, PROVA are now expanding CA based technology in the farmers field. NARS (National Agricultural Research System) institutes especially BARI is now conducting various researches with many crops on the basis of CA technology. Agricultural universities in the country are now involved in CA based research and education.

The tillage implements are being used by the farmers and local service providers for different crop production. Numbers of tillage implements available in the country are shown in Table 2.

Table 2. Numbers of two wheel tractor based CA tillage implement.

Sl No.	Name of CA tillage implement	Number	Remarks
1	Minimum tillage seed drill	865	Local made as well as imported from China
2	Strip tillage seed drill	35	Local made as well as imported from China
3	Raised bed planter	425	Locally made
4	Zero till drill	8	Locally made

Minimum tillage seed drill and raised bed planter are being used by the farmers and service providers as custom hire basis. Zero till drill and strip till drill are still using on farm demonstration basis with different crops by the research organizations under project works. Local manufacturers are gaining experiences producing quality CA machinery. Earlier seed metering devices are imported from China. Presently, these are making in local workshop with imported raw materials.

Adoption of minimum tillage and raised bed technology

Considering the advantages and benefits of the minimum tillage seed drill, farmers are purchasing seeder (PTOS) for their own works as well as custom hiring system. Owners of PTOS in Dinajpur, Rajshahi, Faridpur districts are using for different seeds sowing commercially. It was observed that average 60 units of seeder increasing yearly (Fig.5). At present, there are 865 active numbers of seeders in operating condition.

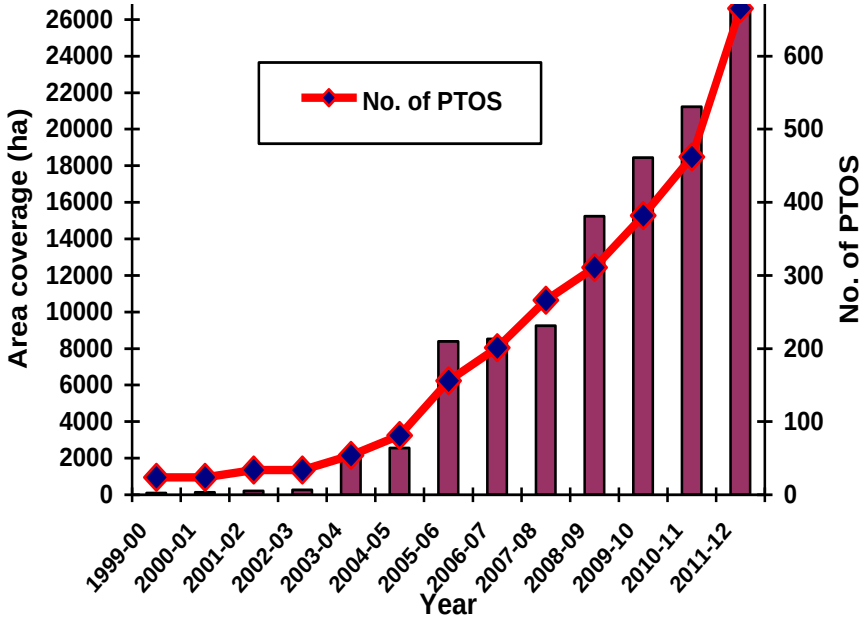

Fig.5. Adoption of minimum tillage

The adoption rate of minimum tillage technology in Faridpur area is much more than other other part of Bangladesh. The seeders are also engaged in onion field preparation in those area. Three local manufacturers started fabrication of seed this seed drill. Number of bed planters also increasing in Rajshahi area. Last year (2013-14), there are about 5764 ha area covered by bed planting technology for wheat, maize, mingbean, rice, vegetables cultivation. Total area under minimum tillage is 21850 ha. Area coverage under different tillage techniques are shown in Table 3. Minimum tillage and raised bed systems are becoming popular among the farmers and yearly area coverage is increasing. There are 20125 numbers of farmers involved in raised bed farming.

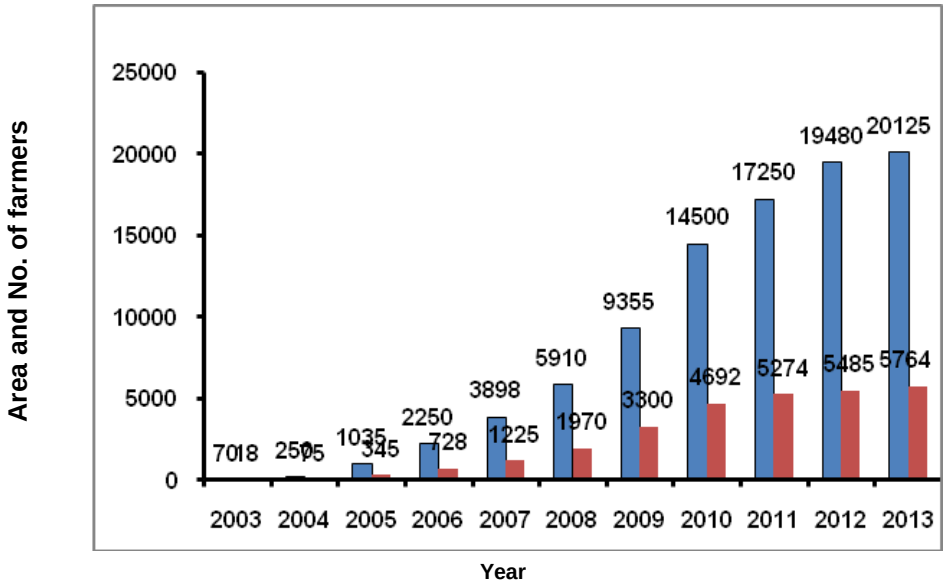

Fig 6 : Adoption of raised bed technology.

Table 3. Area coverage under conservation agriculture tillage system in Bangladesh.

Conservation agriculture Tillage techniques	2010-11 (ha)	2011-12 (ha)	2012-13 (ha)
Minimum tillage	9864	17527	21850
Strip tillage	72	106	108
Zero tillage	79	59	97
Raised bed system	4337	4636	5745
Total	**14352**	**22328**	**27800**

Uplands crops were best suited with CA tillage system. Yields of wheat, maize, pulses were significantly higher than conventional method (Table 4). Seeds and fertilizers can be applied optimum doses maintaining the standard practices. Research experiences revealed that yield of direct seeding rice was similar and some cases lower than conventional transplanting methods. Plant establishment was satisfactory but weed management or proper herbicide was not available. All the three years, it was observed that yield trend same as conservation agriculture tillage system reported higher yield over conventional methods. Farmers are gaining experiences in these new tillage systems for sustaining the crops yield. Crops yields on CA tillage system were much better than conventional system.

Table 4. Yield comparison of major crops under CA tillage systems.

Conservation agriculture tillage system	2010-11 (t/ha)			2011-12 (t/ha)			2012-13 (t/ha)		
	Wheat	maize	Mung bean	Wheat	maize	Mungbean	Wheat	maize	Mungbean
Minimum tillage	4.8 a	8.8	1.2 a	4.9 ab	8.8	1.2 a	4.7 a	9.5	1.3 a
Strip tillage	5.1 a	8.6	1.0 b	5.1 a	8.7	1.1 a	5.2 a	9.3	1.2 a
Zero till	4.4 a	8.5	0.9 b	4.3 bc	8.8	1.1 a	4.4 a	8.8	1.2 a
Bed planting	4.8 a	8.8	0.95 b	5.1 a	9.0	0.95 b	5.2 a	9.7	1.0 b
Conventional system	3.5 b	8.6	0.75 c	3.6 c	9.0	0.75 c	3.5 b	9.0	0.7 c
Level of significance	0.05	NS	0.01	0.01	NS	0.01	0.01	NS	0.01
CV (%)	9.54	8.63	7.29	8.49	9.51	7.03	9.40	8.38	6.53
LSD (0.05)	0.81	1.41	0.13	0.74	1.59	0.13	0.81	1.46	0.13

There were considerable costs saving in CA based tillage technologies (Table 5) over conventional methods. The cost saving by minimum tillage, strip tillage, zero tillage and bed planting system were 65%, 67.5%, 69% and 40%, respectively than that of conventional methods of planting.

Table 5. Cost of planting in different CA tillage system over conventional methods.

Sl. No.	CA tillage methods	Cost of seeding (Tk./ha)
1	Minimum tillage	1950.0 c
2	Strip tillage	1850.0 c
3	Zero tillage	2175.0 c
4	Raised bed system	3394.0 b
5	Conventional method	5695.0 a
	CV (%)	7.29
	LSD (0.05)	414

1 US$=Tk.78.0

Environment aspect

CA based tillage machinery perform seeding operation with minimum disturbance of soil. Less amount of diesel fuel used in CA tillage system compare to conventional tillage method (Table 6). CA tillage system saved 94 l/ha/yr of costly diesel fuel and 44% less emission of CO_2 into the atmosphere. This green

house gas emission can be mitigated by shifting to direct seeded or zero tillage system.

Table 6. Comparative use of diesel fuel on conventional and reduced tillage method.

Tillage option	Diesel used (l/ha/yr)	CO_2 emission* (kg/ha/yr)	Fuel save (l/ha/yr)
Conservation agriculture system	119	309.4	94
Traditional method	213	553.8	

Hossain *et al*., 2009a and *Grace *et al*., 2003.

Constraints to CA tillage technology adoption

Mind set up of high agricultural officials are not much favor convincing these CA tillage technologies. Limited investments of local manufacturers to scale-up production linked with uncertain CA machinery demand. The great numbers of resource poor smallholder farmers are not an attractive potential client group of machinery manufacturers. Manufacturing infrastructure and distribution channels of products are little developed. High price of machinery and low prices of agricultural produce discourage investments in agriculture, including machines and tools. Financial organizations are not much friendly to farmers in terms of reducing rate of interest and price installments. Absentee farmer and small landholder feel risk about crop failure with new technology. Additional learning is more comparing to conventional system. Research –extension-farmers linkage is not well established about these CA technologies transfer. Direct seeding rice is not yet in good shape in terms of weed management.

Challenges in promotion of CA tillage technology

Major challenges are to encourage private sector investment scaling up these technologies for the end users. Build up a mechanism for available appropriate CA implements and tools at an affordable price to farmers. Training needed for different level of workers, considering the advantages of conservation agriculture. Moreover, policy support is necessary for further acceleration of these technologies among the users.

Conclusion

Farmers accept conservation agriculture based tillage technologies considering the advantages of higher yields, reduced cost of tillage operation, and minimum turn around time between the crops. Up land crops are more suitable under these

tillage technologies. Most of the tillage implements are operated by imported Chinese two wheel tractor (power tiller). There are few four wheel tractor CA implement. Minimum tillage seed drill, raised bed planter, zero till drill and strip till drills are being fabricated in different local machinery workshop. Some manufacturers can fabricate implements independently. There are considerable numbers of manufacturers fabricating tillage implement in different districts. Farmers started adopt the CA technologies, especially raised bed planting and minimum tillage technology. Weed management in rice cultivation is not yet in a good shape. Herbicide availability and proper using technique of those herbicides are still a problem. There are about 425 raised bed planters and 865 minimum tillage seed drills in the country. Area coverage under bed planting and minimum tillage system are 5764 ha and 21850 ha, respectively. There is a big prospect accelerating the CA based tillage technology in the farmers' field as irrigation water availability becoming limited or more costly. Mind set up is the big issue for adopting CA tillage technology. Training and multi disciplinary approaches can push forward these tillage technologies ahead.

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EVALUATION OF SWEET POTATO GENOTYPES AGAINST SALINITY

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Abstract

Ten sweet potato lines/varieties were studied for growth response under NaCl salt stress condition. The rooting ability, in terms of root number, root length and root volume was studied. Growth in terms of root and shoot dry weight was also studied. A variation was recorded among the eight varieties and two lines in different doses of NaCl for growth responses in terms of rooting ability. The genotypes BARI SP-9, showed rooting ability up to 20 dS^{-m} among the 10 genotypes. The genotypes BARI SP-2, BARI SP-3, BARI SP-7, BARI SP-9 and line SP-613 showed increase in root number upto 6 dS^{-m} as compared to control. Accumulation of Na^+ increased with a concomitant decrease in K^+. Sweet potato plantlet transport less amount of Na^+ and more amount of K^+ to the shoot. Genotypes BARI SP-7 and BARI SP-9 showed better performance upto15dS^{-m}.

Keywords: Salinity, sweet potato, seedling growth, accumulation of Na^+ and K^+

Introduction

About 52.8 percent of the net cultivated land in the coastal area is affected by various degrees of salinity in Bangladesh (Karim *et. al*., 1990). Most of this vast land remains uncultivated. Introduction of salt tolerant crop is one of the most acceptable ways of intensification of crop production in this area. Salt tolerant lines/varieties are needed to be identified for optimum cultivation in coastal areas. Sweet potato is a root crop of Bangladesh covering an area of 7.51 hactre with annual production of 297539 matric tons (BBS, 2011). Sweet potato is a high energy containing but low input crop. Vitamin A deficiency is a major problem in Bangladesh. About 89% peoples are suffering from vitamin A deficiency (Hossain, 1993). Sweet potato is a rich source of vitamin A as also of starch (Nedunchezhiyan *et al*., 2007). Farmers can grow sweet potato easily in saline belt. Screening of sweet potato germplasm against salinity is one of the acceptable methods to select better varieties / lines for saline soil. The present study was under taken to evaluate the performance of sweet potato in respect of root growth under NaCl stress condition because root growth is much more sensitive to salinity than vine growth resulting in low productivity (Greig and Smith, 1962). It is very difficult to maintain a desirable level of salinity under field conditions. As salinity level in field is sporadic, it differs greatly in the same

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field (Philip and Bradley, 2001). So, screening of salt tolerant genotype under the field condition is very difficult. Therefore, the present study was done under solution culture to select the better performing varieties/lines of sweet potato against salinity.

Materials and Method

A laboratory experiment was conducted in Agronomy laboratory, TCRC, to study the root growth initiation, especially the root number; root length and root dry weight. Ten sweet potato genotypes including eight varieties (BARI SP-1, BARI SP-2, BARI SP-4 BARI SP-5, BARI SP-6, BARI SP-7, BARI SP-8 and BARI SP-9) and two promising lines (SP-613 and SP-625) were used in the investigation. Nodal explants (8-10 cm) of all the genotypes were selected for hydroponics culture in Hoagland nutrient medium. Different doses of NaCl were applied to prepare the treatment solution. Five levels of salinity viz. 1.8 dS^{-m}, 6 dS^{-m}, 10 dS^{-m}, 15 dS^{-m} and 20 dS^{-m} were used. Tap water mixed with Hoagland nutrient solution (1.8 dS^{-m}) was considered as control. Salt of NaCl added to prepare 6 dS^{-m}, 10 dS^{-m}, 15 dS^{-m} and 20 dS^{-m} salinity. Plantlets were grown for two weeks. Root number, root length, root dry weight and shoot dry weight were recorded. Ions were extracted from roots and the shoot by boiling the tissues with distilled water according to the method of Karmoker and Van Steveninck (1978). Amount of Na^+ and K^+ were measured using Atomic Absorption Spectrophotometer (Model SpectrAA-55B, Varian).

Results and discussion

Effect of salinity on root growth and relative root growth in terms of root number, root length and root dry weight.

The mean root number under control was 8.95 which were reduced to 5.75, 3.4, and 0.16 at 10 dS^{-m}, and 15 dS^{-m} respectively (Table 1). Lower salinity stimulated the root initiation easily in BARI SP-2, BARI SP-3, BARI SP-7, BARI SP-9 and line SP-613. The maximum root number was 14 (BARI SP-8) and the minimum (3.3 cm) was observed in SP-625 at 6 dS^{-m}. BARI SP-7 also showed better performance under higher salinity like 15 dS^{-m} (Table 1, Fig.1). Out of ten genotypes, only BARI SP-9 showed rooting ability up to 20 dS^{-m} (Fig. 1). The mean root number of BARI SP-9 was 1 cm and mean root length was 9 cm at 20 dS^{-m} salinity.

The mean root length under control condition was 18.38 cm which was decreased by 14.61 cm at 6 dS^{-m}, 10.61 cm at 10 dS^{-m} and 6.52 cm at 15 dS^{-m} salinity (Table 1). Root length of sweet potato decreased with the increase of salinity level though genotype BARI SP-2 showed an initial increase (10%) in length under lower salinity (6 dS^{-m}) (Table 1, Fig.2) .

Table 1. Effects of salinity on number of roots initiated, root length and root dry weight under salinity.

Genotypes	Salinity Level											
	1.8 dS^{-m}			6 dS^{-m}			10 dS^{-m}			15 dS^{-m}		
	Root/ explant (no.)	Root Length (cm)	Root dry wt. (mg)	Root/ explant (no.)	Root Length (cm)	Root dry wt. (mg)	Root/ explant (no.)	Root Length (cm)	Root dry wt. (mg)	Root/ explant (no.)	Root Length (cm)	Root dry wt. (mg)
BARI SP-1	10.00	12.20	16.90	11.33	9.57	18.00	4.00	13.60	19.90	3.00	6.60	1.50
BARI SP-2	7.00	17.73	15.20	13.00	19.53	29.90	6.00	7.43	7.30	6.00	8.00	5.30
BARI SP-4	7.67	14.63	12.60	8.67	11.00	12.00	4.67	3.50	3.10	3.00	3.40	1.10
BARI SP-5	12.67	17.50	16.00	9.00	11.17	7.30	5.50	6.30	2.10	2.50	3.00	1.50
BARI SP-6	9.67	16.10	13.50	8.00	9.90	5.40	6.00	7.33	2.80	6.33	6.53	2.60
BARI SP-7	6.00	25.23	19.20	6.83	19.83	18.60	7.33	19.03	15.30	4.67	8.97	8.60
BARI SP-8	14.33	22.67	18.60	14.00	15.87	11.70	12.00	12.70	7.30	6.00	6.70	1.20
BARI SP-9	7.50	20.20	9.00	11.00	17.67	15.60	9.00	15.50	16.10	7.00	11.33	9.30
Line SP-613	7.00	23.00	26.00	13.00	21.40	26.40	5.00	15.33	15.20	3.00	7.50	4.40
Line SP-625	7.67	14.50	8.20	3.30	10.20	6.70	1.00	5.36	3.00	1.00	3.21	1.10
Mean	8.95	18.38	15.52	9.81	14.61	15.16	6.05	10.61	9.21	4.25	6.52	3.66
Max.	14.33	25.23	26.00	14.00	21.40	29.90	9.00	19.03	19.90	7.00	11.33	9.30
Min	6.00	12.20	8.20	3.30	9.5	6.70	1.00	3.50	2.10	1.00	3.20	1.10
SE (±)	0.81	1.28	1.56	0.99	1.42	2.48	0.89	1.58	2.03	0.60	0.81	0.94

Table 2. Effects of salinity on net influx and long distance transport (LDT) of Na^+.

Genotypes	Na^+ Accumulation(mequiv g^{-1} dry tissue)							
	Salinity Level							
	1.8 dS^{-m}(cont)		6.0 dS^{-m}		10.0 dS^{-m}		15.0 dS^{-m}	
	Net influx	LDT	Net influx	LDT	Net influx	LDT	Net influx	LDT
BARI SP-1	0.1448	0.0634	0.3597	0.109	0.7522	0.1090	1.6931	0.7801
BARI SP-2	0.2183	0.0809	0.2836	0.1064	0.7555	0.1384	1.2641	0.5910
BARI SP-4	0.1476	0.0434	0.5642	0.2739	1.0622	0.2903	1.7135	0.7316
BARI SP-5	0.2252	0.1525	0.3954	0.166	0.8538	0.1977	1.8144	0.6431
BARI SP-6	0.152	0.0710	0.4197	0.1668	0.7627	0.2129	1.4709	0.6679
BARI SP-7	0.1606	0.0629	0.4195	0.1437	0.9845	0.3437	1.1125	0.4324
BARI SP-8	0.2234	0.0562	0.6033	0.2255	0.8028	0.2255	1.2184	0.5054
BARI SP-9	0.2371	0.1163	0.5465	0.2234	0.6617	0.1634	1.1200	0.4153
LineSP-613	0.1895	0.0946	0.3346	0.1670	0.5685	0.1673	1.1232	0.5099
LineSP-625	0.185	0.0725	0.4458	0.1621	0.5992	0.1621	1.2452	0.5923
Mean	0.19	0.08	0.44	0.170	0.78	0.20	1.38	0.61
SE (±)	0.01	0.01	0.03	0.02	0.05	0.02	0.08	0.04

Since at higher salinity (20 dS^{-m}), only one genotype BARI SP-9 out of ten, showed rooting ability, so, effect of salinity at 20 dS^{-m} is not presented in tables and figures.

