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ESTIMATION OF LEGUME NITROGEN FIXATION GROWN IN NORTHERN PART OF BANGLADESH USING ^{15}N TRACER

M. E. Haque[1], M. A. Sattar[2], M. K. Khan[3] and M. H. Rahman[4]

Abstract

Nitrogen fixations in different legumes were estimated by using ^{15}N isotope dilution technique, at the BNF laboratory of Soil Science Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. The field experiments were conducted at BINA sub-station farm, Rangpur, in the Tista Meander Floodplain soils of Bangladesh, during the year of 2009-10 and 2010-11. Three different legumes (such as; lentil, mungbean and soybean) and two inoculation systems (with and without inoculant) were randomly assigned in a split-plot design with 3 replications. For quantification of the amount of biological N fixation by different legumes, crops were grown in the isotope treated microplots {treated with 10.48% ^{15}N labelled $(NH_4)_2SO_4$ fertilizer} and a non-nodulated crop (wheat) was included in a separate plot as reference.

In all legumes, application of inoculants produced significantly highest amount of total yield than un-inoculated plots. Among the different legumes, soybean crop showed the maximum total yield of 6.57 tha^{-1} (mean of two years result), when the seeds were treated with inoculants. Whereas the minimum total yield (2.43 tha^{-1}) was found in un-inoculated plots of mungbean crop. Quantity of total N (TN) and nitrogen derived from atmosphere (Ndfa) in different legumes were significantly higher in inoculated plots than un-inoculated ones. When the legume seeds were properly treated with inoculants before sowing, the highest amount of TN was quantified in soybean (189.63 kg ha^{-1}), which was followed by lentil (83.52 kg ha^{-1}) and mungbean (70.16 kg ha^{-1}). Similar trend was also noticed in case of total atmospheric nitrogen fixation by different legumes. Soybean crop fixed the highest N (84.18% of its N_2 amounting to 159.62 kg Nha^{-1}), which was followed by lentil (82.82% of its N_2 amounting 69.13 kg Nha^{-1}) and mungbean (% 80.73 of its N_2 amounting 56.64 kg Nha^{-1}). Due to inoculation, the total net N inputs added to the soil system for succeeding crops was comparatively higher than un-inoculated situation and among the different legumes, the maximum net N inputs was observed as 50.95 kg Nha^{-1} from inoculated soybean.

Key words: Legumes, ^{15}N dilution technique, N-fixation and net N inputs

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Introduction

Managing nitrogen inputs in crop production system to achieve economic and environmental sustainability is a major challenge facing agriculture. Relying less on commercial fertilizer N and more on biological N_2 fixation by legumes has been suggested as a way to meet this challenge (Keeney and Nelson, 1982). The N benefits of legume-rhizobium symbiosis include N_2 fixation and mineralization, sparing of soil inorganic N and reduced immobilization of soil inorganic N (Fedorova *et al.*, 2005). Symbiotic N_2 fixation enhances soil fertility and productivity as well as increases carbon sequestration and nutrient conservation (Morgan, 1997). Efficient utilization of the symbiotic nitrogen fixation in agricultural practice is one of the important strategies for establishing sustainable agriculture in the 21st century (Hiroshi, 2003). Using Rhizobia inoculants can be a key part of accelerating rehabilitation of degraded land and ecosystem function, enhancing survival and growth of plants, and reducing costs in establishment and maintenance and also return organic matter and nitrogen to the farm ecosystem naturally (Kim and Craig, 2003).

Declining soil fertility, particularly N is recognized as a major threat to continue rice/cereal cropping in Bangladesh soil. It is widely believed that legumes improve soil fertility because of their N_2-fixing ability. Variation exists in legumes for the amount of N fixed and for the proportion of plant N derived from biological N_2 fixation. It is important to identify legumes and genotypes that yield more and derive a large part of their nitrogen requirement from fixation (Wani *et al.*, 1995). This study was therefore, conducted to quantify the amount of N_2 fixed by three important legumes *viz.* lentil, mungbean and soybean with and without inoculant and also estimate the total net N inputs in soil system.

Materials and Methods

Field experiments were conducted during 2009-10 and 2010-11 at Rangpur sub-station farm of Bangladesh Institute of Nuclear Agriculture (BINA), located at $25^0 43'$ N latitude and $89^0 16'$ E longitude in the north-west part of Bangladesh. The soil of the experimental site was silt loam (19% clay, 51% silt and 30% sand) in Tista Meander Floodplain (agro-ecological zone), having pH 5.7 (in water) with C 1.5%, total N 0.07%, Olsen's P 15.5ppm and exchangeable K 0.10cmol kg^{-1}. Three different legumes, such as; lentil (*Lens culinaris* Medik; cv. Binamusur-1), mungbean (*Vigna sinensis*; cv. Binamoog-4) and soybean (*Glycine max* L.; cv. Sohag) were tested with and without rhizobial inoculant following split-plot design with three replications.

For quantification of biological nitrogen fixation potentials of different legumes, isotope labelled ammonium sulphate $\{(^{15}NH_4)_2SO_4\}$ with 10.48% a.e. @ 20kg N/ha was uniformly sprayed to 1.00 square meter area of the legume plots. The reference crop wheat

(*Triticum aestivum*) received 100kg N/ha in the isotopic subplot. Unlabelled urea was applied to remaining part of each plot to keep the N doses uniform for whole of the plot and as per treatment plan. The P, K and S doses for wheat were 20, 50 and 5 $kgha^{-1}$, respectively. For legume crops, the P, K, and S doses were 15, 20 and 10 $kgha^{-1}$, respectively. The size of the each main plot was 6m x 5m and each plot contained two ^{15}N micro plots (1m x 1m), which were assigned for isotopic study. Crops were harvested at physiological maturity. For total N estimation, the aerial parts were dried in an oven at 65^0C ±1 and %N was determined using micro-kjeldahl digestion apparatus. $^{15}N/^{14}N$ ratio analysis was performed using NOI-7 emission spectrophotometer (Martina, 2002) and ^{15}N related calculations were done by using the equations of Hardarson *et al.*, 1984 and Toomsan *et al*., 1995. Analysis of variance was performed on the data and means were classified following Duncan's New Multiple Range Test (P<0.05).

Results

Different legumes, inoculation and legume yield

Different types of legumes with and without inoculant significantly affected the seed and stover yield in Tista Meander Floodplain soils at Rangpur (Fig. 1). When the different legume seeds were treated with rhizobial inoculant before sowing, comparatively higher grain and stover yield was observed than in un-inoculated ones. On average, due to inoculation, the highest seed yield of 2.10 tha^{-1} was recorded in inoculated soybean, whereas the lowest seed yield (0.80 tha^{-1}) was noted in un-inoculated mungbean. Among the different legumes, due to inoculation the maximum seed yield was increased in soybean (69.35%), whereas in mungbean and lentil the seed yield was increased as 41.25 and 44.04%, respectively. Considering the stover yield of different legumes, it might be noted that inoculation had significant effects on legume stover and the average highest yield was recorded as 4.48 tha^{-1} from inoculated soybean, but the un-inoculated mungbean showed the lowest yield of 1.63 tha^{-1}. Due to inoculation, among the different legumes, the percent stover yield increased as 50.80, 53.37 and 62.54%, in lentil, mungbean and soybean crops, respectively.

Inoculation significantly influenced on total yield of different legumes grown at Rangpur. Comparatively the higher total yield of different legumes was always observed in inoculated plots than in un-inoculated ones. On average, the total yield of 4.03, 3.69 and 6.58 tha^{-1} was recorded in inoculated plots of the crop lentil, mungbean and soybean, whereas in uninoculated plots, the same crops produced the lower yields of 2.71, 2.43 and 3.99 tha^{-1} and due to inoculation, the total yield increased as 42, 37 and 61% in the crop lentil, mungbean and soybean, respectively.

Effect on total nitrogen content

The experimental results revealed that the seed, stover and total nitrogen content in legume was significantly influenced due to the different types of legumes and inoculant (Table 1). The highest average seed N yield was estimated from the soybean plant as 87.06 and 88.75 kg ha^{-1} (during 2009-10 and 2010-11, respectively) which was significantly different with the seed N yield recorded from lentil (38.04 and 38.51 kg ha^{-1}) and mungbean (30.54 and 32.90 kg ha^{-1}). Application of rhizobial inoculant significantly increased the seed N uptake in different legume plants and comparatively the average higher seed N yield (66.56 and 68.92 kg ha^{-1}) was found from the inoculated legumes. The seed N uptake increased as 86.87% in inoculated legumes compared to the un-inoculated ones. Interaction effects of different types of legumes with and without inoculant on seed N yield showed a significant variation and the highest seed N yield (111.56-113.73 $kgha^{-1}$) was estimated from the treatment combination of inoculated soybean and the lowest seed N yield (22.93-22.98 $kgha^{-1}$) was recorded from the un-inoculated mungbean.

Considering the stover N content, the maximum value of 51.85-61.97 kg ha^{-1} was recorded from soybean plant which was followed by lentil (24.35-43.51 kg ha^{-1}) and mungbean (22.37-30.16 kg ha^{-1}) plant. Due to application of rhizobial inoculant, the higher stover N yield (43.23-54.70 kg ha^{-1}) was obtained than un-inoculated ones (22.48-35.73 kg ha^{-1}). Higher stover N content might be due to the higher N_2 fixation from the atmosphere by the inoculated rhizobial strains. Different types of legumes with and without inoculant interacted significantly on the stover N uptake, and the maximum stover N uptake (72.03-75.00 kg ha^{-1}) was obtained from the inoculated soybean plant and the minimum stover N uptake (17.49-25.26 kg ha^{-1}) was obtained from uninoculated mungbean.

The highest total amount of N was observed as 189.63 kg ha^{-1} (mean of two years) in inoculated soybean which was significantly differed with the other treatments and the lowest amount (41.04 kg ha^{-1}) of total N (mean of two years) recorded in un-inoculated mungbean. On average, due to inoculation the total N uptake increased in lentil, mungbean and soybean plant as 77.36, 70.96 and 98.38% than un-inoculated legumes (Table 1).

Quantification of nitrogen derived from atmosphere (Ndfa) in legume

Ndfa in legume seed

Through ^{15}N study, the quantity of Ndfa in legume seed was estimated from the different types of legumes grown with and without inoculant in Tista Meander Floodplains at Rangpur (Table 2). Among the different legumes, it was observed that soybean seed fixed the maximum amount of nitrogen as 63.97 and 65.90 kg ha^{-1} during 2009-10 and 2010-11, respectively from the atmosphere which was statistically different with the amount of Ndfa fixed by lentil (29.13 and 30.34 kg ha^{-1}) and mungbean (22.75 and 25.03 kg ha^{-1}) during the same periods. Application of rhizobial inoculant significantly influenced on N fixation from atmosphere by legume seed and the higher amount of Ndfa (55.56-58.04 kg ha^{-1}) was recorded by inoculated legumes than in uninoculated ones (21.67-22.80 kg ha^{-1}) and due to inoculation, the %Ndfa increased as 155.51%. The interaction effect of different types of legumes with and without inoculant also showed a significant variation among the quantity of Ndfa fixed by legume seeds and the average highest amount of seed Ndfa (95.51 kg ha^{-1}) was recorded from the inoculated soybean plot and the lowest amount of 14.75 kg ha^{-1} Ndfa was observed from uninoculated mungbean plot.

Ndfa in legume stover

Among the different legumes, soybean stover showed the highest N fixation of 40.45 kg ha^{-1} (mean of 2 years data) followed by lentil (20.28 kg ha^{-1}) and mungbean (17.40 kg ha^{-1}). Application of rhizobial inoculant significantly increased the amount of biological N_2 fixation from the air in the stover of different legumes and it ranged from 13.63 kg ha^{-1} in un-inoculated legumes to 40.75 kg ha^{-1} in inoculated ones and due to inoculation, the percent increase of Ndfa in legume stover over un-inoculated legumes was estimated as 178.76%. The interaction effect of different types of legumes with and without inoculant also showed a significant variation on atmospheric N_2 fixing in legume stover. The average highest amount of stover Ndfa (64.12 kg Nha^{-1}) was recorded from the treatment combination of inoculated soybean and the lowest amount was (11.18 kg Nha^{-1}) observed from the un-inoculated mungbean.

Total Ndfa in legume

Considering the mean effect of different legumes, it was observed that the maximum amount of total nitrogen (104.95-105.80 kg ha^{-1}) fixed from air by soybean during 2009-10 and 2010-11, which was followed by lentil (49.18-50.82 kg ha^{-1}) and mungbean (41.14-41.42 kg ha^{-1}). Due to application of rhizobial inoculant, the amount of total Ndfa significantly varied and on average, the higher (95.13 kg ha^{-1}) and lower (35.98 kg ha^{-1}) amount of Ndfa was recorded in the inoculated and un-inoculated legumes, respectively, which revealed that the total Ndfa in legume increased 164.40% over un-inoculated situation. The interaction effect of different legumes with and without inoculant significantly varied on the fixation of total Ndfa and atmospherically the highest amount of total N_2 fixed by inoculated soybean (157.49-161.74 kg ha^{-1}), which significantly differed with inoculated lentil (67.70-70.56 kg ha^{-1}) and inoculated mungbean (56.64-56.69 kg ha^{-1}) and the lowest amount of 25.65-26.19 kg Nha^{-1} fixed from air by un-inoculated mungbean.

Different sources of estimated legume nitrogen

From the study, the total legume nitrogen and their proportional quantity derived from different sources (Ndfa, Ndfs and Ndff) were also estimated by using ^{15}N tracer technique (Fig. 2). From the figure, it was clear that the maximum amount of N came from atmospheric source in both inoculated and un-inoculated situation. When the different legume seeds were treated with rhizobial inoculant, the highest amount of Ndfa quantified in soybean (84.18% of its N_2 amounting 159.62 kg Nha^{-1}), which was followed by the amount of Ndfa in lentil (82.82%; amounting 69.13 kg Nha^{-1}) and mungbean (80.73%; amounting 56.64 kg Nha^{-1}). The minimum amount of 25.92 kg Nha^{-1} was noticed from un-inoculated mungbean.

The legume plant received a considerable amount of N from soil in un-inoculated situation, though some inefficient natural rhizobia were present in soil. Among the different treatment combinations, the highest amount of total Ndfs was recorded in un-inoculated soybean plots (34.29 kg Nha^{-1}), whereas the lowest value of total Ndfs was noted in inoculated mungbean as 10.44 kg Nha^{-1}. The mean total Ndfs of un-inoculated soybean plot was about more than three fold higher than the total Ndfs found from inoculated mungbean. From the study, it was realized that due to inoculation, a considerable amount (on average) of total N was saved from the soil, which expressed as 47.93% in inoculated soybean, 10.62% in inoculated mungbean and 11.25% in inoculated lentil.

It was revealed that all the legume plants received more nitrogen from fertilizer sources in un-inoculated situations than in inoculated conditions. Among the different treatment combinations, significantly highest total Ndff was recorded as 10.17 kg ha^{-1} from un-inoculated soybean, whereas the lowest total Ndff was found as 3.08 kg ha^{-1} from inoculated mungbean. From the mean data, it was observed that in all legumes, a considerable amount of N was saved from fertilizer sources due to inoculation, which expressed as as 32.64, 11.14 and 10.47% in soybean, lentil and mungbean, respectively.

Contribution of legumes to N supply to the system

In legume-rice rotation, different legumes contribute N supply to the system, which causes a significant and positive effect on yield of the subsequent rice. From the experiment, the contribution of different legumes was studied through calculation of the net N inputs to the system from atmospheric nitrogen fixation. The net N inputs to the system from nitrogen fixation was calculated as the fixed nitrogen returned to the soil in the stover minus the soil nitrogen removed in the grain and the details of the experimental results from both locations and years were presented in Fig. 3. Due to application of rhizobial inoculant, the net N inputs to the system showed highly significant variations and the higher amount of net N was added to soil system from the inoculated legumes, whereas in un-inoculated situation, the net N inputs showed a negative result. The maximum amount of net N was recorded (50.95 kg Nha^{-1}) from the inoculated soybean, which was followed by inoculated lentil (20.94 kg Nha^{-1}) and inoculated mungbean (17.88 kg Nha^{-1}). Without inoculant, all the legumes comparatively added the minimum net N to the system and specially soybean showed a negative result (-5.36 kg Nha^{-1}).

Discussion

Among the different inoculated legumes the yield increasing trend was comparatively higher in soybean (63.71-66.00%) than in lentil (43.22-47.65%) and in mungbean (50.61-53.36%). It might be due to inoculation, more biological nitrogen fixation and more nutrient uptake was occurred in soybean and ultimately accumulated more nutrients in seed and stover which cumulatively increased the yield. The positive effects of inoculation on growth and yield of different legumes were reported by different researchers and it was noted that due to effective inoculation, the yield increased as 48-55% in soybean (Egamberdiyeva *et al.*, 2004; Slattery *et al.,* 2004), 24-35% in mungbean (Rangarjan and Purshothaman, 2002; Tlusty *et al.*, 2004) and 23-40% in lentil and pea (Gan and McDonald, 2002; Mckenzie *et al.,* 2001) over control.

Total N content significantly varied by different legumes with and without inoculant and the highest and lowest N uptake was noted as 189.63 and 41.04 kg Nha^{-1} in inoculated soybean and un-inoculated mungbean, respectively. Under inoculated condition on an average, total N content increased up to 85.89-87.80% and among the tested legumes, the maximum increase of N content was noted in soybean (94.66-102.11%) which was followed by lentil (76.28-78.51%) and mungbean (68.55-73.42%). Shaha (2007), showed that the maximum increase of 59 and 81% N uptake by lentil and 63 and 104% by soybean from the plants inoculated with strain-638 and strain-1906 over urea and control. Research results from Hungria *et al.*, 2003, revealed that in Barzil, rates of N fixation in soybean can exceed 300kg of Nha^{-1}, providing from 69 to 94% of total plant N. Similar results of increasing the total N content in different legumes with inoculant was also reported for soybean (Jensen, 1997; Molla *et al.*, 2001, and Hoque *et al.*, 1995), lentil (Bremer *et al.*, 1990; Whitehead *et al.,* 2000;), chickpea and bean (Duc *et al.*, 1988; Rupela, 1994).

Biological Nitrogen Fixation contributes to productivity directly, where the fixed N_2 is harvested in grain or other food for human or animal consumption, or indirectly, by contributing to the maintenance or enhancement of soil fertility in the agricultural system by adding N to the soil. The successful development of legume cereal systems in Bangladesh will partially depend on the ability of legume to produce N (via N_2 fixation) and then effectively to supply this N to subsequent cereals crops. The effectiveness of N derived from legumes will depend on its short term ability to meet crop demand for N as well as its ability to contribute to long term maintenance of soil fertility (organic matter) levels. Several studies have demonstrated the significant contribution of atmospheric N_2 fixation to soybean nutrition and growth (Rennie *et al*., 1982). Most estimates showed that soybean derives between 25 and 75% of its N from fixation (Deibert *et al.*, 1979). Earlier field studies performed on a Typic Eutricrepts soil in Seibersdorf, Austria showed that soybean generally derived less than 50% of its N from fixation (Hardarson *et al.*, 1984) with a greater contribution from soil N. The isotope dilution method offers an accurate integrated measure of dinitrogen fixation in biological system (Rennie *et al*., 1978). Nitrogen-15 methodology is also recognized as a valuable tool for determining the fate and behavior of N applied in the environment (L'Annunziata and Legg, 1984). During this study, by using ^{15}N isotope dilution technique, the quantity of N was estimated in different tested legumes which derived from different sources, (such as- Ndff, Ndfa and Ndfs) and it was observed that soybean fixed the maximum amount of nitrogen from atmosphere comparatively than lentil and mungbean. Before sowing when the seeds of soybean was treated properly with *Bradyrhizobium* inoculant, the fixation of atmospheric nitrogen increased as maximum in both seed (2.78 times higher) and stover (3.82 times higher) over un-inoculated ones. Whereas, comparatively a lower amount of fixed N_2 was recorded in inoculated lentil (2.38 and 2.05 times higher for seed and stover, respectively) and mungbean (2.23 and 2.11 fold higher for seed and stover, respectively) over un-inoculated control. Most interesting was the variability in N_2 fixation measured within the different legumes. The inoculated soybean was the best fixer (total Ndfa = 159.62 kg Nha^{-1}). Next was the lentil (total Ndfa = 69.13 kg Nha^{-1}), while the remaining mungbean was significantly poorer N_2 fixers i.e. total Ndfa was 56.67 kg Nha^{-1} (Table 2). Selection of legumes with higher yields and N_2 fixation ability is a potential tool for increasing the contribution of N from atmospheric N_2 fixation into soil-plant systems. The results from this study clearly demonstrate these findings. For example, the contribution of N_2 fixation from these inoculated three legumes would range from 56.67 kg Nha^{-1} for mungbean to 159.62 kg Nha^{-1} for soybean, i.e., an almost 2.82 fold increasing by substituting inoculated soybean for inoculated mungbean, or a 21.99% greater N by substituting inoculated lentil for the inoculated mungbean. Sattar *et al.*, 2000; Alves *et al.*, 2003; Tien *et al.*, 2002 showed in their study that inoculated soybean met 56-89% of its N requirement from atmosphere, while inoculated chickpea, lentil and mungbean met 65-75, 66-73 and 45-76% of their requirements, respectively but the un-inoculated legumes met only 44-67% of its N need from the atmosphere. The infectiveness and efficiency in N_2 fixation and thus, the response to inoculation by commercial *Rhizobium leguminosarum* inoculant showed a high level of plant genus-rhizobium specificity. In this study, lentil and mungbean had moderate response in un-inoculated situation, might be due to presence of natural rhizobia in soil but in contrast, un-inoculated soybean showed a little response. Oberson *et al.,* 2007, stated that at maturity, the total amount of N fixed by soybean was 150-260 kg Nha^{-1} and during that period, the amount of Ndfa was recorded as 102 kg N ha^{-1}, equivalent to 47% of the total N assimilated (Zapata *et al.,* 1987). Beck *et al.,* 1991 pointed out that pea and lentil had similar %Ndfa values across locations, seasons and cultural practices with an average 70% Ndfa. They also suggested that large-seeded type fixed higher N (74% Ndfa) than the small-seeded type (64% Ndfa).

Understanding the magnitude of N_2 fixation and export of plant N, particularly in the harvested seed and stover, is necessary to assess the potential for grain legumes to contribute to long-term agricultural production stability. From this study, the contribution of different legumes were estimated through calculation of the net N inputs to the system from nitrogen fixation. The net inputs to the system from N fixation were calculated as the fixed N returned to the soil in the stover minus the soil N removed in the seed. Considering the inoculants effect, highly significant variation was observed in the amount of net N input added to the soil system in all legumes and in un-inoculated condition the net N input showed a minimum result, even a negative result (in un-inoculated soybean). It was reported by Beck *et al.,* 1991 that the calculated N balance, where only grain was removed ranged from 44 kg Nha^{-1} net gain to 44 kg Nha^{-1} loss. When the both seed and stover were removed, nearly all calculations were negative with loss of up to 70 kg Nha^{-1} from soil.

Conclusions

Among the tested legumes, soybean showed the maximum total yield of 6.58 $Mgha^{-1}$ in inoculated condition, whereas the minimum total yield was found in un-inoculated plots of mungbean (2.43 $Mgha^{-1}$). When the legume seeds were properly treated with inoculants before sowing, the highest amount of total N was quantified in soybean (189.63 kg ha^{-1}), which was followed by lentil (83.52 kg ha^{-1}) and mungbean (70.16 kg ha^{-1}). Soybean crop fixed the highest amount of atmospheric N (84.18% of its N_2 amounting to 159.62 kg Nha^{-1}), which was followed by lentil (82.82% of its N_2 amounting 69.13 kg Nha^{-1}) and mungbean (% 80.73 of its N amounting 56.64 kg Nha^{-1}). Due to inoculation, the total net N inputs added to the soil system for succeeding crops was comparatively higher than un-inoculated situation and the maximum net N inputs was observed as 50.95 kg Nha^{-1} from inoculated soybean.

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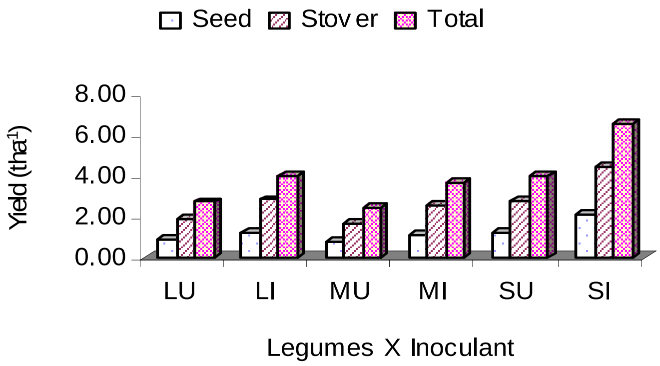

Fig. 1. Grain, stover and total yield of legumes as affected by inoculant at BINA sub-station farm, Rangpur (Average of 2 years data)

Note:

LU	= Lentil un-inoculated	LI	= Lentil inoculated
MU	= Mungbean un-inoculated	MI	= Mungbean inoculated
SU	= Soybean un-inoculated	SI	= Soybean inoculated

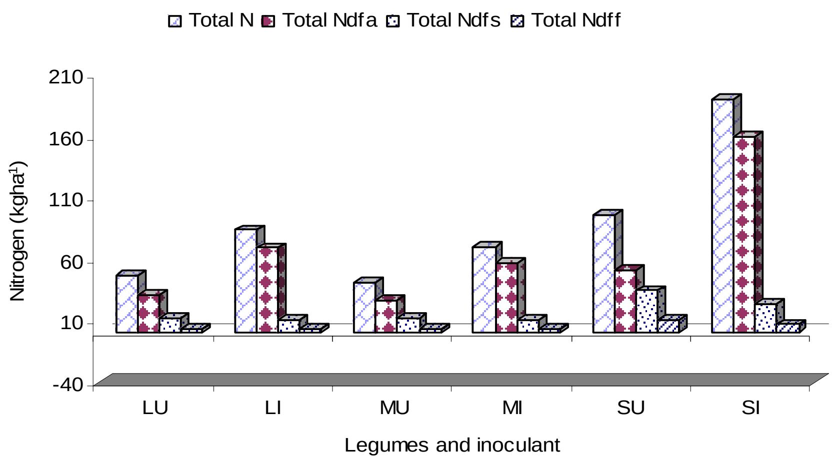

Fig. 2. Total N, Ndfa, Ndfs, and Ndff of legumes as affected by inoculant at BINA sub-station farm, Rangpur (Average of 2 years data)

Note:

LU	= Lentil un-inoculated	LI	= Lentil inoculated
MU	= Mungbean un-inoculated	MI	= Mungbean inoculated
SU	= Soybean un-inoculated	SI	= Soybean inoculated

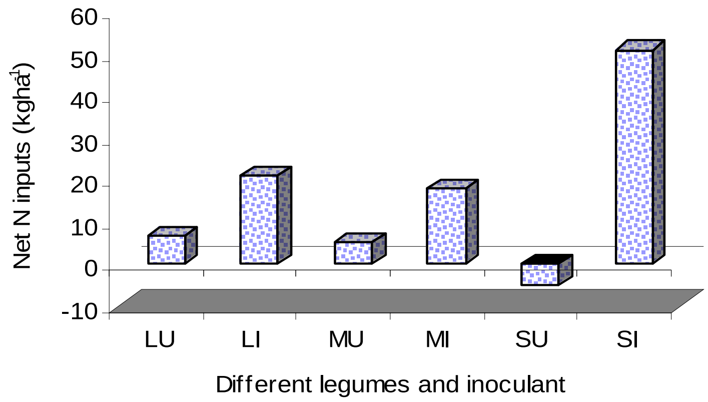

Fig. 3. Net N inputs added to the soil system as affected by different legumes and inoculant

Note:

LU	= Lentil un-inoculated	LI	= Lentil inoculated
MU	= Mungbean un-inoculated	MI	= Mungbean inoculated
SU	= Soybean un-inoculated	SI	= Soybean inoculated

Table 1. Seed, stover and total nitrogen yield (kgha^{-1}) of different legumes with and without inoculant grown in Tista Meander Floodplain soil at Rangpur

Treatments / Year		2009-10			2010-11		
		Seed	Stover	Total	Seed	Stover	Total
Legume type							
Lentil		38.04b	43.51b	67.75b	38.51b	24.35b	62.86b
Mungbean		30.54c	30.16c	55.94c	32.90c	22.37b	55.26c
Soybean		87.06a	61.97a	144.62a	88.75a	51.85a	140.60a
Inoculant							
Uninoculated		37.20b	35.73b	62.15b	37.85b	22.48b	60.33b
Inoculated		66.56a	54.70a	116.72a	68.92a	43.23a	112.15a
Interaction							
Lentil	Uninoculated	26.07e	32.99c	49.04e	26.84e	18.3c	45.14e
	Inoculated	50.01c	54.03b	86.45c	50.17c	30.4b	80.58c
Mungbean	Uninoculated	22.98e	25.26d	41.66f	22.93e	17.49c	40.42e
	Inoculated	38.10d	35.06c	70.22d	42.86d	27.25b	70.10d
Soybean	Uninoculated	62.56b	48.94b	95.74b	63.77b	31.66b	95.43b
	inoculated	111.56a	75.00a	193.50a	113.73a	72.03a	185.76a
CV (%)		4.64	3.49	5.43	3.60	5.46	3.66

Note: Values in a column under a factor/ interaction treatment having same letter(s) do not differ significantly at 5% level of probability.

Table 2. Ndfa (Nitrogen derived from atmosphere, kgha^{-1}) of different legumes with and without inoculant grown at Tista Meander Floodplain soil, Rangpur

Treatments / Year		2009-10			2010-11		
		Seed	Stover	Total	Seed	Stover	Total
Legume type							
Lentil		29.13b	21.70b	50.82b	30.34b	18.85b	49.18b
Mungbean		22.75c	18.39b	41.14c	25.03c	16.40b	41.42c
Soybean		63.97a	41.84a	105.80a	65.90a	39.06a	104.95a
Inoculant							
Uninoculated		21.67b	13.86b	35.53b	22.80b	13.63b	36.43b
Inoculated		55.56a	40.75a	96.31a	58.04a	35.90a	93.94a
Interaction							
Lentil	Uninoculated	16.87d	14.22d	31.08e	18.31d	12.35e	30.67e
	Inoculated	41.38b	29.18b	70.56b	42.36b	25.30b	67.70b
Mungbean	Uninoculated	14.50d	11.15e	25.65f	15.00d	11.20e	26.19f
	Inoculated	31.00c	25.63c	56.64c	35.05c	21.59c	56.69c
Soybean	Uninoculated	33.63c	16.22d	49.85d	35.08c	17.34d	52.42d
	inoculated	94.3a	67.45a	161.74a	96.71a	60.78a	157.49a
CV (%)		8.60	3.84	6.39	4.54	5.13	3.42

Note: Values in a column under a factor/interaction treatment having same letter(s) do not differ significantly at 5% level of probability.

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TRANSLOCATION STUDIES WITH ^{14}C TRACER IN WHEAT UNDER MOISTURE STRESS CONDITIONS

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Abstract

An experiment was conducted at the farm of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during 2004-05 cropping season. Six selected wheat genotypes were tested under different moisture regimes viz. 80, 55 and 30% field capacity (FC) in pot condition to identify the wheat genotypes performed better translocation of current assimilates towards grain using ^{14}C tracer. The translocation studies with ^{14}C isotope resulted in the similar ability of translocation of assimilates in all genotypes under 80% FC treatment. But under 30% FC, the genotypes Shatabdi, Kanchan and BAW-969 could translocate higher amount of ^{14}C assimilate from the fed leaf when data collected after 48 hours of exposure. The drought susceptible one Agrani translocated assimilate slowly and little labelled assimilate translocated towards stem and grain under drought condition. Correlation between leaf area and transpiration rate with % activity of ^{14}C in grain (48 hrs exposure) was almost positive in nature, indicating the straight line regression is quite appropriate. Percent activity of ^{14}C in grain increased (r = 0.838) with the increase of transpiration rate and leaf area.

