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IMPROVING YIELD OF SALT TOLERANT RICE VARIETIES THROUGH SILICON APPLICATION

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Abstract

Climate change creates hazards like cyclone, sea level rise, and storm surge have been increasing the salinityintrusion problem in many folds of Bangladesh. High level of the salinity affectedin Rabi season therefore, current field experiment was carried out at saline prone area,Sodor, Satkhira under natural salinity condition during Rabi season 2017-2018. The experiment was carried out with two varieties namely, Binadhan-10, BRRIdhan67 and four levels of silicon with control S_0: 0 kg ha^{-1}, S_1: 5 kg ha^{-1}, S_2: 10 kg ha^{-1} and S_3: 15 kg ha^{-1}. The experiment was laid out in a split plot design with three replications. The recommended fertilizer doses applied for the experiment were 80 kg N ha^{-1}, 15 kg P ha^{-1}, 50 kg K ha^{-1} and 20 kg S ha^{-1} and silicon as basal dose. Application of silicon had significant effect on plant height, number of effective tiller m^{-2}, length of panicle, total number of spikelets panicle^{-1}, thousand grain weights, number of filled spikelets panicle^{-1}, grain yield and straw yield.It seems that the crop responded to the application of silicon @ 5-15 kg Si ha^{-1} and best dose was reported @ 15 kg ha^{-1} silicon followed by 10 kg ha^{-1}. Results suggest that an application of silicon along with N, P, K, S, Zn, might be necessary to ensure satisfactory yield of rice in saline prone area under natural salinity condition.

Key words: Salinity, Silicon, Rice yield

Introduction

Silicon is the second most available element in soil despite its recognition as essential element for plant growth. It plays an important role in controlling both abiotic and biotic stresses in plant species (Ma, 2004) and as a nutrient to the rice plant (Takahashi, 1968).Silica deposition in the plant leaf decreased transpiration and therefore decreased salt accumulation (Matohet *al*., 1986). Ahmad et *al*. (1992) suggested that silicon complexes sodium in the root,therefore decreasing sodium transport to the shoot. Bangladesh is a densely populated agriculture based small country. She has to feed nearly 160 million mouths from an area of 8 million ha of cultivable land (BBS, 2018). Climate change effect in a recentwarming of 4^{0}C temperature could occur as early as 2060s which would lead a sea level rise of 0.5 to 1 m or more (World Bank, 2013). Sea level rise and salinity interruption are likely to be intensified in future affecting crop production seriously in the low-lying coastal area of Bangladesh. More than 80 per cent of the total area of the Khulna, Bagerhat and Satkhira districts are already affected by different magnitudes of soil salinity of which about 35 per cent is in the grip of strong salinity (Mainuddin*et al*., 2011). Some report has been observed about the effect of salinity level on growth and yield of rice in saline prone area (Yasmine*et al.,* 2011).

The salinity situation in the coastal area of Bangladesh is going to worsen in the future. About 53% of the coastal areas are affected by salinity. Again, the coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country (Karim and Iqbal, 2001). Agricultural land use in these areas is very poor, which is much lower than country's average cropping intensity. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. The factors which contribute significantly to the development of saline soil are, tidal flooding during wet season (June-October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November-May). The severity of salinity problem in Bangladesh increases with the desiccation of the soil.It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Soil reaction values (pH) in coastal regions range from 6.0-8.4. The organic matter content of the soils is also pretty low (1.0-1.5%). Nutrient deficiencies of N and P are quite dominant in saline soils. Micronutrients, such as Cu and Zn are widespread (SRDI, 2003). During the wet monsoon the severity of salt injury is reduced due to dilution of the salt in the root-zone of the standing crop. The dominant crop grown in the saline areas is local transplanted aman rice crop with low yields. The cropping patterns followed in the coastal areas are mainly Fallow-Fallow-Transplanted aman rice. Salinity problem received very little attention in

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the past. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of crops. Thus is necessary to have an appraisal of the present state of land areas affected by salinity.

Increasing level of salinity in the country is posing serious threatening catastrophe for crop production. Salinity is a year round problem in the coastal agriculture; it varies over the year with the peak salinity occurring during December to April (Fig. 1), and the least during July to September. Therefore, boro rice and other Rabi crops are mostly affected in the coastal area due to salinity stress. For increased crop production in the salinity affected coastal area of Bangladesh selection of a crop species/cultivar is very vital, since significant crop interspecies and inter-varietal variation for salinity tolerance exists. For rice cultivation farmers use some landraces of rice endemic to the coastal region whose yield potentiality is very low compared to that of HYVs of rice. The productivity of coastal area is very low compared to other parts of the country. Very recently Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed salinity tolerant rice cultivars BRRI dhan47, BRRI dhan61, BRRI dhan67, Binadhan-8 and Binadhan-10, respectively, for cultivation during boro season. In addition to the development of salt tolerant cultivars, better understanding of nutritional disorders in the context of plant nutrient uptake and physiological as well as biochemical mechanisms of slat tolerance in rice plants may suggest some strategies for plant breeders and growers for developing salinity tolerant varieties and management practices for cultivation in saline areas. Therefore, the present experiment application of Silicon in context of uptake nutrientas agronomic management practices through which salinity level of a soil can be lowered and/or the stress effects on crops can be mitigatedfor the amelioration of salinity stress effect is the key for improving crop productivity in the salinity affected coastal area of Bangladesh.

Materials and Methods

A field experiment was conducted at saline prone area, Suparishata, Sodor, Sathkira under natural salinity condition during in 2017-18, was carried out with two varieties namely, Binadhan-10(V_1), BRRIdhan67(V_2) and four levels of silicon with control S_0: 0 kg ha^{-1}, S_1: 5 kg ha^{-1}, S_2: 10 kg ha^{-1} and S_3: 15 kg ha^{-1}. The experiment was laid out in a split plot design with three replications. The unit plot size was 3m x 4m. The treatments were randomly distributed to the plots within a block. The bunds around individual plots were sufficiently strong to control water movement between the plots. A drain of 1meter wide provided for watering around the whole experimental plot and between the blocks.

Seedlings were raised in well prepared wet seed bed at the sub-station Satkhira farms. Before sowing, seeds were immersed in water for 24 hours and then they were taken out and kept in jute sacks in dark condition for 48 hours. Seedling nurseries for each variety were prepared by pudding the soil. The sprouted seeds were sown on a well prepared wet nursery bed in 1 January, 2018. No manuring and fertilization was done but water and pest management practices were followed in order to raise healthy seedlings.

The land preparation was started one month prior to transplant of the seedlings. The land was thoroughly prepared with the help of a power tiller. Subsequently the land was sufficiently irrigated and ploughed and cross ploughed three times with country plough followed by laddering to have a good tilth. All kinds of stubble and residues of previous crop were removed from the field. After uniform leveling, the experimental plots were laid out according to the requirement of the treatment.

The plots of Boro rice were fertilized with N, P, K, S, Zn at the recommended by the rate of respectively according to the fertilizer recommendation guide of BARC (2012). The whole amount at triple super phosphate, muriatic of potash silicon, gypsum and zinc 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 21 and 45 DAT. The seed bed was wet by application of water both in the morning and evening on the previous day before uprooting the seedling. Thirty days old seedlings were uprooted carefully from the seedling nursery for transplanting in the experimental plots. Only selected healthy seedlings were translated in the experimental plots in 1 February 2018 in 20cm apart line maintaining a distance of 15cm from hill to hill with three seedlings hill^{-1} proper care was taken during the growing period of the crop.

Intercultural operating was done in order to ensure and to maintain the normal growth of the plant as and when needed. After one week of transplanting dead seedling were replaced carefully by transplanting fresh seedlings from the same source. The experiment plots were infested with some common weeds which were removed twice by hand weeding. After transplanting six irrigations were needed to maintain 5-6 cm standing water in each plot. Finally, the field was drained out 7 days before harvest. Observations were regularly made and the field looked nice with normal green plants.

The crops were harvested on 27 April, 2018 with sickle at full maturity. The maturity of crops was determined when some 70% of the seeds became attain their character's color. Grain and straw yields plot were recorded after threshing by a pedal thresher winnowing and drying in the sun properly including the grains and straws of the sample plants. The weight of grains was adjusted to 12% moisture content. Grain and straw yield were them converted to tha^{-1}. From the 10 randomly harvested hills, the following data were recorded, plant height, number of total tillers hill^{-1}, number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1}, number of grain panicle^{-1}, number of unfilled spikelet's panicle^{-1},1000 grain weight, Grain yield (tha^{-1}), Straw yield (tha^{-1}) Biological yield (tha^{-1}), harvest index (%).

Data recorded for different parameters were subjected to analysis of variance (ANOVA) technique(Gomez and Gomez, 1984) and the mean differences were adjudged with Duncan's Multiple Range Test (DMRT) using the statistical computer package, MSTAT-C (Russell, 1968).

Result and Discussion

Crop yield and silicon fertilization

Application of silicon significantly increased plant height, total tillers hill^{-1}, effective tillers hill^{-1}, panicle length, filled grain panicle^{-1},1000 grain weight and yield (Table 1).Silicon doses both 10 and 15 kg ha^{-1} was responded positively for yield characteristics. Minimum plant height (96 cm) was noted for control treatment and maximum of that (101 cm) was obtained for 15 kg ha^{-1}silicon application. The most plant height (104.3 cm) had observed at interaction of 15 kg ha^{-1} silicon application in BRRI dhan67 and the least plant height (91.9 cm) was obtained at interaction of control treatment in Binadhan -10. Total tiller number hill^{-1}found highest @ 10 kg ha^{-1}but in interaction highest number of tillers was observed @ 15 kg ha^{-1} silicon application in BRRI dhan67and the leastwas obtained at interaction of control treatment in Binadhan-10. The most effective tiller number hill^{-1}(13.1 panicles) was shown with 15 kgha^{-1} silicon and the least number of effective tiller hill^{-1} (10 panicles) was obtained in control treatment. The most effective tiller number hill^{-1} (13.5 panicles) was observed at interaction of 15 kg ha^{-1}silicon application in BRRI dhan67 least number of effective tiller hill^{-1} was obtained at interaction of control treatment in Binadhan10 (9.2 panicle). Maximum panicle length (26.1 cm) was observed with application of silicon 15 kg ha^{-1} and minimum panicle length (23.1 cm) was obtained with control treatment. The most panicle length (26.6 cm) was observed at interaction of 15 kg ha^{-1}silicon application in Binadhan10 and the least panicle length (22.5 cm) was obtained at interaction of control treatment in BRRI dhan67. The maximum filled spikelet percentage panicle^{-1} had obtained with application of 15 kg silicon ha^{-1}(110.3 %), and the least filled spikelet percentage 90.03 %) was observed with application of 0 kg silicon ha^{-1}. The highest filled spikelet percentage per panicle had shown under interaction of 15 kg silicon ha^{-1} for var. BRRI dhan67 and the least filled spikelet percentage (90.3%) had obtained at interaction 0 kg silicon ha^{-1} treatment in Binadhan10. The maximum unfilled spikelets per panicle (18.6) had obtained with application of 0 kg silicon ha^{-1} and the least spikelet panicle^{-1} (118) was observed with 15 kg silicon ha^{-1}. The highest unfilled spikelet per panicle (19) had shown under interaction with application of 0 kg silicon ha^{-1} in BRRI dhan67 and the least unfilled spikelet had obtained at interaction with 0 kg silicon ha^{-1} in BRRI dhan67. The beneficial effect of Silicon along with gypsum has been reported on the growth of rice by Khattak*et al.*,(2007). Gong *et al.*, (2003) observed that silicon increased plant height, leaf area and dry mass of rice even under drought. Similarly, Singh *et al.*, (2006) suggested that the increased dry matter and yield in rice. The indirect effects of silicon also cause increase in growth and yield in rice.

There are a statistically significant different in thousand grain weight, grain yield, between rice genotypes (Table 1). The maximum 1000-seed weight(24.7 g) was found with the application of 10 kg silicon ha^{-1} and least 1000-seed wt.(22.8 g) with control treatments. The maximum 1000-seed weight(26 g) interaction with application of 10 kg silicon ha^{-1} for Binadhan-10 followed by15 kg silicon ha^{-1}and least 1000-seed wt. (21.5 g) had obtained at interaction with application of 0 kg silicon ha^{-1} in BRRI dhan67 here is a statistically significant different in grain yield between rice genotypes. The maximum grain yield 7.59tha^{-1} was recorded with application of 15 kg silicon ha^{-1} and minimum grain yield 5.66 tha^{-1} was recorded with control treatment. The minimum grain yield 7.59tha^{-1} was obtained at interaction of 15kg silicon ha^{-1} application in Binadhan10 and the least grain yield 5.56tha^{-1} was obtained at interaction of control treatment in Binadhan10. The maximum straw yield 8.21 t ha^{-1} was recorded with 15 kg silicon ha^{-1} and minimum straw yield 6.58 t ha^{-1}was recorded with control treatment. The maximum straw yield 8.24tha^{-1} was obtained at interaction of 15 kg silicon ha^{-1}application and Binadhan-10 and the minimum straw yield 6.51tha^{-1} was obtained at interaction of 0 kg silicon ha^{-1} and var. BRRI dhan67.In the present study the Silicon levels of 10 and 15 kg/ha had been found positive effects on growth and yield in rice crop.In case of 1000-seed weight and grain yield silicon dose both 10 and 15 kg/ha performed better.

Table 1.Effect of variety and silicon doses and their interaction on grain yield and yield attributes of Boro rice

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Variety									
Binadhan-10 (V_1)	94.7 b	11.8^{ns}	10.8b	25.1a	98.1^{ns}	12.5^{ns}	25.2a	6.51a	7.61a
BRRI dhan67 (V_2)	102.4 a	12.9	12.1a	24.1b	102.2	11.5	22.4b	6.10b	7.37b
Silicon rate									
0 kg silicon ha^{-1} (S_0)	96d	10.9d	10d	23.1d	90.3d	18.6a	22.8d	5.66d	6.58d
5 kg silicon ha^{-1}(S_1)	97.7c	11.9c	10.9c	24.2c	96.7c	14.0b	23.4c	6.21c	7.33c
10 kg silicon ha^{-1} (S_2)	99.5b	13.9a	11.9b	25.0b	103.3b	10.6c	24.7a	6.76b	7.63b
15 kg silicon ha^{-1} (S_3)	101a	12.9b	13.1a	26.1a	110.3a	6.7d	24.2b	7.51a	8.21a
Variety×Silicon rate									
V_1S_0	91.9d	10.3e	9.20g	23.6c	90.3d	18.3a	24.1c	5.56d	6.62d
V_1S_1	93.6cd	11.3d	10.0fg	24.7bc	94.8cd	13.3b	24.9b	6.19c	7.45c
V_1S_2	95.7cd	12.3c	11.2de	25.7ab	100.6bc	11.0c	25.7a	6.73b	7.71bc
V_1S_3	97.7bc	13.4b	12.7ab	26.6a	106.6ab	7.4de	26.0a	7.59a	8.24a
V_2S_0	100.2ab	11.4d	10.8ef	22.5d	90.3d	19.0a	21.5e	5.77d	6.53d
V_2S_1	101.7ab	12.4c	11.7cd	23.8c	98.6bcd	14.6b	22.0e	6.23c	7.22c
V_2S_2	103.3a	13.5b	12.5bc	24.0c	106.0ab	10.2cd	22.8d	6.8b	7.55c
V_2S_3	104.3a	14.5a	13.5a	25.6ab	114.0a	6.1e	23.4cd	7.35a	8.18ab

In a column, values with same letter (s) for individual location/ combined means do not differ -significantly at 5% level

It has been found by various workers that silicon has many positive effects on the growth and yield as well as physiology and metabolism of different crops. Ma & Takahashi (1990) concluded that there is a high phosphate uptake in rice with silicon application which directly correlates the increased growth and yield. Mukkram*et al*., (2006)also found that silicon increased growth and yield due to decreased Na+ uptake in rice under salt stress. Since germination remains un-affected even under usual stress conditions because the seed itself has enough nutrients to germinate. However, it has been found that the initial vigor produced in seeds lasts to the later stages of plant growth thus a remarkable increase in the yield of crop is evident (Rashid *et al*., 2000). The findings of this study showed that when Silicic acid was applied at 0.25-050% level as fertilizer, the rate of germination was increased. While if its levels exceeded the limits it was found harmful resultantly reduced the germination rate and also affected the total crop stand as well as yield. The effects of different levels of Silicon in the form of Silicic acid have been investigated by many investigators. Singh *et al.*, (2006) found that the 180 kg ha^{-1} of Silicon increased nitrogen and phosphate levels in the grain and straw of rice. This suggests that silicon in lesser amounts can be beneficial in increasing grain yield and growth of cereal crops.

In saline condition, excessive concentration of sodium and chloride ion accumulates in their leaves and reduces the growth of rice seedling. Ratio of potassium and sodium (K/Na) ion concentration for root and shoot were measured (Table 2) and compared with control (0 kg silicon ha^{-1}) condition. Result showed thation concentration ratio for shoot and root was higher in control condition for both varieties but this ratio was decreased with the increase of silicon dose. Gong *et. al.*, (2006) was observed silicon decreases transpirational bypass flow and ion concentration.A significant higher efficiency in reclamation of clay saline soil was obtained in terms of reducing Na^+ and EC when Silicon was applied and water was added in comparison to non-treated soil. The highest number of filled spikelet panicle^{-1}, grain and straw yields were obtained when rice plants were grown on soil treated with silicon compared to soil with no silicon. Plant uptake this nutrient which improved soil properties and which effect rice growth and its productivity. This might be due to the valuable nutrient source of silicon, which mitigated the toxicity caused by salts in saline soils. Silicon can also be considered as an effective application for clay saline soil in Satkhira regions of Bangladesh.From above discussion it is revealed that effect of silicon had positive trend for both varieties studied here andconsidering the dose ofsilicon almost all of the agronomic traits performed better@ 15 kgha^{-1} followed by 10 kg ha^{-1} (Table1 and 2).

Table 2. Shoot ion concentration and Root ion concentration of Binadhan-10 and BRRI dhan67 along with different doses of silicon application

Treatments	Shoot ion concentration ratio (K/Na) (µ mol g^{-1}DW)		Root ion concentration (K/Na) (µ mol g^{-1}DW)	
Variety	Binadhan-10	BRRI dhan67	Binadhan-10	BRRI dhan67
Silicon rate				
0 kg silicon ha^{-1} (S_0)	0.41d	0.45d	0.30d	0.38c
5 kg silicon ha^{-1} (S_1)	0.75c	0.70c	0.32c	0.42b
10 kg silicon ha^{-1} (S_2)	0.96b	0.85b	0.37b	0.40b
15 kg silicon ha^{-1} (S_3)	1.20a	1.32a	0.41a	0.53a

In a column, values with same letter (s) for individual location/combined means do not differ -significantly at 5% level

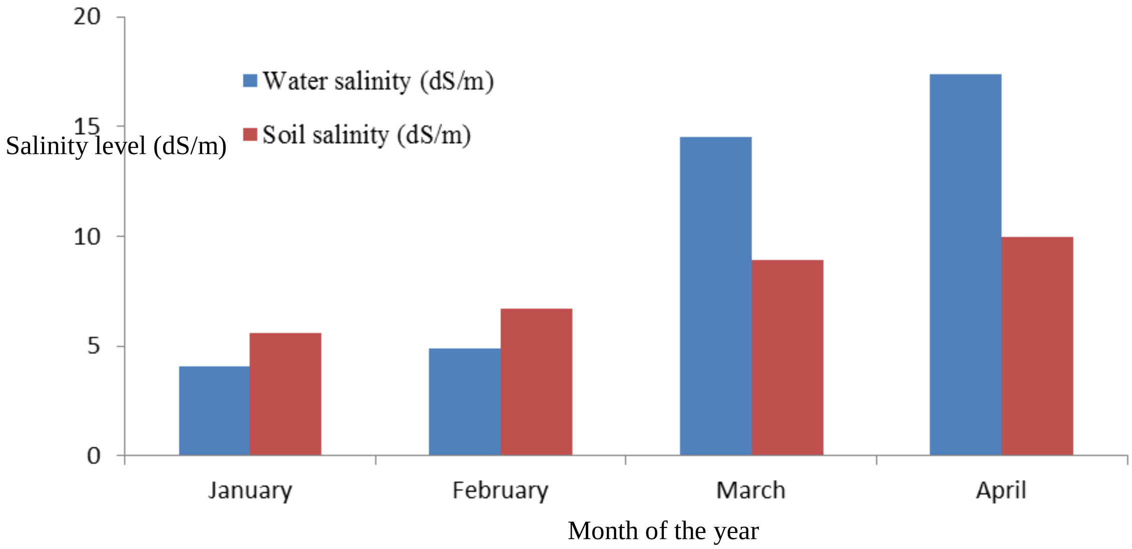

Fig.1: Level of salinity during crop growing season

Conclusions

Silicon application significantly increased Si of the clay saline soilwhich reduces ion concentration at shoot and root zone and enhance rice productivity grown on saline prone area. The improvement of soil chemical properties in terms of removal Na^+ salt and reducing EC that caused a significant reduction in soil salinity obtained from silicon. A significant improvement in growth and increase in yield of rice were obtained from @ 15 kg ha^{-1} followed by 10 kg ha^{-1} when silicon was applied into clay saline soil. Therefore, silicon is considered as effective treatments to leach the soluble salts for reclamation of clay saline soil and better plant growth, and yield of rice genotypes.Further study is needed to optimize the silicon dose based on soil property for more clarification.

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COMPARATIVE PERFORMANCE OF INDIGENOUS AND EXOTIC RHIZOBIAL STRAINS ON THE GROWTH AND YIELD OF LENTIL

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Abstract

Rhizobia, the Gram negative soil bacteria, form root nodules with lentil and influence its growth and yield. We evaluated the ability of the selected rhizobial strains on growth and yield of lentil at high Ganges river floodplain soils of Bangladesh under field conditions. The field experiment included nine treatments- three indigenous rhizobial strains (BLR26, BLR175 and BLR235), two exotic strains (nifTAL638 and nifTAL640), two mixed cultures, one fertilizer-nitrogen treatment and a control. Lentil seeds were inoculated with rhizobial strains as per the treatments and planted. Inoculation of lentil with indigenous strains BLR26 and BLR175 recorded higher grain yields over all other treatments except fertilizer-nitrogen application. Inoculation of indigenous mixed strains also resulted significantly higher lentil grain yield over the exotic strains. Thus, indigenous strains BLR26 and BLR175 can be used for lentil cultivation for improving nodulation, growth and yield of lentil at high Ganges river floodplain soils of Bangladesh.

Keywords: Rhizobia; lentil; legume; nodulation, growth, yield

Introduction

Lentil (*Lens culinaris*) plays an important role in agriculture and daily diet in Bangladesh. In addition to its food value, lentil is important in cropping systems for maintaining soil fertility because of its ability to fix atmospheric nitrogen. Around 5.2% of cultivable lands are subject to legume cultivation in Bangladesh (Rahman *et al*., 2009). Among different legumes lentil is the most popular and has been cultivated since ancient times in Bangladesh. In 2010, lentil was grown on 9,199 hectares of land and the total production was 71,100 tons (FAOSTAT-Agriculture, 2010). Although lentil has been grown in Bangladesh for a long time, farmers have largely been cultivating it without proper fertilizers and management. Therefore, it is necessary to increase the yield of lentil in Bangladesh.

Nitrogen is an essential nutrient for all living organisms and necessary for high crop yield and plant quality in agriculture. Although high amount of nitrogen is present in atmosphere, only prokaryotes can convert atmospheric molecular nitrogen into a form that is available to plants. Among nitrogen fixing prokaryotes rhizobia are able to enter a mutual symbiosis with leguminous plants in the form of root nodules that fully or partially satisfy the nitrogen demand of the plant. The legume-rhizobia symbiosis is highly specific mutual interrelationship between the two partners. Successful rhizobia-legume symbiosis can increase the incorporation of biological nitrogen fixation (BNF) into soil ecosystems (Vance, 2001). The symbiotically fixed nitrogen can meet up 30-90% nitrogen requirement of the plant (Vessey, 2004). In addition to nitrogen fixation, rhizobia increase lentil yield and can improve crop quality and soil fertility. In this study, we evaluated the performance of three indigenous strains (BLR26 from *Rhizobium lentis*, BLR175 from *Rhizobium bangladeshense* and BLR235 from *Rhizobium binae*; Rashid *et al*., 2015) and two exotic rhizobial strains (nifTAL638 and nifTAL640) on the growth and yield of lentil in the Gangetic flood plain soils of Bangladesh.

Materials and Methods

Rhizobial strains and their isolation from nodules:

Three indigenous rhizobial strains (BLR26, BLR175 and BLR235) and two exotic strains (nifTAL638 and nifTAL640) were used in this study. The indigenous strains were isolated from lentil root nodules. Collected nodules were washed with clean water, dried on tissue paper and preserved on silica gel, and desiccated until bacterial isolation. A single nodule was crushed in 50 μL of sterile water using a homogenizer. Then, a loop-full

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of suspension was streaked on yeast-extract mannitol agar (YEMA) plates (Vincent, 1970) and incubated at 28°C for 3-7 days. Isolated single colonies were purified by repeated streaking on YEMA and CRYEMA plates (Rashid *et al*., 2012). Single colonies were then preserved either on agar slants at 4°C, or frozen in broth with 50% glycerol at −80°C until further use. Exotic strains were collected from nifTAL, USA.

Inoculum Preparation and application:

Rhizobial strains from glycerol stocks were grown in YEM liquid media. Liquid sterile media were inoculated with a single colony of each strain. After inoculation, media were placed in an incubator shaker at 28 ^{0}C for 24-36 hours. After sufficient growth (10^7 cell mL $^{-1}$), 25 mL of broth were injected in 75 gm of sterile peat soil to prepare 100 gm peat based rhizobial inoculum. The required lentil seeds for each plot were first coated with molasses (5% of seed weight) and then peat based inoculums (5% of seed weight) were placed on lentil seeds for proper coating the lentil seeds with rhizobial strains. After proper inoculm application, seeds were sown at experimental field.

Nodulation test:

All strains, used in this study, were tested for nodule formation with lentil (CV: Binamasour-5) at sterile conditions. Seeds from lentil (Binamasour-5) were surface-sterilized using 70% ethanol for 1 min and then 3% NaClO for 3 – 5 min. After surface sterilization, the seeds were washed six times with sterile distilled water for removing excess disinfectant from seed surface. After imbibing (4 h in sterile water), seeds were transferred aseptically to 1% water agar plates and allowed to germinate for 2 days at room temperature in the dark. Seedlings were later transferred to glass tubes (32 mm × 170 mm) containing Fåhraeus (1957) agar medium. Rhizobial cultures were grown (2 mL plant-^{1}) in YEM liquid medium (circa 1×10^7 cells mL-^{1}) were used to inoculate 5 days old seedlings (Somasegaran and Hoben, 1994). Plants were alternately irrigated with sterile de-ionized water and Jenson's nitrogen-free seedling solutions. Plants were grown for 3 – 5 weeks in a plant growth chamber set to 25°C with 14 h light / 10 h dark cycles. Three replicates of each bacterial strain were used for nodulation test. Un-inoculated plants were served as negative controls for nodulation test. All strains except nifTAL638 produced nodules after three weeks of inoculation.

Field experiment:

The experiment was carried out at high Ganges river floodplain soils of Bangladesh at BINA sub-station Magura. Experimental farm belongs to clay soil with pH 6.7. The treatments were T_1(control), T_2 (nifTAL638), T_3(nifTAL640), T_4(BLR26), T_5(BLR175), T_6(BLR235), T_7(mixed-1= nifTAL638 and nifTAL640), T_7(mixed-2= BLR26, BLR175 and BLR235), T_9(urea: 33 Kg ha^{-1}). Experimental field was irrigated before sowing to maintain sufficient moistures for seed germination. The land was well prepared before sowing. After land preparation, experimental plots were laid out in randomized complete block design (RCBD) with three replications. As per fertilizer recommendation guide (FRG, 2012), fertilizers like P, K, S, and Zinc were applied at the rate of 16, 20, 12 and 1 Kg ha-^{1}, respectively in all plots as basal dose and nitrogen

A single irrigation was given after one month of sowing. Weeds were cleaned manually after 20 and 40 days of sowing. Soil samples were collected from experimental field using soil sampling Auger and preserved in a poly bag at 4^{0}C until rhizobial population count. Rhizobial populations were determined following the protocols as described previously (Rashid *et al*., 2014). The field soil contains individual rhizobial population which was 3x 10^4g^{-1}.

Data on nodule weight and plant weight were recorded at about 50% flowering stage. At harvest, pod numbers plant^{-1}, 100-seed weight was recorded from randomly selected ten plants of each plot. Seed yields were recorded from 1 m ^{2} of each experimental plot and converted to kg ha^{-1}. Recorded data were analyzed using MSTAT-C software (Gomez and Gomez., 1984) and means were compared with DMRT.

Results and Discussion

Nodule weight at flowering stage: A significant variation was observed in nodules weight of lentil at flowering stage due to different treatments (Table 1). Nodule weight ranged from 13.20 to 19.93 mg plant-^{1}. The highest nodule weight (19.93 mg) was found with the inoculation of the strain nifTAL640 which was statistically similar to that of the strain BLR26 and the minimum value was found in the urea treatment. The treatments T_1, T_2 and T_7 recorded statistically identical nodule weight. Inoculation of lentil with the strains nifTAL638, BLR175 and BLR235 noted lower nodule weight compare to control treatment. The strains nifTAL638, BLR175, BLR235, mixed-1 and mixed-ii exerted similar effect on nodule weight. Exotic mixed strains showed higher nodule weight over the indigenous mixed strains.

Dry matter yield: Dry matter weight of lentil with different treatments showed significant differences (Table 1). All the treatments except T_2 (nifTAL638) recorded higher dry matter yield over control. The strain BLR26 produced the highest dry matter weight (2.96 g plant^{-1}) which was followed by the strain nifTAL640 and the lowest value was noted by the strain nifTAL638. The strain nifTAL 640 performed better compared to BLR175 and BLR235 in producing dry matter yield of lentil. Exotic mixed strain also recorded higher dry matter yield over the indigenous mixed strains. The treatments T_5, T_6, T_7 and T_8 demonstrated similar dry matter yield of lentil. Rashid *et al.*, (2009) reported that rhizobial inoculations to the lentil significantly enhance shoot dry weight than un-inoculated control.

Table 1: Effect of rhizobial strains on growth of lentil

Treatment	At 50% flowering stage	
	Nodule weight (mg plant-^{1})	dry matter weight (g plant-^{1})
T_1 (Control, no nitrogen)	17.43 bc	2.06 ef
T_2 (nifTAL638)	16.90 bc	2.00 f
T_3 (nifTAL640)	19.93 a	2.57 b
T_4 (BLR26)	18.83 ab	2.96 a
T_5 (BLR175)	16.16 c	2.37 cd
T_6 (BLR235)	16.43 c	2.27 d
T_7 (Mixed- I: nifTAL638 & nifTAL640)	17.37 bc	2.27 d
T_8 (Mixed-II: BLR26,BLR75 & BLR235)	16.63 c	2.23 de
T_9 (Urea:33 Kg ha-^{1})	13.20 d	2.48 bc
CV (%)	5.86	4.33

In a column, means followed common letter (s) do not differ significantly at 5% level by DMRT. Abbreviations: Rl= *Rhizobium leguminosarum*, R= *Rhizobium*, BLR=Bangladeshi lentil rhizobia, nifTAL=Nitrogen Fixation by Tropical Agricultural Legumes.

Pod plant^{-1}: Significant variation was observed in the number of pods produced by lentil due to different treatments (Table 2). The highest number of pods (110 pods plant^{-1}) was observed in the treatment T_5 inoculated with the strain BLR26 which was followed by the treatment T9 receiving urea fertilizer (108 pods plant^{-1}) contain the strain BLR175. Inoculation with indigenous mixed strains produced significantly higher number of pods plant-1 over the exotic mixed strains. Again, the control plants recorded higher number of pods compared to the treatments T_2 and T_7. The minimum pods plant-^{1} was noted in the treatment T_2 (87.14 pod plant-1) inoculated with the strain nifTAL638.

Seed weight: There was no significant variation in the 100-seed weight of lentil due to different treatments (Table 2). The highest 100-seed weight (2.25 g plant^{-1}) was recorded with the nifTAL640 and the minimum value (2.11 g plant^{-1}) was recorded in the control treatment. A similar result was observed by Mckenzie *et al.*, (2001) who reported that rhizobial inoculation did not significantly enhance seed weight compared to the control.

Grain yield: Grain yield from different treatments showed significant variation (Table 2) and urea treatment produced the highest seed yield (1671 Kg ha^{-1}) which was statistically identical with that of strain BLR26 (1670 kg ha^{-1}). Inoculation of lentil with indigenous mixed strains produced higher grain yields over the exotic mixed strains. Lentil yield with the indigenous strains BLR26 and BLR175 were higher over all other treatments except fertilizer-N treatment. The minimum yield was observed with the strain nifTAL638. Among rhizobial strains, the strain BLR26 seems to be the best for lentil inoculation. The findings of this experiment is in agreement with Gan and McDonald (2002) who reported that plants inoculated with rhizobial strains increased seed yield by an average of 35% in desi chickpea and 23% in lentil compared to control. Kantar *et al.*, (2003) also observed that bacterial inoculations significantly increased seed yield compared to control treatment.

Legumes have the ability to fix and utilize atmospheric nitrogen with the help of effective rhizobial strains. The can met up full or partial requirement of nitrogen for host plant and improve soil fertility. Effective rhizobial strains were inoculated for nodulation and growth of lentil. The results showed that inoculation of lentil with the strain BLR26 produced the highest plant dry matter yield, pods plant-1 and yield significantly. This may be due

Table 2: Effect of rhizobial strains on yield and yield contributing characters of lentil

Treatment	At harvest		
	Pod plant^{-1} (no)	100- seed weight (g)	Seed yield (kg ha^{-1})
T_1 (Control, no nitrogen)	90.77 fg	2.11	1338 c
T_2 (nifTAL638)	87.14 g	2.18	1199 d
T_3 (nifTAL640)	101.50 cd	2.25	1544 ab
T_4 (BLR26)	110.00 a	2.20	1670 a
T_5 (BLR175)	103.80 bc	2.15	1636 ab
T_6 (BLR235)	94.29 ef	2.13	1512 b
T_7 (Mixed-I: nifTAL638 & nifTAL640)	88.64 fg	2.18	1284 cd
T_8 (Mixed-II: BLR26, BLR75 & BLR235)	97.22 de	2.17	1567 ab
T_9 (Urea: 33 Kg / ha)	108.00 ab	2.21	1671 a
CV (%)	3.01	4.44	4.58

In a column, means followed common letter (s) do not differ significantly at 5% level by DMRT. Abbreviations: Rl= *Rhizobium leguminosarum*, R= *Rhizobium*, BLR=Bangladeshi lentil rhizobia, nifTAL=Nitrogen Fixation by Tropical Agricultural Legumes.

to the effective symbiosis between the rhizobial strain and lentil cultivar Binamasor-5. This might be due to effective nodulation process and availability of more atmospheric nitrogen to the root zone of lentil. Similar results were also observed by Glick (2012) who concluded that bio-fertilizers which contain rhizospheric microorganisms have ability to promote and regulate plant growth directly and/or indirectly. However, enough rhizobial population was present in the field soil and subsequently; sufficient nodules were found in the control treatment. But the growth and yield of lentil in the control was lower compared to other treatments except the treatment T_2 (nifTAL638). Under field condition, rhizobia rhizobia could be mutualistics to parasites, varying dramatically in the N_2-fixing benefits provided to their hosts (Ballard *et al*., 2002; Denton *et al*., 2000; Heath and Tiffin, 2007; Thrall *et al*., 2007). Nonetheless, strains of rhizobia can vary as much as tenfold in net host benefits, even when derived from a single location (Burdon *et al*., 1999). Thus, it is possible that our experimental field soils might contained heterozygous rhizobial population such as less effective, effective and cheater rhizobia. Initially cheater rhizobia may form false nodules with host plant but later they absorb more carbon from host to synthesis more PHB (polyhydroxy-3-butyrate) to enhance their own fitness and reproduction, which negatively compete with nitrogen fixation (Ratcliff *et al*., 2008). Thus, we did not get positive effect of symbiosis from all indigenous rhizobial strains and host lentil cultivar Binamasor-5. The performance of the exotic strains nifTAL638 was also poor compared to other strains. This might be due to lose their nodulation genes during storage (Ibañez *et al.*, 2009). Generally, rhizobial nodulation and nitrogen fixation genes exist in plasmids which are not essential part of bacterial genome and bacterial existence. To survive in adverse situation, for example during long time preservation at low temperature, bacteria release their non essential genes from genome. Therefore, it could be assumed that this strain might lose its nodulation and nitrogen fixation ability during long time preservation and subsequent sub-culturing during preservation.

The performance of indigenous rhizobial strains were better compared to exotic strains in producing lentil yield. Inoculation of lentil with the rhizobial strains BLR26 and BLR175 recorded higher grain yield of lentil over all other treatments except fertilizer-N application. Thus, the strain BLR26 or/and BLR175 may be used for lentil cultivation in the calcareous soils of Bangladesh. Further evaluations are needed to confirm the performance of this strain at field conditions of different locations.

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EFFECT OF ROW SPACING AND DATES OF TRANSPLANTING ON YIELD PERFORMANCE OF KASALATH RICE MUTANT IN T. AMAN SEASON OF BANGLADESH

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Abstract

Proper time of transplanting and appropriate spacing are necessary for standardization the yield potential of advance kasalath rice mutants in Bangladesh climatic condition.Thefield experiments were conducted at BINA Headquarters farm, Mymensingh in T. Amanseason of 2017 and 2018 to see the performance of two mutant lines of Kasalath under different dates of transplanting and spacings. In 2017, two advanced mutant lines namely RM-Kas-60(C)-1, RM-Kas-80(C)-1were evaluated along with BRRI dhan49 at three levels of spacing, viz. 20cm×15cm, 20cm×20cm and 20cm×25cm. Mutant line RM-Kas-60(C)-1 produced statistically higher grain yield (4.8 t ha^{-1}) at 20cm×15cm spacing. In 2018, only RM-Kas-60(C)-1 was evaluated against Binadhan-11, at three row spacing (viz. 20cm×15cm, 20cm×20cm and 20cm×25cm) and three dates of transplanting such as July 15, July 30 and August 15. Among three transplanting dates, RM-Kas-60(C)-1 produced the highest grain yield of 4.86 t ha^{-1} at 20cm x 15cm spacing when transplanted on July 30. Overall observation showed that RM-Kas-60(C)-1 yielded the best at 20cm×15cm when transplanted on July 30 under rainfed condition of Bangladesh.

Key words: Spacing; dates of transplanting; yield; Kasalath rice mutants

Introduction

The deficiency of phosphorus (P) in rice soil is a worldwide problem. Low P in soil may be due to the low P content of the parental material, low pH and/or soil with high P-fixing characteristics (Rose and Wissuwa 2012). Side by side with the application of costly P fertilizer, the development and use of less P uptake rice genotypes could offer a sustainable solution for such situation. Different genetic approaches have been taken to tackle this problem, and perhaps the most successful attempt was the identification and characterization of the major quantitative trait locus (QTL) Phosphorus uptake 1 (*Pup1*). *Pup1* was identified in the rice variety Kasalath (Wissuwa*et al*., 2002), and near isogenic lines (NILs) carrying this QTL showed that *Pup1* conferred a significant yield advantage over the intolerant recurrent parent Nipponbare (Wissuwa 2005). Kasalath, the *Pup1* donor variety, was initially identified in a screening of 30 diverse rice genotypes in a P-deficient soil in Japan under rainfed conditions. Phenotypic data derived from Nipponbare contrasting near isogenic lines (NILs) with and without the QTL showed that *Pup*1 increased P uptake (Wissuwa*et al*., 2002) and conferred a significant yield advantage (2 to 4-fold higher grain weight per plant) in pot experiments using different P-deficient soil types and environments (Chin *et al*., 2010).

The germplasm survey conducted with the above mentioned markers revealed that *Pup1* is largely absent in modern irrigated rice varieties though highly conserved in drought-tolerant breeding lines and upland varieties. This suggested that breeders are unknowingly selecting for *Pup1* in breeding programs that target drought-prone environments (Chin *et al*., 2010).The impact of *Pup1* and other QTLs was the enhancement of grain yield in P-deficient soil and/or under drought stress (Bernier *et al*., 2009).The mutant lines $M_{6,}$ RM-Kas-60(C)-1 and RM-Kas-80(C)-1 were discovered through carbon ion beam irradiation from 60 and 80 Gy doses, respectively of indigenous Kasalath land races (A. K. Azad, 2018). Since most of the Bangladesh rice soils are deficient in P, it is necessary to identify rice genotypes that are tolerant to P deficient soil environment. Moreover, it is also necessary to standardize the optimum planting time and planting spacing for exploiting the potential yield of the mutant under Bangladesh conditions. This study was therefore, undertaken to study the yield performance of the advanced mutant lines of Kasalath under different plant spacing and planting dates for growing under rainfed conditions in Bangladesh.

Materials and Methods

Experiments were carried out at BINA Headquarters farm, Mymensingh during Aman season of 2017 and 2018.The experimental site was situated between 24.6°N and 90.5°E latitude and at 18m high from the sea level. The soil of the experimental field was sandy loam type and belongs to the Old Brahmaputra Flood Plain Alluvial Tract. The experimental plot was under the subtropical climate characterized by heavy rainfall during the month of March to November. The advanced mutant lines RM-Kas-60(C)-1 and RM-Kas-80(C)-1 were collected from

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Plant Breeding Division of BINA and the check variety BRRI dhan 49 from Genetic Resource and Seed Division, Bangladesh Rice Research Institute.In 2017, three levels of spacing, viz. 20cm×15cm (S_1), 20cm×20cm (S_2) and 20cm×25cm (S_3) were considered for transplanting on July 15. The fertilizer doses applied for the experiment were 80kg N ha^{-1}, 40kg P ha^{-1}, 50kg K ha^{-1}, 20kg S ha^{-1} and 2kg Zn ha^{-1}. Twenty five days old seedlings were transplanted in a randomized complete block design with three replications with single seedling per hill. The unit plot size was 3m×4m. The crop was harvested on Oct. 15 and data on yield and yield components such as plant height, total number of tillers hill^{-1}, number of effective tillers hill^{-1}, panicle length, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}, thousand seed weight, grain yield, straw yield were recorded from ten randomly selected plant. Yield data was taken from whole plot and converted into ton hectare^{-1} and analyzed statistically with statistix 10 data analysis software update version 2018 and the means were compared.

In 2018, there were three transplanting dates such as July 15(D_1) July 30(D_2) and Aug. 15(D_3) and three line spacing's followed as 2017 were assigned for comparing the performance of RM-Kas-60(C)-1 with check variety Binadhan-11. Twenty five days old seedlings were transplanted following split plot design with three replications with single seedling per hill. The application of herbicide (Bensulfuron methyl 4% + Acetachlor 14%) was necessary to keep the field free from weeds throughout the growing period along with a hand weeding at 35 days after transplanting (DAT). Furadan 5 G @ 10 kg ha^{-1} was applied to control the infestation of stem borer. Three supplemental irrigations were needed due to less rainfall during the period from end of September to first week of October. After attaining 80% physiological maturity, the plants of Binadhan-11 were harvested on October 15, October30 & November 15and that of RM-Kas-60(C)-1 October 30, November 15 & November 30 for first, second and third dates respectively. The harvested plants were threshed, cleaned, and processed, and then yield and yield contributing characters, grain yield, straw yield were recorded. Weather parameters such as air temperature, soil temperature, relative humidity, rainfalland sunshine hours were also recorded for understanding the growing environment of the crop (Fig. 1).