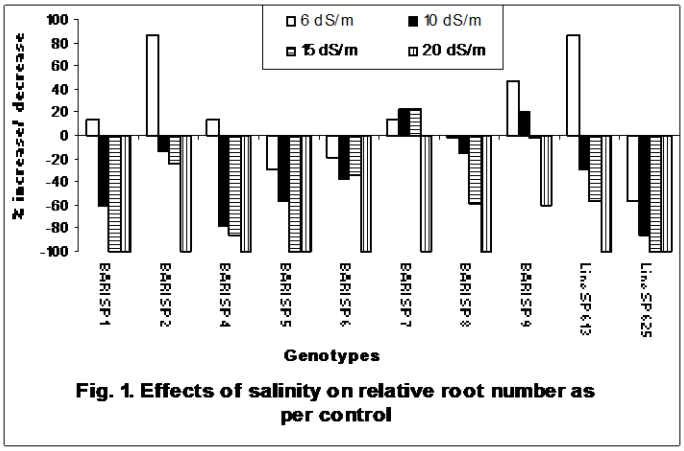

Fig. 1. Effects of salinity on relative root number as per control

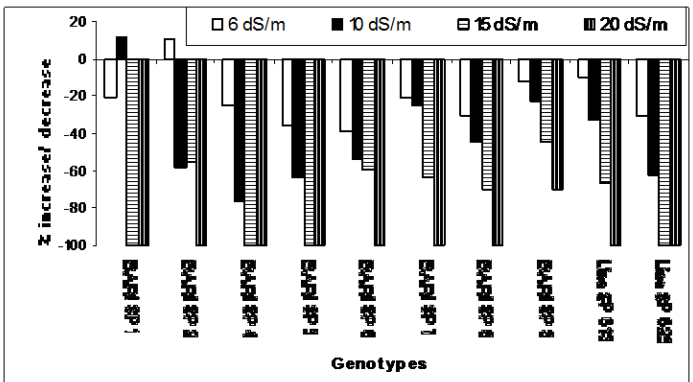

Fig.2. Effects of salinity on relative root length as compared to control

Dry weight of root was presented in Table 1. The mean root dry weight under control condition (1.8 dS^{-m}) was 15.52 mg which was decreased to 15.16 mg at 6 dS^{-m}, 9.21 mg at 10 dS^{-m} and 3.66 mg at 15 dS^{-m} salinity. An initial increase in dry weight was observed in BARI SP-1, BARI SP-2, BARI SP-4 and BARI SP-9 (Table 1 , Fig. 3). The variety BARI SP-9 performed better when dry weight was considered (Table 1 and Fig. 3). All the genotypes failed to survive at 20 dS^{-m} except BARI SP-9. An initial increase in growth in terms of seedling length and dry weight was also observed in maize (Begum *et al*., 2000) and also in barley (Sultana *et al*., 1999). An initial increase in biomass was also observed in wheat (Begum *et al*., 1992, 2008).

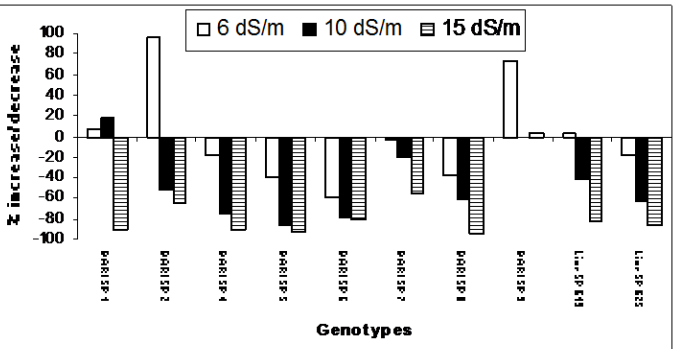

Fig. 3. Effects of salinity on relative root dry weight as compared to control

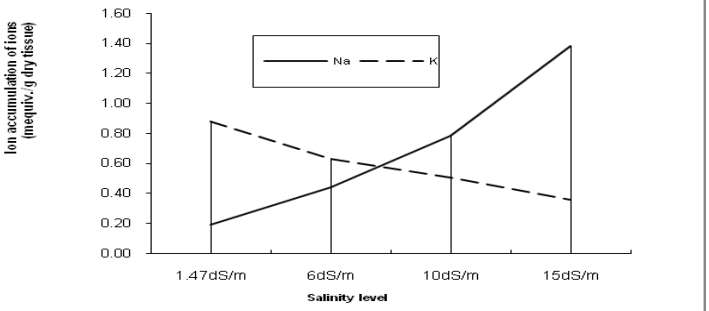

Fig. 4. Accumulation of Na and K ions under different levels of salinity.

Under salinity stress, the growth was reduced as compared to control. This was because under salinity stress plant needs more energy for its survival, consequently affecting the growth. Similar finding was also observed in case of wheat by Barret-Lennard and his associates (1990), where 3% to 4% more energy was found to be needed. Moreover, under salinity condition due to osmotic stress, seeds absorb less water than requirment and the normal activity of the seed was affected and mobility of the seed reserve needed for the growth of seedling was adversely affected (Begum *et al*, 2010). All these have a cumulative effect and ultimately hampering the seedling growth.

Pattern of ion uptake under salinity in sweet potato genotypes.

Accumulation of Na^+ increased in sweet potato genotypes with the increase NaCl concentration (Table 3). The result is similar with the result observed in maize (Begum *et al.*, 2000), in wheat (Begum *et al*., 1992) and also in rice (Roy *et al*., 1995). The mean Na^+ uptake in the case of control (1.8 dS^{-m}) was 0.19

Table 3. Effects of salinity on net influx and long distance transport (LDT) of K^+.

Genotypes	K^+ Accumulation (mequiv g^{-1} dry tissue)							
	Salinity Level							
	1.8 dS^{-m}(cont)		6.0 dS^{-m}		10.0 dS^{-m}		15.0 dS^{-m}	
	Net influx	LDT	Net influx	LDT	Net influx	LDT	Net influx	LDT
BARI SP-1	0.8498	0.5375	0.6700	0.4259	0.5444	0.3482	0.3730	0.2370
BARI SP-2	0.8668	0.4979	0.5732	0.3293	0.4098	0.2379	0.3242	0.1878
BARI SP-4	0.8291	0.504	0.6551	0.3944	0.4622	0.2500	0.2271	0.1335
BARI SP-5	0.9038	0.5000	0.6567	0.3924	0.4712	0.2807	0.2673	0.1532
BARI SP-6	0.8443	0.4834	0.6416	0.3576	0.5574	0.3274	0.4890	0.2995
BARI SP-7	0.9844	0.5372	0.5843	0.3053	0.5846	0.3182	0.4513	0.2667
BARI SP-8	1.0173	0.6149	0.6754	0.4076	0.5812	0.3721	0.4233	0.2711
BARI SP-9	0.8442	0.5041	0.5852	0.342	0.5516	0.3224	0.4402	0.3022
LineSP-613	0.8497	0.5012	0.6597	0.4015	0.5757	0.3736	0.4054	0.2259
LineSP-625	0.8582	0.5228	0.5771	0.3359	0.3499	0.2175	0.2084	0.1261
Mean	0.88	0.52	0.63	0.37	0.51	0.03	0.36	0.22
SE (±)	0.02	0.0	0.01	0.01	0.02	0.02	0.03	0.02

mequiv. g $^{-1}$ dry tissue which was increased by 0.49 , 0.89 , and 1.40 mequiv g $^{-1}$ dry tissue with the increase in salinity at 6, 10 and 15 dS^{-m}. Under salinity the mean K^+ uptake by sweet potato plantlet in the case of control was 0.89 mequiv. g $^{-1}$ dry tissue which decreased by 29%, 43%, and 58% at 6, 10 and 15 dS^{-m} respectively. It was observed from the result that though sweet potato plantlets accumulate more sodium ions under salinity but it transported less amount of Na^+ to the shoot. On the other hand, K^+ decreased with the increase in salinity but the plant tends to maintain K^+ level in the shoot by transporting more K^+ to the shoot (Table 3). Under salinity stress condition, maintenance of K^+ level is essential for plant survival, as most of the physiological activity is going on in the shoot (Datta, 2007). Sweet potato plantlet try to survive by transporting more K^+ to maintain the K^+ level in the shoot and less Na^+ to the shoot as Na^+ was toxic. From the experiment, an initial increase in growth was also observed in some genotypes. The ions absorbed by the plantlet initially helped in partially overcoming the osmotic stress due to salinity but later on due to their excess accumulation under higher salinity, the plantlets were affected adversely.

Growth is maintained at an appreciable level as long as the cellular K^+/Na^+ level did not fall below 1 (Huq *et. al*., 1987). This phenomenon was observed in sweet potato at 8 dS^{-m} (Fig. 4). The experiment therefore indicated that sweet potato is a moderately salt tolerant crop. The results are very consistant with the result obtained under field condition as reported by Amin *et. al.,* (2011). Amin and his co-workers (2011) observed a 50% decrease in yield of sweet potato when the salinity level of the field was more than 8 dS^{-m}. The results under laboratory condition also showed that 8 dS^{-m} salinity was the stress point for sweet potato. These interesting agreements between these two independent experimental findings reinforce the confidence in the results and methodology.

Considering plantlet growth, the sweet potato genotypes like BARI SP-9 and BARI SP-7 are found to be more tolerant to high NaCl stress and can be included in the varietals improvement program to salt stress conditions.

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IMPROVEMENT FROM MUSTARD-*BORO*-T. *AMAN* CROPPING PATTERN TO MUSTARD-*BORO*-JUTE-T. *AMAN*

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Abstract

The experiment was conducted at the farmers field of FSRD site, Elenga and MLT site Modhupur, Tangail during two consecutive years 2011-12 and 2012-13 to study the productivity, production efficiency, land use efficiency and economic return of the improved cropping pattern (Mustard - Boro - Jute -T. Aman) against the existing cropping pattern (Mustard -Boro - T. Aman) through incorporating of modern crop varieties and improved management practices. The experiment was laid out in randomized complete block design with six dispersed replications. The pooled data of improved management practice for the pattern produced significantly higher yield in Mustard and T. Aman rice respectively and also gave additional jute yield. The gross return and gross margin were higher in improved pattern compared to that of existing farmer's pattern with only 149 and 151% extra cost at FSRD site, Elenga and MLT site Modhupur, respectively. The higher benefit cost ratio (1.74 and 1.79), rice equivalent yield (22.41 and 21.82), production efficiency (40.19 and 39.48) and land-use efficiency (95.75 and 96.48) indicated the superiority of the improved pattern over the farmer's existing pattern at both sites. Higher rice equivalent yield indicates that improved cropping pattern (Mustard - Boro - Jute -T. Aman) could be suitable in Tangail region for increasing crop productivity as well as cropping intensity.

Keywords: Improved cropping pattern, rice equivalent yield, land use efficiency and production efficiency.

Introduction

Bangladesh is predominately an agrarian country. Bangladesh has achieved a remarkable progress in increasing food production. Although, there has been a great success in rice production and about to self sufficient in food grain production, but increasing population in future when the natural resources, land and water are shrinking and degrading. Horizontal expansion is very limited, but increase in crop production could be possible with vertical expansion through increasing crop yield per unit area and by reducing production losses.

A cropping pattern is the yearly sequence, temporal and spatial arrangement of crops in a given land area. The cropping pattern and the changes therein depend

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on a large number of factors like climate, soil type, rainfall, agricultural technology, availability of irrigation facilities and other inputs, marketing and transport facilities and growth of agro-industries (Neena, 1998; Gadge, 2003). The cropping pattern in an area depends largely on agro-climatic, technical and institutional factors (Vaidyanathan, 1987).

Rice is the staple food and the economy mainly depends on rice production in Bangladesh and now occupies the 4th position in the world. In self sufficiency of rice, the dominant cropping pattern T. *Aman* (wet season rice)-Fallow-*Boro* (dry season rice) plays an important role which covers about 1.8 million hectare (about 22% of the total land) of land (Elahi *et al*., 1999).

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 variety (Tori 7) in the transition period between T. *Aman* and *Boro* rice. But the farmers harvest poor yield from local var. Tori7 that can be increased manifold by introducing high yielding varieties (Alam and Rahman, 2006; Basak *et al.*, 2007). Recently, Bangladesh Agricultural Research Institute (BARI) has developed high yielding yellow seeded mustard (*Brassica campestris*) varieties, BARI Sarisha-14 and BARI Sarisha-15 whose yield potential is higher than Tori-7 and have been recommended for T. *Aman*-Mustard-*Boro* cropping sequence (BARI, 2011). Inclusion of these new varieties of mustard with growth duration of 80-85 days in between existing medium duration T. *Aman* rice (135-140 days) and *Boro* rice can create opportunity to fit in the T. *Aman* -Fallow-*Boro* cropping sequence. Mustard- *Boro*-T. *Aman* is one of the existing dominant cropping pattern at FSRD site, Elenga and MLT site Modhupur, Tangail. The pattern covers around 16.25 % of the cultivated land of the locality (DAE, 2012). Land remains fallow for more than 80 days after harvest of *Boro* rice. The present cropping intensity is 200%. To boost up crop production, four-crops based cropping pattern need to be developed. Jute may be included after harvest of *Boro* rice. It is only possible, if jute is cultivated early and short duration T. *Aman* and *Boro* rice varieties are included in the pattern. Jute crops can be grown easily under moisture stressed condition in high to medium low land (BJRI, 1990). The crop residue from jute crop contributed to enrich soil fertility and benefit the succeeding rice crop (Singh and Ghosh, 1999).

Therefore, the present study was designed to evaluate the feasibility and profitability of four crops based cropping pattern in Tangail region.

Materials and Method

The improved cropping pattern with Mustard - *Boro* -Jute - T.*Aman* against the existing pattern Mustard-*Boro*- T.*Aman* was initiated under medium high land

situation at the FSRD site, Elenga (AEZ 8) and MLT site Modhupur (AEZ 28), Tangail during 2011-12 and 2012-13. The trial was laid out in RCB design with six dispersed replications in both the locations. Unit plot size was 10 m x 8 m. All agronomic activities including sowing/ transplanting and harvesting dates, seed rate, plant spacing, fertilizer management etc. are shown in Tables 1a and 1b. Recommended fertilizer packages following the application methods were used for all the crops (BARC, 2005). Irrigation, pest managements and other intercultural operations were done as and when necessary. Land use efficiency, production efficiency, sustainable yield index and rice equivalent yield of cropping patterns were calculated by the following formulae:

Land use efficiency

Land use efficiency is worked out by taking total duration of individual crop in a sequence divided by 365 days **(Tomer and Tiwari, 1990**). It is calculated by following formula.

$$\text{Land use efficiency} = \frac{d_1 + d_2 + d_3 + d_4}{365} \times 100$$

Where, d_1, d_2, d_3 and d_4, the duration of first, second, third and fourth crop of the pattern.

Production efficiency

Production efficiency values in terms of Kg. ha^{-1} day^{-1} were calculated by total production in a cropping sequence divided by total duration of crops in that sequence **(Tomer and Tiwari. 1990).**

$$\text{Production efficiency} = \frac{Y_1 + Y_2 + Y_3 + Y_4}{d_1 + d_2 + d_3 + d_4}$$

Where,

Y_1: Yield of 1st crop

Y_2: Yield of 2nd crop

Y_3: Yield of 3rd crop

Y_4: Yield of 4th crop

d_1= Duration of 1st crop of the pattern

d_2= Duration of 2nd crop of the pattern

d_3= Duration of 3rd crop of the pattern

d_4= Duration of 4th crop of the pattern

Rice Equivalent Yield (REY)

For comparison between crop sequences, the yield of all crops was converted into rice equivalent on the basis of prevailing market price of individual crop **(Verma and Modgal, 1983).** The economic indices like gross, net returns and benefit cost ratio were also calculated on the basis of prevailing market price of the inputs and outputs (produces).

Crop management practices of improved and existing cropping pattern are shown in Table 1a and 1b. Crop productivity, LUE, production efficiency are also given in 2a, 2b, 3a and 3b.

Results and Discussion

Grain/Seed Yield

The results showed in Table 2-3. Table 2a and 2b reveal that Mustard-*Boro*-Jute-T. *Aman* cropping pattern under improved practices (IP) gave higher grain yield in case of Mustard and T. *Aman* in all the years. On an average, the yield of Mustard and T. *Aman* in improved pattern increased by 88.32 and 51.34%, respectively at the FSRD site, Elenga and 97.16 and 70.28%, respectively at the MLT site, Modhupur, over the crops of the farmer's pattern because of using high yielding varieties and improved management practices. The yield of *Boro* rice in improved pattern decreased by 9.65% at the FSRD site, Elenga and 9.72% at the MLT site, Modhupur over the crops of the farmer's pattern but additional jute crop was introduced with fiber yield 2.59 t ha^{-1} without hampering the turn around time.

Field duration

Field duration of cropping pattern mainly depends on individual duration of component crops. In farmer's existing cropping pattern (FECP), (Mustard- *Boro*-Fallow-T. *Aman*) farmers used Tori-7 as mustard variety, BRRI dhan-29 in *Boro* and Pajam in *Aman* season. On the other hand in improved pattern BARI Sarisha-14 was used as mustard variety, BRRI dhan-28 was used in *Boro*, O- 9897 as jute variety and Binadhan-7 in *Aman* season. BARI Sarisha-14 needs 4-5 more days to attained maturity than Tori-7 but BRRI dhan-28 matured 20-21 days earlier than BRRI Dhan-29 which helped in growing jute as an additional crop between *Boro* and T. *Aman* rice. Binadhan-7 took maturity 18 days earlier than Pajam. As a result, production efficiency and land use efficiency was higher in ICP than FECP. Though turn around time in improved pattern is very crucial so all inputs including land preparation should be done in proper time.

Table 1a. Crop managements of improved cropping pattern Mustard–*Boro*–Jute-T.*Aman* and existing cropping pattern Mustard-*Boro*–T.*Aman* at the FSRD site, Elenga, Tangail during 2011-12 and 2012-13.

Parameters	**Improved cropping pattern**				**Existing cropping pattern**		
Crop	Mustard	*Boro*	Jute	T. *Aman*	Mustard	*Boro*	T. *Aman*
Variety	BARI Sharisa-14	BRRI dhan-28	O-9897	Binadhan-7	Tori-7	BRRI dhan-29	Pajam
Date of sowing/ Transplanting	14-20 Nov. 2011 and 10-15 Nov. 2012	6-11 Feb. 2012 and 5-8 Feb. 2013	7-10 May, 2012 and 6-12 May, 2013	11-15 Aug. 2012 and 9-14 Aug. 2013	14-21 Nov. 2011 and 12-19 Nov. 2013	2-7 Feb. 2012 and 3-8 Feb. 2013	20-28 July, 2012 and 18-25 July, 2013
Seed rate (kg ha^{-1})	6	50	6	50	8	50	50
Spacing	Broadcast	25 cm x 15 cm	Broadcast	25 cm x15cm	Broadcast	25 cm x 15 cm	25 cm x15 cm
Seedling age (Day)	-	30-35	-	25-30	-	30-40	25-30
Fertilizer dose (N-P-K-S-Zn-B kg ha^{-1})	54-15-24-10-0-1.7	95-7-27-9-1.1-0	75-7-26-6-1.1-0	66-5-18-8-2.15-0	92-34-25-9-0-0	72-0-0-0-0-0	135-11-0-0-0-0
No. of irrigation	1 time at 20 DAS	25 times	-	16 times	-	30-35 times	20 times
No. of weeding/ thinning	1 time	2 times	3 times	2 times	1 time	2 times 10-14 and 28-32 DAT	2 times 10-15 and 30 DAT
Date of harvesting	2-8 Feb. 2012 and 1-6 Feb. 2013	3-8 May. 2012 and 4-10 May. 2013	5-8 Aug. 2012 and 4-10 Aug. 2013	7-13 Nov. 2012 and 6-11 Nov. 2013	27 Jan.- 04 Feb. 2012 and 28 Jan.- 04 Feb. 2013	21-30 May, 2012 and 22-29 May, 2013	10- 16 Nov. 2012 and 8-15 Nov. 2013

Crop duration in field (days), 2011-12	81	89	90	88	76	112	110
Crop duration in field (days), 2012-13	83	89	90	89	77	110	112
Turn around time (days), 2011-12	-	3	3	5	-	5	61
Turn around time (days), 2012-13	3	3	4	4	2	5	59

Table 1b. Crop managements of improved cropping pattern Mustard–*Boro*–Jute-T.*Aman* and existing cropping pattern Mustard-*Boro*–T.*Aman* at the MLT site, Modhupur, Tangail during 2011-12 and 2012-13.