Key words: Translocation, ^{14}C feeding, flag leaf wheat, water stress

Introduction

In Bangladesh, wheat is grown during the dry months from November to March (Rabi season). Rainfall is unevenly distributed in Bangladesh. The amount of rainfall in October ranges from 60-158 mm, whereas negligible rainfall (0-2 mm) is obtained in December to January in northern part of the country (Anonymous, 1997). So, the residual soil moisture gradually depletes after October and reaches into minimum during December to January. During these months (December and January) wheat crop remains generally at reproductive stage and crop suffers from water stress under non-irrigated condition, which affects translocation of assimilates and grain development. Stress during grain filling

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decreases translocation of assimilates to the grain weight and increases empty grains (Anonymous, 1999). Translocation of food materials or a favorable distribution of assimilates during various developmental stages of plant lead to increase grain yield. The distribution pattern of assimilates to different parts of a wheat plant is changed with its ages (Rawson and Hofstra, 1969). In the earlier stages of growth, the second youngest fully emerged leaf is the major supplier of assimilates to the young leaves and shoot apex. The older leaves predominantly supply food to the roots and downward tillers. Leaves-in the intermediate position supply assimilates either on both directions depending on the demands of the sinks. When grains begin to grow, the upper leaves and green parts above the flag leaf node supply the assimilates to grain. However, if there is any reduction of photosynthesis in these parts, increased amount of assimilates are translocated from the lower parts of the plant to supplement the deficiency under any abiotic stress (Wardlaw, 1968). Hence, this study has been undertaken to identify the wheat genotypes performed better translocation ability of current and reserved assimilates toward grains under water stress situation.

Methods and Materials

The pot experiment was carried out in plastic pots at BINA head quarter farm, Mymensingh during November 14 to March 13, 2004-05 cropping year. Six selected genotypes such as Shatabdi, Kanchan, BAW-969, BAW-56, BAW-944 and Agrani and three stress treatments such as; 30% FC, 55% FC and 80% FC were used in the experiment. The design of the experiment was RCBD with 3 replications. Stress treatments were maintained by the application of additional water thrice in a week to the pots following gravimetric method. Seeds were sown in pots on November 14, 2004-05. After germination, seedlings were counted and excess plants -were removed to maintain three plants population in each pot.

Preparation and feeding of ^{14}C ($BaCO_3$) solution in the flag leaf during anthesis

Fifteen mg of ^{14}C (20.90 mci/mmol. $BaCO_3$, in 25 mci. solution) tracer were dissolved in 250 ml distilled water. The flag leaf of the plant was fed by ^{14}C at anthesis stage. At anthesis stage, all tillers excluding 3 fertile tillers in each stress treatment were cut. Then the three tillers containing pot of each treatment was transferred to the isotope laboratory and it was placed under fume hood in the presence of 1000 micro mole light intensity (Licor light meter: Model:LI-250). The in-situ ^{14}C feeding to the leaves was done with the help of menometric flask. Under fume hood, three menometric flasks were set up which had two funnels. One was allowed for ^{14}C solution and HCl to run into the flax and another funnel was used for entering the flag leaf of the exposing plant. After entering flag leaf into the flax, ^{14}C solution and sufficient amount of 0.1N HCL (to acidify carbonate) was added. Then the two funnels were closed by corks. As soon as $^{14}CO_2$ gas was homogeneously distributed within the menometric flask, the incandescent light of 1000 micro-mole was switched on. Then the plants were allowed to assimilate the $^{14}CO_2$ for 5 minutes.

Procedure of data collection

The ^{14}C activity was measured in different plant parts including the fed leaves at 3 times as follows:

(i) Radioactivity was counted for ^{14}C fed leaf, just after ^{14}C feeding from 1st tiller using scintillation counter (Model LSC 2, NE Technology, UK). The leaf was harvested just after feeding and kept in liquid nitrogen to prevent loss of any ^{14}C by any metabolic activities. The measurement of ^{14}C activity resulted in the total intake of ^{14}C through the assimilatory process.

ii) Radioactivity was counted in stem and grain including ^{14}C fed leaf after 48 hours of feeding time using 2nd tiller. All the leaves of the 3rd ^{14}C fed tiller were cut after 48 hours. This tiller with panicle was allowed to grow till maturity.

(iii) At maturity, radioactivity was also counted in the 3rd tiller in grain. The dry weight of fed flag leaf, stem and all the spikelets in the panicle of concerned tiller were measured. 0.5 gm of each sample were taken in to a vial and 18 ml glacial acetic acid was added to digest the sample material. 10 ml of scintillate (PUPUP) was also added to each vial for measuring the ^{14}C activity present in the sample.

Results

^{14}C activity in Flag leaf after 5 minute exposure

Significant variation was found in different stress levels. Translocation of ^{14}C was reduced gradually with the gradual increment of soil moisture stresses. Optimum moisture regime like 80% FC treatment showed the highest uptake of ^{14}C (2850 dps) by flag leaf while 30% FC showed the lowest. Moderate moisture regime (55% FC) showed in ^{14}C uptake intermediate (Table 1).

Genotypic variation was found in activity of ^{14}C. Results demonstrated that two of the genotypes Shatabdi and Kanchan had much higher ^{14}C activity (ranged 2804 to 2725 dps) in fed leaf than that of other genotypes. The genotypes BAW-969 and BAW56 showed intermediate activity of ^{14}C in fed leaf (Table 2).

Interaction effect of moisture stress and genotype had shown significant differences. All the genotypes had shown more or less similar activity of ^{14}C assimilates under 80% FC treatment. Shatabdi and Kanchan showed higher activity of ^{14}C in fed leaf ranged from 2336 to 2477 dps, whereas Agrani and BAW-944 showed the lowest under 30% FC treatment. Under 55% FC treatment, all the genotypes showed medium and similar capacity of ^{14}C uptake excluding Shatabdi and Kanchan. Shatabdi showed the lowest reduction percentage of activity of 4.86 and 18.57% under 55 and 30% FC treatments, respectively, whereas in genotype Agrani there was the highest 21.4 and 42.3 percent reduction in activity under those stress treatments, respectively (Table 3).

^{14}C activity retained in flag leaf after 48 hours exposure

Translocation of ^{14}C from fed leaf was decreased with the gradual increase of stress levels (Table l). The highest translocation percentage (84.6%) of ^{14}C was found from fed leaf under 80% while the lowest (55.5%) was found under 30% FC treatment.

The lowest amount of ^{14}C in fed leaf was found in Shatabdi for its higher translocation capacity. The highest amount of ^{14}C was detected in the flag leaves of Agrani for its poorest translocation capacity. Kanchan showed second position in translocation of assimilate. The genotypes BAW-969, BAW-56 and BAW-944 did not differ in activity of ^{14}C in fed leaf. Shatabdi showed the highest translocation capacity (83.2%) of ^{14}C from fed leaf and the lowest (61.5%) was found in Agrani. The genotypes Kanchan, BAW-969, BAW-56 and BAW-944 showed translocation percentage of 78.7%, 75.5% 68.9% and 67.8%, respectively (Table 2).

All the genotypes showed very low and statistically similar activity of ^{14}C under 80% FC treatment in fed leaf after 48 hrs exposure, which indicated the higher translocation ability of assimilate. The highest amount of ^{14}C activity was detected in flag leaf in Agrani whereas the lowest was found in Shatabdi under 30% FC treatment. Under 55% FC treatment, Kanchan showed the second lowest amount of ^{14}C activity, which was similar to BAW-969 and BAW-56 under the same treatments. Kanchan also showed lower amount of ^{14}C activity under 30% FC treatment, followed by BAW-969, BAW-56 and BAW-944 under the same treatment. The highest translocation percentage (76.2%) was observed in Shatabdi under 30% FC treatment, whereas the lowest was found in Agrani under the same treatment. The other moisture regime of 80% FC showed more or less similar translocation capacity. Under 55% FC treatment, Shatabdi also showed higher and Agrani showed lower capacity of translocation percentage (Table 3).

^{14}C activity in stem after 48 hours exposure

Translocation capacity of ^{14}C from fed leaf to stem was decreased with the increment of stress levels (Table 1). The highest amount of ^{14}C (397 dps) in stem was found in Shatabdi followed by Kanchan. The lowest amount of ^{14}C (209 dps) activity was detected in Agrani. The genotypes BAW-56 and BAW-944 showed lower and similar activity of ^{14}C in culm. Genotypic differences were found significantly influenced by stress levels (Table 2). The genotype Shatabdi showed the highest capability of translocation of ^{14}C (435 dps) in culm from fed leaf followed by Agrani, Kanchan and BAW-969 under 80% FC treatment, whereas Agrani showed the lowest capability (90 dps) under 30% FC treatment. Translocation efficiency of ^{14}C showed higher in Shatabdi under 30% FC treatment and held statistically second highest in Kanchan under the same treatment (Table 3).

^{14}C activity in grain after 48 hours exposure

Activity of ^{14}C from fed leaf towards grain was decreased with the increase of water stress (Table 1). The highest percentage of activity (67.5%) was observed under 80% FC treatment while the lowest (53.4%) was in 30% FC treatment.

Significant genotypic differences were detected in translocation of ^{14}C from fed leaf towards grain after 48 hrs exposure. The highest activity of ^{14}C (1762 DPS) in grain was found in Shatabdi followed by Kanchan. The lowest amount of ^{14}C (683 DPS) activity was detected in Agrani. The genotype BAW-969 had shown 3rd position in translocation of assimilates towards grain. The highest percentage of activity (75.5%) was observed in Shatabdi while the lowest (50.7%) was in Agrani (Table 2).

Genotypic differences were found significantly influenced by stress levels. The genotype Shatabdi showed the highest activity of ^{14}C (2210 dps) in grain followed by Agrani, Kanchan and BAW-969 under 80% FC treatment, whereas Agrani showed the lowest activity of ^{14}C under both 55% and 30% FC treatments (830 and 497 dps, respectively). The genotype Shatabdi also exhibited higher ^{14}C activity of ^{14}C under 30% FC treatment and second highest ability was observed in Kanchan under that same treatment. Under 30% FC treatment, Shatabdi showed the highest percentage of activity (67.8%) in grain where the lowest (23.0%) was found in Agrani (Table 3).

^{14}C activity in grain at maturity

A decreasing trend was found of ^{14}C translocation from fed leaf towards grain at maturity with increment of stress levels (Table 1).

The genotypes Shatabdi and Kanchan had translocated the higher amount of assimilate (^{14}C isotope) from fed leaf towards grain at maturity followed by BAW-969, BAW-56 and BAW-944, whereas the lowest amount of ^{14}C assimilate was detected in Agrani (Table 2).

Table 1. Effect of moisture stress on translocation of ^{14}C isotope in different plant parts

Item	^{14}C activity (dps)							
Moisture regimes	After 5 min. exposure	After 48 hrs exposure					At maturity	
	Flag leaf	Flag leaf	% activity (From fed leaf to wards stem and grain)	Activity in stem	Activity in grain	% of activity in grain	Activity in grain	% of activity in grain
80% FC	2850 a	437 c	84.6	344 a	1629 a	67.5	313 a	19.2
55% FC	2496 b	625 b	74.9	289 b	1167 b	62.37	201 b	17.2
30% FC	1986 c	865 a	56.44	198 c	599 c	53.4	98.8 c	16.4
Sx	29.4	9.17	-	5.38	31.6	-	5.46	-

Table 2. ^{14}C isotope activity in different plant parts of wheat genotypes

Item	^{14}C activity (dps)							
Genotypes	After 5 min. exposure	After 48 hrs exposure					At maturity	
	Flag leaf	Flag leaf	% activity (From fed leaf to wards stem and grain)	Activity in stem	Activity in grain	% of activity in grain	Activity in grain	% of activity in grain
Shatabdi	2804 a	471 d	83.2	397 a	1762 a	75.5	354 a	20.0
Kanchan	2725 a	580 c	78.7	316 b	1448 b	67.5	262 b	18.0
BAW-696	2687 a	655 b	75.6	279 c	1275 c	62.7	221 c	17.3
BAW-56	2198 b	682 b	68.9	246 d	853 d	56.2	142 d	16.6
BAW-944	2144 b	688 b	67.9	241 e	770 de	52.8	127 d	16.4
Agrani	2106 b	759 a	63.9	209 c	683 e	50.7	121 d	17.7
Sx	41.6	12.97	-	22.2	31.6	-	63.2	10.9

Interaction of stress x genotype showed differences in translocation of assimilate under different moisture stress conditions. All genotypes did not show significant variation in ^{14}C activity in grain at maturity under 80% FC treatment. Under 55% FC treatment, Shatabdi showed highest activity in grain followed by Kanchan and BAW-969 under the same treatment. Shatabdi also exhibited higher activity under 30% FC treatment which was similar to Kanchan, BAW-969 and BAW-56 under same treatment. The lowest activity was found in Agrani under 30% FC treatment (Table 3).

Correlation between leaf area and transpiration rate with % activity of ^{14}C in grain (48 hrs exposure) was almost perfect and positive in nature, indicating thereby that the straight line regression is quite appropriate. Percent activity of ^{14}C in grain responded (r = 0.838) increased transpiration rate and leaf area was also highly correlated with that character (Fig. 1).

Table 3. Interaction effect of moisture stress and genotype on translocation of ^{14}C isotope in different plant parts

Item		^{14}C activity (dps)							
Genotypes		After 5 min. exposure	After 48 hrs exposure					At maturity	
		Flag leaf	Flag leaf	% activity (From fed leaf to wards stem and grain)	Activity in stem	Activity in grain	% of activity in grain	Activity in grain	% of activity in grain
80% FC	Shatabdi	3042 a	358 i	88.23	435 a	2210 a	82.3	457 a	20.6
	Kanchan	3032 a	391 hi	87.1	358 b	1850 b	70.0	356 b	19.2
	BAW-696	3042 a	438 gh	85.6	319 b-d	1650 bc	63.4	305 c	18.4
	BAW-56	2665 b-d	448 gh	83.1	304 c-e	1324 d	59.7	245 d	15.5
	BAW-944	2646 cd	449 gh	83.3	302 c-e	1320 d	60.1	240 d	18.1
	Agrani	2675 b-d	483 g	81.9	351 b	1420 cd	64.8	280 cd	19.7
55% FC	Shatabdi	2894 ab	466 g	83.8	412 a	1795 b	73.9	355 b	19.7
	Kanchan	2806 bc	567 f	79.7	330 b-d	1472 cd	65.7	265 cd	18.0
	BAW-696	2759 bc	637 e	76.9	288 d-f	1426 cd	67.2	250 d	17.5
	BAW-56	2242 fg	652 e	70.9	265 e-g	977 ef	61.4	150 ef	15.3
	BAW-944	2176 fg	655 e	69.8	259 fg	820 ef	53.9	120 f	14.6
	Agrani	2101 g	776 d	63.0	180 h	510 g	38.5	71 g	13.9
30% FC	Shatabdi	2477 de	589 ef	76.2	343 bc	1280 d	67.8	250 d	19.5
	Kanchan	2336 ef	784 d	66.4	259 fg	1021 e	65.8	165 e	16.1
	BAW-696	2261 e-g	892 c	60.5	231 g	750 f	54.8	110 f	14.6
	BAW-56	1687 h	946 bc	43.9	169 h	258 h	34.8	32.0 h	12.4
	BAW-944	1611 h	961 ab	40.3	100 i	170 h	26.2	22.0 h	12.9
	Agrani	1542 h	1020a	11.6	90 i	120 h	23.0	14.0 h	12.9
Sx		72.2	64.5	-	13.4	77.4	-	13.3	11.6

*In a column, figures having similar letter (s) are not significantly different at 5% level by DMRT

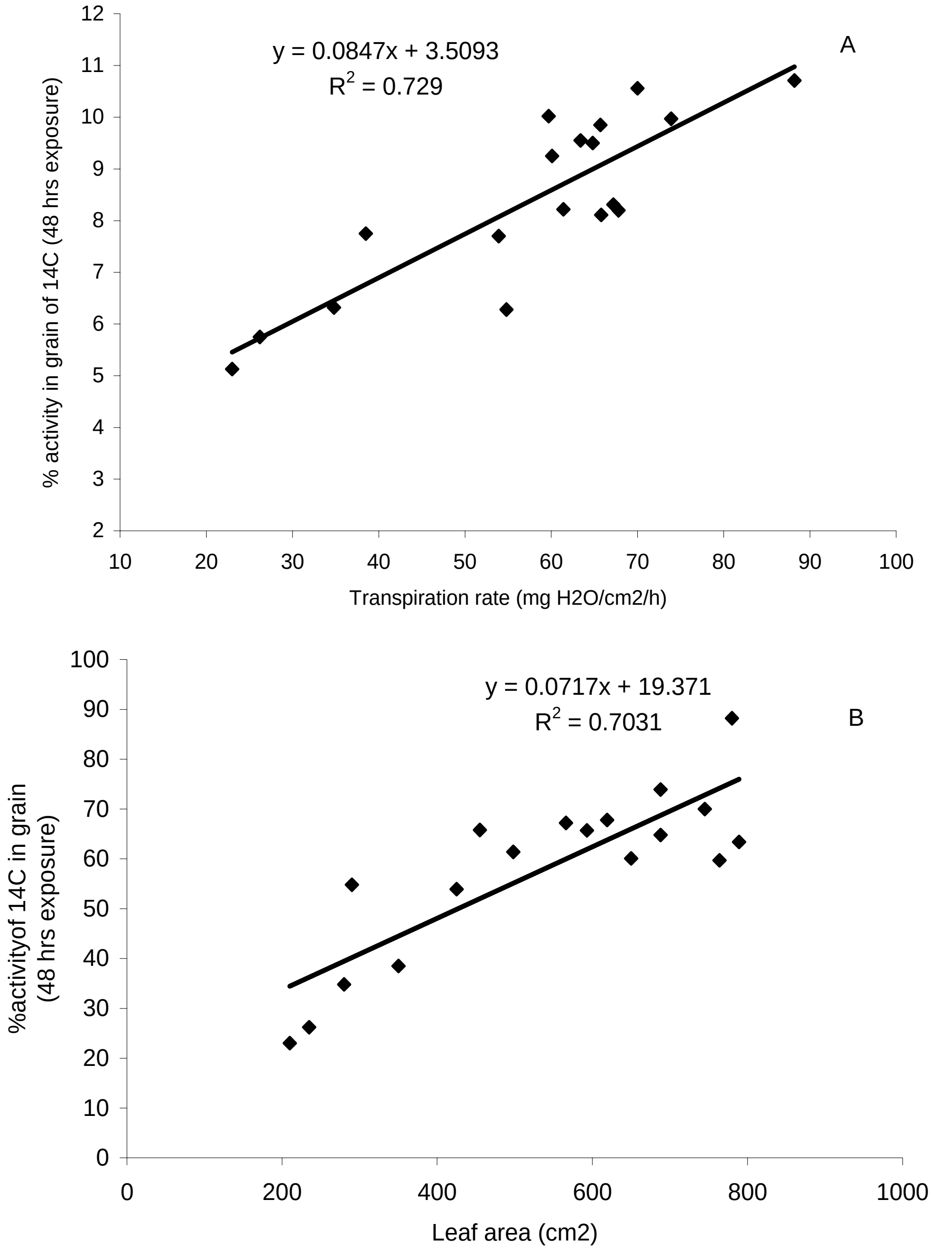

Fig. 1. Relationship between % activity of ^{14}C in grain (48 hrs exposure) with (A) transpiration rate and (B) leaf area

Discussion

Grain formation and grain filling is dependent on transient photosynthesis and translocation of stored plant reserves. When photosynthetic source is limited by stress, then it affects anthesis (Wardlaw, 1968).

Moisture stress decreased translocation of assimilates towards grains and different genotypes showed different ability of translocation under moisture stress. This result agrees with Subbaiah (1985) who observed varietial differences in biomass production and partitioning under different soil moisture regimes. Translocation of ^{14}C calculated as total ^{14}C activity of fed leaf after 5 minute exposure was shown in Tables. The highest amount of ^{14}C assimilate was found under 80% FC treatment whereas the lowest was found in 30% FC treatment. Under 30% FC treatment, Shatabdi exported about a large amount of the ^{14}C (% of primary activity) to stem and grain, while Agrani retained a little amount of the photosynthate in that portion under the same stress treatment. In early flowering stage, the assimilate could be stored in stem and then translocated to grain at grain filling period. The percentage of (84%) current assimilate went directly from leaves to grain, as reported by Stephenson and Wilson (1977). Translocation of assimilated ^{14}C from the leaves of different species which are known to have high photosynthetic rates, such as the tropical grasses sorghum and millet, exported 70% or more of the assimilated ^{14}C during the first 6 h after assimilation, compared to the values of 45 to 50% for tomato, castor bean, Nicotiana affinis and soybean. Experimentally it was found that all of the ^{14}C labeled assimilates from a wheat floret remained within the spikelet and largely within the floret. Some movement to more distal florets on the same side of t-spikelet (Bremmer and Rawson, 1972). The pattern of vascular connections also restricts the translocation process but under conditions of high demand by the sink, this barrier may be broken (Wardlaw, 1968; Hanif and Langer, 1972; Thornley *et al*., 1981). Thus, the amount and pattern of translocation seem to be governed by the relative sizes of source and sink and there appears to be no major hindrance in the translocation path (Milthorpe and Moorby, 1969). The translocation of all genotypes was similar under 80% FC treatment but only Shatabdi, Kanchan and BAW-969 could be able to translocate comparatively higher amount of ^{14}C assimilate under 30% FC treatment. This fact suggests that active translocation of ^{14}C to grain kept higher caused by maintaining turgor through osmotic adjustment capabilities of Shatabdi and Kanchan under stress condition. When ^{14}C was incorporated in flag leaves, the difference in the distribution pattern between 30% FC and 80% FC treatments was higher. Tolerant genotypes Shatabdi and Kanchan showed that a greater portion of ^{14}C assimilated fixed in grain under severe stress condition and susceptible one Agrani translocated slowly and little labeled assimilate towards grain under drought condition.

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SCREENING OF DIFFERENT AROMATIC AND NON-AROMATIC FINE RICE VARIETIES IN *BORO* SEASON IN TERMS OF YIELD POTENTIALITY

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Abstract

A field experiment was carried out at the farm, Banglasesh Institute of Nuclear Agriculture (BINA), Mymensingh during 17 December 2006 to May 2007 to study the growth and yield performance of 33 aomatic and non-aromatic fine rice varieties in *Boro* season. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three Replications. Results showed that the varieties significantly influenced all the studied growth parmaters except number of total tillers hill^{-1} at 60 DAT and Chlorophyll containt leaf^{-1} at 60 DAT, 90 DAT and yield and yield contributing characters. Significantly highest grain yields (3.2 tha^{-1}), (2.66 tha^{-1}), (1.97 tha^{-1}) and (1.80 tha^{-1}) were obtained from Awnless minicat, Basmati, Chiniatab and Chinisagar, while the lowest grain yield was produced by BRRIdhan34 (0.77 tha^{-1}) and Kalozira (0.83 tha^{-1}). The highest straw yield was produced by Ukunimadh$_4$ (5.33 tha^{-1}) and the lowest straw yield by Chiniatab (4.0 tha^{-1}). The highest biological yield was recorded from Awnless Minicat (7.66 tha^{-1}) and the lowest biological yield by Marichbati (5.33 tha^{-1}). The highest harvest index was recorded from non-aromatic fine rice variety Awnless Minicat (45.65%). The second highest harvest index was found in Chinitab (32.99%) and Chinisagar (30.50%) and the lowest harvest index was found in BRRI dhan34 (13.05%). From the present study, it might be concluded that amomg the aromatic finc rice varieties, the highest grain yield was obtained in Chinisagar and Chiniatab. Among the non-aromatic finc rice varieties, Basmatic and Awnless Minicat produced the highest grain yield in *Boro* season.

Key Words: Aromatic and non-aromatic fine rice, yield and *Boro season*

Introduction

Bangladesh is an agro-basedcountry. Most of her economic activities depend on agriculture. Agriculture in Bangladesh is dominated by intensive rice cultivation. The humid tropical climate of this country provides an excellent habitat for rice culture. Rice (*Oryza sativa* L.) is one of the most extensively cultivated cereals of the world and it is

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feeding one-half of the world's total population (Anonymous, 2009). The total area and production of rice in Bangladesh is about 10.5 million hectare and 27.3 million M. ton, respectively (BBS, 2008). There are two types of *Aman* rice viz. coarse and fine rice and most of the fine rices are aromatic in nature e.g. Kataribhough, Badshabhough and Kalizira. The productivity of aromatic fine rice in Bangladesh is very low because of lack of fertilizer management, optimum spacing and date of transplanting. Although the geographical, climatic and ethmic conditions of Bangladesh are favorable for year-round rice cultivation, but histrorically the aromatic rice has been growing in transplanted aman season due to climatic reasons and the T. aman season produces the lesser grain yield. No effort has been made yet by the researchers to develop a fine aromatic rice variety for *Boro* season. Therefore, effort should be made to improve the productivity of aromatic fine rice through agronomic manipulation with suitable cultivars for *Boro* season. There is a huge demand of Bangladeshi aromatic fine rice in the Middle-East countries, Malaysia, Korea, Japan, Australia, U.S.A, Canada, U.K, Italy and Sweden. Several special dishes like *polao, khir, firney, paish, chira, khoi, briany, jorda,* etc. are prepared from this kind of milled rice. Thus, milled rice of such type are used as a luxurious special food. Moreover, the price of 1 kg aromatic fine milled rice is about 110 TK whereas 1 kg HYV coarse milled rice is about 45 TK. So, it indicates that the production of aromatic and fine rice in the country is economically profitable (Raju, 2000).

Hence, the objective of this study was to identify the best performance of aromatic and non-aromatic fine rice vaieties in *Boro* season by screening from a lot of 33 aromatic and non-aromatic fine rice.

Materials and Methods

The experiment was conducted at the Bangladesh Institute of Nuclear Agriculture (BINA) farm, Mymensingh during 17 December 2006 to May 2007 in the *Boro* season. The experimental land was sandy loam in texture having soil pH 6.8. The experimental materials such as seeds for the experiment were collected from the Agronomy Division and Plant Breeding Division of BINA, Germplasom centre of BRRI and Agronomy Farm of BAU. The unit plot size was 4.0 m x 2.5 m. The plots of aromatic and non-aromatic fine rice were fertilized with N, P, K, S, Zn at the rate of 135, 39, 67, 29 and 1.8 kg ha^{-1}, respectively according to the fertilizer recommendation guide (BARC, 2005). The whole amounts of triple super phosphate, muriate of potash, gypsum and zine sulphate were applied to the soil at the time of final land preparation. Urea was applied in three equal splits. One split of urea was applied with other fertilizers as basal dose and the other two splits were applied at 21 and 45 days after transplanting (DAT). The experiment was laid out in a Randomized Complete Block Design with three replications. The average value of daily maximum temperatures during the period of December 2006 to May 2007 was

26.22, 23.64, 24.41, 29.13, 30.44 and 33.33^{o}C, respectively. A total of 33 aromatic and non-aromatic fine rice varieties were evaluated in this study. The varieties were as follows; BRRI dhan38, BRRI dhan34, BRRI dhan37, Jesmin, Chiniatab, Chinisagar, Ukunimadhu, Kalobhough, Kalizira, Dudhsar, Jumadhuma, Binadhan-4, Binasail, Basmati, Kasmiribasmati, Chikonlal, Kala manik, Lalmoi, Lalgilona, Minikichi, Maharani, Marichbati, Pulashi, Sharisaful, Surjamukh, Sonamukhi, Tripunachinal, Chinikahai, Banajira, Kataribhough, Awnless Minicat, Awn Minicat, Kamonisail.

Only selected healthy seedlings were transplanted in the experimental plots on 7 February 2007 in 20 cm apart line maintaining a distance of 15 cm from hill to hill with three seedlings hill^{-1}. Intercultural operations and pesticide application were done as and when necessary. From each plot, 10 hills (excluding border hills) were selected from an inside row for collecting different data at 30 DAT, 60 DAT and 90 DAT. Each plant sample was separated from leaf as their area was measured with the help of a protable area meter (Model Fx-3000 Japan). Just after transplanting, 10 hills were randomly selected and tagged for measuring plant height, total tillers, total dry matter production and chlorophyll contents of leaf. Chlorophyll content of leaves were determined with SPAD meter. During harvest, 10 hills were again randomly seclected from plots excluding border hills and from the hills data on yield contributing characters were collected. Grain and straw yields were sun dried and the weight of grains was adjusted to 12% moisture content. Grain and straw yields were then converted to tha^{-1}. Data were analyzed statistically using “Analysis of Variance” technique and differences among treatments means were adjudged by Duncan’s Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Plant height significantly varied among the varieties under study at 30 DAT, 60 DAT and 90 DAT. Number of total tillers hill^{-1} differed significantly due to variety at 30 DAT and 90 DAT. Total dry matter (TDM g hill^{-1}) varied significantly due to variety at 30 DAT, 60 DAT and 90 DAT. Significant variations were found among the varieties of aromatic and non-aromatic fine rice in respect of chlorophyll content at different growth stages at 30 DAT. Leaf area hill^{-1} differed significantly among the varieties at 30 DAT, 60 DAT and 90 DAT (Table 1). The varieties showed significant difference for plant height, total tillers hill$^{-1,}$ effective tillers hill^{-1}, non-effective tillers hill^{-1}, grains panicle^{-1}, unfilled spikelets grains panicle^{-1}, 1000-grain wt, grain yield, straw yield, biological yield and harvest index.

Growth parameters

Plant height states the status of any kind of plants, its plant type and nature of leaf/canopy arrangement. It determines the nature of lodging, light and air penetration inside the canopy. The increasing patterns of plant height were almost same for all the varieties. At 30 days after transplanting (DAT), the tallest plant (65.0 cm) was recorded in Kamonisail followed by Awn Minicat (64.0 cm) (Table 1). On the other hand, BRRI dhan37 produced the shortest plant (40.5 cm) at 30 DAT. Similar trend of plant height growth was recorded at 60 DAT and 90 DAT. However, at 60 DAT Kamonisail had the tallest plant (99.3 cm) and the shortest one (61.3 cm) was in BRRI dhan38 (Table 1). At 90 DAT, Tripunachinal had the tallest plant (112.3 cm) and shortest one (80.0 cm) was in Basmati (Table 1). At 30 DAT, Basmati, Jesmin and Chinisagar produced the maximum number of total tillers hill^{-1} as; 13.3, 14.0 and 13.3, respectively and minimum was recorded in Marichbati as 4.3. At 60 DAT, as Basmati and Minicat awnless had the highest number of total tillers hill^{-1} (13.3) and the lowest was recorded in Kalamanil (6.6). At 90 DAT, Chinikahai gave the highest number of total tillers hill^{-1} (18.3) and the lowest (7.6) was obtained from Jumadhuma (Table 1). From Table 1, it was observed that at 30 DAT, the highest TDM hill^{-1} (5.6 g) was produced by Jesmin which was statistically similar to Tripunachinal (4.0 g). At 60 DAT, the highest TDM hill^{-1} (14.0 g) was found in Marichbati and the lowest (6.2 g) was observed in BRRI dhan34. At 90 DAT, TDM of Binadhan-4 was the highest TDM (34.6 g) followed by Chinikahai (33.3 g) and the lowest (18.9 g) was observed in Jesmin (Table 1). The variety Sharisaful showed higher chlorophyll content at 30 DAT and the lowest at awnless Minicat. Chlorophyll content was highest (43.8 SPAD value) at 60 DAT in Chiniatab variety, whereas the variety Awnless Minicat showed the lowest at 60 DAT. At 90 DAT, Sharisaful gave highest amount of chlorophyll content (41.4 SPAD value). However, the lowest chlorophyll content (28.6 SPAD) was recorded at Chinisagar (Table 1). At 30 DAT, Chinisagar gave the higher leaf area hill^{-1} (202.3 cm^2). However, the lowest value (53.8 cm^2) was recorded at Kasmiribasmati. At 60 DAT, the highest leaf area hill^{-1} was found in BRRI dhan37 (1829.0 cm^2) and the lowest leaf area hill^{-1} (476.0 cm^2) was produced in Sharisaful. At 90 DAT, Chikonlal produced the highest leaf area hill^{-1} (1129.0 cm^2) (Table 1).