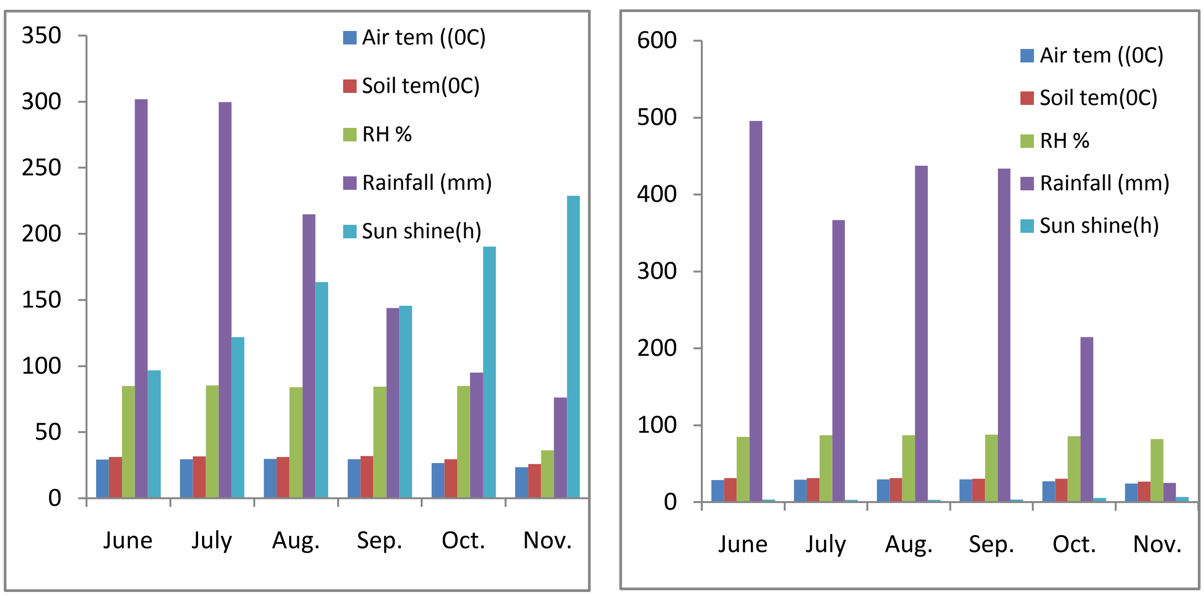

Fig. 1. Weather parameters during experimental period of 2017 and 2018 at BINA, Mymensingh

Results and Discussion

Effect of plant spacings on yield contributing characters of Kasalath rice mutant/variety in T. Aman season 2017: The effect spacings on plant height, total tillers and effective tillers hill^{-1} and grain were significant (Table 1). The highest plant height (107.5cm) was observed at spacing of 20cm×15cm and the lowest (101.5cm) was observed at the spacing of 20cm×25cm. The highest plant height (104.3cm) was obtained in the mutant RM-Kas-60(C)-1 with spacing 20cm×20cm and 20cm×15cm. The highest number of total tillers hill^{-1}(10.5) was observed at the spacing of 20cm×25cm and the lowest (9.7 hill-1) was at the spacing of 20cm×20cm.

Table 1.Effect of different spacing on the yield contributing characters and yield of rice mutants/variety in T. Aman season during 2017

Treatments	Plant height (cm)	Total tillers hill^{-1} (no)	Effective Tillers hill^{-1} (no)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Spacing									
20cm×15cm (S_1)	107.5	9.7	9.0	25.1	112.6	7.7	22.5	4.8	5.8
20cm×20cm (S_2)	106.3	10.4	9.6	25.0	111.4	7.5	22.4	4.5	5.6
20cm×25cm (S_3)	101.5	10.5	9.8	21.9	117.7	7.0	22.3	4.3	5.5
$LSD_{0.05}$	1.5	0.3	0.3	2,73	8.33	0.80	2.55	0.2	0.36
Mutants/Varieties									
RM-Kas-60(C)-1(V_1)	109.0	11.5	10.7	25.1	117.8	7.6	22.5	4.7	5.8
RM-Kas-80(C)-1 (V_2)	104.6	9.6	8.9	23.0	110.5	9.0	22.3	4.5	5.4
BRRIdhan-49 (V_3)	101.6	9.6	8.8	23.9	114.4	5.8	22.4	4.4	5.9
$LSD_{0.05}$	4.5	1.92	0.8	1.1	8.88	3.00	0.48	0.38	0.50
Variety×Spacing									
V_1S_1	103.7	9.1	8.2	25.3	107.4	4.0	22.1	4.8	6.2
V_1S_2	104.3	10.0	9.0	25.0	110.5	6.1	22.2	4.5	6.1
V_1S_3	103.3	10.5	9.6	24.7	116.3	5.7	22.4	4.3	5.5
V_2S_1	104.3	8.3	8.0	24.9	108.1	7.1	22.4	4.6	6.1
V_2S_2	103.0	9.4	8.5	25.1	112.7	7.0	22.3	4.5	6.0
V_2S_3	102.7	10.0	9.4	24.4	115.5	7.9	22.4	4.2	5.3
V_3S_1	98.0	8.8	7.9	21.9	118.2	5.7	22.4	4.6	6.5
V_3S_2	97.7	9.8	9.2	22.2	121.6	4.1	22.8	4.4	5.7
V_3S_3	97.7	10.5	9.8	21.8	119.1	4.7	22.9	4.2	5.5
$LSD_{0.05}$	7.11	1.2	1.77	1.5	6.1	2.3	0.89	0.2	0.4
CV%	6.7	6.3	6.7	3.9	5.3	19.2	2.8	3.1	4.3

The highest number of total tillers hill^{-1}(10.5) was obtained in the mutant RM-Kas-60(C)-1 and BRRIdhan49 with spacing of 20cm×25cm. The lowest number of total tillers hill^{-1} (8.3) was observed in RM-Kas-80(C)-1 with spacing of 20cm×15cm.The highest number of effective tillers hill^{-1} (9.8) was observed at the spacing of 20cm×15cm and the lowest number of effective tillers hill^{-1} (9.0) at the spacing of 20cm×15cm. Amongst genotypes, the highest number of effective tillers hill^{-1} (10.7) was observed at RM-Kas-60(C)-1 and the lowest was in BRRIdhan-49.There was no statistically significant difference of effective tillers hill^{-1}between spacing and genotypes. The interaction effect of genotype and spacing on effective tillers, panicle length, number of filled and unfilled grains panicle-1 and grain and straw yield was significant (Table 1). The highest panicle length (25.1 cm) was recorded at the mutant RM-Kas-60(C)-1 and the lowest (23.0 cm) was in RM-Kas-80(C)-1.For interaction, the highest panicle length (25.3 cm) was obtained in RM-Kas-60(C)-1 with spacing of 20cm×15cm and lowest panicle length (21.8 cm) was in the variety BRRI dhan49 with spacing of 20cm×25cm.The highest number of filled grains panicle^{-1}(121.6) was obtained in BRRI dhan49 with spacing of 20cm×20cm and lowest number of filled grains panicle^{-1}(107.4) in RM-Kas-60(C)-1 with spacing of 20cm×15cm. The highest number of unfilled grains panicle^{-1}(7.9) was obtained in the mutant RM-Kas-80(C)-1 with spacing of 20cm×25cm and the lowest was observed in RM-Kas-60(C)-1 with spacing, 20cm×15cm.The highest grain yield (4.8 t ha^{-1}) was recorded at the spacing of 20cm×15cmand the lowest grain yield (4.3 t ha^{-1}) was recorded at the spacing of 20cm×25cm (Table 1). Among the cultivars, highest grain yield (4.7 t ha^{-1}) was recorded in mutant RM-Kas-60(C)-1 and the lowest grain yield (4.4 t ha^{-1}) in the variety, BRRI dhan49. The highest grain yield (4.8 t ha^{-1}) was obtained in RM-Kas-60(C)-1 with spacing 20cm×15cm and the lowest grain yield (4.2 t ha^{-1}) was recorded in BRRI dhan49 under spacing of 20cm×25cm. The mutant RM-Kas-60(C)-1 produced the highest number of effective tillers/m^2, filled grains panicle^{-1} and thousand grain weightunder the spacing of 20cm×15cm thereby showed the highest grain and straw yield. It might be due to maximum solar radiation interception by the mutant line RM-Kas-60(C)-1 which contributed to produce more assimilates and gives highest growth and development under the spacing of 20cm×15cm, thereby yield.

Effect of plant spacing and transplanting date on yield contributing characters and yield of rice mutant/variety in T. Aman season 2018: Out of three transplanting dates, transplanted on July 30, 2018 produced the highest grain yield (4.71 t ha^{-1})might be due to more filled grains $panicle^{-1}$ (139.7).Among the mutant line/variety, RM-Kas-60(C)-1 produced the highest grain yield (4.39 t ha^{-1})might be due to more filled grains $panicle^{-1}$(136.5). The highest grain yield was recorded under the spacing of 20 cm×15 cm (4.54 t ha^{-1}). It might be due short stature of the plant and highest number of panicles m^{-2} in (20 cm×15 cm) spacing congenial for growth and yield of the mutant. The wider spacing, 20 cm×25 cm showed the lowest grain yield (3.89 t ha^{-1}).

Table 2.Effect of spacings and dates of transplanting on yield contributing characters and grain yield of rice mutant/variety in T. Aman season during 2018

Treatments	Plant height (cm)	Total tillers $hill^{-1}$ (no)	Effective tillers $hill^{-1}$ (no)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	1000-seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Dates of transplanting									
July. 15 (D_1)	105.8	9.9	8.7	28.1	125.6	29.0	22.6	4.32	5.46
July. 30 (D_2)	102.3	9.2	8.3	25.9	139.7	17.1	22.5	4.71	5.45
Aug. 15 (D_3)	98.7	12.6	9.5	23.9	120.5	22.4	21.9	4.18	5.50
$LSD_{0.05}$	3.0	3.4	0.8	1.5	18.2	3.1	0.9	4.8	NS
Mutant/Variety									
RM-Kas-60(C)-1	107.6	13.2	8.8	26.5	136.5	23.5	22.2	4.39	5.39
Binadhan-11	97.0	9.9	8.9	25.4	120.7	15.1	22.4	4.14	5.56
$LSD_{0.05}$	9.70	3.0	0.3	1.4	14.8	6.4	0.3	0.25	0.27
Row spacing									
20cm×15cm (S_1)	101.7	14.2	7.9	25.4	122.3	24.0	22.3	4.54	5.82
20cm×20cm (S_2)	102.4	10.1	9.1	26.0	126.1	21.4	22.3	4.16	5.47
20cm×25cm (S_3)	102.7	10.5	9.4	26.5	137.4	23.1	22.4	3.89	5.12
$LSD_{0.05}$	3.85	4.2	0.7	0.5	6.2	2.8	0.2	0.16	0.18
CV%	5.1	11.1	10.3	6.4	9.6	14.6	2.99	4.56	6.80

The interaction effect of date and variety showed that RM-Kas-60(C)-1 produced the maximum yield (4.34 t ha^{-1}) when transplanted on July 30 (Table 3).There is a statistically significant difference on effect of date and variety. The highest filled grains $panicle^{-1}$(139.7) and lowest unfilled grains $panicle^{-1}$ produced in RM-Kas-60(C)-1 when on July 30.

Transplanting on July 30 produced the maximum yield (4.64 t ha^{-1}) at 20 cm×15 cm spacing. It might be due to the highest genetic expression for the mutant line in Mymensingh region where the rainfall was maximum during 15 June to September 15 when the raising of seedling, seedling transplanting, and tillering happened. Nonetheless, the bright sunshine at reproductive development phase was also congenial for optimum yield of the mutant line.The interaction effect between variety and spacing showed that RM-Kas-60(C)-1 produced maximum yield (4.63 t ha^{-1}) at 20 cm×15 cm spacing. It might be due to 20 cm×15 cm spacing congenial for suitable growth and development for more panicles produced m^{-2} highest for the mutant RM-Kas-60(C)-1 and found maximum yield.

Conclusion

The mutant line RM-Kas-60(C)-1 produced higher grain yield (4.8 t ha^{-1}) at 20cm×15cm spacing when transplanted on 30 July. Overall results suggest that yield of mutant line RM-Kas-60(C)-1 may express full potentialities in T. Aman season if favorable weather, edaphic conditions exist, proper management practices to control weeds, insects,diseases are provided at 20 cm×15 cm spacing and transplanted within 30 July.

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Table 3. Interaction effect between spacing and transplanting dates on the yield and yield contributing characters of Kasalath rice mutant/variety in T. Aman season during 2018

Interaction	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed wt. (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Dates × Genotype									
D_1V_1	110.6	9.8	8.6	29.1	131.6	29.3	22.8	4.15	5.38
D_1V_2	100.9	9.9	8.8	27.1	119.6	28.7	22.4	4.08	5.53
D_2V_1	104.5	9.4	8.6	25.5	149.6	19.0	22.5	4.34	5.35
D_2V_2	100.2	9.0	8.0	26.3	129.7	15.2	22.4	4.21	5.56
D_2V_1	107.6	20.4	9.1	25.0	128.2	22.1	21.3	4.22	5.43
D_2V_2	89.9	10.8	9.9	22.9	112.8	22.8	22.4	4.13	5.58
$LSD_{0.05}$	2.3	NS	1.4	1.1	14.2	10.1	NS	NS	0.20
Genotype × Spacing									
$V_1 S_1$	107.3	19.2	7.9	26.0	127.5	26.0	22.1	4.63	5.83
$V_1 S_2$	107.5	10.5	9.4	26.5	136.4	23.6	22.1	4.16	5.36
$V_1 S_3$	107.9	9.9	9.0	27.1	145.6	20.8	22.4	3.79	4.97
$V_2 S_1$	96.1	9.1	7.9	24.9	117.1	22.0	22.5	4.46	5.81
$V_2 S_2$	97.4	9.7	8.8	25.5	115.8	19.2	22.4	4.16	5.59
$V_2 S_3$	97.6	11.0	9.9	25.8	129.2	25.4	22.4	3.80	5.27
$LSD_{0.05}$	3.1	2.1	1.7	1.3	15.3	13.7	NS	0.14	0.20
CV%	5.1	11.1	10.3	6.4	9.6	14.6	2.99	4.56	6.80

D_1= 15 July, D_2 = 30 July and D_3 = 15 August; S_1 = 20cm×15cm, S_2 = 20cm×20cm and S_3 = 20cm×25cm; V_1 =RM-Kas-60(C)-1, V_2 = Binadhan-11

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IMPACT OF DIFFERENT BORON LEVELS ON YIELD IN GROUNDNUT VARIETIES

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Abstract

An experiment was carried out to study the effect of different levels of boron (B) on yield of three bold seeded groundnut cultivars *viz*., Binachinabadam-1, Binachinabadam-2 and Binachinabadam-3. Plants were grown in sand using nutrient solution in the pots. The experiment comprised six levels of boron *viz*., 0, 1.5, 2.0, 2.5, 3.0 and 3.5 kg ha^{-1}. Results indicated that physiological parameters, reproductive characters, yield attributes and pod yield increased with increasing levels of boron application till 2.5 kg B ha^{-1}. The highest total dry matter (14.02 g $plant^{-1}$), number of opened flowers (44.07 $plant^{-1}$) and reproductive efficiency (46.53%) were recorded in 2.5 kg ha^{-1} and the lowest was recorded in 3.5 kg B ha^{-1} except reproductive efficiency. The highest number of pods $plant^{-1}$ (20.67), single pod weight (832 mg) and pod weight $plant^{-1}$ (17.09 g) was observed in 2.5 kg B ha^{-1} application followed by 2.0 kg B ha^{-1}. In contrast, application of B @ 3.5 kg ha^{-1} showed the lowest number of pods (8.60) and pod yield (6.94 g). Among the varieties, Binachinabadam-1 produced the highest pod yield (12.81 g $plant^{-1}$).

Keyword: Boron level, Physiological parameters, yield, groundnut

Introduction

Peanut (*Arachis hypogaea* L.) is an important legume crop used as oilseed as well as a food crop in Bangladesh and grown in all soil types, under tropical to subtropical climates. Groundnut seed is nutritionally rich due to presence of lipids, proteins, essential minerals, vitamins, phytosterols and phytochemicals. Moreover, it fixes atmospheric nitrogen in the soil through its nodule bacteria which enriches the soil with nitrogen (49-297 kg N ha^{-1} $season^{-1}$), reduces the uses of synthetic fertilizer and keeps the environment more friendly (Hoque, 1989).

Farmers of Bangladesh are mostly habituated with the use of macro-nutrients, especially nitrogen, phosphorus, sulphur and potassium for crop production but in case of micro-nutrients is limited. Boron (B) as a micronutrient plays an important role in the physiological process of plants, such as cell division, nitrogen and carbohydrate metabolism and water relation in plant growth (Ansari *et al.,* 2014). The need for B application in groundnut is therefore, to increase the growth, development and at the same time to increase the yield of crops. The application of B also promotes the absorption of N by groundnut and increases the plant height, plant dry weight and the total number of pods (Ahmad *et al.*, 2011). Boron have important role on pollination, fruit set and total yield (Mondal *et al.,* 2016) which may have positive impact on increases the pod size, number of pods $plant^{-1}$ and yield of oil seed crops (Newaz *et al.*, 2014).

Plant boron requirements of various peanut genotypes vary greatly and genotypes of the same plant species demonstrate a variable response to a specific nutrient supply deficiency (Rerkasem and Jamjod, 2004). Addition of boron (2 ppm) in groundnut increased the yield by 18 per cent and improved the quality through suitable changes in yield attributes (Ansari *et al.*, 2014). BINA has developed three bold seeded high yielding varieties (Binachinabadam-1, Binachinabadam-2 and Binachinabaadam-3) which need to determine B requirement for maximizing pod yield in sandy or sandy loam soil. Therefore, an attempt was made to study the response of bold seeded groundnut genotypes to boron in presence of N, P, K, and S.

Materials and Methods

The experiment was carried out at pot yard, Bangladesh Institute of Nuclear Agriculture, Mymensingh in pot culture condition in sands with three varieties of peanut viz., Binachinabadam-1, Binachinabadam-2 and Binachinabadam-3, bold seeded varieties. Each pots contained 10.0 kg sands. The pots were arranged in a completely randomized design with five replicates. Long Aston complete nutrient solution (-N) in ½ strength was provided in each pot in a week after germination of seeds (Hewitt, 1966). Plants were provided with adequate supply of distilled water when needed. Two plants were allowed to grow in each pot. The six levels of boron treatments were 25, 100, 125, 150 and 175 mg pot^{-1} corresponding to 0.5, 2.0, 2.5, 3.0 and 3.5 kg ha^{-1}. Seeds were sown on 29 November, 2014. Intercultural operations were done as and when necessary for normal

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plant growth and development.

In each plant, flower count began from the date of opening of first flower and continued at every day until flowering ceased. Total flower production and flowering duration were later calculated from the collected data. Per cent pod set to opened flowers (reproductive efficiency, RE) was then estimated as: % pod set = (Number of pod plant^{-1} ÷ Number of opened flowers plant^{-1}) × 100 (Fakir *et al.,* 2011). Leaf Chlorophyll was determined at 70 DAS following the method of Yoshida *et al*. (1976). Total sugar was determined at 70 DAS following the method of Badruddin (2005). Nitrate reductase activity was determined at 75 DAS following the methods of Stewart and Orebamjo (1979). At harvest, the morphological and yield contributing characters were recorded. The total dry matter was calculated from summation of leaves, stem, root and siliqua dry weight per plant. The collected data were analyzed statistically (two factors CRD) to obtain the level of significance following the analysis of variance (ANOVA) technique and the mean differences were compared by Duncan's Multiple Range Test (DMRT) using the statistical computer package programme, MSTAT (Russell, 1986).

Results and Discussion

The effect of different doses of boron on chlorophyll content, total sugar content and nitrate reductase activity in leaves was significant (Table 1). Results showed that chlorophyll and sugar content in leaves, nitrate reductase activity in leaves, total dry mass (TDM), number of flowers and percent pods to opened flowers (Reproductive efficiency, RE) increased with increasing B level till 2.5 kg ha^{-1} followed by a decline. The highest chlorophyll (1.80 mg g^{-1} fw), total sugar (82.3 mg g^{-1} fw), nitrate reductase (0.43 µmol NO_2^-g^{-1} fw), TDM plant^{-1} (14.02 g), number of opened flowers plant^{-1} (44.07) and RE (46.53%) was recorded in 2.5 kg ha^{-1} whereas the lowest value was recorded in 3.5 kg B ha^{-1} except RE. The increases in total dry weight due to B application may be attributable to the fact that B is known to help in absorption of N and P that help in development of more extensive root system (Newaz *et al*., 2014) and nodulation, and thus enables plants to absorb more water and nutrients from depth of the soil. This in turn could enhance the plant's ability to produce more assimilates which were reflected in the high dry weight. The lowest RE was observed in control plant (25.15%) indicating B has tremendous effect on percent pod setting in groundnut. Boron plays an important role in retaining flowering and fruit setting in pulses (Ansari *et al*., 2014). In the present experimental results, boron added plants showed higher RE than control plants indicating boron added groundnut plant has more capability to retain pods than control plant (where no boron was added). Varietal variation was also observed in chlorophyll, nitrate reductase, TDM and flower production and RE except total sugar content in leaves. The highest chlorophyll content in leaves (1.71 mg g^{-1} fw) and TDM (11.62 g plant^{-1}) was recorded in Binachinabadam-2 while the highest flower numbers (35.58 plant^{-1}) and RE (42.54 %) were observed in Binachinabadam-1.

Table 1. Effect of boron on physiological parameters and reproductive characters in groundnut varieties

Treatments	Physiological parameters				Reproductive characters	
	Chlorophyll (mg g^{-1} fw)	Total sugar (mg g^{-1} fw)	Nitrate reductase (µmol NO_2^- g^{-1} fw)	Total dry mass plant^{-1} (g)	Flowers plant^{-1} (no.)	Percent pods to opened flowers
Doses of boron (kg ha^{-1})						
0	1.66 bc	71.2 bc	0.28 c	13.04 e	26.5 d	25.2 f
1.5	1.70 b	80.0 a	0.34 b	16.03 d	34.0 c	37.4 cd
2.0	1.78 ab	80.5 a	0.40 a	18.39 c	40.3 b	39.8 c
2.5	1.80 a	82.3 a	0.43 a	21.03 a	44.1 a	46.5 a
3.0	1.82 a	79.6 b	0.44 a	20.02 b	35.7 c	43.4 ab
3.5	1.56 c	67.0 c	0.30 c	11.75 f	24.7 d	35.0 e
F-test	**	**	**	**	**	**
Varieties						
Binachinabadam-1	1.69 a	75.9	35.5 a	16.01 b	35.6 a	42.5 a
Binachinabadam-2	1.71 a	76.1	34.4 ab	17.42 a	34.8 a	38.5 b
Binachinabadam-3	1.52 b	75.0	32.9 b	16.69 ab	32.3 b	32.6 c
F-test	**	NS	*	*	*	**
CV (%)	4.93	8.67	5.98	4.73	6.92	6.52

In a column, within treatment, same figure (s) indicates do not differ significantly at $P \leq 0.05$ by DMRT

For yield attributes and yield, results indicated that number of pods, single pod weight, pod yield and harvest index increased with increasing levels of boron application till 2.5 kg B ha^{-1} followed by a decline (Table 2). The highest number of pods plant^{-1} (20.67), single pod weight (832 mg), pod weight plant^{-1} (16.09 g) and harvest index (43.35%) was observed in 2.5 kg B ha^{-1}. In contrast, application of B @ 3.5 kg ha^{-1} showed the lowest number of pods and pod yield (8.60 pods plant^{-1} and 6.94 g plant^{-1}, respectively). Among the varieties, Binachinabadam-1 produced the highest number of pods (15.92 plant^{-1}), resulting the highest pod yield (12.81 g plant^{-1}) and Binachinabadam-3 showed the lowest pod yield (9.54 g plant^{-1}) due to production of fewer numbers of pods.

Table 2. Effect of boron on yield attributes and yield in groundnut varieties

Treatments	Number of pods plant^{-1}	Single pod weight (mg)	Pod weight plant^{-1} (g)	Harvest index (%)
Doses of boron (kg ha^{-1})				
0	9.61 d	782 b	7.15 d	35.41 c
1.5	12.75 c	810 a	10.55 c	39.68 b
2.0	16.10 b	825 a	14.06 b	43.33 a
2.5	20.67 a	832 a	16.09 a	43.35 a
3.0	15.58 b	833 a	13.00 b	39.37 b
3.5	8.60 e	813 a	6.94 d	37.13 bc
F-test	**	**	**	**
Variety				
Binachinabadam-1	15.92	804 b	12.81 a	44.45 a
Binachinabadam-2	14.42	808 b	11.55 b	39.87 b
Binachinabadam-3	11.31	835 a	9.54 c	36.37 b
F-test	**	*	**	**
CV (%)	7.04	2.92	6.50	7.88

In a column, within treatment, same figure (s) indicates do not differ significantly at $P \leq 0.05$ by DMRT

Interaction effect between variety and boron dose on number of pods, harvest index and pod yield plant^{-1} was significant but non-significant in pod size (single pod weight) (Table-3). The higher number of pods, harvest index and pod yield was observed at 2.5 kg B ha^{-1} with Binachinabadam-1 and Binachinabadam-2 being the highest in BINA chinabadam-1 × 2.5 kg B ha^{-1} (25.50 plant^{-1} and 20.78 g plant^{-1}, respectively). Binachinabadam-3 showed the highest pod yield under 3.0 kg B ha^{-1}. Control plants showed the lowest pod yield due to production of less number of pods and smaller pod size. Both absolute boron deficient and luxurious condition, grey colour in the leaf edges was observed and the plants became stunted (visual observation, not shown in Table). Many researchers reported increased yield of different crops with application of boron (Singh, 2001; Shankhe *et al*, 2003; Singh *et al*., 2014) that supported the present results. However from the results, it is clearly brought out the need and the benefit of application of boron for improving groundnut production in Bangladesh.

Table 3. Interaction effect between varieties and doses of boron on yield attributes and yield in groundnut varieties.

Interaction		Number of pods plant^{-1}	Single pod weight (mg)	Pod weight plant^{-1} (g)	Harvest index (%)
Varieties	Doses				
Binachinabadam-1	0	10.25 i	770	7.50 g	37.04 f
	1.5	12.50 fgh	800	10.19 ef	41.95 d
	2.0	15.80 d	815	15.88 c	48.19 ab
	2.5	25.50 a	817	19.78 a	49.67 a
	3.0	19.00 c	820	15.49 c	45.48 b
	3.5	12.50 fgh	800	10.00 ef	41.81 d
Binachinabadam-2	0	11.25 ghi	780	7.95 g	35.30 f
	1.5	15.00 de	801	12.25 d	40.78 de
	2.0	18.75 c	817	15.32 c	43.90 c
	2.5	21.25 b	820	16.36 b	42.94 cd
	3.0	13.00 fg	823	10.62 e	49.26 a
	3.5	7.30 j	810	5.77 h	36.78 f
Binachinabadam-3	0	7.33 j	795	6.01 h	33.78 g
	1.5	10.75 hi	828	9.22 f	36.24 f
	2.0	13.75 ef	842	10.97 e	37.21 f
	2.5	15.25 de	858	12.12 d	35.85 f
	3.0	14.75 de	860	12.90 d	38.56 e
	3.5	6.00 j	825	5.04 h	30.68 h
F-test		*	NS	*	**
CV (%)		7.04	2.92	6.50	7.88

In a column, same figure (s) indicates do not differ significantly at $P \leq 0.05$ by DMRT

Conclusion

Application of B @ 2-2.5 kg ha^{-1} may be used for getting higher pod yield of groundnut.

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PATTERN OF ORGANIC RESIDUE DECOMPOSITION IN SALINE SOILS

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Abstract

A pot experiment was conducted to investigate the decomposition of incorporated organic residues in saline soil at the Laboratory of Soil Science Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh. The experiment was arranged in completely randomized design (CRD) with three replications involving four levels of salinity , S_0 = non saline water (0.7 dS m^{-1}), S_1 = 5 dS m^{-1} saline water, S_2 =10 dS m^{-1} saline water and S_3 = 20 dS m^{-1} saline water and three treatments of organic crop residues (C_0 = no incorporation of crop residue, C_1 = incorporation of rice residue @ 10 t ha^{-1} and C_2 = incorporation of groundnut residue @ 10 t ha^{-1}). Decomposition rate of organic crop residues were decreased with the increase of salinity level irrespective of crop residues. The decomposition rate of crop residues varied between 0.63 and 0.71 % per day. The highest decomposition rate (0.71% per day) was observed in non-saline soil (0.7 dS m^{-1} salinity level) and the lowest decomposition rate (0.63% per day) was observed at 20 dS m^{-1} salinity level. The decomposition rate of groundnut residue (0.72% per day) was higher compared to rice residue (0.64% per day). Approximately, 58% rice and 64% groundnut residues were decomposed within 90 days of incubation. The overall results suggest that organic residue decomposition was inversely correlated to the extent of soil salinity.

Key words: Soil salinity, Crop residue decomposition, Soil pH and EC

Introduction

Bangladesh is a deltaic country with total area of 147,570 km^2. The major part (80%) of the country consists of alluvial sediments deposited by the rivers Ganges, Brahmaputra, Tista, Jamuna, Meghna and their tributaries. Terraces with an altitude of 20-30 m cover about 8% of the country, while hilly areas with an altitude of 10-1000 m occur in the southeastern and northeastern part. The coastal region covers almost 29,000 km^2 or about 20% of the country and about 53% of the coastal areas are affected by salinity (Haque, 2006).

Agriculture is the most important sector of Bangladesh's economy. More than 30% of the cultivable land in Bangladesh is in the coastal area. Out of 2.86 million hectares of coastal and off-shore lands about 1.056 million ha of arable lands are affected by varying degrees of salinity, resulting in very poor land utilization (SRDI, 2010). These coastal saline soils are distributed unevenly in 64 upazilas of 13 coastal districts covering portions of 8 agro-ecological zones of the country. It is mentioned that coastal regions of Bangladesh are quite lower in soil fertility (Haque, 2006). Salinity largely reduces the yield of crop in the coastal areas of the country mainly in Khulna, Jessore, Bagerhat, Borguna, Patuakhali, Noakhali and Chittagong districts and in the islands of Bay of Bengal like Bhola, Hatiya and Sandip. Usually 30-50% yield losses occur depending on the level of soil salinity. According to the intergovernmental panel on climate change (IPCC), crop production may fall by 10-30% by 2050 in Bangladesh due to climate change (IPCC, 2007). The severity of salinity problem in Bangladesh increases with the desiccation of the soil. It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Soil reaction values (pH) in coastal regions range from 6.0-8.4. The organic matter content of the soils is also low (1.0-1.5%). Nutrient deficiencies of N and P are quite dominant in saline soils. Deficiencies of micronutrients such as Cu and Zn are also widespread in saline soils (Haque, 2006). Application of crop residues will supply the nutrients in addition to improving physical, chemical and biological properties of soil towards improving and conserving the soil fertility.

The management of crop residues has become an important aspect of sustaining long-term fertility in cropping systems. Crop residue decomposition is a complex process strongly affected by environmental factors, crop residue composition and soil native organisms (FAO, 2003). Several mechanisms are well understood while others such as the effect of frequent crop residue addition, mixing of residues of different quality, spatial interactions between crop residues and saline soil are poorly understood although crop residues

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can be added to the soil continuously, often in mixtures of residues from different crop species in the presenceof growing plants.These knowledge gaps were addressed in the present study.

However, few research works have been conducted in Bangladesh regarding the available nutrient release pattern and their effects on saline soil. With such information in views, the present study was undertaken to analyze the decomposition rate of rice and groundnut residues in saline soils and to see the changes in pH and EC values in organic residue amended saline soil.

Materialsand Methods

A pot experiment was laid out in a completely randomized design (CRD) with three replications at the Laboratory of Soil Science Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. The treatment consists of two factors, such as – i) Four levels of saline water and ii) Three types of crop residue,which were analyzed under different incubation periods (seven harvest date) following destructive method. Hence, totally 252 (two hundred fifty two) pots were required (4 levels of salinity × 3 types of crop residue × 7 harvest time ×3 replication = 252) for the implementation of the study as follows:

Factor-1 (Saline water):S_0 = Normal water (0.7 dS m^{-1}); S_1 = Saline water with 5 dS m^{-1}; S_2 = Saline water with 10 dS m^{-1} and S_3 = Saline water with 20 dS m^{-1}

Factor-2 (Crop residue):C_0 = No incorporation of crop residue; C_1 = Incorporation of rice residue @ 10 tha^{-1} and C_2 = Incorporation of groundnut residue @ 10tha^{-1}

Time of the soil harvest:H_0 = 0 days after incubation = 0 DAI; H_1 = 15 days after incubation = 15 DAI; H_2 = 30days after incubation = 30 DAI; H_3 = 45 days after incubation = 45 DAI; H_4 = 60 days after incubation = 60 DAI; H_5 = 75 days after incubation = 75 DAI and H_6 = 90 days after incubation = 90 DAI

Eight grams (8g) of crop residue (from each rice and groundnut) were taken in a nylon mesh bag and kept in the soil of each pot for incubation. The experiment was designed to observe the decomposition pattern of tested crop residue and also monitor the changing pattern of soil pH and EC value of incubated soil.

Soil pH was determined by glass electrode pH meter as described by Ghosh*et al.* (1983). Fifteen gram of incubated soil was taken in a plastic container and 50 ml of distilled water was added to it. The suspension was shaken for half an hour and allowed to stand for about an hour and pH value was measured. To measure electrical conductivity, 10 mL of extracted sample was taken in a beaker and EC of the samples was measured with the help of EC meter (Model- D.6072 Dreieich, West Germany) following the method as outlined by Ghosh*et al.* (1983) and Singh and Parwana (1999).

Results and Discussion

From the study, it was observed that the decomposition rates of crop residues were decreased with the increase of salinity level irrespective of crop residues. Within the 90 days incubation period, crop residues were decomposed as 64, 63, 60 and 56% in 0.7, 5, 10 and 20 dS m^{-1} salinity level, respectively (Fig. 1). The decomposition rate of rice and groundnut residues are depicted in Fig.2. The decomposition rate of crop residues seems quite faster. Hot and humid climate of Bangladesh and incubation environment (waterlogged situation) help this rapid decomposition. The congenial environmental conditions associated with the leaching losses of readily digestible water soluble compounds from the crop residues might have triggered the activity of soil fauna and soil microbes, which are responsible for this decomposition.

Saline soils are characterized by high concentrations of soluble salts and low organic matter and nitrogen content (Asmalodhi*et al*., 2009). The decrease of decomposition with the increase of salinity level might be the depressing of microbial activity at high salinity level (Anjum*et al*., 2005). Changes in soil pH during decomposition of rice and groundnut residues under different level of soil salinity were presented in Fig 3 to Fig 6. In case of 0.7 dS m^{-1} salinity level (non saline), pH value increased initially and maximum pH value was found 5 for control, 5.2 for rice and 5.45 for groundnut at 90, 90 and 60 DAI, respectively. The pH value increased up to 15 days, then decreased up to 60 DAI and then increased up to 90 DAI in control soil. However, in groundnut residue treated soil, pH value increased up to 60 DAI and then decreased up to 75 days. In rice residue treated soil, pH value remain unchanged up to 30 days and then increased up to 60 days, then it decreased up to 75 days. After 75 days it was increased up to 90 DAI. Between the residues, maximum pH value was found for groundnut residues. Changes in electrical conductivity during decomposition of rice and groundnut residues under different level of soil salinity were presented in Fig 7 to Fig 10. In case of 0.7 dS m^{-1} salinity level (non saline), EC increased up to 45 DAI for all the treatments and then changed irregularly. However, the increase of EC was much higher in residue-treated soil compared to control. Initially EC value increased in groundnut residue-treated soil. It increased up to 75 DAI in groundnut residue and reached to maximum EC point (6.97 dS m^{-1}). After 75 days it declined. In case of rice residue, the EC value increased initially. After 15 days it decreased up to 30 days and then increased again. After 60 days it was increased again. The maximum EC value was recorded at 90 DAI (6.89 dS m^{-1}) and the minimum was at 0 DAI (6.64 dS m^{-1}). Between the residues, maximum EC value was found for groundnut residue-treated soil (Fig 7).

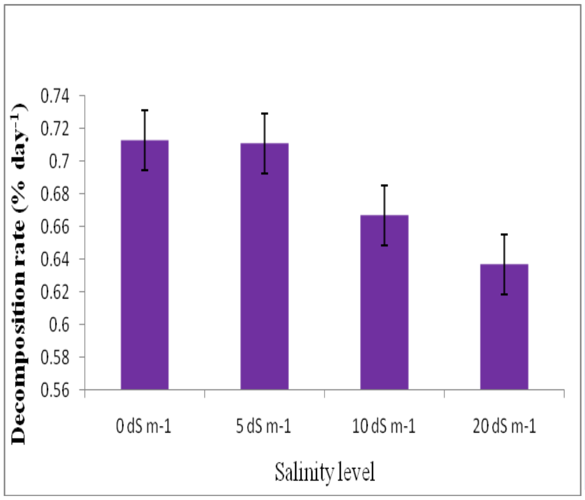

Fig. 1. Crop residue decomposition rate at different salinity levels

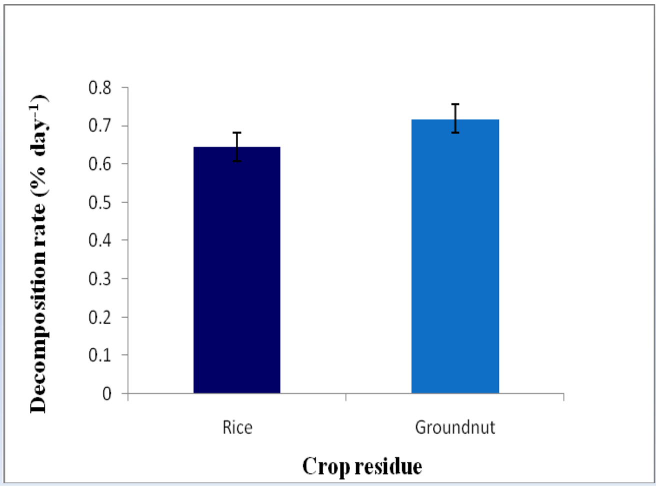

Fig. 2. Decomposition rate of different crop residues

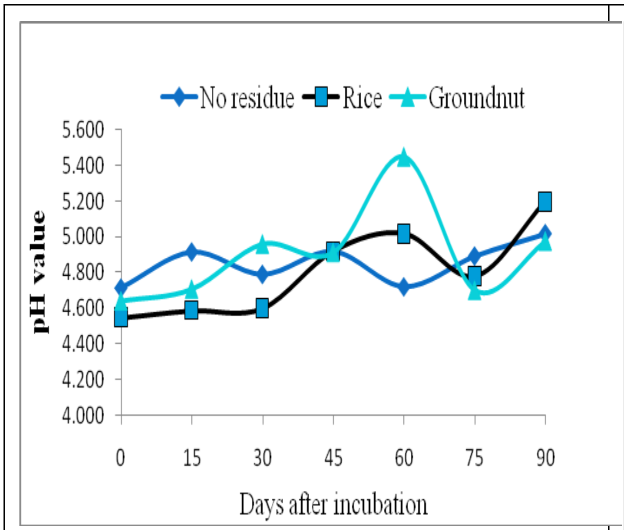

Fig. 3. Changes in pH value of different crop residue treated soils at normal water (0.7 dS m^{-1})

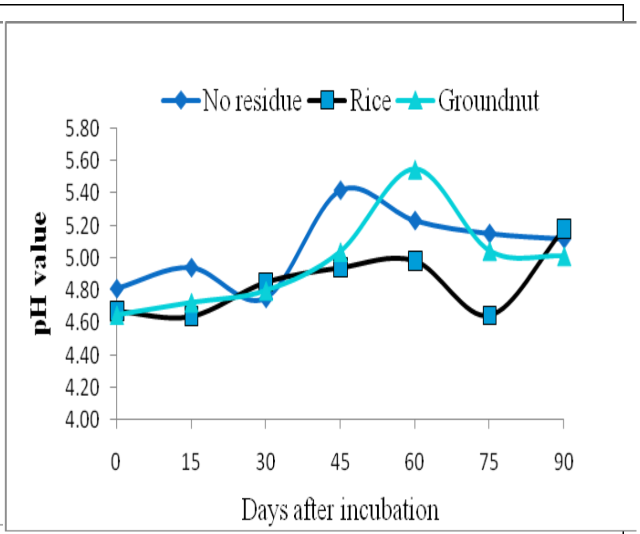

Fig. 4. Changes in pH value of different crop residue treated soils at 5 dS m^{-1} salinity level

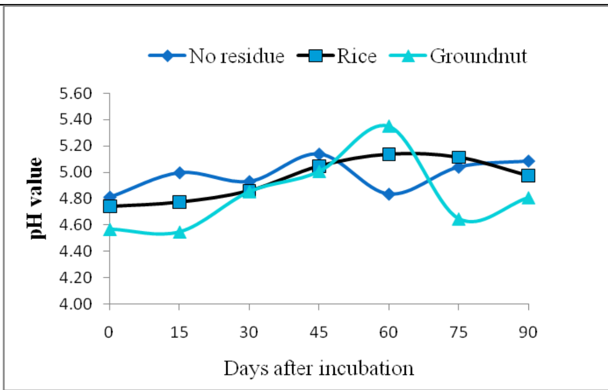

Fig. 5 . Changes in pH value of different crop residue treated soils at 10 dS m^{-1} salinity level

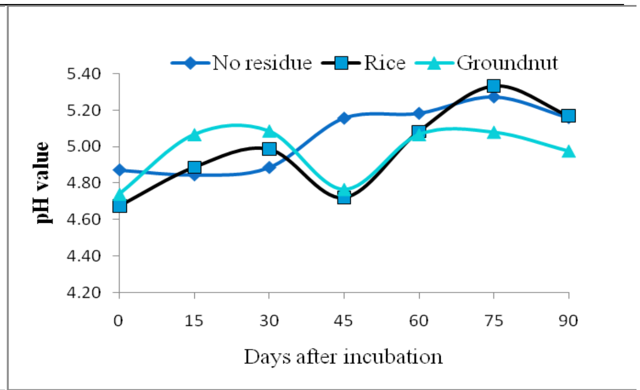

Fig. 6 . Changes in pH value of different crop residue treated soils with 20 dS m^{-1} salinity level

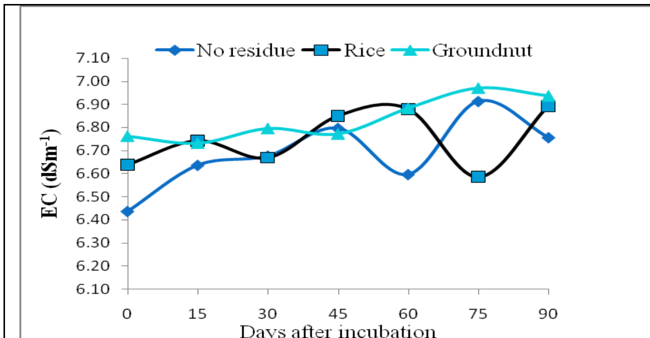

Fig. 7. Changes in EC value of different crop residue treated soils at normal water (0.7 dS m^{-1})