Observation	**Improved cropping pattern**				**Existing cropping pattern**		
Crop	Mustard	*Boro*	Jute	T. *Aman*	Mustard	*Boro*	T. *Aman*
Variety	BARI Sharisa-14	BRRI dhan-28	O-9897	Binadhan-7	Tori-7	BRRI dhan-29	Pajam
Date of sowing/ Transplanting	15-18 Nov.2011 and 13-17 Nov.2012	9-14 Feb.2012and 4-10 Feb,2013	11-15 May.2012 and 6-11 May, 2013	12-15 Aug. 2012and 7-12 Aug. 2013	15-19 Nov. 2011and 10-16 Nov, 2012	4-11 Feb.2012 and 06 -12 Feb, 2013	22-30 July, 2012and 25-30 July 2012
Seed rate (kg ha^{-1})	6	50	6	50	8	50	50
Spacing	Broadcast	25 cm x15 cm	Broadcast	25 cm x 15cm	Broadcast	25 cm x 15 cm	25 cm x 15 cm

Seedling age (Day)	-	30-35	-	25-30	-	30-40	25-30
Fertilizer dose (N-P-K-S-Zn-B kg ha^{-1})	115-34-60-31-0-2	101-10-27-10-2-0	83-18-65-20-0-0	91-21-37-12-0-0	22-25-41-15-0-0-	115-24-50-0-0-0	129-0-0-0-0-0
No. of irrigation and date	2 time and 18-22 and 50-56 DAS	20-25 times	-	6 times	-	30-35 times	2 times
No. of weeding and date	-	2 times, 10-15 and 28-32 DAT	3 times	2 times, 10-15 and 30 DAT	-	2 times, 10-14 and 28-32 DAT	2 times, 10-15 and 30 DAT
Date of harvesting (range)	6-10 Feb.2012 and 01-07 Feb. 2013	08-12 May.2012 and 03-08 May, 2013	9-13 Aug. 2012 and 3-7Aug. 2013	10-14 Nov. 2012 and 9-12 Nov, 2013	1-5 Feb. 2012 and 2-5 Feb. 2013	22-29 May. 2012 and 26-30 May 2013	6-11 Nov. 2012. and 12-16 Nov. 2013
Crop duration in field (days), 2011-12	83	90	88	92	79	110	108
Crop duration in field (days), 2012-13	81	88	90	95	82	109	109
Turn around time (days), 2011-12	-	2	2	3	-	2	60
Turn around time (days), 2012-13	2	2	2	3	3	3	59

Table 2a. Productivity of Mustard-*Boro*-Jute- T. *Aman* rice cropping patterns under improved and farmer's practices at the FSRD site, Elenga, Tangail during 2011-12 and 2012-13.

Year	Pattern	Grain/seed/fiber yield (t ha^{-1})				By product yield (t ha^{-1})			
		Mustard	*Boro* Rice	Jute	T. *Aman*	Mustard	*Boro* Rice	Jute	T. *Aman*
2011-12	FP	0.73	6.37	-	2.73	1.58	7.24	-	5.63
	IP	1.41	5.79	2.56	4.29	1.85	6.55	2.83	4.72
2012-13	FP	0.78	6.48	-	2.86	1.38	6.94	-	5.96
	IP	1.44	5.82	2.61	4.17	2.17	6.83	2.93	4.68
Mean	FP	0.76	6.43	-	2.80	1.48	7.09	-	5.80
	IP	1.43	5.81	2.59	4.23	2.01	6.69	2.88	4.70

Table 2b. Productivity of Mustard-*Boro*-Jute- T. *Aman* rice cropping patterns under improved and farmer's practices at the MLT site, Modhupur, Tangail during 2011-12 and 2012-13

Year	Pattern	Grain/seed/fiber yield (t ha^{-1})				By product yield (t ha^{-1})			
		Mustard	*Boro* Rice	Jute	T. *Aman*	Mustard	*Boro* Rice	Jute	T. *Aman*
2011-12	FP	0.79	6.32	-	2.58	1.67	7.16	-	5.28
	IP	1.51	5.61	2.41	4.56	2.21	6.11	2.97	4.81
2012-13	FP	0.76	6.13	-	2.67	1.79	6.57	-	5.28
	IP	1.54	5.63	2.27	4.38	2.46	6.37	2.74	4.68
Mean	FP	0.77	6.23	-	2.63	1.73	6.87	-	5.28
	IP	1.53	5.62	2.34	4.47	2.34	6.24	2.86	4.75

Note- FP: Farmer's pattern, IP: Improved pattern.

Table 3a. Rice equivalent yield, production efficiency, land use efficiency and cost benefit analysis of farmers and improved cropping pattern at the FSRD site, Elenga, Tangail during 2011-12 and 2012-13.

Year	Pattern	Rice equivalent yield (t ha^{-1})	Production efficiency Kg. $ha^{-1}day^{-1}$	Land use efficiency (%)	Gross return (Tk.ha^{-1})	Cost of cultivation (TK.ha^{-1})	Gross margin (Tk.ha^{-1})	BCR
2011-12	FP	11.59	32.99	81.64	196787	130113	66674	1.51
	IP	22.33	40.37	95.34	346582	194492	152090	1.78
2012-13	FP	12.01	33.85	81.92	201290	137362	63928	1.47
	IP	22.49	40.00	96.16	349645	204829	144816	1.71
Mean	FP	11.80	33.42	81.78	199039	133738	65301	1.49
	IP	22.41	40.19	95.75	348114	199661	148453	1.74

Unit price (Tk. kg^{-1}): Mustard= 50, *Boro* rice= 13.75, *Aman* rice= 14.00, Rice straw= 2.00, Jute fibre= 40.00, Jute stick= 4.00.

Table 3b. Rice equivalent yield, production efficiency, land use efficiency and cost benefit analysis of farmers and improved cropping pattern at the MLT site, Modhupur, Tangail during 2011-12 and 2012-13.

Year	Pattern	Rice equivalent yield (t ha^{-1})	Production efficiency Kg. $ha^{-1}day^{-1}$	Land use efficiency (%)	Gross return (Tk.ha^{-1})	Cost of cultivation (TK.ha^{-1})	Gross margin (Tk.ha^{-1})	BCR
2011-12	FP	11.27	33.13	81.37	188860	123506	65354	1.53
	IP	22.05	39.92	96.71	342390	184862	157528	1.85
2012-13	FP	11.07	32.53	82.19	185355	130127	55228	1.42
	IP	21.59	39.04	96.99	339693	196990	142703	1.72
Mean	FP	11.17	32.83	81.78	187108	126817	60291	1.48
	IP	21.82	39.48	96.85	341042	190926	150116	1.79

Unit price (Tk. kg^{-1}): Mustard= 50, *Boro* rice= 13.00, *Aman* rice= 14.00, Rice straw= 2.00, Jute fibre= 40.00, Jute stick = 4.00.

Rice equivalent yield

The mean rice equivalent yield revealed that improved cropping system produced higher rice equivalent yield over farmer's traditional cropping system (Tables 3a and 3b). Inclusion of a four crops with high yielding varieties and improvement management practices in the improved pattern increased the rice equivalent yield (22.41 and 21.82 t ha^{-1}). The lower rice equivalent yield (11.80 and 11.17 t ha^{-1}) was obtained in the farmer's pattern with three crops, local variety in mustard & *Aman* rice and traditional management practices at the FSRD site, Elenga and MLT site Modhupur respectively.

Production efficiency

The lower production efficiency was observed in farmer's pattern (Tables 3a and 3b). The result indicates that the crops remained in the field for shorter time and yields were also lower in farmer's traditional system, leading to lower production per day. On the contrary, crops remain standing in the field for longer time with higher yield in improved practices, leading to higher production efficiency.

Land use efficiency

Land use efficiency is the effective use of land in a cropping year, which mostly depends on crop duration. The average land-use efficiency indicated that improved pattern used the land for 95.75% period of the year at the FSRD site, Elenga and 96.85% at the MLT site Modhupur, whereas farmer's pattern used the land for 81.78% period of the year. This higher land use efficiency in improved pattern is due to cultivation of jute as a component crop in fallow period.

Economic analysis

From the economic point of view, the ICP (improved cropping pattern) showed its superiority over FECP (farmer's existing cropping pattern). Gross return of the ICP was Tk.348114, which was about 74.89% higher than that of farmers pattern (Table 3a) at the FSRD site, Elenga. At the MLT site, Modhupur, gross return of the ICP was Tk.341042, which was about 82.27% higher than that of farmers pattern (Table 3b). The production cost per hectare of the improved pattern was higher than that of FECP. Higher cost for improved cropping pattern was due to cultivation of jute as a component crop, labor intensive, cultural operations, cost of fertilizer and other inputs. The gross margin was substantially higher in the improved pattern than that of the farmer's pattern. Though cost of cultivation in ICP was much higher but BCR was also higher due to higher benefit from the pattern.

Farmer's opinion

The yield performances of the BARI Sharisha-14, BARI Sharisha-15, BRRI dhan-28, Falgunitusa (O-9897), Binadhan-7 and BRRI dhan-49 are found almost satisfactory performance. After harvest of T. *Aman* rice, short duration modern mustard variety (BARI Sharisha-14) could easily be grown which doesn't hamper or delay the *Boro* cultivation. Jute crop could easily be grown between *Boro* and T. *Aman* rice by using short duration *Boro* rice variety (BRRI dhan-28). Improved knowledge on production technology for four crops is needed.

Conclusion

Improved cropping pattern mustard (var. BARI Sarisha-14)–*Boro* (var. BRRI dhan-28)-Jute (var. O-9897)-T.*Aman* (var. Binadhan-7) is economically viable and biologically suitable technology. The findings may be used as extension message for large scale production but more training is required for the farmers before disseminated the technology.

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PERFORMANCE OF LENTIL VARIETIES UNDER RELAY AND MINIMUM TILLAGE CONDITIONS IN T.AMAN RICE

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Abstract

A study on comparative productive efficiency and feasibility of lentil varieties both at relay and minimum tillage were conducted at the Regional Agricultural Research Station, BARI, Ishurdi, Pabna, Bangladesh during the *Rabi* season of 2007-08 and 2008-09. Three lentil varieties viz. BARI Masur-2, BARI Masur-3 and BARI Masur-4 and two sowing methods viz. relay sowing and furrow sowing (Minimum tillage) were compared. The highest seed yield (1.59 t/ha) was obtained from BARI Masur-4 because of highest number of pods/plant and plant population/m^2 while lowest from BARI Masur-2 (1.39 t/ha). The sowing methods had significant effect on the seed yield of lentil. Crops sown in furrows produced higher seed yield (1.60 t/ha) than that of crops in relay sowing. The interaction effect between varieties and sowing methods also had significant effect on the seed yield and yield attributes. The lentil variety BARI Masur-4 when grown in furrows gave the highest seed yield (1.70 t/ha). Though seed yield and gross return were highest in furrow sowing but highest benefit cost ratio (4.67) was found in relay sowing method.

Keywords: Lentil, relay, minimum tillage

Introduction

Lentil is grown in many regions following the Transplant *Aman* rice crops in Bangladesh. Recently many high yielding varieties of T.Aman rice has been released but due to long duration variety of rice, it is difficult to cultivate lentil timely. Hence, lentil yields in the T.Aman rice area are much lower. On the other hand, delay sowing of lentil results in poor growth and ultimately lower yield (Anon., 1990). Thus, there is a need to develop a method, which would facilitate timely sowing of lentil in rice fields where T.Aman rice-lentil cropping system is followed. Delay sowing of lentil is one of the main constraints in harvesting good yield of the crop planted after rice (Mahmood *et al.*, 2003). Relay cropping technology (zero tillage) is one of the method where growing a crop few days before harvesting of another crop. In Bangladesh, many crops viz. lentil, grasspea, chickpea, field pea, mustard etc are relayed with T.Aman rice. This cropping is generally adopted in areas where T.Aman harvesting delayed and/or land remains moist which takes few to more days to become optimum condition

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for land preparation. Under this situation, farmers can grow the crop in optimum time by adopting relay cropping. Moreover, this practice makes the best use of the residual moisture of rice field. Relay cropping is beneficial in terms of utilize residual moisture from previous crop and reduced planting cost (Saleem *et al.*, 2000; Malik *et al.*, 2002; Jabbar *et al.*, 2005). Roysharma *et al.* (1984) reported from India that relay cropping of lentil produced 1.27 t/ha compared with 0.54 t/ha when planting was done after the rice harvest. They also said that after the harvest of rice, row planting was better than broadcast. Chakraborty *et al.* (1976) also reported high productivity of lentil (2.25 t/ha) under relay cropping with late Aman rice. Nazir *et al.* (1992) also reported that inter-relay cropping system is very effective technique for increasing production per unit area. The monocropping system of lentil decreased day by day due to increase of production area of staple food crop (rice) and other cereals crop like wheat and maize.

As such minimum tillage may also be adopted besides relay cropping. In this case, after harvest of T.Aman rice, furrows can be made between the rice rows and seeding could be done in the furrows. Joy *et al.* (1986) and Sharma *et al.* (1987) reported that legumes grown after rice at zero/minimum tillage are less affected by the compact puddled soil than the cereal crops probably due to their deep rooting system. Lentil genotypes show wide variation with respect to their productivity, stability and adaptability. However, performance of different lentil varieties needs to be evaluated for productive efficiency and economic feasibility under relay and minimum tillage condition.

Materials and Method

The experiment was conducted at the Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh during the rabi season of 2007-08 and 2008-09 to find out the comparative productive efficiency and feasibility of lentil varieties under relay and minimum tillage. The climate of the experimental site was subtropical in nature. The two years average total rainfall of 36.54 mm (about 53% of which falls in the last quarter of January), average minimum temperatures of 7–10 ^{0}C, and average maximum temperatures of 28–31 ^{0}C occurred during the growing periods (Fig.2). The experimental field was medium high and the soil was clay loam in texture having 7.50 p^H, 1.35% organic matter, 0.071% total nitrogen, 11µg/ml available phosphorus, 0.12 meq/100g soil available potassium, 15 µg/ml sulphur, 0.66 µg/ml boron and 2.0 µg/ml zinc. Which indicated that soil contain amount of total nitrogen, Phosphorus, potassium below the critical level (0.10 %, 14 µg/ml, 0.20 meq/100g); sulphur, boron above the critical level (14, 0.20 µg/ml) and zinc equal to critical level (2.0 µg/ml). The experiment was laid out in a split-plot design with three replications. Three lentil varieties viz. BARI Masur-2, BARI Masur-3 and BARI Masur-4 and

two sowing methods viz. relay sowing and seed sowing in furrows at 40 cm apart rows were included in the study. In varietal characteristics, BARI Masur-2 needs 105-110 days to mature and its 1000 seed weight is about 12.50 g (at 8.0% moisture content) having an average yield of 1.8-1.9 ton/ha. BARI Masur-3 requires 100-105 days to mature having 1000 seed weight about 23.80 g (at 8.0% moisture content) which seed yield ranged from 1.9-2.0 ton/ha. BARI Masur-4 takes 110-115 days to mature and its 1000 seed weight about 19.84 g (at 8.0% moisture content) as well as seed yield ranged from 1.9-2.0 ton/ha (Afzal *et al.*, 1999). The lentil varieties were assigned to the main-plot and the sowing methods in the sub-plot. The unit plot size was 6m x 5m. The crop was fertilized with 20-18-20 kg N- P - K/ha (BARI, 2011). In case of relay sowing, the fertilizer was broadcast in the standing T. Aman crop just before relay sowing of seeds. Seed and fertilizer were placed in the same furrow in case of furrow sown crop. The seeds of lentil were broadcast in a standing rice crop after the excess water drained out i.e., 10 days before the rice harvest. The seed rate of BARI Masur-2 and BARI Masur-4 were used @ 40 and 35 kg/ha, respectively in relay and furrow method. In case of BARI Masur-3, 45 and 40 kg seed/ha were used in relay and furrow method, respectively. T.Aman rice was harvested at a height of straw 30 cm. The crop was sown on 31 October 2007 and 1 November 2008, respectively in case of relay sowing while in case of crop sown in furrows on 9 and 10 November 2007 and 2008, respectively. The crop was harvested in between 15-20 February in both the years, respectively. The changes of soil moisture level at different days after emergence is depicted in Fig. 1. Soil sample was collected from 0-30 cm depth and moisture content was calculated by oven dry method. Data on yield and yield components were recorded, statistically analyzed and mean values were adjudged by LSD test at 0.05 levels of probability.

Results and Discussion

The result obtained from the two consecutive years was almost similar in yield and yield attributes and therefore pooled analysis was done.

Effect of variety

The yield and yield contributing characters influenced by different lentil varieties are presented in Table 1. Plant population was insignificant among the lentil varieties. The plant height was significantly influenced by the different varieties where maximum plant height (30.93cm) was obtained from BARI Masur-4 followed by BARI Masur-3. Similar trend was also followed in case of seeds/pod and pods/plant. The highest 1000-seed weight was obtained from BARI Masur-3 (21.24g) while BARI Masur-2 gave the lowest (16.10g). The highest 1000-seed weight occurred in BARI Masur-3 due to bolder seed size as compared to others.

Weight of 1000-seed of BARI Masur-3 was 31.92% higher than BARI Masur-2 and 8.42% higher than BARI Masur-4. The maximum seed yield was obtained from BARI Masur-4 (1.59 t/ha) due to higher pods/plant and seeds/pod while lowest yield attributes resulted lower seed yield in BARI Masur-2.

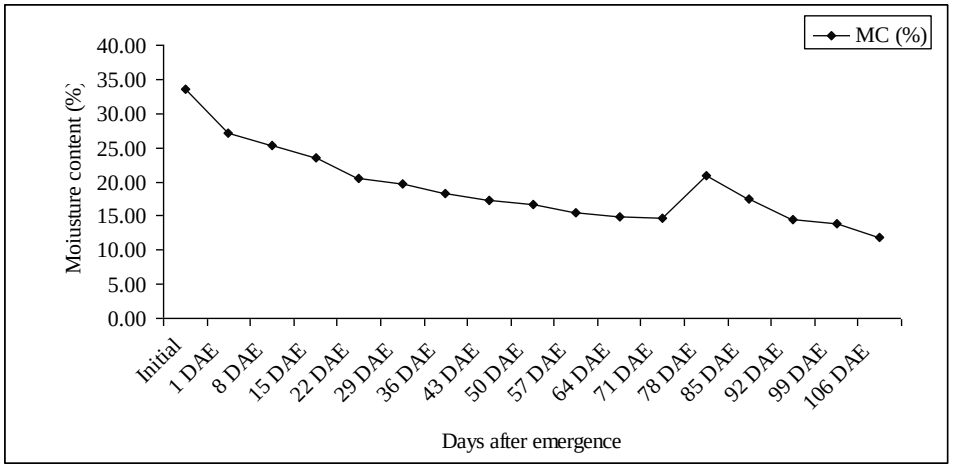

Fig.1. Changes of soil moisture level (seven days interval) at different days after emergence during the growing period of lentil.

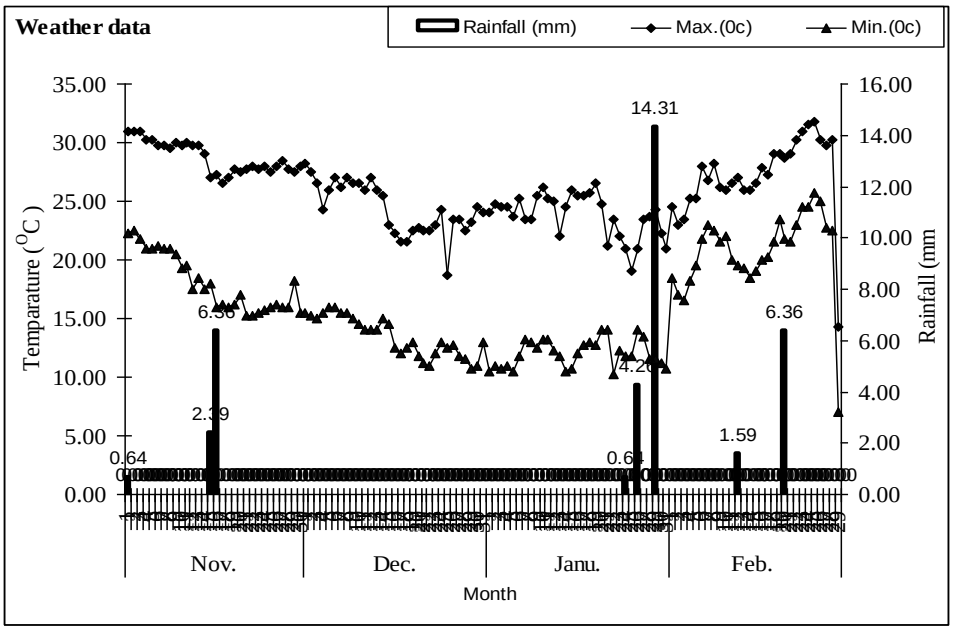

Fig. 2. Two years prevailing mean maximum and minimum temperature and rainfall during the growing period of lentil (Source: BSRI).