Yield and yield contributing characters

Results showed that Kasmiribasmati produced the tallest plants (129.9 cm), which was statistically similar to the Surjamukhi (124.1 cm), Ukunimadhu (123.6 cm) and Maharani (124.7). While Awn Minicat produced the shortest plants (84.1 cm) which was statistically identical to the variety Minikichi (88.2 cm) (Table 2). The variation in plant height might be due to the genetic make up of the varieties. The results were in agreement with those of Hossain and Alam (1991) and Mia (1993) who showed that plant height varied significantly among the varieties. Results presented in Table 2 showed that the number of total tillers hill^{-1} ranged from 8.2-20.3. The highest number of total tillers hill^{-1} was counted in Basmati (20.3), which was statistically similar to those of BRRI dhan34 (19.4 cm) and Minicat awnless (18.8). The lowest number of tillers hill^{-1} was observed in BRRI dhan37 (8.2) and Marichbati (8.2), which was statistically identical to those of the varieties Binadhan-4 (9.0), Binasail (9.4), Chiniatab (9.9), Lalmoni (9.0), Lalgilona (9.1), Maharani (9.0) and Banajira (9.0). Variable effect of variety on number of total tiller hill^{-1} was also reported by Guowei *et al.* (1998) who noticed that total tillers hill^{-1} varied significantly among the varieties in *Boro* season. These variations in the production of total tillers might be due to differential growth characters governed by genetic variation. A rice plant may produce a number of tillers during its early growth period but all of them may not become effective i.e., they do not bear panicles. So, this character is directly related to the yield of rice. The results indicated that the highest number of effective tillers hill^{-1} (16.0) and (15.6) was produced by Minicat awnless and Basmati, respectively. Variety Chininsagar (12.6), Chiriatab (11.0) and Jesmin (10.3) gave the second highest and statistically similar number of effective tillers hill^{-1}. The lowest number of effective tillers hill^{-1} (4.1) was observed at Kalizira (Table 2). The probable reason of difference in producing effective tiller hill^{-1} is the genetic make up of the variety, which is primarily influenced by heridity.

The results showed that the number of non-effective tillers hill^{-1} ranged from 1.2-12.7 (Table 2). It was found that the highest number of non-effective tiller hill^{-1} was produced by BRRI dhan38 (12.7) and the lowest number of the same was produced by Tripunachinal (1.2) and Dudhsar (1.2). Varietal differences concerning non-effective tiller hill^{-1} might be due to their variations in gentic make up. Table 2 showed that variety Chiniatab gave the maximum number (145.0) of filled grain panicle^{-1} followed by Chinisagar (152.0), Awnless Minicat (112.6) and Basmati (115.6). The lowest number (36.33) of filled grains panicle^{-1} was observed at Kalizira. Kamal *et al.* (1988) reported variable number of filled grains panicle^{-1} among the varieties. Varietal variations regarding the number of filled grains panicle^{-1} might be due to their variation in genetic constitents and also due to variation in photosynthetic assimilate accumulation, especially after heading. Among the undesirable traits, number of unfilled grains panicle^{-1} is the most significant factor and plays the major role in yield reduction. Table 2 showed that the variety Kalizira produced the highest number of unfilled grains panicle^{-1} (73.33). The variety Kalamanil produced the lowest number of unfilled grains panicle^{-1} (6.0). Chowdhury *et al.* (1993) also reported variation in number of sterile spikelets panicle^{-1} due to varietal variations. These variations might be due to genetic characters of the rice varieties and also due to response to fertilizer and environment. The results (Table 2) revealed that the highest 1000-grain weight was obtained from Kalamanil (28.93 g) which

Table 1. Screening of different growth aromatic and non-aromatic fine rice varieties in boro season in terms of yield potentiality.

Treatments	Plant height (cm)			Total tillers hill^{-1} (no)			TDM (g) hill^{-1}			Chlorophyll contains leaf^{-1}			Leaf area hill^{-1}		
Varieties	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60DAT	90DAT
BRRI dhan38	50.0d-h	61.3m	89.0l	10.6e	12.3	12.6efg	2.8hi	11.6gh	27.4d-g	38.7e	40.5	36.2	123.8de	1349.0e	913.0de
BRRI dhan34	57.8bc	61.6m	85.3m	12.6bc	10.6	12.3fgh	3.0fgh	6.2n	19.6op	35.0ef	39.1	36.0	106.8efg	664.0q	421.0q
BRRI dhan37	40.3 l	65.0l	89.3l	9.fg6	10.6	14.0cd	1.9o-r	8.8lm	28.7cde	33.1gh	33.2	38.6	82.0t	1829.0a	965.0e
Jesmin	47.6g-j	72.0j	96.0jk	14.0a	10.0	11.6ghi	5.6a	12.2ef	18.9p	38.2e	36.6	33.6	196.9a	1098.g	888.0ef
Chinisagar	49.6f-j	73.6ij	108.0d-f	13.3ab	13.0	13.6cde	3.5d	12.0fg	23.1j-n	30.8jk	34.9	28.6	202.3a	1111.0g	860.0fg
Chiniatab	46.6j	59.6n	99.0i	12.3cd	12.3	17.0b	2.1k-o	13.3bc	33.3a	32.3hi	43.8	34.2	126.2d	1413.0d	1057.0b
Ukunimadhu	55.6c	75.3i	104.0gh	10.3ef	9.0	8.3m	3.2ef	8.9lm	24.1i-l	30.3k	33.3	30.6	127.8d	826.0klm	598.6kl
Kalobhog	48.6e-j	86.0f	106.0fg	7.3kl	8.6	13.3c-f	2.2k-n	8.8lm	29.1cd	30.1k	34.0	34.1	89.6ghi	1021.6h	683.0i
Kalizira	48.3f-j	83.3g	102.3h	8.6hij	10.6	14.0cd	1.9q-r	11.9fg	22.9j-n	32.4hi	36.1	35.4	74.1i	1212.0f	950.0cd
Dudhsar	44.0k	72.3j	109.0b-e	10.6e	12.3	13.0def	3.6cd	8.6m	24.6h-k	33.2gh	40.5	32.5	105.0fgh	1360.6de	511.0no
Jumadhuma	41.6kl	93.0e	110.3a-d	5.3n	8.3	7.6m	1.6r	8.5m	21.9mn	30.1k	31.9	30.5	106.9efg	852.0j-l	882.0ef
Binadhan-4	49.3e-j	70.0k	94.6jk	9.6fg	10.3	10.6ijk	2.2k-n	10.9j	34.6a	34.7ef	35.2	31.4	78.2i	1649.6b	1030.6b
Binasail	42.6kl	80.3h	97.0ij	8.3ij	11.6	14.3e	1.8pqr	12.8cd	26.0gh	30.8jk	34.7	31.6	83.2i	1235.6f	925.0cde
Basmati	47.3h-j	69.0k	80.0n	13.3ab	13.3	12.3fgh	2.4jk	9.1l	21.5mno	34.1efg	34.7	36.6	103.fgh5	874.3jk	833.0gh
Kasmiribasmati	51.3de	82.0gh	107.0ef	6.3m	8.3	9.3l	1.9n-q	11.1ij	27.0e-g	36.6d	35.1	36.9	53.8j	1500.0e	582.0lm
Chikonlal	48.3f-j	91.6cd	109.0b-e	10.3ef	12.0	11.3hi	2.9fgh	12.6dc	29.5bc	32.9h	38.1	39.3	83.6i	1321.0e	1129.0a
Kalamanik	47.0ij	90.3d	94.0k	7.0lm	6.6	9.6kl	1.7qr	12.0fg	22.7k-n	34.0fg	38.3	33.1	87.3hi	862.6j-l	408.0q
Lalmoi	47.3h-j	91.3cd	107.3ef	5.0no	7.6	11.3hl	1.9n-q	12.7fg	21.3no	38.0c	34.0	38.2	165.8bc	1239.6f	789.0h
Lalgilona	43.6k	86.0f	109.3b-e	8.0jk	7.3	9.6kl	2.0m-p	11.0ij	23.2j-n	30.6jk	32.9	32.2	120.5def	1084.3g	785.0h
Minikichi	52.0d	73.6ij	90.6l	6.6lim	9.3	11.0ij	3.0fgh	9.2l	23.6j-m	36.2d	36.4	38.2	162.6bc	900.0j	622.0jkl
Maharani	50.3def	72.0j	111.0abc	9.0ghi	9.0	13.6cde	2.5j	11.hi4	31.1b	40.6b	39.2	35.0	116.0def	957.3i	627.0jkl
Marichbati	49.0e-j	88.3e	102.3h	4.3g	7.0	11..0ij	2.1l-p	13.0cd	28.1e-f	32.6h	37.6	35.8	156.5e	772.6mno	433.6pq
Pulashi	49.3e-j	85.f	109.3b-e	7.0lg	11.0	11.6ghi	2.3j-m	14.0a	21.3no	28.3l	37.4	33.9	155.1e	706.0q	585.0lm
Sharisaful	48.6e-j	91.0d	96.0jk	11.6b	11.3	10.0jkl	3.4dc	10.4k	23.5j-m	42.3a	37.3	41.4	167.7bc	476.0s	388.6q
Surjamukhi	55.6c	75.0i	107.3ef	11.6b	9.0	12.3fgh	4.0b	13.6ab	27.0e-g	42.3a	35.6	36.5	177.8b	767.0nop	642.6ijk
Sonamukhi	58.3b	88.6e	111..3ab	6.3m	8.6	9.6kl	3.8bc	12.1f	26.2f-h	34.8ef	40.1	36.5	213.3a	723.0opq	680.0i
Tripunachinal	48.6e-j	86.6f	112.3a	9.6gh	9.0	13.3c-f	3.1efg	8.8lm	22.5l-n	35.1e	36.7	34.1	167.2bc	695.0q	474.3op
Chinikahai	49.3e-j	82.0gh	103.3h	8.3ij	9.0	18.3a	2.3jkl	13.8a	34.1a	30.4k	33.8	34.5	132.7d	973.3hi	790.0h
Banajira	58.3b	95.0b	111.0abc	8.6hij	9.0	10.6ijk	3.0fgh	8.9lm	24.8hij	38.5c	34.9	33.0	105.4e-g	596.0q	433.6pq
Awnlee Minicat	64.6a	81.0h	88.6l	12.3cd	13.0	10.6ijk	3.0fgh	8..9lm	22.8i-n	30..0k	33.1	34.6	106.0efg	766.0nop	598.0kl
Awn Minicat	55.6c	72.6j	80.3n	10.3ef	13.3	12.6efg	2.6ij	9.2l	27.4d-g	28.0l	31.9	34.0	131.3a	806.0lmn	541.0mn
Kamonisail	65.0a	99.3a	108.3e-f	8.3ij	8.6	12.6efg	2.9gh	10.9j	25.7ghi	32.8ij	37.1	35.2	90.9ghi	712.6pq	651.3ij
$LSD_{0.05}$	2.317	1.624	2.4	0.7474	NS	0.9513	0.261	0.4153	1.81	0.9572	-	-	16.5	54.03	46.18
Level of Significance	0.05	0.01	0.05	0.01	NS	0.01	0.05	0.01	0.01	0.05	NS	NS	0.05	0.01	0.05
CV (%)	11.96	5.31	6.20	20.99	15.11	20.67	24.78	9.93	18.43	7.34	9.09	6.99	34.4	13.93	16.99

In a column, figures with same letters or without letters do not differ significantly where as figures with dissimilar letter differ significantly as per DMRT.
NS = Not significant.

Table 2. Effect of yield and yield contributing characters of aromatic and non aromatic fine rice varieties in *boro* season

Variety	Plant height (cm)	Total tillers hill^{-1} (No.)	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Filled Grains Panicle^{-1} (No.)	Unfilled grains Panicle^{-1} (No.)	1000-grain wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
BRRI dhan38	96.5 j-n	19.4 ab	6.7 d-g	12.7 a	72.66c-f	22.0 cde	18.15 hij	0.99fgh	4.76a-g	5.75 cde	17.21ghi
BRRI dhan34	93.8 k-o	17.2 abc	5.1 fg	12.1 ab	72.66c-f	43.0 a-d	12.75 mn	0.77h	5.13abc	5.90 e	13.05 i
BRRI dhan37	97.6 i-n	8.2 e	5.4 e-g	2.8 de	78.36c-f	58.0 ab	14.08 lm	0.86gh	4.80a-g	5.66de	15.19hi
Jesmin	100.3 g-n	12.0 cde	10.3 bcd	1.7 de	93.00cde	20.3 cde	25.63 b	1.80c-h	4.63a-g	6.43a-d	27.99c-g
Chiniatab	101.8 g-l	14.4 a-e	12.6 ab	1.8 de	154.0a	23.66 cde	11.13 n	1.97c-h	4.00g	5.97 b-e	32.99 bcd
Chinisagar	105.8 e-j	12.2 b-e	11.0 bc	1.2 e	152.0ab	28.00 b-e	10.50 n	1.80c-h	4.10fg	5.90a-e	30.50b-f
Ukunimadhu	123.6abc	11.7 cde	7.7 c-g	4.0 de	76.3c-f	40.33 b-e	10.88 n	1.20e-h	5.33a	6.53a-e	18.37 f-i
Kalobhog	114.3 b-f	17.6 abc	10.3 bcd	7.3 a-d	78.66c-f	48.66 abc	13.80 lm	1.30e-h	4.40b-g	5.70a-d	22.80 d-i
Kalizira	106.1 d-j	14.9 a-d	4.1g	10.8 ab	36.33 f	73.33 a	14.05 lm	0.83h	4.73a-g	5.56b-e	14.92 hi
Dudhsar	117.3 bcd	17.5 abc	7.8 c-g	9.7abc	60.0ef	23.00 cde	24.96 b	1.50hd-h	4.70a-g	6.20b-e	24.19 c-i
Jumadhuma	113.5 c-f	14.5 a-e	8.1 c-g	6.4 a-e	115.6abc	30.66 b-e	15.40 kl	1.20e-h	4.80a-g	6.00b-e	20.00 fi
Binadhan-4	104.6 f-k	9.0 de	7.6 c-g	1.4 e	86.16cde	16.6 cde	23.68 bcd	1.13fgh	4.83a-g	5.96b-e	18.95 f-i
Binasail	117.0 b-e	9.4 de	6.6 d-g	2.8 de	85.33cde	31.0 b-e	14.00 lm	1.33e-h	5.00a-f	6.33a-e	21.01e-i
Basmati	99.0 h-n	20.3 a	15.6 a	4.7 cde	110.6b-d	30.66 b-e	21.33 efg	2.83ab	4.20c-g	7.03a-d	40.25 ab
Kasmiribasmati	129.9 a	11.6 cde	8.7 b-f	2.9 de	114.33abc	26.33 b-e	20.41 e-h	2.20b-e	4.83a-g	7.03 de	31.29 b-e
Chikonlal	109.6 d-h	9.9 de	8.4 c-f	1.5 e	66.0def	11.33 de	12.56 mn	1.13fgh	5.10a-e	6.23 b-e	18.13 f-i
Kalamanil	92.8 l-o	15.0 a-d	9.0 b-f	6.0 b-e	76.00c-f	6.00 e	28.93 a	1.50d-h	4.16a-g	5.66cde	26.50 c-h
Lalmoi	111.4d-g	9.0 d-e	7.7 c-g	1.3 e	79.66c-f	19.00 cde	16.47 jk	1.29e-h	4.40a-g	5.63de	22.71 d-i
Lalgilona	109.0d-h	9.1 d-e	7.8 c-g	1.3 e	105.66cde	19.66 cde	16.85 jk	1.23e-h	4.96a-g	6.13 b-e	20.06 f-i
Minikichi	88.2no	10.8 de	8.8 b-f	2.0 de	95.0cde	41.33 bcd	25.11 b	1.33e-h	4.33a-g	5.66cde	23.49 c-i
Maharani	124.7ab	9.0 de	7.7 c-g	1.3 e	93.66cde	17.00 cde	20.70 efg	1.40d-h	4.63a-g	6.03 b-e	23.21 c-i
Marichbati	94.5k-o	8.2 e	5.4 efg	2.8 de	83.0cde	20.66 cde	22.46 cde	0.90gh	4.43a-g	5.33e	16.88 hi
Pulashi	109.2d-h	10.3 de	8.9 b-f	1.4 e	100.0cde	22.33 cde	15.15 kl	1.88b-g	4.53a-g	6.41 a-e	29.32 c-g
Sharisaful	102.1g-l	11.4 cde	8.0 c-g	3.4 de	91.33cde	12.33 de	19.46 f-i	1.13fgh	4.56a-g	5.69 cde	19.85 f-i
Surjamukhi	124.1abc	11.9 cde	8.1 c-g	3.8 de	88.0cde	36.66 b-e	24.21 bc	1.60d-h	4.83a-g	6.43a-e	24.88 c-i
Sonamukhi	108.2d-i	10.8 de	9.3 b-e	1.5 de	87.3cde	13.66 de	16.78 jk	1.73c-h	4.70a-g	6.43a-e	26.90 c-h
Tripunachinal	108.9d-h	9.4 de	8.2 c-f	1.2 e	93.6cde	27.66 b-e	17.38 ijk	2.00b-f	4.40a-g	6.40a-e	31.25 b-e
Chinikahai	109.7 d-h	18.4 ab	5.8e-g	12.6 a	85.33cde	29.00 b-e	12.77 mn	1.15fgh	5.00a-f	6.15 a-e	18.69f-i
Banajira	116.6b-e	9.0 de	7.6 c-g	1.4 e	96.0cde	18.33 cde	21.61 def	1.55d-h	5.26ab	6.81a-e	22.76 d-i
AwnleeMinicat	90.3mno	18.8 a	16.0a	2.8 de	112.6a-d	17.33 cde	22.36 cde	3.20a	4.13efg	7.33ab	43.65 a
Awn Minicat	84.1o	12.3 b-e	10.6 bcd	1.7 de	105.6cde	33.00b-e	19.25 ghi	2.66abc	5.00a-d	7.66 a	34.72 abc
Kamonisail	104.6f-k	12.3b-e	10.4 bcd	1.9de	90.66cde	17.73 cde	15.90 jkl	2.40a-d	5.10a-d	7.57 abc	31.70 bcd
Level of Significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.05	0.01
$LSD_{0.05}$	9.726	5.304	3.394	4.783	38.49	28.01	2.123	0.8598	0.7742	1.196	9.418
CV (%)	4.21	19.30	18.11	55.90	19.33	62.50	5.41	25.42	10.12	11.77	17.83

In a column, figures with same letters or without letters do not differ significantly where as figures with dissimilar letter differ significantly as per DMRT.

was statistically identical with that of the variety Binadhan-4 (23.680). The lowest (10.50 g) 1000-grain weight was found in Chinisagar, which was statistically similar to Chiniatab (11.13 g). These results are in agreement with the reports of Rafey *et al.* (1989) and Singh and Ganwer (1989). The result (Table 2) showed that non-aromatic fine rice variety Awnless Minicat produced the maximum grain yield (3.20 tha^{-1}) which was statistically alike to those of variety Basmati (2.66 tha^{-1}), Kasmiribasmati (2.2 tha^{-1}), Awn Minicat (2.66 tha^{-1}), Tripunachinal (2.0 tha^{-1}) and Kamonisail (2.40 tha^{-1}). On the other hand, aromatic rice variety Chiniatab produced the least grain yield (1.97 tha^{-1}), which was statistically identical with those of aromatic rice variety Chinisagar (1.80 tha^{-1}). Biswas *et al,* (1998), Guowei *et al.* (1998) and Chandra *et al. (*2000) recorded variable grain yields among different varieties. The lowest grain yield was produced by BRRI dhan34 (0.77 tha^{-1}) and Kalizira (0.83 tha^{-1}). The highest straw yield was produced by Ukunimadhu (5.33 tha^{-1}). Banajira gave the second highest straw yield (5.26 tha^{-1}), which was similar to those of Kamonisail (5.10 tha^{-1}), BRRI dhan34 (5.13 tha^{-1}) and Chikonlal (5.10 tha^{-1}). Chiniatab gave the lowest straw yield (4.0 tha^{-1}) (Table2). The highest biological yield was recorded from Awnless Minicat (7.66 tha^{-1}). The second highest biological yield was achived by Kamonisail (7.57tha^{-1}) and the lowest biological yield by Marichbati (5.33 tha^{-1}) (Table 2). Harvest index refers to the ratio of economic yield and biological yield. In general, grain is the economic yield in case of rice while grain and straw together refer to the biological yield. The highest harvest index was recorded from non-aromatic fine rice varieties. Minicat awnless (43.65) that statistically similar with Basmati (40.25%). The second highest harvest index was gained by Chiniatab (32.99%) and Chinisagar (30.50%) and the lowest harvest index was gained by BRRI dhan34 (13.05%) (Table2)

Conclusion

From the present study, it might be conclueded that amomg the aromatic finc rice varieties, the highest grain yield was obtained in Chinisagar and Chiniatab. Among the non-aromatic finc rice varieties, Basmatic and Awnless Minicat produced the highest grain yield in *Boro* season.

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EVALUATION OF SOYBEAN GENOTYPES BASED ON MORPHO-PHYSIOLOGICAL CRITERIA

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Abstract

An experiment was conducted at BINA farm, Mymensingh, during the period from February to May 2012 to investigate growth, morpho-physiological characters, yield attributes and seed yield of four soybean mutants *viz.*, SBM-13, SBM-17, SBM-20 and SBM-22 along with a newly released variety, Binasoybean-1. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Results revealed that plant height, branch number, leaf area (LA), total dry matter (TDM), absolute growth rate (AGR), relative growth rate (RGR) and Net Assimilation Rate (NAR) differed significantly at all growth stages. LA and TDM increased with age till 80 and 90 days after sowing (DAS), respectively. The AGR increased till 80 DAS. The mutant SBM-20 showed the highest plant height, branch, TDM, LA and growth parameters like AGR and RGR at the latter growth stages. It also produced the highest seed yield (2.84 tha^{-1}) whilst Binasoybean-1 showed the least plant height, branch number, LA and AGR and resulted lower seed yield. However, in general, higher dry matter partitioning to grain was observed in low yielding genotypes than the high yielding ones.

Key words: Crop growth rate, relative growth rate, net assimilation rate, yield attributes and soybean

Introduction

Soybean (*Glycine max* (L.) Merr.) is one of the most important oil seed legume crops in the world. It is considered as an important economic food. Soybean accounts for approximately 50% of the total production of oilseed crops in the world (FAO, 2009). More than 90% of total production comes from only four countries, the USA, Brazil, Argentina and China (FAO, 2009). During the last 15 years, soybean production has been increased in all soybean producing countries with more than 10-fold increase in several countries (FAO, 2009). Despite suitable climatic and edaphic conditions, the yield of soybean is very low in Bangladesh. The average yield of soybean in the world is about 3.0 t ha^{-1} while that in Bangladesh is only 1.2 t ha^{-1} (SAIC, 2007). The yield of soybean at farmers' level is low and also susceptible to pests and diseases. The principal constraint of

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soybean production is its low yield potential. About 70 to 85% of soybean flowers do not develop into mature pods (Egli and Bruening, 2003) indicating that potential fruit or seed number is usually much larger than the number actually produced by the plant community. The number of fruits with developing seeds increase after growth stage R1 (starting of flowering stage) and reaches to a maximum after growth stage R5 (maximum seed growth stage) (Egli and Bruening, 2003) but during this period the plant still grows vegetatively. Therefore, developing reproductive sinks compete for assimilates with vegetative sinks. It is also evident that seeds per unit area are related to canopy photosynthesis during flowering and pod setting stages. Furthermore, canopy photosynthesis rate determines through leaf area index and crop growth rate.

Important physiological attributes such as leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and specific leaf weight (SLW) can address various constraints of a variety for increasing its productivity (Tandale and Ubale, 2007). A plant with optimum LAI and NAR may produce higher biological yield. For optimum yield in soybean, the LAI should be ranged from 3.5 to 4.5 (JinWoong *et al.*, 2005). The dry matter accumulation may be the highest if the LAI attains its maximum value within the shortest possible time (Tandale and Ubale, 2007).

In Bangladesh, several research Institutes like BARI, BINA and BAU have developed a couple of soybean varieties, which are high yielding compared to local landraces. But the farmers are reluctant to soybean cultivation for poor economic return compared to cereals and vegetable crops. Recently, BINA has developed several promising soybean mutants of high yield potentials. These mutants need to be assessed for their physiological growth and morphological maneuvering that takes place compared to the existing soybean cultivars. The present research work has been designed to study different growth parameters and other morpho-physiological characteristics responsible for higher biological yield as well as their interrelation to the grain yield. Thus, the research work was undertaken to evaluate the growth and development of four elite soybean mutants compared to the variety Binasoybean-1 and to select better mutant in respect to growth, yield and yield components.

Materials and Methods

The experiment was conducted with 4 soybean mutants *viz*. SBM-13, SBM-17, SBM-20 and SBM-22 along with a check variety Binasoybean-1 at BINA farm, Mymensingh during the period from 11 January to 30 May 2012. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. The size of the unit plot was 3 m × 4 m. Distances between block to block and plot to plot were 1.0 and

0.5 meter, respectively. Urea, triple super phosphate (TSP), muriate of potash (MP) and gypsum were used as a source of nitrogen, phosphorus, potassium and sulphur @ 40, 120, 80 and 40 kg ha^{-1}, respectively. Total amount of Urea, TSP, MP and gypsum were applied at basal doses during final land preparation. The seeds of five soybean genotypes were hand sown in rows on 11 January 2012. Plant protection measures were taken at 45 and 60 DAS against fruit and shoot borer by spraying Diapam 60 EC @ 0.25%. To study ontogenetic growth characteristics, a total of six harvests were made and at final harvest, data were collected from randomly selected 10 plants from each plot on some morpho-physiological parameters, yield attributes and yield. The first crop sampling was done for collecting data on growth parameter at 35 DAS and continued at an interval of 10 days up to 110 DAS i.e. till attaining physiological maturity. From each sampling, five plants were randomly selected from each plot and uprooted for collecting necessary parameters. The plants were separated into leaves, stems and roots and the corresponding dry weight were recorded after oven drying at 80 ± 2°C for 72 hours. The leaf area of each sample was measured by LICOR automatic leaf area meter (Model: LICOR 3000). The growth analyzing attribute like AGR, RGR and NAR were calculated using the formulae of Radford (1967). The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjusted with Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C (Russell, 1986).

Results and Discussion

The ontogenetic plant height, leaf area and total dry mass production of soybean genotypes differed significantly at all growth stages (Table 1-3). Of the mutants/variety, SBM-20 was the tallest (64.3 cm) whilst Binasoybean-1 was the shortest (40.3 cm) of all. These results are in agreement with the result of Haque (2005) who stated that plant height differed significantly among the soybean genotypes studied.

The maximum number of branches, leaf area and TDM plant^{-1} as well as biological yield was observed in SBM-20 whilst the lowest was recorded in Binasoybean-1. However, total dry mass and leaf area increased till 80 DAS. Results also indicated that high yielding genotypes showed higher TDM and LA than the low yielding ones. The result is supported by the result of Dean *et al.* (2006) in soybean who reported that high yielding genotypes produced higher TDM than low yielding ones. In the present study, the high yield genotypes showed higher number of branches plant^{-1}. Redzepovic *et al.* (2006) stated that high yielding genotypes of soybean had higher number of pod bearing nodes plant^{-1} than low yielding ones. The variation in growth parameters like AGR and RGR of soybean genotypes were significant at all growth stages (Table 4-5). AGR increased till

70-80 DAS followed by a declining rate with age. On the other hand, the RGR and NAR showed higher values at early growth stages and declined latter on (Table 6). The mutant SBM-20 showed higher AGR and RGR at most of the growth stages compared to others. In contrast, Binasoybean-1 showed lesser in case of AGR but reverse trend was observed in RGR during growth period. This result is in agreement with the findings of Prasad *et al.* (1978). AGR is positively correlated with LAI (Bhardway *et al.*, 1987). The lower value of AGR at initial stages of growth was the result of lower LAI. At 80 DAS, the AGR value was found to be maximum which means that plants expended it's assimilate for the growth of leaf area for feeding of pods. The declining of AGR after reaching the maximum in all genotypes might be the result of abscission of leaves. The results of the present study are in agreement with the results of Tandale and Ubale (2007) in soybean who stated that the maximum RGR was observed during vegetative stage and declined rapidly with the advancement of growth stages.

Pod number, the most important yield attribute, was found significant difference among the genotypes (Table 7). Results revealed that high yielding genotypes produced higher numbers of pods plant^{-1}. SBM-20 produced the highest number of pods plant^{-1} (23.1) whilst SBM-17 produced the lowest (19.2 plant^{-1}). The result of the present study are in agreement with the result of Foloni *et al.* (2006) in soybean who stated that maximum NAR was observed during vegetative stage and declined rapidly with the advancement of growth stage. Yield is the ultimate feature and goal in any agronomic or varietal improvement programs. The mutant SBM-20 produced the highest seed yield plant^{-1} (8.51 g plant^{-1}) as well as seed yield hectare^{-1} (2.84 t ha^{-1}) followed by SBM-13 (7.62 g plant^{-1} and 2.54 t ha^{-1}). In contrast, Binasoybean-1 produced the lowest seed yield (6.65 g plant^{-1} and 2.22 t ha^{-1}) due to fewer pods plant^{-1} (Table 7). This result is in agreement with result of many other workers (Datta, 2004; Haque, 2005; Jian *et al.*, 2007) who stated that high yielding genotypes had greater number of pods plant^{-1} than low yielding ones. This result of variability in 100-seed weight agrees with the results of Egli (1990) and Datta (2004) in soybean. However, in case of unit area basis, results revealed that seed yield ha^{-1} was rationale to seed yield plant^{-1}. This result is consistent with the result of Islam (2005), Haque (2005) and Jian *et al.* (2007) in soybean who observed that there was significant variation for seed yield among the studied genotypes. Further, the low yielding genotype, Binasoybean-1 showed the highest harvest index (36.9%). According to Poehlman (1991), high harvest index (HI) does not contribute to high yield. Rather high yield is determined by physiological process leading to a high net accumulation of photosynthates and it's partitioning into plant and seed. This opinion was also reflected in the present study, where SBM-20 was the high yielding mutant with lower HI.