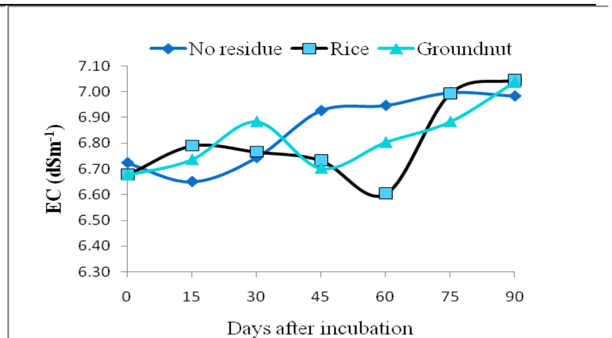

Fig. 8. Changes in EC value of different crop residue treated soils at 5 dS m^{-1} salinity level

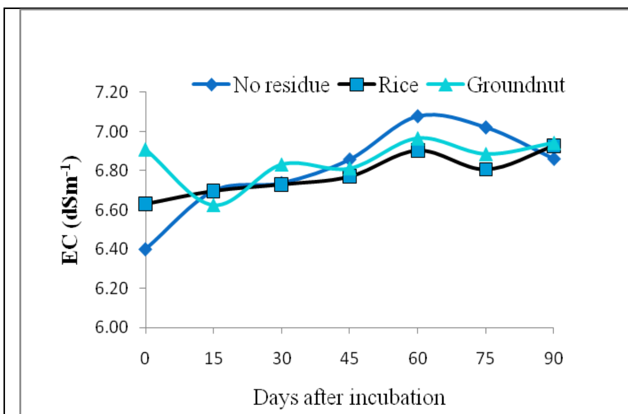

Fig. 9 . Changes in EC value of different crop residue treated soils at 10 dS m^{-1} salinity level

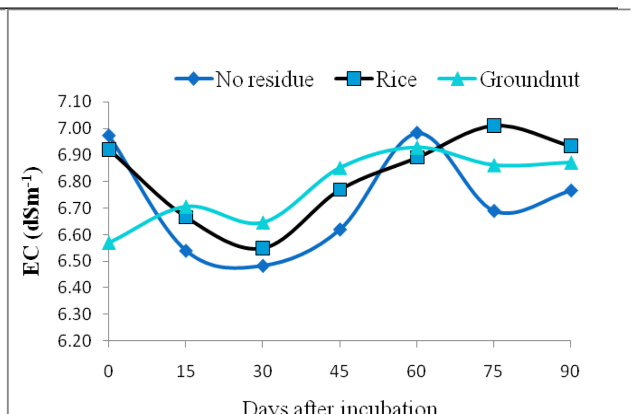

Fig.10 : Changes in EC value of different crop residue treated soils at 20 dS m^{-1} salinity level

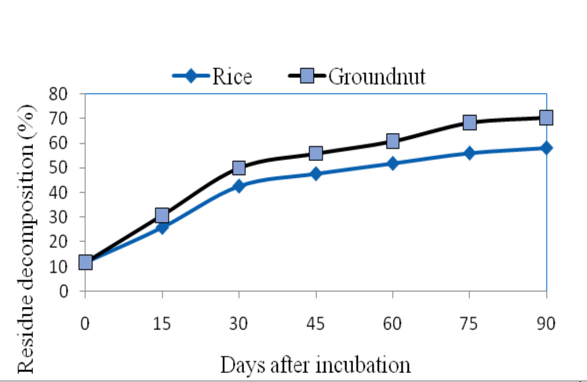

Fig. 11: Decomposition pattern of different crop residues at 0.7 dS m^{-1} salinity level

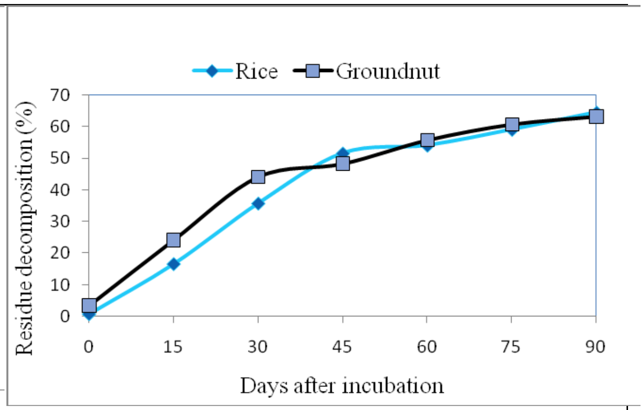

Fig. 12: Decomposition pattern of different crop residues at 5 dS m^{-1} salinity level

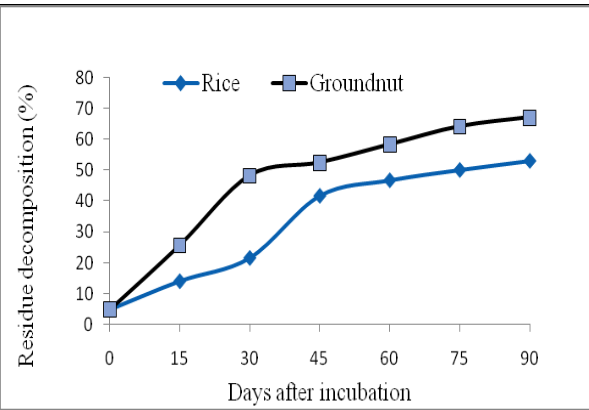

Fig. 13: Decomposition pattern of different crop residues at 10 dS m^{-1} salinity level

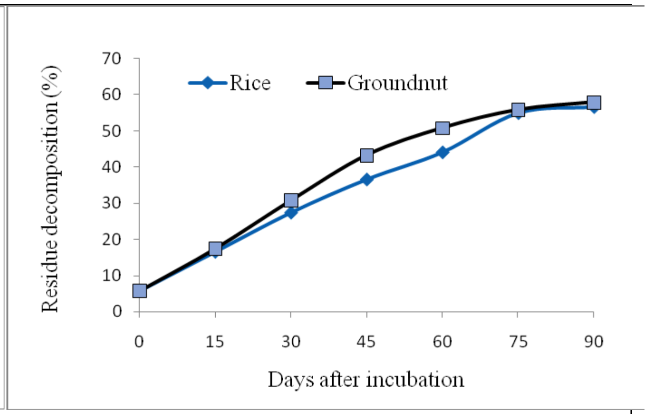

Fig. 14 : Decomposition pattern of different crop residues at 20 dS m^{-1} salinity level

Conclusion

Decomposition rate of organic crop residues were decreased with the increase of salinity level and the decomposition rate varied between 0.63 and 0.71 % per day. The decomposition rate of groundnut residue (0.72% per day) was higher compared to rice residue (0.64% per day) and approximately, 58% rice and 64% groundnut residues were decomposed within 90 days of incubation. The overall results suggest that organic residue decomposition was inversely correlated to the extent of soil salinity.

The obtained findings may lead to conclude that decomposition rate of crop residue was decreased with the increasing of soil salinity. Release of N from rice and groundnut residue was relatively same; but higher in groundnut compared to rice residue soil and control soil. Release of N from crop residues depends on the quality of crop residue predominantly the C:N ratio of crop residue. Since the C:N ratio of everything in and on the soil can have a significant effect on crop residue decomposition, particularly residue cover on the soil and crop nutrient cycling predominantly nitrogen. There was a difference in the rate of N mineralization for different residues but the difference was insignificant.

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IMPACT OF MORPHO-PHYSIOLOGICAL TRAITS ON SEED YIELD IN RAPESEED

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Abstract

The field experiment was conducted at the experimental farm of the Bangladesh Institute of Nuclear Agriculture, Mymensingh, during the period from November 2014 to February 2015 to investigate morpho-physiological characters, yield attributes and seed yield in three mustard mutants *viz.*, MM 05, MM 25 and MM 98 along with a check variety, Binasarisa-4. Leaf area (LA), leaf area index (LAI) and AGR increased till 65 days after sowing followed by a decline due to leaf shedding at later growth stages. The mutant MM 05 showed superiority in respect of branch number, TDM, LA, and growth parameters like LAI and AGR at most of the growth stages and also produced the highest seed yield whilst Binasarisa-4 and MM 98, the low yielding genotypes, showed the inferiority in case of plant height, branch number, LA, LAI and AGR. Moreover, high yielding genotypes showed superiority in chlorophyll content, photosynthesis, total sugar content and nitrate reductase activity in leaves. The highest seed yield both plant^{-1} (2.88 g) and hectare^{-1} (2218 kg) was observed in MM 05 because of production of higher number of siliquae plant^{-1}, seeds siliqua^{-1} and had capacity to superior dry matter partitioning to economic yield. In contrast, the lowest seed yield both plant^{-1} and hectare^{-1} was observed in MM 98 and BINAsarisa-4 due to inferiority in growth and yield contributing characters.

Key words: Rapeseed, Morpho-physiological traits, Seed yield

Introduction

Mustard (*Brassica* spp.) is one of the most important oil crops of global economic importance. About ten oil crops are grown in Bangladesh. Among these, Brassica oil crop is the most important group of the species that supplies major edible oil in Bangladesh. It covers about 80% of the total oilseed acreage and about 71% of the total production (BBS, 2016). Mustard oil is used mostly for edible purpose and a part finds industrial applications. Oil cake is used as manure and animal feed. The seeds contain 40-45% oil and 20-25% protein.

At present, the oil seed production is about 0.35 million tons, which covers only 28% of the domestic need (BBS, 2016). More than 70% of requirement of oil has been imported every year by spending huge amount of foreign currency involving over Tk. 4100 Crore (BBS, 2016). In Bangladesh, the seed yield of mustard/rapeseed is about 960 kg ha^{-1} which is very low in comparison to other developed countries (2400 kg ha^{-1}) (FAO, 2016). The low yield is due to lack of high yielding varieties and improper agronomic practices. That is why, improvement of existing oilseed crops and introduction of a new oilseed crop species as well as proper cultural management practices need urgent attention to meet increasing demand of edible oils for the fast growing population of Bangladesh. To keep pace with the present population growth and oil seed production, the modern variety with mustard area need to be expanded by replacing the local low yielding cultivars under cultivation, and the seed yield per unit area is needed to be increased. There is very little scope for horizontal expansion of mustard area. However, there remains a potential scope where more than 60% of the area is cultivated by the low yielding local cultivars (mainly Tori-7), which should be replaced by the modern varieties developed at different Institutes. Furthermore, the wide gap between achievable (2.4 t ha^{-1}) and average yield (0.96 t ha^{-1}) should be reduced.

The main constraint of mustard production is its low yield potential. From 30 to 50% of mustard flowers do not develop into mature pods (Mondal and Malek, 2017) 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 increases after growth stage R1 (Fruit setting stage) and reaches to a maximum after growth stage R5 (maximum seed growth stages) (Mondal *et al*, 2012; Mondal *et al,* 2013) but during this period the plant is still growing vegetatively. Therefore, developing reproductive sinks are competing for assimilates with vegetative sinks. It is evident that seeds per unit area are related to canopy photosynthesis during flowering and pod set. 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 (Malek *et al*., 2012; Mondal *et al*, 2013). A plant with optimum LAI and

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NAR may produce higher biological yield. The capability of efficient partitioning between the vegetative and reproductive parts may produce high economic yield (Mondal *et al*., 2014). For optimum yield in mustard, the LAI should be ranged from 3.5 to 4.5 (Bhat *et al*., 2006). Any reduction of leaf area or the amount/intensity of light may have an adverse effect on yield (Mondal *et al*., 2011). The dry matter accumulation may be the highest if the LAI attains its maximum value within the shortest possible time (Mondal *et al*., 2014).

Recently, BINA has developed three promising mustard mutants (MM 05, MM 25 and MM 98) of high yield potentials. These mutants need to be assessed for their physiological growth and morphological maneuvering that takes place compared to the existing mustard cultivars. Hence, the present research work has been designed to study morpho-physiological parameters, biochemical, reproductive characters and other yield attributes responsible for higher seed yield. Thus, the research work was undertaken to evaluate the growth and development of three elite mustard mutants compared to the existing variety, Binasarisa-4; and to select better genotype in respect to growth, biochemical, reproductive, yield and yield components in mustard.

Materials and Methods

The field experiment was performed at the experimental field of Bangladesh Institute of Nuclear Agriculture, Mymensingh during November 2014 to February 2015. Three advanced mutants (MM 05, MM 25 and MM 98) and one variety (Binasarisa-4) of mustard were used as treatment in the experiment. The experiment was laid out in a Randomized Complete Block Design with 3 replications. The size of the unit plot was 4 m x 3 m. Plant to plant distance was 6 cm and row to row distance was 30 cm. Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and borax were used as source of nitrogen, phosphorus, potassium, sulphur and boron, respectively. Total amount of TSP, MP, gypsum, borax and half of urea were applied at basal doses during final land preparation. The rest half of urea were applied as top dress at 21 days after sowing. The doses of fertilizers were: urea 250, TSP 160, MP 80, gypsum 180 and borax 2.0 kg ha^{-1}. The seeds of mustard were hand sown in rows on 10 November, 2014. Seeds were placed at about 3-4 cm depth from the soil surface. Plants were thinned to 5-8 cm distance from one another at 20 days after sowing (DAS). Weeding was done once at 20 DAS only. Two irrigations were applied. The first irrigation was applied at 21 DAS and second one at 45 DAS. Insecticide (Malathion 57 EC at 0.025%) was sprayed at flowering and fruiting stages (30 and 45 DAS) to control aphid.

To study ontogenetic growth characteristics, a total of six harvests were made and at final harvest, data were collected on some morpho-physiological parameters, yield attributes and yield. The first crop sampling was done at 35 DAS and continued at an interval of 10 days up to 90 DAS. 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 0C for 72 hours. The leaf area of each sample was measured by automatic leaf area meter (Model: LICOR 3000). The growth analyses like AGR, RGR and NAR were carried out following the formulae of Hunt (1978). Photosynthesis was measured at flowering and pod development stage by portable photosynthesis meter ((LI-6400XT, USA). Leaf chlorophyll was determined by following the method of Yoshida *et al*. (1976). Total sugar was determined following the method of Dubois *et al*. (1956). NRase was estimated following the procedure of Stewart and Orebanjo (1979). Reproductive efficiency was calculated by dividing total reproductive unit to siliqua number of plant multiplying with 100 and expressed in percentage.

The yield contributing characters were recorded at harvest from ten competitive plants of each plot. The seed yield was recorded from five rows of each plot (2.50 m × 3.0 m) and converted into seed yield $hectare^{-1}$ and seed weight $plant^{-1}$ was determined by dividing the plant number. Harvest index was calculated from the collected data using formula: (economic yield $plot^{-1}$ ÷ biological yield $plot^{-1}$) × 100. The collected data were analyzed statistically by using computer package program, MSTAT-C.

Results and Discussion

Morphological and biochemical parameters

The effect of mutants/variety on days to maturity, morphological characters such as plant height and number of branches $plant^{-1}$, biochemical parameters such as total sugar, nitrate reductase and photosynthesis was significant except chlorophyll content in leaves (Table 1). The two mutants, MM 05 and MM 25 took 96 days for maturity and Binasarisa-4 took the longest days (100 days) to maturity while MM 98 matured the earliest (93.1 days). The mutant MM 25 was the tallest plant (83.3 cm) followed by MM 05 (81.3 cm) with same statistical rank. The shortest plant height was recorded in MM-98 (75.8 cm) which was statistically similar Binasarisa-4 (76.6 cm). The highest number of branches $plant^{-1}$ was recorded in MM 05 and the lowest was recorded in Binasarisa-4. These results are in agreement with the result of Mondal *et al*., (2003) and Malek *et al*. (2014) who stated that days to maturity, plant height and number of branches $plant^{-1}$ differed significantly among the studied genotypes in mustard.

Table 1. Variation in days to maturity, some morphological and biochemical parameters of 3 rapeseed mutants along with check variety

Mutants/ variety	Days to maturity	Plant height (cm)	Number of branches $plant^{-1}$	Chlorophyll (mg g^{-1}fwD)	Photosynthesis (µmol CO_2 s^{-1} dm^{-2})	Nitrate reductase (µmol NO_2^- g^{-1} fw)	Total sugar (mgg^{-1}fw)
MM 05	96.0 b	81.3 a	2.80 a	2.03	14.22 a	6.66 a	63.50 a
MM 25	96.0 b	83.3 a	2.25 b	1.98	13.85 a	5.42 b	58.21 a
MM 98	93.1 c	75.8 b	2.51 ab	2.13	11.11 c	5.12 b	50.11 b
Binasarisa-4	100.0 a	76.6 b	2.45 b	2.10	12.00 b	5.60 b	48.60 b
F-test.	**	**	*	NS	**	**	**
CV (%)	2.49	5.41	11.56	4.09	3.50	4.14	6.71

In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; *, ** indicate significant at 5% and 1% level of probability, respectively; NS = Not significant

High yielding mutants showed higher chlorophyll, phosynthates, total sugar content in leaf, nitrate reductase activity than low yielding ones. It means photosynthesis, NR activity are positively correlated with yield. The highest photosynthesis (14.22 µmol CO_2 s^{-1} dm^{-2}), nitrate reductase and total sugar was observed in MM 05, the high yielding mutant and the lowest/lower was recorded in MM 98, the low yielding mutant.

Growth parameters

The development of leaf area (LA) and leaf area index (LAI) over time in mustard mutants/variety is presented in Fig. 1. Result revealed that LA and LAI increased till 65 DAS followed by a sharp decline because of leaf shedding. The increment of LA and LAI varied significantly due to mutants/variety at all growth stages. At peak LA and LAI developmental stage (65 DAS), the mutant MM 05 showed the highest LA (587.4 cm^2 $plant^{-1}$) and LAI (3.6) followed by MM 25 (500.0 cm^2 $plant^{-1}$). The lowest LA and LAI were recorded in Binasarisa-4 at most of the growth stages. The variation in LA and LAI might occur due to the variation in number of leaves and the expansion of leaf. The results obtained from the present study are

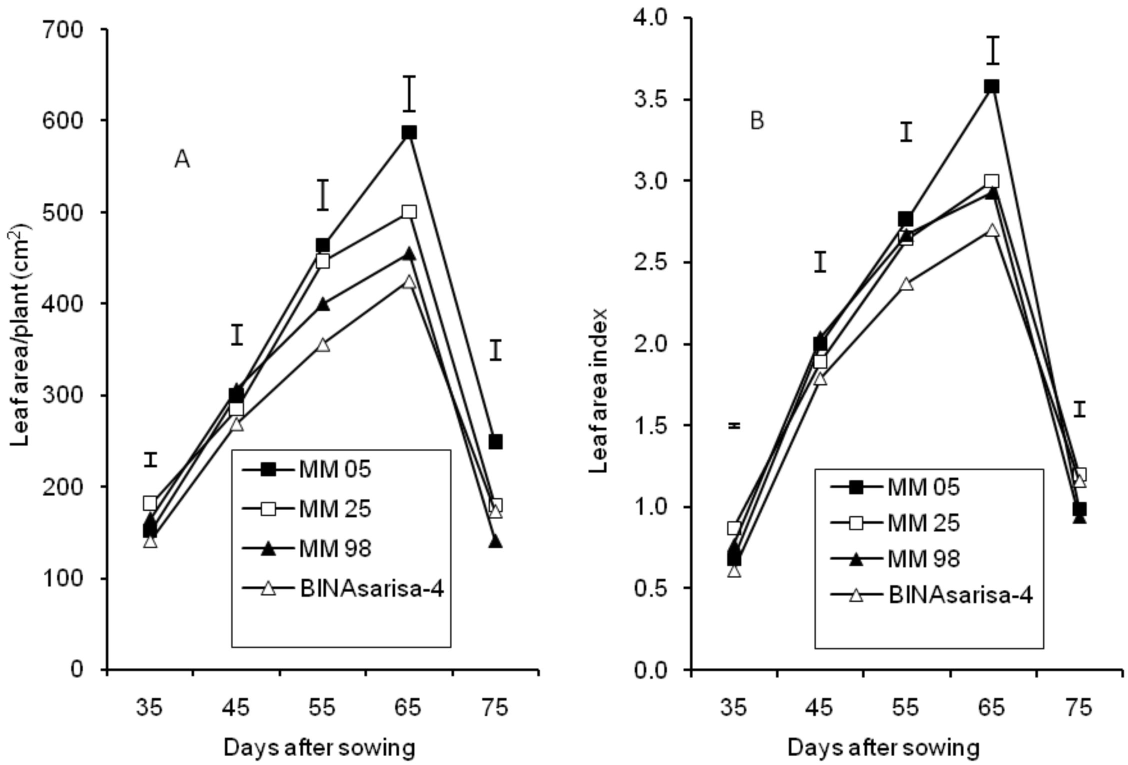

Fig. 1. Variation in (A) leaf area $plant^{-1}$ and (B) leaf area index in four rapeseed mutants/variety at different growth stages. Vartical bars represent LSD (0.05)

consistent with the result of Mondal *et al*. (2014) who stated that the variation in LAI could be attributed to the changes in the number of leaves and rate of leaf expansion and abscission.

Result revealed that TDM production increased with time up to near maturity (Fig. 2). The mutant MM 05 maintained the highest TDM at all growth stages and the lowest TDM was recorded in Binasarisa-4 at most of the growth stages. Increased TDM in MM 05 was possibly due to greater LAI (Fig. 1) and AGR (Fig. 2). Result further revealed that high yield genotypes produced higher TDM than the low yielding ones. The result is supported by the result of Mondal *et al.* (2015) who reported that TDM increased with increasing plant age up to physiological maturity.

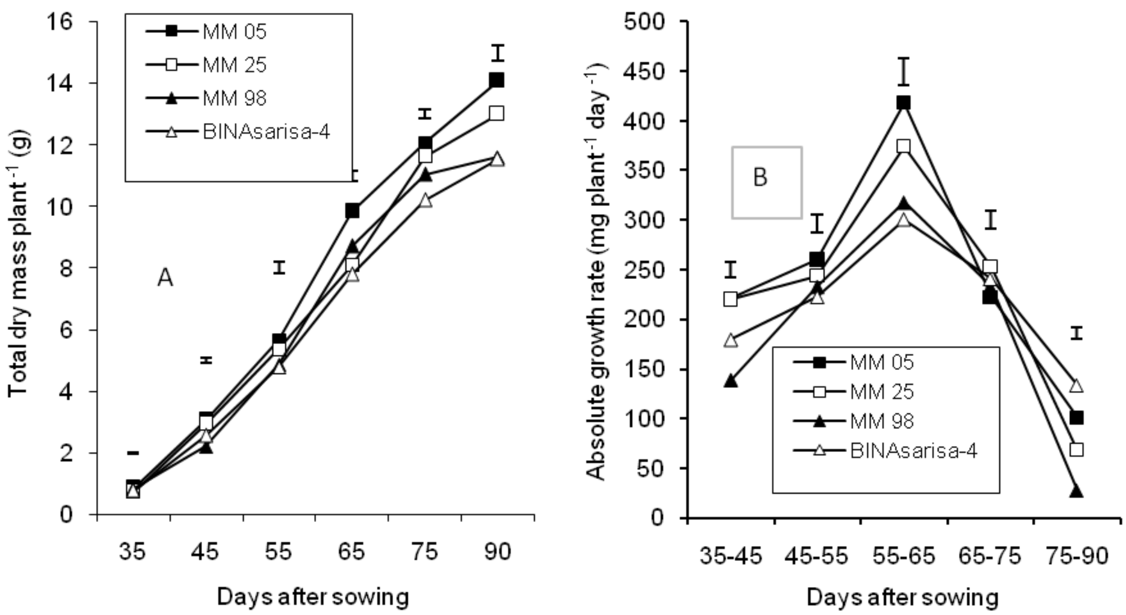

Fig. 2. Pattern of (A) total dry matter production and (B) absolute growth rate in four rapeseed mutants/variety during their growth period. Vartical bars represent LSD (0.05)

The AGR was increased till 65 DAS in all mutants/variety followed by a decline till physiological maturity (Fig. 2). The mutant MM 05 maintained the highest AGR value at 35-65 DAS. In contrast, Binasarisa-4 maintained the lower AGR at peak growth stages. The AGR was higher in MM 05 might be due to production of higher TDM plant^{-1}. The lower value of AGR at initial stages of growth was the result of lower LAI. This result is in agreement with the findings of Prasad *et al.* (1978). At 55-65 DAS, the AGR value was found to be maximum which mean that plants expanded it's assimilate for the growth of leaf area and feeding of pods. The declining of AGR after reaching the maximum in all genotypes might be the result of abscission of leaves. These results are consistent with the results of Malek *et al*. (2012).

Reproductive characters

The effect of mutants/variety on reproductive characters such as number of aborted flowers plant^{-1}, number of siliquae plant^{-1} and reproductive efficiency (RE) was significant (Table 2). The highest number of aborted flowers plant^{-1} was observed in Binasarisa-4 (24.60) followed by MM 25 (24.43) and MM 98 (22.87) with same statistical rank. In contrast, MM 05 showed the lowest number of aborted flowers plant^{-1} (20.43). Results revealed that there was a relation between RE and seed yield in mustard. MM 05, the high yielding mutants showed the highest RE (76.4%) followed by MM 25 (70.5%), the second highest yielder mutant. In contrast, MM 98, the lowest yielder mutant, showed the lowest RE (68.7%). Genotypic variation in RE was also observed by Mondal and Malek (2018) in mustard that supported the present experimental result. The highest number of siliquae plant^{-1} was recorded in MM 05 (66.0) and this mutant also produced the highest seed yield plant^{-1} (2.88 g) (Table 2). The second highest siliquae plant^{-1} was recorded in MM 25 (58.4) that also produced the second highest seed yield (2.27 g plant^{-1}). This result indicates that siliqua production is the most yields attributes for getting higher seed yield. The mutant MM 98 produced the lowest number of siliquae plant^{-1} (50.2). Mondal *et al.* (2003) studied 20 mutants/varieties based on

Table 2. Variations in reproductive characters, yield attributes and seed yield in four rapeseed mutants along with check variety

Mutants/ variety	Aborted flowers $plant^{-1}$ (no.)	RE (%)	Siliqua $plant^{-1}$ (no.)	Siliquae length (cm)	Seeds $siliqua^{-1}$ (no.)	1000-seed weight (g)	Seed weight $plant^{-1}$ (g)	Seed yield (kg ha^{-1})	Harvest index (%)
MM 05	20.4 b	76.4 a	66.0 a	6.27 a	23.1 a	3.78 a	2.88 a	2218 a	20.45 a
MM 25	24.4 a	70.5 b	58.4 b	6.13 a	22.4 ab	3.47 b	2.27 b	2067 ab	17.46 b
MM 98	22.9 ab	68.7 b	50.2 c	6.07 a	20.9 bc	3.28 b	1.72 d	1835 c	14.82 c
Binasarisa-4	24.6 a	69.4 b	55.8 bc	5.80 b	20.4 c	3.58 b	1.99 c	1911 bc	17.23 b
F-test	*	*	**	**	*	*	**	**	**
CV (%)	6.20	4.19	5.21	1.69	5.19	3.81	5.30	5.37	4.54

In a column, means followed by same letter (s) do not differ significantly at 5% level by DMRT; *, ** indicate significant at 5% and 1% levels of probability, respectively; RE = Reproductive efficiency

yield attributes and yield and reported that high yielding mutants produced higher number of siliquae $plant^{-1}$ that also supported the present experimental result.

The effect of mutants/variety on yield attributes and seed yield both per plant and per hectare was significant (Table 2). The highest seed yield both $plant^{-1}$ (2.88 g) and $hectare^{-1}$ (2218 kg) was observed in MM 05 because of production of higher number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$ and bolder seeds. The mutant MM 05 also showed the highest harvest index (20.45%). In contrast, the mutant MM 98 had the lowest HI (14.82%). The mutant MM 98 was a low yielding mutants and also showed lower HI which indicating that dry matter partitioning to economic was poor in MM 98 than the others while reverse trend was observed in MM 05, the high yielding mutant. In contrast, the lowest seed yield both $plant^{-1}$ and $hectare^{-1}$ was observed in MM 98 due to production of lowest number of siliqua $plant^{-1}$ and smaller seed size.

Conclusion

Based on the experimental results, it may be concluded that high yielding mutants have taller plant, having higher number of branches, higher LA as well as LAI, TDM and AGR which resulted higher number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$ than the low yielding ones in rapeseed.

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EVALUATION OF MUNGBEAN MUTANTS AGAINST YELLOW MOSAIC AND CERCOSPORA LEAF SPOT

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Abstract

Ten advanced Mungbean mutants were evaluated along with five varieties against yellow mosaic (MYM) and cercospora leaf spot (CLS) during Kharif-I season in 2014 and 2015 under field conditions at BINA sub-station, Ishurdi, Pabna. The mutant/varieties were categorized into resistant and susceptible depending upon severity of the diseases (0- scale). The induced mutants MBM-390-94-y, MBM-427-87-3, MBM-347-13 and MBM-07-y-1 were recorded as moderately resistant to yellow mosaic and the mutants MBM-390-94-y, MBM-656-52-2, MBM-427-87-3, MBM-347-13, MBM-07-y-1 and MBM-07-g-2 were found as moderately resistant to cercospora leaf spot. None of the mutants was found to be resistant to the diseases. Considering yield contributing characters, the mungbean mutants MBM-347-13 and MBM-07-y-1 were found superior than others and these were found to be moderately resistant to yellow mosaic ad CLS. Therefore, these two mutants could be used in breeding programme for the development of yellow mosaic and cercospora leaf spot resistant mungbean variety in Bangaldesh.

Key words: Mungbean, mutant, resistance, yellow mosaic, cercospora leaf spot.

Introduction

Mungbean (*Vigna radiata* L. wilczek) is one of the most important pulse crops in Bangladesh and the third most important pulse crop in south and southeast Asia. More than 90% of global mungbean production occurs in this region. As mungbean is a short duration crop and high demand, it can well fit as a cash crop between major cropping patterns in Bangladesh. It is grown two seasons (Kharif-I and Kharif-II) in a year covering 205700 ha area with total production of 225500 metric tons (Krishi Diary, 2017). It contributes 23% of total pulse area and 22% production in the country (Krishi Diary, 2017). It provides seed for human consumption and the plants fix substantial amount of nitrogen in addition of organic matter to the soil (Sharma and Prasad, 1999). Mungbean also can increase the yield of the following rice crop up to 8% through the fixation of nitrogen in the soil, and reduce pest and disease problems (Nair, 2012). Sprouts and green pods of mungbean are rich in vitamins and minerals, thus are good sources of dietary protein for people.

Among the diseases, mungbean yellow mosaic virus (MYMV) is considered to be the most destructive, widely distributed and that incurred significant yield reduction every year in Bangladesh, India, Pakistan, Philippines, Sri Lanka and Thailand (Jalaluddin and Shaikh, 1981; Malik and Bashir 1992). Yield loss due to mungbean yellow mosaic was recorded 63% in Bangladesh (Bakr, 1994), but may cause 10-100% yield loss depending on crop growth stage at the infection time (Marimuthu *et al.*, 1981). Mungbean yellow mosaic virus belonging to the genus begomovirus is transmitted by white-fly (*Bemisia tabaci*) and also causes the yellow mosaic disease in a number of economically important grain legumes and soybean. The virus causes irregular chlorotic yellow patches on the leaf lamina and with the spread of the virus the entire leaf lamina becomes yellow, reducing the agronomic yield due to the photosynthetic inefficiency (Verma and Sandhu, 1992). Resistance in mungbeam germplasm against MYMV has been recognized earlier by different workers using scale based disease severity (Jalaluddin and Shaikh, 1981; Jalaluddin *et al.*, 1999; Iqbal *et al.*, 2004; Bashir *et al.*, 2006, Khattak *et al.*, 2008).

Cercospora leaf spot (CLS) caused by the biotrophic fungi *Cercospora cruenta* and *C. canescens* Illis & Martin is also serious disease of mungbean. The disease causes serious losses to mungbean and 23% losses in yield have been reported (Quebral and Cagampang, 1970). Maximum loss of 61% was observed in case of grain yield (Iqbal *et al.*, 1995). The disease is widespread in south east Asia and especially devastating in the warm-wet growing season. The fungus initially causes small spotting on mungbean leaves, the spots increase in number and size during flowering, but the increment is the most rapid at the pod-filling stage. Depending upon the temperature and humidity, it spreads rapidly in susceptible varieties causing premature defoliation and reduction in size of pods and grains (Grewal *et al.*, 1980). Although the diseases can be controlled by spraying with insecticide and fungicide, the practice increases farmers' production costs and has adverse affects on human health and the environment. Moreover, regular spraying can cause development of chemical resistance in the pathogen. The use of resistant varieties is the most desirable strategy to manage the disease in an economical and environmentally-friendly way. Therefore, the present research work was undertaken to find out the

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resistant/tolerant sources of mungbean germplasms against yellow mosaic and cercospora leaf spot under field conditions.

Materials and Methods

Ten advanced mutants and five varieties were assessed for their resistance to yellow mosaic (MYMV) and cercospora leaf spot (*Cercospora cruenta* and *C. canescens*) diseases at BINA sub-station farm, Ishurdi, Pabna (24.12347688546462, 89.07926122479039) in kharif-I season of 2014 and 2015 under natural field condition. The seeds of the mutants and varieties were collected from Plant Breeding Division, BINA. The experiments were conducted in a randomized complete block design with three replications. The seeds were sown in rows apart from 30 cm apart and maintaining seed to seed distance 5 cm. The unit plot size was 4.0 m x 2.5 m each. Fertilizers were applied at the time of final land preparation as per recommended doses (Anonymous, 2012). Weeding was performed two times during the growing period of the crop at 25 and 40 days after sowing. No pesticides were applied in the field. Mungbean yellow mosaic severity was recorded from each plot at flowering and maturity stage following 0-9 scoring scale (Jalaluddin and Shaikh, 1981). Cercospora leaf spot severity was recorded using disease severity score (0-9) of Jalaluddin (1984) at flowering and maturity stage. Data were recorded on days to maturity, plant height (cm), number of pods per plant, pod length (cm), number of seeds per pod and yield (kg ha^{-1}). Analysis of variance and LSD test were done to find out the significant difference among the treatment means using computer based program MSTATC.

Results and Discussion

The severity of yellow mosaic varied significantly among the tested mutants and varieties. The disease severities were higher in 2014 than 2015. The mean severities of yellow mosaic ranged from 3.0 to 6.5 in 2014 and 2.6 to 5.8 in 2015 (Table 1). The highest disease severity was recorded in the mutant MBM-80 and graded as susceptible to yellow mosaic. Three mutants (MBM-390-94-y, MBM-427-87-3, MBM-347-13 and MBM-07-y-1) and all the varieties were found to be moderately resistant and rest of the mutants were moderately susceptible against yellow mosaic according to the disease severity score.

The mean severity of cercospora leaf spot ranged from 3.0 to 7.0 in 2014 and 3.0 to 6.2 in 2015 (Table 1). The highest disease severity was recorded in the mutant MBM-80 and graded as susceptible. Six mutants (MBM-390-95-y, MBM-656-52-2, MBM-427-87-3, MBM-347-13, MBM-07-y-1 and MBM-07-g-2) and all the varieties were found to be moderately resistant and four mutants were moderately susceptible against cercospora leaf spot.

Table 1. Severities of yellow mosaic and cercospora leaf spot of mungbean mutants/varieties at Ishurdi during 2014 and 2015

Mutant/varieties	Yellow mosaic (0-9 score)			Cercospora leaf spot (0-9 score)		
	2014	2015	Disease reaction	2014	2015	Disease reaction
MBM-527-114	3.0	5.0	MS	4.8	4.0	MS
MBM-390-94-y	4.0	3.0	MR	4.3	3.8	MR
MBM-656-52-2	5.7	5.0	MS	4.4	3.7	MR
MBM-07-y-2	4.2	5.2	MS	4.0	4.7	MS
MBM-427-87-3	3.0	3.4	MR	4.3	3.6	MR
MBM-347-13	3.0	3.2	MR	3.6	4.2	MR
MBM-80	6.5	5.8	S	7.0	6.2	S
MBM-07-y-1	4.0	4.0	MR	4.0	3.2	MR
MBM-07-g-2	4.2	4.6	MS	3.0	4.0	MR
MBM-477-60	4.5	4.2	MS	5.0	4.5	MS
Binamoog-5	3.0	4.0	MR	3.6	3.0	MR
Binamoog-6	3.0	3.4	MR	3.5	3.0	MR
Binamoog-7	3.0	2.6	MR	4.0	3.0	MR
Binamoog-8	3.5	3.1	MR	4.2	3.0	MR
BARI Mung-6	3.0	3.6	MR	3.5	4.0	MR

MR = Moderately resistant, MS = Moderately susceptible, S = Susceptible.

The variation of disease reactio among the lines/varieties of mungbean against yellow mosaic and cercospora leaf spot under natural field conditions were reported by different workers (Mondal *et al.*, 2013; Paul *et al.*, 2013; Iqbal *et al.*, 2004; Jalaluddin *et al.* 2000; Jalaluddin 1984). It is very difficult to maintain same weather condition in every year, that's why the resistant nature of germplasms not sustains in field conditions.

The mean data of two consecutive years reveal that significant variation was observed in all yield contributing characters (Table 2). The mungbean mutants and varieties were matured within 64 to 72 days. The early maturing mutant was MBM-347-13 where as MBM-80 took the highest days to mature. The plant height ranged from 40.7 to 48.4 cm. The mutant MBM-427-87-3 was recorded as the tallest followed by MBM-527-114 and MBM-07-y-1 while MBM-390-94-y was the shortest plant. The pod number, seed number in pod and individual seed weight are the most important attributes responsible for the increased yield. The number of pods per plant was ranged from 16.4 to 22.2. The highest number of pod per plant was recorded in the mutant MBM-80 followed by MBM-347-13. The lowest number pod per plant was recorded in MBM-07-g-2 and MBM-477-60. Pod length ranged from 7.50 to 8.55 cm. Significantly similar pod length was recorded in the mutant MBM-347-13 and variety Binamoog-8 while the shortest pods were recorded in MBM-80.

Table 2. Mean yield attributes of mungbean mutants/varieties at Ishurdi

Mutants/varieties	Plant height (cm)	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	Days to maturity	Seed yield (kg ha^{-1})
MBM-527-114	48.3 a	18.9 e	8.28 abc	10.9 hi	66 c	1615 efg
MBM-390-94-y	40.7 e	17.2 g	7.90 cde	10.7 i	65 ef	1527 h
MBM-656-52-2	42.3 d	19.6 cd	8.05 bcd	11.8 bcd	65 ef	1683 c
MBM-07-y-2	41.9 d	18.1 f	7.82 def	11.6 c-f	68 bc	1632 de
MBM-427-87-3	48.4 a	19.6 cd	7.98 cd	11.4 d-g	65 ef	1623 def
MBM-347-13	46.3 bc	20.3 b	8.55 a	12.1 ab	64 f	1795 a
MBM-80	48.1 a	22.2 a	7.50 f	10.2 j	72 a	1087 i
MBM-07-y-1	48.2 a	19.2 de	8.00 cd	11.9 abc	66 cde	1725 b
MBM-07-g-2	46.6 b	16.4 h	7.93 cde	11.5 c-f	67 bc	1592 fg
MBM-477-60	42.7 d	16.4 h	7.55 ef	11.3 e-h	66 def	1583 g
Binamoog-5	42.9 d	20.1 bc	7.98 cd	11.7 b-e	69 b	1643 de
Binamoog-6	42.1 d	19.1 de	8.12 bcd	11.1 fgh	64 f	1617 efg
Binamoog-7	41.9 d	19.2 de	8.28 abc	10.9 ghi	67 bc	1605 def
Binamoog-8	45.3 c	17.2 g	8.43 ab	12.2 a	67 bc	1658 cd
BARI Mung-6	45.5 c	16.7 gh	8.28 abc	11.8 bcd	68 bc	1612 efg

In a column, values with same letter(s) do not differ significantly at p = 0.05 by DMRT.

The number of seeds per pod varied from 10.2 to 12.2. The maximum seeds per pod were recorded in Binamoog-8 followed by MBM-347-13 and MBM-07-y-1. The lowest number of seeds per pod was recorded in MBM-80. The mean seed yield of genotypes was ranged from 1087 to 1795 kg per hectare. The mutant MBM-347-13 produced the highest seed yield followed by MBM-07-y-1 and the lowest seed yield was found in MBM-80. The results indicated that there are some mutants which have good yield potentiality than the tested varieties. Seed yield is a complex quantitative character controlled by many genes and is greatly influenced by environmental conditions.

The disease severity of yellow mosaic and cercopora leaf spot varied from year to year among the mutants. Therefore, the highest score obtained during the two years trial was considered for final grading of each mungbean mutant. Similar grading system was followed by Jalaluddin *et al.* (1999). None of the induced mutants of mungbean were found resistant to the diseases.

The mungbean mutants MBM-390-94-y, MBM-427-87-3, MBM-347-13 and MBM-07-y-1 were found to be moderately resistant to yellow mosaic and cercospora leaf spot the diseases. Considering yield contributing characters, the mutants MBM-347-13 and MBM-07-y-1 found superior than others. Therefore, these two mutants may be used in breeding programme for the development of yellow mosaic and cercospora leaf spot resistant mungbean variety or release as variety.

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WATERLOGGED TOLERANCE OF SESAME GENOTYPES ON THE BASIS OF MORPHO-ANATOMICAL FEATURES AND YIELD

M. T. Islam* and M. Khatoon

Abstract

Waterlogging is an environmental factor that reduces gas exchange between plant tissues and the atmosphere and limits plant growth and yield and damages root and shoot structures. A pot experiment was conducted with four sesame genotypes *viz*. Rajshahi Khoyeri, KistotilChapai, KathtilChapai and Binatil-2 during March to June 2019. Four waterlogged treatments *viz*. Control, 24, 48 and 72 hours were imposed at flowering stage of the sesame genotypes. Plant height, shoot and root dry weight, total dry matter plant^{-1}, capsules plant^{-1}, number of seeds capsule^{-1}, number of seeds plant^{-1}, 1000-seed weight and seed yield plant^{-1} were significantly decreased with increasing water logging periods. Rajshahi Khoyeri produced the highest seed yield followed by KathtilChapai. Total dry matter reduction was less in Rajshahi Khoyeri and yield reduction was less in KathtilChapaiunder different water logging treatments. Root and stem anatomy of all the genotypes was investigated under control and 72 hours water logging and found that water logging at 72 hours partially damaged its epidermis, hypodermis and vascular bundle and adventitious roots were formed to help storage and exchange of gases within stressed plants to maintain a hypoxia tolerance pathway for survival.

Key words: Sesame, water logging, root anatomy, stem anatomy, yield

Introduction

Water logging reduces gas exchange between plant tissues and the atmosphere, resulting in an imbalance between slow diffusion and rapid consumption of oxygen in the rhizosphere that drastically reduces the oxygen supply and induces anoxia in plants (Sachs *et al*. 1980). Short-term water logging often firstly causes oxygen deficiency (hypoxiaor anoxia) in plants and leads to root damage (Grassini*et al*. 2007). Water logging causes a shortfall in oxygen availability to plants which is felt directly by the root system, and indirectly by the shoots (Capon *et al*. 2009). In tissue suffering hypoxia (and specially anoxia), oxygen-depending processes are suppressed, both carbon assimilation and photosynthate utilization are inhibited, and functional relationships (especially the internal transport of oxygen) between roots and shoots are disrupted (Chugh*et al*. 2012). The response of a plant to hypoxia can be conceptually divided into three stages. Initially, the plant rapidly induces a set of signal transduction components, which then activates the second stage, a metabolic adaptation involving fermentation pathways. Finally, the third stage involves morphological changes such as the formation of gas filled air spaces (aerenchima) and/or adventitious root, depending on the tolerance of the plant (Jackson and Colmer, 2005; Evans 2003; Justin and Armstrong, 1987).