Effect of sowing method

Sowing methods showed significant variations in different crop characters (Table 2). The maximum plant population (276/m^2) was recorded in crop sown in furrows while lowest in relay sowing method (268/m^2). It might be due to the damage of seeds in relay sowing method by insect and birds in the field before germination. On the contrary, the highest plant population was found in furrow sowing method because the seeds were covered by soil that ensures maximum germination of seeds. Plant height was significantly influenced by sowing method while highest plant height (31.34cm) was obtained from furrow sowing method. Similar trend were also observed in case of number of primary branches/plant (4.11), number of pods/plant (26.40), number of seeds/pod (1.89) and 1000-seed weight (19.38g). Seed yield was significantly affected by sowing method (Table 2). Furrow sowing method gave higher seed yield (1.60 t/ha) than that of relay sowing (1.37 t/ha). Seed yield benefits on an average was 17% higher in furrow sowing (Minimum tillage) than relay sowing. Furrow sowing method resulted higher seed yield due to higher yield attributes and plants/m^2.

Table 1. Varietal performance of lentil on the seed yield and yield components (Pooled, 2007-2008 and 2008-09).

Treatments	Plant population /m ^{2}	Plant height (cm)	No. of primary branches / plant	No. of pods / plant	Number of seeds/pod	1000- seed weight (at 9% MC) (g	Seed yield (t/ha)
BARI Masur-2	268	29.14	3.52	23.42	1.74	16.10	1.39
BARI Masur-3	274	30.23	3.48	24.82	1.83	21.24	1.47
BARI Masur-4	275	30.93	4.07	25.07	1.91	19.59	1.59
LSD(0.05)	NS	0.75	0.17	0.28	0.11	0.69	0.52
CV (%)	1.26	2.64	4.77	1.21	6.24	3.91	3.68

Table 2. Effect of sowing methods on the seed yield and yield components of lentil (Pooled, 2007-2008 and 2008-09).

Sowing methods	Plant population /m ^{2}	Plant height (cm)	No. of primary branches / plant	No. of pods / plant	Number of seeds/pod	1000-seed weight (at 9% MC) (g)	Seed yield (t/ha)
Relay sowing	268	28.86	3.28	22.47	1.77	18.57	1.37
Furrow sowing	276	31.34	4.11	26.40	1.89	19.38	1.60
LSD(0.05)	NS	0.83	0.25	1.11	0.07	0.48	0.15
CV (%)	2.65	2.29	5.67	3.79	5.24	2.10	8.60

Combined effect

The interaction effect between variety and sowing method was also found significant on all the characters under the study (Table 3). It was observed that furrow sowing method produced better results compared to relay sowing method in all the yield parameters. The highest seed yield (1.70 t/ha) was recorded from BARI Masur-4 when sown in furrows, which was similar to BARI Masur-3 at same method of sowing. The highest plant population/m^2, plant height, number of primary branches/plant, number of pods/plant and 1000-seed weight were contributed highest seed yield in these treatment combination. The lowest seed yield (1.29 t/ha) was found in BARI Masur-2 in relay sowing. Relay sowing method failed to show higher seed yield than furrow sowing.

Table 3. Combined effects of varieties and sowing methods on the seed yield and yield components of lentil (Pooled, 2007-2008 and 2008-09).

Interaction (varieties × sowing methods)	Plant population /m^2	Plant height (cm)	No. of primary branches / plant	No. of pods/ plant	Number of seeds/pod	1000- seed weight (at 9% MC) (g)	Seed yield (t/ha)
V_1 × R	264	28.23	3.172	21.57	1.67	15.51	1.29
V_1 × F	271	30.05	3.870	25.27	1.82	16.68	1.50
V_2 × R	269	29.45	2.983	22.77	1.78	20.69	1.34
V_2 × F	278	31.04	3.977	26.87	1.89	21.78	1.60
V_3 × R	270	28.93	3.670	23.07	1.86	19.51	1.49
V_3 × F	279	32.93	4.475	27.07	1.97	19.68	1.70
LSD(0.05)	9.07	0.87	0.26	1.17	0.11	0.50	0.16
CV (%)	2.65	2.29	5.67	3.79	5.24	2.10	8.60

V_1 = BARI Masur-2, V_2 = BARI Masur-3, V_3 = BARI Masur-4, R= Relay sowing, F = Furrow sowing and MC = Moisture content.

Soil moisture level

It is clear evident from the Fig.1 that trend of soil moisture level gradually decreased with time. Effective rainfall occurred between 71 to 78 days after emergence which lead rising soil moisture at 78 days after emergence. This curve also showed that crop take essential moisture from the soil and need no irrigation water supply for crop growth and development.

Cost benefit analysis

In the present study relay cropping system generated substantial higher benefit than furrow sowing method. The highest seed yield (1.70 t/ha), gross return (Tk.

85000/ha) and gross margin (Tk. 61240/ha) was recorded in furrow sowing method but highest cost of cultivation was involved in furrow sowing. As a result, higher BCR was recorded from BARI Masur-4 in relay cropping. But cultivation of lentil in relay sowing was profitable as reported by Jabbar *et al.* (2005) who reported that rice/legumes relay cropping system such as rice/chickpea and rice/lentil proved to be more productive and economically viable.

Table 4. Cost and benefit analysis of lentil varieties under relay and furrow sowing (minimum tillage) condition (average of two years).

Treatments	Gross return (Tk./ha)	Total cost (Tk./ha)	Gross margin (Tk./ha)	BCR
$V_1 \times R$	64500	15960	48540	4.04
$V_1 \times F$	75000	23760	51240	3.16
$V_2 \times R$	67000	15960	51040	4.20
$V_2 \times F$	80000	23760	56240	3.37
$V_3 \times R$	74500	15960	58540	4.67
$V_3 \times F$	85000	23760	61240	3.58

V_1= BARI Masur-2, V_2 = BARI Masur-3, V_3 = BARI Masur-4, R= Relay sowing and F = Furrow sowing

Market price:

Lentil seed: TK 50/kg

Conclusion

Furrow sowing method was found superior to relay cropping in terms of highest seed yield of lentil but due to higher cost was involved in this system. As a result, relay cropping was found better benefit than furrow method of sowing. This technology could be demonstrated to resource poor farmers who have limited fund to grow lentil.

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EFFECTIVENESS OF DIFFERENT SUBSTRATE MATERIALS TO PREPARE *Trichoderma harzianum* BASED BIO-FUNGICIDES TO CONTROL FOOT AND ROOT ROT *(Fusarium oxysporum)* OF TOMATO

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Abstract

An investigation was undertaken to evaluate the effectiveness *Trichoderma harzianum* based bio-fungicides multiplied on different substrates. The substrates was rice bran, wheat bran, grass pea bran and their combinations with mustard oilcake (MOC) were used to mass culture *T. harzianum* for the management of foot and root rot disease of tomato seedling caused by *Fusarium oxysporum* in seedbed. All combinations of carrier materials were found effective for preparing *T. harzianum* based bio-fungicides to promote germination, seedling growth and reducing pre-emergence and post-emergence mortality of tomato seedling under *F. oxysporum* inoculated seedbed soils. The shoot length, shoot weight, root length and root weight of tomato seedling were enhanced significantly by the application of different substrate materials of *T. harzianum* based bio-fungicides under *F. oxysporum* inoculated seedbed conditions. The individual (rice bran, wheat bran, grass pea bran) and combination of substrates (rice bran + wheat bran, rice bran + mustard oilcake, rice bran + wheat bran + MOC and wheat bran + grass pea bran + MOC) were equally suitable for mass culturing of effective *T. harzianum* bio-fungicides for the management of foot and root rot disease of tomato seedling in seedbed condition.

Keyword: *Trichoderma harzianum*, bio-fungicide, *Fusarium oxysporum*, tomato seedling, seedbed

Introduction

Tomato *(Solanum lycopersicum* L.) is one of the most popular vegetables in Bangladesh. The crop is cultivated in 24,800 hectare of land and the production is 232459 mt of fruit annually (Anon., 2012). The crop suffers from many diseases and incurs 30-40% yield loss every year (Anon., 1992). Among the diseases, seedling mortality due to the soil borne fungus, *Fusarium oxysporum* is prevalent throughout the tomato growing areas of the country (Anon., 19992). Management of *F. oxysporum* is difficult using fungicides and cultural practices.

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Therefore, an alternative method like biological control of disease management may be practice if available. Growth of pathogenic fungus can be reduced by means of antagonistic microorganisms, which kill or compete with the pathogenic fungus. The bio-control agent, *T. harzianum* is abundant in soil under all climates over different geographical regions. It is known as efficient decomposers of various substrates having rapid growth rates and antimicrobial properties. The bio- control agents are naturally present in soil usually in low population. Thus increasing of its population density through artificial inoculation is necessary to achieve successful control of target fungus in soil. Available reports reveal that rice bran, wheat bran, maize bran, sawdust (Das *et al.*, 1997); rice straw, chickpea bran, ,grasspea bran, rice course powder, blackgram bran (Shamsuzzaman *et al.* 2003) and cow dung, poultry manure, groundnut shell, black ash (Rettinassababady and Ramadoss, 2000) are good substrates materials for multiplication of *T harzianum.* Reports on the results of conclusive study on the use of substrates for multiplication of *T harzianum* for the preparation bio-fungicides are not available in Bangladesh. The present investigation was conducted to evaluate effectiveness of different organic substrates for the preparation of *T. harzianum* based bio-fungicides against *F. oxysporum* causing foot and root rot disease of tomato in seedbed.

Materials and Method

Effectiveness of ten *T. harzianum* based bio-fungicides multiplied on three substrate materials was evaluated in the present experiment to control foot and root rot of tomato in seedbed. The substrate materials were rice bran, wheat bran, grasspea bran and their combinations mixed with or without mustard oilcake (MOC) were used to prepare the bio-fungicides. The experiment was conducted in a seedbed used under nethouse conditions of Plant Pathology Division, Bangladesh Agricultural Research Institute (BARl), Gazipur during three consecutive years from 2010 to 2014. In this experiment barley grains colonized with *F. oxysporum* were incorporated in the seedbed soils @ 100g/m^2 soil. The pathogen was allowed to colonize the soil in seedbed for 10 days. A pure culture of *T. harzianum* (TM7) was grown in potato dextrose agar (PDA) medium which was used as inocula for preparation bio-fungicides.

The experiment was conducted in seedbed under nethouse condition of Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur during three consecutive years from 2010 to 2014. In this experiment barley grains colonized with *F. oxysporum* were incorporated in the seedbed soils @100 g/m^2 soil for inoculation. The pathogen was allowed to multiply in seedbed soil for 10 days. A pure culture of *T. harzianum* (TM7) was grown in potato dextrose agar (PDA) medium which was used as inocula of bio-fungicide. The treatments 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 + Grass pea 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 ^{0}C) for 15 days. After incubation the colonized substrates were removed from the flasks and air dried and finally preserved in refrigerator at 10 ^{0}C. 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 BARI Tomato-2 (Raton) were sown in the seedbed @ 200 seeds per treatment. The initial germination of the seeds was 98% as per blotter test result. 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 tomato 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 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 tomato was significantly increased over control due to treatment of *F. oxysporum* inoculated seedbed soil with *T harzianum* bio-fungicides. Among the treatments the seedling emergence varied from 65.67- 75.00, 75.67-78.33 and 70.67-76.67% where the emergence under control was 50.67, 61.00 and 49.67% in first, second and third year, respectively. Seedling emergence under various treatments with the bio-fungicides was not significantly different (Table 1).

Table 1. Effect of different carrier material based *T. harzianum* bio-fungicides on the emergence and pre-emergence mortality of tomato seedling in *F. oxysporum* inoculated seedbed soil.

Name of substrates	Seedling emergence of tomato (%)				Pre-emergence seedling mortality (%)			
	1st year	2nd year	3rd year	Mean	1st year	2nd year	3rd year	Mean
Rice bran	69.67 ab	75.67 a	73.00 a	72.78 a	30.33 b	24.33 b	27.00 c	27.22 c
	(56.62)	(60.47)	(58.74)	(58.60)	(33.30)	(29.53)	(31.26)	(31.36)
Wheat bran	69.67 ab	76.00 a	72.33 a	72.69 a	30.33 b	24.00 b	28.67 c	27.67 c
	(56.58)	(61.37)	(58.30)	(58.75)	(33.41)	(28.58)	(31.70)	(31.23)
Grasspea bran	65.67 ab	76.33 a	75.67 a	72.56 a	34.33 b	23.67 b	25.33 c	27.78 c
	(54.13)	(62.75)	(59.82)	(58.90)	(35.86)	(29.06)	(30.18)	(31.70)
Rice bran + Wheat bran	71.00 ab	77.33 a	76.67 a	75.00 a	29.00 b	22.33 b	23.33 c	24.89 c
	(57.42)	(60.95)	(61.21)	(59.86)	(32.25)	(28.13)	(28.79)	(29.72)
Rice bran + Grass pea bran	68.67 ab	78.33 a	76.67 a	74.56 a	31.33 b	21.67 b	23.33 c	25.44 c
	(55.96)	(62.31)	(61.15)	(59.81)	(33.94)	(27.69)	(28.85)	(30.16)
Rice bran + Mustard oilcake	75.00 a	77.33 a	75.33 a	75.89 a	25.00 b	22.67 b	23.67 c	23.78 c
	(60.00)	(61.66)	(60.29)	(60.65)	(31.12)	(28.40)	(29.72)	(29.75)
Rice bran + Wheat bran + MOC	71.67 ab	77.33 a	74.33 a	74.44 a	28.33 b	22.33 b	25.67 c	25.44 c
	(57.84)	(60.87)	(59.66)	(59.46)	(31.98)	(28.34)	(30.34)	(30.22)
Rice bran + Grasspea bran + MOC	66.67 ab	78.33 a	74.33 a	73.11 a	33.33 b	21.67 b	25.67 c	26.89 c
	(54.74)	(62.43)	(59.62)	(58.93)	(35.21)	(27.57)	(29.71)	(30.83)
Wheat bran + Grass pea bran + MOC	72.00 ab	78.00 a	70.67 a	73.56 a	28.00 b	22.00 b	29.33 c	26.44 c
	(58.05)	(62.37)	(57.27)	(59.23)	(31.74)	(27.63)	(32.74)	(30.70)
Wheat bran + Grass pea bran+ Rice bran + MOC	69.00 ab	77.33 a	71.33 a	72.55 a	31.00 b	22.67 b	28.67 c	27.45 c
	(56.17)	(61.60)	(57.67)	(58.48)	(33.76)	(28.40)	(32.33)	(31.50)
Seed treatment with Provax	59.67 bc	77.00 a	60.00 b	65.56 b	40.33ab	23.00 b	40.00 b	34.44 b
	(50.58)	(60.60)	(50.78)	(53.99)	(39.41)	(28.63)	(39.22)	(35.75)
Control	50.67 c	61.00 b	49.67c	53.78 c	49.33 a	39.00 a	50.33 a	46.22 a
	(45.38)	(52.58)	(44.81)	(47.59)	(46.61)	(38.63)	(45.19)	(43.48)

Values in a column having same letter did not differ significantly (p=0.05) by LSD; values within the parentheses were the Arcsine Transformed values.

On the contrary, treatment of seedbed soils with the bio-fungicides caused significant reduction in pre-emergence seedling mortality of tomato compared to control. The range of seedling mortality was 25.00-34.33% in first year, 21.67-24.33% in second year and 23.33-29.33% in third year. The corresponding mortality under control was 49.33, 39.00 and 50.33%, respectively. Efficacy of all treatments with the bio-fungicides to reduce the pre-emergence mortality was not significantly different (Table 1).

b) Post-emergence mortality

Post-emergence mortality of tomato in *F. oxysporum* inoculated seedbed soil was 23.67, 31.67 and 21.67% under control in 1st, 2nd and 3rd year of study, respectively. Treatment of seedbed soil with the bio-fungicides reduced the disease incidence to 60.58-74.65, 58.95-67.38 and 64.61-67.70%, respectively. The reduction was significant under every bio-fungicide. Efficacy of all treatments with the bio-fungicides to reduce the disease incidence was not significantly different (Table 2).

c) Shoot growth

Under control, shoot length was 23.53 cm in first year, 14.87 cm in second year and 16.13 cm in third year. Treatment of seedbed soils with *T harzianum* based bio- fungicides multiplied on rice bran, wheat bran, grasspea bran alone or in different combinations increased the shoot length to 27.07-30.13, 15.87-19.33 and 24.17-33.60 cm in 1st, 2nd and 3rd year, respectively. The shoot weight under control was 4.66, 4.10 and 4.23 $gplant^{-1}$ in first, second and third year, respectively. *T. harzianum* based bio-fungicidal treatments of seedbed soils increased the parameter to 7.34- 8.01, 5.51-6.71 and 6.97-10.03 $gplant^{-1}$, respectively. Every year, the increase in length and weight of shoot of tomato seedling due to bio-fungicidal seedbed soil treatment was significant compared to control. Effect of the treatments on shoot growth was more or less similar (Table 3).

d) Root growth

Every year, the root length of tomato seedling was significantly lower in non-treated seedbed (control) compared to bio-fungicide and Provax treated beds. In first, second and third year, the root length of tomato seedlings ranged 7.13-10.17, 6.93- 8.27 and 6.87-10.67 cm under different treatments and 5.50, 4.70 and 4.97 cm in control seedbeds, respectively (Table 4).

In first, second and third year, the ranges of root weight were 0.42-0.46, 0.50-0.58 and 0.71-0.95 $gplant^{-1}$, respectively in seedbed treated with bio-fungicides multiplied on various substrate materials and 0.33, 0.39 and 0.54 $gplant^{-1}$ in control seedbeds, respectively (Table 4). The root weight was significantly higher compared to seedbeds received no bio-fungicide or Provax. Effect of the treatments on root growth was more or less similar (Table 4).

Table 2. Effect of various carrier material based *T. harzianum* bio-fungicides on the post-emergence mortality of tomato seedling in *F. oxysporum* inoculated soils in seedbed.

Name of substrates	Post-emergence seedling mortality (%)				Seedling mortality reduced than control in consecutive three years (%)			
	1st year	2nd year	3rd year	Mean	1st year	2nd year	3rd year	Mean
Rice bran	9.00 b (17.46)	13.00 b (21.09)	7.33 b (15.66)	9.78 b (18.07)	61.98	58.95	66.17	61.90
Wheat bran	9.33 b (17.79)	11.00 b (19.36)	7.33 b (15.70)	9.22 b (17.62)	60.58	65.27	66.17	64.08
Grasspea bran	7.67 bc (16.08)	12.67 b (20.81)	7.33 b (15.60)	9.22 b (17.50)	67.58	59.99	66.17	64.08
Rice bran + Wheat bran	7.33 bc (15.71)	12.33 b (20.54)	7.33 b (15.70)	8.99 b (17.32)	69.03	61.07	66.17	64.98
Rice bran + Grasspea bran	8.00 bc (16.43)	10.33 b (18.72)	7.67 b (16.07)	8.67 b (17.07)	66.20	67.38	64.61	66.23
Rice bran + Mustard oilcake	7.67 bc (16.08)	12.33 b (20.51)	7.33 b (15.60)	9.11 b (17.40)	67.58	61.07	66.17	64.51
Rice bran + Wheat bran + MOC	8.33 bc (16.78)	12.00 b (20.26)	7.00 b (15.24)	9.11 b (17.43)	64.81	62.11	67.70	64.51
Rice bran +Grasspea bran +MOC	8.00 bc (16.43)	11.33 b (19.97)	7.33 b (15.68)	8.89 b (17.36)	66.20	64.22	66.17	65.37
Wheat bran + Grasspea bran + MOC	9.00 b (17.79)	12.67 b (21.07)	7.00 b (15.32)	9.56 b (18.06)	61.98	59.99	67.70	62.76
Wheat bran + Grasspea bran+ Rice bran + MOC	6.00 c (14.18)	12.33 b (20.54)	7.33 b (15.68)	8.55 b (16.80)	74.65	61.07	66.17	66.89
Seed treatment with Provax	8.67 bc (17.12)	13.00 b (21.09)	7.00 b (15.32)	9.56 b (17.84)	63.33	58.95	67.70	62.76
Control	23.67 a (28.66)	31.67 a (34.22)	21.67 a (27.70)	25.67 a (30.19)	-	-	-	

Values in a column having same letter did not differ significantly (p=0.05) by LSD; values within the parentheses were the Arcsine Transformed values.

Table 3. Role of different carrier material based *T. harzianum* bio-fungicides on the shoot growth of tomato seedling in *F. oxysporum* inoculated seedbed soil.