Table 1. **Plant height at different ages in five soybean mutants/variety**

Variety/Mutants	Plant height (cm) at different days after sowing					
	40	50	60	70	80	90
Binasoybean-1	17.2 b	27.4b	30.0b	33.2b	40.3c	45.3c
SBM-13	21.1 a	35.9a	38.6a	42.6a	47.1b	53.2b
SBM-17	20.0ab	32.9a	38.4a	44.6a	63.0b	50.1bc
SBM-20	21.3 a	34.9a	40.6a	50.9a	63.3a	65.1a
SBM-22	18.6ab	35.0a	42.7a	45.4a	48.5 b	51.6bc
F-test	**	**	**	**	**	**
CV (%)	6.96	9.29	8.87	10.45	3.94	6.42

Same letter (s) in a column do not differ significantly at $P \leq 0.05$ by DMRT
** indicate significance at 1 % level of probability

Table 2. Leaf area production at different days after sowing in five mutants/variety of soybean

Variety/Mutants	Leaf area (cm^2) $plant^{-1}$ at different days after sowing					
	40	50	60	70	80	90
Binasoybean-1	83.9d	333.3c	633.9c	1230.1d	1431.8c	1118.7c
SBM-13	106.6bc	361.6bc	893.5c	1230.1d	1435.1d	1245.9b
SBM-17	149.3a	400.0a	1603.1a	1171.1d	2653.1a	1220.0bc
SBM-20	152.2b	495.4b	1632.0b	1478.9a	2683.0a	1320.0a
SBM-22	92.5cd	335.7c	760.8d	1681.9b	2090.7b	1122.0c
F-test	**	**	**	**	*	*
CV (%)	9.18	10.54	5.97	3.21	3.39	4.59

Same letter (s) in a column do not differ significantly at $P \leq 0.05$ by DMRT
** indicate significance at 1 % level of probability

Table 3. Total dry mass production as influenced by genotypes of soybean at different days after sowing

Variety/Mutants	Total dry mass $plant^{-1}$ (g) at different days after sowing					
	40	50	60	70	80	90
Binasoybean-1	5.7b	7.0b	10.0b	13.6c	21.1b	31.8b
SBM-13	7.0a	9.6a	12.8a	15.7b	22.8b	33.3b
SBM-17	6.6a	9.3a	12.8a	14.7b	21.7b	33.4b
SBM-20	7.0a	10.0a	13.4a	21.1a	26.9a	41.7a
SBM-22	6.2ab	9.7a	12.2a	16.1b	22.2b	33,8b
F-test	**	*	**	**	**	**
CV (%)	6.96	6.8	8.86	3.95	4.58	1.26

Same letter (s) in a column do not differ significantly at $P \leq 0.05$ by DMRT
*, ** indicate significance at 5% and 1 % level of probability, respectively

Table 4. Effect of genotypes on absolute growth rate at different growth stages of soybean

Variety/Mutants	Absolute growth rate (mg plant^{-1} day^{-1}) at different days after sowing				
	40-50	50-60	60-70	70-80	80-90
Binasoybean-1	57 c	73 d	136 d	297 b	168 b
SBM-13	75 b	122 b	278 b	327 c	250 a
SBM-17	85 a	99 c	195 c	390 b	155 b
SBM-20	79 ab	147 a	344 a	400 b	211 a
SBM-22	75 b	126 b	255 b	461 a	164 b
F-test	**	**	**	**	**
CV (%)	5.25	10.86	11.30	6.95	12.48

Same letter (s) in a column do not differ significantly at $P \leq 0.05$ by DMRT
** indicate significance at 1 % level of probability

Table 5. Relative growth rate at different growth stages of five soybean mutants/variety

Variety/Mutants	Relative growth rate (mg g^{-1} day^{-1}) at different days after sowing				
	40-50	50-60	60-70	70-80	80-90
Binasoybean-1	138.6 a	52.9 c	75.2 b	72.0 a	26.1 a
SBM-13	130.2 b	78.1 a	80.4 ab	50.1 c	26.3 a
SBM-17	132.0 ab	61.7 b	64.5 c	66.8 b	17.7 b
SBM-20	134.0 ab	76.5 a	84.4 a	51.1 c	19.1 b
SBM-22	127.7 b	79.4 a	74.6 b	67.5 ab	16.0 b
F-test	**	**	**	**	**
CV (%)	6.22	4.13	5.24	3.94	11.35

Same letter (s) in a column do not differ significantly at $P \leq 0.05$ by DMRT
** indicate significance at 1 % level of probability

Table 6. Net assimilation rate at different growth stages of five soybean mutants/variety

Variety	Net assimilation rate (mg dm^2 day^1) at different days after sowing				
	40-50	50-60	60-70	70-80	80-90
Binasoybean-1	70.19c	74.07b	40.46b	49.20a	53.03ab
SBM-13	131.14b	54.03bc	27.77c	55.19a	60.96a
SBM-17	76.97c	35.31d	18.21d	23.36c	40.18c
SBM-20	117.92d	42.84cd	53.7a	27.45bc	48.65bc
SBM-22	178.70a	83.67a	20.63d	35.00b	53.58ab
F-test	**	**	**	**	**
CV%	15.39	12.58	1082	13.43	10.19

Same latter (s) in a column do not differ significantly at $P \leq 0.05$ by DMRT
** Indicate significance at 1% level of probability

Table 7. Some morpho-physiological characters and yield components and seed yield of five soybean mutants/variety

Variety/Mutants	Branches plant^{-1} (no)	Biological yield plant^{-1} (g)	Pods plant^{-1} (no)	Seeds pod^{-1} (no)	100-seed weight (g)	Seed weight plant^{-1} (g)	Seed yield (t ha^{-1})	Harvest index (%)
Binasoybean-1	2.33 ab	12.86 b	19.4 b	2.81	12.2 d	6.65 c	2.22 c	36.9 a
SBM-13	2.33 b	113.67 b	21.3 ab	2.84	12.6 c	7.62 b	2.54 ab	35.3 a
SBM-17	2.20 ab	13.66 b	19.2 b	2.57	14.0 a	6.90 bc	2.30 bc	30.2 b
SBM-20	3.00 a	16.70 a	23.1 a	2.75	13.4 b	8.51 a	2.84 a	31.2 b
SBM-22	2.53 ab	13.00 b	21.9 ab	2.63	12.8 c	7.37 bc	2.46 b	31.3 b
F-test	**	**	*	NS	*	**	**	**
CV (%)	13.04	2.89	7.78	4.98	5.69	5.00	6.26	4.98

Same letter (s) in a column do not differ significantly at $P \leq 0.05$ by DMRT
*, ** indicate significance at 5% and 1% level of probability, respectively; NS = Not significant

Conclusion

Among the genotypes, SBM-20 produced the highest seed yield due to superiority of yield attributes than in the others. High yielding genotypes had taller plant, higher number of branches, LA, TDM and AGR, which resulted in higher number of pods plant^{-1} than the low yielding soybean genotypes.

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SEED QUALITY OF CHICKPEA GENOTYPES AS AFFECTED BY DRYING LEVEL AND TYPES OF STORAGE CONTAINER

M. M. Islam[1], M. Ahmed[2], S. A. Fakir[3] and K. Begum[4]

Abstract

Chickpea seeds (Var. Binsola-3) were dried for one, two and three days and stored in metal, plastic, clay and polythene bag. Three days dried seeds when stored in metal, plastic container and polythene bag contained minimum moisture (9.95, 10.23, and 11.05%, respectively). Maximum germination was obtained when seeds were dried for three days and stored in metal (93.4%), plastic container (91.9%) and polythene bag (90%). Highest vigour index was found when seeds were dried for three days and stored in metal container. Moreover, protein content was also found more in 2-3 days dried seeds than one day drying.

Key words: Chickpea seeds, drying level, storage container

Introduction

The rice-based diet of the people of Bangladesh contains minimal amounts of proteins and more lysine and threonine (Oram *et al.*, 1987). Chickpea seeds contain considerable amount of proteins and vitamins (Singh, 1986). Its protein content is 3 to 4 times higher than the cereals. Chickpea proteins are nutritionally valuable for lysine and threonine (Williams and Singh, 1986). Therefore, the declining trend of its production is alarming because any further reduction in the lysine rich legumes in the diet of the rural people may lead to serious amino acid imbalance (Oram *et al.,* 1987). The excellent nutritive value of pulses is highly complementary to a cereals-based diet in developing countries. In Bangladesh, a large number of people are suffering from malnutrition. For alleviating human malnutrition for the poorest segment of the country's population, pulses have been identified as crops with exceptional potential. The present per capita per day availability of pulses is only 12.5 g which is far below than the recommended 45 g for the people of Bangladesh. Usually harvested seeds contain high moisture and are unsafe for storage. So, drying of seeds after harvesting becomes necessary. At above 12 per cent moisture level, insect attack and their multiplication is faster. With moisture content in

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excess of 14 per cent, seeds subject to damage by mold. Moisture content of 16 per cent and more, seeds induce chemical changes and insects, mold and chemical changes all jointly or singly cause the seeds to heat up, which leads to grain being rendered unfit for use (Pingle, 1998). Therefore, an experiment was designed to find out seed quality of chickpea genotypes as affected by drying levels and types of storage containers.

Materials and Methods

The experiment was carried out at Agronomy laboratory, BINA, Mymensingh during 2007 (May- October). The clean chickpea seeds of Binasola-3 were sun dried for one day (6 hours), two days (12 hours) and three days (18 hours) and stored them in four containers such as; metal, plastic, clay pot and course polythene bags. The design of the experiment was Completely Randomized Design (CRD) with four replications. The total pots of the experiment were 36. The dried seeds were cooled at room temperature and moisture content were determined by digital grain moisture meter and finally the seeds were stored in different containers. Each container contained about 200 g seeds. The seed samples were tested in terms of moisture content, germination test, root and shoot studies, vigour index and protein content.

Results and discussion

Data on seed quality such as; moisture content, germination, seedling dry weight, root length, shoot length, ratio of root and shoot length, vigour index and protein content were recorded. All the characters under the study differed significantly for drying levels and types of storage containers. Interaction effect differed significantly for all the characters, except shoot length. Different characters of the study were described below.

Moisture content

Different drying levels showed variations of moisture content of seeds. Drying for three days (Table 1a) obtained minimum moisture content (10.37%). Storing seeds in metal, plastic container and polythene bag showed moisture content 11.18-11.42% and seeds stored in clay pot obtained maximum moisture content 12.46%. It was observed from the interaction (Table 1b) that drying seeds for three days in metal, plastic container and polythene bag contained minimum moisture (9.95, 10.23, and 11.05%, respectively). Seeds dried for three days in clay pot showed acceptable level of moisture content (11.05%). The highest moisture content (14.05%) was obtained when seeds were dried for one day in clay pot.

Germination

Germination per cent increased with the increase of drying duration. Better germination (87 and 90%) was obtained from two and three days of drying (Table 1a). The seeds stored in metal, plastic container and polythene bag showed better germination (88-89%) than clay pot (81%). Interaction showed higher germination as 93.4% in three day x metal, 91.9% in three day x plastic, 90% in three day x polythene bag and 90% in two day x metal container. Moreover, a significantly negative relation was found between moisture percent in stored seed and percent of germination (Fig. 1). But positive relation was found between percent of germination and vigour index i.e. seeds having higher of germination percent also showed higher vigour index (Fig. 2).

Dry weight of seedling

Maximum dry weight (520 mg) was obtained from three days drying and this might be due to minimum moisture and highest germination percentages (Table 1a). Seeds stored in metal and polythene bag produced higher dry weight (530 and 520 mg, respectively). Interaction showed (Table 1b) highest dry weight in three days x metal treatment (546 mg) and second highest in three days x polythene bag (537 mg). Other treatments, two days x metal, two days x polythene bag and three days x plastic container produced considerable dry weight (529 mg, 518 mg and 527 mg, respectively).

Table 1a. Mean values of chickpea characters as affected by drying levels and types of storage containers

Characters / Treatments	Moisture content (%)	Germination (%)	Dry weight of seedling (mg)	Shoot length (cm)	Root length (cm)	Ratio of root and shoot	Vigour index	Protein (%) content
Drying levels:								
One day	12.65 a	82.58 c	495.0 c	10.93 c	9.19 c	0.84	1661c	23.08 b
Two days	11.68 b	87.92 b	503.0 b	11.29 b	10.53 b	0.93	1917 b	23.59 a
Three days	10.37 c	90.31 a	520.0 a	11.62 a	10.89 a	0.94	2032 a	23.66 a
LSD $_{0.05}$	0.29	1.15	5.27	0.17	0.08	ns	17.12	0.15
Storage containers:								
Metal (C_1)	11.18 b	89.37 a	530.0 a	11.99 a	10.22 b	0.85	1984 a	23.56 b
Plastic (C_2)	11.42 b	88.14 a	511.0 c	11.80 a	10.00 c	0.85	1921 c	23.47 b
Clay pot (C_3)	12.46 a	81.47 b	462.0 d	9.98 c	7.36 d	0.73	1412 d	22.82 c
Polythene (C_4)	11.20 b	88.77 a	520.0 b	11.34 b	10.58 a	0.93	1944 b	23.95 a
LSD $_{0.05}$	0.34	1.33	6.09	0.33	0.19	ns	20.35	0.17
CV (%)	1.60	0.45	1.24	3.90	4.39	5.21	5.17	0.57

Shoot length

Tallest shoot (11.62 cm) was produced in seeds dried for three days followed by two days drying (11.29 cm). Among the containers, metal and plastic produced the statistically identical shoot as; 11.99 and 11.80 cm, respectively (Table 1b). Minimum shoot length (9.98 cm) was obtained in clay pot. Although the combined effect was insignificant, three days drying of seeds when stored in metal, plastic container and polythene bag produced taller shoot (12.55 cm, 12.60 cm and 12.70 cm, respectively). Drying seeds for two days and stored in polythene bag also showed maximum shoot (12.37 cm). Seed dried for two days and stored in clay pot produced shortest shoot length.

Root length

Three days drying of seeds produced tallest root (10.89 cm) followed by two days drying (10.53 cm) and minimum was produced by one day drying (9.19 cm). Among different storage containers, metal, plastic and polythene bag produced the highest root length (10.22, 10.00 and 10.58 cm, respectively). Combined effect showed higher root length 11.56 and 11.83 cm, respectively in the seeds dried for three days and stored in metal container and polythene bag. Two days drying of seeds and stored in plastic containers produced second highest root length (11.33 cm). Seeds stored in the clay pot for different drying levels produced the shortest root length.

Table 1b. Chickpea characters as affected by the interactions of drying conditions and types of storage containers

Characters / Treatments	Moisture content (%)	Germi-nation (%)	Dry weight of seedling (mg)	Shoot length (cm)	Root length (cm)	Ratio of root and shoot	Vigour index	Protein content (%)
Interaction: (Drying x Container)								
One day x Metal	12.10 bc	84.57 fg	516.3 def	9.50	8.77 e	0.92	1545 f	22.93 de
One day x Plastic	12.29 a	82.60 g	495.0 g	9.47	8.53 e	0.90	1486 g	23.06 d
One day x Clay	14.05 a	75.73 h	465.0 h	8.77	7.03 f	0.80	1196 h	22.73 c
One day x Polythene	12.15 b	87.43 de	505.3 fg	9.97	8.43 e	0.84	1608 f	23.62 c
Two days x Metal	11.50 cde	90.13 bc	529.6 bc	10.80	10.33 c	0.96	1904 d	23.74 bc
Two days x Plastic	11.75 bcd	89.93 bc	511.6 ef	10.77	10.13 c	0.94	1879 cd	23.68 bc
Two days x Clay	12.28 b	82.77 g	452.0 i	8.93	8.20 g	0.92	1417 h	22.83 de
Two days x Polythene	11.18 de	88.83 cd	518.6 cde	12.37	11.47 e	0.93	2117 c	24.11 a
Three days x Metal	9.95 f	93.40 a	546.0 a	12.55	11.56 a	0.92	2251 a	23.99 ab
Three days x Plastic	10.23 f	91.90 ab	527.0 bcd	12.60	11.33 b	0.89	2199 b	23.65 c
Three days x Clay	11.05 e	85.90 ef	469.6 h	10.23	9.83 d	0.96	1723 e	22.89 de
Three days x Polythene	10.27 f	90.03 bc	537.6 ab	12.70	11.83 a	0.93	2208 a	24.11 a
LSD $_{0.05}$	0.58	2.30	10.55	ns	0.16	ns	74.25	0.30
CV (%)	1.60	0.45	1.24	3.90	4.39	5.21	5.17	0.57

Ratio of root and shoot

Drying seeds for two and three days showed higher ratio of root and shoot (0.93 and 0.94, respectively). Among the storage containers, polythene bags showed the highest ratio (0.93) followed by metal and plastic containers. Interaction showed (Table 1.b) higher ratio of root and shoot (0.89-0.96) in three days and two days drying and stored in all containers. One day drying and stored in clay pot and polythene bag showed the lowest ratio (0.80 and 0.84) of root and shoot.

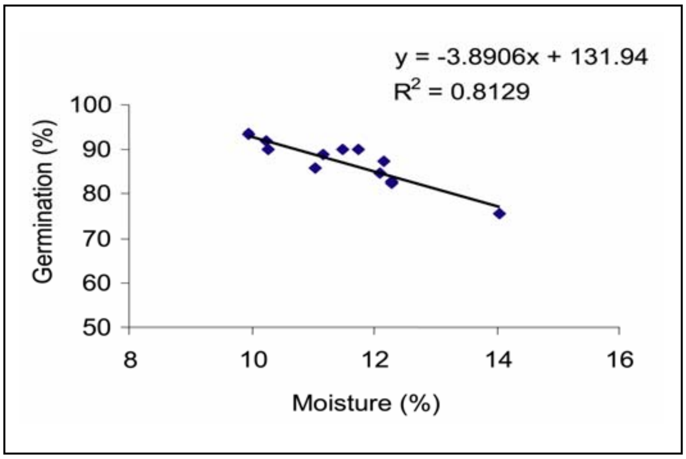

Fig. 1. Relationship between germination (%) and moisture content (%), irrespective of drying conditions and types of storage containers

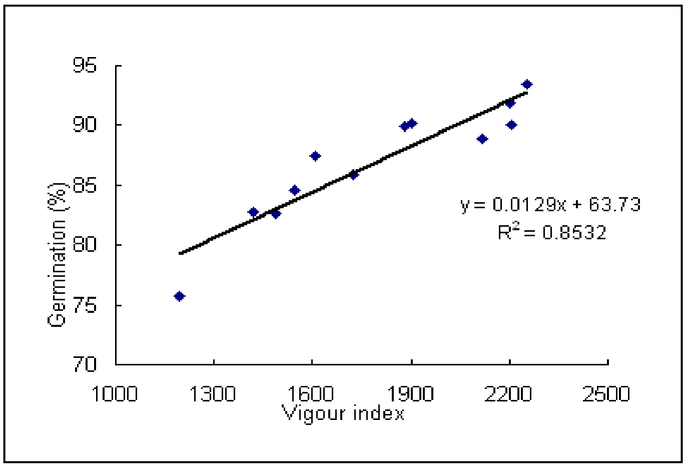

Fig. 2. Relationship between germination (%) and vigor index, irrespective of drying conditions and types of storage containers

Vigour index

From Table 1b, it showed that the highest vigour index (2032) was obtained from three days drying of seeds followed by two days drying (1917). Lowest vigour index (1661) was found in one day drying. Except clay pot, all the three containers produced higher vigour index (1984, 1921 and 1944 in metal, plastic container and polythene bag, respectively). Seeds stored in clay pot produced the lowest vigour index (1412). Interaction effect showed higher vigour index in three days x metal container (2251) and three days x polythene bag (2208). Two days drying of seeds and stoered in metal, plastic containers and polythene bag showed better vigour index than one day drying.

Protein content

Highest protein contents were obtained from two and three days drying of seeds (23.59 and 23.66%, respectively), which were statistically identical. In different containers, Polythene bags showed maximum content of protein 23.95% and incase of metal and plastic containers it was 23.56% and 23.47%, respectively. Highest protein content from the interaction was obtained in two days x polythene bag and three days x polythene bag (24.11%), but one day x clay pot showed the lowest protein content (22.73%) (Table 1b).

The results indicated that drying of seeds for three days showed the lowest moisture content and higher germination, dry weight, root and shoot length, vigour index and protein content. This result was in agreement with Khatun (2007), where it was reported that farmers seeds which were dried for 1-2 days showed high moisture resulting lower germination percent (48%) and vigour index. In the present study, seeds which were dried for 1-2 days also showed higher moisture content and lower germination and vigour index than seeds which were dried for 3 days. Hossain (1991) conducted an experiment and concluded that seeds without being properly dried and stored in earthen jar, metal container or polythene bags, resulted high infestation and thus, germination as well as purity became lower. Pingle (1998) concluded that moisture below 12 per cent, insect attack and their multiplication were lower. Moreover, it was also reported that with moisture content in excess of 14 per cent, seeds were subjected to damage by mold, and moisture content of 16 per cent and more, induced chemical changes and insects, mold and chemical changes. Thus, all jointly or singly caused the seeds to heat up and unfit for use. It was also reported that the high seed moisture was the single most cause of losses in seed viability and vigour (Harrington, 1972 and Kreyger, 2002).

Conclusion

From the study it could be concluded that dried chickpea seeds for three days performed better when stored them in metal, plastic container and in polythene bag for six months. Moreover, seeds dried for three days and stored in metal, plastic and polythene bag contained minimum moisture (9-11%), and showed maximum germination and higher vigour index.

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COMPARISON OF SOIL SULPHUR EXTRACTANTS AND DETERMINATION OF CRITICAL LIMIT FOR SESAME

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Abstract

The study was conducted during 2008-09 to observe the relative suitability of various sulphur extractants and determination its critical limit for sesame (Binatil-1) at growth glass house of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, with seventeen selected soil series collected from different AEZs of Bangladesh namely; Ruhia, Baliadangi, Ranishankoil, Manda, Jamun, Gangachara, Pirgacha, Polashbari, Silmondi, Sonatala, Ghatail, Sara, Barisal, Jhalokathi, Amnura, Noadda and Nachol. The range of physico-chemical characteristics of the studied soils were: pH from 5.07 to 7.50, organic matter from 1.14 to 2.13%, total nitrogen from 0.05 to 0.21%, available P from 10.05 to 21.09 ppm and exchangeable K from 0.07 to 0.21 meq%. Three extractants were used for extraction of S viz. 0.15% $CaCl_2$, 0.5 M NH_4OAc (pH 8.5) and ASI. Considerable variation was found among the extractable S depending upon the soils and extractants used. On an average, the maximum amount of S (38.03 ppm) was extracted by 0.5 M NH_4OAc and the minimum (8.40 ppm) by 0.15% $CaCl_2$. The ability of extractants to extract S followed the order of NH_4OAc > ASI > $CaCl_2$. Dry matter yield responded better to applied S, where the extractable S was very close or below critical level. Application of S also increased in S concentration of plant. The critical limit of extractable S following graphical approach for 0.15% $CaCl_2$, 0.5 M NH4OAc and ASI methods were 14.25, 15.75 and 16.50 ppm, respectively. The corresponding limits for statistical method appeared to be 19.79, 26.29 and 13.26 ppm. Among the three extraction methods, based on R^2 value it might be concluded that 0.15% $CaCl_2$ method of S extraction might be the best for the estimation of critical limit of S for sesame.

Key wards: Sesame, Sulphur, Critical limit

Introduction

In Bangladesh, fertilizer recommendation is done on the basis of soil fertility classes. It is admissible that when sulphur is applied, crop response is not always obtained due to the organic mater deficiency and waterlogged condition of the soil. Organic matter application is impossible in the field of standing crop. By drying the field through stopping irrigation or adding chelating agents like EDTA, Zn-EDTA, etc. to the soil, this problem

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can be overcome to some extent. This process increases the availability of sulphur but it is absolutely dependent on the natural condition. Sulphur fertilizer use must be primarily based on critical limits for different crops and soils. Critical limit refers to the level of nutrients in soil below which the crop will suffer from its deficiency and thus, the crop will show economic response to the added fertilizer. Several extraction technique have been developed to determine the available S in soil viz. 0.15% $CaCl_2$ (Williams and Sterinbergs, 1959) 1 N NH_4OAc (Bardsley and Lancaster, 1960), ASI (Hunter, 1984), etc. For estimating plant available S in soils, heat-soluble S and 0.15% $CaCl_2$ extractable S methods are usually recommend. A sound soil testing program for judicious fertilizer use to obtain desired crop response must be based on critical limits of respective nutrient element in soil of that area. Among the essential nutrients, sulphur exerts an important role, which is responsible for characteristics taste and smell of sesame. It is, therefore, important to know the critical limit of S in soils in order to optimize the use of S fertilizer for higher yield and quality of sesame. Sesame in general have high sulphur requirement owing to higher seed and oil yield. For high yield goal of sesame and medium soil interpretation, 8-14 kg ha^{-1} S is needed, whereas P and K are needed 10-18 and 17-32 kg ha^{-1}, respectively (BARC, 2005). There are reports on response of sesame to sulphur fertilization in different parts of the country. Among the oil seed crops, sesame is covering an area of 88 thousand acreage and total production of 32 thousand metric tons. Maximum area of sesame covers in Dinajpur district in Bangladesh that is about one-third area and production as well (BBS, 2010). Realizing the importance of sulphur needs, a glass-house experiment was conducted in glass house at the Bangladesh Institute of Nuclear Agriculture (BINA) farm, Mymensingh with 17 soil series of different mineralogical make-up from different agro-ecological zones of Bangladesh with the objective of determination of the critical levels of soil S for sesame.

Materials and methods

Seventeen soil series (0-15 cm) possessing a wide range of characteristics were collected from various locations of Bangladesh (Table 1 and Table 2). The selected soil series included Ruhia, Baliadangi, Ranishankoil, Manda, Jamun, Gangachara, Pirgacha, Polashbari, Silmondi, Sonatala, Ghatail, Sara, Barisal, Jhalokathi, Amnura, Noadda and Nachol. The soils possessed a wide range of topography and land use. A pot culture experiment was conducted in a glasshouse of the Bangladesh Institute of Nuclear Agriculture (BINA) farm, Mymensingh. There were three doses of sulphur viz. 0, 20 and 40 ppm. The experiment was set up in a Completely Randomized Design (CRD) with three replications and a total of 9 pots for every soil. Thus, the total number of pots in the experiment was 153 (3 treatments × 3 replication × 17 soils). One kilogram air-dried sub-sample, 2 mm sieved soil was weighed in each of 9 for each soil series. The selected sesame variety (Binatil-1) was used as a test crop. Six plants in every pot were allowed to grow till harvesting. All pots were kept submerged with distilled water to a depth of 5 cm. Plant and soil samples (both initial and after harvest) were analyzed following standard method. Three extractants were used for extraction of S viz. 0.15% $CaCl_2$, 0.5M NH_4OAc (pH 8.5) and ASI.

Table 1. Brief description of the soil series under study

Sl No.	Soil series	AEZ	Location	Land type	Existing cropping patterns
1	Ruhia	1	Horihorpur, Thakurgao	High land	Wheat-Jute-Fallow
2	Baliadangi	1	Dinajpur sadar	Medium high land	Rabi-T.aus/Jute-Fallow
3	Ranishankoil	1	do	High land	Aus/Jute-T.aman-Vagetable
4	Manda	1	Karanai, Dinajpur	Medium high land	Wheat/Pulse-T.aman-Fallow
5	Jamun	1	Kaharol, Dinajpur	High land	Tobacco-Jute-Fallow
6	Ganggachara	3	Rangpur sadar,	Medium high land	Boro-Fallow-T.aman
7	Pirgacha	3	Pirgacha Rangpur	High land	Sugarcane/Wheat-Fallow-T.aman
8	Polashbari	3	Mithapukur Rangpur	High land	Tobacco-Jute-T.aman
9	Silmondi	9	Fulpur, Mymensingh	Medium high land	Wheat/Pulse-Jute-T. aman
10	Sonatala	9	BAU, Mymensingh	High land	Boro-Fallow-T.aman
11	Ghatail	9	Ghatail, Tangail	Medium high land	Boro-Fallow-T.aman
12	Sara	11	Jessore sadar	High land	Potato-T.aus-Fallow
13	Barisal	13	Khepupara, Patuakhali	Medium high land	Boro-Aus-T. aman
14	Jhalokathi	13	Jhalokathi sadar	Medium high land	Boro-Aus-T.aman
15	Amnura	25	Kahalu, Bogra	High land	T.aman-Mustard/Potato-Boro
16	Noadda	25	Sherpur, Bogra	High land	Rabi-Aus-T.aman
17	Nachol	26	Chapai Nowabgonj	High land	rabi/Boro-B.aus/T.aus-T.aman

Note: AEZ No. 1 = Old Himalayan Poedmondplain, 3 = Tista Mender Floodplain, 9 = Old Brahmaputra Floodplain, 11 = High Ganges River Floodplain, 13 = Ganges Tidal Floodplain, 25 = Level Barind tract, 26 = High Barind Tract

Table 2. Extracts used for determining available sulphur in soil

Extractants	Soil : Solution ratio	Shaking time (min)	References
Calcium chloride (0.15%)	1 : 5	30	Williams and Steinbergs (1959)
0.5 M Ammonium acetate (pH 8.5)	1 : 5	30	Bardsley and Lancaster (1960)
ASI	1 : 5	30	Hunter (1984)

Results and discussion

The textural classes of the soil series of different AEZ varied widely and they were sandy loam, silt loam and loam (Table 3). Percent of clay of the soil was positively correlated with exchangeable calcium. Soil pH ranged from 5.07 to 7.5. The soils were acidic in nature except Sara series. The highest amount of organic matter was found in Ruhia soil series (1.73%), while the lowest was found in Silmondi series (1.13%). The mean value of organic matter content in soil was 1.48% and it varied from 1.13 to 2.13%. The mean value of total nitrogen, available phosphorus, available zinc, exchangeable potassium, calcium and magnesium were 0.11%, 14. 49 (ppm), 0.33 (ppm), 0.11, (meq%), 1.98 (meq%) and 1.17 (meq%), respectively.

The status of extractable S varied considerably depending on the soils and extractants used (Table 4). The $CaCl_2$ extractable S varied from 8.40 to 54.20 ppm with a mean value of 18.39 ppm in all the soil under study. The highest amount of $CaCl_2$ extractable S (54.20) was found in soil of Barisal soil series. Huda *et al*. (2004) reported that 0.15% $CaCl_2$

Table 3. Physico-chemical characteristics of the soils under study

Sl No.	Soil series	Textural class	pH	OM %	Total N %	Avl. P ppm	Ex. K meq%	Av. Zn ppm	Ex. Ca meq%	Ex. Mg meq%
1	Ruhia	Sandy loam	5.40	2.13	0.21	17.33	0.09	0.43	2.16	0.69
2	Baliadangi	Sandy loam	5.68	1.47	0.15	10.05	0.12	0.45	2.10	0.78
3	Ranishankoil		5.60	1.35	0.10	21.09	0.10	0.44	0.86	0.68
4	Manda	Sandy loam	6.05	1.73	0.15	11.62	0.07	0.29	2.04	1.02
5	Jamun	Sandy loam	6.16	1.57	0.07	16.88	0.13	0.38	1.75	0.67
6	Ganggachara	Sandy loam	5.63	1.47	0.11	14.25	0.11	0.38	2.19	1.13
7	Pirgacha	Sandy loam	5.25	1.40	0.10	16.80	0.13	0.25	1.74	0.60
8	Polashbari	Silty loam	5.70	1.30	0.08	21.08	0.21	0.61	1.19	0.29
9	Silmondi	Loam	6.16	1.13	0.10	14.01	0.09	0.13	0.66	0.55
10	Sonatala	Silty loam	6.78	1.33	0.06	15.50	0.11	0.41	1.68	1.92
11	Ghatail	Silty clay loam	6.14	1.73	0.14	12.12	0.13	0.32	1.93	0.83
12	Sara	Loam	7.50	1.60	0.09	14.08	0.07	0.25	5.04	2.65
13	Barisal	Silty loam	5.60	1.70	0.12	12.06	0.09	0.11	0.86	2.12
14	Jhalokathi	Silty loam	5.60	1.68	0.13	14.09	0.18	0.29	0.99	2.08
15	Amnura	Silty loam	5.50	1.48	0.07	11.35	0.10	0.42	0.73	0.66
16	Noadda	Sandy loam	5.07	1.33	0.08	12.06	0.08	0.20	1.44	0.79
17	Nachol	Sandy loam	5.90	1.20	0.12	12.06	0.10	0.38	1.90	0.92
Range			5.07-7.50	1.13-2.13	0.06-0.21	10.05-21.09	0.07-0.21	0.11-0.61	0.66-5.04	0.29-2.65
Mean			5.77	1.48	0.11	14.49	0.11	0.33	1.98	1.17

extractable S of some selected area of Bangladesh ranged from 3.0 to 86.9 ppm. While working with some major soils of Bangladesh, Islam *et al.* (1997) reported that $CaCl_2$ extractable S varied from 5.9 to 44.8 ppm at 0-20 cm depth. Sulphur extraction by NH_4OAc ranged from 12.14 to 38.03 ppm with an average of 25.78 ppm. The highest amount (38.03 ppm) of NH_4OAc extractable S was from soil of Baliadingi series followed by 36.81 ppm in Nachol, 35.08 ppm in Sonatola, 32.87 ppm in Polashbari and 25.65 ppm in Sara series. The rest of the soil series under study had below 25 ppm. The lowest NH_4OAc extractable S was found in soils from Silmondi series. Similar result was observed by Alam (2003).