Sesame (*Sesamumindicum*), a crop with high oil content, has the potential capacity to combat nutritional deficiencies in developing regions and countries. Most current cultivars contain 50–60% oil and 18–24% protein in their seeds (Mondal*et al*. 2010). In particular, greater than 80% of its oil is in the form of unsaturated fatty acids, which are more beneficial for human health than are saturated fatty acids. In addition, the antioxidant properties of sesame lignans, primarily sesamin and sesamolin, are used for therapeutic and cosmetic applications (Nakano *et al*. 2006). Sesame is typically considered drought-tolerant but susceptible to water logging, a property that can be ascribed to its suspected origin in Africa or India and its subsequent dispersal to tropical or semitropical regions (Ram *et al*. 1990 and Bedigian 2004).

To understand the effects of abiotic stress in an effort to maintain a stable food supply, a number of studies have investigated the responses of model plants and crops to stresses (Rasmussen *et al*. 2013). These studies have revealed that plant responses to different stresses are coordinated by complex and often interconnected signaling pathways that regulate numerous metabolic networks (Miro and Ismail,2013). At the protein level, low oxygen selectively induces the synthesis of anaerobic proteins, especially enzymes involved in sugar metabolism, glycolysis and fermentation (Komatsu *et al*. 2009). The vast majority of these proteins have been investigated in water logging-susceptible or tolerant strains of Arabidopsis or rice (Nakashima *et al*. 2009; Atkinson *et al*. 2013). Sesame mutants/varieties/land races show some tolerance to water logging (Islam and Khatoon, 2018). In this study, morphological attributes and yield of some selected sesame genotypes were investigated under water logging along with root and shoot structures of the tolerant genotype.

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Material and Methods

A pot experiment was conducted with four sesame genotypes *viz*. Rajshahi Khoyeri, KistotilChapai, KathtilChapai and Binatil-2 at BINA farm, Mymensingh during March to June 2019. The sesame land races were collected from different agro-ecological zones of Bangladesh. The objective of the study was to find out the waterlogged tolerant genotypes. Each pot contained 8 kg soil collected from BINA farm. Urea, TSP, MP and Gypsum were applied 1.25, 1.5, 0.5 and 1.1 g pot^{-1} corresponding 125, 150, 50 and 110 kg ha^{-1}, respectively. Half of urea and all other fertilizers were mixed with pot soils and remaining urea was applied at 30 days after sowing. Seeds were sown on 3 March 2019. After seedling establishment one seedling was allowed to grow in each pot. The experiment was laid out in completely randomized design with three replications. Four water logging treatments *viz.* control and waterlogged periods of 24, 48 and 72 hours were imposed at flowering stage of the sesame genotypes.Anatomical features of both root and stem of all the genotypes under 72 hours water logging and controlled condition were efficiently observed by sectioning and finally by using Stereo Microscope having fixed slide. Data on plant height, root and shoot dry weight, total dry matter plant^{-1}, number of capsule plant^{-1}, number of seeds capsule^{-1}, number of seeds plant^{-1}, 1000-seed weight and seed yield plant^{-1} of all the genotypes under the treatments were collected at maturity. Data were analyzed statistically and DMRT was done to compare the means.

Results and Discussion

Results revealed that plant height, shoot and root dry weight, total dry matter plant^{-1}, capsules plant^{-1}, number of seeds capsule^{-1}, number of seeds plant^{-1}, 1000-seed weight and seed yield plant^{-1} were significantly decreased with increasing water logging periods (Table 1). Similar results were observed by many researchers (Wei *et al*. 2013; Islam *et al*. 2018, 2017). Rajshahi Khoyeri produced higher seed yield (3.73g) followed by KathtilChapai (3.22g) and KistotilChapai (2.74g) under the treatments.Rajshahi Khoyeriproduced the longest plants (57.67cm) and Kristotil produced the shortest (41.67cm) (Table 2). Higher shoot dry weight was observed in KistotilChapai (4.01g) and Rajshahi Khoyery (4.01g) whereas higher root dry weight was found in KathtilChapai (1.03g) and Rajshahi Khoyery (0.82g). The highest seed was observed in Rajshahi Khoyeri (8.43g) under control condition and the lowest in KistotilChapai (0.32g) at 72 hours water logging (Table 3). Rajshahi Khoyery reduced less reduction of total dry matter and KathtilChapaireduced less seed yield under different water logging conditions. So, Rajshahi Khoyery and KathtilChapaishowed better performance under water logging compared to others.

Table 1. Effect of water logging period on morphological, physiological, seed yield and yield components of sesame genotypes

Treatments	Plant height (cm)	Shoot dry wt. plant^{-1} (g)	Root dry wt. plant^{-1} (g)	Total dry matter plant^{-1} (g)	Capsules plant^{-1} (no.)	Seeds capsule^{-1} (no.)	Seeds plant^{-1} (no.)	1000 seed wt. (g)	Seed yield plant^{-1} (g)
Control	60.1a	5.25a	1.12a	6.05a	32.67a	53.67a	1080a	3.74a	5.44a
24 hrs	51.3b	4.12b	0.97b	5.01b	25.32b	41.21b	745.2b	2.99b	4.01b
48 hrs	40.7 c	2.57c	0.84bc	3.21c	19.29c	30.62c	603.7c	2.82c	1.52c
72 hrs	40.1 d	1.51d	0.76c	2.24d	10.52d	22.19d	265.2d	1.27d	0.34d

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT

Table 2. Plant height, biomass production, yield and yield components of sesame genotypes under waterlogged condition

Genotype	Plant height (cm)	Shoot dry weight plant $^{-1}$ (g)	Root dry weight plant $^{-1}$ (g)	Total dry matter plant^{-1} (g)	Capsules plant $^{-1}$ (no.)	Seeds capsule^{-1} (no.)	Seeds plant^{-1} (no.)	1000 seed weight (g)	Seed yield plant^{-1} (g)
Rajshahi Khoyeri	57.67a	4.00a	0.82a	4.33a	21.23d	48.8a	1283ab	2.34a	3.73a
KistotilChapai	41.67d	4.01a	0.76b	4.77a	21.57cd	46.9ab	1219ab	2.21bc	2.74ab
KathtilChapai	48.00bc	3.23b	1.03a	4.15ab	29.53a	45.7bc	1301a	2.32ab	3.22a
Binatil-2	52.92b	3.24b	0.77b	4.0b	28.25a	35.8c	1143ab	2.03c	2.66b

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT

Anatomy of root and shoot of all the sesame genotypes under control and 72 hours water logging are shown (Figs. 1-16). In control both root and stem, the orientation of epidermis, hypodermis and vascular bundle looks

Table 3. Interaction effect of waterlogged condition on plant height, biomass production, yield and yield components of sesame genotypes

Interaction	Plant height (cm)	Shoot dry wt. plant^{-1} (g)	Root dry wt. plant^{-1} (g)	Total dry matter plant^{-1} (g)	Capsules plant^{-1} (no.)	Seeds capsule^{-1} (no.)	Seeds plant^{-1} (no.)	1000 seed wt. (g)	Seed wt. plant^{-1} (g)
V_1T_1	57.3b-d	6.63ab	1.12b-e	7.81a	39.0a-d	75.3a	2833a	3.01ab	8.43a
V_1T_2	46.1g-j	4.21e-g	0.65c-e	4.85c-e	21.0hi	58.7a-d	1236ef	2.50c-e	3.05d
V_1T_3	45.1g-j	3.13h-k	0.95b-e	4.11e-h	15.3ij	43.3b-j	658.7gh	2.57cd	1.69e-g
V_1T_4	34.3kl	2.16j-m	0.95b-e	3.05h-j	7.0k	30.7g-m	215.3i	1.70lm	0.36h-j
V_2T_1	56.6c-e	6.82a	1.04b-e	7.87a	37.0b-e	75.3a	2679ab	2.43c-g	6.40b
V_2T_2	41.2i-k	4.86c-f	0.92b-e	5.77b-d	23.7gh	56.6a-f	1342ef	2.64b-d	3.56d
V_2T_3	39.6i-k	2.87i-k	1.03b-e	3.91e-h	18.0hi	34.7f-m	628gh	2.43c-g	1.53f-i
V_2T_4	29.02l	1.44 lm	0.85b-e	2.33i-k	9.01k	22.0j-m	197.3i	1.6m	0.32ij
V_3T_1	67.0ab	5.62cd	1.40ab	7.04ab	42.61a	51.6b-g	2213cd	3.08a	6.79b
V_3T_2	43.3g-k	3.47g-i	1.02b-e	4.78c-f	32.7d-f	41.0b-k	1342ef	2.53c-e	3.37d
V_3T_3	38.7jk	2.31j-l	1.27a-c	3.48f-i	28.3fg	35.7e-l	1003fg	2.36c-i	2.36d-f
V_3T_4	43.0h-k	1.25m	0.83b-e	2.12jk	15.7ij	54.3a-f	697gh	1.73k-m	1.16f-j
V_4T_1	67.0ab	5.50cd	1.2bcd	6.71ab	41.31ab	58.0a-e	2399bc	2.74a-c	6.57b
V_4T_2	50.01d-i	3.68g-i	1.0bc-e	4.55d-g	32.3d-f	39.6c-k	1288ef	2.13e-k	2.75de
V_4T_3	52.01c-h	2.54jk	0.65c-e	3.3g-j	23.7gh	26.7i-m	628.7gh	2.00h-m	1.25f-j
V_4T_4	42.6h-k	1.24m	0.62de	1.89jk	15.61-j	18.6k-m	295.3hi	1.68lm	0.48g-j

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT; Where, T_1= Control, T_2= 24 hours water logging, T_3= 48 hours water logging, T_4= 72 hours water logging, V_1=Rajshahi Khoyeri, V_2= KistotilChapai, V_3= KathtilChapai, V4= Binatil-2

normal (Figs. 1, 3, 5, 7, 9, 11, 13 & 15). Water logging at 72 hours almost damaged epidermis, hypodermis and vascular bundle of most of the varieties (Figs. 6, 8, 10, 12, 14 & 16). But water logging at 72 hours partially damaged epidermis, hypodermis and vascular bundle of Rajshahi Khoyeriand adventitious roots were formed to help storage and exchange of gases within stressed plants to maintain a hypoxia tolerance pathway for survival (Figs. 2 & 4). The results are in conformity of Wei *et al.* (2013) who found less damaged tissue, adventitious root and aerenchyma in tolerant type of sesame. Water uptake, nutrient and oxygen supply hamper due to damage of vascular bundle and plants show wilting and may die. In oxygen-deprived condition the plant rapidly induces a set of signal transduction components, activates a metabolic adaptation involving fermentation pathways and involves morphological changes such as the formation of gas filled air spaces (aerenchyma) and/or adventitious root, depending on the tolerance of the plant (Jackson and Colmer, 2005; Evans 2003; Justin and Armstrong, 1987). So, better yield and less damaged tissue under waterlogged condition of Rajshahi Khoyeri showed its tolerance to water logging.

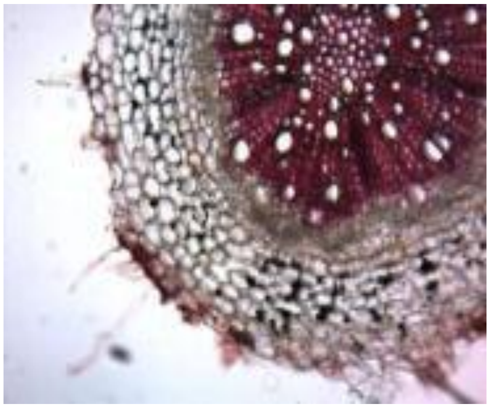

Fig. 1. Anatomy of root of a sesame cultivar, RajshahiKhoyeri (Control)

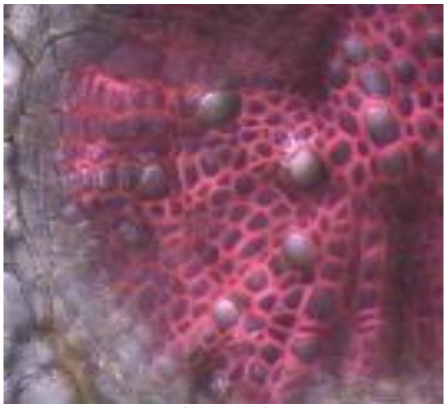

Fig. 2. Anatomy of root of a sesame cultivar, Rajshahi Khoyeri under 72 hours water logging

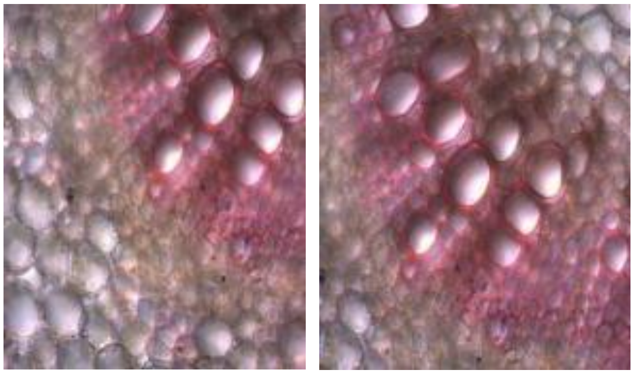

Fig. 3. Anatomy of stem of a sesame cultivar, Rajshahi Khoyeri (Control)

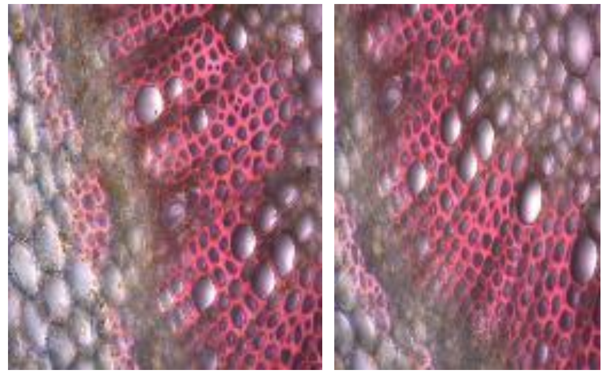

Fig. 4. Anatomy of stem of a sesame cultivar, Rajshahi Khoyeri under 72 hours water logging

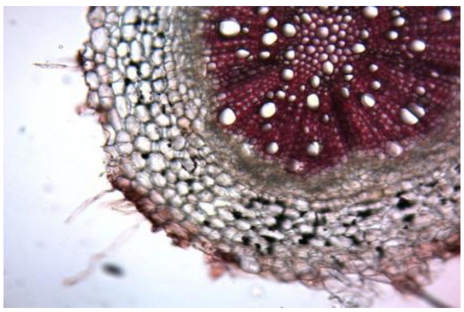

Fig. 5. Anatomy of root of a sesame cultivar, KistotilChapai (Control)

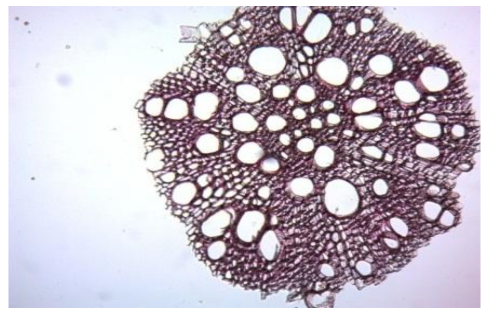

Fig. 6. Anatomy of root of a sesame cultivar, KistotilChapai under 72 hours water logging

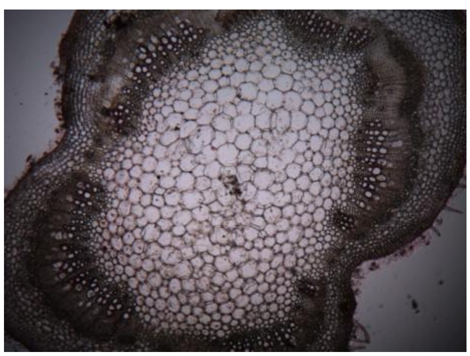

Fig. 7. Anatomy of shoot of a sesame cultivar, KistotilChapai (Control)

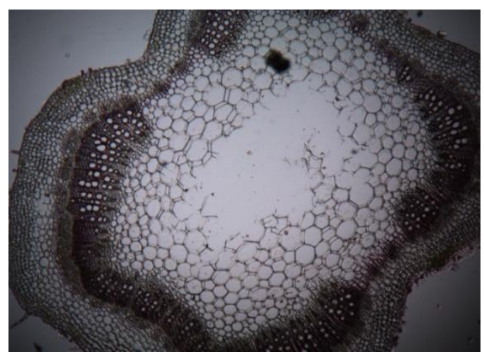

Fig. 8. Anatomy of shoot of a sesame cultivar, KistotilChapaiunder 72 hours water logging

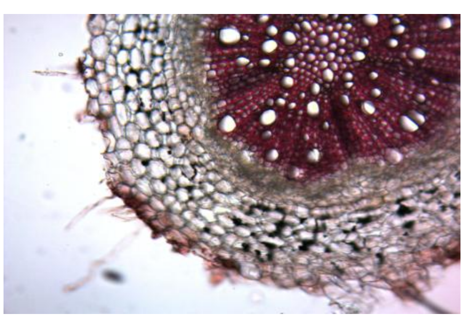

Fig. 9. Anatomy of root of a sesame cultivar, KathtilChapai (Control)

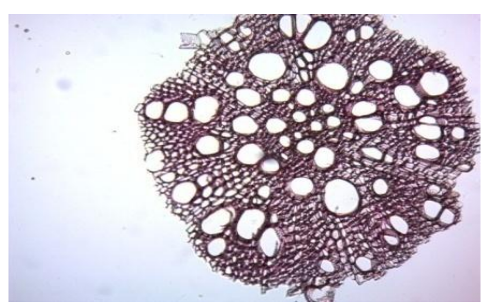

Fig. 10. Anatomy of root of a sesame cultivar, KathtilChapai under 72 hours water logging

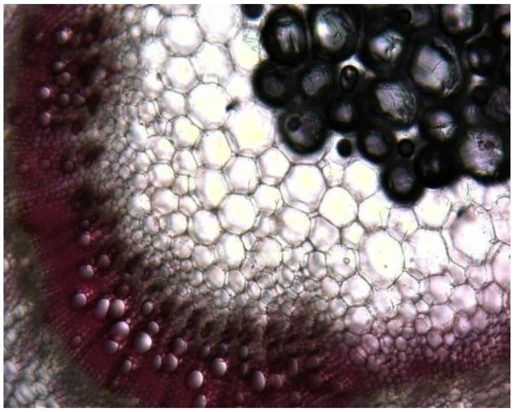

Fig. 11. Anatomy of shoot of a sesame cultivar, KathtilChapai (Control)

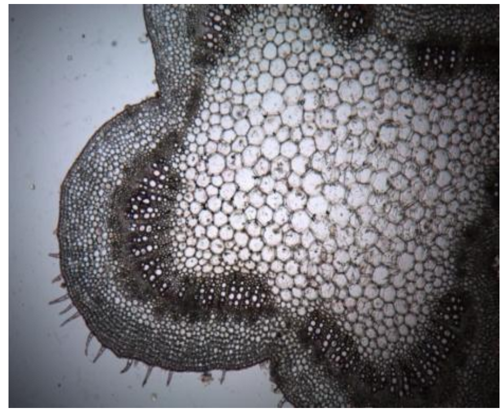

Fig. 12. Anatomy of shoot of a sesame cultivar, KathtilChapai under 72-hours water logging

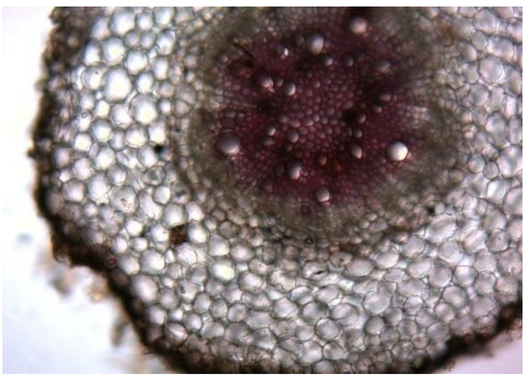

Fig. 13. Anatomy of root of a sesame cultivar, Binatil-2 (Control)

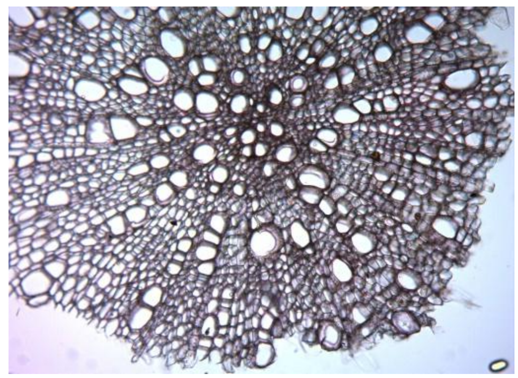

Fig. 14. Anatomy of root of a sesame cultivar, Binatil-2 under 72 hours water logging

Fig. 15. Anatomy of shoot of a sesame cultivar, Binatil-2 (Control)

Fig. 16. Anatomy of shoot of a sesame cultivar, Binatil-2 under 72 hours water logging

Conclusion

Plant height, shoot and root dry weight, total dry matter plant^{-1}, capsules plant^{-1}, number of seeds capsule^{-1}, number of seeds plant^{-1}, 1000-seed weight and seed yield plant^{-1} were significantly decreased with increasing water logging periods. Among the genotypes, Rajshahi Khoyeri produced higher seed yield under the treatments followed by KathtilChapai. Rajshahi Khoyerihad less damaged epidermis, hypodermis and vascular bundle and adventitious roots under water logging at 72 hours. So, Rajshahi Khoyeri and KathtilChapaishowed moderately tolerance to waterlogged condition.

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EFFECT OF STORAGE CONTAINER ON SEED QUALITY OF JUTE AND ONION

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Abstract

An experiment was conducted to evaluate the effect of storage containers (tin container, polythene bag and gunny bag) on the quality (Moisture content, 1000-seed weight and germination percent) of tossa jute seed for two months storage at the Plant Pathology Laboratory, Hajee Mohammad Danesh Science and Technology Universy, Dinajpur during the period from April to July, 2010. Tossa jute seeds were stored with moisture level of 12.2% in ambient condition. Moisture content of the seeds of tin container was found increased significantly to 12.9% from initial moisture content 12.2%. Seed moisture content of polythene bag and gunny bag also increased very significantly from 12.2 to 13.2% and 12.2 to 14.5%, respectively. Germination percentage decrease gradually from 82.00% to 70.00% in the seeds of polythene bag and 82.00% to 62.00% in gunny bag with high moisture content. However, slowly decreasing of germination from 82.00% to 75.00% was observed in the seeds of tin container with lower initial moisture content of 12.9% than that of gunny bag and polythene bag. Interaction effects were showed better performance with tin container than the others i.e. gunny bag and polythene bag.

Key words: Storage container, seed quality, jute, onion

Introduction

Onion (*Allium cepa*), family Alliaceae is a biennial herb and one of the five most important fresh market vegetables worldwide (Cramer, 2000). In Bangladesh it is considered as the most important spice crop. Onions contain sulphur, fibres, potassium, iron, calcium, vitamin B, vitamin C with potential anticholesterol, anticancer and antioxidant property (Slimestad*et al.*, 2007). Like other crops onion suffers from diseases including seed borne fungi like *Alternariaporri*, *Fusarium*spp. (Maude and Presly, 1977). Jute (*Corchoruscapsularis*L. and *C. olitorius*L.), the main cash crop of Bangladesh has great impact on socio economic condition of the country. Bangladesh supplies about 70% jute to global market (Hossain and Abdulla, 2015). However, jute suffers from more than a dozen of diseases of which 10 are known to be seed borne (Rashid *et al.*, 1995).

Among the factors that reduce crop yield, quality seed is the most important one (Ahmad, 2001). In order to obtain high yield, seed quality should be maintained properly. Good seeds alone can give an increased production of 5-50% compared to the seeds of a poor stock (Huda, 2001). Seed quality is mainly controlled by genetic makeup but it is commonly deteriorated during storage. During storage period seeds may lose their quality due to the effect of several biotic and abiotic factors (Harrington, 1972). Poor storage condition greatly affects seed vigor that decreases seed longevity(Heydecker, 1979). The decreasing rate depends on storage condition that is temperature, relative humidity, seed moisture content, storage container (Usberti*et al.*, 1998). Seed quality has also been found to be influenced by mycoflora during storage (Fakir, 1989). Storage fungi are mostly saprophytes and have some advantage that they can grow without free water. For every 5% reduction in storage temperature *Aspergillus* sp. and *Penicillium*sp.are reported to be cable of growing more in seeds (Christensen and Kaufmann, 1969). Thus maintenance of seed quality during storage period is important for next year crop production as well as for the maintenance of integrity of seeds. Storage containers are one of the deciding factors for maintaining seed quality during storage. Type of container regulates temperature, relative humidity, seed moisture content. The suitability of air tight metal container has been observed by Islam (2008) in durum wheat seed, Hasan*et al.* (2017) in lentil seed, Islam *et al.* (2018) in blackgram seed. To maintain the quality of stored seed selection of proper storage container should be an important consideration to reduce seed loss and increase crop production (Samajpati*et al.*, 1978). In view of the above facts, the present research work was undertaken to evaluate the effect of different containers on moisture content, germination and mycoflora during the storage period in jute and onion seeds.

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Materials and Methods

The experiment was carried at in the laboratory of Plant Pathology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh during October, 2017 to May, 2018. Seed samples of tosha jute (*Corchorusolitorious*, var. O-9897) was collected from Bangladesh Jute Research Institute, Dhaka. Seed samples of onion (*Allium cepa*, var. BARI Piaj-1) were collected from Bangladesh Agricultural Research Institute, Gazipur. The experiment was laid out in Completely Randomized Design (CRD) with four replications. Seeds were stored in four different types of container:(i) tin container, (ii) cotton cloth bag, (iii) polythene bag (transparent) and (iv) plastic container. Tin and plastic containers were covered tightly and cotton cloth bag and polythene bags were tight with rope. The containers were kept in the laboratory under ambient room condition for 75 days.Seeds were observed at sixstage: before storage, at 15, 30, 45, 60 and 75 days after storage. Each time moisture percentage (%), germination percentage (%) of sample seeds and prevalence of seed associated fungi were recorded.

Determination of moisture percentage

Moisture content was determined by using high constant temperature oven method following International Rules for Seed Testing (ISTA, 1999). Four grams of seeds from each container were taken and poured in a small container with cover and kept in an oven at a temperature of 103º C for a period of 17 hours. The moisture content of seeds was measured by the following formula (ISTA, 1999). The procedure was followed for five storage period.Moisture content (%) = $[(M_2\text{-}M_3)x100]/ (M_2\text{-}M_1)$ where M_1= weight of container+ cover; M_2= weight of container+ cover+ seeds before drying and M_3= weight of container+ cover+ seeds after drying

Determination of germination percentage

The germination test was done in petridish with moist blotter paper taking 400 seeds for each storage container with four replications. The plates were kept at room temperature for 15 days. Germination percentage was calculated using the following formula (Krishnasamy and Seshu, 1990). The germination percentage was measured for five storage period with the following formula.

Germination (%)= (Number of seed germinated x100)/ Number of seeds tested

Determination of fungal flora infection

To detect seed borne pathogens associated with seeds, four hundred seeds of each sample were assayed for the presence of fungal flora following standard blotter method (ISTA, 1996). In this method three layers of moist filter paper (Whatman No. 1) were placed in petridishes. The plates were incubated at 22 ± 2^0C under 12/12 h alternating of light and darkness for eight days. The seeds were examined under stereo microscope at 25x magnification to observe the presence of seed borne fungi. Most of the associated fungi were identified by observing the growth characters on the incubated seeds on blotter paper. For proper identification of fungi temporary slides were prepared from the fungal colony and were observed under compound microscope. The fungi were identified following the key outlined by Sing (1982).

Result and Discussion

Effect on moisture content

The initial moisture was 12.3% in jute seeds and 10.1% in onion seeds but it increased with increasing of storage time (Tables 1 and 2). After 75 days, the amount of moisture content was higher in cloth bag (18.0% in jute seeds and 15.9% in onion seeds) and was lower in tin container (14.2% in jute seeds and 11.7% in onion seeds) and plastic container (14.2% in jute seeds and 11.6% in onion seeds) followed by polythene bag (14.6% in jute seeds and 11.8% in onion seeds).Our result is supported by other workers who reported that moisture absorption by seeds increased with increasing storage period (Barua*et al.*, 2009; Ansari *et al.*,1996). If the relative humidity of the storage is higher than the seed moisture then it absorbs moisture from the air as seed is a hygroscopic living material (Copeland and McDonald, 2001). The moisture content of seeds in cloth bag was higher compared to other containers. As cloth bag was not air tight, during the experimental period the seeds in cloth bag might absorb moisture from the air to keep equilibrium with relative humidity of the surrounding.

Effect on seed germination

The germination rate (%) of jute and onion seeds varied in different containers (Table 3 and 4). The initial rate of germination was similar for all containers and it decreased with increase of storage period. After 75 days, the seed germination rate was better in tin containers (87% in jute seed and 85% in onion seeds) followed by plastic

Table 1. Moisture content (%) of jute seeds stored in different containers during the storage period

Containers	Moisture content (%)					
	Before storage	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Tin container	12.3	12.5a	13.0a	13.4a	13.7a	14.2a
Plastic container	12.3	12.7a	13.1a	13.5a	13.9a	14.2a
Polythene bag	12.3	12.9a	13.3a	13.9a	14.3a	14.6a
Cloth bag	12.3	13.6a	15.7b	16.4b	16.9b	18.0b
Level of sig.	NS	NS	*	**	**	**

DAS= Days after storage, Figures followed by the same letter in a column do not differ significantly at P≥0.05

Table 2. Moisture content (%) of onion seeds stored in different containers during the storage period

Containers	Moisture content (%)					
	Before storage	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Tin container	10.1	10.3a	10.6a	10.9a	11.1a	11.7a
Plastic container	10.1	10.2a	10.5a	10.9a	11.0a	11.6a
Polythene bag	10.1	10.3a	10.6a	10.8a	11.3a	11.8a
Cloth bag	10.1	10.6a	11.9b	12.6b	14.7b	15.9b
Level of sig.	NS	NS	*	*	**	**

DAS= Days after storage, Figures followed by the same letter in a column do not differ significantly at P≥0.05

containers (84% in jute seed and 83% in onion seeds) compared to cloth bags (74% in jute seed and 71% in onion seeds). In storage, seed deterioration with the passage of time is a natural phenomenon and it depends on different environmental factors. Seed moisture content is the most important factor that regulates the viability of seeds and deterioration of seed quality through reduced germination percentage that increases with increasing moisture content in seed (Agrawal, 2003).The reduction of germination percentage of seeds in cloth bag might be due to the absorption of moisture from the surrounding atmosphere over the storage period as it was not air tight container. The respiratory activity and other physiological activities in seeds increased by increasing moisture content which decreased stored food in seeds and thus seeds stored in a high relative humidity lost their viability and vigor more quickly than those stored in dry air (Tithi*etal.*, 2010; Gorechi, 1982).

Table 3. Germination (%) of jute seeds stored in different containers during the storage period

Containers	Germination (%)					
	Before storage	15 DAS	30 DAS	45 DAS	605 DAS	75 DAS
Tin container	91	90a	89a	88a	88a	87a
Plastic container	91	88a	86b	86a	85a	84b
Polythene bag	91	86a	85b	82b	81b	81c
Cloth bag	91	82b	80c	77c	75c	74d
Level of sig.	NS	**	**	**	**	**

DAS= Days after storage, Figures followed by the same letter in a column do not differ significantly at P≥0.05

Table 4. Germination (%) of onion seeds stored in different containers during thestorage period

Containers	Germination (%)					
	Before storage	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Tin container	88	87a	87a	86a	86a	85a
Plastic container	88	85a	85a	84b	84a	83a
Polythene bag	88	85a	83a	83b	80b	80b
Cloth bag	88	78b	76b	74c	73c	71c
Level of sig.	NS	**	**	**	**	**

DAS= Days after storage, Figures followed by the same letter in a column do not differ significantly at P≥0.05

Effect on prevalence of fungi

The fungi *Colletotrichumcorchori, Macrophominaphaseolina,Fusarium*sp.,*Aspergillus*sp.were found to be associated with jute seed (Table 5) and in onion the associated fungi were*Alternariaporri,Fusarium*sp.,*Aspergillus*sp.and*Curvularia*sp.(Table 6).However, the prevalence of fungi varied with different containers. At initial stage the range of different fungi was 9.1-12.3% in jute seed and 5.5-12.7% in onion seed. Then the prevalence of all type of fungi in jute and onion seeds increased with storage time. In jute seed, after 75 days of storage the range of seed associated fungi increased to 10.7-13.9% in tin container, 11.6-14.2% in plastic container, 11.8-14.0% in polythene bag and 14.2-16.7% in cloth bag. In onion seed, after 75 days of storage the range of fungi increased to 6.0-13.3% in tin container, 6.8-14.0% in plastic container, 6.9-14.1% in polythene bag and 8.8-16.3% in cloth bag. The prevalence of fungi was the lowest in tin container followed by plastic container whereas the highest one was recorded in cloth bag. Moisture content plays a vital role in amplifying fungal biomass during storage period (Malaker*et al.*, 2008; Begum *et al.*, 2005). In the present study moisture content of seed was found to be higher in cloth bag than that of in tin container and polythene bag and this excess moisture might enhance the fungal population. The result of our study is in accordance with Manira (2012) who observed that cloth bag was not safe for storage of soybean seed compared to tin container and polythene bag as the prevalence of seed associated fungi was found to be more in cloth bags than other containers.

Table 5. Prevalence of fungi associated with jute seeds stored in different containerduring the storage period

Container	Days	Prevalence of fungi (%)			
		Colletotrichumcorchori	*Macrophominaphaseolina*	*Fusarium*sp.	*Aspergillus* sp.
Tin container	Before storage	9.1	10.3	11.6	12.3
	15 DAS	10.0	10.8	11.9	12.9
	30 DAS	10.3	10.6	12.4	13.0
	45 DAS	10.3	10.8	12.4	13.5
	60 DAS	11.5	11.0	12.6	13.7
	75 DAS	**10.7**	**11.2**	**12.0**	**13.9**
	LSD (P≥0.05)	0.61	0.57	0.53	0.45
Plastic container	Before storage	9.1	10.3	11.6	12.3
	15 DAS	10.0	10.8	11.9	12.8
	30 DAS	10.0	11.3	11.8	13.2
	45 DAS	10.5	11.6	12.5	13.3
	60 DAS	10.8	11.5	12.7	13.5
	75 DAS	**11.6**	**11.8**	**13.0**	**14.2**
	LSD (P≥0.05)	0.82	0.63	0.71	0.70
Polythene bag	Before storage	9.1	10.3	11.6	12.3
	15 DAS	10.5	10.8	12.0	12.7
	30 DAS	10.7	11.3	12.1	12.9
	45 DAS	10.7	11.5	12.5	12.9
	60 DAS	10.4	11.8	12.4	13.3
	75 DAS	**11.8**	**11.9**	**12.8**	**14.0**
	LSD (P≥0.05)	0.52	0.46	0.51	0.61
Cloth bag	Before storage	9.1	10.3	11.6	12.3
	15 DAS	10.1	11.9	12.3	13.2
	30 DAS	11.4	12.5	13.5	14.7
	45 DAS	12.2	13.8	42.7	15.6
	60 DAS	12.9	14.3	14.0	16.3
	75 DAS	**14.2**	**14.9**	**15.5**	**16.7**
	LSD (P≥0.05)	0.57	0.52	0.74	0.69

Conclusion

The present study indicates that seeds of onion and jute stored tin container was found better in aspect of germination. The prevalence of seed associated fungi was also lower in tincontainer at the end of storage period. Therefore, tin container is effective for storing seeds of jute and onion for 75 days than other containers like polythene bag, plastic container and cloth bag.

Table 6. Prevalence of fungi associated with onion seeds stored in different container during the storage period

Container	Days	Prevalence of fungi (%)			
		Alternariaporrri	*Fusarium* sp.	*Aspergillus* sp.	*Curvularia* sp.
Tin container	Before storage	9.3	10.1	12.7	5.5
	15 DAS	9.8	10.7	12.9	5.9
	30 DAS	9.1	10.9	13.0	6.0
	45 DAS	9.7	11.4	13.2	6.2
	60 DAS	9.7	11.0	13.2	6.1
	75 DAS	**9.8**	**11.4**	**13.3**	**6.0**
	LSD (P≥0.05)	1.02	0.83	1.10	0.91
Plastic container	Before storage	9.3	10.1	12.7	5.5
	15 DAS	9.6	10.5	12.3	5.8
	30 DAS	9.8	10.8	12.8	5.9
	45 DAS	9.4	10.6	12.9	5.9
	60 DAS	10.2	11.8	13.6	6.4
	75 DAS	**10.5**	**12.5**	**14.0**	**6.8**
	LSD (P≥0.05)	0.10	0.95	0.82	0.77
Polythene bag	Before storage	9.3	10.1	12.7	5.5
	15 DAS	9.7	10.7	12.8	5.9
	30 DAS	9.4	10.9	12.7	6.0
	45 DAS	10.3	11.6	13.0	6.5
	60 DAS	10.0	11.9	13.5	6.6
	75 DAS	**10.5**	**12.3**	**14.1**	**6.9**
	LSD (P≥0.05)	0.53	0.62	0.81	0.58
Cloth bag	Before storage	9.3	10.1	12.7	5.5
	15 DAS	10.3	10.7	13.0	5.9
	30 DAS	11.6	12.4	13.7	6.8
	45 DAS	11.9	13.1	15.5	6.9
	60 DAS	12.3	14.0	15.9	7.6
	75 DAS	**13.7**	**15.3**	**16.3**	**8.8**
	LSD (P≥0.05)	0.90	0.84	0.96	0.89

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YIELD PERFORMANCE OF RAPESEED MUTANTS AT M_8 GENERATION

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Abstract

To study the performances of rapeseed mutants based on seed yield and yield attributes experiments was conducted at various locations of Bangladesh. Analysis of variance showed highly significant variations among the mutants and check for most of the characters studied in individual location and combined over locations. Interaction between genotype and location also showed significant variations for all the agronomic traits. Mutant RM20 produce the highest plant height (101.1cm) and mature earlier than all other mutants. At BINA Sub-station farm Ishurdi and Magura all the mutant produce significantly higher number of siliquae plant^{-1} then parent BARI Sarisha-15 and check BARI Sarisha-17. RM-18 and RM-20 produce maximum seeds siliquae^{-1} (30) whereas; the mutant RM07 produced lowest number of seeds siliquae^{-1} (22). Combined means over locations showed that mutants namely RM-18 and RM-20 produced significantly higher seed yield (1551.1 and 1385 kg/ha, respectively). These two mutants had also higher number of siliquae than the mother variety. This suggests that gamma rays irradiation can be fruitfully applied to develop mutants with higher seed yield and other agronomic traits in oleiferous *Brassica*.

Key Words*:* Rapeseed, Mutants and Yield

Introduction

Oils and fats supply calories that help our body to absorb fat-soluble vitamins and K. The sources of fats and oils are vegetable oils, palm oils, industrial oils and animal oils. Vegetable oils are a group of fats that are derived from some cereal grains, and fruits. The major world sources of vegetable oils are soybeans, sunflowers, rapeseed, cotton, and peanuts. Rapeseed represents an argonomically significant oilseed crop belongs to genus Brassica. There are 37 species in the genus Brassica cultivated in different region of the world (Encyclopedia Britannica, 2019). The oil producing B. rapa and B, napus are commonly known as rapeseed, while B. juncea species is familiar as mustard. Rape seed and mustard ranks first among the all oil crops grown in Bangladesh. About 78% of the total oil seed crops cultivated in Bangladesh is mustard (BBS, 2019). In Bangladesh, the average yield of rapeseed is 463.243kg/acre whereas world average is 836.36 kg/acre. Therefore genetic improvement of yield potential is foremost breeding objective for fill up this gap. The primary gene pool of oil seed has a low genetic diversity (Bus *et al.*, 2011). Therefore, new genetic sources and approaches are needed to diversify the genetic basis of rapeseed germplasm, which will make the current breeding programs more effective (Delourme *et al.,* 2013). Mutation is the ultimate source of genetic variation and it also creates a new DNA sequence for a particular gene, creating a new allele. It is an effective and simple method for obtaining valuable starting material that can further be used in crop improvement programs. Mutations can be induced by physical or chemical mutagens. Among physical mutagens, gamma rays are the most frequently used, accounting for 64% of the radiation-induced mutant varieties (Maluszynski *et al.*, 2000; Ahloowalia *et al.*, 2004; Jankowicz-Cieslak and Till, 2015). Induced mutation has been successfully used for the improvement of many crops including oilseed. More variability of rapeseed germplasms can be created via mutagenesis (Amosova *et al.*, 2019; Malek *et al.*, 2016; and Sharafi *et al.*,2015). Seed yield is the most important character for considering as a promising variety of a particular crop. Yield is a complex quantitative character governed by large number of genes and is greatly affected by environmental fluctuations. But induced mutations significantly contribute to creating genetic variations (Malek *et al.,* 2016). Henceforth an attempt was made to estimates the yield performance of advanced rapeseed mutant's lines (M_8) at various locations.

Materials and Method

Seeds of rapeseed variety BARI Sarisha-15 were irradiated with 600, 700, 800 and 900 Gy doses of gamma rays using Co^{60} gamma radiation to create genetic variations. Irradiated seeds were sown to grow M_1 generation at BINA, Mymensingh in 2013 for selecting desirable mutants in subsequent generations. Selection was made in

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each of M_2, M_3 and M_4 generation based on desired agronomic traits. From M_5 generation, two mutants namely RM-07 and RM-10 from 600 Gy, RM-18 from 800 Gy and another one mutant RM-20 from 900 Gy were selected for further evaluation. These four true breeding (homozygous) mutants along with the mother variety BARI Sarisha-15 were evaluated on preliminary yield trial and regional yield trial. Considering there agronomic performance Four M_8 rapeseed mutants were put into this trial to assess their performance through on-station and on-farm trial. For on station trial the experiment was conducted at the experimental farms of BINA HQs farm, Mymensingh and BINA sub-station farms at Nalitabari, Ishurdi, Chapainowabgonj, Rangpur & Magura and also for on farm trials the experiment was conducted at farmer's field Mymenshing, Jamalpur, Rangpur, Nalitabari, Manikganj, & Magura. The experiment was laid out in a randomized complete block design with three replications. Seeds were sown on 28th October 2019 to 3th November 2019. Unit plot size was $20m^2$ (5m X 4m) with 25cm line to line spacing and 6-8cm from plant to plant within line was maintained. Recommended production packages i.e., application of fertilizers, weeding, thinning, irrigation, application of pesticide etc. were followed to ensure normal plant growth and development.

Data were taken on morphological yield contributing characters such as plant height (avg. of 10 randomly selected representative plants), branches/plant (avg. of 10 randomly selected representative plants) and yield attributes like siliqua length (avg. of 10 randomly selected siliqua of 10 representative plants), siliqua/plant (avg. of 10 randomly selected representative plants) and seeds/siliqua (avg. of 10 randomly selected siliqua of 10 representative plants) and 1000 seed weight (from each experimental plot 1000 seed counted and weighted). All the data were collected from each plot at maturity. Maturity period was counted when approximately 70% siliqua of each plot turned into yellowish brown color. Plot seed yield was taken after proper drying of seeds. Seed yield was taken from all the experimental plots and converted into ton ha^{-1}.