Name of substrates	Shoot length (cm)				Shoot weight (g/plant)			
	1st year	2nd year	3rd year	Mean	1st year	2nd year	3rd year	Mean
Rice bran	27.43 b	15.87 de	24.50 b	25.93 a	7.38 b	5.51 b	8.07 ab	6.99 ab
Wheat bran	27.20 b	16.93 c	24.43 b	22.85 ab	7.37 b	5.54 b	6.97 bc	6.63 a
Grasspea bran	27.10 b	17.23 c	24.17 b	22.83 ab	7.42 b	5.57 b	7.63 b	6.87 ab
Rice bran + Wheat bran	30.13 a	19.33 a	32.13 a	27.20 a	8.01 a	6.48 a	8.47 ab	7.65 a
Rice bran + Grasspea bran	27.80 b	18.63 ab	33.60 a	26.68 a	7.29 b	6.24 a	10.03 a	7.85 a
Rice bran + Mustard oilcake	27.07 b	18.47 ab	31.67 a	25.74 a	7.36 b	6.24 a	9.17 ab	7.59 a
Rice bran + Wheat bran + MOC	27.67 b	16.60 cd	31.33 a	25.20 a	7.34 b	5.63 b	8.30 ab	7.09 a
Rice bran +Grasspea bran +MOC	27.87 b	18.40 b	31.40 a	25.89 a	7.35 b	6.49 a	8.50 ab	7.45 a
Wheat bran + Grasspea bran + MOC	27.57 b	18.13 b	33.00 a	26.23 a	7.59 b	6.71 a	9.13 ab	7.81 a
Wheat bran + Grasspea bran+ Rice bran + MOC	27.80 b	16.73 cd	30.13 a	24.89 a	7.59 b	5.60 b	8.50 ab	7.23 a
Seed treatment with Provax	27.13 b	15.47 ef	22.83 b	21.81 ab	5.64 c	4.43 c	5.20 cd	5.09 c
Control	23.53 c	14.87 f	16.13 c	18.18 b	4.66 d	4.10 c	4.23 d	4.33 c

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

Table 4. Role of various carrier material based *T. harzianum* bio-fungicides on the root growth of tomato seedling in *F. oxysporum* inoculated seedbed soil.

Name of substrates	Root length (cm)				Root weight (mg/plant)			
	1st year	2nd year	3rd year	Mean	1st year	2nd year	3rd year	Mean
Rice bran	7.20 b	6.93 b	8.47 b	7.53 abc	0.45 b	0.55 ab	0.71 ab	0.57 ab
Wheat bran	7.50 b	7.07 ab	6.87 cd	7.15 bc	0.42 e	0.50 b	0.72 ab	0.55 ab
Grasspea bran	7.97 b	7.47 ab	8.13 bc	7.86 ab	0.43 d	0.52 b	0.71 ab	0.55 ab
Rice bran + Wheat bran	7.77 b	7.20 ab	8.93 b	7.97 abc	0.43 d	0.58 a	0.95 a	0.65 a
Rice bran + Grasspea bran	7.43 b	7.87 ab	8.97 b	8.09 abc	0.43 d	0.54 ab	0.85 ab	0.61 a
Rice bran + Mustard oilcake	7.40 b	7.20 ab	9.73 ab	8.11 abc	0.42 e	0.57 a	0.93 a	0.64 a
Rice bran + Wheat bran + MOC	7.67 b	7.23 ab	9.23 ab	8.04 abc	0.43 d	0.52 b	0.87 a	0.61 a
Rice bran +Grasspea bran +MOC	8.50 b	8.27 a	9.53 ab	8.77 a	0.43 d	0.56 ab	0.90 a	0.63 a
Wheat bran + Grasspea bran + MOC	7.13 b	7.20 ab	10.67 a	8.33 ab	0.44 c	0.58 a	0.91 a	0.64 a
Wheat bran + Grasspea bran+ Rice bran + MOC	10.17 a	7.80 ab	8.53 b	8.83 a	0.46 a	0.58 a	0.81 ab	0.62 a
Seed treatment with Provax	7.73 b	5.80 c	6.27 de	6.60 c	0.37 f	0.42 c	0.67 ab	0.49 bc
Control	5.50 c	4.70 d	4.97e	5.06 d	0.33 g	0.39 d	0.54 b	0.42 c

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

e) Effect of Provax

Treatment of seedbed soil infested with *F oxysporum* with Provax also reduced the incidence of foot and root rot and increased shoot and root growth of tomato seedlings over control. However, its efficacy was lower compared to bio-fungicides (Tables 1- 4).

Results of the present experiment reveal that efficacy of all *T harzianum* based bio- fungicides multiplied on rice bran, wheat bran, grasspea bran used alone or in different combinations mixed with or without MOC are effective to control foot and root disease of tomato seedling in seedbed and to achieve satisfactory increase in seed germination, pre- and post-emergence seedling mortality. Similar findings have been reported by other researchers (Bentez *et al.,* 2004; Mausam *et al.,* 2007; Pros ad and Anes, 2008; John *et al.,* 2010). The fungus *Trichoderma harzianum*, a well-known antagonistic fungus 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). It was reported that *T. harzianum* remarkably proliferated the root system and accelerated biological nitrogen fixation in addition to the reduction of diseases caused by *F. oxysporum* and *Pythium* spp. in legume crops (John *et al*., 2010). This findings are in accordance with the observation of the present study where soil is treated with different carrier material based *T. harzianum* bio-fungicides that enhanced the growth of tomato 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 is significant increase in emergence, shoot and root length and also shoot and root weights of tomato seedling due to *T. harzianum* bio-fungicides which is supported by the findings of many investigators (Prasad and Anes, 2008; Mishra and Sinha, 2000; Chaur-Tsuen and Chien-Yih, 2002). Enhanced seed germination due to *Trichoderma* species has also been reported by Mukhtar (2008). It has been 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 has been noticed by Tjamos *et al*. (1992) that *T. harzianum* controls *F. oxysporum* by competing for both rhizosphere colonization and nutrients. They observe that bio-control of targeted pathogen became more effective with the decline of nutrient concentration of the soil. The study confirm 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).

Rice bran based *Trichoderma* bio-fungicide gave maximum seed germination, reduced seedling mortality and increased growth of tomato seedling. Similar observation with wheat and rice bran for the formulation of *T harzianum* bio-fungicide was reported by Sangeetha *et at.* (1993). Disease incidence of tomato, water melon and cotton was reported to be reduced considerably by the application of *T harzianum* (Sivan and Chet, 1986). 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.

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TECHNICAL AND ECONOMIC PERFORMANCE OF COMBINED HARVESTER IN FARMERS' FIELD

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Abstract

Labour scarcity, harvesting loss, timely harvesting and harvesting cost are crucial in rice and wheat harvesting in Bangladesh. Combine harvester is a newly introduced harvesting machine in Bangladesh. This study was undertaken to evaluate the technical and economic performance of combine harvester available in farmers' field and farmer's perception regarding the use of combine. Field tests of two new (CLASS andDaedong) and two refresh (Kukje and Anower) combine harvesters were conducted for harvesting rice and wheat in the farners' field of Jessore, Pabna,Dinajpurand Thakurgaon districts during 2011-12. Primary data were collected from 30 adopter and 30 non-adopter farmers from each district of Bogra, Rangpur, Dinajpur and Thakurgaon through direct interviewingduring 2012-13. Information was also collected from different combine harvester traders available in Bangladesh. Average time, cost and grain saving by combine harvester over manual methods were 97.50, 35.00 and 2.75%, respectively. Benefit cost ratio of CLASS, Daedong, Kukje and Anower combine harvesters were found to be 2.68, 2.11, 2.29 and 2.70, respectively. The payback periods of refresh combine harvesters were lower than the new combine harvester. There were some mechanical problems observed in refresh combine harvesters during field operations. New harvester was observed almost trouble free and popular to the famers. Scarcity of spare parts and mechanic service were the main problems for repair and maintenance of the combine harvesters in farm level. Considering the technical performance of combine harvester and demand of the farmers, new combine harvester may be introduced in commercial basis in Bangladesh.

Keywords: Benefit cost ratio, field capacity, harvesting efficiency,harvesting loss, payback period, rice, wheat.

Introduction

Rice and wheat are the most important and staple food of Bangladesh. At present, rice and wheat production is about 30.52 million ton over an area of 11.73 million hectares. More than 80% of the cultivable land is under rice and wheat cultivation (Talukder, 2013). Almost allamount of these crops are harvested manually by sickle which is laborious, time consuming and costly. Harvesting and threshing are the most important operations in the entire range of field

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operations, which are laborious involving human drudgery and requires about 150-200 man-h/ha for harvesting of paddy alone (Salassi and Deliberto, 2010; Veerangouda*et al.*, 2010).

Timely harvesting is utmost important, as delayed harvesting leads to a considerable loss of grain and straw owing to over maturity resulting in loss of grains by shattering and also delays in seed bed preparation and sowing operations for the next crop. The paucity of labour in the peak harvesting season is forcing the farmers delay harvesting causing high postharvest losses and sometimes loss of the crop by natural calamities. Due to increase of cropping intensity and production of different crops, the demand of agricultural labour has increased significantly. The labour scarcity is very high during the harvesting period of wheat and *boro* rice (Ahmmed, 2014). On the other hand, many agricultural labours have been migrating to other off-farm activities like garments and other industries, transportation, small business, road and building construction, etc. Due to delay harvesting, a large quantity of grain is lost each year in the country. Bala et al.*(*2010) reported that post harvest losses of rice at farm level were 9.49%, 10.51% and 10.59% for *aman*, *boro* and *aus* season respectively.

To reduce the harvesting loss and cost, timely harvesting of paddy and wheat is very important. A well designed, combine harvester can play an important role in harvesting of paddy and wheat in time, efficiently and in less cost. There are different types of combine harvestersintroduced by different traders and DAE (Department of Agriculture Extension) and using in the farmers' fields. Therefore, this study was undertaken to evaluate the technical and economic performance of combine harvestersavailable in farmers' fieldsand to find out the suitability of the machines in the socio-economic conditions of the farmers of Bangladesh.Main features of different types of combine harvesters imported/made by different companies are given in Table 1. The Metal Private Limited, ACI Motors and Corona Tractors Limited started to import combine in 2008, 2010 and 2011, respectively. The Metal Private Limited imported new CLAAS combine harvester from India. ACI Motors imported both new and refresh Daedong combine harvester from South Korea. The Corona Tractors Limited imported both new and refreshDaedong and Kukje combine harvesters from South Korea. CLAAS had both wheel type and crawler type combine harvester whereas Daedong and Kukje had crawler type combine harvester. Wheel type combine harvester is suitable in dry land harvesting especially for wheat harvesting. On the other hand, crawler type combine harvester can be used in wet land harvesting. It can also be used in dry land but wheel type was difficult in use in wet land harvesting. The Metal Private Limited and ACI Motors sold 69% and 90%, respectively of their imported combine harvesters but

Corona Tractors Limited and AnowerHossain could not sell any combine harvesters up to the data collection time. Engine power, weight, cutting width, grain tank capacity and field capacity of CLAAS combine were higher than other combine harvesters. Also the price of CLAAS combine harvester was much higher than Daedong and Kukje combines. Price of new Daedong combine was Taka 25,000,00, whereas the price of refresh combine (800 hours used) of same model was Taka 9,40,000. The price of AnowerHossain fabricated combine harvester was the lowest, Taka 7,50,000. Anower's combine harvester worked well in both dry land and wetland conditions but it was not extensively used and not commercialized.

Materials and Method

In 2010, refresh combine harvesters were imported from South Korea by ACI Motors Limited and was sold to the project "Enhancement of crop production through farm mechanization" implemented by Department of Agriculture Extension (DAE). The Metal Private Limited, ACI Motors and Corona Tractors Limited are the main importers of combine harvesters in Bangladesh. Mr. AnowerHossain of Fulbari, Dinajpur fabricated two combine harvesters locally (Fulbari Engineering Workshop, Fulbari, Dinajpur) in 2012 withmost of the spare parts of other rejected imported combine harvesters (Prothomalo, 2013). He used a 35 hp single cylinder old diesel engine as power source. He also made some parts with locally available materials such as reel, conveyer belt, thresher, etc.

Refresh combine harvesters (Daedong (DSM-55) and Kukje (KC-515)) were tested in the farmers field for harvesting rice and wheat in Dinajpur and Jessore and new combine harvesters, CLASS (Crop Tiger 30) and Daedong (DSC48) were tested inThakurgaon and Pabna during 2010-11. Most of the owners used the combine harvesters commercially rented for harvesting wheat, transplanted *aman* rice and *boro* rice. Data were collected directly from farmers' field during operation. Harvesting suitability, capacity, fuel consumption, problems during operation and farmers perceptions were recorded during operation in the farmers' fields. Data were also collected from marketing companies (traders) of combine harvester such as ACI Motors, The Metal Private Limited and Corona Tractors Limited through structured questionnaire during 2011-12. During 2012-13 field survey were conductedin the farmersfields in Sherpurupazila of Bogra,Fulbariupazil of Dinajpur, Baliadangaupazila of, Thakurgaon and Peergonjupazila ofRangpur districts. The study locations were selected purposely where combine harvesters were used for harvesting rice and wheat. The respondents were, farmers and they were categorized as adaptor and non-adaptor groups. Thirty adaptor farmers and 30 non-adaptor farmers were interviewed through pre-tested questionnaire.

Table 1. Main features of different types of combine harvesters.

Brand, model and country of manufacture	CLAAS (Crop Tiger30) India	Daedong (DSC48) South Korea	Daedong (DSM55) and Kukje (KC515) South Korea	Anower (Given name) Dinajpur Bangladesh
1. Trader/fabricator	The Metal (Pvt.) Ltd.	ACI Motors	Corona Tractors Ltd.	AnowerHossain
2.Year of starting marketing	2008	2010	2011	2012
3.Total numbers imported/made	29	40	45	2
4.Total number sold	20 (69%)	36 (90%)	-	-
5. Condition	New	New	Refresh	Refresh
6.Type of combine	Crawler and wheel	Crawler	Crawler	Wheel
7. Overall dimensions (L×W×H) (m)	6.99×2.96×3.66	4.34×1.78×2.27	4.33×1.86×2.21	3.96×2.13×2.44
8. Engine power (hp)	60	50	50	35
9.Weight (kg)	4620	2180	2560	-
10. Cutting width (m)	2.60	1.44	1.44	2.00
11.Threshing mechanism	Axial flow	Head feed	Head feed	Head feed
12.Capacity of grain tank (kg)	1000	80	80	500
13. Price (Taka)	Wheel type 28,50,000 Crawler type 42,00,000	25,00000	9,40,000	7,50,000

Depreciation of combine harvester was calculated by straight line method. Gross return was obtained from income generated by each of the combine harvester from custom hire basis during the harvesting of *aman* rice, *boro* rice and wheat in a year. Seasonal use, harvesting rate, fuel consumption, operator's wage etc. data were collected from the selected locations by direct interviewing of the combine harvester owners and adopter farmers.Data were analyzed by standard statistical methods and presented in tabular form.

Results and Discussion

Field performance evaluation

The field performance of different types of combine harvesters are given in Table 2. The threshing mechanism of CLASS combine harvester was axial flow mode but other combine harvesters had head feed mode. The highest theoretical and effective field capacities were found for CLASS combine harvester due to its highest width of cut and forward speed. The filed capacities of Daedong and Kukje combine harvesters were almost similar but the lowest field capacity was found for AnowerHossain's combine harvester. The reason might be that AnowerHossain'scombine harvester was operated at the lowest forward speed,because this combine harvester was operated by a single cylinder engine and more vibration at higher speed. The harvesting efficiencies of all combine harvesters were found above 95% and those quite good for harvesting rice. Grain loss of rice was higher that of wheat because normally shattering loss of rice is higher than wheat. Kabir and Zaman found 4.62% field loss during harvesting of *boro* rice by CLASS combine harvester. Pawar et al. (2008) reported that total field loss of combine harvester for wheat in India was 4.20%. So, the data presented in this study agreed well with this result.During harvesting of crops by combine harvester, harvesting, threshing and winnowing are done at a time. So, the colour and appearance of grains remains same as for standing crops. But for manual harvesting, threshing and winnowing methods, these operations are done separately and different times. Therefore, the colour of grains becomes pale. In machine harvesting method, the straw broken and fractured in axial flow mode and straw remained long but fractured in head feed mode of threshing. But in manual harvesting and threshing method straw remains well condition. This was a disadvantage of combine harvesters reported by the farmers.

Uses of different types of combine harvesters during 2011-12 are given in Table 3.Total operating days per year for harvesting rice and wheat during 2011-12 by 3 model (CLAAS (Crop Tiger 30), Kukje (KC-515)/ Daedong (DSM55) and Anower model) were 40 days but that ofDaedong (DSC48) model was25 days. The reason was that Daedong (DSC48) had some mechanical problems during the *boro* rice harvesting season.In this period The Metal (Pvt.) Limited, ACI Motors, Corona Tractors Limited and AnowerHossain used 25, 4, 25 and 2

Table 2. Field performance of different types of combine harvesters.

Items		CLAAS Crop Tiger 30	Daedong (DSC48)	Daedong (DSM-55) and Kukje (KC-515)	Anower
1. Average forward speed (km/h)		3.00	2.65	2.50	1.75
2. Theoretical field capacity (ha/h)		0.78	0.38	0.36	0.35
3. Effective field capacity (ha/h)		0.62	0.30	0.28	0.26
4. Field efficiency (%)		79.49	78.94	77.78	74.29
5. Harvesting efficiency (%)		97.65	96.43	95.88	96.78
6. Total grain loss (%): Rice		4.42	4.63	4.58	4.38
	Wheat	3.84	4.06	3.98	3.88
7. Fuel consumption (L/ha)		18.50	18.50	21.00	15.00
9. Condition of grains		Clean and bright colour	Clean and bright colour	Clean and o bright colour	Clean and bright colour
10. Condition of straws		Partially broken and fractured and thrown in the field	Remained long but partially fractured and thrown in the field	Remained long but partially fractured and thrown in the field	Remained long but partially fractured and thrown in the field

numbers of combine harvesters, respectively for harvesting of rice and wheat. With these combine harvesters, The Metal Private Limited, ACI Motors and Corona Tractors Limited and AnowerHossainharvested 203, 57 and 410 and 15 ha of crops, respectively. AnowerHossain could not harvest any wheat during 2011-12 period because his harvesters were not completed in fabrication before wheat harvesting season. Average harvested by one harvester per year was the highest by Kukje (KC-515)/ Daedong (DSM55) combine harvester followed by Daedong (DSC48), and CLAAS (Crop Tiger 30) models and the lowest was recorded for Anower model.

Table 3.Uses of different types of combine harvesters in the farmers' fields during 2011-12.

Items	The Metal (Pvt.) Ltd.	ACI Motors	Corona Tractors Ltd.	AnowerHossain
Model of combine harvester	CLAAS (Crop Tiger 30)	Daedong (DSC48)	Kukje (KC-515)/ Daedong (DSM55)	Anower
1.Operation days per year	40	25	40	40
2.Total numbers used	25	4	25	2
3.Total area harvested (ha/yr)	203.00	57.00	410.00	15.00
(a) Aman rice	61.00	20.00	130.00	-
(b) Boro rice	61.00	27.00	140.00	15.00
(c) Wheat	81.00	10.00	140.00	-
4. Average area harvested by each harvesters (ha)	8.12	14.25	16.40	7.50

The Metal Private Limited imported 29 numbers of combine harvesters and sold 20 numbers since 2008. Among 20 combine harvesters, 13 were sold to government organizations and seven were sold to farmers (Table 4). The ACI Motors imported 40 numbers of combine harvesters and sold 36 numbers since 2010. Among them, only one combine harvester was sold to farmer and another 35 were sold to government organizations. ACI Motors sold 25 refresh combine to DAE and other sold combine harvesters were new. The Corona Tractors Limited could not sell any combine harvester although they imported 45 in 2011. They were mainly using these combine harvesters for demonstration and custom hire service. Mr. AnowerHossain of Dinajpur fabricated two combine harvesters locally in 2012 and harvested *boro* rice on custom hire basis during of 2013 in Dinajpur area.

Table 4. Numbers of combine harvesters sold/demonstrated by different companies.

The Metal (Pvt.) Ltd.		ACI Motors		Corona Tractors Ltd.	
District/ Organization	Number	District/ Organization	Number	District/ Organization	Number
BADC	12	DAE (Refresh)	25	Faridpur	1
BAU	1	BARI (New)	3	Natore	1
Dinajpur (Farmer)	1	BADC (New)	6	Bogra	1
Comilla (Farmer)	1	BRRI (New)	1	Netrokona	1
BrahmonBaria (Farmer)	1	Dinajpur (New)	1		
Dhaka (Farmer)	1				
Bogra (Farmer)	1				
Joypurhat (Farmer)	1				
Mymensingh (Farmer)	1				
Total	20		36		4*

* Demonstrated only.