Table 4. Amount of available S of soils as determined by different extractants

Sl No.	Soil series	$CaCl_2$ (ppm)	NH_4OAc (ppm)	ASI (ppm)
1	Ruhia	12.79	20.51	30.63
2	Baliadangi	18.32	38.03	24.50
3	Ranishankoil	14.50	23.40	31.14
4	Manda	15.67	15.18	32.16
5	Jamun	16.79	21.75	33.69
6	Ganggachara	21.03	23.50	20.93
7	Pirgacha	10.69	32.87	28.07
8	Polashbari	13.74	17.80	17.87
9	Silmondi	13.74	12.14	22.46
10	Sonatala	21.38	36.08	18.38
11	Ghatail	25.17	23.65	34.20
12	Sara	8.40	25.65	21.44
13	Barisal	54.20	23.16	31.14
14	Jhalokathi	19.09	14.67	23.99
15	Amnura	17.56	19.07	12.76
16	Noadda	17.41	18.08	20.93
17	Nachol	12.21	36.81	20.93
	Range	8.40-54.20	12.14-38.03	12.76-34.20
	Mean	18.39	25.78	25.01

In case of ASI extraction method, sulphur extracted found different and ranged from 12.76 to 34.20 ppm with an average of 25.01 ppm. The highest amount of S was found in Ghatail series followed by 33.69 ppm in Jamun, 32.16 ppm in Manda, 31.14 ppm in Barisal and Ranishankoil, 30.63 ppm in Ruhia and 28.07 ppm in Palashbari series. The rest of the soils under study had S below 25 ppm. However, the lowest ASI extractable S was found in soils from Amnura soil series.

Application of S considerably influenced the S concentration and S uptake of sesame. Like dry matter yield, S concentration and S uptake also varied remarkably among the soils under study (Table 5). Sulphur concentration in the treated samples was higher than that in the S concentration in control treatment. Mean S concentration in S control and S treated (20 and 40 ppm) pots were 0.21%, 0.23% and 0.26%, respectively. The range of S content of control (S_0) and treated pots (S_{20} and S_{40}) were 0.09 to 0.32, 0.11 to 0.38 and 0.15 to 0.44%, respectively. However, minimum and maximum S contents of control (S_0) and treated pots (S_{20} and S_{40}) were 0.09 to 0.32, 0.11 to 0.38 and 0.15 to 0.44%, respectively. The minimum and maximum S-uptake by sesame in S_0, S_{20} and S_{40} were ranged from 2.79 to 28.54, 4.93 to 35.11 and 5.60 to 32.47 mg pot^{-1}, respectively.

Table 5. Sulphur content and S-uptake of sesame plant at 46 DAS of growth

Sl No.	Soil series	Control (S_0)		Treated (S_{20})		Treated (S_{40})	
		Content (%)	Uptake mg/pot	Content (%)	Uptake mg/pot	Content (%)	Uptake mg/pot
1	Ruhia	0.32	12.10	0.35	13.44	0.38	15.47
2	Baliadangi	0.32	6.14	0.37	9.95	0.29	7.05
3	Ranishankoil	0.23	9.45	0.27	13.66	0.21	10.56
4	Manda	0.14	3.82	0.16	6.56	0.16	5.60
5	Jamun	0.13	8.26	0.15	10.65	0.18	11.61
6	Ganggachara	0.28	11.48	0.17	7.77	0.27	14.63
7	Pirgacha	0.18	7.51	0.28	16.77	0.23	11.96
8	Polashbari	0.32	28.54	0.38	35.11	0.28	25.20
9	Silmondi	0.25	11.00	0.27	17.77	0.26	13.36
10	Sonatala	0.09	4.72	0.11	7.26	0.18	9.63
11	Ghatail	0.18	11.05	0.14	10.71	0.21	16.78
12	Sara	0.15	6.77	0.15	8.36	0.18	9.00
13	Barisal	0.22	9.17	0.26	13.70	0.26	14.95
14	Jhalokathi	0.21	1.00	0.16	9.65	0.21	14.36
15	Amnura	0.25	10.48	0.11	5.95	0.17	9.79
16	Noadda	0.18	2.79	0.22	4.93	0.29	5.68
17	Nachol	0.20	10.56	0.35	21.60	0.44	32.47
	Range	0.09-0.32	2.79-28.54	0.11-0.38	4.93-35.11	0.16-0.44	5.60-32.47
	Mean	0.21	9.70	0.23	12.58	0.26	13.41

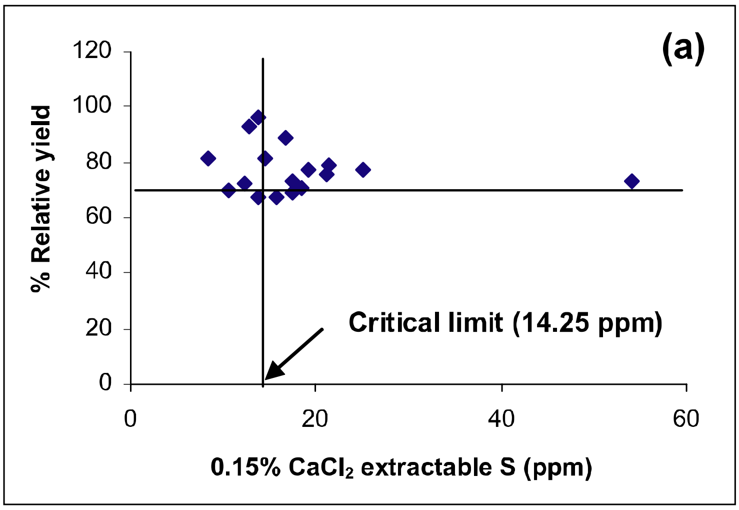
Critical limit

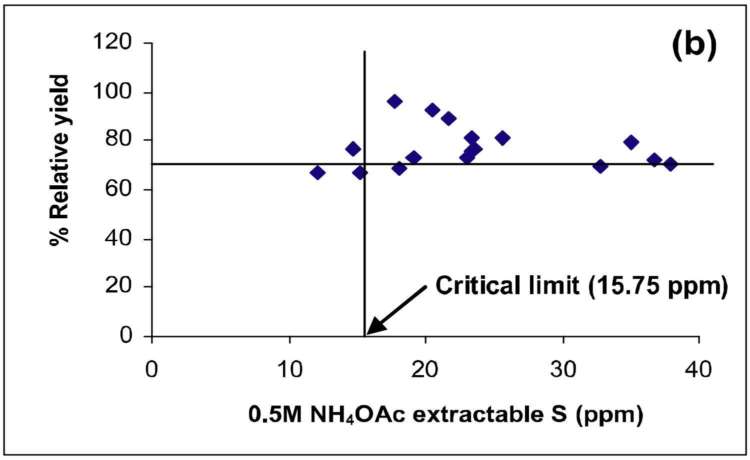
The critical limit of sulphur by using graphical approach (Cate and Nelson, 1965) of sesame by $CaCl_2$, 0.5 M NH_4OAc and ASI extraction methods were found to be 14.25, 15.75 and 16.50 ppm, respectively (Table 6 and Figs. 1a-1c). The statistical approaches for

S extraction methods were in Table 6. Critical limit of S for sesame by statistical methods were 13.26, 19.79 and 26.29 ppm for 0.15% $CaCl_2$ and 0.5 M NH_4OAc and ASI extractable S, respectively. Considering the principle, higher is the R^2 value, better is the fit. Among the three extraction methods under study, the highest R^2 value of 0.33 was recorded at 0.15% $CaCl_2$ extraction method followed by 0.32 for 0.5M NH_4OAc and 0.26 for ASI. Based on R^2 value, it might be concluded that 0.15% CaCl2 method of S extraction was the best for predicting S responses of sesame.

Table 6. Critical limits for soil extraction methods as determined by graphical and statistical approaches of the soils.

Extractants	Critical limits for S (ppm)		R^2 value
	Graphical	Statistical	
0.15% $CaCl_2$	14.25	13.26	0.33
0.5M NH_4OAc	15.75	19.79	0.32
ASI	16.50	26.29	0.26





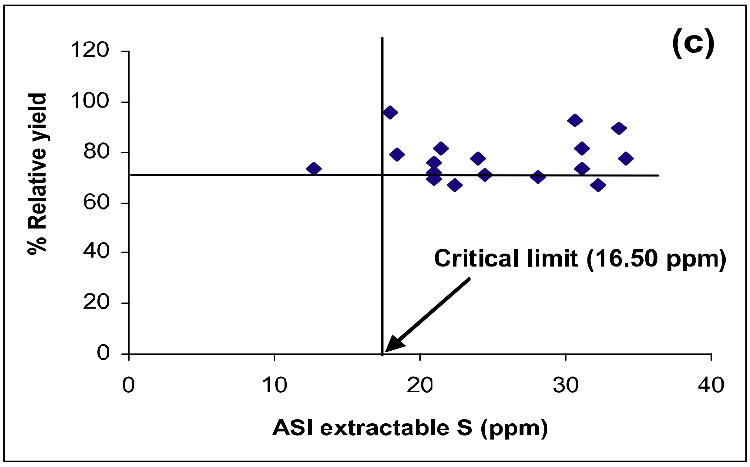


Fig 1. Critical limit of 0.15% $CaCl_2$ (a), 0.5 M NH_4OAc (b) and ASI (c) extractable S for sesame

Conclusion

The soil S under this study had a wide range of characteristics and depending on the soils and extraction methods, the critical limit of S for sesame following graphical method was 14.25, 15.75 and 16.50 ppm for 0.15% $CaCl_2$, 0.5 M NH_4OAc and ASI, respectively. The corresponding limit for statistical method appeared to be 13.26, 19.79 and 26.29 ppm for 0.15% $CaCl_2$, 0.5 M NH_4OAc and ASI, respectively. The critical limit clearly suggested that the 0.15% $CaCl_2$ extraction method might be the best for predicting S response of sesame (Binatil-1).

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IRRIGATION MANAGEMENT FOR OPTIMIZING RICE YIELD AND NITRATE LEACHING

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Abstract

Groundwater is the main source of drinking water in Bangladesh. However, intensification of rice-based cropping system through the use of irrigation and nitrogen fertilizer is of great concern for groundwater contamination through nitrate leaching. Field and lysimeter experiments were conducted at the experimental farm of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh, for six consecutive years on different irrigation management practices for optimizing rice yield and nitrate leaching. The different irrigation practices were: continuous ponding by 3-5 cm, continuous saturation, alternate wetting (5 cm) and drying for 3, 5, and 7 days after disappearance of the ponded water, thereby referred to as T_1, T_2, T_3, T_4, and T_5, respectively. Nitrogenous fertilizer (as urea) was applied according to the recommended dose for the crop. Water samples were collected from the bottom of the lysimeter and from ceramic suction cup installed at 38 to 120 cm depth in the field. The results revealed that yield obtained under different irrigation practices did not differ significantly, but irrigation water required in alternate wetting and drying methods (T_3 to T_5) were 44 to 54% less than that of continuous ponding and 23 to 36% less than that of saturation method (T_2). The pattern of NO_3-N concentration and thus the loss of NO_3-N varied among treatments as well as lysimeter and field condition. Nitrate leaching during crop growing period in lysimeter ranged from 1.5 to 2.0 kg ha^{-1}. The cumulative NO_3-N concentration data showed that the total NO_3-N loss were higher in continuous ponding and continuous saturation under field condition. Thus, it revealed that the alternate wetting and drying of 5 to 7 days seemed to be the best irrigation strategy for rice irrigation considering yield, water saving and nitrate management.

Keywords: Nitrate leaching, Rice, Irrigation management

Introduction

Application of water and nitrogen (N) fertilizer are very essential input and highly effective means to increase the yields of many crops. Although yield-N rate relation of a crop is curvilinear, there is usually a general linear relationship between N uptake in crop and N rate until the maximum yield is reached. However, if N application exceeds the uptake rate and there is sufficient water in the soil, it causes nitrate (NO_3-N) leaching.

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Nitrate is a highly mobile form of N to leach through the crop root zone and eventually into groundwater (Zupanc *et al*., 2008; Ritter, 1989). Thus, groundwater is directly contaminated and polluted by N fertilizer application.

Groundwater is the major source of water supply for drinking and irrigation purpose in Bangladesh as well as in many parts of the world. Water containing NO_3-N up to 10 mg/l is acceptable for drinking purposes (Ali, 2010; GOB, 1997). Beyond this limit, NO_{3}-N may cause methemoglobinemia (blue baby syndrom), a health problem of infants (Stone *et al.*, 1997) and additionally, nitrate interaction with other dietary substances may also cause health problems in adult human bodies (Maidson and Brunett, 1985). So, managing N for groundwater quality is an important concern for health, economically viable agriculture and environmental quality.

Bangladesh is a rice dominated country. Most of the cultivable lands have been occupied by high yielding varieties (HYV) of rice which are cultivated both in rain fed (July-November) and irrigated (January-May) conditions in the Juvenile yearly cycle. In both the cultivation conditions, rice consumes major share of water for its production. It is also reported that about 50 % of the world's rice area is irrigated by ponding of the field and produces 75 % of the world's rice production (Tabuchi and Hasegawa, 1995). Soil-crop-area specific fertilizer doses are recommended, but farmers usually do not follow them. Rather, they set unrealistic higher yield goal and apply excess irrigation and fertilizer, ignoring their fate and consequences. Under rainfed condition it involves surface runoff and NO_3 leaching below crop root zone if heavy rainfall event(s) closely follows fertilizer application. In irrigated condition, when rainfall is absent or scanty, farmers have a general tendency to hold more water than need during the whole rice growing period. This certainly causes misuse of water allowing the surplus water containing NO_3 to percolate to groundwater. The mass of NO_3 leached down to groundwater is reported to be directly proportional to the percolation volume (Ritter, 1989). Contamination of groundwater by nitrate is one of the major sources of non-point pollution from the agricultural fields (Yates *et al.*, 1992). There is a direct relationship between large NO_3-N losses, excess N inputs and inefficient irrigation management (Santos *et al.*, 1997). Zupanc *et al.* (2008) concluded from N^{15} isotopic study with vegetable that applying mineral fertilizer by fertigation and covering 100% of potential evapotranspiration caused the lowest nitrate leaching in soil water, thus presenting the lowest risk of groundwater contamination. They also found that nitrate leaching from 50% irrigation plots was lower than that under farmers' practice but higher than that under 100% irrigation and values ranged from 10 to 90 mg/L.

Numerous research articles are available dealing with the problems of nitrate leaching under different soils, crops and cultural practices, and crops grown under unsaturated or non-ponded conditions (Moreno *et al.*, 1999; Yates *et al*., 1992; Ferguson *et al*., 1991; Casey *et al*., 2002; Roth and Fox, 1990). But in irrigated rice cultivation, water is ponded in the field during the whole growing period. Under such conditions, the leaching of nitrate (amount and patterns) in agricultural soils can be different from that occurred from dry-land crops.

Although there has been research on water saving irrigation strategies for several decades (Rashid *et al*., 2005; Sarkar *et al*., 2002), less focus on the relationship between irrigation strategies and nitrate leaching are given. Based on the above explained facts, long-term experiments were conducted with irrigated rice under different water management practices to optimize yield, water use and groundwater pollution by NO_3^-N under field and lysimeter conditions.

Materials and Methods

Experimental site

A long-term (6-years) field experiment was conducted during 1999-2000 to 2004-05 at the experimental farm of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. The geographical location of the area is 24^0 $43^'$ N, 90^0 $26^'$ E and 7 m above mean sea level. The local climate is humid and sub-tropic with summer dominant rainfall. The average annual rainfall (1991-2004) is 2260 mm, mostly concentrated over the months of April to September (monsoon period). The soil of the area belongs to the Old Brahmaputra Alluvial Flood Plain and historically the area is under cultivation for more than seven decades or more. The topography of the experimental area is completely flat and high land. Texturally the soil is sandy loam to silt loam with bulk density ranging from 1.3 to 1.5 gm/cm^3. Flood never enters the area, but water accumulates due to rainfall of high intensity and long duration. The inundated water drains out shortly after the cessation of rainfall.

Crop and water management strategies

The experiment was conducted in two different environments; one with free hydrologic condition following traditional cultivation practices in the field and another in a controlled condition in brick made lysimeter. However, the treatments and management practices were same for both the conditions. There are ten lysimeter tanks (drainage type) having a surface area of 2 m^2 (2 m x 1 m) with soil depth of 1.5 m for each tank. The investigation was carried out in 5 tanks, one treatment in each tank without replication. Each tank has separate arrangements for irrigation, drainage and soil water measurements, etc. (Hassan *et al.,* 1995).

In the field, the experiment was set up in randomized completely block design (RCBD) with four replications. The unit plot size was 5 m x 4 m. Line to line and plant to plant distances within lines were maintained as 20 cm and 15 cm, respectively. The experiment was fertilized with the recommended doses of Urea @215 kg ha^{-1}, TSP @180 kg ha^{-1} and MP @100 kg ha^{-1}. A high yielding rice variety Binadhan-6 was used in the experiment. Seedling of 35 to 40 days old were transplanted variably on second or third week of January of the experimental years and the crop was harvested on maturity at 130 to 140 days in May. As a recommended practice, urea was applied as top dressing in three equal installments at 7, 39, and 64 days after transplanting. Weeding, spraying of insecticides, etc. were done as per need of the crop. The land surrounding the experimental plots was cropped every year with the same seedlings as a buffer crop and to minimize advection. The same layout was used every year for the experiment. In between harvest and beginning of the next experiment, the soil of the plots was transplanted with rice crop as mass cultivation in monsoon. Soil samples from each treatment plot for both field and lysimeter were also collected up to 90 cm depth at land preparation and at harvest to determine the NO_3-N content in profile.

Water management practices used for the study were:

- T_1 = Continuous ponding (3-5 cm)
- T_2 = Continuous saturation
- T_3 = Alternate flooding (5 cm) and drying for 3-days after disappearance of the ponded water
- T_4 = Alternate flooding (5 cm) and drying for 5-days after disappearance of the ponded water and
- T_5 = Alternate flooding (5 cm) and drying for 7 days after disappearance of the ponded water

To maintain the pre-scheduled treatments, the applied irrigation water was held in the plots by providing dikes around them. Irrigation water was delivered to the treatment plots through small channels left in between the replications. Irrigation depth was measured by inserting graduated scales in soils in each plot. After transplanting, common irrigation was given up to three weeks for crop establishment and then the treatments were imposed. Finally, irrigation was stopped at about 20 days before harvest. Following standard procedure, yield data was recorded at harvest and the unit plot yield was converted to kg ha^{-1} which were then analyzed in accordance with the analysis of variance technique using MSTATC statistical package. The means were separated using ‘Least Significant Difference (LSD)’ at 5 % significance level.

Determination of water balance and NO_3 leaching

The general water balance equation at plot level in paddy field can be written as:

$$P + I = ET + R + D \quad \text{......................................(1)}$$

where, P is precipitation (cm), I is irrigation water (cm), ET is evapotranspiration (cm), R is surface runoff (cm) and D is deep percolation. The 'soil moisture storage' term was not considered as the field was prepared for transplantation in saturated condition for all the treatment plots.

The sum of the terms in the left hand and right hand side of the equation are water gain and water loss, respectively. Simplifying the equation it becomes:

$$ET = I + (P - R) - D \quad \text{......................................(1)}$$

or,

$$ET = I + P_{effective} - D \quad \text{......................................(2)}$$

where, $P_{effective}$ is effective rainfall which was calculated following the method outlined by Dastane (1974). Any rainfall amount above 75 mm/day or in excess of 125 mm in 10 days was treated as non-effective. In case of deep percolation, it was taken as 2 mm/day (for this soil type, equal to saturated hydraulic conductivity) for the whole growing period for ponding and saturated treatments, and one-third of the growing days with the same rate for the other treatments (as these treatments include dryness for 3 to 7 days after ponding water disappearance). For lysimeter, excess water was collected from the drainage outlet pipe provided at the bottom of each tank and the cumulative amount was considered as the total deep percolation for each treatments.

Vacuum gauge water samplers were installed in one replication in the field at 38, 85 and 120 cm depth. At sampling time each sampler was sucked for 20-30 minutes by a hand suction pump and kept air tight. Then the sample was collected after the normal accumulation of water into the sampler through the ceramic cup which was then analyzed in laboratory for NO_3-N concentration following the procedure of Rand *et al.* (1976) (micro-jeldal analytical method). On the other hand, effluent from the lysimeter plots was collected from the out let situated at 120 cm depth of the lysimeter and analyzed for NO_3-N.

The NO_3-N leached below the root zone at the sampling depth in each sampling was calculated using the following formula;

$$L_N = D \times C_N \quad \text{...(4)}$$

where,

L_N = amount of NO_3-N (mg) leached below the root zone

D = volume of water leached below the root zone (liter) and

C_N = concentration of NO_3-N (mg/l) of the drainage water collected below the root zone.

Total NO_3-N leached during the growing season was calculated by summing up L_N for each sampling and expressed as amount (kg) per unit area (ha).

Results and Discussion

Rainfall amount during the crop period

The amount and distribution of rainfall during the rice growing period (transplanting to harvest) were shown graphically in Fig.1. The amount of rainfall up to 90 days from transplanting (at the starting of grain formation) in all the years were low, thus, there was no problem to maintain the scheduled treatments.

Yield, water use and water productivity

Crop yield, water use and water productivity in field

The irrigation treatments showed insignificant difference in yield. Pattern of yield variation among the treatments also observed among the years (not shown). Average yield, components of water use and water productivity of rice under different irrigation management practices are summarized and produced in Table 1. On an average, the treatment T_2 produced the highest yield followed by T_5 (Table 1).

On an average, the treatment T_1 consumed the highest amount of irrigation water (128 cm) followed by T_2 (89 cm), but the yield difference was only 0.28 tha^{-1}. The treatment T_3 saved 20 cm of irrigation water compared to T_2 accompanied by a yield reduction of 0.31 tha^{-1}. Similarly, the treatment T_5 saved 32 cm water with a yield reduction of only 0.25 tha^{-1}. Water productivity and productivity of irrigation water were the highest with the lowest irrigation water (T_5) and the lowest with the highest irrigation water (T_1).

The alternate drying and re-watering might have contributed to phisio-biochemical changes and adjustment, which made the plants less sensitive to water stress, thus less adverse impact on yield. The results are comparable with the recent findings of Liang *et al.,* 2002. They demonstrated that alternate drying and re-watering had a significant compensatory effect that could reduce transpiration. Turner (1986) reported that plants can adapt to slowly developing water deficit so that the water potential at which physiological activity is affected is changed. Osmotic adjustment allows for the maintenance of photosynthesis and growth by stomatal adjustment and photosynthetic adjustment (Turner, 2004).

Another aspect is that monocarpic plants such as wheat and rice need the initiation of whole plant senescence so that stored carbohydrates in stems and leaf sheaths can be remobilized and transferred to their grains. Delayed whole plant senescence lead to poorly filled grains and unused carbohydrate in straws (Zhang and Yang, 2004). Slow grain filling may often be associated with delayed whole plant senescence. Zhang and Yang

(2004) showed that the early senescence induced by water deficit does not necessarily reduce grain yield even when plants are grown under normal nitrogen (N) condition. The gain from accelerated grain-filling rate and improved translocation outweighed the possible loss of photosynthesis as a result of shortened grain filling period when subjected to water stress during grain filling.

Lysimeter

The average yield, water use and water productivity for the lysimeter grown rice are presented in Table 2. It is observed that yield in lysimeter is higher than that of the field. This might be due to less competition of climatic factors in the lysimeter crops, specially the sunlight. Alike field, yield varied among treatments by narrow range. Here, the treatment T_4 produced the highest yield. The irrigation water consumed followed the similar trend as that of the field.

NO_3-N leaching

Nitrate in drainage water

The cumulative concentration of NO_3-N in the drainage water under different treatments of field and lysimeter are shown in Fig. 2 and Fig. 3, respectively. The figures indicated that the NO_3-N concentration were higher in T_1 and T_2 in most cases under field condition, but in lysimeter it was higher in T_3 and T_4. The higher value under stressed condition in lysimeter might be due to the reason that the creation of fine crack (developed due to dry condition) between the lysimeter wall and the soil column facilitated the bypass of water after irrigation. The NH_4-N is sorptive (to soil) and moves slowly in soil, but N moves faster when it converts to NO_3-N. The total amount of NO_3-N loss under lysimeter condition varied between 1.09 to 2.0 kg ha^{-1} (Table 3). Increased decomposition and mineralization rates in the field soil might have contributed to the elevated total nitrate in percolated water.

From the field data, it was observed that there was a reduction in nitrate leaching under the irrigation strategy in which irrigation water was applied at 3 to 7 days after disappearance of ponded water (treatment T_3 to T_5), without insignificant reduction in rice yield. Other studies (Skoop *et al.*, 1990; Doran, 1980) have demonstrated that increased soil-water increased mineralization rates, exposing more nitrate to leaching. Lower mineralization in lysimeter may occur due to a decrease in organic matter (Casey *et al.*, 2002). Unfortunately, a record of soil organic-matter content at various stages of the study was not kept to verify whether mineralization rates were increasing or decreasing.

NO_3-N concentration in soil profile

The NO_3-N concentration at various depths at sowing and harvest under different treatments of field and lysimeter are shown in Fig. 3. The NO_3-N concentration showed fluctuating pattern at different depths, and also varied among treatments. Moreover, it was found that the maximum NO_3-N concentration was at 90-120 cm soil depth in T_1. On the other hand, in lysimeter, the highest NO_3-N was found at 0-30 cm depths in T_1.

Table 1. Average yield, irrigation water use, evapotranspiration (ET), water productivity (WP) and irrigation water productivity (IWP) under different water management practices under field condition.

Treat-ments	Yield (t/ha)	Irrigation (cm)	Effective Rainfall (cm)	Deep percolation (cm)	ET (cm)	WP (kg/ha-mm)	IWP (kg/ha-mm)
T_1	4.55	128	39	24	143	3.18	3.55
T_2	4.83	89	39	24	104	4.64	5.43
T_3	4.52	69	39	8	100	4.52	6.55
T_4	4.43	62	39	8	93	4.76	7.15
T_5	4.58	57	39	8	88	5.20	8.04

Table 2. Average yield, water use (ET), water productivity (WP) and irrigation water productivity (IWP) under lysimeter

Treat-ments	Yield (t/ha)	Irrigation (cm)	Rainfall (cm)	Runoff (cm)	Deep percolation (cm)	Water use (cm)	WP (kg/ha-mm)	IWP (kg/ha-mm)
T_1	7.54	77.0	56.8	21.0	14.8	101.7	7.4	9.8
T_2	7.79	68.2	56.8	21.0	13.0	77.1	10.1	11.4
T_3	7.91	48.5	56.8	21.0	9.2	75.0	10.5	16.3
T_4	7.98	42.6	56.8	21.0	13.7	68.1	11.7	18.7
T_5	7.22	41.8	56.8	21.0	11.9	68.6	10.5	17.3

Table 3. Average estimated amount of NO_3-N leaching under lysimeter and field condition

Treatment	NO_3-N leaching (kg ha^{-1})	
	Lysimeter	Field
T_1	1.59	52.3
T_2	1.56	48.3
T_3	1.53	23.5
T_4	2.00	17.6
T_5	1.09	16.9

In lysimeter, higher concentration trend was observed in T_1 followed by the water stressed plots (T_3 and T_4). This might be attributed by the interspaces in between soil and lysimeter wall. But in the field, NO_3-N concentration was highest in T_3 followed by T_1. It showed an indication that the irrigated plots with ponded water allowed the free downward movement of NO_3-N causing its higher leaching rate.