The data were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done following the experimental design with the help of the computer package Statistix 10. 5% level of significance was used to compare mean differences among the treatments (Gomez & Gomez,1984).

Results and Discussion

Analysis of variance indicated highly significant variations ($p \leq 0.01$) among the mutants and check for most of the studied characters in individual locations and combined over locations indicating the presence of sufficient amount of genetic variability (Table 1). The presence of variability is the prerequisite for any breeding program.

Table 1. Analysis of variance (mean_squares) for quantitative traits in M_8 mutant of rapeseed for genotype, environment and interaction of genotype and environments.

Souece of Variation	Df	MS						
		Days to maturity	Plant height (cm)	Branches Plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Siliquae Length (cm)	Seeds siliquae^{-1} (no.)	Seed yield (kg ha^{-1})
Genotype	5	106.2**	538.8**	1.3*	1263.9**	0.2*	376.7*	1280.6**
Location	11	349.8**	392.7**	21.0^{NS}	8859.4**	13.1^{NS}	800.0^{NS}	2762.8**
Genotype✕Location	**55**	84.7**	44.6**	2.0*	394.7**	0.2*	57.6**	2367.6**

*, ** Significant at 5% and 1% levels, respectively

Mean squares for location were not significant for all the traits like branches plant^{-1}(no.), siliquae length (cm) and seeds siliquae^{-1}(no.). Mean must be significant when any one of the mean of component is significant. Seed yields, days to maturity, plant height and siliquae plant^{-1} provide significant variation for genotype, location and genotype and location interaction. Significant mean square of genotype indicates the influence of gene to the expression of the characters. There is no way to avoid the effect of location or environments on gene expression. Yield is the most important characters that controlled by many gene. Interaction of multiple gene as well as environment and agronomic practices directly influenced the yield. Significant mean square of yields is expectable for all case that indicates the presence of variation on treated materials. In rapeseed genotypes significant variations for yield have been reported by Mahmud *et al.*, 2008; Mondal *et al*. 2018 and Channaoui *et al.*, 2019.

Results of mean values of twelve individual locations and combined over locations for all the characters have been presented in Table 2. Maturity period is the most important and frequent character which can be modified in oilseed *Brassica* using induced mutation. Significant differences were observed for days to maturity in different locations. In combined over locations, days to maturity varied from 86 to 90 days. Parent BARI Sarisha-15 and check variety BARI Sarisha-17 required shortest maturity period (86 days) having non-significant difference with each other's. Among the mutants RM-10 and RM-20 required the shortest period of 88 days to mature. While without BINA Headquarters' Farm Mymensingh, BINA sub-station Ishurdi and Chapainawabganj, the mother variety BARI Sarisha-15 took the highest maturity period. Mutant RM-20 required shortest maturity period of 78 days at Jamalpur sub station and longest maturity period of 103 days at Ishurdi sub station. Moreover RM-07 required the longest maturity period having significant difference with other mutants and check at all locations. At Ishurdi sub-station, BARI Sarisha-17 required the longest duration of 99 days to mature. So, in all locations mutants have significantly different maturity period than the mother and check variety. Variation for duration in the mutants of oilseed *Brassica* has been reported by Shah & Rahman (2009) and Malek *et al*., (2012a) which confirm the present result.

The high yielding ability of a variety depends upon some important plant characteristics; short stature is one of them. For plant height semi dwarf plant type is desire because they show somewhat resistance against not only lodging but also other yield increasing characters (Bhuiyan *et. al.,* 2017 and Sayed *et. al.,* 2020).

Table 2: Mean performance of M_8 rapeseed mutants grown at different locations during 2018-2019

Locations	Mutants/ varieties	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Siliquae length (cm)	Seeds siliquae^{-1} (no.)	Seed yield (kg ha^{-1})
BINA HQs Farm, Mymensingh	RM07	91.0ab	92.0d	3.0b	104.0b	6.3ab	18.0c	995.0e
	RM10	91.0ab	99.6bc	3.0b	106.0a	6.5a	19.0bc	1185c
	RM18	92.0a	96.4c	3.0b	93.0d	6.0b	26.0a	1298a
	RM20	92.0a	99.2bc	4.0a	103.0b	6.0b	25.0ab	1232b
	BARI Sarisha-15 (P)	85.0b	101.6b	4.0a	94.0d	5.9b	19.0bc	1008d
	BARI Sarisha-17(CV)	84.0b	104.3a	3.0b	98.0c	6.0b	20.0b	905.0f
Farner's Field Mymensingh	RM07	92.0b	85.0e	3.0b	95.0b	5.6b	16.0c	965.0e
	RM10	80.0e	94.6ab	4.0a	85.0d	5.2d	17.0abc	1078d
	RM18	94.0a	92.6c	3.0b	97.0a	5.8a	17.0bc	1268a
	RM20	81.0de	97.3a	3.0b	89.0c	5.6b	18.0b	1150c
	BARI Sarisha-15 (P)	82.0d	92.2c	4.0a	94.0b	5.3cd	23.0ab	1090d
	BARI Sarisha-17(CV)	84.0c	89.4d	3.0b	84.0d	5.4c	24.0a	1202b
Farner's Field Manikganj	RM07	95.0a	90.0d	2.0b	103.0ab	5.8b	18.0c	985.0bc
	RM10	83.0e	99.6ab	3.0a	93.0b	5.4c	19.0abc	998.3bc
	RM18	93.0b	97.6b	2.0b	105.0a	6.0a	19.0bc	1175ab
	RM20	84.0de	102.3a	2.0b	97.0c	5.5c	20.59d	895.0c
	BARI Sarisha-15 (P)	85.0d	97.2b	3.0a	102.0b	5.5c	25.0ab	1222a
	BARI Sarisha-17(CV)	87.0c	94.4c	2.0b	92.0d	5.5c	26.0a	1288a
Ishurdi Sub-Station	RM07	94.0c	94.6ab	7.0a	45.0c	4.0a	25.0a	1325b
	RM10	91.0d	91.3b	4.0b	46.0c	4.0a	24.0b	1891b
	RM18	91.0d	91.0b	6.0ab	81.0a	4.0a	22.0c	1947a
	RM20	103.0a	103.3a	4.0b	60.0b	4.0a	28.0a	1835b
	BARI Sarisha-15 (P)	101.0ab	101.0ab	5.0ab	44.0c	4.0a	21.0c	1305c
	BARI Sarisha-17(CV)	99.0b	99.3ab	6.0ab	40.0c	4.0a	27.0a	1874b
Magura Sub-station	RM07	81.0c	100.0b	3.0b	72.0b	4.0a	22.0c	960bc
	RM10	90.0a	90.6d	3.0b	84.0a	4.0a	22.0b	1137b
	RM18	82.0c	102.0ab	3.0b	74.0b	4.0a	44.0a	1305a
	RM20	82.0c	105.0a	4.0a	72.0b	4.0a	42.0a	1111b
	BARI Sarisha-15 (P)	88.0b	95.0c	4.0a	55.0c	4.0a	26.0bc	886.7c
	BARI Sarisha-17(CV)	88.0b	100.0b	4.0a	55.0c	4.0a	31.0b	1027bcd
Farmer's Filed Magura	RM07	83.0c	97.0ab	3.0c	87.0bc	4.0a	40.0c	1075d
	RM10	92.0a	90.6c	4.0b	96.0bc	4.0a	40.0c	1281c
	RM18	84.0c	99.0a	5.0a	111.0ab	4.0a	51.0a	1917a
	RM20	89.0bc	102.0a	4.0b	108.0b	4.0a	40.0c	1805b
	BARI Sarisha-15 (P)	91.0b	92.0bc	4.0b	121.0a	4.0a	44.0b	1175c
	BARI Sarisha-17(CV)	90.0b	97.0ab	3.0c	80.0c	4.0a	40.0c	1144d
Rangpur Sub-station	RM07	85.0a	95.3bc	3.0c	82.0cd	3.0b	21.0c	1137c
	RM10	83.0b	94.0bc	4.0b	91.0c	3.0b	30.0b	1167c
	RM18	83.0a	103.0ab	4.0b	103.0b	3.0b	31.0b	1951a
	RM20	83.0b	107.0a	5.0a	106.0b	4.0a	32.0ab	1820b
	BARI Sarisha-15 (P)	84.0ab	102.0ab	4.0b	116.0a	3.0b	21.0c	1190c
	BARI Sarisha-17(CV)	79.0c	93.0c	3.0c	75.0d	3.0b	35.0a	1187c

Table 2: Contd.

Locations	Mutants/ varieties	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Siliquae length (cm)	Seeds siliquae^{-1} (no.)	Seed yield (kg ha^{-1})
Farmer's Field Rangpur	RM07	90.0a	98.0bc	3.0c	87.0cd	3.0b	22.0c	1137cb
	RM10	89.0ab	97.0bc	4.0b	96.0c	3.0b	31.0b	1163c
	RM18	87.0b	110.0a	5.0a	111.0ab	4.0a	33.0ab	1433a
	RM20	87.0b	106.6ab	4.0b	108.0b	4.0a	32.0ab	1278b
	BARI Sarisha-15 (P)	88.0ab	105.0abc	4.0b	121.0a	3.0b	22.0c	1190c
	BARI Sarisha-17(CV)	88.0ab	96.3c	3.0c	80.0d	3.0b	36.0a	1187b
Jamalpur Sub-statuio	RM07	81.0a	84.5bc	2.0b	53.0a	7.0a	22.0c	1160b
	RM10	80.0ab	86.3b	3.0ab	54.0a	6.0ab	22.0b	1157b
	RM18	78.0b	91.2a	3.0ab	39.0bc	5.0c	44.0a	1777a
	RM20	78.0b	92.2a	4.0a	46.0b	5.0c	42.0a	1775a
	BARI Sarisha-15 (P)	78.0b	84.87bc	4.0a	41.0bc	6.0ab	26.0bc	1186b
	BARI Sarisha-17(CV)	79.0ab	80.8c	3.0ab	33.0c	5.0c	31.0b	1188b
Chapai-nawabganj Sub-Station	RM07	91.0ab	98.3bc	3.0c	87.0bc	3.0b	22.0d	1137cb
	RM10	91.0ab	97.0bc	4.0b	96.0bc	3.0b	31.0c	1163c
	RM18	92.0a	106.6ab	5.0a	111.0ab	4.0a	33.0b	1567a
	RM20	92.0a	110.3a	4.0b	108.0b	4.0a	32.0b	1483a
	BARI Sarisha-15 (P)	85.0b	105.0bc	4.0b	121.0a	3.0b	22.0d	1190b
	BARI Sarisha-17(CV)	84.0b	96.3bc	3.0c	80.0c	3.0b	36.0a	1187b
Nalitabari Sub-Station	RM07	96.0a	85.0c	4.0b	89.0a	5.0a	16.0c	950.0d
	RM10	94.0b	94.6ab	5.0a	79.0cd	5.0a	17.0abc	1207b
	RM18	94.0b	92.6b	4.0b	91.3a	5.0a	17.0bc	1397a
	RM20	90.0d	97.3a	4.0b	83.0c	4.0b	18.0abc	1260b
	BARI Sarisha-15 (P)	92.0c	92.2b	5.0a	88.0b	4.0b	23.0ab	1087cb
	BARI Sarisha-17(CV)	88.0e	89.4bc	4.0b	78.0d	5.0a	24.0a	1153cb
Farmer's Field Nalitabari	RM07	95.0ab	85.7b	4.0ab	80.0a	6.0a	17.0c	1033cd
	RM10	93.0bc	85.3b	4.0ab	70.0b	5.b	21.0bc	1267bc
	RM18	94.0b	90.6a	3.0b	31.0d	4.0c	24.0b	1533a
	RM20	94.0b	91.7a	5.0a	48.0c	5.0b	28.0a	1300b
	BARI Sarisha-15 (P)	92.0c	85.4b	4.0ab	39.0cd	5.0b	19.0bc	1200c
	BARI Sarisha-17(CV)	96.0a	79.7c	3.0b	31.0d	5.0b	24.0b	867d
Combined Means Over Locations	RM07	90.0a	92.1c	3.0b	82cd	4.7a	22.0bc	1072c
	RM10	88.0b	93.3c	4.0a	83c	4.5b	25.0b	1224c
	RM18	89.0ab	97.7b	4.0a	87.0a	4.5b	30.0a	1551a
	RM20	88.0b	101.1a	4.0a	85.0b	4.5b	30.0a	1385b
	BARI Sarisha-15 (P)	87.0bc	96.1b	4.0a	86.0ab	4.3c	25.0b	1144d
	BARI Sarisha-17(CV)	87.0bc	93.3c	3.0b	68.0d	4.4bc	29.0ab	1184d

P=Parent and CV= Check variety; In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level

Plant height may vary due to the genetic effects present among the genotypes as well as the proper agronomic management. A significant variation was observed in plant height. In combined over locations, plant height ranged from 92.1 cm to 101.1 cm. Mutation has strong effect on plant height. Mutant induced taller as well as shorter type plants. Mutant RM-20 produced the highest plant height (101.1 cm) significantly higher than parent BARI Sarisha-15, where as mutant RM-10 and RM-07 produced significantly shortest one. Plant height of BARI Sarisha -17, RM-07 and RM-10 was statistically similar and dwarf than other two mutants as well as parent BARI Sarisha -15. Except BINA farm mutant RM-20 was tallest one, while at farmer's field at Rangpur, both of RM-20 and BARI Sarisha-15 provide statistically similar plant height. Mutant RM-10 showed tallest plant at farmer's field Rangpur. At farmer's field Rangpur, BARI Saridha-17 also showed the shortest plant (96.3cm) which was closely followed by RM-10 and RM-07, whereas RM-07 showed the shortest plant in all other locations. In combined over locations, it was sharply reflect that mutant RM-07 produced the shortest plant height than all other mutants and check variety. Influence of mutation on plant height also obtains by Mondal *et al.*, 2018 and Channaoui *et al.*, 2019.

The number of branches is one of the important selection criteria for oilseed improvement programs. Higher number of branches enables bearing more siliquae per plant and result in higher seed yield. Lowest number of branches/plant was observed in farmer's field Manikganj and higher in BINA Sub-station Ishurdi. At Manikganj, mutant RM-07 produced the highest number of branches/plant (3.0) similar with BARI Sarisha-15. All other mutants including BARI Sarisha-17 produced the lowest number of branches plant^{-1}. At BINA Sub-station Ishurdi, mutant RM-7 produced the highest number of branches plant^{-1} (7) closely followed by RM-18 and BARI Sarisha-17. On an average number of branches plant^{-1} ranged from 3 to 5. Without RM-7 all other mutants produced similar as well as significantly higher number of branches than mother BARI Sarisha-15. The present results having different number of branch in the rapeseed mutants and other oilseed than the mother confirms the findings of Malek *et al.*, 2016; and Bhuiyan *et al.*, 2019.

A significant variation was found among the mutants and mother variety on the number of siliquae plant^{-1} in individual location and combination over locations. It is the most important agronomic character link with seed yield. Considering combined over locations, siliquae plant^{-1} ranged from 68 to 87. At BINA Sub-station farm Ishurdi and Magura, all the mutants produced significantly higher number of siliquae plant^{-1} than the parent BARI Sarisha-15 and check BARI Sarisha-17. At Magura, RM-07 produced the highest number of siliquae plant^{-1} (84) and the mother variety produced the lowest number (55). At Ishurdi, RM-18 produced the highest siliquae plant^{-1} (81) followed by RM-20. Significant differences were also observed for siliquae length in different locations. On an average, the mutant RM-07, produced significantly higher siliquae length than others. Mutants produced RM-10, RM-18 and RM-20 had equal siliquae length and the parent BARI Sarisha-15 was the shortest one. In oilseed Brassica, as a consequence of mutagenesis for siliquae plant^{-1} and siliquae length reported earlier by Malek *et al*., 2016 and Ali *et at.*, 2020.

Like siliquae plant^{-1} another important yield controlling trait is seeds siliquae^{-1}. Number of seeds siliquae^{-1} differ significantly both in individual locations and combined over locations. Mutant RM-07, RM-10 and BARI Sarisha-15 were formed double chamber whereas mutant RM-18, RM-20 and BARI Sarisha-17 were four chambered type siliquae. Double chambered type siliquae have been produced by the mutants RM-07, RM-10 and BARI Sarisha-15. Mutant RM-10 and BARI Sarisha-15 produced similar number of seeds siliquae^{-1}. Four chambered mutant RM-18 and RM-20 produced the highest number of seeds siliquae^{-1}.

Seed yield is the most important character for considering as a promising variety of a particular crop. The mutants RM-18 produced the highest seed yield of 1950 kg ha^{-1} at BINA Sub-station farm Rangpur, while RM-18 gave the lowest seed yield of 1175.0 kg/ha at Manikganj. Combined means over twelve locations showed that three mutants namely RM-10, RM-18 and RM-20 produced significantly higher seed yield (1224.5, 1551.1 and 1385 kg ha^{-1}, respectively) than mother variety BARI Sarisha-15 (1144.2 kg/ha). In location wise performance of yields, Magura showed the best performance followed by Chapainawabganj and Rangpur may be due to the environmental and soil characteristics of a particular location. Maximum seed yield of 1916.7 kg ha^{-1} was obtained from farmer's field at Magura. Considering promising variety of a particular crop, seed yield is the most important trait. Rapeseed yield varies depending on the variety and favorable ecosyatems with proper agronomic management practices. In rapeseed-mustard and other oilseed mutants having higher seed yield over mother varieties also reported by Zhao *et al.*, 2009; Brave *et al*., 2009; Ali *et al.*,2020 and Mondal *et al.*,2020.

Conclusion

The present study revealed the presence of high levels of variations for different morphological traits including yield attributes. For Oilseed *Brassica*, the most important yield attributes responsible for the increased seed yield are the siliquae number and seed number in siliqua. It was observed that among the mutants and mother variety, mutants RM-18 and RM-20 performed better for seed yield and yield contributing characters which can be selected for further trials to be registered as varieties. These mutants could be served as breeding materials for further genetic improvement of different characters of the rapeseed also. Moreover, this finding suggests that gamma rays irradiation can be fruitfully applied to induce mutants in rapeseed with higher seed yield and other improved agronomic traits.

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BINAMORICH-1: A HIGH YIELDING MUTANT VARIETY OF CHILI USE AS SPICES, SALAD AND VEGETABLES

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Abstract

With a view to develop a high yielding mutant variety of chili, 1000 seeds of the local landrace of china with low yield but highly to most of the pest and disease were irradiated with (75 Gy, 150 Gy and 300 Gy) gamma rays in 2012 at seibersdorf laboratory, Vienna, Austria. At maturity, all M_1 plants were harvested and seeds were kept separately. During M_2 and M_3 generations, selection was conducted following high mean and high/low variances compared to the check. In M_4 and M_5 generations, comparative yield assessment was done in several locationsviz; Mymensingh, Ishwardi, Magura,Rangpur, Bogura, Khagrachari, Cumilla and farmer's field in rabi season.Five true breeding lines were selected in a preliminary yield trial at M_5 generation, based on plant height, number of fruits, fruit length, fruit diameter, average single fruit weight and fruit yield. Based on the same criteria, in an advance yield trial, these mutant lines were further evaluated. Of these five mutant lines, chili$D_{75}P_1$ produced the highest average yield with higher fruit length and diameter than the parent line and check variety, found in both, farmer's field and on-station trials. This chili$D_{75}P_1$ has been registered as high yielding variety of chili (Binamorich-1) for commercial cultivation by National Seed Board of Bangladesh(NSB) in 2017.

Keywords: chili, gamma irradiation ,mutant variety,yield

Introduction

Chili is a valuable spice and also one of the most important cash crops grown in Bangladesh. It is available and used in the form of green, dried and powdered. It has become an essential ingredient in Bangladeshi meals. Most of our households always keep a stack of fresh hot green chilies at hand, and use them to flavor most curries and dry dishes. It is typically lightly fried with oil in the initial stages of preparation of the dish. It has diversified uses like meat, fish, vegetables, pulses etc. for its typical color, taste and flavor. Red chilies contain large amounts of vitamin-C and small amounts of carotene (pro-vitamin A). Green chilies (unripe fruit) contain a considerably lower amount of both substances. In addition, peppers are a good source of most vitamin-B and vitamin-B6 in particular. They are very high in potassium, magnesium and iron.

Mutagenesis has been widely applied in the development of new breeding materials with novel characteristics as well as in studies of functional genomics in important crops(Roychowdhury and Tah, 2013).It is one of the important techniques to mainstream plant breeding. With this technique, 15-20% yield improvement and correction of the defects to a top cultivar are very easy and straight forward (Gaul, 1961). Gamma radiation, a type of electromagnetic radiation produced by the decay of radioisotopes such as cobalt-60 and cesium-137, has been the most commonly used mutagen among ionizing radiation for at last the past forty years owing to its wide availability and versatility in application (Oladosu*et al.*, 2015).Pleotropic effects are very common and help fix the breeding lines even in M1 generation (Azad *et al.*, 2013a). Genetic improvement of any yield attribute either qualitative or quantitative in nature has been successful with this technique (Azad *et al.*, 2012 and Azad *et al.*, 2013b). So far, 3,246 crop varieties worldwide have been released through this technique that also includes some varieties of chilies (IAEA, 2017).

Various strategies to increase chili genetic variability can be pursued by such as seed introduction, hybridization, and mutation. Mutation seems more preferable than the other two since seed introduction sometimes may function as a media of transferring seed borne diseases, while hybridization will not be effective if there is no resistant gene available. Furthermore, conventional breeding by hybridization usually takes longer, yet sometimes also carries unexpected traits. This may result in an output that is not as good as expected as a commercial variety. Mutation is one of possible alternatives to conventional breeding for crop improvement program (Soeranto, 2011). Mutation is a sudden heritable change in an organism and generally induces structural and composition changes in genome, chromosome, gene, or DNA (Soeranto*et al.*, 2001; Dhanavel*et al.*, 2012). Exposing plant genetic material (seed, pollen, rhizome, callus, etc.) to mutagens enhances the chance for isolating unique genetic material. Induced mutation can rapidly create the variability of inherited traits in crops, both quantitatively and qualitatively (Muduli and Misra, 2007). Post inducedmutation has been effectively

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utilized in developing new and valuable alternation in plant characteristics that have contributed to increase yield potential or disease resistance. One of physical mutagens in mutation breeding is gamma rays. Gamma rays irradiation is an efficient tool to produce mutants in crop breeding. In breeding program, this approach has not only contributed several crop varieties to national agriculture, but also generated hundreds of promising mutant lines that are ready for further multi-location trials. However, it is noted that no work on desired, high yielding, pest resistant chili mutant development has been carried out yet. In order to improve yield and yield related characteristics induced mutation breeding programmes through gamma rays of chili were undertaken for creation of variability and selection for improved mutant lines.

Materials and Methods

The chili seeds were irradiated with 75 Gy, 150 Gy and 300Gy doses of gamma rays from a ^{60}Co source and sprouted seeds were sown dose wise at Seibersdorf Laboratory glasshouse, IAEA, Vienna in 2012. Seedlings were transplanted in a tray bed of 3 m×1 m at a distance of 40 cm within rows of 50 cm apart. At maturity, the plants that produced fertile seeds were harvested and kept separately plant and dose-wise. Seeds of M_2 populations and the parent variety were sprouted and sown. The seedlings were transplanted after 35 days at a distance of 40 cm within rows of 50 cm apart following non replicated plant-progeny-rows. Fertilizers were applied at the rate of N 110 kg, K 70 kg, P 50 kg, S 20 kg, Zn 1.0 kg and B 1.0 kg/ha in the form of Urea, Muriate of Potash (MoP), Triple Super Phosphate (TSP), Zypsum, Zinc Oxide and Boric Acid together with 10 tons/ha of farm yard manure (FYM). At maturity, seeds were harvested population wise and kept separately. Seeds of M_3 population were sown Seibersdorf Laboratory glass house, IAEA, Vienna and the seedlings were transplanted in 2014 after 35 days following non replicated plant-progeny-rows. Fertilizers and FYM were applied as applied in M_2 generation. At maturity, M_4seeds were harvested population wise and kept separately.In M_4 the 28 mutants were evaluated for high yield potential, crop duration and other agronomic characters and five plants per mutant were evaluated. A total of 12 superior mutants for high yield with good features were selected and advanced to M_5 for further trial during rabi season 2015-16at BINA HQs farm at Mymensingh. In $M_{5,}$ some of the mutants exhibiting morphological variation and poor performing compared to parent were rejected and ended up with five mutants. These five mutants along with the parent (check) were further evaluated for high yield and other agronomic and quality traits to advance preliminary yield trial and advanced yield trial.

Preliminary yield trial

This experiment was carried out with five M_5 mutant lineswith a check variety of BARI morich-1 at BINA HQs Farm,Mymensingh Sutiakhali farm, BINA sub-stationCumilla, Khagrachari and Magura experimental field during 2015-2016, following Randomized Completely Block design with three replications with spacing 50cm × 40cm. A unit plot size was 3m × 1m. Fertilizers were applied following the Fertilizer Recommendation Guide (BARC, 2005) during final land preparation. Recommended production packages with cultural and intercultural operations were followed to ensure normal plant growth and development. Data on various characters, such as plant height, fruit length, fruit diameter, number of fruit, fruit yield and average fruit weight were taken from each mutants.

Advanced yield trial

This experiment was carried out with five M_6 mutant lines with a check variety of BARI morich-1 at BINA HQ Farm and farmers' field Mymensingh, Cumilla, Khagrachari and Magura during 2016-2017. Randomized Complete Block design with three replications was followed. A unit plot size was 3m × 1m. In all following yield trials, spacing, fertilizer doses, cultural and intercultural operations, and data collection methods were the same. Finally, all the recorded data underwent proper statistical analysis following Gomez and Gomez (1984) and are presented in Table 1 and Table 2.

Results and Discussion

Chili varieties/genotypes showed a good response to radiation with gamma rays. In M_1gamma rays influenced germination, seedling height, survival of plants and pollen fertility/sterility, producing deleterious effects on these characters. Moreover, studies on quantitative characters including total yield revealed the induction of mutants in both positive and negative directions for such traits which made a good scope of selection of desirable mutants in M_2 generation. Mutants selected in M_2 were raised in M_3 in plant to progeny rows and further selection was made. Compared to the M_2 generation, the range of family means became narrower in M_3 which indicated the effectiveness of selection in the M_2. True breeding lines isolated in M_3 generation have given potentially higher yield and yield attributing characters in a preliminary yield trial in M_5 compared to parents. Five promising mutant lines were evaluated in M_5 and M_6 generations for yield and other agronomic parameters at various locations of Bangladesh under variable environments. Mutants Chili$D_{75}P_1$ have produced significantly the highest yield at all locations with other yield parameters.

Performances of the selected mutants and check variety on yieldand yield attributingcharacters revealed significant variations for most of the characters in preliminary yield trial (Table 1). Among the mutants and control variety, performance of Chili$D_{75}P_1$was found to be promising regarding yield and yield attributing characters. Results of preliminary yield trial during rabi 2015-16 showed that Chili$D_{75}P_1$produced the highest fruit length, average fruit^{-1}, yield plant^{-1} and total yield (t ha^{-1}).

Table 1. Yield and yield contributing characters of M_5 mutants of Chili during Rabi, 2015-16 at HQs Farm, Sutiakhali, Mymensingh, Sub-station Farm, Cumilla, Khagrachari and Magura

Mutant/ Variety	Plant height (cm)	No. of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Average weight (g fruit^{-1})	Fruit yield (g plant^{-1})	Fruit yield (t ha^{-1})
BINA HQs Farm, Mymensingh							
Chili$D_{75}P_1$	54.5	63.5	14.55	5.58	13.29	725.7	34.74
Chili$D_{75}P_2$	53.7	45.1	11.80	5.13	11.08	682.0	27.28
Chili$D_{150}P_5$	46.6	41.8	11.60	4.63	11.02	583.8	26.84
Chili$D_{150}P_8$	44.5	36.5	12.17	4.91	10.87	511.7	23.23
Chili$D_{300}P_9$	37.7	30.9	12.57	5.14	9.30	484.0	21.87
BARI Morich-1	51.5	114.3	6.50	2.82	1.60	178.0	12.00
$LSD_{0.05}$	2.26	1.53	0.54	0.10	0.59	12.91	0.83
CV	2.78	3.16	2.54	1.18	3.19	0.77	1.84
Sutiakhali, Mymensingh							
Chili$D_{75}P_1$	53.2	60.3	13.94	5.49	13.14	678.90	33.95
Chili$D_{75}P_2$	51.3	44.3	11.34	5.12	11.02	632.04	26.17
Chili$D_{150}P_5$	46.5	39.5	11.42	4.82	10.94	570.08	25.02
Chili$D_{150}P_8$	43.1	35.8	12.33	4.78	13.04	494.36	23.04
Chili$D_{300}P_9$	38.6	30.4	12.64	5.04	10.95	471.15	22.10
BARI Morich-1	48.2	106.7	6.35	2.94	1.65	182.25	11.90
$LSD_{0.05}$	2.13	1.64	0.48	0.08	0.54	2.80	0.76
CV	3.14	3.54	2.79	1.31	3.35	1.02	2.04
BINA sub-station,Cumilla							
Chili$D_{75}P_1$	51.5	62.8	14.06	5.55	14.20	705.46	33.26
Chili$D_{75}P_2$	48.4	45.3	12.00	5.17	12.31	661.58	26.00
Chili$D_{150}P_5$	51.3	42.6	11.66	5.02	11.89	602.55	24.92
Chili$D_{150}P_8$	42.2	38.2	12.47	4.85	12.68	524.67	23.45
Chili$D_{300}P_9$	41.7	32.7	12.65	5.08	11.12	468.54	22.04
BARI Morich-1	50.2	110.5	6.51	3.03	1.73	188.55	11.28
$LSD_{0.05}$	3.05	1.57	0.43	0.12	0.62	2.71	0.64
CV	3.48	3.76	2.94	1.92	3.87	1.48	2.48
BINA Sub-station,Khagrachari							
Chili$D_{75}P_1$	49.9	60.4	13.96	5.42	14.27	695.75	32.55
Chili$D_{75}P_2$	47.2	48.2	12.07	5.06	12.26	645.07	25.92
Chili$D_{150}P_5$	46.6	44.7	11.52	4.89	11.83	597.80	24.24
Chili$D_{150}P_8$	46.9	37.4	12.86	4.74	12.22	512.73	22.56
Chili$D_{300}P_9$	42.3	33.6	13.05	5.02	11.39	451.00	21.58
BARI Morich-1	48.0	108.8	6.39	3.12	1.68	175.00	11.07
$LSD_{0.05}$	2.83	1.52	0.39	0.08	0.57	2.57	0.53
CV	3.79	3.81	3.10	2.07	3.95	1.93	2.71
BINA Sub-station,Magura							
Chili$D_{75}P_1$	52.8	65.3	14.03	5.89	13.04	702.29	33.32
Chili$D_{75}P_2$	47.5	49.8	12.38	5.56	12.12	662.38	26.96
Chili$D_{150}P_5$	52.3	42.1	11.32	5.23	11.31	593.46	25.02
Chili$D_{150}P_8$	52.8	38.6	12.81	5.56	11.08	518.25	24.42
Chili$D_{300}P_9$	47.9	32.3	12.92	5.64	12.08	466.78	22.02
BARI Morich-1	48.3	105.7	6.23	3.14	1.62	181.12	12.42
$LSD_{0.05}$	2.79	1.47	0.33	0.12	0.52	2.48	0.48
CV	3.92	4.04	3.29	2.32	4.07	2.02	2.92

Maximum plant height was scored from Chili$D_{75}P_1$ (54.5 cm) and minimum from Chili$D_{300}P_9$ (37.7 cm) at HQs Farm, Mymensingh. At Magura sub-station, the highest plant height was recorded from Chili$D_{75}P_1$ (52.5 cm) whereas the lowest from Chili$D_{75}P_2$ mutantwhich is statistically similar with Chili$D_{300}P_9$ mutant.An increased plant height may increase the branches and leaves number of plant. There was a significant variation in height of Capsicum plants obtained by Hosmani (1982). High phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) were found for plant height obtained by Mini and Khader (2004). The result indicates that the highest number of fruits (114.3 plant^{-1}) was obtained from the check variety BARI Morich-1 and the second highest (63.5) from mutant Chili$D_{75}P_1$while Chili$D_{300}P_9$ (30.9) attained the lowest number of fruits plant^{-1}at BINA HQs Farm. Obidiebube*et al.* (2012) found similar result i.e. significant variation from one mutant to another in number of fruits of chili.

Though mutant Chili$D_{75}P_1$ gave lower number of fruits plant^{-1} compared to check variety but its single fruit weight is higher compared to check, as a result total yield is the highest than the other mutants and check variety. The longest fruit length (14.55 cm) was recorded from Chili$D_{75}P_1$ mutantwhile BARI Morich-1 gave the smallest fruit (6.50) at BINA HQs Farm, Mymensingh. Similar results were observed in all other locations at preliminary yield trial during 2015-16. Fruit diameter of six mutants and check variety were ranged from 5.58 cm to 2.82 cm. The mature fruits of Chili$D_{75}P_1$ mutantshowed maximum fruit diameter (5.58 cm) and minimum (2.82 cm) were recorded fromcheck variety BARI Morich-1 (Table 1). Smitha and Basavaraja (2006) observed significant differences among the chili mutants in respect of fruit length.Significant variations in yield plant^{-1}as well as total yield (t ha^{-1}) were noticed among the mutants in preliminary yield trial. The highest yield plant^{-1} (725.75 g) and total yield (34.74 t ha^{-1}) were recorded fromChili$D_{75}P_1$ mutant at BINA HQs Farm while the lowest yield (178.2 g plant^{-1}) and total yield (11.07 t ha^{-1}) were noted from the check variety BARI Morich-1 at BINA substation Khagrachari farm (Table 1). More or less similar results were observed at all the locations.

Results of advanced yield trial during 2016-17 showed that one mutant line performed better regarding fruit length, diameter as well as yield attributes than the control variety with the similarities of previous year result. Chili$D_{75}P_1$ mutant produced the highest yield (34.86 t ha^{-1}) followed by Chili$D_{75}P_2$ mutant (27.89 t ha^{-1}) and Chili$D_{75}P_5$ mutant (26.04 t ha^{-1}) at BINA HQ farm, Mymensingh. It was also observed that all the high yielding mutants performed better above average for most of the morphological characters and yield attributes. Results of advanced yield trial at farmers fields of different areas of Bangladesh showed that Chili$D_{75}P_1$ mutantproduced better plant height (55.7 cm), acceptable number of fruits plant^{-1} (64.2), the longest fruit (14.67 cm), the highest fruit diameter (5.65 cm), the highest single fruit weight (15.56 g), the highest yield plant^{-1} (770.56 g) as well as total yield (34.86 t ha^{-1}) than the other mutants and check variety (Table 2). Differences found in different plant parameters among the mutant population and control variety attributed to the effect of mutagenic radiations that can directly cause DNA double-strand breaks, and then prevent plant growth or make it slow. The reduction of growth rate with increase in dose of irradiation may interrupt cell division as a result of DNA mutation that DNA synthesizes at the interphase. A little variation was observed in yield and yield attributing characteristics among the mutant lines and control variety within locations, and also in years, and this phenomenon is attributed to the prevailing environmental factors. The incidence of anthracnose, wilting and mosaic diseases, and insect (thrips and aphid) infestation were also studied in different locations under field conditions (data not presented). Chili$D_{75}P_1$ mutant was found to be tolerant to anthracnose, wilting and mosaic diseases and also showed lower infestation by insects. Overall infestation caused by leaf feeder insects like aphid and thrips were lower in Chili$D_{75}P_1$ mutant compared to the check variety.

Main distinguishing characteristics of Chili$D_{75}P_1$ mutant (new variety Binamorich-1) which makes the variety different from other varieties:

- High yielding, yield is two folds higher compared to traditional varieties
- Used as a spice, salad and also vegetables
- Low pungency but very much succulent and scented
- Fruit length and diameter is high (10-14 cm and 3-5 cm, respectively)
- Profusely branched and bushy type plant
- Yield plant^{-1} (650-730 g) and yield (30-34 t ha^{-1})

Table 2. Advanced yield trial of M_6 mutants of Chili during Rabi, 2016-17 at HQ Farm, Mymensingh, farmers field of Mymensingh, Cumilla, Khagrachari and Magura

Mutant/ Variety	Plant height (cm)	Fruits plant^{-1}(no.)	Fruit length (cm)	Fruit diameter (cm)	Average weight (g fruit^{-1})	Fruit yield (g plant^{-1})	Fruit yield (t ha^{-1})
BINA HQs Farm, Mymensingh							
ChiliD$_{75}$P$_1$	55.7	64.2	14.67	5.65	15.56	770.56	34.86
ChiliD$_{75}$P$_2$	51.2	46.6	11.94	5.21	13.26	697.04	27.89
ChiliD$_{150}$P$_5$	47.6	42.4	12.04	4.82	14.53	622.80	26.04
ChiliD$_{150}$P$_8$	44.4	38.9	12.28	5.02	14.56	532.73	23.54
ChiliD$_{300}$P$_9$	41.2	33.2	12.76	5.19	12.23	481.00	22.53
BARI Morich-1	48.1	118.2	6.58	2.95	1.86	185.00	13.02
LSD$_{0.05}$	2.71	1.31	0.27	0.11	0.47	2.04	0.35
CV	4.12	4.12	3.53	2.65	4.34	2.57	3.41
Farmers field, Sutiakhali, Mymensingh							
ChiliD$_{75}$P$_1$	52.5	60.2	13.76	5.48	14.63	689.52	31.59
ChiliD$_{75}$P$_2$	50.9	46.1	11.63	5.15	13.02	618.23	24.57
ChiliD$_{150}$P$_5$	46.6	40.5	11.74	4.66	13.92	593.46	25.73
ChiliD$_{150}$P$_8$	42.2	38.6	12.12	4.82	14.15	480.65	26.46
ChiliD$_{300}$P$_9$	40.1	31.4	12.23	5.05	12.05	409.98	21.58
BARI Morich-1	49.4	100.5	6.26	2.91	1.86	192.08	10.40
LSD$_{0.05}$	2.50	1.23	0.19	0.09	0.35	1.91	0.28
CV	4.42	4.55	3.80	2.90	4.60	3.78	3.90
Farmers field, Cumilla							
ChiliD$_{75}$P$_1$	50.9	56.9	13.28	5.27	14.46	670.09	32.32
ChiliD$_{75}$P$_2$	48.7	45.8	11.46	5.13	13.12	625.23	25.76
ChiliD$_{150}$P$_5$	44.6	40.6	11.44	4.72	12.56	558.08	24.15
ChiliD$_{150}$P$_8$	42.4	38.7	12.06	4.78	13.77	487.74	24.64
ChiliD$_{300}$P$_9$	40.5	33.2	12.24	4.97	12.16	407.12	22.05
BARI Morich-1	49.3	103.5	6.21	2.90	1.83	195.56	11.39
LSD$_{0.05}$	2.56	1.20	0.16	0.07	0.30	1.82	0.22
CV	4.52	4.80	3.78	3.15	4.52	3.90	4.12
Farmers field, Khagrachari							
ChiliD$_{75}$P$_1$	52.9	53.4	13.89	5.42	14.70	692.04	32.92
ChiliD$_{75}$P$_2$	47.1	48.6	11.45	5.18	13.56	630.16	26.06
ChiliD$_{150}$P$_5$	45.8	42.7	11.63	4.84	13.08	565.52	24.40
ChiliD$_{150}$P$_8$	43.2	38.3	12.45	4.92	13.73	496.65	25.00
ChiliD$_{300}$P$_9$	40.7	32.5	12.64	5.02	12.32	423.12	22.24
BARI Morich-1	48.4	108.1	6.56	3.02	1.92	204.00	12.02
LSD$_{0.05}$	2.40	1.09	0.17	0.13	0.34	1.09	0.18
CV	3.48	5.20	4.24	3.54	4.10	3.45	4.00
Farmers field, Magura							
ChiliD$_{75}$P$_1$	54.1	56.6	14.08	5.54	14.94	701.21	33.40
ChiliD$_{75}$P$_2$	49.3	48.5	11.45	5.15	13.45	628.05	26.13
ChiliD$_{150}$P$_5$	47.2	40.1	11.77	4.83	13.78	536.56	24.62
ChiliD$_{150}$P$_8$	44.9	37.7	12.49	5.00	12.84	503.14	24.97
ChiliD$_{300}$P$_9$	42.5	31.2	12.32	5.15	11.43	442.02	22.41
BARI Morich-1	48.7	110.9	6.74	3.10	1.72	201.52	12.25
LSD$_{0.05}$	2.04	1.00	0.20	0.10	0.30	1.02	0.12
CV	3.12	4.65	4.04	4.16	3.91	3.78	4.18

Conclusion

The effective mutations for higher yield and yield attributing characteristics along with better plant morphology could be induced in winter chili by gamma irradiation dose range of 75Gy-300 Gy. The most spectacular result of this study is almost all the induced mutant lines, in M1 to M6 generations, produced better yield while the parent and check variety produced lower yield. In rabi season, the mutant line ChiliD$_{75}$P$_1$ had significantly higher yield attributes than the parent and check variety BARI Morich-1. Due to higher yield, ChiliD$_{75}$P$_1$ was found suitable for selection and registration. BINA applied to the National Seed Board of Bangladesh (NSB) for registration of ChiliD$_{75}$P$_1$. Consequently, the NSB registered ChiliD$_{75}$P$_1$ in 2017 as a new chili mutant variety, Binamorich-1 for commercial cultivation in Bangladesh.

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REGENERATION POTENTIALITY OF POTATO IN *IN VITRO* CONDITION UNDER DIFFERENT HORMONAL COMBINATIONS

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Abstract

The present investigation was conducted to study the effects of different concentrations and combinations of growth regulators on the callus induction and plant regeneration of potato cvs. Diamant, Cardinal and Granula.The internodal segments of three virus tested potato cultivars were used for the establishment of culture.The interaction effects between cultivars and growth regulators showed significant differences for all the parameters used in the experiment except only root length. The *in vitro* callus proliferation was the best in Diamant when MS medium was fortified with 3.0 mgL^{-1} 2,4-D + 0.25 mgL^{-1}KIN in terms of the highest percentage (100) of callus, the maximum callus size (11.04 mm), the maximum fresh weight (1.126 g) of callus and the maximum dry weight (0.1044 g) of callus. In case of shoot regeneration, MS medium fortified with 1.0 mgL^{-1}BAP+ 0.5 $mgL^{-1}GA_3$ in Granula was best in terms of the highest no. of shoots/callus (2.920), no. of nodes/shoot (6.50) and shoot length (6.760 cm) with the minimum days (14.40). The root regeneration showed the highest results in terms of no. of roots/plantlets(10.80) in Cardinal when MS medium was fortified with 1.0 mgL^{-1}IAA + 0.25 $mgL^{-1}GA_3$. It was found that the *in vitro* regeneration and multiplication potentiality was the highest in the variety Granula followed by Cardinal and Diamont.

Key words: growth regulators, *in vitro* regeneration,MS media, plantlets, potato

Introduction

Potato is an important tuberous food crop. It is also the most productive economically important and widely grown vegetable crop cultivated and consumed in Bangladesh. In 2008, several international organizations highlighted the role of potato in world food production, in the face of developing economic problems. Thus the United Nations officially declared the year 2008 as the International Year of the potato, to raise its profile in developing nations, calling the crop a "hidden treasure". This crop ranks fourth amongst allglobal food crops after wheat, rice and maize (Moeinil*et al.*, 2011), while ranks first both in area and production among the vegetable crops grown in Bangladesh. In Bangladesh, about 8.6 million tons of potato were produced from nearly 0.444 million ha with an average yield of 19 tons/haduring 2015-2016(BBS, 2017). Demand for potato is rapidly increasing. However, production has to be increased even with the current rate of demand.