Field survey result

Socio-economic conditions of combine harvester adaptor and non-adopter farmers in the selected study areas are given in Table 5 and Table 6, respectively. Thirty adaptor farmers and 30 non-adaptor farmers were interviewed in each study area (district). Average age of an adaptor farmer (40.00 years) was higher than non-adaptor farmers (37.50 years) but their difference was not much higher. Age of adaptor farmers in the study areas ranged from 35 to 45 years. But the age of non-adaptor farmers in the same study areas ranged from 31 to 44 years.

In case of combine harvester adaptor farmers, they were all educated at different levels. But, average 12.57% of farmers were illiterate in the non-adaptor group. Degree level educated farmers were in the adaptor group. But in non-adaptor group no degree level educated farmers were found in Bogra, Rangpur and Dinajpur districts. Only 6.25% degree level non-adaptor farmers were in Thakurgaon district. It is evidence from the study that education was an important factor for adopting combine harvester for harvesting rice and wheat. It is observed from the tables that adaptor farmers owned more cultivated land than non-adaptor farmers. Generally rich farmers are more progressive and influential than the poor farmers in the society and the rich farmers come forward to adopt new technology. So, land size was another factor for adopting combine harvester. It is also observed from the table that both adaptor and non-adaptor farmers of Thakurgaon district cultivated wheat along with *aman* and *boro* rice.

Table 5. Socio-economic conditions of combine harvester adaptor farmers in the selected areas.

Parameters		Bogra	Rangpur	Dinajpur	Thakurgaon	Average
Age of respondents (year)		35	45	44	37	40
Education of respondents (%)	Illiterate	0	0	0	0	0
	Primary	36.36	28.57	42.86	31.25	34.76
	SSC	36.36	31.46	29.86	43.75	35.36
	HSC	18.18	25.47	25.28	6.25	18.80
	Degree	9.10	14.50	2.00	18.75	11.09
Cultivated land (ha)		1.87	2.13	1.60	4.00	2.40
Aman (ha)		1.73	1.73	1.60	2.40	1.87
Boro (ha)		1.73	1.73	1.60	0.80	1.46
Wheat (ha)		0	0	0	2.00	0.50
Other crops (ha)		0.42	0.35	0.23	1.56	0.64

Table 6. Socio-economic conditions of combine harvester non-adaptor farmers in the selected areas.

Parameters		Bogra	Rangpur	Dinajpur	Thakurgaon	Average
Age of respondents (year)		31	34	44	41	37.50
Education of respondents (%)	Illiterate	8.33	15.87	13.58	12.50	12.57
	Primary	41.67	35.20	43.56	37.50	39.48
	SSC	36.42	30.56	28.57	27.00	30.64
	HSC	13.58	18.37	14.29	16.75	15.75
	Degree	0	0	0	6.25	1.56
Cultivated land (ha)		1.07	0.67	1.06	1.46	1.06
Aman (ha)		1.06	0.53	0.93	0.93	1.07
Boro (ha)		1.06	0.40	1.06	0.40	0.86
Wheat (ha)		0	1.07	0	0	0.73
Other crops (ha)		0.34	0.36	0.14	0.86	0.43

Uses and resource saving by different combine harvesters in the selected study areas during 2012-13 are shown in Table 7. In Bogra and Thakurgaon CLASS combine harvester was used for harvesting *boro* rice and wheat, respectively. Crawler type and wheel type combine harvesters were used for harvesting rice and wheat, respectively. In Rangpur, crawler type Kukje combine harvester was used for harvesting *boro* rice. In Dinajpur, Mr. AnowerHossainmade combine harvester was used for harvesting *boro* rice. Mr. Al Amin of Sherpurupazila, Bogra bought CLASS combine harvester in 2009. He harvested his own crops, 23 ha and used it for other farmers' field as custom hire basis. Corona Tractor Limited and The Metal (Pvt) Limited harvested rice and wheat in Rangpur and

Thakurgaon, respectively. All the study areas, custom hire basis was used for harvesting of rice and wheat. Harvesting charge varied from location to location. The highest harvesting charge of rice was in Bogra (10,500 Tk./ha) and the lowest was in Rangpur (9,000 Tk./ha). The reason was that in Bogra harvesting was done commercially by a combine harvester owner but in Rangpur, harvesting was done under a demonstration type program by a company. By combine harvester harvesting threshing and winnowing are done at a time but in manual method these operations are done simultaneously. In manual method average harvesting, threshing and winnowing cost per hectare (Tk. 16131) was 35% higher than average cost of harvesting (Taka 10500) by combine harvester. Pawar et al. (2008) reported the cost of operation for combine harvester was (817.84 Rs/ha) was less than the combination of self propelled reaper with thresher (1816.79 Rs/ha). Average time saving for harvesting, threshing and winnowing of rice and wheat by combine harvester over manual method was 97.5%. Average 2.75% of grain loss reduced by harvesting of rice and wheat by combine harvester. Time and grains savings attracted the farmers for using combine harvester.

Economic performance

Economic performance of different types of combine harvesters in farm level is given in Table 8. The basic data presented in this table were collected from the combine harvester owner. Economic lives of new and refresh combine harvesters were assumed to be 10 and five years, respectively. During the harvesting season, combine harvester was effectively operated for 10 hours in a day.The highest gross return was obtained from CLASS combine harvesters followed by Daedong and Kukje combine harvesters. The highest net return was found from CLASS combine harvesters (37,20,000 Tk./year) followed by Anower combine harvester. The net return from Daedong and Kukje combine harvesters were similar. The highest benefit cost ratio (BCR) was obtained from Anower combine harvester followed by CLASS, Kukje and Daedong combine harvesters. The reason was that the fixed and variable costs of Anower combine harvester were the lowest due to its lowest price, lowest fuel consumption and low cost of somelocally made spare parts. But the harvesting charge was the same for all types of combine harvesters. BCR of CLASS, Daedong, Kukje and Anower combine harvesters were found to be 2.68, 2.11, 2.29 and 2.70, respectively. Thepayback periods of refresh combine harvesterswere the lower than the new ones due to lower price of refresh combine harvesters. Thoughthe highest BCR and low payback period of Anower model were obtained, it is hardly possible to make it commercially available in large scale due to multivariable spare parts. So, new and refresh combine harvester may be introduced. Because, a good demand of use of combine harvester has been created in the study areas.

Table 7. Uses and resources saving of combine harvester in farm level in the selected areas during 2012-13.

Parameters	Bogra	Rangpur	Dinajpur	Thakurgaon	Average
Type of combine harvester used	CLASS (Crawler)	Kukje (Crawler)	Anower (Wheel)	CLASS (Wheel)	-
Entrepreneur of combine harvester	Mr. Al- Amin SherpurBogra	Corona Tractors Ltd., Dhaka	AnowerHossainFulbariaDinajpur	The Metal (Pvt.) Ltd. Dhaka	-
1. Crop harvested by combine	Boro rice	Boro rice	Boro rice	Wheat	-
2. Harvesting charge by combine harvester (custom hire basis) (Tk./ha)	11500	9000	11000	10500	10500
3.Total manual HTW* cost (Tk./ha)	16200	14700	16750	16875	16131
4. Time required by combine harvester for HTW (man-day/ha)	0.94	1.25	1.44	0.60	1.06
5. Cost saving over manual HTW (%)	29.01	38.78	34.32	37.78	34.97
6. Time saving over manual HTW (%)	97.65	96.88	96.40	99.00	97.48
7. Grain loss reduction by combine harvester over manual HTW (%)	3.00	3.00	2.00	3.00	2.75

HTW = Harvesting, threshing and winnowing, Time required for manual HTW = 40 man-day/ha.

Table 8.Economic performance of different combine harvesters in farm level.

Cost items	CLASS (Crop Tiger 30) (New)	Daedong (DSC48) (New)	Kukje (KC-515) (Refresh)	Anower (Refresh)
1.Price (Tk.)	42,00,000	25,00,000	9,40,000	7,50,000
2. Economic life (year)	10	10	5	5
3. Depreciation (Tk./yr)	3,78,000	2,25,000	1,69,200	1,35,000
4. Bank interest (14%) (Tk./yr)	3,23,400	1,92,500	72,380	57,750
5. Shelter (Tk./yr)	10,000	10,000	10,000	10,000
a. Fixed cost (3+4+5) (Tk./yr)	7,11,400	4,27,500	2,51,580	2,02,750
6. Effective harvesting hour per day	10	10	10	10
7. Average harvesting hour per year (Aman-15, boro-25, wheat-20 days)	600	600	600	600
8. Fuel (diesel) consumption (L/h)	18.5	18.5	21.0	15.0
9. Harvested area (ha/year)	372	180	168	156
10. Fuel and oil cost (Tk./year)	5,01,740	2,53,100	2,71,960	1,83,800
11. Repair and maintenance cost (Tk./ year)	60,000	60,000	1,00,000	80,000
12. Operators cost(One operator + two helpers) (Tk/year)	1,00,000	1,00,000	1,00,000	1,00,000
13. Other cost (Tk./year)	10,000	10,000	10,000	10,000
b. Variable cost (10+11+12+13) (Tk/year)	6,71,740	4,23,100	4.81,960	3,73,800
c. Total cost (a+b) (Tk/year)	13,83,140	8,50,600	7,33,540	5,76,550
d. Gross return (Tk/year)	37,20,000	18,00,000	16,80,000	15,60,000
e. Net return (d-c) (Tk/year)	23,36,890	9,49,400	9,46,460	9,83,000
f. Benefit cost ratio (d/c)	2.68	2.11	2.29	2.70
g. Payback period (year)	1.80	2.63	0.99	0.76

Price of diesel = 70 Tk./L and lubricating oil = 400 Tk./L, harvesting charge 10,000 (Tk/ha).

Farmers' opinions

Almost 100% farmers are interested and happy for using combine harvester on custom hiring basis. They expressed the following reasons of their satisfaction and also opined the disadvantages in using combine harvester.

Advantages

(a) Combine harvesting reduces the human drudgery
(b) It is very quick harvesting method
(c) Harvesting, threshing and winnowing are done at a time and no space is required for threshing and winnowing
(d) It saves the crop from natural calamities as well as shattering loss due to over maturity
(e) It reduces grain loss compared to conventional harvesting, threshing and winnowing methods
(f) It reduces the dependency of scarce farm labour during peak harvesting season. It also reduces turn around time for planting next crop
(g) Harvesting cost is lower than those of manual harvesting, threshing and winnowing of crops.

Disadvantage

(a) There is no road for transportation of combine harvester through crop field and canal
(b) Price is too high and not affordable to the farmers
(c) Sometimes mechanical disturbances occurred during operation of the machine
(d) It is difficult to harvest inclined (>45^{o}) crops
(e) Rice straw is partially and wheat straw is fully damaged and spread out in the field
(f) For small plot, harvesting by combine harvester is difficult. Corner of the field cannot be harvested properly
(g) If mud in field is more than 15 cm and sticky harvesters cannot work. Combine harvester is not readily available during the peak harvesting season
(h) Spare parts and skill mechanic are scarce in the rural areas for repair and maintenance of combine harvester
(i) Lack of trained operator for efficient field operation of combine harvester.

Conclusion

The Metal Private Limited, ACI Motors and Corona Tractors Limited are mainly marketing new and refresh combine harvester in Bangladesh. The Metal Private

Limited is marketing new CLAAS (India) combine suitable for harvesting both rice and wheat. There are problems of frequent mechanical disturbances and shattering loss of refresh Daedong and Kukje combines. Average time, cost and grain saving by combine harvester over manual methods were 97.5%, 35% and 2.75%, respectively. The benefit cost ratio of CLASS, Daedong, Kukje and Anower combine harvesters were found to be 2.68, 2.11, 2.29 and 2.70, respectively. The payback periods of refresh combine harvesters were lower than the new combine harvester.There were some mechanical problems were observed in refresh combine harvesters during field operations. New harvester was observed almost trouble free and popular to the famers. Scarcity oftrained operator, mechanic service and spare parts are the main problemsin operation, repair and maintenance of the combine harvesters in the field level. Considering the technical performance of combine harvester and demand of the farmers, new combine harvester may be introduced in commercial basis in Bangladesh.

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GENETIC VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS IN *BRASSICA rapa* L. GENOTYPES

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Abstract

Thirty three genotypes of *Brassica rapa* L. were evaluated in order to find out their inter-genotypic variability; character association and path coefficient of seed yield/plant and its component characters. BARI sarisha-6 x TORI-7 S-45 showed best result in terms of early maturity (75 days) and higher seed yield/plant (5.28g) than check varieties. The character, plant height, was highly influenced by the environment whereas, all other characters influenced the least. Number of secondary branches/plant showed the highest phenotypic and genotypic coefficient of variation. Moreover, number of siliquae/plant, number of secondary branches/plant and number of primary branches/plant showed high heritability (93.16%, 75.69% and 68.03%, respectively) couple with high genetic advance in percent of mean (37.74%, 73.55% and 26.82%, successively). The seed yield/plant showed significant positive correlation with number of siliquae/plant (r_g = 0.7011**, r_p = 0.5684**), number of primary branches/plant (r_g = 0.5611**, r_p = 0.4016*) and number of secondary branches/plant (r_g = 0.5160**, r_p = 0.4098*) revealing that selection based on these traits would be judicious. Path analysis showed that the number of siliquae/plant (0.4679), number of primary branches/plant (0.2823) and number of secondary branches/plant (0.0092) were the most important contributors to seed yield/plant. The results indicated that number of siliquae/plant, number of primary branches/plant and number of secondary branches/plant can be used as selection criteria to increase seed yield/plant in rapeseed.

Keywords: Genetic variability, heritability, character association, path analysis, *Brassica rapa* L.

Introduction

The seeds of *Brassica rapa* L. contain 42% oil and 25% protein (Khaleque, 1985). It also serves as important source of raw material for industrial use such as in making soaps, paints, hair oils, lubricants, textile auxiliaries, pharmaceuticals and so on. On the other hand, oil cakes and meals are used as animal feeds and manures. *Brassica rapa* L. occupies the first position in respect of area and production among the oil crops grown in Bangladesh (Anonymous, 2011). In this country, 0.252 million hectare of land was under rapeseed and mustard cultivation where produced about 0.271 million tons of seed with national

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average yield of 1.075 ton/ha during 2010-2011. Total annual edible oil production was about 0.833 million tons which is very low against the requirement of Bangladesh. Bangladesh imported 89.97 thousand tons of edible oil of rapeseed to meet up the annul requirement in the year of 2010-2011, which costs Tk.3718.457 million (Anonymous, 2011). The main reasons behind these are the use of low yielding local indigenous cultivars and low management practices (Hasanuzzaman and Karim, 2007). Although number of high yielding varieties have been released but short duration high yielding varieties are not enough. Thus, farmers still use low yielding indigenous varieties. Therefore, high yielding and short duration *Brassica rapa* L. varieties need to be developed to fit into the existing cropping pattern (Rice-Mustard-Rice).

Analysis of variability among the traits and the association of a particular character in relation to other traits contributing to yield of a crop would be of great importance in planning a successful breeding program (Mary and Gopalan 2006). Development of high-yielding cultivars is required a thorough knowledge of the existing genetic variation for yield and its components. The observed variability is a combined estimate of genetic and environmental causes, of which only the former one is heritable. However, estimates of heritability alone do not provide an idea about the expected gain in the next generation, but have to be considered in conjunction with estimates of genetic advance, the change in mean value among successive generations (Shukla *et al*., 2006). Seed yield is a complex character that can be determined by several components reflecting positive or negative effect upon this trait, whereas it is important to examine the contribution of each of the various components in order to give more attention to those having the greatest influence on seed yield (Marjanovic-Jeromela *et al*., 2007). Determination of correlation coefficients is an important statistical procedure to evaluate breeding programs for high yield, as well as to examine direct and indirect contributions to yield variables (Ali *et al.*, 2003). Path-coefficient technique splits the correlation coefficients into direct and indirect effect via alternative characters or pathways and thus permits a critical examination of components that influence a given correlation and can be helpful in formulating an efficient selection strategy (Sabaghnia *et al.*, 2010). Therefore, correlation in combination with the path coefficient analysis quantifies the direct and indirect contribution of one character upon another (Dewey and Lu, 1959). Hence the present study was conducted to find out the variability, character association and the direct and indirect effect of different characters on yield which are very important for launching an effective breeding program to select the desired plant types to meet the existing demand.

Materials and Method

Thirty-three *Brassica rapa* L. genotypes were used in this experiment where three of them were used as check. Among the genotypes, thirty were selected from F_9

segregating generation on the basis of their variation in different traits. The experiment was laid out in Randomized Complete Block Design with three replications at the field of Sher-e-Bangla Agricultural University farm, Dhaka, during rabi, 2011-2012. Each plot was 3 m long with two rows. Distance between row- row 30 cm and plant-plant 10 cm and block-block 1 m were maintained. Recommended doses of fertilizers and standard cultural practices were applied for raising healthy crops. Data were recorded on days to maturity, plant height (cm), number of primary branches/plant, number of secondary branches/plant, number of siliquae/plant, siliqua length (cm), number of seeds/siliqua, 1000 seed weight (g) and seed yield/plant (g). All the collected data of the study were used to statistical analysis. Analysis of variance (ANOVA), mean, range were calculated by using MSTATC software program and then phenotypic and genotypic variance was estimated by the formula used by Johnson *et al*. (1955). Genotypic and phenotypic co-efficient of variation were calculated by the formula of Burton (1952) and values were categorized as low (0-10%), moderate (10-20%) and high (20% and above) as suggested by Shivasubramanian and Menon (1973). Heritability was measured using the formula given by Singh and Chaudhary (1985) and the heritability percentage was categorized as low (0-30%), moderate (30-60%) and high (60% and above) as given by Robinson *et al.* (1949). Genetic advance for different characters under selection was suggested by Allard (1960). Genetic advance in percentage of mean was calculated and values were categorized as low (0-10%), moderate (10-20%) and high (20% and above) as per Johnson *et al*. (1955). Genotypic and phenotypic correlation coefficient was obtained using the formula suggested by Miller *et al.* (1958); and path co-efficient analysis was done following the method outlined by Dewey and Lu (1959).

Results and Discussion

Variability, heritability and genetic advance

Highly significant variation was observed among the genotypes for all the characters under study which revealed the presence of considerable variability among the studied genotypes. The number of siliquae/plant showed the highest range of variation (78.00 -180.33) which means the presence wide range of variation for this character. This character also showed the highest mean value (130.79). [Table 1]

BARI sarisha-6 x TORI-7 S-45 showed the earliest maturity (75 days) with higher yield/plant (5.28g) than check varieties. BARI sarisha-6 x TORI-7 S-62, BARI sarisha-6 x TORI-7 S-37, BARI sarisha-9 x BARI sarisha-6 S-62, BARI sarisha-6 x TORI-7 S-11 and BARI sarisha-6 x TORI-7 S-49 also showed higher yield/plant [5.78, 5.44, 5.72, 5.33 and 5.30g, respectively] with early maturity [80.33, 81, 83, 83 and 84.33 days, accordingly] than check varieties (BARI sarisha-6 and BARI sarisha-15). [Table 2]

Table 1. Variability parameters for seed yield and its contributing characters in 33 genotypes of *Brassica rapa* L.

Characters	GMS	EMS	Range	Mean	CV%	SE
DM	61.63**	12.19	75.00-90.00	83.97	5.54	0.47
PH	101.80**	0.40	78.33-113.33	93.56	6.86	0.65
NPBP	2.99**	0.50	4.33-9.00	5.88	15.06	0.09
NSBP	5.17**	45.27	1.33-7.33	3.04	23.36	0.07
NSP	1894.19**	0.04	78.00-180.33	130.79	15.23	2.00
SL	0.33**	1.83	4.64-6.29	5.29	6.91	0.04
NSS	15.51**	2.41	14.33-26.67	17.66	14.36	0.25
TSW	0.20**	0.03	2.50-3.53	2.95	9.84	0.03
SYP	1.53**	0.31	3.11-5.81	4.76	17.77	0.09

** Significant at 1% level of probability.

GMS = Genotypic mean sum of square, EMS = Error mean sum of square, CV% = Percent co-efficient of variation and SE = Standard error

DM = Days to maturity, PH= Plant height (cm), NPBP = Number of primary branches/plant, NSBP = Number of secondary branches/plant, NSP = Number of siliquae/plant, SL = Siliqua length (cm), NSS = Number of seeds/siliqua, TSW = 1000 seed weight (g) and SYP = Seed yield/plant (g).

Table 2. Mean performance of 33 genotypes of *Brassica rapa* L. for seed yield and its contributing characters.