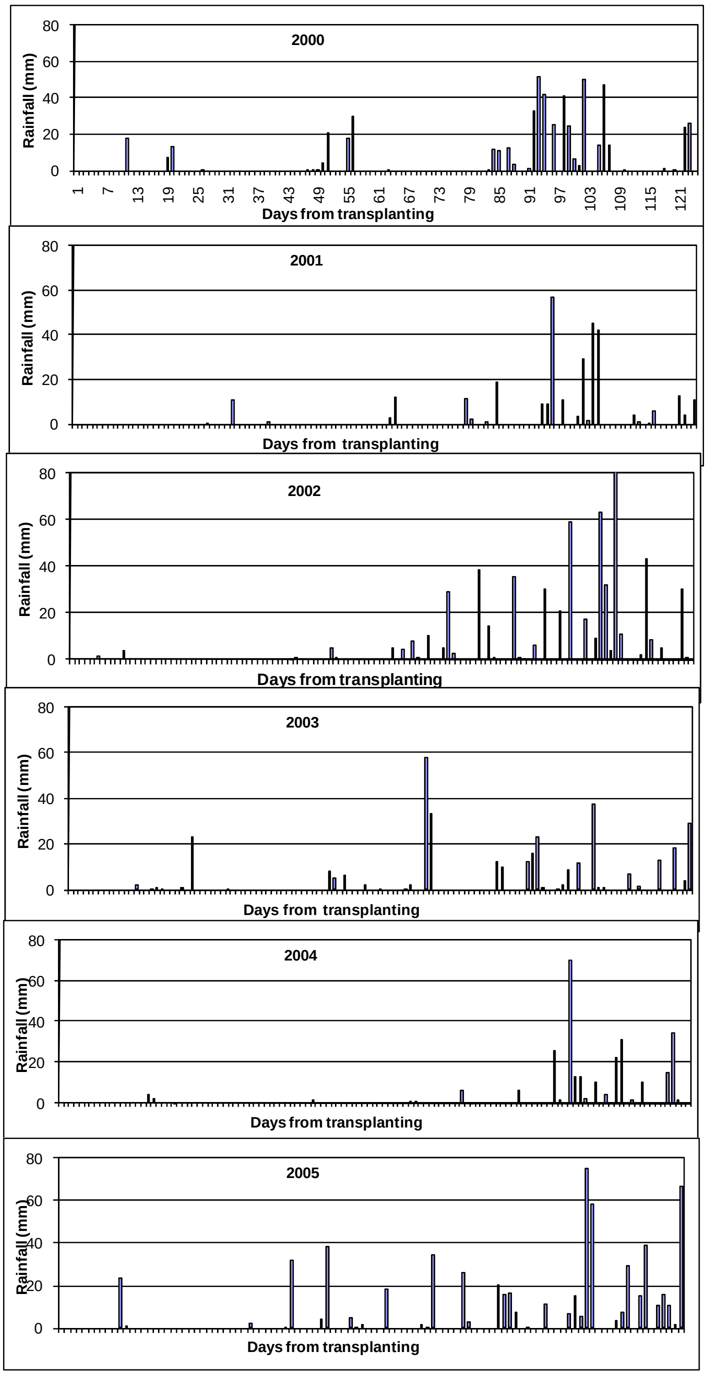

Fig. 1. Rainfall amount during crop growing period

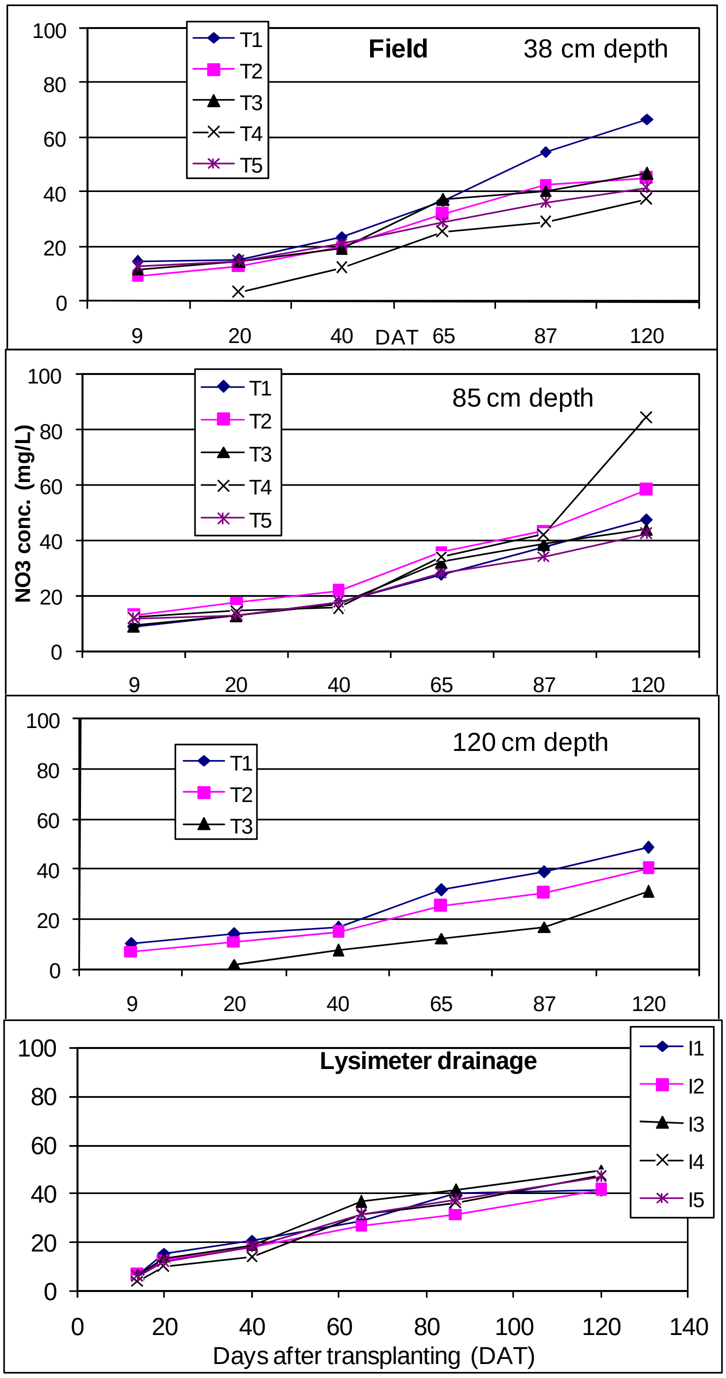

Fig. 2. NO_3-N concentration of drainage water collected from the field.

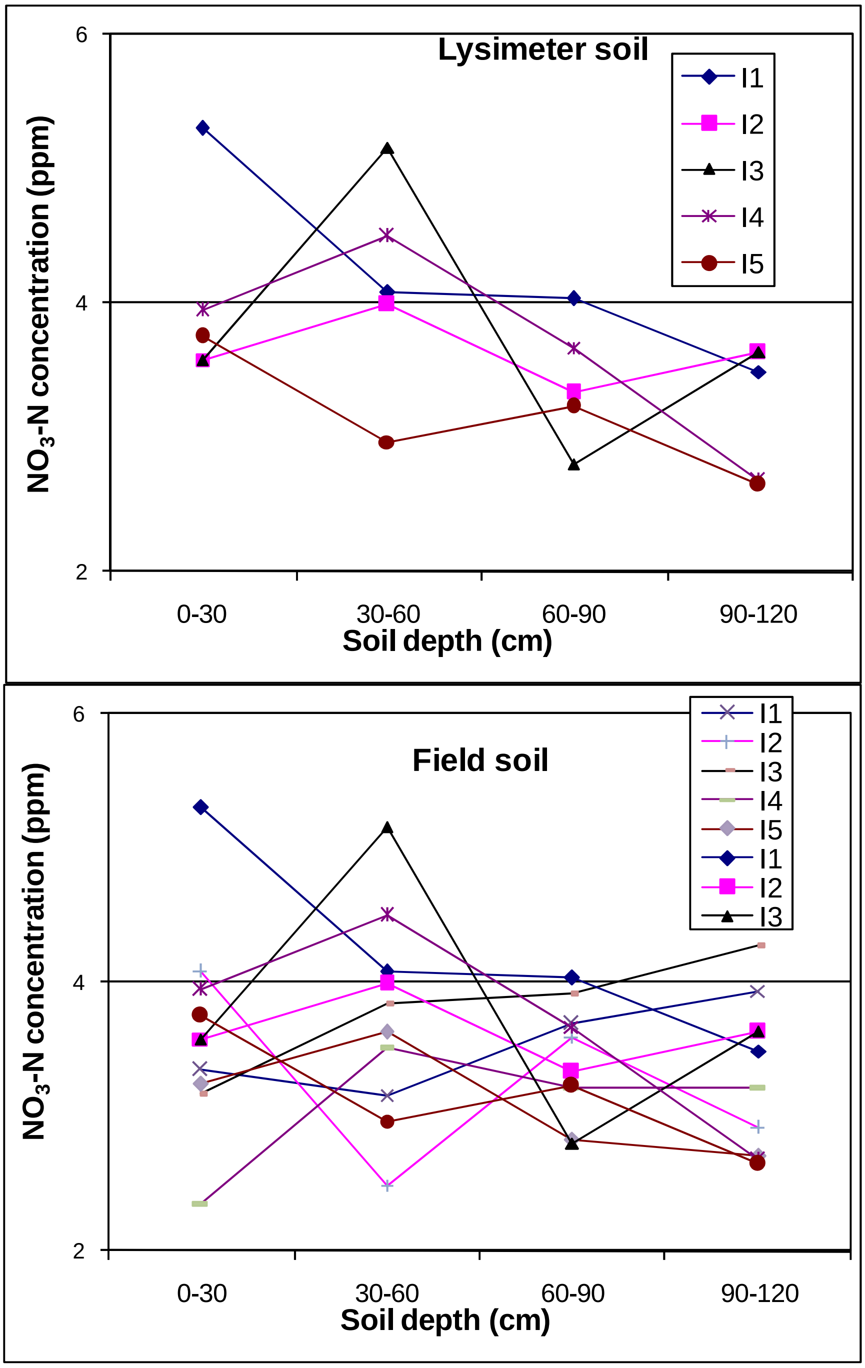

Fig. 3. Cumulative NO_3 -N concentration of field and lysimeter soil at harvest

Conclusion

Different irrigation strategies showed insignificant effect on the yield of rice. The alternate wetting and drying up to 5 to 7 days showed the lowest nitrate leaching presenting the lowest risk of groundwater contamination. Considering the nitrate loss, yield, water saving and irrigation water productivity, the alternate wetting and drying of 5 to 7 days seemed to be the best irrigation strategy for rice irrigation.

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INDUCTION OF RESISTANCE IN RICE AGAINST SHEATH BLIGHT DUE TO SEED TREATED WITHBIO-EXTRACTS

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Abstract

The effect of different bio-extracts such as; *Rhizoctonia solani, Trichoderma* sp, mixture of *R. solani* + *Trichoderma* sp, fruit and leaf of datura, bacillus and fungicide (Provax) were assessed against sheath blight of rice under laboratory and pot condition. To induce resistance in rice against sheath blight, the bio-extracts were applied in seeds in laboratory condition. Then seedlings were transplanted in pot and data were taken at seedling and maximum tillering stages. The highest 87.2% germination was found in suspension of *Trichoderma* and the lowest 49.6% in untreated control. Root length, shoot length, root weight and shoot weight were found higher in mixture of *R. solani* + *Trichoderma* sp. and lower in untreated control. At maximum tillaring stage, the lowest 30.00 mm (15 Days After Inoculation, DAI) lesion length, the highest 93.28% healthy tiller and 74.25 cm plant height were observed in mixture of *R. solani* + *Trichoderma* sp. and all were the lowest in control. The highest 59.06% infected tiller was also recorded in untreated control.

Key words: Sheath blight, Bio-extracts, Resistance, Rice

Introduction

Rice is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories to the human beings (BBS, 2009). In 79.4 % of the total cultivable land is under rice crop (FAO, 2008). Disease plays an important role to damage rice plants. Sheath blight caused by *R. solani* is a major disease of rice that affects yield and grain quality in Bangladesh. Application of high doses of Nitrogen fertilizer, close spacing, low light intensity, cloudy sky and high relative humidity favors epidemic development of sheath blight (Kannaiyan and Prasad, 1983). In biological control, *Trichoderma* has an antagonistic character against many soil borne fungi such as *R.solani*. (Starshnow *et al.,* 1985). Biological control based on microbial antagonism, induces resistance in plants, and use of plant extract with antagonistic properties that influence production. Induced resistance involves the activation of latent resistance mechanisms which are expressed after subsequent challenge inoculation with a pathogen.

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Induced resistance may be triggered by pathogens and certain chemicals. Generally, resistance is not induced locally only but also in plant parts (Sticher *et al*., 1997; Van loon *et al.,* 1998). So, for the development of friendly environmental bio-fungicide, the biological control of plant diseases has been given top priority. Therefore, the present research work was undertaken to study the induction of resistance against sheath blight of rice using bio-extracts.

Materials and methods

Different bio-agents and plant parts were collected from around the BINA office. Bio-extracts were prepared at the Laboratory of Plant Pathology Division, BINA and applied in laboratory and pot experiment during March to August 2011. The seeds of T. amon rice line (TN-1), susceptible to sheath blight was collected from BINA, Mymensingh. The experiment was laid out in a Completely Randomized Design (CRD) with four replications. Different treatments prepared in the laboratory were used in pot at different form such as; suspension of *R. solani*, macerated extract of *Rhizoctonia solani*, suspension of *Trichoderma* sp., macerated extract of *Trichoderma* sp., mixture of *R. solani*+ *Trichoderma* sp., datura fruit extract, provax (fungicide) and macerated extracts of bacteria. Each suspension was prepared with a ratio of 1:10. For seed germination, fifty petridishes were cleaned and four blotter papers were set in each petridish. Twenty five seeds were set in each petridish. A total of 40 pots were prepared, filling with 8 kg/pot of air dried soil. Seven days old seedlings were transplanted in the pot. Three seedlings were transplanted in each pot. Intercultural operations were done as and when necessary. The plants were inoculated with mycelial block of 5 mm diameter and 10 days old culture of *R. solani*. Different parameters such as; germination percentage, root length, shoot length, root weight, shoot weight, lesion length, disease severity, number of infected tiller, number of healthy tiller and plant height were collected. The data on different parameters were statistically analyzed using Analysis of Variance (ANOVA) technique to find out the level of significance (Gomez and Gomez, 1984) and grading was done using DMRT. Disease severity were assessed using the scale (0-9) described in Table1.

Table1. Disease severity measurement scale

Grade	Description
0	No infection
1	Lesion limited to lower half of the leaf sheath
3	Lesion up to lower half of the sheath
5	Lesion on more than half of the 3^{rd} or 4^{th} leaf
7	Lesion present on more than half of flag leaf sheath
9	Lesion on more than half of each leaf sheath with dead tillers

Results and discussion

The highest germination (87.2%), root length (6.4 cm), shoot length (5.5 cm), root weight (0.04 g) and shoot weight (0.07 g) were found in the suspension of *Trichoderma* sp treated in rice seedling and the lowest was in untreated control (Table 2). This finding was in agreement with findings of Mathivanan *et al.* (2006). They reported that application of *Trichoderma* sp. increased germination percentage, root length, shoot length, root weight and shoot weight of rice compared to untreated control.

Table 2. Effect of different bio-extracts on seed germination, root length, shoot length, root weight and shoot weight of rice seedlings

Treatments	Seed germination (%)	Root length (cm)	Shoot length (cm)	Root weight (g)	Shoot weight (g)
Control	49.6	1.48	3.80	0.006	0.021
Suspension of *R. solani*	80.8	5.76	5.41	0.032	0.053
Macerated extracts of *R. solani*	77.6	4.99	5.19	0.028	0.030
Suspension of *Trichoderma* sp.	87.2	6.97	5.53	0.039	0.065
Macerated extract of *Trichoderma* sp.	72.8	4.59	4.09	0.021	0.026
Mixture of *R. solani*+ *Trichoderma* sp.	78.4	5.67	5.21	0.028	0.032
Datura fruit extract	76.8	4.83	4.36	0.027	0.029
Provex (fungicide)	64.0	4.17	4.06	0.016	0.026
Datura leaf extract	76.0	4.72	4.12	0.027	0.029
Macerated extract of bacteria	80.0	5.68	5.30	0.029	0.041
LSD ($P \leq 0.05$)	11.79	2.15	1.12	0.012	0.014

After 5, 10 and 15 days of inoculation, the lowest lesion length of 8.3 mm, 15.0 mm and 30.0 mm were found in mixture of *Rhizoctonia solani* + *Trichoderma* sp., respectively which followed by suspension of *Trichoderma* sp. (10.8 mm, 20.5 mm and 38.0 mm). The lesion length was the highest in untreated control (Table 3). The findings of the present study were in agreement with the findings of Pathak *et al*. (2004). They reported that the application of interacted treatment reduced disease incidence of rice to a significantly greater degree than the other single treatment. The highest disease severity (7) was observed in control and the lowest disease severity **(**1) was observed in mixture of *Rhizoctonia solani* + *Trichoderma* sp. This finding was in agreement with the findings of Arunyanart *et al*. (1984). They reported that correlation between disease severity and percent yield loss was a linear regression (Table 3). The plant height, infected tiller and healthy tiller of rice were shown in Table 4. The highest plant height (74.25 cm) was observed in mixture of *Rhizoctonia solani* + *Trichoderma* sp. and the lowest plant height (57.00 cm) was observed in control. This finding was in agreement with Sinha and Sinha (2007). They reported that commercial formulation of bio-agents increased plant height.

The highest infected tiller (59.06%) was observed in control and the lowest infected tiller (8.79%) was observed in mixture of *Rhizoctonia solani* + *Trichoderma* sp. The highest healthy tiller (93.28%) was observed in mixture of *Rhizoctonia solani* + *Trichoderma* sp. and the lowest healthy tiller (40.93%) was observed in control. These findings were in agreement with the findings of Singh *et al.* (2005). They reported that a sophisticated interaction between pathogen and the interacting gene might be the key target for controlling of sheath blight of rice.

Table 3. Effect of different bio-extracts on lesion length and disease severity of sheath blight at different days after inoculation in rice

Treatments	Lesion length (mm)			Disease severity (0-9 scale)
	5 DAI	10 DAI	15 DAI	
Control	19.50	39.75	59.00	7
Suspension of *R. solani*	12.25	24.7	41.25	3
Macerated extracts of *R. solani*	14.25	28.00	48.50	5
Suspension of *Trichoderma* sp.	10.75	20.50	38.00	3
Macerated extract of *T.* sp.	11.75	25.00	37.75	3
Mixture of *R. solani*+ *T.* sp.	8.25	15.00	30.00	1
Datura fruit extract	13.50	24.50	49.25	5
Provex (fungicide)	16.25	35.75	51.25	5
Datura leaf extract	13.50	30.00	44.50	5
Macerated extract of bacteria	14.25	23.75	40.75	3
LSD ($P \leq 0.05$)	5.11	11.36	17.49	2.99

DAI = Days After Inoculation

Table 4. Effect of different bio-extracts on plant height, number of infected tiller and number of healthy tiller of rice

Treatments	Plant height (cm)	Infected tiller (%)	Healthy tiller (%)
Control	57.00	59.06	40.93
Suspension of *Rhizoctonia solani*	72.00	15.59	84.39
Macerated extracts of *Rhizoctonia solani*	69.50	17.52	82.47
Suspension of *Trichoderma* sp.	73.50	11.18	88.81
Macerated extract of *Trichoderma* sp.	73.50	9.31 d	90.68
Mixture of *Rhizoctonia solani*+ *Trichoderma* sp.	74.25	8.79	93.28
Datura fruit extract	69.25	17.76	82.24
Provex (fungicide)	66.25	18.18	81.83
Datura leaf extract	70.25	16.15	83.84
Macerated extract of bacteria	72.50	12.79	87.11
LSD ($P \leq 0.05$)	7.81	6.28	6.08

Conclusion

To reduce the sheath blight severity of rice, and enhance the seed germination, root and shoot length, root and shoot weight, the mixture of *Rizoctonia solani* + *Trichoderma* sp. might be used.

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MEASUREMENT OF SOIL EROSION-DEPOSITION USING FALLOUT RADIONUCLIDE (FRN) TECHNIQUE ON A CULTIVATED SLOPE

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Abstract

The measurement of fallout nuclides is a useful tool for the assessment of soil erosion and sedimentation rates. Scientists established models for converting ^{137}Cs depletion/enrichment amounts to net soil loss/deposition. These models are based in the comparison between a reference ^{137}Cs inventories in a long term undisturbed site (control site) and the ^{137}Cs inventories in the suspected eroded or deposited sites in the landscape. A study was conducted on a cultivated slope at Loess Plateau Valley Shaangxi province, Pucheng County at Nangwang, China with an elevation of approximately 723.5 m above mean sea level and 10.5-15^0 slope gradient to measure the soil erosion-deposition of different positions (upper, middle and lower) from ^{137}Cs inventories. Soil sampling depths at upper positions were 0–30 cm, at middle position 0-45 cm and at the lower position in the slope were 0-60 cm with 5 cm increment to ensure the complete ^{137}Cs inventories of the soil profile. Radiocaesium analyses were made by a hyperpure coaxial Ge detector. To make an interpretation of ^{137}Cs inventories distribution to soil losses and sedimentation the mass balance model 2 was used. ^{137}Cs inventories ranged from 1.36±0.19 to 2.4 ±0.2, 1.06±0.21 to 3.35±0.24 and 0.65±0.19 to 3.66±0.23 Bq kg^{-1} in upper, middle and lower slope positions, respectively. The total inventory for the upper (468.85 Bq m^{-2}) and middle position (738.1 Bq m^{-2}) were 63% and 41.7% lower, and lower position (1905.2 Bq m^{-2}) was 50.4% higher than the reference inventory which means soil erosion was 25.8 and 14.5 t ha^{-1} yr^{-1} on upper and middle position, respectively and 19.6 t ha^{-1} yr^{-1} deposition on lower slope position.

Key words: Soil, erosion, deposition, ^{137}Cs

Introduction

Soil erosion is a serious environmental problem. Soil erosion and associated land degradation represent a major problem for the sustainable intensification of the agricultural production. This is particularly acute in the developing world, which is characterized by limited land and water resources and a rapidly growing population (Lal, 2000; Walling, 2002). It has been estimated that the world's croplands are currently losing 23 billion tones

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of soil in excess of new soil formation each year. This is equivalent to a depletion of the global soil resource by 7% each decade (Brown, 1984).

Field measurements of soil erosion and sediment deposition using classical techniques are difficult, time consuming, and expensive but indispensable to feed the prediction models (Bujan *et al.,* 2000). Natural and artificial radionuclide tracers have been used to assess the intensity and pattern of soil and sediment redistribution at a range of locations and spatial scales (Lal *et al.,* 1991; Foster and Lees, 2000). The Chernobyl derived ^{137}Cs is a very good marker for the assessment of sedimentation rates at different locations (Walling and Quine, 1992; Golosov *et al.,* 1999a). Walling and He (1997) have developed several models for converting ^{137}Cs data to net soil loss/gain. The purpose of this study was to measure the soil erosion-deposition from the loss-gain of ^{137}Cs of different positions (upper, middle and lower) of a cultivated slope.

Materials and methods

The study site

This study was conducted in 2011 on a cultivated slope at Loess Plateau Valley Shaangxi province, Pucheng County at Nangwang (109^0 38' 56.18"- 109^0 38' 57.03"E, 35^0 3' 21.33" - 35^0 3' 21.95"N), China. The elevation is approximately 723.5 m above mean sea level and slope gradient is 10.5-15^0. The climate was classified as semi-arid continental monsoon, the annual average temperature was 13.2 °C, frost free period was 180-220 days, average rainfall was 550 mm and about more than 60% rainfall was concentrated from June to September which overlaps with high temperature of the year. The soil was silt loam (sand 4.56%, silt 70% and clay 25.44%). Wheat, maize and mustard were the major crops of the cultivated area in the Loess Plateau.

Soil sampling

To determine the profile variations of ^{137}Cs, soil samples were collected from three positions (upper, middle and lower) on the cultivated slope. The terraced slope was 30 m long and 7 m wide. Three sampling points were selected from each position. Samples were collected using a 8-cm diameter hand-operated core sampler at 7-m intervals along each hillslope transect and 2-m intervals along the down slope transect on terraces. Two cores were collected at each sampling point and were then bulked to make a composite sample. To ensure complete ^{137}Cs inventories of the soil profile, soil sampling depths at upper positions in the plot were 0–30 cm, at middle position were 0-45 cm and at the lower portion in the slope were 0-60 cm with 5 cm increment.

Analysis

Soil samples were air-dried, weighed, and passed through a 2 mm sieve. ^{137}Cs concentration was measured using a hyperpure coaxial Ge detector coupled to a multi channel analyzer (Li *et al.*, 2003). ^{137}Cs concentration of samples was detected at 662 keV using counting time over 80,000 s, which provided an analytical precision of ±6% for ^{137}Cs. Soil erosion-deposition rate was calculated using mass balance model 2 (Walling and He, 1997).

Result and discussion

^{137}Cs was found distributed in the top 0-20 cm at upper position (Fig. 1a) ^{137}Cs activity varied from 1.36±0.19 to 2.4 ±0.2 Bq kg^{-1}. The highest value was obtained from 0-5 cm and the lowest from 15-20 cm soil depth. For middle slope position (Fig. 1b), ^{137}Cs inventory ranged from 1.06±0.21 to 3.35±0.24 Bq kg^{-1}, with the highest value between 5-10 cm and the lowest in 30-35 cm depth. At lower slope (Fig. 1c), ^{137}Cs inventory was distributed all over the 0-60 cm depth with the value ranged from 0.65±0.19 to 3.66±0.23 Bq kg^{-1} of which the highest value in 5-10 cm and the lowest in 55-60 cm depth. No ^{137}Cs inventory was found below 20 cm and 35 cm at upper and lower slope position, respectively.

Total ^{137}Cs inventory of reference site and different slope positions (upper, middle and lower) were shown in Fig. 2. An average value of 1266.6 Bq m^{-2} was obtained for the local reference ^{137}Cs inventory. It was slightly higher than the ^{137}Cs values of global distribution given by Garcia Agudo (1998). The total inventory for the upper (468.85 Bq m^{-2}) and middle slope position (738.1 Bq m^{-2}) were respectively, 63% and 41.7% lower than the reference inventory. It indicated that these positions experienced soil erosion. In contrast, the inventory for the lower position (1905.2 Bq m^{-2}) was 50.4% higher than the reference inventory. It thus indicated that this position experienced soil sedimentation. This value of erosion and deposition was in the range of the findings of Collins *et al.*, (2001).

The estimated erosion/deposition rates from Mass Balance Model 2 indicated that soil eroded from upper and middle slope positions by 25.8 and 14.5 t ha^{-1} yr^{-1}, respectively and deposited on lower position by 19.6 t ha^{-1} yr^{-1}. The gross erosion rate was 14.8 t ha^{-1} yr^{-1}, net erosion rate was 6.9 t ha^{-1} yr^{-1} and sediment delivery ratio was 46%.

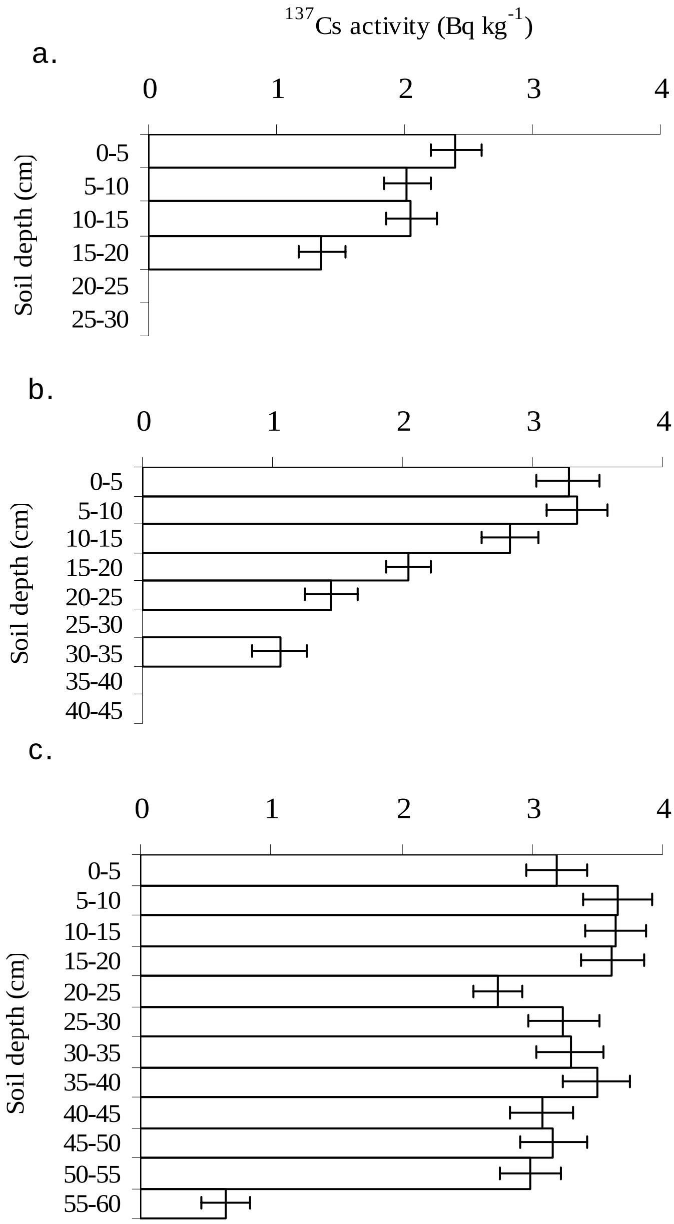

Fig: 1. Distribution of ^{137}Cs activity (Bq kg^{-1}) in different depths at (a) upper (b) middle and (c) lower position of the cultivated slope.

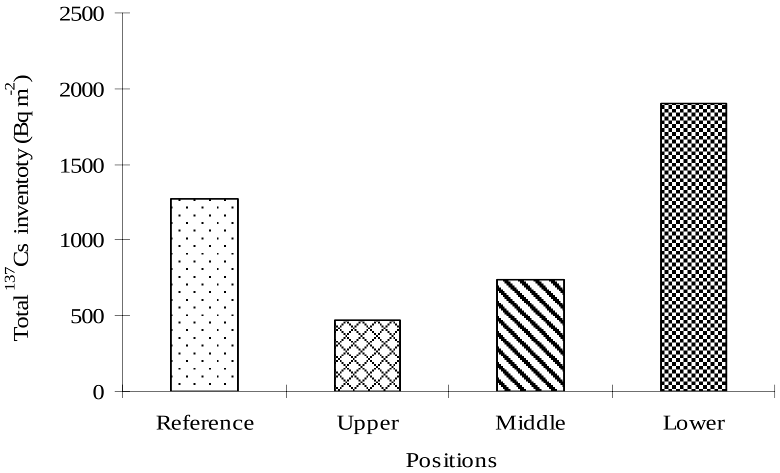

Fig 2. Total ^{137}Cs inventory (Bq m^{-2}) of reference site and different slope positions (upper, middle and lower).

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ASSESSMENT OF SEASONAL EFFICACY AND PLANTING DATE ON FUSARIUM WILT OF TOMATO

H. A. Begum[1] and M. B. Meah[2]

Abstract

Two experiments were carried out at the Bangladesh Institute of Nuclear Agriculture (BINA) farm, Mymensingh using 4 varieties of tomato (including 2 tomato varieties of BINA) to evaluate the efficacy of growing seasons and find out the optimum transplanting date in reducing the incidence and severity of fusarium wilt caused by *Fusarium oxysporum* f. sp. *lycopersici* during summer and winter seasons of 2008-09. Disease incidence and severity of the diseases were comparatively lower in the winter season than the summer season. The lower disease incidence and severity were recorded in Binatomato-3 and BARI Tomato-5. A susceptible variety Pusaruby, transplanted on 1 and 16 November had remarkably less percent wilted plants by fusarium wilt than the plants planted on 16th September to October.

Key words: *F. oxysporum* f. sp. *lycopersici*, Tomato, Season, Transplanting date

Introduction

Fusasium wilt of tomato (*Lycopersicon esculentum*) is a potential threat to successful cultivation of tomato. It is a serious disease resulting 10-50% yield loss around the world (Luckyanenko, 1991). It is also a devastating disease affecting vascular bundle of plants (Singh, 2002). The disease is caused by others pathogens such as; bacteria (*Ralstonia solanacearum*) and fungus (*Verticillium albo-atrum*). The organism is soil borne. Seed borne nature and seed transmission of the pathogen is also known. High moisture and high temperature soil conditions are favorable for tomato wilt. Poorly drained soil is also a conductive factor for plant wilting. A susceptible host is also an added factor. All these make the tomato wilt a complex. Growing season has an important influence on the disease incidence and yield of tomato. Adjustment of transplanting dates to check specific disease(s) has already been emphasized in different parts of Bangladesh (Rahman, *et al.*, 1995). Some diseases are very destructive when susceptible stage of the host and optimum soil and atmospheric conditions for aggressiveness of the pathogen coincide. Alternation in the date of transplanting in such a way that the susceptible stage of the plant growth does not coincide with the favorable environment for the pathogen that

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helps in reducing losses from such disease. Sowing season is the most important factor which not only helps in avoiding disease (s) but also influences yield of tomato. As the climatic conditions of Bangladesh are favorable for the development of various diseases, therefore, the present study was undertaken to determine the effect of growing season and transplanting time on disease incidence and severity of fusarium wilt of tomato.

Materials and Methods

Assessment of seasonal efficacy

Tomato plants were transplanted on two subsequent growing seasons, summer and winter in the field of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Seeds were sown on 15 March and 15 October, 2008 to determine the effect of seasons on the incidence and severity of the disease. The experiment was conducted in a 2 factors randomized complete block design with three replications. The factors were (i) seasons (summer and winter) and (ii) varieties (four varieties such as; Binatomato-2, Binatomato-3, BARI Tomato-4 and BARI Tomato-5). Thirty day-old seedlings were transplanted with a spacing of 50 cm. between rows and plants. Twelve healthy seedlings of each variety plot^{-1} were inoculated by soil drenching method (Gangopadhyay, 1984) with conidial suspension @ 10^7 conidia ml^{-1} of 7 day-old culture of *F. oxysporum* f. sp. *lycopersici*. Fertilizers were applied at recommended doses. Recommended cultural practices were followed. Wilting of plants was recorded regularly. Disease severity was computed by adopting (0-4) scale (Kapoor, 1987). Percent disease index was evaluated using the following formulae.