Although potato is being considered as one of the main food crop in Bangladesh, its productivity is hampered due to infection of virus, fungus and bacterial diseases. The total loss caused by these diseases is 30-100% during cultivation and storage. Potato varieties with higher yield, better agronomic quantities, and resistance to disease are immense importance for increased production. To overcome these impediments, both conventional and biotechnological breeding programmes need to be applied. Disease free and genetically uniform plantlets may be produced by meristem culture through micro-propagation techniques (Hoque*et al.*, 2010).

Micro-propagation offers an efficient and accepted method for rapid propagation and production of pathogen-free seed tubers. Micro-propagation or tissue culture techniques have several advantages over traditional propagation methods. High frequency regeneration of plants from *in vitro* culture tissues is a pre-requisite for crop improvement and for engineering of this crop to supplement conventional breeding. Thus improvementin the growth of such cultures could be benefit in both basic and applied plant biotechnology.Although successful *in vitro* potato regeneration protocol was established in many laboratoriesfrom different explants like leaf and stem in the world but still there are very less information regarding the comparative studies among the different varieties of potato. Which genotypes are more efficient for rapid multiplication is need to identify. There is necessity to assess the regeneration potentiality of available released varieties of potato for better utilization in commercial purpose. Growth regulators play an important role in potato regeneration.Individual hormone has its own effect on regeneration. Combine effect of rooting and shooting growth hormoneis needed to study for better regeneration of potato. The present study was therefore, designed to establish an effective protocol for rapid callus induction and plantlet regeneration of three potato cultivars from internodes explants under different concentrations and combinations of plant growth regulators.

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Materials and Methods

The present investigation was carried out at the Plant Biotechnology Lab,Department of Horticulture, Patuakhali Science and Technology University,Dumki, Patuakhali.The experiment was laid out in a Completely Randomized Design (CRD) with five replications and each replication contains three samples. The virus tested three potatocultiverscvs. Diamant, Cardinal and Granula were obtained from the University of Rajshahi, Rajshahi-6205, Bangladesh. The internodal segments were used as explants for the establishment of culture.
Murashige and Skoog (1962) medium were used with different hormone supplements as the culture medium.

Table 1. Experimental treatments

Experiment	Treatment combinations (mgL^{-1})						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Callus initiation	2,4-D+KIN 0.0 + 0.25	2,4-D+KIN 0.5 + 0.25	2,4-D+KIN 1.0 + 0.25	2,4-D+KIN 1.5 + 0.25	2,4-D+KIN 2.0 + 0.25	2,4-D+KIN 2.5 + 0.25	2,4-D+KIN 3.0 + 0.25
Shoot regeneration	GA_3+BAP 0.0 + 1.0	GA_3+BAP 0.5 + 1.0	GA_3+BAP 1.0 + 1.0	GA_3+BAP 1.5 + 1.0	GA_3+BAP 2.0 + 1.0	-	-
Root regeneration	GA_3+IAA 0.0 + 1.0	GA_3+IAA 0.25 + 1.0	GA_3+IAA 0.5 + 1.0	GA_3+IAA 1.5 + 1.0	GA_3+IAA 2.0 + 1.0	-	-

T_1: 2,4-D 0.0 mg/L + KIN 0.25 mg/L; T_2: 2,4-D 0.5 mg/L + KIN 0.25 mg/L; T_3: 2,4-D 1.0 mg/L + KIN 0.25 mg/L;
T_4: 2,4-D 1.5 mg/L + KIN 0.25 mg/L; T_5: 2,4-D 2.0 mg/L + KIN 0.25 mg/L; T_6: 2,4-D 2.5 mg/L + KIN 0.25 mg/L;
T_7: 2,4-D 3.0 mg/L + KIN 0.25 mg/L.

The abovementioned treatment combinations were used with different stock solutions for the effective callus proliferations. Separate stock solutions for macronutrients, micronutrients, iron source,vitamins/organics and growth regulators etc. were prepared prior to media preparation and stored in a refrigerator at 4^0C for subsequent use. For efficient cultures the semi-solid MS medium having pH 5.8 were prepared from the stock solutions during the studies carefully.The vial containing prepared media were autoclaved at 15 psi and 121^0C for 20 minutes. Metal instruments, glass wares and other instruments were sterilized for the purpose of aseptic conditions. Collected explants were taken in beaker and were thoroughly washed in running tap water for 2-3 minutes and then washed with sterilized water. The explants were transferred to the laminar airflow cabinet in sterilized petridish. They were surface sterilized first with 70% ethyl alcohol for 30 seconds then with 0.1% mercuric chloride ($HgCl_2$) with two drops/100 ml of Tween-20 for 5 minutes. The surface sterilized explants were then rinsed 4-5 times with sterile distilled water inside the clean bench to remove all traces of $HgCl_2$. The excised explants were then inoculated into each culture bottle containing MS medium with various concentrations of hormonal supplements for in vitro callus initiation. The culture vessels with inoculated explants were incubated in both dark and light in a temperature controlled growth room (25 ± 1^0C) under 16 hours photoperiod with a light intensity 1500 lux and relative humidity 60-70%. Subcultures were repeated at least once in a fortnight into a fresh medium and cultured under same culture condition as mentioned previously for calli and organogenesis. Visual observation of cultures was made every week and the data were recorded after different days. Data were taken on, for callus (days required for calli initiation, percentage for calli initiation, callus size, fresh weight of callus, dry weight of callus after 28 DOC (days of culture), for shoots (days required for shoot initiation, percentage of shoot initiation, no. of shoots/explants, no. of nodes/shoot, shoot length (cm), for root (days required for root initiation, no. of roots/plantlet, root length (cm).
The analyses of variances of collected datawere performed and the means were compared by Least Significant Difference (LSD) test for interpretation of results. The significance of the difference between the pair of means was evaluated at 1% level of probability using MSTAT-C computer package programs (Gomez and Gomez, 1984).

Results and Discussion

Callus proliferation

The different cultivars showed significant differences for the days required for callus initiation. Cardinal took the significantly highest number of days (14.27). In contrast, Granula took least number of days (13.36) and was statistically similar to Diamant (13.44) (Table 2 and Plate 1). Different levels of 2,4-D and KIN concentrations significantly influenced the days required for callus initiation. Concentration 2,4-D 0.5 mgL^{-1}+ KIN 0.25 mgL^{-1}took the significantly highest days (17.97) followed by 17.07 days at concentration 2,4-D 1.0mgL^{-1}+ KIN 0.25 mgL^{-1}but statistically similar with each other while concentrations 2,4-D 3.0 mg/L + KIN 0.25 mgL^{-1}took the shortest days (13.93). The maximum days (18.50) required was in Diamant with concentration 0.5 mgL^{-1}2,-D + 0.25 mgL^{-1}KIN followed by (18.22 days) in Cardinal with same concentration but both are statistically similar with each other and so on (Figure 1). In contrast, the minimum days (13.10) required was observed in Granula with concentration 2.5 mgL^{-1}2,-D + 0.25 mgL^{-1}KIN followed by (13.70 days) Diamant cultivar with concentration 3.0 mgL^{-1}2,-D + 0.25 mgL^{-1}KIN. These effective behaviors of 2, 4-D in callus induction were reported in previous studies on potato (Khatun*et al*., 2003; Vargas *et al*., 2005). Cytokinins (Kinetin) added to the medium are very important during tissue culture of plants as those induce cell division and organogenesis, and affect other physiological and developmental processes.

The significant variation was observed among the cultivars regarding percentage of callus initiation. Cardinal produced significantly the highest percentage (80.00) followed by Diamant (78.57) but statistically similar with each other while Granula did produced lowest percentage (72.86) of callus (Table 2). The concentrations 2.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN and 3.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN produced significantly the highest percentage (100) of callus followed by (96.67%) at concentration 2.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN, but those were statistically similar. In contrast, the concentration 0.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN produced the lowest percentage of callus (73.33%). The highest percentage of callus initiation (100) was observed in Diamant with 2.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN, 2.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN and 3.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN concentration, in Cardinal with concentration 1.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN, 2.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN and 3.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN and Granula with concentration 2.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN, 2.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN and 3.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN followed by (90%) in Diamant × concentration 1.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN, 1.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN, in cv. Cardinal × 0.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN, 2.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN and these are statistically similar. In contrast, the lowest (60%) were found in Granula with 0.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN concentrations (Figure 2).

The size of callus had significant differences among the cultivars. Diamant produced significantly the highest size (7.69 mm) followed by Cardinal (7.41 mm) but ranked equal, while Granula produced the least size (7.00 mm) of callus (Table 2 and Plate 1). The growth regulators of 3.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN showed the highest callus size (9.98 mm) while the lowest (7.33 mm) was observed with 1.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN (Table 3).The highest callus size (11.04 mm) was observed with Diamant cultivar on 3.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN while the lowest (6.90 mm) was found at 1.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}KIN in Granula cultivar followed by (7.20 mm) in same cultivar with concentration 0.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin (Plate 1). This result agrees with that of Forooghian*et al.* (2013) who also observed the significant interaction effects among cultivars and concentrations of 2,4-D and KIN but used 5 mgL^{-1}2,4-D and 2 mgL^{-1}Kinetin.

The effect of different cultivars on callus fresh weight varied significantly. Diamant produced the highest fresh weight (0.84 g) followed by 0.82 g in Cardinal but statistically similar with each other. The lowest callus fresh weight was observed in Granula (0.76 g) (Table 2). The growth regulators of 3.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin gave the highest fresh weight of callus (1.02 g), followed by 2.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin (0.99 g) but ranked equal. The lowest weight of callus (0.86 g) was observed with 1.0 mgL^{-1}2,4-D +0.25 mgL^{-1}Kinetin followed by 0.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin (0.89 g) (Table 2). The highest callus fresh weight (1.13 g) was observed in Diamant at 3.0 mgL^{-1}+ 0.25 mgL^{-1}Kinetin followed by 1.03 g in Cardinal with concentration 2.0 mgL^{-1}2,4-D +0.25 mgL^{-1}Kinetin. In contrast, the lowest callus fresh weight (0.80 g) was found at 0.5 mgL^{-1}2,4-D + 0.25mgL^{-1}Kinetin from Granula cultivar followed by (0.81 g) in same cultivar on concentration 1.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin (Table 3).

Remarkable variations were found among the different cultivars in respect of callus dry weight. Diamant produced the highest dry weight (0.075 g) followed by Cardinal 0.073 g but statistically similar with each other. The lowest callus dry weight (0.063g) was found in Granula (Table 2). The growth regulators 3.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin gave the highest dry weight of callus (0.089 g), followed by2.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin (0.088 g) but both were of equal rank. The lowest dry weight of callus (0.076 g) with 0.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin followed by 1.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin (0.079 g) and 1.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin (0.080 g) but all are ranked equally (Table 3). The highest callus dry weight (0.104 g) was observed with Diamant on 3.0 mgL^{-1}+ 0.25 mgL^{-1}Kinetin followed by Cardinal (0.099 g) with concentration 2.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin but was of equal rank with each other. In contrast, the lowest callus dry weight was found (0.068 g) at 0.5 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin from Granula cultivar followed by (0.071 g) in same cultivar on concentration 2.0 mgL^{-1}2,4-D + 0.25 mgL^{-1}Kinetin (Table 3).

Table 2. Effects of different cultivars on the days to callus initiation, percentage of callus initiation, callus size, callus fresh weight and callus dry weight after 28 days of inoculation

Varieties	Fresh weight of explants inoculated(g)	Days to callus initiation	Percentage of callus formation	Callus size (mm)	Callus fresh weight (g)	Callus dry weight (g)
$V_{1(Diamant)}$	0.004	13.44b	78.57a	7.69a	0.840a	0.075a
$V_{2(Cardinal)}$	0.004	14.27a	80.00a	7.41a	0.818a	0.073a
$V_{3(Granula)}$	0.004	13.36b	72.86b	7.01b	0.76b	0.063b
Level of significance		**	**	**	**	**

In a column values having different letter (s) differ significantly at 1% level of probability; ** Significant at 1% level of probability

Table 3. Effects of different concentrations and combinations of 2,4-D and Kinetin on the days to callus initiation, percentage of callus initiation, callus size, callus fresh weight and callus dry weight after 28 days of inoculation

Concentrations and combinations of PGRs (mgL^{-1})	Fresh weight of explants inoculated (g)	Days to callus initiation	Percentage of callus formation	Callus size (mm)	Callus fresh weight (g)	Callus dry weight (g)
T_1 (0.0 2,4-D +0.25 KIN)	0.004	-	-	-	-	-
T_2 (0.5 2,4-D +0.25 KIN)	0.004	17.97a	73.33c	7.99c	0.89cd	0.076c
T_3 (1.0 2,4-D +0.25 KIN)	0.004	17.07ab	83.33b	7.33d	0.86d	0.080c
T_4 (1.5 2,4-D +0.25 KIN)	0.004	16.13bc	86.67b	8.57bc	0.93bc	0.079c
T_5 (2.0 2,4-D +0.25 KIN)	0.004	15.80cd	100.0a	8.83b	0.98ab	0.088ab
T_6 (2.5 2,4-D +0.25 KIN)	0.004	14.93d	96.67a	8.86b	0.95ab	0.089bc
T_7 (3.0 2,4-D +0.25 KIN)	0.004	13.93e	100.0a	9.98a	1.01a	0.089a
CV (%)		7.19	7.21	8.41	7.45	10.10
Level of significance		**	**	**	**	**

In a column values having different letter (s) differ significantly at 1% level of probability; ** Significant at 1% level of probability

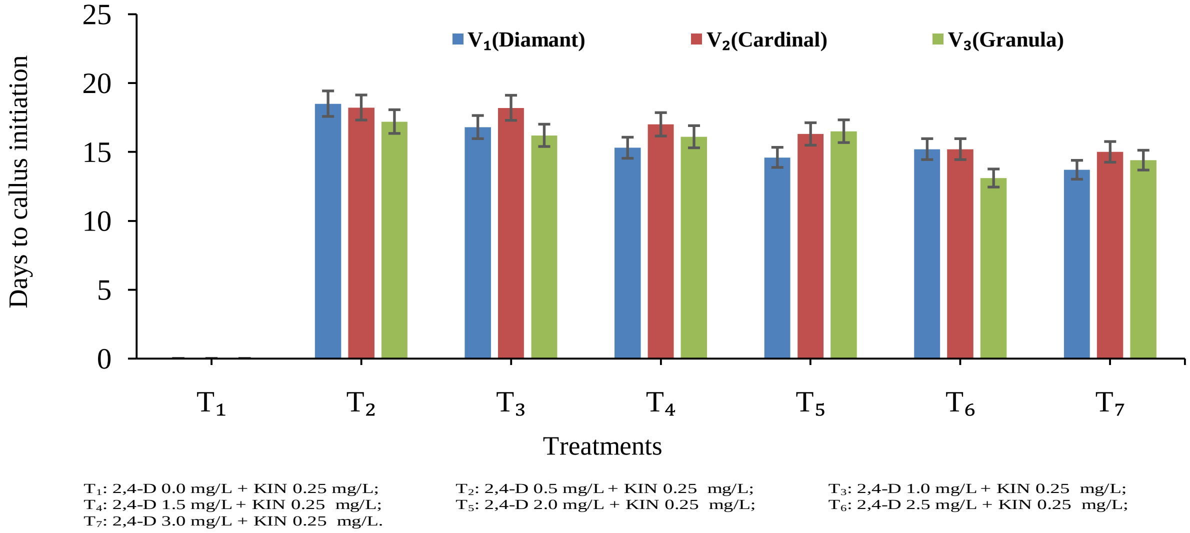
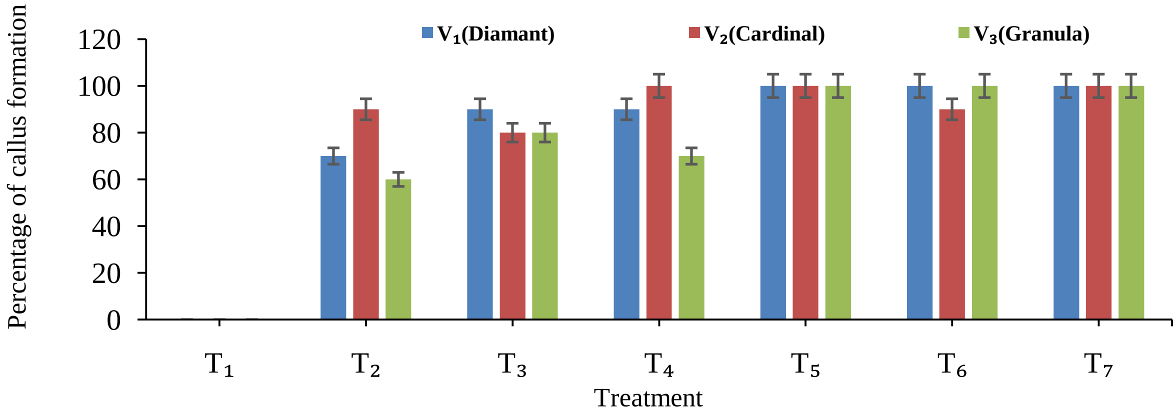


Fig. 1. Effects of cultivars on the days to callus initiation under different concentrations and combinations of 2,4-D and KIN(Vertical bars represent the standard error)

Shoot regeneration

There were no significant differences among different cultivars on days required for shoot initiation. Out of three cultivars, Cardinal took the highest number of days (16.26) for shoot initiation. In contrast, Granula took the lowest number of days (15.94) (Table 4). This result agrees with that of Minar (2005). The interaction effects among different cultivars and concentrations of growth regulators showed significant differences on days required for shoot initiation. Granula with 1.0 mgL^{-1}BAP + 2.0 $mgL^{-1}GA_3$ took the highest days (18.20) for shoot initiation followed by 14.80 days in Cardinal x 1.0 mgL^{-1}BAP + 1.5 $mgL^{-1}GA_3$. In contrast, lowest number of days was required (14.40 days) for shoot initiation in Granula with concentration 1.0 mgL^{-1}BAP + 0.5 $mgL^{-1}GA_3$ followed by 14.80 days with Diamant x 1.0 mgL^{-1}BAP + 0.5 $mgL^{-1}GA_3$ (Table 5 and Plate 2). The minimum days (14.40) to shoot initiation, the maximum no. of shoots (2.92) per callus, the maximum no. of node (6.50) per callus and the tallest shoot (6.76 cm) were noted in Granulaat GA_3 0.5 mgL^{-1}+ BAP 1.0 mgL^{-1}treatment combinations. Remarkable variations were found among different cultivars in respect of percentage of shoot initiation. Granula cultivar produced significantly the highest percentage (90.00) of shoot while Diamant produce the lowest percentage (72.00) of shoots (Table 4). The percentage of shoot initiation was also influenced by the supplementation of different concentration and combinations of BAP and GA_3 (Table 5). The interaction effects between different cultivars and concentrations of growth regulators showed significant effects



T_1: 2,4-D 0.0 mg/L + KIN 0.25 mg/L; T_2: 2,4-D 0.5 mg/L + KIN 0.25 mg/L; T_3: 2,4-D 1.0 mg/L + KIN 0.25 mg/L; T_4: 2,4-D 1.5 mg/L + KIN 0.25 mg/L; T_5: 2,4-D 2.0 mg/L + KIN 0.25 mg/L; T_6: 2,4-D 2.5 mg/L + KIN 0.25 mg/L; T_7: 2,4-D 3.0 mg/L + KIN 0.25 mg/L.

Fig. 2. Effects of cultivars on the percentage of callus formation under different concentrations and combinations of 2,4-D and KIN(Vertical bars represent the standard error)

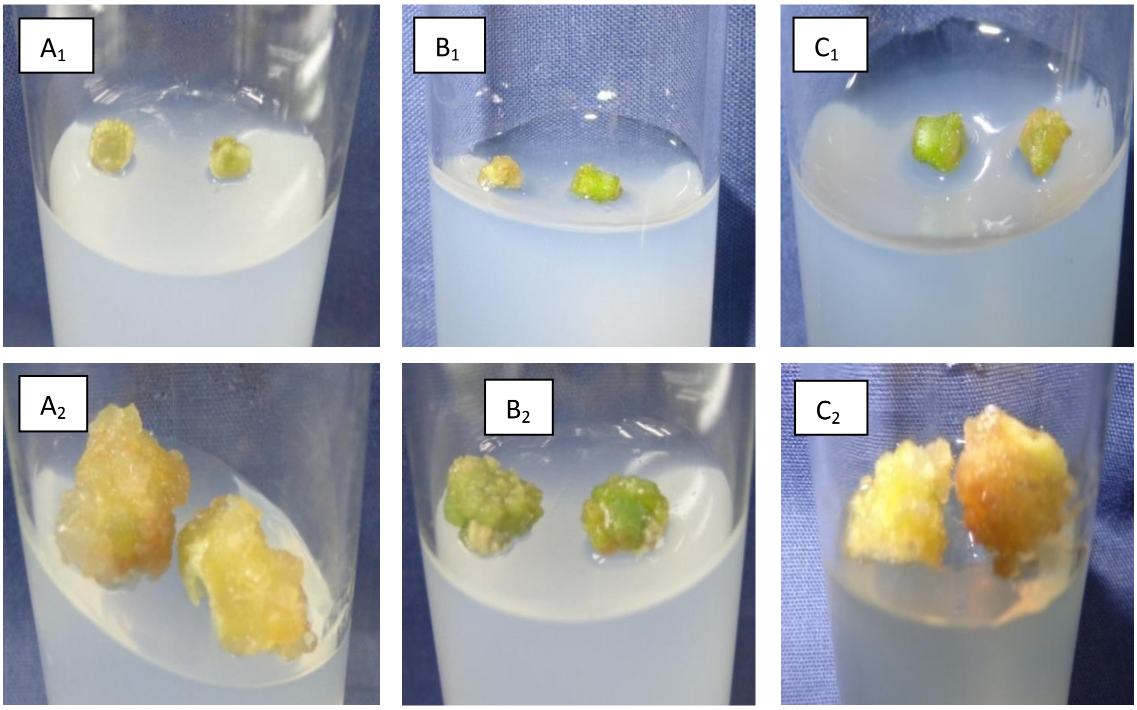


Plate 1. The callus initiation and the maximum callus size (mm) in cultivarDiamant with 2,4-D 3.0 mg L^{-1} + Kinetin 0.25 mg L^{-1} (A_1-A_2), cultivar Cardinal with 2,4-D 3.0 mg L^{-1} + Kinetin 0.25 mg L^{-1} (B_1-B_2), cultivar Granula with 2,4-D 3.0 mg L^{-1} + Kinetin 0.25 mg L^{-1} (C_1-C_2)

on the percentage of shoot initiation. The highest percentage of shoot initiation (100) was observed in Cardinal and Granula cultivars with 1.0 mgL^{-1}BAB + 1.0 $mgL^{-1}GA_3$ treatment concentration followed by (90%) with concentrationof 1.0 mgL^{-1}BAB + 0.5 $mgL^{-1}GA_3$ in cvs. Diamant and Cardinal, concentrations 1.0 mgL^{-1}BAP + 1.5 $mgL^{-1}GA_3$ and 1.0 mgL^{-1}BAP + 2.0 $mgL^{-1}GA_3$ in Granular cultivar but ranked equal. In contrast, the lowest (60%) was found in Diamant cultivar with 1.0 mgL^{-1}BAP + 1.5 $mgL^{-1}GA_3$ and 1.0 mgL^{-1}BAP + 2.0 $mgL^{-1}GA_3$ concentrations. That variable response in regeneration potential might be dependent on cultivar-specific effect.

Remarkable variations were found among different cultivars in respect of number of shoots per plantlet. Among different cultivars, Granula produced the highest number of shoots (2.49), while the Cardinal had the lowest number (1.56) of shoots per explants (Table 4).The maximum number of shoots (2.407) was produced by 1.0 mgL^{-1}BAP + 0.5 $mgL^{-1}GA_3$ treatment combination followed by 2.320 at 1.0 mgL^{-1}BAP + 1.0 $mgL^{-1}GA_3$ but both are ranked equal. In contrast, the minimum number (1.561) of shoot was produced with 1.0 mgL^{-1}BAP + 2.0 $mgL^{-1}GA_3$ treatment combination followed by 1.895 at 1.0 mgL^{-1}BAP + 1.5 $mgL^{-1}GA_3$ treatment combination (Table 5).Distinct variations were found in respect of number of shoots per callus due to the interaction effect of cultivars and different concentrations of growth regulators. Granula cultivar x 1.0 mgL^{-1}BAP + 0.5 $mgL^{-1}GA_3$ produced highest number (2.92) of shoot followed by 2.76 shoots with same cultivar at 1.0 mgL^{-1}BAP + 1.0 $mgL^{-1}GA_3$ treatment combination while ranked equal. In contrast, lowest number of shoots was (1.40) produced in cv. Cardinal with 1.0 mgL^{-1}BAP + 0.0 $mgL^{-1}GA_3$ and 1.0 mgL^{-1}BAP + 2.0 $mgL^{-1}GA_3$ (Figure 3).

Table 4. Effects of different cultivars on the days to shoot initiation, percentage of shoot initiation, no. of shoots/callus, no. of nodes/shoot and shoot length (cm) after 28 days of inoculation

varieties	Days to shoot initiation	Percentage of shoot initiation	No. of shoot per callus	No. of node per shoot	Shoot length (cm)
V_1(Diamant)	16.06a	72.00c	2.16b	4.20b	3.87b
V_2 (Cardinal)	16.26a	82.00b	1.56c	4.94a	4.72a
V_3 (Granula)	15.94a	90.00a	2.49a	5.02a	4.82a
Level of significance	ns	**	**	**	**

In a column values having different letter(s) differsignificantly at 1% level of probability.
** Significant at 1% level of probability

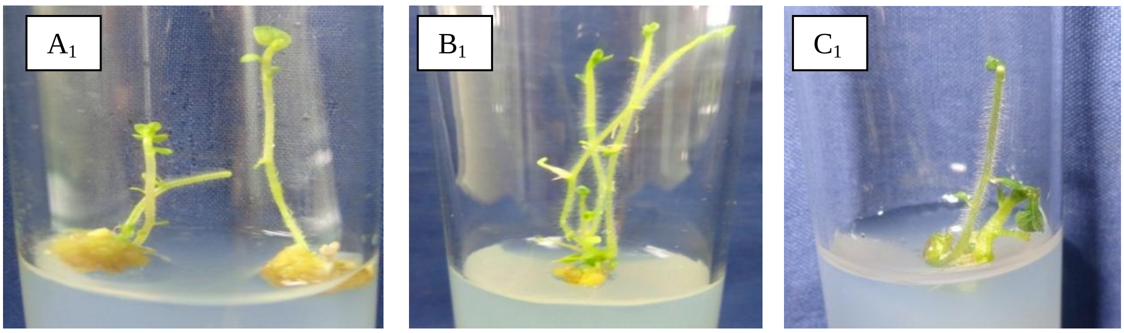


Plate 2. The shoot initiation and the highest shoot length in cv. Diamant with GA_3 0.5 mg/L + BAP 1.0 mgL^{-1}(A_1), cv. Cardinal with GA_3 1.0 mgL^{-1}+ BAP 1.0 mgL^{-1}(B_1), cv. Granula with GA_3 0.5 mgL^{-1}+ BAP 1.0 mgL^{-1}(C_1)

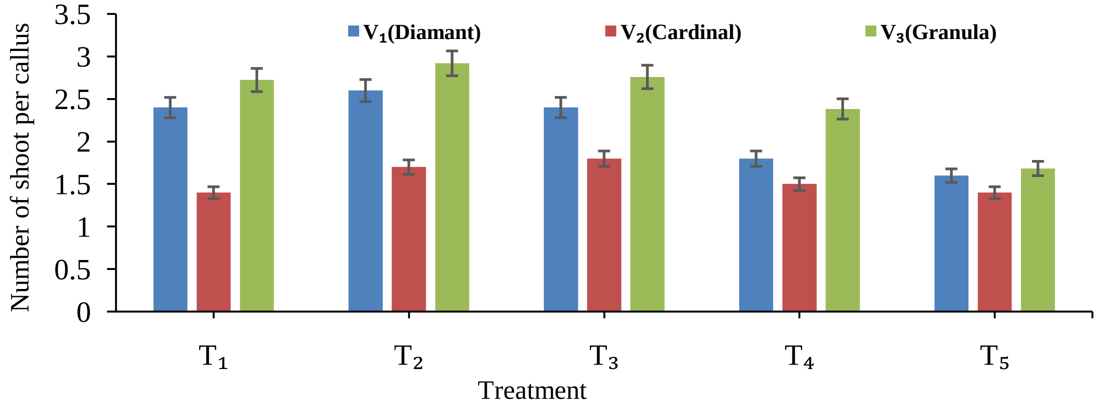
Different cultivars showed significant differences in shoot length. Granula produced the tallest shoot (4.82 cm) followed by Cardinal (4.72 cm) but both were ranked equal while Diamant produced the shortest shoot (3.87 cm) (Table 4 and Plate 2). Different concentrations of growth regulators showed significant differences in shoot length 1.0 mgL^{-1}BAP + 0.5 $mgL^{-1}GA_3$ combinations produced significantly the longest shoot (5.607 cm). In contrast, the shortest shoot (3.702 cm) was with 1.0 mgL^{-1}BAP + 0.0 $mgL^{-1}GA_3$ followed by 4.101 cm with 1.0 mgL^{-1}BAP + 2.0 $mgL^{-1}GA_3$ (Table 5).

The interaction effects between cultivars and the concentrations of growth regulators on shoot length also showed significant differences. The longest shoot (6.76 cm) was produced by the treatment combination of 1.0 mgL^{-1}BAP + 0.5 $mgL^{-1}GA_3$ with Granula but the shortest one (3.23 cm) was in the treatment combination of 1.0 mgL^{-1}BAP + 0.0 $mgL^{-1}GA_3$ with Diamant followed by 1.0 mgL^{-1}BAP + 1.5 $mgL^{-1}GA_3$ with same variety (Figure 4).

Table 5. Effects of different concentrations and combinations of BAP and GA_3 on the days to shoot initiation, percentage of shoot initiation, no. of shoots/callus, no. of nodes/shoot and shoot length (cm) after 28 days of inoculation

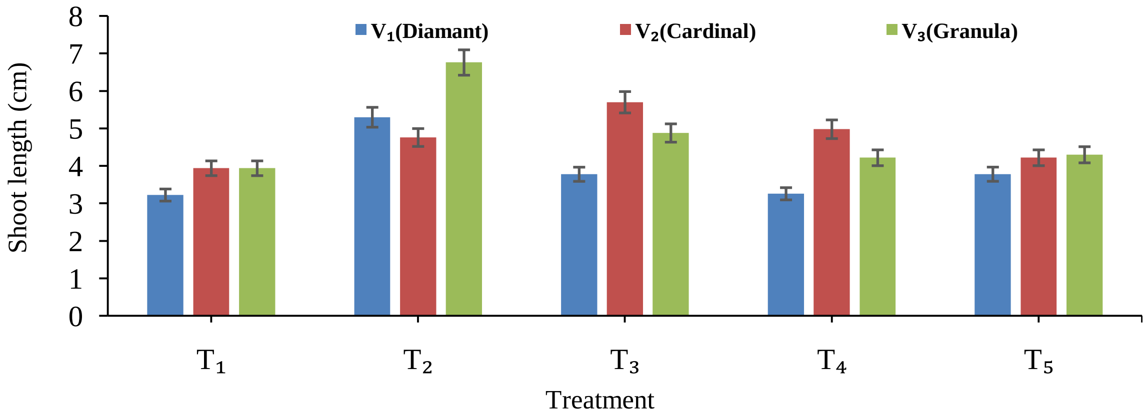
Concentrations and combinations of PGRs (mg/L)	Days to shoot initiation	Percentage of shoot initiation	No. of shoot per callus	No. of node per shoot	Shoot length (cm)
T_1 (GA_3 0.0 + BAP 1.0)	15.80b	73.33b	2.18ab	4.16c	3.70c
T_2 (GA_3 0.5 + BAP 1.0)	14.73c	90.00a	2.41a	5.87a	5.61a
T_3 (GA_3 1.0 + BAP1.0)	15.90b	93.33a	2.32a	4.93b	4.79b
T_4 (GA_3 1.5 + BAP 1.0)	16.50b	76.67b	1.90bc	4.37c	4.15c
T_5 (GA_3 2.0 + BAP 1.0)	17.50a	73.33b	1.56c	4.27c	4.10c
Level of significance	**	**	**	**	**

In a column values having different letter (s) differ significantly at 1% level of probability
** Significant at 1% level of probability



T_1: GA_3 0.0 mg/L + BAP 1.0 mg/L; T_2: GA_3 0.5 mg/L + BAP 1.0 mg/L; T_3: GA_3 1.0 mg/L + BAP 1.0 mg/L; T_4: GA_3 1.5 mg/L + BAP 1.0 mg/L; T_5: GA_3 2.0 mg/L + BAP 1.0 mg/L

Fig.3. Effects of cultivars on the no. of shoots/callus under different concentrations and combinations of BAP and GA_3 (Vertical bars represent the standard error)



T_1: GA_3 0.0 mg/L + BAP 1.0 mg/L; T_2: GA_3 0.5 mg/L + BAP 1.0 mg/L; T_3: GA_3 1.0 mg/L + BAP 1.0 mg/L; T_4: GA_3 1.5 mg/L + BAP 1.0 mg/L; T_5: GA_3 2.0 mg/L + BAP 1.0 mg/L

Fig.4. Effects of cultivars on shoot length (cm) under different concentrations and combinations of BAP and GA_3 (Vertical bars represent the standard error)

Root regeneration

Distinct variations were found in respects of roots per plantlets due to the interaction effect of cultivars and different concentrations of growth regulators. Granula produced the highest number of roots (10.24) followed by (9.688) in Cardinal and those ranked equal while the lowest number (8.920) was found from Diamant (Table 6 and Plate 3). The *in vitro* regeneration and multiplication potentiality were highest in the cultivarGranula followed by Cardinal and Diamant. This result agrees with that of Hoque (2010).
The effects of different concentrations of IAA (Indole acetic acid) and GA_3(Giberellic acid) on the number of roots showed significant differences. The maximum number of roots (10.03) appeared with 1.0 mgL^{-1}IAA + 0.25 $mgL^{-1}GA_3$ concentrations followed by 9.780 at 1.0 mgL^{-1}IAA + 0.5 $mgL^{-1}GA_3$ concentrations and the lowest number of roots (9.033) was observed in 1.0 mgL^{-1}IAA + 0.0 $mgL^{-1}GA_3$ concentrations (Table 7 and Plate 3).The present study has similar finding with those of Laboney*et al.* (2013), Minar(2005) and Amezqueta*et al.* (1989) who also observed that the highest regenerated plants and fastest growth rates were with IAA and GA_3.
Distinct variations were found in respects of roots per plantlets due to the interaction effect of cultivars and different concentrations of growth regulators. The maximum number of roots (10.80) was observed with Cardinal at 1.0 mgL^{-1}IAA + 0.25 mgL^{-1}(Figure 3 and plate 3). Distinct variations were found in respects of roots per plantlets due to the interaction effect of cultivars and different concentrations of growth regulators. The highest number of roots (10.80) was observed with Cardinal at 1.0 mgL^{-1}IAA + 0.25 $mgL^{-1}GA_3$ followed by 10.64 on the same cultivar at 1.0 mgL^{-1}IAA + 0.5 $mgL^{-1}GA_3$ concentrations (Figure 3 and plate 3). But, the lowest number of roots (8.30) was observed with Cardinal × 1.0 mgL^{-1}IAA + 0.0 $mgL^{-1}GA_3$ followed by 8.700 on Diamant at 1.0 mgL^{-1}IAA + 0.5 $mgL^{-1}GA_3$ concentrations.

Table 6. Effects of different cultivars on the days to root initiation, no. of roots/plantlet and root length (cm) after 28 days of inoculation

Varieties	Days to root initiation	No. of root per plantlet	Root length (cm)
V_1(Diamant)	14.46b	8.920b	5.584b
V_2 (Cardinal)	15.56a	9.688a	5.444b
V_3 (Granula)	14.18b	10.24a	6.028a
CV (%)	5.15	8.70	7.55
Level of significance	**	**	**

In a column values having different letter (s) differ significantly at 1% level of probability; ** Significant at 1% level of probability

Table 7. Effects of different concentrations of IAA and GA_3 on the days to root initiation, no. of roots/plantlet and root length (cm) after 28 days of inoculation

Concentrations and combinations of PGRs (mgL^{-1})	Days to root initiation	No. of root per plantlet	Root length (cm)
T_1 (GA_3 0.0 + IAA 1.0)	14.57ab	9.03b	5.37c
T_2 (GA_3 0.25 +IAA 1.0)	14.33b	10.03a	6.15a
T_3 (GA_3 0.5 + IAA 1.0)	14.37b	9.78ab	5.92ab
T_4 (GA_3 1.0 + IAA 1.0)	15.07ab	9.70ab	5.40c
T_5 (GA_3 2.0 + IAA 1.0)	15.33a	9.53ab	5.59bc
$LSD_{0.01}$ value	0.74	0.81	0.42
Level of significance	**	*	**

In a column values having different letter(s) differ significantly at 1% and 5% level of probability.

** Significant at 1% level of probability* Significant at 5% level of probability

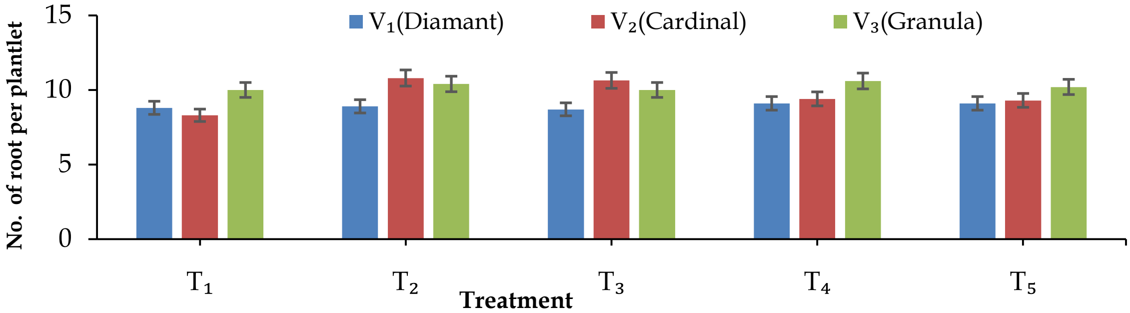


Fig. 5. Effects of cultivars on the no. of roots/plantlet under different concentrations and combinations of IAA and GA_3

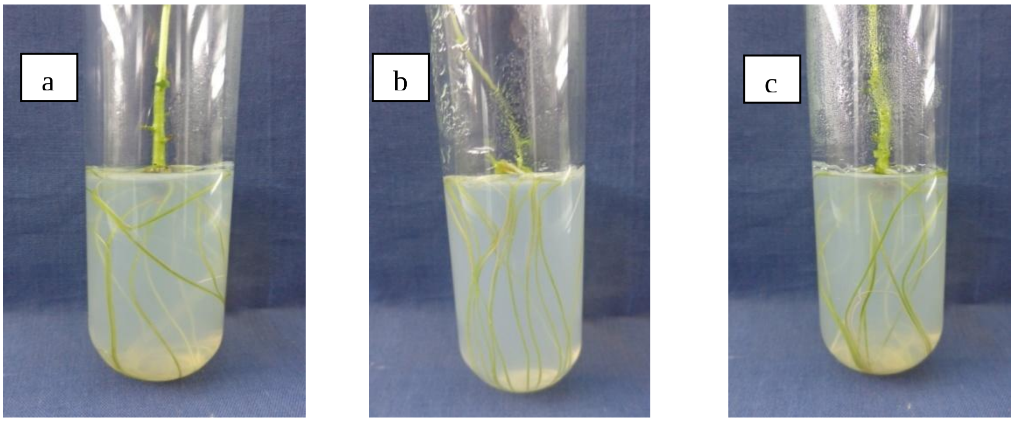


Plate 4. The maximum number of root in cv. Diamant at IAA 1.0 mgL^{-1}+ GA_3 1.0 mgL^{-1}(a), cv. Cardinal at IAA 1.0 mgL^{-1}+ GA_3 0.25 mgL^{-1}(b) and cv. Granula at IAA 1.0 mgL^{-1}+ GA_3 1.0 mgL^{-1}(c)

The highest length (6.028 cm) of root after 28 days was observed in Granula. The lowest length (5.444 cm) of root was found in Cardinal followed by 5.584 cm with Diamant but those ranked equal (Table 6). Different concentrations of growth regulators on the root length after 28 days also showed significant difference. The longest root (6.147 cm) appeared with 1.0 mgL^{-1}IAA + 0.25 $mgL^{-1}GA_3$ concentrations followed by 5.920 cm at 1.0 mgL^{-1}IAA + 0.5 $mgL^{-1}GA_3$ concentrations while the shortest roots (5.373 cm) was observed in 1.0 mgL^{-1}IAA + 0.0 $mgL^{-1}GA_3$ followed by 5.400 cm at 1.0 mgL^{-1}IAA + 1.0 $mgL^{-1}GA_3$ concentrations (Table 7). The other treatments produced intermediate root length. The present study has similar results with those of Laboney*et al.* (2013),Minar(2005) and Amezqueta*et al.* (1989) who also observed that the highest regenerated plants and fastest growth rates were with IAA and GA_3.

The *in vitro* performance of Granula was best followed by Cardinal and Diamant. From the above discussion, it is revealed that different growth regulators with their different concentration and combination provided the best results in *in vitro* plant regeneration of different cultivars of potato. In the conclusion, the findings of the present study could be useful to develop protocol to identify the potentiality of exact concentration of different growth regulators. Furthermore, the results could be used to produce large scale production of healthy and disease free planting materials commercially.

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FACTORS CONTRIBUTING TO ADOPTION OF MODERN SESAME PRODUCTION TECHNOLOGIES IN SOME SELECTED AREAS

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Abstract

The study was conducted to assess the extent of adoption and also to determine the contribution of the selected factors to the adoption of modern sesame production technologies by the farmers of five villages of five districts (Kushtia, Chuadanga, Faridpur, Jashore and Narail). Data were obtained from 100 randomly selected farmers in five selected villages of five districts using the interview schedule. Data were collected from the sample during 15 September to 25 October, 2014. Half (51 percent) of the farmers had low adoption while 37 percent had medium and 12 percent had high adoption of modern sesame production technologies. Six factors out of 16 contributed significantly to the adoption of modern sesame production technologies by the farmers. The contributing factors were extension media contact, profitability of technology, cropping intensity, suitability of technology, credibility of extension agents andcosmopoliteness and their contributions were 40.7%, 15.2%, 12.3%, 8.9%, 1.6% and 1.8%, respectively. These six variables explained 80.5 percent of total variation in adoption of technological package of practices in relation to the adoption of modern sesame production technologies.