Genotypes	Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant
BARI sarisha-9x BARI sarisha-6 S-73	85.33cde	95.50 b-g	6.67 b-e	1.67 ij	140.33gh
F_6 x BARI sarisha-9 S-89	85.67cd	87.87 kl	5.33f-i	3.67 def	110.00 nop
BARI sarisha-9x BARI sarisha-6 S-51	79.00 jk	90.47 g-l	4.67 hi	2.00 hij	122.00 lm
BARI sarisha-6 x TORI-7 S-19	85.33cde	93.63 d-j	6.67 b-e	3.00 e-h	132.00 h-k
BARI sarisha-9 x BARIsarisha-6 S-87	83.67d-g	78.33 m	5.67e-h	1.67 ij	115.00 mn
BARI sarisha-6 x TORI-7 S-62	80.33 ij	93.50 d-k	7.00 bcd	3.00 e-h	134.67g-k
BARI sarisha-9x BARI sarisha-6 S-42	85.00cde	96.53 b-f	5.67 e-h	2.67 f-i	150.00 d
F_6 x BARI sarisha-9 S-25	85.00cde	93.17 d-j	5.33 f-i	3.00 e-h	140.00 e-h
BARI sarisha-6 x TORI-7 S-45	75.00 l	98.33 b-e	6.00 d-g	3.67def	154.00 c
BARI sarisha-6 x TORI-7 S-29	80.67hij	93.73 d-j	6.33 c-f	2.00 hij	101.00 p
BARI sarisha-9x BARI sarisha-6 S-50	85.67 cd	89.40 h-l	5.67e-h	3.33 d-g	136.00 f-k
BARI sarisha-6 x TORI-7 S-49	84.33def	100.30 bc	6.00 d-g	3.67 def	141.33 d-h
F_6 x BARI sarisha-9 S-75	81.67ghi	91.43 f-l	5.00 ghi	2.33 g-j	102.67 op
F_6 x BARI sarisha-9 S-31	85.00cde	89.03 i-l	5.33 f-i	4.33 bcd	111.00 no
BARI sarisha-6 x TORI-7 S-11	83.00 e-h	90.70 g-l	5.67 f-i	5.00 bc	144.00 d-g
BARI sarisha-9x BARI sarisha-6 S-35	85.00cde	98.77 bcd	7.67 b	4.00 cde	148.00 cde
F_6 x BARI sarisha-9 S-19	85.00cde	101.10 b	5.00 ghi	2.33 g-j	143.67 d-g

BARI sarisha-6 x TORI-7 S-5	82.00 f-i	88.07 jkl	9.00 a	1.67 ij	121.33 lm
BARI sarisha-6 x TORI-7 S-48	86.00 cd	96.00 b-g	7.33 bc	3.00 e-h	170.00 b
F_6 x BARI sarisha-9 S-52	86.00 cd	95.50 b-g	6.33 c-f	4.33 bcd	180.33 a
F_6 x BARI sarisha-9 S-59	85.00cde	91.87 f-l	5.00 ghi	1.67 ij	110.00 nop
BARI sarisha-9x BARI sarisha-6 S-92	75.33 l	86.20 l	5.00 ghi	2.67 f-i	109.00 nop
BARI sarisha-6 x TORI-7 S-32	80.00 ij	91.13 f-l	6.33 c-f	2.33 g-j	129.67 jkl
F_6 x BARI sarisha-9 S-23	86.00 cd	95.47 b-g	5.67 e-h	2.33 g-j	130.00 i-l
F_6 x BARI sarisha-9 S-29	90.00 b	96.63 b-g	5.67 e-h	4.00 cde	138.33 e-j
F_6 x BARI sarisha-9 S-15	92.00 b	94.90 c-h	4.67 hi	1.67 ij	87.67 q
BARI sarisha-9x BARI sarisha-6 S-62	83.00 e-h	93.00 e-k	7.67 b	7.33 a	174.00 ab
BARI sarisha-9x BARI sarisha-6 S-81	87.00 c	89.07 i-l	5.67 e-h	2.67 f-i	145.33 c-f
BARI sarisha-9 xBARI sarisha-6 S-69	82.00 f-i	94.10 d-i	6.00 d-g	2.33 g-j	127.00 kl
BARI sarisha-6 x TORI-7 S-37	81.00hij	95.77 b-g	5.67 e-h	5.33 b	166.00 b
BARI sarisha-15	85.00cde	97.67b-e	5.33 f-i	1.33 j	78.00 q
TORI-7	77.00 kl	86.90 l	5.33 f-i	4.33 bcd	139.67 e-i
BARI sarisha-6	99.00 a	113.3 a	4.33 i	2.00 hij	84.00 q

Table 2. Continued.

Genotypes	Siliqua length (cm)	No. of seeds/ siliqua	1000 seed weight (g)	Seed yield/ plant (g)
BARI sarisha-9 x BARI sarisha-6 S-73	6.29 a	18.67 cde	2.90 g-l	5.56 abc
F_6 x BARI sarisha-9 S-89	5.75 b	17.67 c-g	3.30 abc	4.17 g-j
BARI sarisha-9 x BARI sarisha-6 S-51	5.18 ghi	18.67 cde	2.63 l-o	3.75bcd
BARI sarisha-6 x TORI-7 S-19	5.12 g-j	19.33 cd	2.57 no	4.47 e-i
BARI sarisha-9 x BARIsarisha-6 S-87	5.62 bcd	18.00 c-f	2.83 h-n	4.29 f-j
BARI sarisha-6 x TORI-7 S-62	5.51 b-f	16.67 e-i	2.97 e-j	5.78 a
BARI sarisha-9 x BARI sarisha-6 S-42	5.39 c-g	15.00 ij	3.07 c-h	5.70 a
F_6 x BARI sarisha-9 S-25	5.07 h-k	15.67 g-j	3.53 a	5.35 a-e
BARI sarisha-6 x TORI-7 S-45	4.77 klm	17.00 e-i	2.87 g-m	5.28 a-e
BARI sarisha-6 x TORI-7 S-29	5.20 f-i	16.67 e-i	3.23b-e	4.59 d-i
BARI sarisha-9 x BARI sarisha-6 S-50	4.84 klm	16.00 f-j	2.97 e-j	5.33 a-e
BARI sarisha-6 x TORI-7 S-49	5.22 f-i	16.00 f-j	3.03c-h	5.30 a-e
F_6 x BARI sarisha-9 S-75	5.50 b-f	17.33 d-h	2.97 e-j	5.04 a-g
F_6 x BARI sarisha-9 S-31	5.29 e-i	16.00 f-j	2.97 e-j	4.92 a-g
BARI sarisha-6 x TORI-7 S-11	5.56 b-e	18.00 c-f	2.83 h-n	5.33 a-e
BARI sarisha-9 x BARI sarisha-6 S-35	5.40 c-g	17.67 c-g	3.13 b-g	5.12a-f
F_6 x BARI sarisha-9 S-19	5.69 bc	17.67 c-g	3.13 b-g	4.58d-i
BARI sarisha-6 x TORI-7 S-5	5.05 h-k	16.00 f-j	2.93 f-k	4.94 a-d

BARI sarisha-6 x TORI-7 S-48	5.33 d-h	19.33 cd	2.67 k-o	5.27 a-e
F_6 x BARI sarisha-9 S-52	4.86 j-m	14.33 j	2.73 i-o	5.81 a
F_6 x BARI sarisha-9 S-59	5.29 e-i	17.00 e-i	3.30 abc	3.83 hij
BARI sarisha-9 x BARI sarisha-6 S-92	5.43 c-g	16.00 f-j	2.93 f-k	3.44 jk
BARI sarisha-6 x TORI-7 S-32	5.25 f-i	17.67 c-g	2.87 g-m	4.68 c-h
F_6 x BARI sarisha-9 S-23	5.29 e-i	19.33 cd	3.00 d-i	4.61 d-i
F_6 x BARI sarisha-9 S-29	5.00 i-l	18.00 c-f	2.73 i-o	4.85 b-g
F_6 x BARI sarisha-9 S-15	5.41 c-g	19.33 cd	2.60 mno	3.11 k
BARI sarisha-9 x BARI sarisha-6 S-62	5.40 c-g	15.33 hij	3.20 b-f	5.72 ab
BARI sarisha-9 x BARI sarisha-6 S-81	5.42 b-f	19.67 c	2.57 no	4.15 g-j
BARI sarisha-9 x BARI sarisha-6 S-69	5.64 bcd	16.33 f-j	2.70 j-o	4.19 g-j
BARI sarisha-6 x TORI-7 S-37	4.73 lm	17.33 d-h	2.87 g-m	5.44 a-d
BARI sarisha-15	4.64 m	22.00 b	3.27 a-d	4.25 f-j
TORI-7	5.06 h-k	16.33 f-j	2.50 o	3.80 hij
BARI sarisha-6	5.21 f-i	26.67 a	3.40 ab	4.59d-i

Yield is polygenically controlled and highly influenced by environment; selection based on yield alone is not effective. The range of mean values also could present a rough estimate about the variation of magnitude of divergence present among different genotypes. But genotypic and phenotypic coefficients of variation are of greater use in determining the extent of variability present within the materials. In the present investigation, the phenotypic variance and phenotypic coefficient of variation were higher than the corresponding genotypic variance and genotypic coefficient of variation for all the characters under study but in many cases, the two values differed only slightly suggesting the presence of environmental influence to some extent in the expression of these characters. On the other hand plant height showed the phenotypic variance (42.06) was much higher than the corresponding genotypic variance (29.87) which indicated that there was large influence of environment on this character. Number of siliquae/plant showed highest phenotypic variance (661.58) and genotypic variance (616.31). High genotypic variance indicates the better transmissibility of the character from parent to their offspring (Ushakumari *et al.*, 1991). Number of primary branches/plant showed low differences between the phenotypic variance (1.27) and genotypic variance (0.86) which indicated that there was less influence of environment on this character. Hosen (2008) showed least difference between phenotypic and genotypic variances for number of primary branches/plant. Low environmental influence was also observed in rest of the characters (number of siliquae/plant, number of secondary branches/plant, siliqua length, number of seeds/siliqua and thousand seed weight and seed yield/plant). Number of secondary branches/plant showed the highest phenotypic coefficient of variation (47.33) and genotypic coefficient of variation (41.17) which indicated that the genotypes were highly variable for this trait. The high phenotypic coefficient of variation and genotypic coefficient of variation observed are the evident of their high genetic variability that in turn offers good scope for selection. Yin (1989) reported the highest genotypic co-efficient of variation for number of secondary branches/plant. The moderate value of phenotypic coefficient of variation (19.67) and genotypic coefficient of variation (18.98) was observed for number of siliquae/plant which indicated the existence of adequate variation among the genotypes. Higher estimates of genotypic coefficient of variation was also observed by Rashid (2007) and maximum genotypic and phenotypic coefficients of variability were found for number of siliquae/plant by Ali *et al.* (2003). Moderate value of phenotypic coefficient of variation and genotypic coefficient of variation was observed for number of primary branches/plant, number of seeds/siliqua and seed yield/plant indicated the presence of considerable variability among the genotypes. Days to maturity showed low phenotypic coefficient of variation (5.60) and genotypic coefficient of variation (5.29) which indicated that the genotypes showed less variation for this trait. Sharma (1984) found low genotypic coefficient of variation and phenotypic coefficient of variation values. Less variation among the genotypes also showed in plant height, siliqua length and thousand seed weight. [Table 3]

Table 3. Estimation of some genetic parameters in respect of 33 genotypes of *Brassica rapa* L. for seed yield and its coresponding characters.

Characters	Genotypic variance	Phenotypic Variance	Genotypic Coefficient of Variation (GCV)	Phenotypic Coefficient of Variation (PCV)	Broad sense Heritability	Genetic Advance (%)	Genetic Advance in percent of Mean
Days to maturity	19.74	22.15	5.29	5.60	89.14	8.64	10.29
Plant height (cm)	29.87	42.06	5.84	6.93	71.01	9.49	10.14
No. of primary branches/plant	0.86	1.27	15.79	19.14	68.03	1.58	26.82
No. of secondary branches/plant	1.56	2.06	41.04	47.17	75.69	2.24	73.55
No. of siliquae/plant	616.31	661.58	18.98	19.67	93.16	49.36	37.74
Siliqua length (cm)	0.10	0.13	5.91	6.94	72.48	0.55	10.36
Number of seeds/siliqua	4.56	6.39	12.09	14.31	71.36	3.72	21.04
1000 seed weight (g)	0.06	0.08	8.13	9.85	68.20	0.41	13.84
Seed yield/plant (g)	0.41	0.71	13.40	17.74	57.05	0.99	20.85

The coefficient of variation shows only the extent of total variability and does not separate the variability into heritable and non-heritable portion. Therefore heritable variation can be found out with the greater degree of accuracy when heritability is studied in conjunction with genetic advance. Number of siliquae/plant showed high heritability (93.16%) with high genetic advance in percent of mean (37.74%). Similar result was also found by Rameeh (2013) for this trait. Number of secondary branches/plant exhibited high heritability (75.69%) with very high genetic advance in percentage of mean (73.55%). Mahmud (2008) found high heritability values along with high genetic advance in percentage of mean for number of secondary branches/plant. Number of seeds/siliqua and number of primary branches/plant showed high heritability (71.36% and 68.03%, respectively) coupled with high genetic advance in percentage of mean (21.04% and 26.82%, accordingly). Similar result was also reported by Mahmud (2008) for number of seeds/siliqua and number of primary branches/plant successively. As a whole, high heritability with high genetic advance in percent of mean indicated that the character is mostly governed by additive gene effects, hence their improvement can be done through mass selection. These results confirm the findings of Aytac *et al*. (2008) and Ali *et al.* (2003), and selection based on phenotypic performance of these characters would be judicious for future breeding program. Days to maturity, siliqua length and plant height also exhibited high heritability (89.14%, 72.48% and 71.01%, respectively) with moderate genetic advance in percentage of mean (10.29%, 10.36% and 10.14%, accordingly). This indicated that a trait having high heritability did not essentially produce high genetic advance. However, characters showed high values of heritability coupled with moderate genetic advance suggest that greater role of non-additive gene action in their inheritance, which supported limited scope of improvement by direct selection; heterosis breeding could be useful for improving these traits (Paikhomba *et al.*, 2014). Moderate heritability (57.05%) and high genetic advance as percent of mean (20.85%) was observed for seed yield/plant which also indicated limited scope for the improvement through individual plant selection (John *et al.*, 2013). [Table 3]

Depending upon the variability, heritability and genetic advance in percentage of mean, it could be predicted that improvement by direct selection was possible in *Brassica rapa* L. for traits like number of siliquae/plant, number of secondary branches/plant and number of primary branches/plant.

Correlation co-efficient

Correlation co-efficient revealed that most of the characters showed the genotypic correlation co-efficient higher than the corresponding phenotypic correlation co-efficient suggesting a strong inherent association between the

characters studied, the phenotypic expression of the correlation being reduced under the influence of the environment. Similar result was found by Pankaj *et al.* (2002). In few cases, phenotypic correlation co-efficient were higher than their corresponding genotypic correlation co-efficient suggesting that both environmental and genotypic correlation acted in the same direction and finally maximized their expression at phenotypic level.

However, number of siliquae/plant showed highly significant positive interaction with seed yield/plant ($r_g = 0.7011^{**}$, $r_p = 0.5684^{**}$). Rameeh (2011) also reported that number of siliquae/plant had significant positive correlation (0.80^{**}) with seed yield. So any change or variation for this trait will have considerable effect on seed yield/plant. Similar result was also found by Esmaeeli-Azadgoleh *et al.* (2009) and Marjanovic-Jeromela *et al.* (2007). Seed yield/plant showed positive significant interaction with number of primary branches/plant ($r_g = 0.5611^{**}$, $r_p = 0.4016^{*}$) and number of secondary branches/plant ($r_g = 0.5160^{**}$, $r_p = 0.4098^{*}$) at both genotypic and phenotypic level. That indicated that branching was an important contributor to seed yield/plant, this result supported by Thurling and Das (1980). [Table 4]

On the other hand, seed yield/plant had negative significant interaction with number of seeds/siliqua ($r_g = -0.4239^{*}$) at genotypic level and negative non-significant interaction at phenotypic level ($r_p = -0.1824$). Malik *et al.*, (2000) reported that number of seeds/siliqua had negative correlation with seed yield/plant. Siliqua length also showed negative non-significant interaction with seed yield/plant ($r_g = -0.1014$, $r_p = -0.0246$) at both the levels. Nasim *et al.* (1994) found significant negative correlation between seed yield/plant and siliqua length. [Table 4]

Seed yield/plant showed non-significant positive interaction with thousand seed weight ($r_g = 0.2254$, $r_p = 0.078$) and plant height ($r_g = 0.2813$, $r_p = 0.2426$) at both the genotypic and phenotypic level. Days to maturity showed highly significant positive interaction with number of seeds/siliqua ($r_g = 0.6450^{**}$, $r_p = 0.5105^{**}$) and plant height ($r_g = 0.5576^{**}$, $r_p = 0.4508^{*}$) at the both genotypic and phenotypic level and negative non-significant interaction with seed yield/plant ($r_g = -0.365$) at genotypic level which indicated that if days to maturity decrease then all of the negatively associated parameter increase as well as yield increases. Number of siliquae/plant showed positive significant interaction with number of primary branches/plant ($r_g = 0.4920^{**}$, $r_p = 0.4093^{*}$) and number of secondary branches/plant ($r_g = 0.6868^{**}$, $r_p = 0.5760^{**}$) at both the levels. [Table 4]

The results of correlation co-efficient indicated that number of siliqua/plant, number of primary branches/plant and number of secondary branches/plant were considered to be important characters for yield improvement in *Brassica rapa* L.

Table 4. Genotypic and phenotypic correlations co-efficient among different characters of the 33 genotypes of *Brassica rapa* L.

Characters	Correlation	PH	NPBP	NSBP	NSP	SL	NSS	TSW	SYP
DM	r_g	0.5576**	-0.2262	-0.1688	-0.2459	0.0842	0.6450**	0.2409	-0.0256
	r_p	0.4508*	-0.1489	-0.1327	-0.2045	0.1004	0.5105**	0.1738	0.0254
PH	r_g		-0.1230	-0.0123	0.0208	-0.1719	0.5499**	0.3620*	0.2813
	r_p		-0.0351	0.0349	0.0243	-0.1068	0.4094*	0.2723	0.2426
NPBP	r_g			0.2410	0.4920**	-0.0202	-0.3774*	-0.0695	0.5611**
	r_p			0.1829	0.4093*	0.0510	-0.2292	-0.0931	0.4016*
NSBP	r_g				0.6868**	-0.2077	-0.4398*	-0.0735	0.5160**
	r_p				0.5760**	-0.1637	-0.3069	-0.0095	0.4098*
NSP	r_g					-0.0729	-0.5289**	-0.2928	0.7011**
	r_p					-0.0579	-0.4215*	-0.2364	0.5684**
SL	r_g						-0.0218	0.0053	-0.1014
	r_p						0.0632	0.0240	-0.0246
NSS	r_g							0.0926	-0.4239*
	r_p							0.0657	-0.1824
TSW	r_g								0.2254
	r_p								0.2096

** and * Significant at the 1% and 5% level of probability, respectively, r_g = genotypic correlation, r_p = phenotypic correlation,

DM = Days to maturity, PH= Plant height (cm), NPBP = Number of primary branches/plant, NSBP = Number of secondary branches/plant, NSP = Number of siliquae/plant, SL = Siliqua length (cm), NSS = Number of seeds/siliqua, TSW = 1000 seed weight (g) and SYP = Seed yield/plant (g).

Table 5. Path coefficient analysis showing direct and indirect effect of yield components on seed yield/plant in 33 genotypes of *Brassica rapa* L.

Characters	DM	PH	NPBP	NSBP	NSP	SL	NSS	TSW	SYP
DM	**0.1474**	0.1812	-0.0638	-0.0016	-0.1150	-0.0021	-0.2351	0.0634	-0.0256
PH	0.0822	**0.3249**	-0.0347	-0.0001	0.0097	0.0044	-0.2004	0.0953	0.2813
NPBP	-0.0333	-0.0400	**0.2823**	0.0022	0.2302	0.0005	0.1376	-0.0183	0.5611**
NSBP	-0.0249	-0.0040	0.0680	**0.0092**	0.3214	0.0053	0.1603	-0.0194	0.5160**
NSP	-0.0362	0.0068	0.1389	0.0064	**0.4679**	0.0019	0.1928	-0.0771	0.7011**
SL	0.0124	-0.0559	-0.0057	-0.0019	-0.0341	**-0.0255**	0.0079	0.0014	-0.1014
NSS	0.0951	0.1787	-0.1065	-0.0041	-0.2475	0.0006	**-0.3644**	0.0244	-0.4239*
TSW	0.0355	0.1176	-0.0196	-0.0007	-0.1370	-0.0001	-0.0337	**0.2634**	0.2254

Bold faces are direct effect

Residual effect 0.45

DM = Days to maturity, PH= Plant height (cm), NPBP = Number of primary branches/plant, NSBP = Number of secondary branches/plant, NSP = Number of siliquae/plant, SL = Siliqua length (cm), NSS = Number of seeds/siliqua, TSW = 1000 seed weight (g) and SYP = Seed yield/plant (g).