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of total scores}}{\text{Maximum grade x Total number of plant assessed}} \text{ x 100}$$

Effect of transplanting dates

The experiment was set up during the winter season i.e. from September 2008 to March 2009. Tomato plants were transplanted on five different dates starting from 16 September at 15 days interval. The experiment was carried out in a randomized complete block design with 3 replications. Tomato seedlings of susceptible variety Pusaruby (Ramkishum, 1987) were transplanted. The spacing between line and plant were 50 cm apart. Seeds/ plants were not given any insecticidal and fungicidal treatments. Method of inoculation, inter cultural operation and method of data recording were the same as described earlier.

Results and Discussin

Assessment of seasonal efficacy

During the winter season the disease index and severity of fusarium wilt of tomato were comparatively lower than the summer season (Table 1). Maximum disease index (65.0%) and severity (2.7) of fusarium wilt were recorded in plants transplanted in the summer season (April) and minimum disease index (54.63%) and severity (2.2) were recorded in the winter season. In winter, the varieties showed moderately resistant reaction while they showed susceptible reaction during the summer season.

Response of four varieties to wilt index and severity were significantly different. BARI Tomato-4 showed the highest disease index (73.75%) and severity (3.0) followed by Binatomato-2 (Disease index = 70.00% and Disease severity = 2.8) while Binatomato-3 exhibited the lowest disease index (46.25%) and severity (1.9) followed by BARI Tomato-5 (Disease index = 49.27% and Disease severity = 2.0).

Table 1. Efficacy of growing seasons and different varieties on the index and severity of fusarium wilt of tomato

Treatments	Disease index (%)	Disease severity (0-4)	Disease reaction
Growing seasons			
Winter	54.63	2.2	MS
Summer	65.00	2.7	S
LSD $_{(0.05)}$	10.7	0.25	
Varieties			
Binatomato-3	46.25	1.9	MS
BARI Tomato-5	49.27	2.0	MS
Binatomato-2	70.00	2.8	S
BARI Tomato-4	73.75	3.0	S
LSD (P > 0.01)	21.82	0.88	

MS = Moderately susceptible, S = Susceptible

Irrespective of season, BARI Tomato-4 and Binatomato-2 showed significantly higher disease index and severity of fusarium wilt (Table 2). On the other hand, the lower disease index and severity were recorded in the varieties of Binatomato-3 and BARI Tomato-5.

In the present study, sowing season was found to influence the index of wilt of tomato. The index and severity of fungal wilt of tomato were comparatively lower in the winter season than the summer season. This might be due to low temperature and low moisture content during the period from November to the middle of April. Meah (1994, 1997) and Babar (1999) supported the present findings who stated that for some pathogens, wet season or summer season was found to be favorable for higher disease incidence and severity. Further, support comes from Rahman *et al.* (1995) who observed that the incidence of foliar diseases viz. alternaria leaf spot, anthracnose, rhizoctonia aerial blight was significantly higher in early sown crops than the later sown crops. The later sown crops matured later than early sown crops, due to the occurrence of lower temperature and humidity less disease incidence occurred in later sown crops.

Table 2. Effect of interactions between season and varieties on the development of fusarium wilt of tomato

Treatments		Disease index	Disease severity	Disease
Seasons	Varieties	(%)	(0-4)	reaction
Summer	Binatomato-3	50.00	2.1	MS
	BARI Tomato-5	50.00	2.1	MS
	Binatomato-2	76.67	3.1	S
	BARI Tomato-4	83.33	3.3	S
Winter	Binatomato-3	42.50	1.7	MS
	BARI Tomato-5	48.53	1.9	MS
	Binatomato-2	63.33	2.5	MS
	BARI Tomato-4	64.17	2.6	S
LSD ($p > 0.01$)		22.24	0.9	

MS = Moderately susceptible, S = Susceptible

Effect of planting dates

Different dates of transplanting significantly influenced the index of the disease. Maximum index (85.08%) of fusarium wilt was recorded in tomato plants transplanted on September 16 which gradually decreased in later transplanting times (Fig. 1).

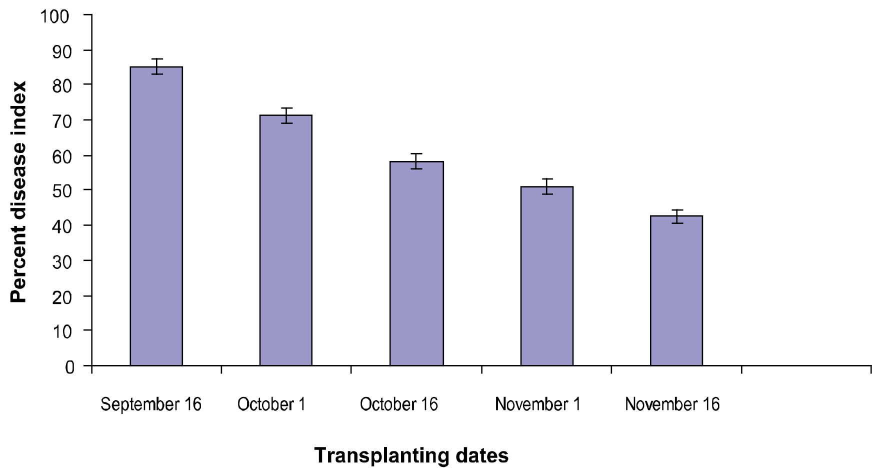

Fig. 1. Effect of transplanting dates on the index of fusarium wilt of tomato

The difference in disease index in plants transplanted on October 16 and November 1 was not significant, while the difference among other transplanting dates in respect of index of the disease was significant. In the present study, the disease index was recorded below 50% only in plants transplanted on November 16 (42.42%).

Disease index and severity of fusarium wilt were significantly higher in early transplanted (not later than October) crops than the later transplanted crops (from 1 November). Kapoor (1987) found that tomato crop sown during July to August had higher disease and crop sown after October had decreased wilt severity. The early sown crops showed more vegetative growth forming a dense canopy which provided high humidity under the plants that also favored these pathogens (Singh, 2002). The reports of Kapoor (1987) and Singh (2002) supported the present findings, although information was not available on exactly the same sowing time. The disease severity depends on the susceptibility of host as well as the climatic factors, especially temperature. Gradual decrease in the index of the disease from November 15 onwards might be due to decrease in residual soil moisture and consequently changes in biotic factors and in temperature (Ahmed and Talukder, 1978).

Conclusion

Between the two seasons, disease incidence and severity of fusarium wilt of tomato were comparatively minimum in the winter season than the summer season. Tomato plants transplanted on the 1^{st} and 16 November had remarkably less percent wilted plants of fusarium wilt than the plants transplanted on 16 September to October. Therefore, in Mymensingh late transplanting (November 16) of tomato is suitable for farmers against the disease.

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PRODUCTIVITY AND PROFITABILITY OF RICE PRODUCTION IN BANGLADESH

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Abstract

The study was designed to identify and explain the possibilities for improving the productivity and profitability of rice. The investigation was undertaken in three major rice growing areas representing three agro-ecological zones of Bangladesh. The analysis was mainly based on a set of field level primary data collected from 300 sample farmers from the three areas. The Stochastic Frontier production function analysis was used to determine the productivity and profitability of rice production. Productivity of boro, aman and aus rice varied across areas and among farm categories. Boro rice showed the highest productivity (6198.78 kg) in all farm groups in all the studied areas followed by aman rice (4073.73 kg) and aus rice (1583.66 kg). Net returns per hectare estimated for different rice crops were statistically different from each other. Net return per hectare was significantly higher for boro rice (Tk. 29995.58) followed by aman rice (Tk. 21749.26) and aus rice (Tk. 4536.57). All rice crops were profitable in respect of benefit-cost ratios (full cost basis) which were 1.77, 1.88 and 1.38 for boro, aman and aus, respectively in all the areas. The maximum likelihood estimates of stochastic frontier production function model showed that plot size, seed, urea, TSP, manure, pesticide cost, seedling age, land type and area (dummy) had a significant positive impact on boro rice production. For aman rice, plot size, urea, TSP, manure, pesticide and crop duration had positive and significant coefficients whereas plot size, TSP, pesticides and land rent had positively significant coefficients for aus rice. For all rice crops, the estimated coefficients of education and extension contact of the farmers had negatively significant effect upon the inefficiency effects.

Key words: Productivity, Profitability, Rice

Introduction

Taking into account the total rice production in the global context, Bangladesh ranked fourth in position among the rice growing countries, while China ranked first. Rice ranks first among the cereals accounting for 92 percent of total foodgrain production of the country. In Bangladesh, rice production increased over the last three decades after adoption of modern varieties, but the cost of rice production also increased because of the increased price of the major inputs during the same period (Jabbar *et al.,* 2006).

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In 1986/87, production of rice was 18.25 million tonnes and in 1995/96 the production increased to 24.30 million tones, the annual growth rate being 3.28 percent. During this time the population growth rate was 1.54 percent. But during 2007/08, production of rice was 28.93 million tonnes, the rate of increase of production being 58.52 percent, with its annual growth rate of 4.69 percent. In the same period, the population growth rate was 1.39 percent (BBS, 2008).

Rice as the principal food crop provides 54 percent of the agricultural value added and more than 90 percent of the population consume rice as their main source of calories. In Bangladesh, people living in rural areas are more habituated with rice consumption than those living in the urban areas. Cereals supply 78.27 percent of calorie to the diet of the people of which 70 percent come from rice. Moreover, 54 percent of the daily protein requirement is obtained from rice (BBS, 2008).

Rice alone occupies about 76 percent of the total cropped area of the country covering the total area of about 10.58 million hectares of which modern varieties cover nearly 70 percent area (BBS, 2008). With the passage of time, due to continuous increase in population, per capita cultivated land area has been decreasing. The cultivable land area for rice is also decreasing due to the increased use of land for various non-agricultural purposes. At present, population growth rate per annum is 1.30 percent and per capita availability of cultivated land area is 0.058 hectare. Due to weather condition, high production cost, less remunerative price and competition of other food crops, rice cultivation is being relegated to marginal land and farmers are switching over to other non-cereal crops. In 1996/97, the total cultivated area under rice was 10.17 million hectares while in 2000/01 it increased to 10.80 million hectares but in 2007/08 it decreased to 10.58 million hectares at the rate of 2.04 percent per annum (BBS, 2008 and MOF, 2008).

By increasing rice production it is possible to feed the teeming millions of people and thereby reduce rural poverty and raise the standard of living of the people. It is, therefore, necessary to reorganize and develop the rice production system into a more efficient and commercially profitable sector. There are many opportunities and constraints prevailing in the rice sector which must be taken into consideration for enhancing performance of the rice sector. Rice output could be raised to increase the utilization of inputs, such as; land, labour and capital and organizing the management of production effectively so as to use these inputs efficiently. As there is a limited scope for further increase of rice area, production can be increased by increasing the productivity of rice using existing modern technologies.

The specific objectives of the present study were:

i. to estimate the productivity and profitability of rice production by locations and seasons
ii. to examine the prospect of attaining self-sufficiency in rice production in Bangladesh and
iii. to suggest some policy guidelines/recommendations

Methodology

The study was undertaken in 2008 in three major rice growing areas representing three agro-ecological zones of Bangladesh namely; the Old Meghna estuarine floodplain area in Comilla (AEZ-19), the Old Brahmaputra floodplain area in Mymensingh (AEZ-9) and the Tista Meander floodplain area in Rangpur (AEZ-3). To collect primary data, the sample farmers were selected with stratified random sampling technique with arbitrary allocation. In total three hundred owner operator farmers were interviewed in this study. A total of 100 farmers were selected from the collected lists of each location by adopting simple random sampling methods, taking 50 farmers from each village. Relevant secondary data were obtained from various published and unpublished reports of government and non-government agencies whichever were deemed appropriate. To obtain the secondary data, a checklist of different items was prepared to avoid missing of information. To determine comparative advantage of rice production, necessary data were obtained from different secondary sources.

Both tabular and statistical analyses including mean, standard deviation, gross margin (GM) analysis, net return (i.e. profit) analysis were done. The study was made on the basis of two analyses, namely partial analysis and marginal analysis of variables. Descriptive tabular method was used for a substantial part of data analysis. Finally, to meet particular research objectives, several analytical methods were employed in this study.

The explicit form of the stochastic Cobb-Douglas production frontier is given as

$$LnY_i = \beta_0 + \beta_1 lnX_{1i} + \beta_2 lnX_{2i} + \beta_3 lnX_{3i} + \beta_4 lnX_{4i} + \beta_5 lnX_{5i} + \beta_6 lnX_{6i} + \beta_7 lnX_{7i} + \beta_8 lnX_{8i} + \beta_9 lnX_{9i} + \beta_{10} lnX_{10i} + \beta_{11} lnX_{11i} + \beta_{12} lnX_{12i} + \beta_{13} lnX_{13i} + \beta_{14} lnX_{14i} + \beta_{15} lnX_{15i} + \beta_{16} lnX_{16i} + \beta_{17} lnX_{17i} + \beta_{18} lnX_{18i} + \beta_{19} lnX_{19i} + V_i - U_i \text{ ....(1)}$$

Where,

Y_i	=	Output of rice (kg)
X_1	=	Plot size (decimal)
X_2	=	Quantity of human labour used (man days)
X_3	=	Cost of power tiller used (Tk)

X_4 = Quantity of seed/seedlings used (kg)
X_5 = Quantity of Urea used (kg)
X_6 = Quantity of TSP used (kg)
X_7 = Quantity of MP used (kg)
X_8 = Quantity of Sulphur (S) used (kg)
X_9 = Quantity of manure used (kg)
X_{10} = Cost of irrigation (Tk)
X_{11} = Cost of pesticides (Tk)
X_{12} = Land rent (Tk)
X_{13} = Seedling age (days)
X_{14} = Crop duration (days)
X_{15} = Dummy for land type (MHL = 1, 0 otherwise)
X_{16} = Dummy for transplanting date (Optimum = 1, 0 otherwise)
X_{17} = Dummy for variety (HYV = 1, 0 otherwise)
X_{18} = Dummy for location (Comilla = 1, 0 otherwise)
X_{19} = Dummy for location (Mymensingh = 1, 0 otherwise)
β_0 = Constant or intercept
β_i = Parameters to be estimated
ln = Natural logarithm
V_i and U_i = V_i is an independently and identically distributed two sided random error and U_i is a non-negative variable, associated with technical inefficiency in production
i = 1, 2, 3, ..., 19

The model for the technical inefficiency effects in the stochastic frontier of equation μ_I is defined by $\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + w_i$ .....(2)

Where,

Z_1 = Age of the selected farmers (years)
Z_2 = Year of schooling of the selected farmers (years)
Z_3 = Occupation (Dummy variable which receives '1' for agriculture and '0' for otherwise)
Z_4 = Experience of the selected farmers in farming (years)
Z_5 = Family size (persons)
Z_6 = Extension contact (Dummy variable which receives '1' for yes and '0' for otherwise)
Z_7 = Training on rice cultivation (Dummy variable which receives '1' yes and '0' otherwise)
Z_8 = Farm size (decimal)
δ_j = Delta
μ = Mean technical inefficiency
j = 1, 2, 3, 4, 5, 6, 7 and 8
i = 1, 2, 3, 4, ..., 300

w_i were unobservable random variables or classical disturbance term, which assumed to be independently distributed, obtained by truncation of the normal distribution with mean zero and unknown variance, δ^2, such that u_i is non negative.

Results and Discussion

The yield of boro, aman and aus rice in different areas of Bangladesh was shown in Table 1. Boro rice showed the highest productivity (6198.78 kg ha^{-1}) in all farm groups in all areas followed by aman rice (4073.73 kg ha^{-1}) and aus rice (1583.66 kg ha^{-1}).

Table 1. Yield of boro, aman and aus rice in the study areas

Areas	Farm category	Production in kg ha^{-1}		
		Boro	Aman	Aus
Comilla	Small	6729.22 (913.48)	4705.63 (406.24)	1954.66 (1948.44)
	Medium	6733.44 (904.71)	4700.43 (376.89)	1934.68 (1937.74)
	Large	6710.02 (1008.99)	4831.35 (394.21)	2073.08 (2144.32)
	All	6729.22 (908.86)	4714.81 (391.14)	1987.47 (1941.43)
Mymensingh	Small	5850.70 (2954.73)	3483.14 (771.89)	3051.54 (618.67)
	Medium	7883.47 (7735.29)	3657.10 (553.82)	2656.94 (1107.20)
	Large	5060.55 (2933.80)	3385.81 (873.73)	2465.74 (1078.48)
	All	6492.27 (5686.37)	3528.50 (724.64)	2690.46 (1016.87)
Rangpur	Small	5379.84 (1052.19)	3876.90 (633.73)	1109.92 (1671.75)
	Medium	5365.30 (901.32)	4021.87 (741.80)	1064.63 (1878.40)
	Large	5383.81 (1006.80)	3997.62 (749.90)	1150.40 (1928.83)
	All	5374.86 (964.63)	3977.87 (714.45)	1103.40 (1827.77)
All areas	Small	5689.18 (1902.66)	4110.56 (720.93)	1082.90 (1575.90)
	Medium	6672.16 (4783.25)	4241.96 (786.34)	1687.07 (1987.27)
	Large	6059.86 (1506.53)	3728.79 (812.29)	2081.45 (1674.37)
	All	6198.78 (3411.41)	4073.73 (795.92)	1583.66 (1820.61)

Figures in the parentheses indicate standard deviations.

The productivity of boro rice was found to be approximately 1.5 times more than that of aman rice and 4.0 times more than aus rice in all areas. The productivity differences between boro & aman, aman & aus, and aus & boro were highly significant since the t values between them were found to be 5.22, 7.82, and 4.76, respectively, which were highly significant. There was no difference in the productivity of boro rice between areas (F = 2.29) but there was a difference in the productivity of boro rice between areas (F = 3.67) for all farm groups. Duncan's test suggested that there was no difference in the productivity of boro between Comilla (6729.22 kg) and Mymensingh (6492.27 kg) areas but the productivities of the two areas were significantly higher than that of Rangpur area (5374.86 kg). The productivity (yield) differences of Aus and Aman rice between farm groups within each area were also found to be insignificant but between areas for all farm groups they were found to be significant. Farmers of Mymensingh produced significantly more (F = 28.92") aman rice per hectare (4714.81 kg) than farmers of Rangpur (3997.62 kg) and Comilla (3528.50 kg). Duncan's test suggested that farmers of Mymensingh produced per hectare more aus rice (2690.46 kg) than farmers of Comilla (1987.47 kg) and Rangpur (1103.40 kg).

Net return on full cost basis

This measure was calculated as the difference between gross return and the total variable and fixed costs. Gross return was the gross value of the main product and by-product produced. The value of the main product and by-product was calculated using the market price. It was expressed as value per hectare in Taka. The variable costs included the costs of buying variable inputs. These were the out-of-pocket expenses during the production process. On the other hand, fixed costs included the costs related to land, fixed labour and fixed capital. Cost involved in the services of fixed labour (family and annually hired labour) and fixed capital used in rice production were estimated through the opportunity cost approach.

There was no difference in net return per hectare (full cost basis) between areas (F = 1.69) or between farm groups for boro rice. Similarly, for aman rice there was no difference in net return per hectare between areas or between farm groups. For aus rice, net return per hectare varied between areas (F=16.98) for all farm groups. There was also variation in net return per hectare between farm groups in each area. The net return per hectare of aus rice was significantly higher for Mymensingh (Tk. 5544.17) followed by Rangpur (Tk 4458.11) and Comilla (Tk. 3607.43) as suggested by Duncan's test. The t-values of net return per hectare (full cost basis) between boro & aman, boro & aus, and aman & aus were found to be 2.36, 2.14 and 2.25, which were highly significant. This means that the estimated net returns for different rice were not same. Net return per hectare was significantly higher for boro rice (Tk. 29995.58) followed by aman rice (Tk. 21749.26) and aus rice (Tk. 4536.57) (Table 2).

Table 2. Per hectare net returns for boro, aman and aus rice

Area	Farm category	Net return ($Tkha^{-1}$) (Full cost basis)			Net return (Tkha-1) (Cash cost basis)		
		Boro	Aman	Aus	Boro	Aman	Aus
Comilla	Small	33627.80 (13672.79)	24024.06 (10775.09)	3593.60 (9072.81)	32823.18 (10461.68)	10378.57 (323.56)	5103.02 (11634.63)
	Medium	33733.82 (13530.95)	23900.16 (10770.10)	3512.58 (8803.69)	32705.99 (10440.38)	10377.27 (319.43)	4985.18 (11398.69)
	Large	33123.73 (15023.52)	25037.30 (12026.53)	4116.39 (9844.17)	33830.75 (11655.68)	10381.94 (356.22)	5793.52 (12718.38)
	All	33625.90 (13593.00)	24064.45 (10775.78)	3607.43 (8939.56)	32865.81 (10453.99)	10378.34 (321.40)	5116.85 (11515.90)
Mymensingh	Small	34662.02 (13057.31)	17468.88 (8735.52)	6891.12 (6198.54)	25382.95 (8948.09)	7967.68 (3706.86)	13548.45 (6134.27)
	Medium	39826.11 (9030.69)	20410.10 (6517.91)	4654.18 (5466.61)	28339.99 (6549.84)	10109.88 (2725.20)	10527.21 (6337.38)
	Large	26587.21 (10428.12)	15849.88 (9701.15)	5757.69 (6271.96)	23726.46 (9817.92)	8276.06 (3272.44)	11164.81 (7547.29)
	All	34350.28 (10832.74)	18244.94 (8350.68)	5544.17 (5918.66)	26153.97 (8461.16)	9008.93 (3278.18)	11456.34 (6745.00)
Rangpur	Small	21488.16 (9101.62)	21884.40 (10369.03)	3427.77 (6884.81)	28783.47 (10131.03)	29961.72 (654.48)	4854.30 (8289.55)
	Medium	22602.07 (10840.90)	23317.68 (10121.64)	4882.18 (9147.85)	31347.66 (9957.69)	8670.38 (401.98)	6398.61 (11624.15)
	Large	21623.87 (10535.90)	23252.19 (9996.33)	4693.23 (9799.04)	31311.07 (9837.24)	8752.44 (564.27)	6338.24 (11729.15)
	All	22010.57 (10245.48)	22938.40 (10059.44)	4458.11 (8799.11)	30989.46 (9879.57)	8724.91 (523.93)	5993.22 (10839.67)
All areas	Small	26331.05 (4745.54)	19013.42 (8226.28)	2292.61 (3709.16)	27372.00(8 203.72)	9216.28 (2464.66)	4435.18 (6711.30)
	Medium	32065.00 (8011.10)	25105.38 (11232.19)	5319.63 (10214.50)	33357.92 (11032.48)	9726.05 (1656.52)	8427.75 (12317.50)
	Large	30302.21 (11476.21)	19574.81 (8449.57)	6206.72 (7315.87)	27688.81 (8658.55)	8957.16 (1981.94)	10120.63 (9429.20)
	All	29995.58 (6910.46)	21749.26 (10070.45)	4536.57 (8020.28)	30003.08 (10011.40)	9370.73 (2050.88)	7522.14 (10284.49)

Figures in the parentheses indicate standard deviations.

Net return above cash cost

Net return above cash cost was the balance between gross output and cash costs. That is, it was the difference between gross output and the cash costs incurred in the production process. Net return (above cash cost) per hectare for boro rice between farm group was same within areas but difference between areas for boro rice (F = 2.62). Duncan's test implied that the net returns from boro rice for Comilla (Tk. 32865.81) and Rangpur (Tk. 30989.46) areas were same but they were significantly higher than Mymensingh (Tk. 26153.97). For aman rice, net returns between farm groups within areas were same (F = 2.32). Medium farmers (Tk. 9726.05) and small farmers (Tk. 9216.28) got the same net returns and these were significantly higher than those of large farmers (Tk. 8957.16) for all areas. Rahman *et al.* (2002) found similar results while studying the returns of HYV boro rice in Bangladesh.

There was no significant difference in the net return of aman rice per hectare between areas. All farmers received the same levels of net return for aman rice per hectare between areas. Farmers of Comilla area received different levels of net return (F = 18.23*) for aus rice. Farmers of Mymensingh area received the highest net return (Tk. 11456.34) for aus rice in comparison with those of Rangpur (Tk. 5993.22) and Comilla (Tk. 5793.52) areas as indicated by Duncan's test. All the three rice crops had significantly different levels of net return as the t-values of net returns between boro & aman, boro & aus, and aman & aus were found to be 3.95**, 4.12** and 3.21**, respectively, which were highly significant. Boro rice producers had highest net return (Tk. 30003.08) followed by aman rice (Tk. 9370.73) and aus rice (Tk. 7522.14) producers for all areas and all farm groups (Table 2).

Benefit-Cost Ratio

Benefit cost ratio was a common measure used in agriculture to evaluate the profitability of farming. It refered to return per monetary unit (Tk) of cost. The benefit cost ratios, i.e. return per monetary unit of cash cost and full cost for different farm sizes were estimated. Table 3 showed benefit-cost ratios for boro, aman and aus rice on full cost and cash cost basis. The benefit-cost ratio (full cost basis) for boro rice showed no variation between farm groups but the benefit-cost ratio (cash cost basis) for boro rice exhibited some variation between farm groups. A multiple comparison test (Duncan's) suggested that there was no variation between benefit-cost ratios (cash cost basis) between small (2.65) and medium farm (2.65) groups but these two had significantly higher benefit-cost ratios than large farm groups. Both benefit-cost ratios (full cost and cash cost basis) for boro rice showed significant variation between areas for all farms since the F-values were found to be 9.12** and 8.18**, respectively. Duncan's test suggested that for boro rice the benefit-cost ratios (full cost basis) were significantly different in each area. Significantly higher benefit-cost ratio (1.90) was produced in Comilla area followed by Mymensingh (1.79) and Rangpur (1.62). On the other hand, benefit-cost ratios (cash cost basis) for Mymensingh (3.20) and Rangpur areas (2.83) were higher than that of Comilla (2.42) were for boro rice for all farm groups.

Table 3. Per hectare Benefit-Cost-Ratio for boro, aman and aus rice

Area	Farm category	BCR (Full cost basis)			BCR (Cash cost basis)		
		Boro	Aman	Aus	Boro	Aman	Aus
Comilla	Small	1.89 (0.40)	1.88 (0.55)	1.34 (0.73)	2.42 (0.81)	1.42 (0.81)	1.28 (0.72)
	Medium	1.90 (0.40)	1.88 (0.54)	1.33 (0.72)	2.35 (0.30)	1.35 (0.30)	1.48 (0.36)
	Large	1.88 (0.45)	1.92 (0.61)	1.38 (0.80)	2.70 (0.12)	1.70 (0.12)	1.46 (0.39)
	All	1.90 (0.40)	1.88 (0.54)	1.34 (0.73)	2.42 (0.61)	1.42 (0.61)	1.30 (0.84)
Mymensingh	Small	1.90 (1.03)	1.75 (0.36)	1.31 (0.29)	3.54 (1.06)	2.54 (1.06)	1.86 (1.04)
	Medium	1.88 (0.61)	1.87 (0.29)	1.13 (0.44)	3.06 (1.11)	2.06 (1.11)	2.68 (1.19)
	Large	1.59 (0.96)	1.67 (0.41)	1.19 (0.49)	3.12 (1.12)	2.12 (1.12)	1.95 (1.31)
	All	1.79 (0.84)	1.78 (0.36)	1.19 (0.43)	3.20 (1.21)	2.20 (1.21)	2.25 (1.40)
Rangpur	Small	1.61 (0.31)	1.97 (0.63)	1.49 (0.77)	3.33 (0.53)	2.33 (0.53)	1.34 (1.15)
	Medium	1.64 (0.33)	1.99 (0.55)	1.47 (0.83)	2.75 (0.61)	1.75 (0.61)	3.00 (1.27)
	Large	1.60 (0.33)	1.99 (0.53)	1.50 (0.86)	2.53 (0.39)	1.53 (0.39)	2.24 (1.01)
	All	1.62 (0.32)	1.98 (0.56)	1.48 (0.82)	2.83 (0.61)	1.83 (0.61)	2.34 (1.11)
All areas	Small	1.64 (0.56)	1.80 (0.43)	1.02 (1.26)	2.65 (0.84)	1.65 (0.84)	1.43 (0.80)
	Medium	1.91 (0.62)	2.05 (0.63)	1.64 (0.85)	3.13 (1.12)	2.13 (1.11)	2.13 (1.68)
	Large	1.80 (0.52)	1.78 (0.34)	1.89 (0.57)	2.65 (0.54)	1.65 (0.54)	2.66 (1.10)
	All	1.77 (0.58)	1.88 (0.50)	1.38 (0.59)	2.81 (0.91)	1.81 (0.91)	1.96 (1.27)

Figures in the parentheses indicate standard deviations.

The benefit-cost ratio (full cost basis) for aman rice showed no significant difference between farm groups (F=0.69) but it showed significant variation between areas (F=5.13**) for all farm groups. A multiple comparison test (Duncan's test) revealed that the benefit-cost ratio (full cost basis) for Comilla area (1.90) was similar to that of Mymensingh area (1.79). These two areas showed significantly higher benefit-cost ratios than Rangpur area (1.41). On the other hand, the benefit-cost ratio (cash cost basis) showed a significant variation between farm groups within each area, confirming that the highest ratio was for the medium group (2.13) for aman rice. But they were significantly similar for large and small group (1.65).

There was no difference on benefit-cost (full cost & cash cost basis) between farm groups within area or between areas for all farmers of aus rice as the F-values were found insignificant at 0.47 and 1.05, respectively for farm groups and 0.001 and 1.11, respectively for areas. The benefit-cost ratios (full cost basis) for boro, aman and aus rice crops in all areas were 1.77, 1.88 and 1.38, respectively, while the benefit-cost ratios (cash cost basis) of these crops were 2.81, 1.81 and 1.96, respectively.

Self sufficiency and food security status of rice in Bangladesh

Bangladesh has made steady progress in the expansion of domestic rice production. Rice production has doubled in last two decades with the use of green revolution technology i.e. high yielding varieties, fertilizer, irrigation and pesticide. Remarkable progress has been made in production during the last ten years. In 1994/95, rice production was 16.83 million metric tons, which increased to 26.19 million metric tons in 2003/04 and further increased to 28.93 million metric tons in 2007-08 with annual compound growth rate of 2.49 percent.

Table 4. Production, import and procurement of rice in million metric tonne

Year	Production	Share in total food grain (%)	Import	Share in total food grain (%)	Food aid	Share in total food grain (%)	Domestic Procurement
1994-95	16.83	95.67	0.814	49.82	0.00	0.00	0.278
1995-96	17.87	95.07	1.140	67.42	0.001	0.13	0.400
1996-97	18.88	99.22	0.016	4.69	0.010	1.62	0.615
1997-98	18.86	97.05	1.085	78.45	0.00	0.00	0.617
1998-99	19.91	84.04	3.008	70.66	0.060	4.86	0.753
1999-2000	23.07	87.36	0.428	34.68	0.005	0.57	0.967
2000-01	25.09	88.04	0.529	49.76	0.033	6.71	1.088
2001-02	24.30	93.25	0.118	9.22	0.009	1.76	1.053
2002-03	25.19	93.74	1.553	52.34	0.00	0.00	0.952
2003-04	26.19	91.59	0.797	31.75	0.004	1.38	0.828
2004-05	25.16	94.97	1.269	41.17	0.027	9.31	0.897
2005-06	26.55	95.56	0.498	21.03	0.034	17.53	0.945
2006-07	27.32	94.39	0.695	29.84	0.025	27.47	1.144
2007-08	28.93	94.07	1.977	61.55	0.082	31.78	0.868

Source: BBS, 2008 and MOF, 2008.