Key words: Credibility of extension agents, risk orientation, suitability of technology and profitability of technology

Introduction

Edible oils play a very important role in human nutrition. It is not only a high energy food but also a carrier for fat soluble vitamins (A, D, E and K) in the body. Oils are not only important for human diets but also services as important raw material for industrial use such as in making soaps, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc. Oil cakes and meals are used as animal feeds and manures. The major oilseed crops grown in Bangladesh are mustard, sesame, groundnut and linseed. The major contribution of oil comes from mustard (69.9%) followed by sesame (8.9%) and groundnut (invisible oil 7.8%) (BBS, 2016).Sesame is the second largest source of edible oil in Bangladesh next to mustardboth in respect of acreage and production. Sesame is one of the world's oldest spice and oilseed crop grown mainly for its seeds that contain approximately 35-50% oil, 20-25% protein, 20% sugar, 6% fibre and many kinds of minerals. Sesame oil is quality edible oil. The oil is tasteless, odourless and also used as hair oil and as a component of cosmetics. The seed is used in making various food items like cakes, khaja, biscuits, etc. Dry plants and leaves are used as fuel and oilcakes as cattle feeds and manures. Sesame has also been used as folk medicine. In India and Bangladesh, sesame and its oil have been used traditionally to cure various ailments, such as asthma, in "ayurveda" since ancient times. It is well known that sesame has nutritive, laxative, demulcent, emollient, diuretic and lactagogue properties. The roots, usually unused parts of sesame, contains antifungal compound such as chlorosesamone, hydroxysesamone and 2-3 epoxysesamone (Hasan*et al*, 2000 and 2001). The climate of Bangladesh is more suitable for sesame cultivation. In Bangladesh it is grown in almost all districts but grows well in greater Khulna, Faridpur, Pabna, Barisal, Rajshahi, JashoreKushtia, Comilla, Dhaka, Rangpur, Sylhet, and Mymensingh districts. Due to increase of area under cereal crops for meeting the increasing demand of food-stuff, land under oilseed crops has declined and price of oil has gone up. Cultivation of traditional varieties, imbalance use of fertilizers, inability to seed sowing in proper time,non adoption of other production technologies, natural calamities, socio-economic barrier, large yield gap (20-40%), nutrient mining in existing cropping pattern, unavailability of seeds of suitable HYV varieties etc. are the main constraints of maximizing yield of oilseeds.At present, the domestic production of edible oil can only meet about 20% of the country annual demand and rest is imported which cost more than taka 20 billion. The national average yield of sesame is 0.63 t/ha which is very low compared to potential yield of 1.4 t/ha of modern varieties. The government of Bangladesh has, therefore, provided priority to the agriculture sector to increase the production of oilseeds by giving subsidy to the farmers on different inputs such as fertilizer, irrigation etc. to achieve self-sufficiency in

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oilseeds. In view of the foregoing discussion, the researcher undertook a study entitled, "Factors contributing to the adoption of modern sesame production technologies in some selected areas" along with the following objectives. The study was conducted (i) to assess the extent of adoption of modern sesame production technologies by the farmers in some selected areas and (ii) to determine the contribution of the selected factors in explaining the variation of adoption of modern sesame production technologies.

Materials andMethoeds

Study areas and source of data: Considering the sesame growing area the study was conducted in five villages such as SadarofKushtia,AlamdangaofChuadanga, Modhukhali of Faridpur,BagharparaofJashore and LohagoraofNarail districts. All the 300 farmers of selected five villages who cultivated sesame constitute the population of the study. A list of sesame growers of selected villages was prepared with the help of local Sub-Assistant Agriculture Officer (SAAO) of DAE of the concerned area. Thus, 100 (33% of population) sesame growers were the sample of the study selected in a stratified way. They were considered as the representative of the five villages of respective districts.

Variables of the study and their measurement: Age, education, family size, farm size, cropping intensity, Family annual income, training exposure, extension media contact, innovativeness, cosmopoliteness, organizational participation, agricultural knowledge on sesame cultivation, credibility of extension agents, risk orientation, suitability of technology and profitability of technology was consisted as the independent variable whereas 'Factors contribution to the adoption of modern sesame production technologies in some selected areas' was considered as the dependent variable of the study. The selected modern technologies were consisted of recommended package of five practices. The five practices were adoption of improved seed, adoption of recommended rate of fertilizer, adoption of weeding and thinning, adoption of irrigation and adoption of pesticide use were selected to measure the adoption level. It was measured on the basis of the extent of adoption of modern sesame production technologies by the farmers for a period of two years (2013, 2014). Adoption Index (AI) for modern sesame production technologies in this study was computed by using the formula developed by Chattapadhyay (1963) and simplified by Ray (1998). Adoption of modern sesame production technologies was measured for recommended package of five practices. The adoption score was expressed in percentage. The Adoption Index (AI) of sesame grower could range from 0 to 100, where 0 indicate no adoption and 100 indicate highest adoption.

Data collection and statistical analysis: Data was collected throughout interview schedule from the respondents during Sep 15, to Oct 25, 2014. Data were collected by the researcher himself through interview schedule from the farmers of the selected villages. The interview was conducted with the respondents individually in their respective houses. The SPSS (Statistical Package for Social Science) computer package was used to perform data analysis. Descriptive analysis such as mean, range, number and percentage, standard deviation and rank order were used whenever necessary. Pearson's Product Moment Correlation Coefficient (r) was computed to explore the relationships between the dependent and independent variables (Ray and Mondal, 2004). For computing contribution and variability of the independent variables in predicting adoption, stepwise multiple regression analyses were employed.

Findings and Discussion

Level of adoption

The overall adoption scores of the farmers on five packages of practices ranged from 6.95-80.51 against 0-100. The average adoption score was 36.58 with a standard deviation of 19.21. According to overall adoption score, the farmers were classified into three categories namely, "low adopter" (up to 33), "medium adopter"(34 to 66) and "high adopter" (above 66). The distribution of farmers on the basis of their overall adoption scores is shown in Table1.

Data presented in Table 1 revealed that the highest proportion (51 percent) of farmers fell under the low adoption category, while 37 percent had medium adoption and 12 percent had high adoption. Thus an overwhelming majority of the farmers had low to medium (88%) adoption. These results that the majority of the farmers adopted modern sesame production technologies but they have not adopted the recommended packages practices in full. For clarity of understanding a bar diagram has been presented in Fig. 1.

Table 1. Distribution of the farmers on the basis of their overall adoption

Categories	Farmers		Range	Mean	SD
	Number	Percent			
Low adoption (up to 33)	51	51	6.95 - 80.51	36.58	19.21
Medium adopter (34 - 66)	37	37			
High adopter (above 66)	12	12			
Total	100	100			

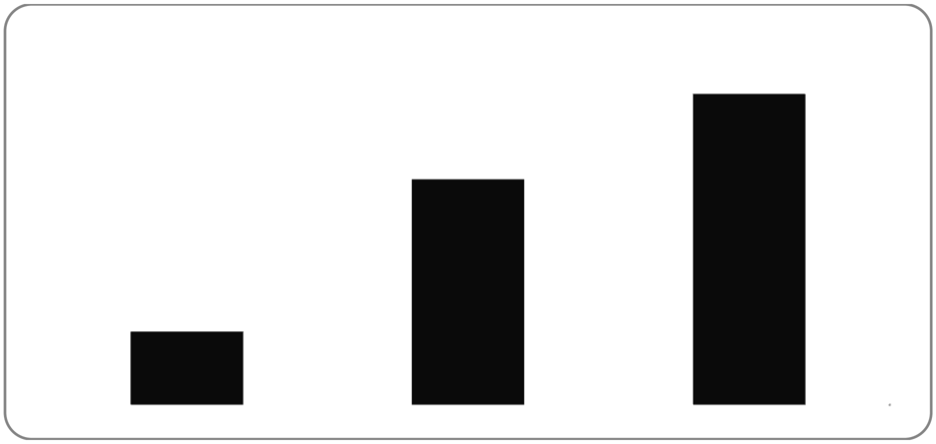

Fig.1. Farmers' adoption of modern sesame production technologies measured according to their extent of adoption.

Relationship between the Selected Growers's characteristics & other factors and their Adoption of Modern Sesame Production Technologies.

The relationship between the selected sesame growers' characteristics & other factors and their adoption of modern sesame production technologies were ascertained by the Pearson's product moment coefficient of correlation and the summary of the result has been presented in Table 2.

Table 2. Co-efficient of correlation of the selected characteristics of the respondents and their adoption of modern sesame production technologies (N=100)

Selected characteristics of the farmers and others factors	Co-efficient of correlation ('r')
Age	0.047
Education	0.209*
Family Size	- 0.166
Farm Size	0.252*
Cropping Intensity	0.466**
Family Annual Income	0.203*
Training Exposure	0.580**
Extension Media Contact	0.574**
Innovativeness	0.376**
Cosmopoliteness	0.223*
Organizational Participation	0.154
Knowledge on sesame cultivation	0.307**
Credibility of the extension agents	0.401**
Risk Orientation	0.365**
Suitability of the technology	0.206*
Profitability of the technology	0.522**

***** = Correlation is significant at the 0.05 level (2-tailed); ****** = Correlation is significant at the 0.01 level (2-tailed).

Out of sixteen factors, thirteen factors namely: education of the farmers, farm size of the farmers, Cropping intensity, family annual income, training exposure of the farmers, extension media contact, innovativeness, cosmopoliteness, agricultural knowledge on sesame cultivation, credibility of extension agents, risk orientation, suitability of technology, profitability of technology had significant and positive relationship with their adoption of modern sesame production technologies and rest of the factors (age, family size of the farmers, organizational participation) shown no significant relationship with their adoption.

Contribution of selected independent variables to the adoption

The result of correlation analyses did not reflect effects and contributions of various factors (independent variables) to the adoption of modern sesame production technologies (dependent variable). For computing contribution and variability of the independent variables in predicting adoption, stepwise multiple regression analyses were employed in the present study. According to Draper and Smith (1981) the method of stepwise multiple regression analysis is to insert variables in turn until the regression equation is satisfactory. The stepwise multiple regression analysis indicated that out of sixteen variables, thirteen variables had significant relationship with the adoption in the Pearson correlation test. However all of the sixteen variables were used in the stepwise regression analysis but out of 16 only 6 variables finally entered in the model and contribution of these 6 variables were statistically significant. The whole model of six variables explained 80.5 percent of total variation in adoption of packages of practices in relation to the adoption of modern sesame production technologies. Remaining 10 variables were excluded from the model as their F values or tolerance was too small to continue. The computed results of stepwise multiple regression analysis is shown in Table 3.

Table 3. Changes in multiple R^2 for enter of a variable into the step-wise multiple regression analysis models for adoption

Variables entered in steps	R^2	R^2 Change	Variation Explaining Percentage	Unstandardized Coefficients (B)	Standardized Coefficients (Beta)
Extension Media Contact (X_8)	0.407	-	40.7	.320**	0.204**
Profitability of technology (X_{16})	0.559	0.152	15.2	.660*	0.175*
Cropping Intensity (X_5)	0.682	0.123	12.3	.227**	0.467**
Suitability of technology (X_{15})	0.771	0.089	8.9	1.483**	0.327**
Credibility of extension agents (X_{13})	0.788	0.016	1.6	.271*	0.152*
Cosmopoliteness (X_{10})	0.805	0.018	1.8	.545*	0.194*

Coefficient of multiple determinant (R^2)= 0.805, Constant = -76.880, F Value = 36.561**

***** = Significant at the 0.05 level of probability; ****** = Significant at the 0.01 level of probability

Viewing at the significant contributions of the six variables to the variations in adoption, the researcher concluded that each of the six variables had significant effect on the adoption of modern sesame production technologies. The explicit form of the concerned regression equation is as follows:

$$Y = -76.880 + 0.320X_8 + 0.660X_{16} + 0.227X_5 + 1.483X_{15} + 0.271X_{13} + 0.545X_{10} + e$$

Where, Y=Adoption of modern sesame production technologies

X_8 = Extent of extension contact, X_{16} = Profitability of technology, X_5 = Cropping intensity, X_{15} = Suitability of technology, X_{13} = Credibility of extension agents, X_{10} = Cosmopoliteness and e = Error Term

Since the F value or tolerance of other 10 variables were too small to continue, it may be assumed that whatever contribution is there, it was due to six variables included in the stepwise regression model. The contributions of different variables are discussed below:

1. **Extension Media Contact:** Extension media contact of the farmers had a positive and highly significant relationship with their adoption of modern sesame production technologies. It indicates that the more extension media contact the farmers had, the more was their adoption of modern sesame production technologies. The extension contact strengthened the base of their knowledge, which definitely acts as motivator towards adoption of new technologies. Hussen (2001), Chowdhury (1997) also found the similar findings. This variable contributed the highest among all other variables, which accounted for 40.7 percent in

predicting adoption. The adoption would be increased by 0.320 units with the one unit increase in “extension media contact” as indicated by the regression coefficient (0.320).

2. **Profitability of technology:** Profitability of technology of the farmers had a positive and highly significant relationship with their adoption of modern sesame production technologies. It means the technologies with higher profitability had higher adoption of modern sesame production technologies. Pathak and Majumdar (1985) study supports this findings. The perception about the profitability of technologies is important because a strong incentive and reward for any new act generally motivate the farmers. When they embank on the very high yield and profit given modern sesame varieties and package of practices might served as a strong force to convince the farmers and motivate them to go for these varieties and technologies. This variable contributed 15.2percent in predicting adoption. Based on regression coefficient (0.660) the adoption would be increased by 0.660 unit with the one unit increase in “Profitability of technology”.

3. **Cropping Intensity:**Cropping Intensityof the farmers had a positive significant relationship with their adoption of modern sesame production technologies. This means that the farmers with high cropping intensity, the more were their rate of adoption due to cultivate short duration crop varieties such as Binadhan-7, Binamasur-5,Binatil-1, Binatil-2 etc in their fields. This variable contributed 12.3 percent in predicting the adoption. According to regression coefficient (0.227) the perception would be increased by 0.227 units with the one unit increase of “Cropping Intensity”.

4. **Suitability of technology:**The result indicates that adoption will be increased with the increase of suitability of technologies. Technological suitability influences in adopting new technologies. These are: proper knowledge about technology, adequate rainfall, and improved varieties appropriate to the land and climate, control over the unwanted volume of water during monsoon, adequate water holding capacity of the soil and drainage facilities. Hence, agro-ecological suitability of any technology enhances its adoption. This variable contributed 8.9 percent in predicting the adoption. According to regression coefficient (1.483) the perception would be increased by 1.483 units with the one unit increase of “Suitability of technology”.

5. **Credibility of extension agents:**Credibility of extension agents to the farmers had a positive and highly significant relationship with their adoption of modern Sesame production technologies. The effectiveness of sources in communicating developmental information to the rural people depends on the people’s perception of the credibility of the sources. This variable contributed 1.6 percent in predicting the adoption. The adoption would be increased by 0.271units with the one unit increase in “Credibility of extension agents” as indicated by the regression coefficient (0.271).

6. **Cosmopoliteness:**Cosmopoliteness of the farmers had a significant relationship with their adoption of modern Sesame production technologies. This variable contributed 1.8 percent in predicting the adoption. According to regression coefficient (0.545) the perception would be increased by 0.545 units with the one unit increase of “Suitability of technology”. Similar findings were also observed by Chowdhury (1997).Cosmopoliteness changes farmers’ attitude and make them active and also have a good orientation with new technologies. They get different information of latest technologies from different institutions and offices or from other sources. The farmers who have high cosmopoliteness i.e. out-going nature are more advanced to adopt modern sesame cultivation technologies.

All of the above six variables were considered as important in predicting the independent variable. Findings of the stepwise regression analysis revealed that extension media contactwas the most important factor which strongly influenced the adoption of modern sesame production technologies. Next important variable was profitability of technology followed by cropping intensity, suitability of technology, credibility of extension agents and cosmopoliteness. All of the factors contributed positively and significantly towards the adoption. It means adoption would be higher with the increase of these variables. Other variables pertaining to different elements of adoption namely age, education, family size, farm size, family annual income, training exposure, innovativeness, organizational participation, knowledge on sesame cultivation and risk orientation did not show any significant contribution to the adoption prediction in relation to modern sesame production technologies as these variables did not enter in the stepwise regression model. From these above findings it is apparent that above mentioned 10 variables had either minimum contribution or due to their multi-colinearity stepwise regression model excluded these variables from analysis.

Conclusion

Based on the findings the following recommendations put forward for maximize production of modern sesame:

- Training exposure and extension media contact of the sesame growers showed high significant and positive relationship with their adoption of modern sesame production technologies. Farmers' level of knowledge should be increased through training, extension contact and other extension methods, in order to develop clear understanding about the use and benefit of technologies.

- Frequent contact with extension media can makes farmers more innovative and cosmopolitan which will ultimately lead to their adoption of modern sesame production technologies. Hence, the concern authorities should take cognizance of these facts and take necessary steps to increase the frequency of extension contact of the farmers and to provide necessary training sessions to the farmers.

- Increased adoption rate of modern sesame production technologies are important for meeting the national demand of edible oil. To achieve higher degrees of adoption of modern sesame production technologies, the farmers' knowledge, attitude and perception have to be increased. Henceforth, DAE and other extension service providing organizations should be given more emphasis to take necessary steps to increase knowledge and perception level of farmers for dissemination and adoption of modern sesame production technologies. For this regard Government and non-government organizations should provide effective training program on modern sesame production packages for the farmers at regular intervals to build their farming skills.

- DAE should strengthened the field level services by the field workers (SAAOs) to give farmers proper information, suggestions and advice regarding adoption of modern sesame production technologies.

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IN VITRO EVALUATION OF SIX FUNGICIDES AGAINST FOUR MAJOR SOIL BORNE FUNGI

M. K. Hasna

Abstract

An experiment was conducted in the laboratory of Plant Pathology Division, Bangladesh Institute of Nuclear Agriculture to evaluate the efficacy of six different fungicides against four major soil borne plant pathogens. The selected fungicides were Antracol 70 WP, Bavistin 50 DF, Dithane M-45, Folicur 250 EC, Ridomil Gold MZ 68 WP and Secure 600 WG. The efficacy of these fungicides were evaluated by poison food technique against four major soil borne fungi, *viz.*, *Rhizoctonia solani*, *Macrophomina phaseolina*, *Fusarium oxysporum* and *Sclerotium rolfsii*. Among them, Bavistin 50 DF was found to be the most effective which completely inhibited the growth of *R. solani*, *S. rolfsii* and *M. phaseolina* after 7 days of inoculation. Folicur was also effective against *R. solani* that inhibited its 96% growth after 7 days of inoculation. Dithane M-45 was found to be effective for inhibiting the growth of *M. phaseolina* (85%) and *S. rolfsii* (81%). The growth inhibition of the fungi by Secure, Antracol and Ridomil Gold ranged between 32 and 44%.

Key words: Fungicide, Growth inhibition, In vitro evaluation, Soil borne fungi

Introduction

Soil borne plant pathogenic fungi are considered as one of the major constrains in crop production. The major soil borne fungi that attack cereals, legumes, fruits, vegetables include *Pythium* spp., *Phytophthora* spp., *Fusarium* spp., *Sclerotium* spp., *Rhizoctonia* spp, *Macrophomina* spp. These fungi develop typical disease symptoms in plants such as seedling damping off, root blackening, root rot, wilting, yellowing, die back and may cause up to 50-75% yield loss for economically important crops (Baysal-Gurel and Kabir, 2018; Mihajlovic *et al.*, 2017). These devastating fungi may persist in soil for a long time as they are capable of producing resistant structures like sclerotia, microsclerotia, chlamydospore or oospore and when the crops are grown in the field they attack the host plants immediately. Therefore, the soil borne fungi are often difficult to control. As the soil ecology is a vast a complex issue, it is often challenging to suppress the soil borne pathogens.

Application of chemical is the most widely method for plant disease management and for killing soil borne fungi, synthetic fungicides are being used during crop production (Maitlo *et al.*, 2014). However, Frequent and indiscriminate use of these fungicides can cause environment and health hazard and also may lead develop fungicide resistance in plant pathogens (Christopher *et al.*, 2010). However, with increasing disease problems in the field, more new fungicides are being developed and used in crops. Several initiatives have been taken to manage soil borne plant pathogens by the use of different fungicides (Abdul *et al.*, 2015; Rekha *et al.*, 2012; Khalikar *et al.*, 2011; Jaiman and Jain, 2010). Moreover, many of these fungicides often have inconsistent results or are less effective in controlling plant diseases (Keinath and Batson, 2020). Due to genetic variability, the same fungicide may not be equally effective to all strains of a fungus. So there is a need for continuous study to evaluate the efficacy of the fungicides that are popularly used for controlling disease in the country. The present study was therefore taken for observing the effectiveness of six fungicides against four major soil borne plant fungi.

Materials and Methods

The experiment was conducted in the laboratory of Plant Pathology Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during June–September, 2019. The experiment was carried out in a completely randomized design (CRD) with six replications. Six chemical fungicides viz. Bavistin 50 DF, Dithane M-45, Secure 600 WG, Antracol 70 WP, Ridomil Gold MZ 68 WP and Folicur 250 EC, purchased locally, were evaluated against four major soil borne phytopathogenic fungi viz. (i) *Rhizoctonia solani* Kuhn (ii) *Macrophomina phaseolina* (Tassi) Goid (iii) *Fusarium oxysporum* (iv) *Sclerotium rolfsii* Sacc. Details of the six fungicides are listed in Table 1. The culture of the fungi was collected from the Plant Pathology Division of BINA. The fungi were purified by hyphal tip method and were grown in petridishes (9 cm diameter) containing Potato Dextrose Agar (PDA) medium. The pure culture were kept in a refrigerator (5°C) for further use.

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The sensitivity of the fungicides against the fungi were tested by poison food technique. Mother culture of the fungi was prepared from pure culture and was used as the source of mycelium of the fungi. The concentration of the fungicides was used as per recommended dose mentioned in the label of the packets of fungicide. Stock solution of each fungicide was prepared by adding the appropriate weight of the fungicide to 1 L of sterile distilled water. Then 60 ml of stock solution for each fungicide was mixed with 60 ml of double-strength PDA in separate Erlenmeyer flask of 250 ml before sterilization. Twenty ml of autoclaved PDA and fungicide mixture (autoclaved at 121°C, 15 lb/inch^2 pressure for 15 minutes) was poured into a petridish (9 cm diameter) and allowed to solidify. Six plates were maintained for each fungicide. The control plate contained PDA without fungicide. After solidification, a mycelium block of 5 mm was taken from the edge of five days old culture of the fungi and kept at the center of petridishes containing fungicide mixed PDA. The mycelial block was placed in an inverted position so that the mycelia were in direct contact with the poisoned media. The control plates were made without the addition of fungicides to PDA. The inoculated plates were incubated at 26±1°C. Data on radial mycelial growth was taken at 24 hours interval for seven days. The percent inhibition of the fungi was calculated by using the following formula (Bashar, 1990).

Percent growth inhibition (I) = $\{(A-B)/A\} \times 100$; Where, A= Radial growth of the fungus in control plate, B= Radial growth of the fungus in treated plate

Data were analyzed statistically and the means were separated by LSD following MSTAT-C program.

Table 1. List of fungicides used in the study

Trade name	Active ingredient	Application rate
Bavistin 50 DF	Carbendazim 50%	1g/L
Dithane M-45	Mancozeb 80%	2g/L
Secure 600 WG	Mancozeb 50% and Fluazinam 40%	1g/L
Antracol 70 WP	Propineb 70%	2g/L
Ridomil Gold MZ 68 WP	Mancozeb 64% and Metalaxyl 18%	2g/L
Folicur 250 EC	Tebuconazole 25%	1 ml/L

Results and Discussion

From Table 2, it is observed that all the tested fungicides had inhibitory effect on the mycelial growth of the fungi used in the study. For *Rhizoctonia solani*, the inhibition growth at 6 days after inoculation (DAI) ranged between 32.4 and 100%. Complete inhibition of growth (100%) was recorded by Bavistin followed by Folicure (95.4%). Ridomil Gold had the least inhibitory effect (32.4%) on *R. solani*. Bavistin and Folicur have been reported as effective fungicides in inhibiting the mycelial growth of *R. solani* in an *in vitro* evaluation by Khalil and Rashid (2013).

In *F. oxysporum*, the inhibition growth at 6 DAI ranged between 31.0 and 80.0%. The highest inhibition (80.0%) was shown by Bavistin and the lowest inhibition was found by Antracol. Secure (34.3%) and Ridomil Gold (30.4%) were not significantly different from Antracol in inhibiting the mycelial growth. Bavistin was recorded as the most effective against *F. oxysporum* f. sp. *lentis* by Dahal and Srestha (2018) and against *F. oxysporum* f. sp. *cubens* by Somu *et al.* (2014).

Bavistin was found to be the most effective against *S. rolfsii* as it could inhibit 97.4% radial growth of the fungus within 6 days of inoculation followed by Dithane M-45 (80.3%) and Folicur (57.9%). Among the tested fungicides, Antracol was found to be the least effective in inhibiting *S. rolfsii* since it showed only 31.6% growth inhibition. Siddique *et al.* (2016) reported Bavistin as the most effective one among five tested fungicides in agar medium for inhibiting the mycelial growth of *S. rolfsii*.

Bavistin gave 96.6% inhibition of mycelial growth of *M. phaseolina* followed by Dithane M-45 (83.5%) where Antracol gave the least inhibition (37.4%). Folicur was able to inhibit mycelial growth 46.4%. Carbendazim was reported as the most effective fungicide for the suppression of the radial growth of *M. phaseolina* in the *in vitro* evaluation by Khalikar *et al.* (2011) and Parmar *et al.* (2017). In another study Suryawanshi *et al.* (2008) proved mancozeb to be the best for the growth inhibition of *M. phaseolina.*

Figure 1 indicates that on the 7th day after inoculation Bavistin gave complete inhibition for *R. solani, S. rolfsii* and *M. phaseolina*. Dithane M-45 was observed to be effective for *S. rolfsii* and *M. phaseolina* since the fungicide could inhibit the growth of these fungi 81% and 85%, respectively. The effect of Secure, Antracol and Ridomil Gold on all the tested fungi was almost similar and the growth inhibition (%) ranged between 34 and

42% for Secure, 32 and 39% for Antracol and 33 and 43% for Ridomil Gold. The fungicide Folicur gave 96% inhibition of *R. solani* and 70% inhibition of *S. rolfsii*.

Table 2. Effect of six different fungicides on the inhibition of radial mycelial growth of *R. solani*, *F. oxysporum*, *S. rolfsii* and *M. phaseolina*

Fungi	Fungicides	Inhibition growth (%)					
		1 DAI	2 DAI	3 DAI	4 DAI	5 DAI	6 DAI
	Bavistin 50 DF	25.5a	42.6a	60.7a	73.2a	85.8a	100a
	Dithane M-45	15.7b	20.2b	28.5b	39.6b	41.6b	42.2b
R. solani	Secure 600 WG	10.7c	18.3b	23.1c	32.5c	34.4c	35.0c
	Antracol 70 WP	11.9c	16.4b	25.3c	30.4c	33.3c	35.1c
	Ridomil Gold MZ 68 WP	12.5c	17.4b	22.7c	27.3c	28.2c	32.4c
	Folicur 250 EC	23.4a	40.6a	57.3a	70.3a	82.6a	95.4a
	Bavistin 50 DF	21.8a	36.6a	54.3a	66.5a	71.9a	80.0a
	Dithane M-45	17.2b	22.2b	23.3c	30.1b	34.7b	38.0b
F. oxysporum	Secure 600 WG	12.3c	16.5c	22.2c	29.5b	33.3b	34.3c
	Antracol 70 WP	15.7c	18.9c	24.1c	25.3c	28.5c	31.0c
	Ridomil Gold MZ 68 WP	14.6c	16.5c	21.7c	23.8c	26.5c	30.4c
	Folicur 250 EC	19.5b	23.7b	29.9b	30.5b	33.4b	34.4c
	Bavistin 50 DF	30.1a	40.6a	57.5a	73.2a	83.2a	97.4a
	Dithane M-45	23.4b	39.5a	50.8b	67.6b	77.4b	80.3b
S. rolfsii	Secure 600 WG	19.5c	22.6c	25.0d	31.5d	32.3d	34.6d
	Antracol 70 WP	16.8c	19.7c	23.4d	30.4d	31.4d	31.6d
	Ridomil Gold MZ 68 WP	19.4c	21.3c	22.6d	33.3d	34.2d	35.0d
	Folicur 250 EC	25.6b	28.9b	33.5c	38.7c	44.6c	57.9c
	Bavistin 50 DF	30.7a	37.9a	59.5a	80.8a	90.2a	96.6a
	Dithane M-45	21.3b	29.6b	38.3b	44.7b	70.4b	83.5b
M. phaseolina	Secure 600 WG	13.8c	20.2c	23.7c	30.7d	38.4d	39.6d
	Antracol 70 WP	15.6c	19.8c	24.5c	31.3d	37.3d	37.4d
	Ridomil Gold MZ 68 WP	16.6c	20.4c	25.2c	28.6d	37.2d	39.0d
	Folicur 250 EC	23.4b	30.6b	38.5b	40.2c	45.5c	46.4c

Mean followed by the same letter in a column did not differ significantly at $P \geq 0.05$ by LSD; DAI= Days after inoculation

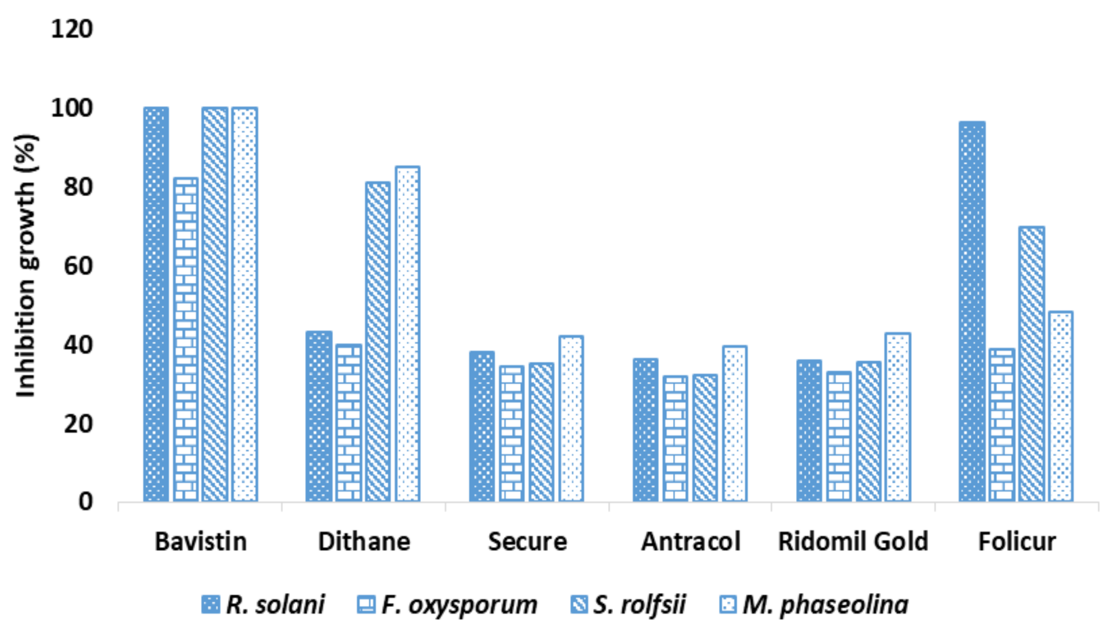

Fig. 1. Effect of six different fungicides on growth inhibition (%) of *R. solani*, *F. oxysporum*, *S. rolfsii* and *M. phaseolina* in PDA plates on 7th day after inoculation

Conclusion

In the present study, the *in vitro* evaluation of the efficacy of six different fungicides against four soil borne fungi indicated that Bavistin was the most effective as this fungicide could completely inhibit the growth of *R. solani*, *S. rolfsii* and *M. phaseolina* at 7 DAI. Folicur was also found to be effective against *R. solani* as it gave 96% inhibition of the fungus at 7 DAI. Dithane M-45 was effective for inhibiting the growth of *M. phaseolina* (85%) and *S. rolfsii* (81%). The information from the study is helpful in preparing the program of soil borne disease management. However, further evaluation of the selected fungicides under field condition is needed.

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AREA COVERAGE OF BINA DEVELOPED RICE, PULSE AND OILSEED VARIETIES IN BANGLADESH

M. H. Rahman*, R. Sultana, M. M. A. Sarkar and S. Islam

Abstract

The study was conducted in 64 districts of Bangladesh to examine the area coverage of BINA developed rice, pulse and oilseed varieties during 2019-2020 and suggest some policy guidelines. Field survey data were used for this study and those were collected from 64 districts through concerned DAE office and substations of BINA. Both tabular and descriptive statistical analysis was used to fulfill the objectives. Finally, data were classified into 14 agricultural regions to identify the area coverage of BINA developed rice, pulses and oilseed varieties. The results showed the overall area coverage of BINA developed rice varieties were 6.45%. Among the three seasons; Aus, Aman and Boro the highest area coverage was found in Aman season i. e. 10.45% followed by Boro 2.46% and Aus 1.26%, respectively, The overall area coverage of BINA developed pulse and oilseed varieties were 2.03% and 1.73%., respectively.

Keywords: Area coverage, BINA variety, Rice, Pulse, Oilseed

Introduction

Crop land is one of the most important issues for growth and expansion of human civilization. Agriculture is a greater contributor to poverty alleviation through jobs creation, food security and nutrition to world economies (Dan 2013). Bangladesh is one of the least developed countries in the world (Hasan, 2015), and is mostly dependent on agriculture (Sultana, 2010). In Bangladesh, Agriculture plays a leading role in the development and stability of the economy. The arable land in Bangladesh is 15.92 million hectares about 60 percent of the total land area which is contributing to feed 160 million people in Bangladesh (BBS, 2019). The country has a favorable natural environment for crop production. Of the arable land, 13.39 percent is under single cropping, 25.57 percent double cropping, 11.5 percent triple cropping, 0.10 quadruple cropping and 2.86 percent currently fallow land (BBS, 2019). As our population is increasing, cultivable land is decreasing day by day. Bangladesh has faced many factors in recent years that driving land use and land cover changes (LUCC) such as population dynamics; rapid changes in economic growth; climate change; construction of roads and highways; electrification; more advanced agriculture, technology and irrigation facilities; extended education; improved health services; new residential infrastructure; etc. (Hasan *et al* 2017). Rapid land use and land cover change (LUCC) induced land degradation, together with climate change and human activities, is thought to be a threat worldwide (Biro *et al*, 2013, Leh, M. *et al*, 2013, Wu, X, *et al*.2008). Keeping this in mind scientist of different institutes developed modern/ high yielding varieties. As a result, Bangladesh agriculture is now transforming from a traditional to a modern agricultural system. Now the country has been successful in maintaining most of its food demand for the existence of the fertile soils on the few vast floodplains that are annually refilled by siltation during the annual flood (Rahman and Islam, 2014), though there are considerable imports of some agricultural commodities. Area coverage of high yielding modern variety is increasing by replacing traditional variety. Here, Cropping Intensity increases up to 197 % (BBS 2019). The specific objectives of the present study were: i) to examine the area coverage of BINA developed rice, pulse and oilseed varieties; ii) to identify major constraints of BINA developed rice, pulse and oilseed varieties cultivation; and iii) to suggest some policy guidelines.

Materials and Methods

The study was conducted in 64 districts under 14 agricultural regions of Bangladesh (Fig. 1). The 14 regions were assigned such as Reg-1: Cumilla region (Cumilla, B. Baria, Chandpur), Reg-2: Mymensingh region (Mymensingh, Sherpur, Kishoregonj, Netrokona, Jamalpur), Reg-3: Sylhet region (Sylhet, Moulovi Bazar, Hobiganj, Sunamganj), Reg-4: Rangamati region (Khagrachari, Bandorban, Rangamati) Reg-5: Khulna region (Khulna, Bagerhat, Meherpur, Kushtia, Chuadanga, Sathkhira), Reg-6: Barishal (Potuakhali, Jhalokati, Bhola, Borguna, Pirojpur, Barishal), Reg-7: Rajshahi region (Rajshahi, Pabna, Nawgaon, Sirajganj, Natore, Chapainawabganj), Reg-8: Ranpur Region (Gaibandha, Lalmonirhat, Rangpur, Kurigram), Reg-9: Dinajpur

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region (Dinajpur, Panchagorh, Thakurgaon, Nilphamary), Reg10: Bogura region (Bogura, Joypurhat), Reg-11: Dhaka region (Narsingdi, Narayanganj, Gajipur, Tangail, Manikganj, Munsiganj), Reg-12: Chattagram region (Noakhali, Cox's Bazar, Feni, Lakshmipur, Chattagram), Reg-13: Jashore region (Jashore, Narail, Magura, Jhenaidah), Reg-14: Faridpur region (Rajbari, Madaripur, Faridpur, Sariatpur, Gopalganj). Data were collected through pre designed interview schedule using structural questionnaire from DAE personnel. In the questionnaire per hectare area of BINA developed rice (Aus, Aman and Boro), pulses and Oilseed were included to fullfill the objectives. Besides, secondary data from Bangladesh Bureau of Statistics (BBS) was also used. Tabular and descriptive statistics using mean, average and percentage were used to analyze the collected data. The period of data collection was 2019-2020.

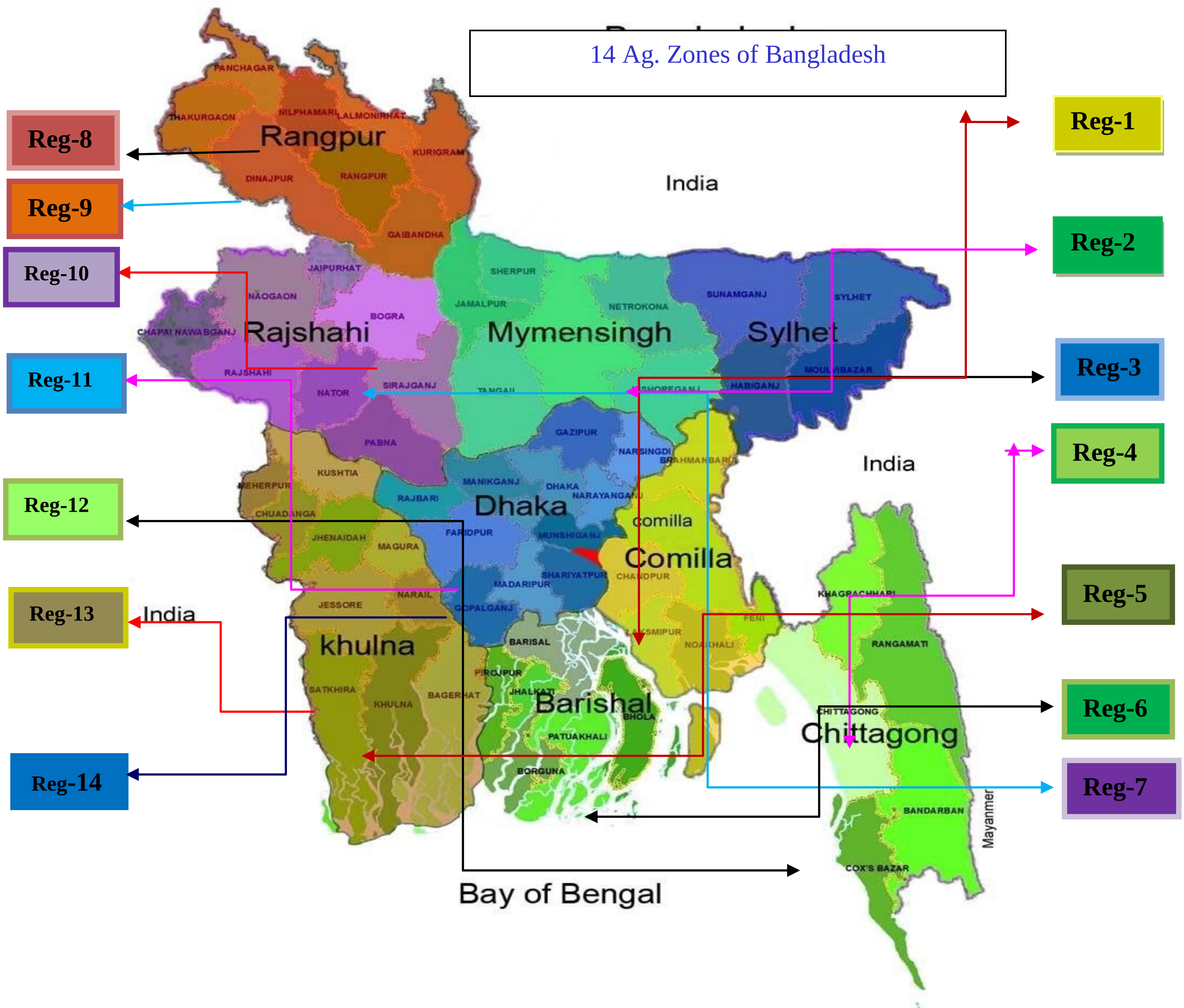


Fig. 1: Map of the Study area in 14 Agricultural regions of Bangladesh

Results and Discussion

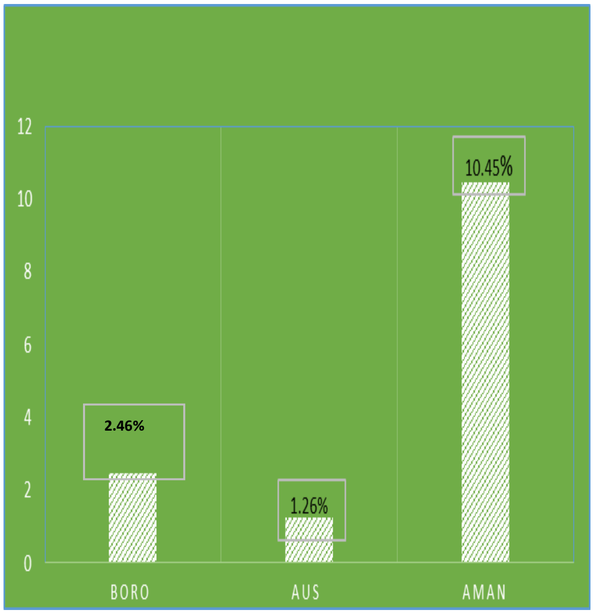
The overall area coverage of BINA developed rice varieties were 6.45% (Tble-1). Among the three rice seasons such as; Aus, Aman and Boro season the highest area coverage was found in Aman (10.45%) followed by Boro (2.46%) and Aus (1.26%), respectively (Fig 2). In Aman season, the highest coverage was 9.55% for Binadhan-7 and the lowest was 0.00016 % for Binadhan-22 as it was a newly developed variety. In Boro season, the highest coverage was 1.58% for Binadhan-10 and the lowest was 0.038 % for Binadhan-6. In Aus season, the highest coverage was 0.69% for Binadhan-19 and the lowest was 0.002 % for Binadhan-21(Fig 3).