Path analysis

Association of characters determined by correlation co-efficient may not provide an exact picture of the relative importance of direct and indirect influence of each yield components on yield. Correlation co-efficients were partitioned into direct and indirect effect to find out a clear picture of the inter-relationship between yield and other yield attributes by using path analysis.

Path coefficient analysis showed that the number of siliquae/plant had maximum positive direct effect on seed yield/plant (0.4679). It had positive indirect effect on yield via number of seeds/siliqua (0.1928) followed by number of primary branches/plant (0.1389), plant height (0.0068), number of secondary branches/plant (0.0064) and siliqua length (0.0019) and negative indirect effect were found on thousand seed weight (-0.0771) and days to maturity (-0.0362). Finally it made highly significant positive correlation with seed yield/plant (r_g= 0.7011**). The genotypic correlation of number of siliquae/plant with seed yield/plant was positive and considerably higher in magnitude. It is mainly due to high positive direct effect and positive indirect effects of other characters. Therefore, selection would be effective for number of siliquae/plant. Ara (2010) found number of siliquae/plant had the highest positive direct effect on seed yield which supported the present findings. [Table 5]

Plant height had positive direct effect on seed yield/plant (0.3249) and positive indirect effect on seed yield via thousand seed weight (0.0953) followed by days to maturity (0.0822), number of siliquae/plant (0.0097) and siliqua length (0.0044). It had also negative indirect effect via number of seeds/siliqua (-0.2004) followed by number of primary branches/plant (-0.0347) and number of secondary branches/plant (-0.0001). It was observed to have high positive direct effects on seed yield/plant but its influence was nullified by the negative indirect effects which resulted non-significant positive correlation with seed yield/plant (r_g=0.2813). [Table 5]

Number of primary branches/plant had positive direct effect on seed yield/plant (0.2823) and positive indirect effect on seed yield/plant through number of siliquae/plant (0.2302) followed by number of seeds/siliqua (0.1376), secondary branches/plant (0.0022) and siliqua length (0.0005). Negative indirect effect through days to maturity (-0.0333) followed by plant height (-0.0400) and thousand seed weight (-0.0183). Finally, it had highly significant positive genotypic correlation with seed yield/plant (r_g= 0.5611**). Mahmud (2008) also found the highest direct effects on seed yield/plant of *Brassica spp* for number of primary branches/plant. [Table 5]

Thousand seed weight had a positive direct effect (0.2634) on seed yield/plant and positive indirect effect through days to maturity (0.0355) and plant height (0.1176). Hosen (2008) found that thousand seed weight had the highest positive direct effect on seed yield/plant. Days to maturity had direct positive effect (0.1474) on seed yield/plant. This trait showed indirect positive effect on seed yield/plant through plant height (0.1812) and thousand seed weight (0.0634). Rashid (2007) observed that seed yield had the highest direct effect on days to maturity. Number of secondary branches/plant had positive direct effect (0.0092) on yield and this trait had high positive indirect effect on yield via number of siliquae/plant (0.3214) followed by number of seeds/siliqua (0.1603), number of primary branches/plant (0.0680) and siliqua length (0.0053). Finally it made highly significant positive correlation with seed yield/plant (r_g= 0.5160**). Thus increase in the seed yield/plant were not only influenced by direct effects of the number of secondary branches/plant but also by the indirect selection of genotypes with high number of secondary branches/plant could be effective. Khan (2010) also found positive direct effect with seed yield for number of secondary branches/plant. [Table 5]

Number of seeds/siliqua had a negative direct effect (-0.3644) on seed yield/plant and it had also negative significant correlation with seed yield/plant (-0.4239). The negative direct effect was mainly counter balanced by indirect positive effect of different characters. Afrin (2011) had the negative direct effect on seed yield/plant for number of seeds/siliqua. Siliqua length had also direct negative effect (-0.0255) on seed yield/plant. Han (1990) observed negative direct effect of siliqua length on seed yield. The residual effect (R) of path analysis was 0.45, which indicated that the characters under study contributed 55% of the seed yield/plant. It is suggested that there were some other factors those contributed 45% to the seed yield/plant not included in the present study. [Table 5]

The path coefficient analysis indicated that number of siliquae/plant, number of primary branches/plant and number of secondary branches/plant were the most important contributors to seed yield/plant which could be taken in consideration for future hybridization program.

Wide variability has been found among the genotypes for all the characters. The result of the study will provide the ability of breeders to develop desirable plant types having high yield with early maturity. Analyzed value from genotypic and phenotypic coefficient of variation, heritability and genetic advance in percent of mean, correlation co-efficient and even path coefficient, number of siliquae/plant, number of primary branches/plant and number of secondary branches/plant were the such traits which could be considered for future hybridization program.

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SUITABILITY STUDY OF LOCAL BUSH BEAN CULTIVARS INTERCROPPED WITH HYBRID MAIZE UNDER DIFFERENT PLANTING SYSTEM IN HILLY AREAS

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Abstract

An intercropping experiment was conducted on hill valley at Hill Agricultural Research Station, Ramgarh and Kharachari during two consecutive *rabi* seasons of 2012-13 and 2013-14 to select suitable local bush bean cultivar for intercropping with hybrid maize in hilly areas of Bangladesh. Seven intercropping treatments viz., T_1 = Normal maize spacing (75 cm × 25 cm) + 2 rows black seeded bush bean,T_2 = Normal maize spacing (75 cm × 25 cm) + 2 rows pink seeded bush bean,T_3 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows black seeded bush bean,T_4 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows pink seeded bush bean, T_5 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows black seeded bush bean, T_6 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows pink seeded bush bean and T_7 = Sole maize spacing (75 cm × 25 cm) were used. Sole hybrid maize produced the highest grain yield at both the locations. Bush bean cultivars in intercropped situation depressed hybrid maize yields by 7.15-37.29% at Ramgarh and 2.56-37.51% at Khagrachari compared to sole hybrid maize. The highest maize equivalent yield of 23.10 t/ha at Ramgarh and 24.08 t/ha at Khagrachari was recorded in maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows pink seeded bush bean combination (T_4). The same treatment also showed the highest gross return (Tk 277200/ha at Ramgarh and Tk 288960/ha at Khagrachari), gross margin (Tk 180050/ha at Ramgarh and Tk 191810/ha at Khagrachari) and benefit cost ratio (2.85 at Ramgarh and 2.97 at Khagrachari). The result revealed that maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows pink seeded bush bean could be suitable and economically profitable for hybrid maize and bush bean intercropping in hill valleys of Bangladesh.

Keywords: Suitability, Intercropping, Hybrid maize, Bush bean, Hilly areas.

Introduction

Intercropping is an excellent technique to increase total productivity (Islam *et al.*, 2010), monetary return (Begum *et al.*, 2010), and resource use efficiency (Islam *et al.*, 2006) as well as to fulfill the diversified need of farmers (Akhteruzzaman

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et al., 2008). The use of early maturing crop varieties, row arrangement, spacing and plant population are some important methods that help to increase the yield of intercrop (Craufard, 2000; Ahmed *et al*., 2000 and Rahaman *et al.*, 2009). Moreover, by changing planting geometry of tall crop, incident light on the under storey crop canopy may be increased which also accelerate the production.

Evans (2001) reported that cereal-legume intercropping is more productive and profitable cropping system than other intercropping systems. Islam (2002) stated that hybrid maize and bush bean intercropping is competent because of differing in growth duration, demand of nutrient requirement, photosynthetic path way etc. Bush bean cultivars (Black seeded and pink seeded) are very popular to tribes and they grow those in hilly areas as sole crop. Green seeds of bush bean are preferable to them. Similarly, the hill farmers also grow hybrid maize as sole crop. Possibility of increasing production of these two crops by increasing area under cultivation is limited. So, intercropping is the only way to enhance production of those crops. Therefore, this experiment was conducted to find out the local bush bean cultivars suitable for intercropping with hybrid maize under different planting systems.

Materials and Method

The experiment was conducted on hill valley at Hill Agricultural Research Station, Ramgarh and Khagrachari during two consecutive *rabi* seasons of 2012-13 and 2013-14. The soil of the experimental field of Khagrachari was clay loam in texture with pH 4.6, medium in organic matter (2.51%), low in total nitrogen (0.132%), very high in phosphorus (34 µg/g), low in potassium (0.12 meq/100g), optimum in sulphur (29 µg/g), medium in zinc (1.27 µg/g) content belonging to Mirersharai series under AEZ-29. On the contrary, the soil of the experimental field of Ramgarh was clay loam in texture with pH 4.5, medium in organic matter (2.36%), low in total nitrogen (0.130%), very low in phosphorus (4 µg/g), low in potassium (0.11 meq/100g), low in sulphur (17 µg/g), low in zinc (0.57 µg/g) content belonging to Mirersharai series under AEZ-29. Seven intercropping treatments viz., T_1 = Normal maize spacing (75 cm × 25 cm) + 2 rows black seeded bush bean, T_2 = Normal maize spacing (75 cm × 25 cm) + 2 rows pink seeded bush bean,T_3 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows black seeded bush bean,T_4 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows pink seeded bush bean, T_5 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows black seeded bush bean, T_6 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows pink seeded bush bean and T_7 = Sole maize spacing (75 cm × 25 cm) were used in this study. The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 3 m × 3 m. Hybrid maize (var. BARI Hybrid maize-7) and bush bean cultivars (Black seeded and pink seeded) were used in this experiment. Seed rate of bush bean was considered as 36 kg/ha. Seeds of maize and bush bean were sown on 24 November 2012 and 25 November 2013

in both the location according to treatments. Sole hybrid maize and intercrop was grown with 250-55-110-40-4-2 kg/ha of NPKSZnB (FRG, 2012). Fifty percent N and full amount of all other fertilizers were applied as basal. Remaining N was applied as top dressing at 30 days after sowing (DAS). Two irrigations were given at 30 and 60 DAS. Other intercultural operations were done as and when required. Plant population of both the crops was taken in linear metre from randomly selected 3 places in each plot and converted to plants/m^2. Data on yield components of maize and bush bean were taken from randomly selected 5 plants from each plot. Hybrid maize was harvested at 150 DAS in both years and locations. Harvesting of bush bean pods was started from 100 DAS and continued up to 110 DAS in both years and locations. The mean comparisons were done by using Least Significant Difference (LSD) test. Cost of land preparation, seeds, fertilizers, labour for different operations and irrigation etc. were considered as production cost. Benefit cost analysis was also done. Maize equivalent yield was computed by converting the yield of intercrops on the basis of prevailing market price of both the crops following the formula of Bandyopadhyay (1984).

$$\text{Maize equivalent yield (MEY)} = Yim + \frac{Yib \times Pb}{Pm}$$

Where, Yim= yield of intercrop maize (t/ha)

Yib= yield of intercrop bush bean (t/ha)

Pm =selling price of maize grain (Tk/kg)

Pb = selling price of bush bean green seed (Tk/kg)

Results and Discussion

Similar trend was observed in yield and yield attributes in both the years so pooled analysis was done and discussed the results below accordingly.

Effect on maize

Number of cobs/m^2 and grain yield/ha of hybrid maize were influenced significantly due to intercropping with bush bean under different planting systems at both the locations but number of grains/cob and 1000-grain weight were not significantly affected (Table 1). The maximum number of cobs/m^2 (5.3) was recorded in sole maize (T_7) which was at par with T_1 and T_2 combinations at both the locations. Identical number of cobs/m^2 in these treatments was attributed to the similar planting system. The minimum number of cobs/m^2 at Ramgarh (3.6) and at Khagrachari (3.7) was found in T_6 combination and it was statistically identical to T_3, T_4 and T_5 combinations. Three rows of bush bean as intercrop in T_5 and T_6 drastically reduced cobs/m^2 than 2 rows of bush bean by reducing cobs/plant though grains/cob and 1000-grain weight were identical. The

grain yield of hybrid maize varied from 6.93 to 10.26 t/ha at Ramgarh and 7.08 to 11.11.04 t/ha at Khagrachari due to intercropping with bush bean under different planting systems. The maximum grain yields of hybrid maize at Ramgarh (11.05 t/ha) and at Khagrachari (11.33 t/ha) were obtained from sole maize (T_7). Higher grain yield of hybrid maize in those combinations were contributed mainly by the number of cobs/m^2. In the rest treatments grain yield of hybrid maize were statistically lower (6.93-7.81 t/ha) at Ramgarh and (7.08-7.89 t/ha) at Khagrachari. The results indicated that intercropping reduced grain yield of hybrid maize (7.15-37.29% at Ramgarh and 2.56-37.51% at Khagrachari) compared to sole maize. Minimum grain yield reduction was observed in treatment T_1 and T_2 whereas maximum in T_6. Similar results were reported by Islam *et al.* (2004) in maize-bush bean intercropping systems.

Table 1. Grain yield and yield components of hybrid maize in maize-bush bean intercropping under different planting systems at Ramgarh and Khagrachari (pooled of 2012-13 and 2013-14).

Treatment	Cobs/m^2 (no.)		Grains/cob (no.)		1000-grain wt. (g)		Grain yield (t/ha)	
	Ram	Kha	Ram	Kha	Ram	Kha	Ram	Kha
T_1	5.2	5.3	547.1	562.5	360.5	370.3	10.26	11.04
T_2	5.1	5.2	517.2	549.5	350.7	360.0	10.19	11.00
T_3	3.8	3.9	543.2	550.7	370.0	380.1	7.64	7.69
T_4	3.8	3.9	550.9	550.0	360.5	377.2	7.81	7.89
T_5	3.8	3.8	543.8	535.0	360.0	370.4	7.44	7.53
T_6	3.6	3.7	550.2	530.5	350.0	360.7	6.93	7.08
T_7	5.3	5.3	548.1	540.5	380.5	395.5	11.05	11.33
$LSD_{(0.05)}$	0.3	0.8	NS	NS	NS	NS	3.10	3.31
CV (%)	4.2	8.8	9.1	10.3	8.0	3.9	7.8	11.0

NS: Not significant, Ram: Ramgarh and Kha: Khagrachari

T_1 = Normal maize spacing (75 cm × 25 cm) + 2 rows black seeded bush bean, T_2 = Normal maize spacing (75 cm × 25 cm) + 2 rows pink seeded bush bean,T_3 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows black seeded bush bean,T_4 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows pink seeded bush bean, T_5 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows black seeded bush bean, T_6 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows pink seeded bush bean and T_7 = Sole maize spacing (75 cm × 25 cm).

Effect on Bush bean

Only green seed yield/ha of bush bean was varied significantly in hybrid maize bush bean intercropping under different planting systems at both the locations. Number of plants/m^2, green pods/plant, green seeds/pod and 100-green seed weight did not differ significantly among the treatments at both the locations (Table 2). Maximum green seed yield (9.17 t/ha at Ramgarh and 9.71 t/ha at Khagrachari) were recorded in T_4 combination which was identical with T_6

Table 2. Seed yield and yield components of bush bean in maize-bush bean intercropping under different planting systems at Ramgarh and Khagrachari (pooled of 2012-13 and 2013-14).

Treatment	Plants/m^2 (no.)		Green pod/plant (no.)		Green seed/pod (no.)		100-green seed wt. (g)		Green seed yield (t/ha)	
	Ram	Kha	Ram	Kha	Ram	Kha	Ram	Kha	Ram	Kha
T_1	26.5	26.4	7.3	7.4	4.8	4.5	60.0	59.9	5.67	5.35
T_2	26.4	26.3	8.0	7.6	4.9	4.7	64.3	69.1	6.66	6.39
T_3	26.1	26.2	8.1	8.3	6.3	6.3	67.9	69.0	7.84	8.10
T_4	26.0	26.1	8.4	8.5	6.5	6.5	68.8	69.2	9.17	9.71
T_5	25.8	25.0	8.0	8.2	6.2	6.3	65.0	67.8	7.61	7.47
T_6	26.6	26.5	8.3	8.4	6.4	6.4	62.6	68.5	9.10	9.37
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	1.05	1.17
CV (%)	9.7	9.7	13.5	11.2	11.2	5.5	7.2	7.4	4.9	10.7

NS: Not significant, Ram: Ramgarh and Kha: Khagrachari

T_1 = Normal maize spacing (75 cm × 25 cm) + 2 rows black seeded bush bean, T_2 = Normal maize spacing (75 cm × 25 cm) + 2 rows pink seeded bush bean,T_3 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows black seeded bush bean,T_4 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows pink seeded bush bean, T_5 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows black seeded bush bean, T_6 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows pink seeded bush bean and T_7 = Sole maize spacing (75 cm × 25 cm)

Table 3. Maize equivalent yield (MEY) and benefit cost analysis of maize-bush bean intercropping under different planting systems at Ramgarh and Khagrachari (pooled of 2012-13 and 2013-14).

Treatment	Maize equivalent yield (t/ha)		Gross return (Tk/ha)		Total cost of production (Tk/ha)		Gross margin (Tk/ha)		Benefit cost ratio (BCR)	
	Ram	Kha	Ram	Kha	Ram	Kha	Ram	Kha	Ram	Kha
T_1	19.71	19.96	236520	239520	101100	101100	135420	138420	2.34	2.37
T_2	21.29	21.65	255480	259800	101100	101100	154380	158700	2.53	2.57
T_3	20.71	21.19	248520	254280	97150	97150	151370	157130	2.56	2.62
T_4	23.10	24.08	277200	288960	97150	97150	180050	191810	2.85	2.97
T_5	20.13	19.98	241560	239760	97670	97670	143890	142090	2.47	2.45
T_6	22.10	22.70	265200	272400	97670	97670	167530	174730	2.72	2.79
T_7	11.05	11.33	132600	135960	60230	60230	72370	75730	2.20	2.26

Local market price: Maize grain Tk.12//kg, Bush bean green seed Tk. 20/kg

Ram: Ramgarh and Kha: Khagrachari

T_1 = Normal maize spacing (75 cm × 25 cm) + 2 rows black seeded bush bean, T_2 = Normal maize spacing (75 cm × 25 cm) + 2 rows pink seeded bush bean,T_3 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows black seeded bush bean,T_4 = Maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows pink seeded bush bean, T_5 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows black seeded bush bean, T_6 = Maize wider spacing (100 cm × 50 cm) with 2 plants/hill + 3 rows pink seeded bush bean and T_7 = Sole maize spacing (75 cm × 25 cm)

combination. Higher green seed yields in those combinations were attributed to the cumulative effect of yield components. Similar results were reported by Ahmed *et al.* (2006) in maize/spinach-red amaranth intercropping. The results indicated that number of pod/plant, seed/pod, seed size and green seed yield of bush bean was influenced by planting systems of hybrid maize. The values of these parameters were more in wider spacing of hybrid maize might be for availability of more light on bush bean canopy. When two maize plants/hill were maintained, those values were reduced slightly probably for less light availability. On the contrary, pink seeded bush bean cultivar was superior to black seeded one in respect of pods/plant, seeds/pod, seed size and seed yield.

Intercrop efficiency

Maize equivalent yield (MEY) and benefit cost analyses are presented in Table 3. All the intercrop combinations produced much higher MEY over sole hybrid maize. Among those, the highest MEY (23.10 t/ha at Ramgarh and 24.08 t/ha at Khagrachari) was recorded in T_4 combination which was followed by T_6 combination (22.10 t/ha at Ramgarh and 22.70 t/ha at Khagrachari). Maximum MEY in aforesaid combination was observed due to additional seed yield of bush bean without affecting the grain yield of maize.

The highest gross return (Tk. 277200/ha at Ramgarh and Tk. 288960/ha at Khagrachari) was obtained from T_4 combination at both the locations which was close to T_6 combination (Tk. 265200/ha at Ramgarh and Tk. 272400/ha at Khagrachari). Higher gross return in these combinations was contributed by the higher MEY. Cost of production of all intercropping systems was more than sole hybrid maize because of the involvement of higher seed cost as well as cost of more labours engaged in different operations. The highest gross margin (Tk. 180050/ha at Ramgarh and Tk. 191810/ha at Khagrachari) was found from T_4 combination at both the locations which was very close to T_6 combination (Tk. 167530/ha at Ramgarh and Tk. 174730/ha at Khagrachari) owing to higher gross returns and lower cost of production than T_1 and T_2. The highest benefit cost ratio (2.85 at Ramgarh and 2.97 at Khagrachari) was also recorded in T_4 combination at both the locations and it was close to T_6 combination (2.72 at Ramgarh and 2.79 at Khagrachari). Uddin *et al.* (2006) also obtained higher MEY and economic returns from hybrid maize and bush bean intercropping system.

Conclusion

The results revealed that maize wider spacing (100 cm × 25 cm) with 1 plant/hill + 3 rows pink seeded bush bean might be suitable and economically profitable for hill valleys of Bangladesh. So, the farmers of hilly areas could be suggested to grow pink seeded bush bean cultivar as intercrop with hybrid maize for getting maximum profit.

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