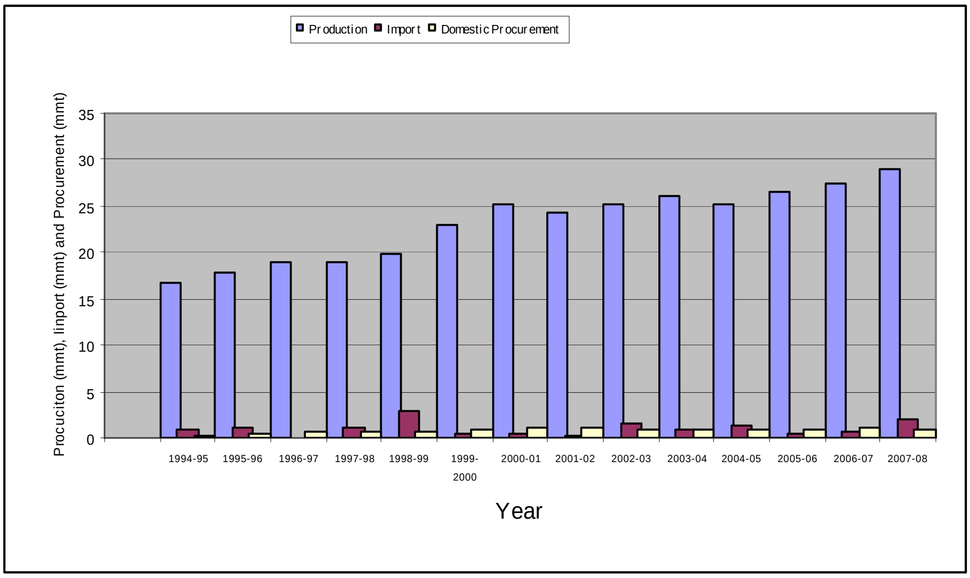

Fig.1 Production, Import and Procurement of rice of Bangladesh

Growth rate of boro, aman and aus rice area was the highest (7.31, 1.92 and -0.90 percent) during 1981-90 and decreased (2.74, -0.39 and -2.04 percent) during 2000-07. Growth rates of boro and aman rice production were 8.53 and 1.82 percent, respectively in 1981-90 and decreased to 6.16 and -1.53 percent, respectively during 2000-07, whereas growth rates of aus rice production was -3.73 percent in 1981-90 and increased slightly to -3.57 percent in 2000-07.

Self Sufficiency Ratio (SSR) is the way of expressing the rice deficiency in the country. The self-sufficiency ratio expresses magnitudes of production in relation to domestic utilization. Based on the official and private food grain production and import figures, the food grain SSR for Bangladesh was gradually increasing. The lowest self-sufficiency rate was found in 1998-99, which could be attributed to the crop damage during the severe flood and natural calamities (Table 4 and Fig. 1).

Food security and self-sufficiency in rice nexus is rather complex for a developing country, like Bangladesh. Although global rice prices are showing upward trends, the current global financial meltdown may impact on the macroeconomic health precariously. Taking these into consideration, Bangladesh should concentrate on agricultural development, especially, self-sufficiency in rice production, mitigation and adapting to climate change.

Due to continuous increasing population pressure and rapid urbanization, the cultivable land is decreasing rapidly. Consequently both the total cropped area and non cropped area have been slowing down. Cropping intensity increased substantially earlier but it remains stagnant at present. The substantial increase in MV rice acreage has contributed to the total increase in the country's overall rice production during last two decades. Bangladesh reached to marginally self sufficient status in rice production after 1999. But sustaining the self sufficiency status would remain as a major challenge. Investment in technological research and improvement of resource management would be the critical issues in accomplishing the desired goal.

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EFFICACY OF IPM BIOPESTICIDE IN CONTROLLING FOOT/COLLAR ROT OF EGGPLANT CAUSED BY *Sclerotium rolfsii*

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Abstract

The effect of IPM biopesticide and *Trichoderma* suspension in reducing foot/collar rot of a susceptible eggplant var. Dhohazari was studied in net house and field condition. In net house experiment, both the *Trichoderma* formulation and *Trichoderma* suspension treatment produced the lowest plant infection compared with inoculated control. But incase of percent plant recovery, *Trichoderma* formulation showed the better performance over *Trichoderma* suspension. In field condition, formulated *Trichoderma* needs 6-9 days of incubation period to act as an antagonist applied before inoculation. However, for complete inhibition of the pathogen 9 days of incubation is required.

Key words: Eggplant, incubation period, *Sclerotium rolfsii*, *Trichoderm*a

Introduction

Foot/collar of eggplant (*Solanum melongena* L.) caused by *Sclerotium rolfsii* is one of the most important and damaging disease. The pathogen attacks the collar zone of the host adjacent to the soil level causing death by disrupturing translocation of food from top to root zone. The disease has become a major constraint in successful cultivation of eggplant mainly due to aggressive nature of the pathogen, its soil borne nature and continuous cropping of eggplant in many areas (Begum *et al.*, 1985). The disease foot/collar rot causes 60-100% death of eggplants (Siddique, 1997). Infestation from seedling to flowering stages may result 100% crop loss. The diseases of plants caused by soil borne pathogens are in general difficult to control. It has, however, been reported from various countries that fungicidal treatment of soil has some effect on the control of *S. rolfsii* and other soil borne pathogens (Fellman *et al*., 1983; Sharma and Verma, 1985). As there are no any effective fungicides for the management of these soil-borne plant pathogens (diseases), the management of these diseases is possible through the use of resistant varieties. However, there is no recognized resistant variety of eggplant against

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foot rot disease till today. The potential of the antagonistic micro-organisms in reducing the intensity of crop damage by the soil-borne plant pathogens has been reported (Roberts *et al*., 1997 and Lewis and Larkin, 1997). Biological control represents a natural and ecological approach for controlling diseases that reduces chemical inputs and their effects. *Trichoderma* spp. gained considerable recognition as biological agent (Papavizas and Lewis, 1985). Several strains of *Trichoderma* spp. have been found to be effective as biocontrol agent of various soil borne plant pathogenic fungi such as; *Fusarium*, *Sclerotium*, *Rhizoctonia,* etc. (Chet and Inbar, 1994). *Trichoderma* produces chemicals called trichodermin which is responsible for its antagonistic properties (Tverdyukov *et al.*, 1994). Thus, *T. harzianum* may ecofriendly be used as a biocontrol agent and the nature will relatively be undisturbed and many beneficial micro-organisms in the soil will be saved. Considering the above facts, the present study was undertaken to determine the efficacy of *Trichoderma* based biopesticide and the incubation period for *Trichoderma* to act as an antagonist against *Sclerotium rolfsii*.

Materials and Methods

Net house experiment

The experiment was conducted in the net house of the Department of Plant Pathology, Bangladesh Agricultural University (BAU), Mymensingh during May to July 2007. The IPM Biopesticide (formulated) and the bioagent *Trichoderma harzianum* CP were collected from IPM laboratory, Bangladesh Agricultural University, Mymensingh. The experiment was conducted following completely randomized design with four replications. Seedlings were raised in tray (40 cm x 30 cm). Tray soil was prepared by mixing soil, sand and well decomposed cowdung in the proportion of 2:1:1 and sterilized with formalin (Dasgupta, 1988). Collar rot susceptible cultivars Dohazari G were used in the study. *Trichoderma* suspension was prepared by using 7 days old pure culture of *Trichoderma harzianum* on Potato Dextrose Agar and distilled water. Thirty gram IPM biopesticide @ 0.6% (w/w) and 200ml *Trichoderma* suspension (5 x 10^6 conidia ml^{-1}) were applied per tray. The virulent isolate of *Sclerotium rolfsii* was isolated from naturally infected eggplant and grown on barely grains were used as inocula. Inoculations were done seven days after antagonist used. Ten gram of barley culture was used per tray. Data were recorded on number of plants infected, number of plants non-infected and number of plants recovered from infection in different ages in different treatments.

Field experiment

The experiment was conducted in the field laboratoty of the Department of Plant Pathology, BAU, Mymensingh during September 2007 to April 2008. Collar rot susceptible cultivars Dohazari G were used in the study and seedlings were raised in tray.

Twelve healthy seedlings of 30 days were transplanted in each plot following randomized complete block design with three replications maintaining plant to plant distance 50 cm and line to line 1 meter. Irrigation and weeding were done as and when necessary. Following the application of biopesticide (20 g plant^{-1}) ten gram barley culture of *S. rolfsii* was applied to each of those plants first immediately after and then at 24 h interval for 14 days. For the determination of the effect of *Trichoderma* based biopesticide data were recorded on number of plants infected, number of plants killed and number of plants recovered from infection. Data collected during experimental period were tabulated and analyzed following statistical package MSTAT.

Result and Discussion

Net house experiment

IPM Biopesticide and the *Trichoderma* suspension treatment produced the lowest plant infection compared to inoculated control both in one month and two month aged seedlings (Fig. 1 and Fig. 2). This was supported by the report of Kashem (2005) who reported that in pot trials soil treated with *Trichoderma harzianum* resulted decreased collar rot by 99.55%. Biswas and Sen (2000) observed that the isolate of *Trichoderma harzianum* reduced disease incidence significantly caused by *S. rolfsii* when deliberated as soil application. Begum *et al.* (1999) and Sariah and Cheng (1999) reported that *Trichoderma* successfully controlled collar rot diseases of lentil. The percent plant recovery was significantly higher in *Trichoderma* formulation treated tray compared to *Trichoderma* suspension treated tray both in one month and two months aged seedlings. No plants were recovered in control trays (Fig. 1 and Fig. 2).

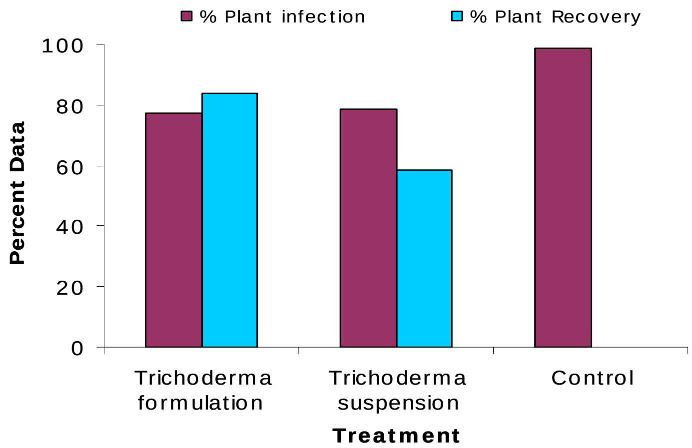

Fig. 1. Effect of biopesticide on percentage of plant infection and plant recovery of one month aged eggplant

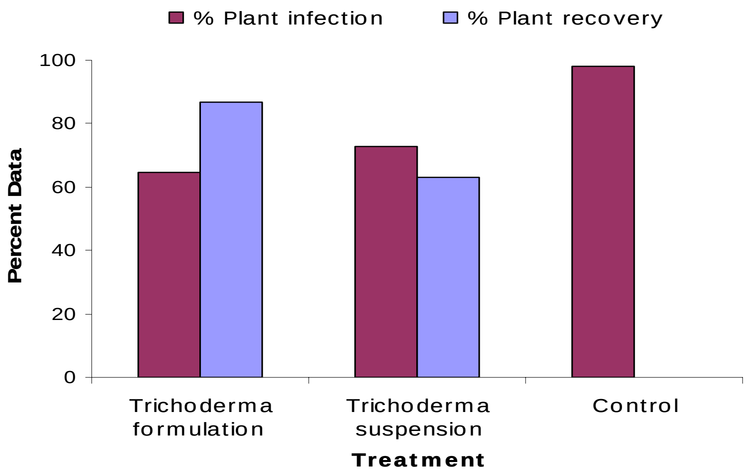

Fig. 2. Effect of biopesticide on percentage of plant infection and plant recovery of two month aged eggplant

This finding was in agreement with Bhuiya (2006) who found that soil treated with formulated *T. harzianum* showed regeneration and plants shot new leaves and shoots. Kashem (2005) reported that the maximum plant stand was recorded in soil which was treated with *T. harzianum*. Sariah and Cheng (1999) and Faruk *et al.* (2002) reported that 100% plants were survived in the *Trichoderma* treated cultivation slabs.

Field experiment

Trichoderma needs some incubation period to act as an antagonist. There was no significant effect of formulated *Trichoderma* on *S. rolfsii* upto 6 days of inoculation and control trays (Table 1). Afterwards, percent infection decreased gradually and the lowest number of infected plant was found in plots inoculated with *S. rolfsii* after 13 days of treatment with formulated *Trichoderma*. On the other hand, infected plants started to recover in plots inoculated with *S. rolfsii* after 4 days of treatment with formulated *Trichoderma*.

The per cent recovered plants increased sharply with the increase of incubation period of formulated *Trichoderma* and after 9 days of incubation, 100 percent plants were recovered. No plant was recovered in control plots. Per cent plant infection and days after treatment were strongly correlated (r = -0.9299) and the relationship was negative and linear (y = -6.4088 x +118.56) (Table 1 and Fig. 3). Percent plant recovery and days after treatment were also strongly correlated (r = 0.9299) but the relationship was positive and linear (y = 9.4973 x -8.0937) (Table 1 and Fig. 3). These findings were supported by Prasad *et al*. (2003) who showed that soil application of *T. harzianum* and *T. viride* one

Table 1. Determination of incubation period of *Trichoderma* to act as antagonist against *Sclerotium rolfsii*

Days after treatment with biopesticide	Plant infection	Plant recovery (%)
0	100.00 a	00.00 d
1	100.00 a	00.00 d
2	100.00 a	00.00 d
3	100.00 a	00.00 d
4	100.00 a	8.03 cd
5	100.00 a	22.22 c
6	94.44 a	65.56 b
7	88.87 ab	86.67 a
8	77.78 bc	93.33 a
9	72.22 c	100.00 a
10	55.56 d	100.00 a
11	38.89 e	100.00 a
12	33.33 e	100.00 a
13	22.22 e	100.00 a
14	22.22 e	100.00 a
Control	100.00 a	00.00d
$LSD_{0.01}$	15.53	14.41

Figure in a column having common letter (s) do not differ significantly at 5% level of significance

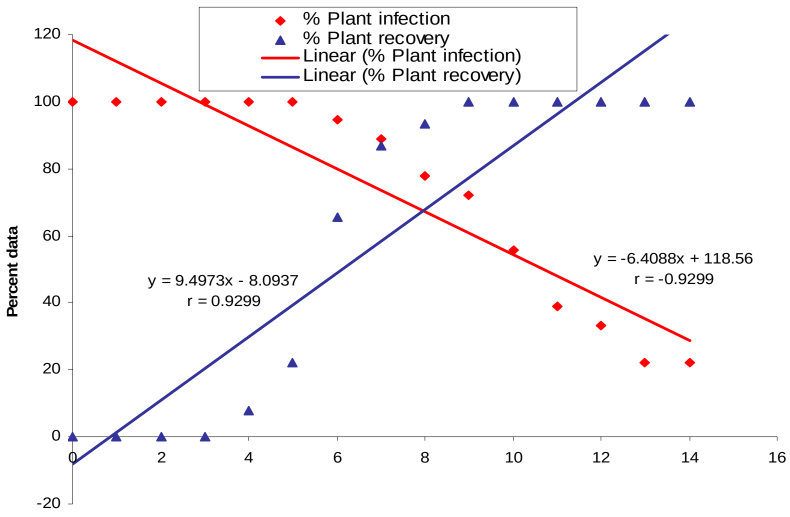

Fig. 3 Effect of length of time after treatment with biopesticide on the percent infection and percent recovery in eggplant var. Dohazari G inoculated with *S. rolfsii*

week before sowing was more effective in reducing root rot. Hassan *et al*. (2002) expressed that root rot and wilt caused by *Fusarium sp*. was lowest when *T. harzianum* was applied 5 days before soil infestation. Cuevas *et al*. (2001) found that control of pathogenic activity of *Sclerotium rolfsii* as shown by per cent seed germination and percent survival of seedlings in pots was most effective where *Trichoderma* was given 2 weeks and 1 week before seed sowing.

Conclusion

From the study results, it could be concluded that *Trichoderma* based biopesticide could be used as a protective measure against foot/collar rot diseases for susceptible varieties of eggplant.

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ADOPTION OF DIFFERENT VARIETIES OF BORO RICE IN SADAR UPAZILA OF MYMENSINGH DISTRICT

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Abstract

The study examined the variety-wise adoption of different boro rice by the farmers and identified the reasons for cultivating each variety in sadar upazila of Mymensingh district. Data were collected from 189 farmers following three-stage random sampling technique using interview schedule during April to May 2009. The results revealed that a total of 45.08 per cent harvest areas were covered by BRRI dhan28 followed by 17.59 per cent areas by hybrid rice. Other improved boro rice varieties like BRRI dhan26, BRRI dhan29, Binadhan-5, Iratom-24 and pajam were cultivated in 13.40, 10.49, 3.57, 1.56 and 1.56 per cent areas, respectively, while local cultivars of boro rice were cultivated in 8.31 per cent areas. Grain quality and market price of BRRI dhan26, BRRI dhan28, BRRI dhan29 and Binadhan-5 were reported to be medium fine and good taste. The most important reasons for cultivating BRRI dhan28 as opined by majority of farmers were short crop duration with good quality of rice and having acceptable yield. On the other hand, BRRI dhan26 and BRRI dhan29 were preferred by some farmers due to low water requirement, higher yield and better cooking quality despite their long crop duration. The reasons for cultivating Binadhan-5 by some other farmers were also due to low water requirement, higher yield, better cooking quality and easy to thresh that help getting more straw. On the other hand, hybrid rice was cultivated due to higher yield with moderate crop duration but feeding quality was not so good. Pajam was preferred due to higher market price and with acceptable yield. Iratom-24 was cultivated for its higher yield and moderate crop duration. Local varieties of boro rice were cultivated due to ecological suitability in some areas.

Key words: Adoption, boro rice, yield

Introduction

Bangladesh is a country of rice-based agriculture. Rice in Bangladesh is so to speak, the lifeblood of the people. The land and climate of Bangladesh offer a highly congenial environment of the growth of rice plants. Rice is the staple food of Bangladesh. It accounts for about 60 per cent of the total food intake per day per family (Halim, 1985). Out of the total cropped area, almost three-forth (74 per cent) is covered by rice alone (BBS, 2010). Adoption of the modern varieties (MV) of rice coupled with an entirely new technology

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and strategy has imparted a new dynamism to Bangladesh Agriculture. The MV has played a prominent role in boosting the crop yields and it is considered as a catalytic agent to bring green revolution in Bangladesh. Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed so many modern rice varieties, which have been disseminated to the farmers for adoption. As a result, the average yield of rice has increased remarkably. However, the increase in yield could have been much more since the MVs have a potential yield up to 6.5 t/ha (BINA, 2011, BRRI, 2011). The potential yield of rice has not been attained possibly because of low area coverage under the highest yielding variety and non-adoption of the entire package of practices recommended by the scientists.

There are three rice-growing seasons in Bangladesh as; Aus, Aman and Boro. Of these, Aus produces 8.09 per cent, Aman produces 46.56 per cent and Boro produces 45.35 per cent of the total rice. Coverage of modern varieties (MV) has been to an extent of 66.6, 66 and 98 per cent in Aus, Aman and Boro season, respectively (BBS, 2010). In case of Aus, there is little scope to increase coverage of MV rice due to scarcity of water. In Boro season, adoption of MV rice is quite satisfactory. But in Aman season, MV adoption is still far below its potentiality. Apart from these, there are many evidences that rice production packages are not followed properly by the farmers (Haider *et al.,* 2001; Ray *et al.,* 1995; Kashem and Islam, 1990; Rahman, 1986). In spite of all sorts of efforts, adoption of MV practices has not been made in full swing. Adoption is a decision to make full use of an innovation as the best course of action available. Adoption of any technology depends on the farmers' preference and decision of adoption or rejection. Farmers' decisions are generally based on some desirable attributes of innovation or technology. These attributes are relative advantages, compatibility, complexity, trial ability and observe ability (Ray, 1998). In case of rice production technologies, relative advantages and compatibility (suitability) are the most important attributes of the technologies for farmers' decision in Bangladesh condition. Farmers` generally consider the yield, duration, market price, quality of the rice and some other good attributes as the relative advantages. When a new crop variety suits the agro-climatic condition of the farmers, this variety is said to be compatible (Ray, 1998). These two attributes such as relative advantage and suitability associated with some other reasons determine the adoption or rejection of modern varieties of production in most cases. There are some studies on adoption of improved practices of T. Aman rice (Hassanulla, 1990; Kashem and Islam, 1990; Rahman, 1986). But there are very few studies in relation to variety-wise adoption of different modern and local varieties with clear understanding about the framers' reasons for cultivation of specific varieties in boro season. These facts call for an empirical study on the variety–wise adoption of different improved varieties of boro rice cultivation. This study would help to formulate an appropriate and effective programme for technology transfer. Therefore, the present study was designed to-

i) Assess the variety-wise adoption of boro rice,

ii) Identify the farmers` reasons for cultivation of different modern varieties of boro rice and

iii) Formulate some policy guidelines for extensive adoption of MV of boro rice cultivation.

Materials and Methods

Sadar upazila under Mymensingh district was selected previously as the location of the study. All the farm family heads (Except landless) of 48 blocks under 12 unions of sadar upazila constituted the population of the study. Data were collected from a sample following three stage-sampling techniques. At the first stage of sampling, 50 per cent of unions from the total unions i.e. out of 12 unions, 6 were selected using random numbers. At the second stage, two blocks from each of the six unions totaling 12 blocks were selected randomly. Selected blocks were Charishwardia and Charkalibari from Charishwardia union, Shikta and Charshikta from Shikta union, Khagdahar and Kismat from Khagdahor union, Austodhar and Mahishmari from Austodhar union, Kustiapara and Charkhabpur from Bororchar and Sutiakhali and Narayanpur from Bhabokhali union. At the third stage, the number of rice growers in each block was selected. A total of 180 farmers were selected from 12 blocks taking 15 farmers from each block. Data were collected through personal interview using interview schedule during April to May 2009. Adoption of different rice varieties and farmers` reasons for cultivating modern varieties of boro rice were measured using open ended questionnaire. The farmers were asked to mention the variety-wise area of boro rice cultivation. The level of variety adoption was measured by modified Adoption Quotient (AQ) originally developed by Chattopadhyay (1963) and simplified by Ray (1998). The farmers were also asked to indicate the reasons for cultivating each of the varieties. Answers of the farmers were documented categorically. All the reasons were computed and weighted based on coverage of the total harvest area and number of respondent indicating any problem were expressed in per centage.

Results and Discussion

Personal and socio-economic characteristics of the respondents, adoption of different varieties and reasons for adopting different boro rice varieties by the respondents were presented below:

Personal and socio-economic characteristics of the respondents

Age of the farmers of the study area ranged from 17 to 77 years with an average of 46.30 years, a standard deviation of 13.28 and the standard error of 0.96. About half of the farmers belonged to old aged compared to 37.6 per cent middle and 12.7 per cent young aged (Table 1). The education scores of the farmers ranged from 0 to 18 per cent with an average of 6.25 per cent, a standard deviation of 13.28 and the standard error of 0.30. The farmers, according to their education scores were classified into four categories namely; illiterate, primary, secondary and higher secondary level. About half (46.6 per cent) of the farmers had secondary education compared to 23.3 per cent having primary education, 20.1 per cent illiterate and 10.1 per cent had higher secondary level of education. Farm size of the respondents ranged from 0.03 to 16.60 ha with an average of 2.03 ha, a standard deviation of 2.24 and the standard error of 0.16. The farmers based on their farm size were classified into four categories namely; marginal, small, medium and large farm level. About half (45.4 per cent) of the farmers had medium farm compared to 31.7 per cent having small farm, 19.0 per cent large and 4.2 per cent had marginal farm. The family income of the respondents ranged from Tk 20 to Tk 164 thousands with an average of Tk 285.5 thousands, a standard deviation of 270 and standard error of 19.70. Based on income level, the farmers were classified into three categories namely; low, medium and high income level. Social participation of the respondents was from 0 to 2.22 per cent with an average of 2.22 per cent. Majority (66.1%) had under small credit received category and 39.9% of the farmers having high level of credit received while there was no farmers under medium credit received category.

Adoption of Different Modern Varieties of Boro Rice

Adoption of different modern verities of rice was determined and the findings were presented in Table 2.

Data presented in Table 2 indicated that about half of the boro rice area was covered by BRRI dhan28 (45.08 per cent) followed by Hybrid rice (17.59 per cent), BRRI dhan26 (13.40 per cent), BRRI dhan29 (10.49 per cent), Binadhan-5 (3.57), local cultivars (8.31 per cent) and Iratom-24 (1.56 per cent). The above findings indicated that the modern variety BRRI dhan28 was widely adopted by the farmers as perceived it more suitable for cultivation in this locality.

Farmers' Reasons for Cultivating Mordern Varieties of Boro Rice

There were many reasons for cultivating the modern varieties of boro rice. The opinions of the farmers in this regard were presented in Table 3.

Table 1. Personal and socio-economic traits of farmers

Personal traits	Category	No.	% Farmer	Range	Mean	SD	SE
Age (year)	Young (≤30)	24	12.7	17-77	46.30	13.28	0.96
	Middle aged(31-45)	71	37.6				
	Old (>45)	94	49.7				
Education (year of schooling)	Illiterate (0)	38	20.1	0-18	6.25	13.28	0.30
	Primary (1-5)	44	23.3				
	Secondary (6-10)	88	46.6				
	Higher secondary (>10)	19	10.1				
Family Farm size (hectare)	Marginal (0.021-0.2)	8	4.2	0.03-16.6	2.03	2.24	0.16
	Small (0.21-1.0)	66	31.7				
	Medium (1.1-3.0)	85	45.4				
	Large (>3.0)	36	19.0				
Annual family income ('000'Tk.)	Low (≤50)	7	3.7	37.0-1639.8	285.5	270.4	19.70
	Medium (50.1-100)	32	16.9				
	High (>100)	150	79.4				
Social participation	Non (0)	87	46.0	0-2.22	2.22	2.73	0.19
	Low (1-5)	78	41.3				
	Medium (6-10)	22	11.6				
	High (>10)	2	1.1				
Credit received ('000' Taka.)	Small (≤10)	125	66.1	0-12.0	2.22	2.73	0.19
	Medium (11-20)	0	0				
	High (>20)	64	39.9				

Table 2. Adoption of different modern varieties of boro rice

Variety	% Harvest area	Farmers		Rank
		No.	%	
BRRI dhan28	45.08	137	71.40	1
BRRI dhan29	10.49	53	28.60	3
BRRI dhan26	13.40	46	24.30	4
Binadhan-5	3.57	23	12.10	5
Hybrid	17.59	65	34.30	2
Local	8.31	23	12.10	5
Iratom-24	1.56	7	3.70	6

Data presented in Table 3 indicated that majority (73.02 per cent) of the farmers cultivated BRRI dhan28 followed by followed by Hybrid rice (42.86 per cent), BRRI dhan29 (32.80 per cent), BRRI dhan26 (25.40 per cent), Binadhan-5 (14.81), local variety (11.64 per cent), Iratom-24 (3.17 per cent) and Pajam (2.65 per cent). The most important reason for cultivating any modern variety of boro rice by farmers was short duration associated with fine rice, good taste and higher market price. Attributes of fine rice, good taste and higher market price were common in BRRI dhan28, BRRI dhan26, BRRI dhan29 and Binadhan-5. Binadhan-5 has a unique positive attribute of easy to thresh that facilitate getting more straw for animal fodder. But an extra quality of short crop duration with acceptable moderate grain yield made BRRI dhan28 more popular among the farming community. On the other hand, one negative attribute of BRRI dhan28 was relatively lower grain yield compared to other long duration rice varieties. Farmers viewed long crop duration as restricting characteristics of BRRI dhan26, BRRI dhan29 and Binadhan-5. Coarse grain size of Iratom-24 was marked as the negative quality for adoption of this variety in this locality. Similarly, higher grain yield attracted some farmers for cultivating hybrid rice and coarse grain size and lower market price limited its adoption as well.

Table 3. Reasons for adopting boro rice varieties by the farmers in sadar upazila of Mymensingh district

Adopted varieties	No. of farmers	%	Farmers' Comments	
			Positive	Negative
BRRI dhan28	138	73.02	Short duration, fine rice, good taste and higher market price	Relatively lower yield compared to long duration rice varieties
BRRI dhan26	48	25.40	Good taste, higher yield, needs low water and higher market price	Boiled rice is very soft which is not comfortable for eating
BRRI dhan29	62	32.80	Good taste, higher yield and higher market price	Long duration and very hard to thresh which need higher cost and machine threshing reduce the straw quality
Binadhan-5	28	14.81	Good taste, higher yield, very easy to thresh that make more straw, lower fertilizer requirement, higher market price and it gives higher cleaned rice	Some time this variety lodges when high doses of urea are applied
Hybrid	81	42.86	Yield relatively higher	High cost of production and lower market price
Local	22	11.64	Suitable for production in low land	Grain is comparatively big size
Pajam	5	2.65	Fine rice and higher market price	Yield is relatively low
Iratom-24	6	3.17	Higher yield and moderate duration	Grain is comparatively big size

Conclusion

Majority of the farmers were cultivating BRRI dhan28 for its short crop duration, fine grain, good taste, better market price and moderate grain yield. Other modern varieties like BRRI dhan29, BRRI dhan26 and Binadhan-5 had limited adoption due to longer crop duration, despite these producing higher yields with other similar qualities. Coarse grain size, long crop duration, lower feeding quality and lower market price were the restricting factors for the adoption of any rice variety. It was also observed that higher adoption of BRRI dhan28 had been reducing the total rice production of the country. Nevertheless, farmers were cultivating this variety to get early harvest and avoiding risk. Based on the above findings, the following recommendations were put forward for wider adoption of the high yielding boro rice varieties and increasing rice production:

1. Short duration and high yielding rice varieties need to be developed by the research institutes to meet the farmers demand and boost up total rice production.
2. Demonstration programe of the suitable high yielding varieties like BRRI dhan29 and Binadhan-5 should be extended for the better understanding about the techniques of risk aberration and benefit of these varieties and motivate farmers to follow recommended techniques through field days and farmers' training.

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Bangladesh Journal of Nuclear Agriculture is published by the Bangladesh Institute of Nuclear Agriculture. It is a yearly journal and one issue will be published in each year in the month of January. The journal is intended for publishing original research contributions and a limited number of review articles commissioned by the editors concerning all aspects of peaceful uses of atomic energy in agricultural research. The aspects of agricultural research will include broad fields of Crop Improvement, Soil-Plant Relations, Crop Protection, Irrigation & Water Management, Crop Husbandry, Animal Husbandry, Fisheries and Veterinary Science. It will be concerned also with the technical aspects of agricultural research.

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8. Contributions should be prepared in the usually accepted from with an Introduction, Materials and Methods, Results and Discussion. Acknowledgements, if any and References. An Abstract not exceeding 200 words should immediately proceed the Introduction. It should contain in brief objectives, the materials and methods used and the main results obtained. The presentation of short communication should be continuous and paragraphed i.e. A short communication paper should have an abstract containing the gist of the paper and should not exceed 50 words.

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