Table 1. Variety wise area coverage of BINA developed rice varieties in 2019-2020 (in ha)

Rice	Varieties	Cultivated Area (%)	Area Coverage (%)
Boro 3224627.00 **(2.46 %)**	Binadhan-5	5502.25 (1.00)	0.1706
	Binadhan-6	1195 (0.22)	0.0371
	Binadhan-8	11195 (2.03)	0.3472
	Binadhan-10	50853.6 (9.2)	1.577
	Binadhan-14	8965.19 (1.62)	0.278
	Binadhan-18	1650.00 (0.3)	0.0512
Aus 929824.00 **(1.26 %)**	Iratom	5273 (0.95)	0.5671
	Binadhan-19	6444(1.17)	0.693
	Binadhan-21	20.00 (0.001)	0.0022
Aman 4411036.00 **(10.45 %)**	Binashail	1204.00 (0.22)	0.0273
	Binadhan-7	421080 (76.22)	9.5461
	Binadhan-9	30.00 (0.01)	0.0007
	Binadhan-11	11697 (2.29)	0.2652
	Binadhan-12	2193.00 (0.43)	0.050
	Binadhan-13	45.00 (0.01)	.0010
	Binadhan-15	49.00 (0.01)	.0011
	Binadhan-16	1870 (0.3)	.0420
	Binadhan-17	22305 (4.04)	0.5056
	Binadhan-20	906.00 (0.16)	0.0205
	Binadhan-22	6.00 (0.001)	0.00016
Total (6.45 %)		552483.04 (100%)	

The results presented in Table 2 depicted that among three seasons, area coverage was the highest for Aman 83.51% followed by Boro 14.36 % and the lowest for Aus i.e. 2.12 %. Among the 14 agricultural regions the highest area coverage was found 22.59 % in Jashore region (Reg-13) and the lowest found 0.67% in Rangamati region (Reg-04) (Fig 4.). In Jashore region, the highest area was found for Aman season 121811 ha and for Binadhan-7 about 1 lac hectare and the lowest was found for Aus season 111 ha. In Rangamati region, total Aman area was 2552.5 ha and Aus area was 127 ha. That is modern rice variety expansion is the lowest in hilly areas.

The results presented in Table 3 showed that the overall area coverage of BINA developed pulse varieties were 2.03%. The highest area as well as coverage was found 0.73 % for Binamoog-5 and lowest was 0.00016 % in case of Binachola-6 (Fig 5).



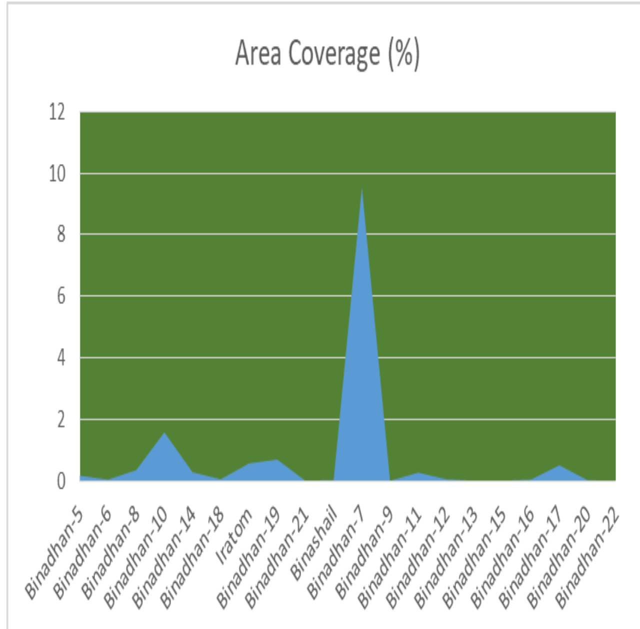


Fig. 2 Cultivated areas of BINA developed rice (%)

Fig: 3 Area coverage of BINA developed rice (%)

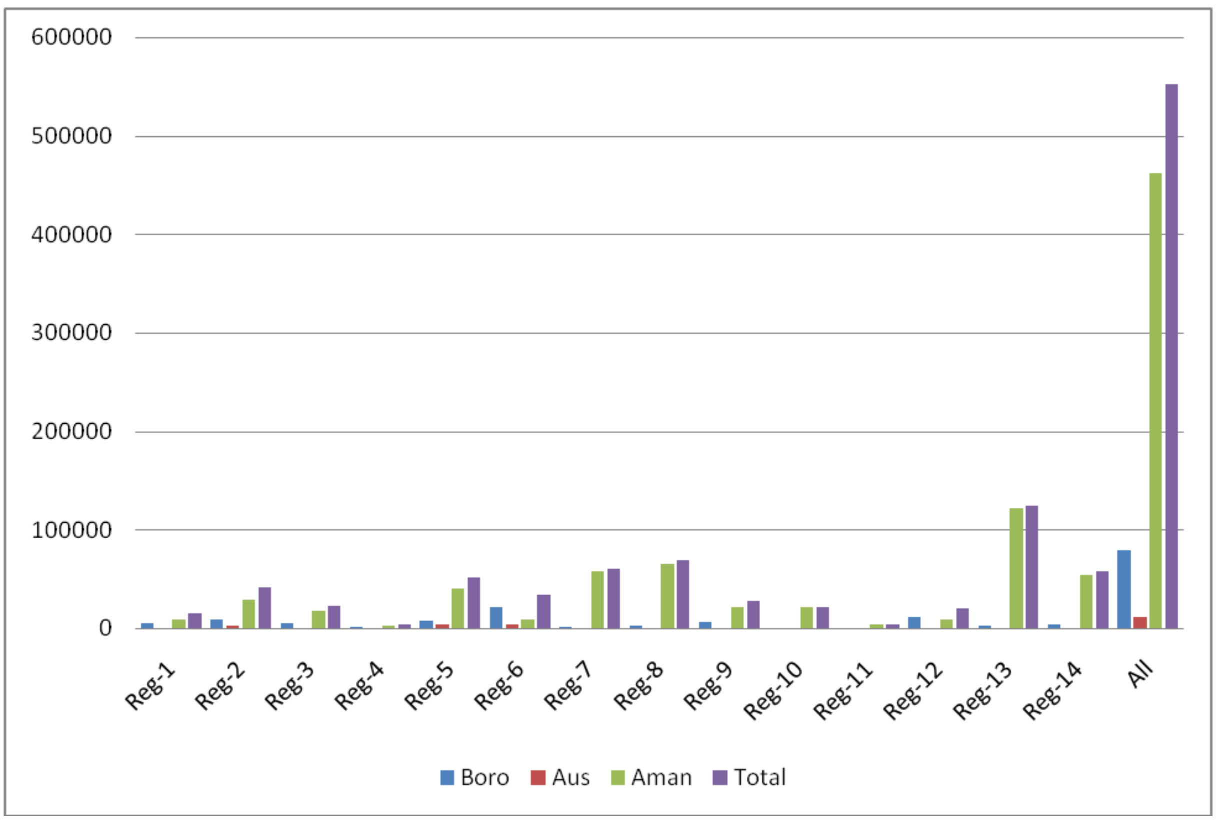


Fig 4: Regional coverage of BINA developed rice varieties during 2019-2020 in ha

Table. 2 Region wise area coverage of BINA developed rice varieties during 2019-2020

(in ha)

Rice	Reg-1	Reg-2	Reg-3	Reg-4	Reg-5	Reg-6	Reg-7	Reg-8	Reg-9	Reg-10	Reg-11	Reg-12	Reg-13	Reg-14	All
Boro	5797.5	9482.8	5428.5	1008.5	7622	21422.2	1435.5	2466	6231	234	423.1	11043	2829	3937	79360.1
	(7.31)	(11.95)	(6.84)	(1.27)	(9.60)	(26.99)	(1.81)	(3.11)	(7.85)	(0.29)	(0.53)	(13.92)	(3.56)	(4.96)	(14.36)
Aus	49.5	2639.5	280.5	127.5	3609	3306	468	465	405	0	55	37.5	184	111	11737.5
	(0.42)	(22.49)	(2.39)	(1.09)	(30.75)	(28.17)	(3.99)	(3.96)	(3.45)	(0.00)	(0.47)	(0.32)	(1.57)	0.95	(2.12)
Aman	9373.5	29313.5	17229.5	2550.5	39742	9242.5	58049.2	65708.5	21350	21519	3293.4	8841.5	121811	53361	461385.1
	(2.03)	(6.35)	(3.73)	(0.55)	(8.61)	(2.00)	(12.58)	(14.24)	(4.63)	(94.66)	(0.71)	(1.92)	(25.59)	(11.57)	(83.51)
Total	15220.5	41435.8	22938.5	3686.5	50973	33970.7	59952.7	68639.5	27986	21753	3771.5	19922	124824	57409	552482.7
	(2.75)	(7.50)	(4.15)	(0.67)	(9.23)	(6.15)	(10.85)	(12.42)	(5.07)	(3.94)	(0.68)	(3.61)	(22.59)	(10.39)	(100.00)

Note: **Reg-1:** Cumilla region (Cumilla, B. Baria, Chandpur), **Reg-2:** Mymensingh region (Mymensingh, Sherpur, Kishoregonj, Netrokona, Jamalpur), **Reg-3:** Sylhet region (Sylhet, Moulovi Bazar, Hobiganj, Sunamganj), **Reg-4:** Rangamati region (Khagrachari, Bandorban, Rangamati) **Reg-5:** Khulna region (Khulna, Bagerhat, Meherpur, Kushtia, Chuadanga, Sathkhira), **Reg-6:** Barishal (Potuakhali, Jhalokati, Bhola, Borguna, Pirojpur, Barishal), **Reg-7:** Rajshahi region (Rajshahi, Pabna, Nawgaon, Sirajganj, Natore, Chapainawabganj), **Reg-8:** Ranpur Region (Gaibandha, Lalmonirhat, Rangpur, Kurigram), **Reg-9:** Dinajpur region (Dinajpur, Panchagorh, Thakurgaon, Nilphamary), **Reg10:** Bogura region (Bogura, Joypurhat), **Reg-11:** Dhaka region (Narsingdi, Narayanganj, Gajipur, Tangail, Manikganj, Munsiganj), **Reg-12:** Chattagram region (Noakhali, Cox's Bazar, Feni, Lakshmipur, Chattagram), **Reg-13**: Jashore region (Jashore, Narail, Magura, Jhenaidah), **Reg-14:** Faridpur region (Rajbari, Madaripur, Faridpur, Sariatpur, Gopalganj).

Table 3. Variety wise area coverage of BINA developed Pulse varieties in 2019-2020

(in ha)

Pulse	Varieties	Cultivated area (ha) (%)	Coverage (%)
1861298 (2.03 %)	Binamasur-5	3304.50 (8.73)	0.17754
	Binamasur-6	937.50 (2.48)	0.05037
	Binamasur-7	156.00 (0.41)	0.00838
	Binamasur-8	1412.25 (3.73)	0.07587
	Binamasur-9	120.00 (0.32)	0.00645
	Binamoog-4	97.50 (0.26)	0.00524
	Binamoog-5	13569.00 (35.84)	0.72901
	Binamoog-6	9620.25 (25.41)	0.51686
	Binamoog-7	1401.00 (3.70)	0.07527
	Binamoog-8	6373.50 (16.83)	0.34242
	Binamoog-9	9.00 (0.02)	0.00048
	Binachola-6	3.00 (0.01)	0.00016
	Binakhesari-1	724.50 (1.91)	0.03892
	Binamas	135.00 (0.36)	0.00725
	Total	37863.00 (100.00)	

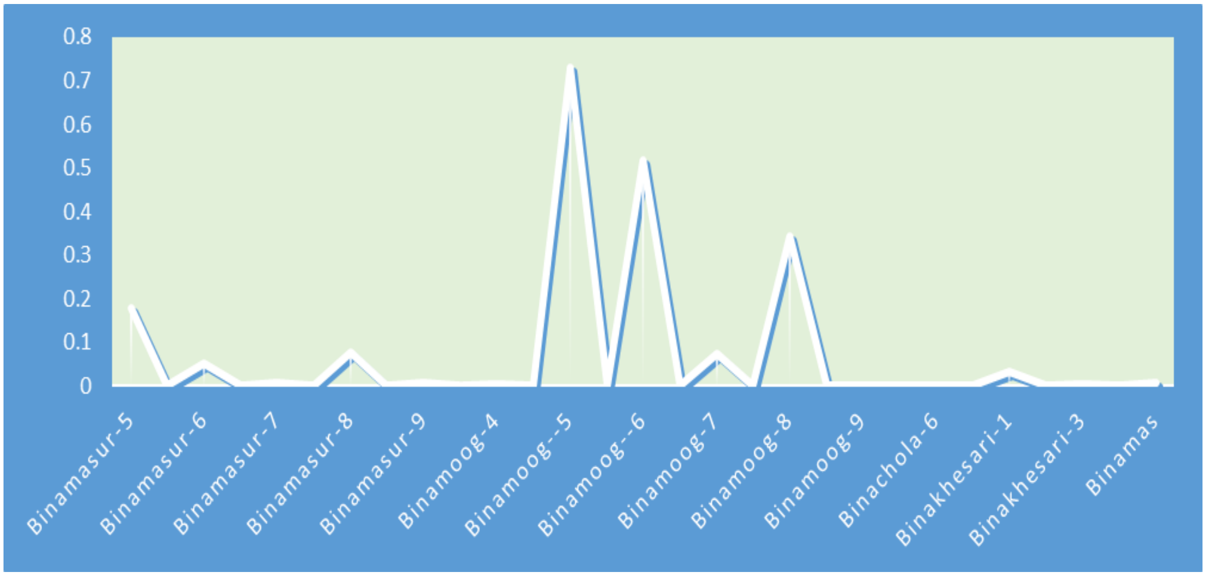


Fig 5 : Variety wise area coverage of BINA developed Pulse varieties in 2019-2020 in %.

It was observed in Table 4, among the 14 regions the highest area coverage for pulses was found in Barishal region 67.05% (Reg-6) and the lowest was found in Sylhet and Chattagram region 0.00% (Reg-3 and Reg-12), respectively.

Tabe 4. Region wise adoption of BINA developed Pulse and Other varieties in 2019-2020

(in ha)

Pulse	Reg-1	Reg-2	Reg-3	Reg-4	Reg-5	Reg-6	Reg-7	Reg-8	Reg-9	Reg-10	Reg-11	Reg-12	Reg-13	Reg-14	All (%)
Binamasur	0.00	0.00	0.00	24.8 (.42)	227.25 (3.83)	1.14 (0.02)	1231.1 (20.76)	12.5 (.21)	0.00	0.00	0.00	0.00	1348 (22.73)	3085.5 (52.03)	5930.29 (15.66)
Binamoog	244.5 (0.79)	67.5 (0.22)	0.00	11.96 (.04)	153.25 (.49)	24945.5 (80.30)	2238.26 (7.21)	114.88 (0.37)	1296.25 (4.17)	9 (0.02)	0.00	0.00	1408.5 (4.53)	580.65 (1.87)	31064.50 (82.04)
Binachola	0.00	0.00	0.00	0.00	0.00	0.00	3 (100)	0.00	0.00	0.00	0	0.00	0.00	0.00	3 (0.01)
Binakhesari	0.00	0.00	0.00	0.00	0.00	439 (60.59)	216 (29.81)	0.00	0.00	0.00	69.5 (9.59)	0.00	0.00	0.00	724.5 (1.91)
Binamas	0.00	0.00	0.00	0.00	0.00	0.00	135 (100)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	135 (0.36)
Sub total	244.5 (0.65)	67.5 (.18)	0.00	36.76 (.10)	380.5 (1.00)	25385.64 (67.05)	3829.36 (10.11)	127.38 (0.34)	1296.25 (3.42)	3.00 (0.01)	69.50 (0.18)	0.00	2756.5 (7.23)	3666.15 (9.68)	37863.04 (100)
Binarasun	0	0	117	0	0	0	153	0	0	0	0	0	0	0	270
Binagom	0	0	0	0	0	0	0	0	0	0	0	0	0	319.5	319.5

Note: **Reg-1:** Cumilla region (Cumilla, B. Baria, Chandpur), **Reg-2:** Mymensingh region (Mymensingh, Sherpur, Kishoregonj, Netrokona, Jamalpur), **Reg-3:** Sylhet region (Sylhet, Moulovi Bazar, Hobiganj, Sunamganj), **Reg-4:** Rangamati region (Khagrachari, Bandorban, Rangamati) **Reg-5:** Khulna region (Khulna, Bagerhat, Meherpur, Kushtia, Chuadanga, Sathkhira), **Reg-6:** Barishal (Potuakhali, Jhalokati, Bhola, Borguna, Pirojpur, Barishal), **Reg-7:** Rajshahi region (Rajshahi, Pabna, Nawgaon, Sirajganj, Natore, Chapainawabganj), **Reg-8:** Ranpur Region (Gaibandha, Lalmonirhat, Rangpur, Kurigram), **Reg-9:** Dinajpur region (Dinajpur, Panchagorh, Thakurgaon, Nilphamary), **Reg10:** Bogura region (Bogura, Joypurhat), **Reg-11:** Dhaka region (Narsingdi, Narayanganj, Gajipur, Tangail, Manikganj, Munsiganj), **Reg-12:** Chattagram region (Noakhali, Cox's Bazar, Feni, Lakshmipur, Chattagram), **Reg-13**: Jashore region (Jashore, Narail, Magura, Jhenaidah), **Reg-14:** Faridpur region (Rajbari, Madaripur, Faridpur, Sariatpur, Gopalganj).

The results presented in Table 5 were found that, the overall area coverage of BINA developed oilseed varieties were 1.73 %. The highest area coverage was found 0.391 % for Binasarisha-4 and the lowest 0.0002 % was seen in case of Binachinabadam-5 (Fig 6).

Table 5. Variety wise area coverage of BINA developed oil seed varieties during 2019-20

(in ha)

Oil Seed	Varieties	Cultivated Area (%)	Coverage (%)
2248344 (1.73 %)	Binasoybean-3	280.75 (0.72)	0.012487
	Binasoybean-5	4268.75 (10.95)	0.189862
	Binachinabadam-2	191.25 (0.49)	0.008506
	Binachinabadam-3	90.56 (0.23)	0.004028
	Binachinabadam-4	5606.03 (14.38)	0.24934
	Binachinabadam-5	4.46 (0.01)	0.000198
	Binachinabadam-6	424.84 (1.09)	0.018896
	Binachinabadam-7	306.00 (0.78)	0.01361
	Binachinabadam-8	884.48 (2.27)	0.039339
	Binachinabadam-9	21.73 (0.06)	0.000966
	Binachinabadam-10	12.32 (0.03)	0.000548
	Binatil-1	1060.34 (2.72)	0.047161
	Binatil-2	1815.50 (4.66)	0.080748
	Binatil-3	1150.00 (2.95)	0.051149
	Binatil-4	1108.00 (2.84)	0.049281
	Binasarisha-4	8786.92 (22.54)	0.390817
	Binasarisha-5	350.10 (0.90)	0.015571
	Binasarisha-7	1045.50 (2.68)	0.046501
	Binasarisha-8	2706.15 (6.94)	0.120362
	Binasarisha-9	7468.91 (19.16)	0.332196
	Binasarisha-10	1399.00 (3.59)	0.062224
	Total	38981.59 (100.00)	

The result presented in Table 6 revealed that, among the 14 regions the highest area coverage was found 9562.80 (24.53 %) ha in Region 13 and the lowest was found 0.00 ha in region 3 (Figs 7 and 8).

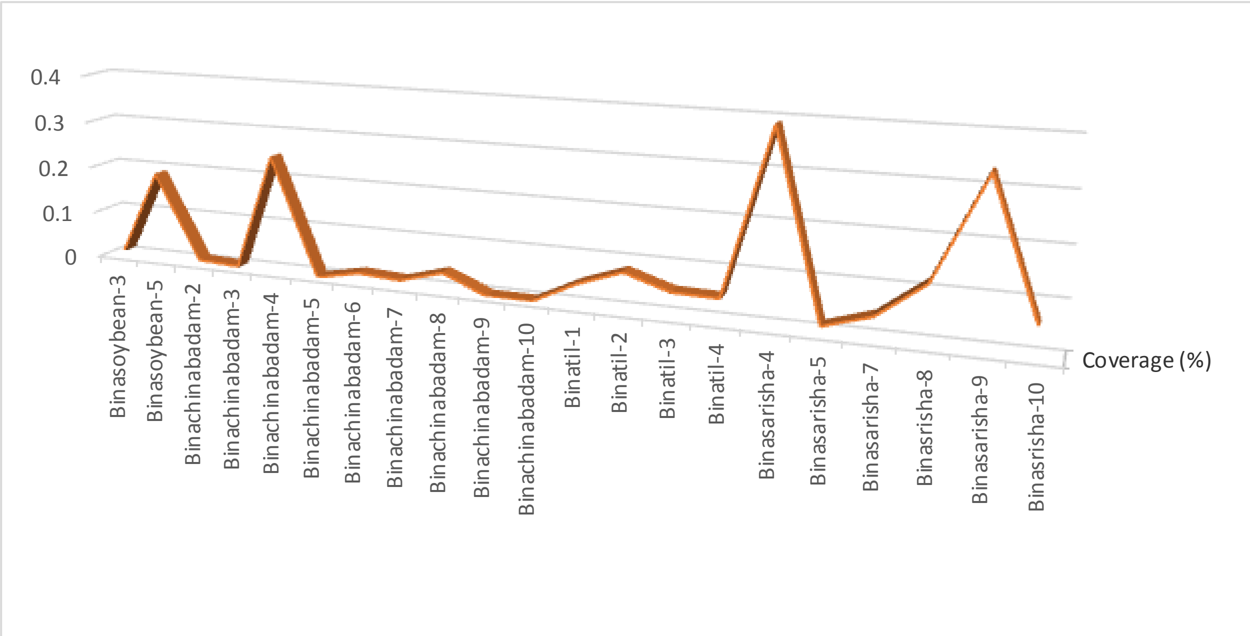


Fig 6: Variety wise area coverage of BINA developed oil seed varieties during 2019-20.

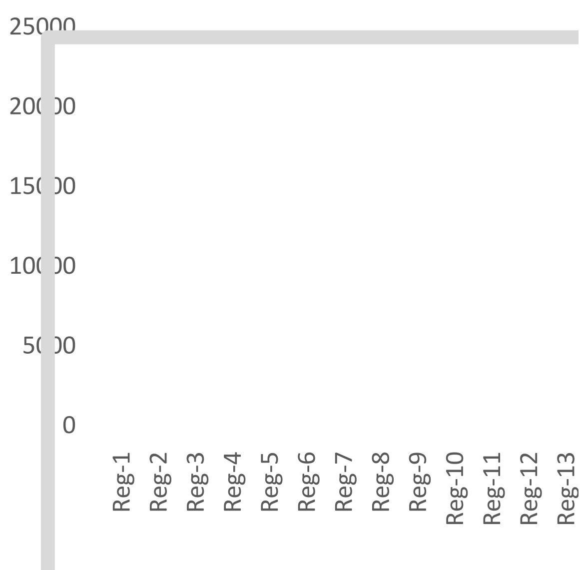


Fig 7: Cultivated areas of BINA developed oilseed varieties in 14 Ag. regions of Bangladesh

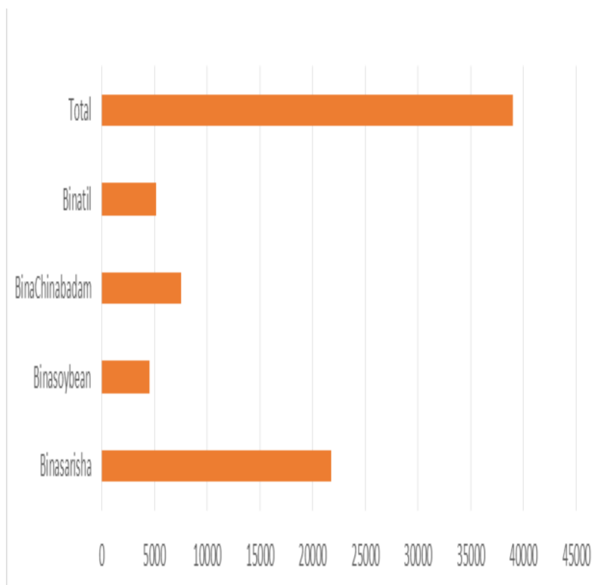


Fig 8: Total areas of BINA developed oilseed varieties in Bangladesh

Table 6. Region wise adoption of BINA developed Oilseed varieties during 2019-2020

(in ha)

Oil seed	Reg-1	Reg-2	Reg-3	Reg-4	Reg-5	Reg-6	Reg-7	Reg-8	Reg-9	Reg-10	Reg-11	Reg-12	Reg-13	Reg-14	All %
Binasarisha	780 (3.59)	1578.66 (7.26)	0 (0.00)	820 (3.77)	47.55 (0.22)	2915.25 (13.40)	2245.5 (10.32)	450 (2.07)	529.01 (2.43)	701.25 (3.22)	998.86 (4.59)	130.5 (0.60)	6450 (29.65)	4110 (18.89)	21756.58 (55.81)
Binasoybean	360 (7.91)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4177.5 (91.82)	0 (0.00)	0 (0.00)	0 (0.00)	0 0.00 ()	0 (0.00)	0 (0.00)	12 (0.26)	0 (0.00)	4549.5 (11.671
Binachinabadam	106.5 (1.41)	434.5 (5.76)	0 (0.00)	232.74 (3.09)	52.13 (0.69)	645 (8.55)	975 (12.93)	457.5 (6.07)	2505 (33.22)	0 (0.00)	3 (0.04)	486 (6.44)	738.3 (9.79)	906 (12.01)	7541.67 (19.35)
Binatil	3 (0.06)	38 (0.74)	0 (0.00)	30 (0.58)	0.3 (0.01)	57 (1.11)	687 (13.38)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2362.5 (46.02)	1956 (38.10)	5133.8 (13.17)
Total	1249.5 (3.21)	2051.16 (5.26)	0 (0.00)	1082.7 (2.78)	99.98 (0.26)	7794.75 (20.00)	3907.5 (10.02)	907.5 (2.33)	3034.01 (7.78)	701.25 (1.80)	1001.9 (2.57)	616.5 (1.58)	9562.8 (24.53)	6972 (17.89)	38981.55 (100.00)

Note: **Reg-1:** Cumilla region (Cumilla, B. Baria, Chandpur), **Reg-2:** Mymensingh region (Mymensingh, Sherpur, Kishoregonj, Netrokona, Jamalpur), **Reg-3:** Sylhet region (Sylhet, Moulovi Bazar, Hobiganj, Sunamganj), **Reg-4:** Rangamati region (Khagrachari, Bandorban, Rangamati) **Reg-5:** Khulna region (Khulna, Bagerhat, Meherpur, Kushtia, Chuadanga, Sathkhira), **Reg-6:** Barishal (Potuakhali, Jhalokati, Bhola, Borguna, Pirojpur, Barishal), **Reg-7:** Rajshahi region (Rajshahi, Pabna, Nawgaon, Sirajganj, Natore, Chapainawabganj), **Reg-8:** Ranpur Region (Gaibandha, Lalmonirhat, Rangpur, Kurigram), **Reg-9:** Dinajpur region (Dinajpur, Panchagorh, Thakurgaon, Nilphamary), **Reg10:** Bogura region (Bogura, Joypurhat), **Reg-11:** Dhaka region (Narsingdi, Narayanganj, Gajipur, Tangail, Manikganj, Munsiganj), **Reg-12:** Chattagram region (Noakhali, Cox's Bazar, Feni, Lakshmipur, Chattagram), **Reg-13**: Jashore region (Jashore, Narail, Magura, Jhenaidah), **Reg-14:** Faridpur region (Rajbari, Madaripur, Faridpur, Sariatpur, Gopalganj).

The study identified some problem and solution to increase area coverage of BINA developed varieties such as i) Non availability of seed which was rank I and then ii) increasing number of demonstrations in the union level; iii) more training facilities and iv) develop collaboration with DAE personnel and v) more location specific variety is needed (Table 7). For BINA variety cultivation, the highest suggestion was adequate seed supply in every season as early as possible which was rank I and then more training, demonstration, leaflet is needed. Besides inter-linkage among DAE-BADC-BINA and the farmers through project and storage capacity should be increased was found (Rank V).

Table 7. Constraints and suggestions by DAE personnel

Item	No. of respondents	(%)	Rank
Constraints			
Non availability of seed	12	10.43	I
Lack of demonstration	9	7.83	II
Lack of marketing facilities	6	5.22	IV
Lack of training facilities both in extension worker and farmers	8	6.96	III
Lack of proper planning between DAE and BINA	6	5.22	IV
More location –specific variety is needed	5	4.35	V
Suggestions			
Ensure adequate seed in every season as early as possible	12	10.43	I
More demonstration is needed to popularize these variety through DAE	8	6.96	III
Inter-linkage is needed among DAE-BADC-BINA and the farmers through project	6	5.22	V
Arrangement of proper training for DAE officer, extension worker and farmer	10	8.70	II
Storage capacity should be increased	6	5.22	V
More distribution of leaflet	7	6.09	IV

Conclusion

Area coverage of BINA developed variety is increasing day by day and the continuation for variety expansion, it should be ensured the seed demand at proper time. To facilitate the dissemination more training, demonstration, collaboration with DAE and BADC as well as research and its budget should be increased which would support in food production.

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A COMPARATIVE STUDY ON THE ADOPTION OF MODERN SESAME PRODUCTION TECHNOLOGIES BY THE PROJECT FARMERS AND NON-PROJECT FARMERS IN SELECTED AREAS

A. F. M. F. Hasan[1], M. B. Rahman[2] and M. R. Haider[1]

Abstract

The main focus of the study was to determine the difference between the Project Farmers (PFs) and Non-Project Farmers (NPFs) in respect of their adoption of modern sesame production technologies. The study also aims at differentiating the PFs and NPFs on the basis of their sixteen selected characteristics in terms of their adoption of modern sesame production technologies. Data were obtained from 60 randomly selected project farmers and 60 randomly selected non-project farmers of the five villages of five districts (Kushtia, Chuadanga, Faridpur, Jashore and Narail) using the interview schedule during 15 September to 25 October, 2014. Five recommended practices were selected to measure the adoption level. Adoption level of PFs and NPFs of five practices such as adoption of improved seed, adoption of recommended dose of fertilizer, adoption of weeding and thinning, adoption of irrigation and adoption of pesticide use were 39.42 & 1.93, 39.12 & 0.60, 38.65 & 23.71, 34.71 & 18.33 and 33.65 & 0.79 with a mean of 37.11 & 9.07 percent, respectively. Considering overall adoption level, the findings revealed that the highest proportion (48.3 percent) of project farmers fell under the low adoption category, 40.0 percent had medium adoption and 11.7 percent had high adoption with an average adoption quotient was 37.11 percent while all (100 percent) of the non-project farmers were low adoption category with an average adoption quotient was 9.07 percent. More than half (51.7 percent) of the project farmers had medium to high adoption category while no non-project farmers were in the medium to high adoption category.

Key Words: Adoption, Sesame, Project farmer, Non-project farmer, Comparative study

Introduction

Oilseeds are an important group of crops which play a significant role in rainfed agriculture of Bangladesh. The major oilseed crops grown in Bangladesh are mustard, sesame, groundnut and linseed. The major contribution of oil comes from mustard (69.9%) followed by sesame (8.9%) and groundnut (invisible oil 7.8%) (BBS, 2016). Sesame is the second largest source of edible oil in Bangladesh next to mustard both in respect of acreage and production. It is one of the world's oldest spice and oilseed crop grown mainly for its seeds that contain approximately 35-50% oil, 20-25% protein, 20% sugar, 6% fibre and many kinds of minerals. Sesame oil is quality edible oil. The oil is tasteless, odourless and also used as hair oil and as a component of cosmetics. The seed is used in making various food items like cakes, khaja, biscuits, etc. Dry plants and leaves are used as fuel and oilcakes as cattle feeds and manures. Sesame has also been used as folk medicine. In India and Bangladesh, sesame and its oil have been used traditionally to cure various ailments, such as asthma, in "ayurveda" since ancient times. It is well known that sesame has nutritive, laxative, demulcent, emollient, diuretic and lactagogue properties. The roots, usually unused parts of sesame, contains antifungal compound such as chlorosesamone, hydroxysesamone and 2-3 epoxysesamone (Hasan *et al*, 2000 and 2001). The climate of Bangladesh is more suitable for sesame cultivation. Sesame is cultivated in both kharif-1 and kharif-2 seasons, but two-third sesame is produced in kharif-1 season. High land with sandy loam is best suited for sesame cultivation. In Bangladesh it is grown in almost all districts but grows well in greater Khulna, Faridpur, Pabna, Barisal, Rajshahi, Jashore, Kushtia, Comilla, Dhaka, Rangpur, Sylhet districts. But Bangladesh has been an oilseed deficient country since last few decades. Due to increase of area under cereal crops for meeting the increasing demand of food-stuff, land under oilseed crops has declined and price of oil has gone up. Cultivation of traditional varieties, imbalance use of fertilizers, inability to seed sowing in proper time, non adoption of other production technologies, natural calamities, socio-economic barrier, large yield gap (20-40%), nutrient mining in existing cropping pattern, unavailability of seeds of suitable HYV varieties etc. are the main constraints of maximizing yield of oilseeds. At present, the domestic production of edible oil can only meet about 20% of the country annual demand and rest is imported which cost more than taka 20 billion. The national average yield of

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sesame is 0.63 t/ha, which are very low compared to potential average yield of 1.4 t/ha of modern varieties. The government of Bangladesh has, therefore, provided priority to the agriculture sector to increase the production of oilseeds by giving subsidy to the farmers on different inputs such as fertilizer, irrigation etc. to achieve self sufficiency in oilseeds. In this perspective, BINA implemented a project entitled, “Yield Maximization of Mustard and Sesame through Improved Package of Production Practices in Some Selected Areas of the Country” in major oilseeds growing areas like Jashore, Faridpur, Chuadanga, Narail, Jhenaidah and Kushtia districts. Proposed activities of adaptation trials, farmers’ motivation to adopt improved technologies, their knowledge & skill development and block farming using suitable varieties and addressing the constraints to adopt sesame in sustainable way to maximize the yield of oilseed crops by reducing yield gap and improving cropping pattern are imperative to maximize oilseeds production. The approaches were included Focus Group Discussion, working with Common Interest Group (CIG) Farmers, On-farm Adaptation Trial for variety selection, production package validation and training to upgrade agricultural knowledge of farmers and extension personnel, intervening modern cultivation techniques for increased yield and cropping intensity etc. Main focus was given to include Sesame in T. Aman and Lentil cropping sequence and vertical improvement of sesame yield within the existing pattern through improved package of production practices. Considering the above fact, the researcher undertook a study entitled, “A comparative study on the adoption of modern sesame production technologies by the project farmers and non-project farmers in some selected areas” along with the following objectives - (i) to determine the difference between the project farmers and non-project farmers in respect their adoption of modern sesame production technologies in some selected areas, (ii) to measure the selected factors (independent variables) associated with adoption of improved sesame production technologies, (iii) to find out the degree of relationship of different factors with the adoption of modern sesame production technologies.

Methodology

Study areas and source of data: Considering the sesame growing area the study was conducted in five villages of Kushtia, Chuadanga, Faridpur, Jashore and Narail district. The study aims at comparing PFs and NPFS in terms of their adoption of modern sesame production technologies. Therefore, all the farmers who were under the project and who were out of the project and also cultivated the sesame were considered as population of the study. Two lists of 100 project farmers and 100 non-project farmers of selected villages were prepared with the help of local Sub-Assistant Agriculture Officer (SAAO) of DAE of the concerned area. These two lists were the population of the study. Out of them 60% of the farmers were selected following random sampling method. Thus, 60 PFS and 60 NPFs were the sample of the study.

Variables of the study and their measurement: Age, education, family size, farm size, cropping intensity, family annual income, training exposure, extension media contact, innovativeness, cosmopoliteness, organizational participation, agricultural knowledge on sesame cultivation, credibility of extension agents, risk orientation, suitability of technology and profitability of technology was consisted as the independent variable whereas ‘adoption of modern sesame production technologies in some selected areas’ was considered as the dependent variable of the study. The selected modern technologies were consisted of recommended package of five practices. The five practices were adoption of improved seed, adoption of recommended rate of fertilizer, adoption of weeding and thinning, adoption of irrigation and adoption of pesticide use were selected to measure the adoption level. It was measured on the basis of the extent of adoption of modern sesame production technologies by the farmers for a period of two years (2013 & 2014). Adoption Index (AI) for modern sesame production technologies in this study was computed by using the following formula of Chattapadhyay (1963) and simplified by Ray (1998). Adoption of modern sesame production technologies was measured for recommended package of five practices. The adoption score was expressed in percentage. The Adoption Index (AI) of sesame grower could range from 0 to 100, where 0 indicate no adoption and 100 indicate highest adoption.

Data collection and statistical analysis: Data was collected from the respondents during Sep 15, to Oct 25, 2014. It was collected by the researcher himself using interview schedule from the farmers of the selected villages. The interview was conducted with the respondents individually in their respective houses. The SPSS (Statistical Package for Social Science) computer package was used to perform data analysis. Descriptive analysis such as mean, range, number and percentage, standard deviation and rank order were used whenever necessary. Pearson’s Product Moment Correlation Coefficient (r) was computed to explore the relationships between the dependent and independent variables (Ray and Mondal, 2004).

Findings and Discussion

Adoption of Modern Sesame Production Technologies by the Farmers

Adoption level on technological package of five practices have been computed separately and presented in table 1 and 2. These practices were adoption of improved seed, adoption of recommended rate of fertilizer, adoption of weeding and thinning, adoption of irrigation and adoption of pesticide use.

Table 1. Adoption level of five recommended package of practices for adoption of modern sesame cultivation technologies

Selected technologies	Observed range		Mean		SD	
	PFs	NPFs	PFs	NPFs	PFs	NPFs
Adoption of improved seed	7.26 - 93.07	0 - 32.74	39.42	1.93	22.55	6.53
Adoption of recommended dose of fertilizer	7.26 - 93.07	0 - 17.73	39.12	0.60	22.13	2.81
Adoption of weeding and thinning	7.26 - 88.57	0 - 45.33	38.65	23.71	22.04	11.47
Adoption of irrigation	7.26 - 80.32	0 - 45.33	34.71	18.33	17.30	13.95
Adoption of pesticide use	7.26 - 80.51	0 - 26.84	33.65	0.79	16.03	4.33
Overall adoption	7.26 - 82.37	0 - 21.47	37.11	9.07	19.11	5.04

Measuring unit: Percentage, Possible Range: 0-100, PFs: Project Farmers, NPFs: Non-Project Farmers, SD: Standard Deviation

Table 2. Comparetive adoption categories of PFs and NPFs

Selected technologies	Categories	Farmers (N = 60)			
		PFs		NPFs	
		No.	%	No.	%
Adoption of improved seed	Low (up to 33)	29	48.3	60	100
	Medium (34-66)	22	36.7	0	0
	High (above 66)	9	15.0	0	0
Adoption of recommended dose of fertilizer	Low (up to 33)	29	48.3	60	100
	Medium (34-66)	23	38.3	0	0
	High (above 66)	8	13.3	0	0
Adoption of weeding and thinning	Low (up to 33)	29	48.3	47	78.3
	Medium (34-66)	22	36.7	13	21.7
	High (above 66)	9	15.0	0	0
Adoption of irrigation	Low (up to 33)	31	51.7	49	81.7
	Medium (34-66)	25	41.7	11	18.3
	High (above 66)	4	6.7	0	0
Adoption of pesticide use	Low (up to 33)	32	53.3	60	100
	Medium (34-66)	27	45.0	0	0
	High (above 66)	1	1.7	0	0
Overall adoption	Low (up to 33)	29	48.3	60	100
	Medium (34-66)	24	40.0	0	0
	High (above 66)	7	11.7	0	0

Measuring unit: Percentage, Possible Range: 0-100, PFs: Project Farmers, NPFs: Non-Project Farmers

Comparative discussion on five recommended package of practices

Adoption of improved seed: The adoption of improved seeds of the PFs ranged from 7.26 to 93.07 and of the NPFs ranged from 0 to 32.74 against the possible range of 0 to 100. The average adoption of PFs and NPFs were 39.42 and 1.93 with the standard deviation of 22.55 and 6.53 respectively. Based on the adoption scores the respondents were classified into three categories: "low adoption" (up to 33), "medium adoption" (34 - 66), and "high adoption" (above 66). The distribution of respondents according to their adoption of improved seeds has been shown in Table 1. Data contained in Table 1 revealed that the highest proportion (48.3 percent) of project farmers fell under the low adoption category, while 36.7 percent had medium adoption and 15 percent had high adoption while all the NPFs were felt under low category (100%) of adoption. The majority (85 percent) of the project farmers had medium to high adoption and all (100 percent) the non- project farmers had low adoption.

Adoption of recommended rate of fertilizer: The adoption of recommended rate of fertilizer of the PFs ranged from 7.26 to 93.07 and of the NPFs ranged from 0 to 17.73 against the possible range of 0 to 100. The average adoption of PFs and NPFS were 39.12 and 0.60 with the standard deviation of 22.13 and 2.81 respectively. Based on the adoption scores the respondents were classified into three categories: “low adoption” (up to 33), “medium adoption” (34-66), and “high adoption” (above 66). The distribution of respondents according to their adoption of recommended rate of fertilizer has been shown in Table 1. Data contained in Table 1 revealed that the highest proportion (48.3 percent) of project farmers fell under the low adoption category, while 38.3 percent had medium adoption and 13.3 percent had high adoption while all the NPFs were low category (100%) of adoption. The majority (86.6 percent) of the project farmers had medium to high adoption and all the non-project farmers had low adoption.

Adoption of weeding and thinning: The adoption of irrigation of the PFs ranged from 7.26 - 88.57 and of the NPFs ranged from 0 - 45.33 against the possible range of 0 to 100. The average adoption of PFs and NPFS were 38.65 and 23.71 with the standard deviation of 22.04 and 11.47 respectively. Based on the adoption scores the respondents were classified into three categories: “low adoption” (up to 33), “medium adoption” (34 - 66), and “high adoption” (above 66). The distribution of respondents according to their adoption of irrigation has been shown in Table 1. Data contained in Table 1 revealed that the highest proportion (48.3 percent) of project farmers fell under the low adoption category, 36.7 percent had medium adoption and 15.5 percent had high adoption while majority (78.33 percent) of the NPFs were low adoption category, 21.67 percent had medium with no high adoption category. Half (51.7 %) of the project farmers had medium to high adoption and all the non- project farmers had low to medium adoption.

Adoption of irrigation: The adoption of irrigation of the PFs ranged from 7.26 – 80.32 and of the NPFs ranged from 0 - 45.33 against the possible range of 0 to 100. The average adoption of PFs and NPFS were 34.71 and 18.33 with the standard deviation of 17.30 and 13.95 respectively. Based on the adoption scores the respondents were classified into three categories: “low adoption” (up to 33), “medium adoption” (34 - 66), and “high adoption” (above 66). The distribution of respondents according to their adoption of irrigation has been shown in Table 1. Data contained in Table 1 revealed that the highest proportion (51.7 percent) of project farmers fell under the low adoption category, 41.7 percent had medium adoption and 6.7 percent had high adoption while majority (81.7 percent) of the NPFs were low adoption category, 18.3 percent had medium category with no high adoption category. Half of the project farmers had medium to high adoption and all the non- project farmers had low to medium adoption.

Adoption of pesticide use: The adoption of pesticide use of the PFs ranged from 7.26 - 80.51 and of the NPFs ranged from 0 – 26.84 against the possible range of 0 to 100. The average adoption of PFs and NPFS were 33.65 and 0.79 with the standard deviation of 16.03 and 4.33 respectively. Based on the adoption scores the respondents were classified into three categories: “low adoption” (up to 33), “medium adoption” (34 - 66), and “high adoption” (above 66). The distribution of respondents according to their adoption of pesticide use has been shown in Table 1. Data contained in Table 1 revealed that the highest proportion (53.3 percent) of project farmers fell under the low adoption category, 45.0 percent had medium adoption and 1.7 percent had high adoption category while all the NPFs were low adoption category. Nearly half (46.7 percent) of the project farmers had medium to high adoption while all the non- project farmers had low adoption.

Overall adoption of modern sesame production technologies: The overall modern sesame production technologies of the PFs ranged from 7.26 - 82.51 and of the NPFs ranged from 0 - 21.47 against the possible range of 0 to 100. The average adoption of PFs and NPFS were 37.11 and 9.07 with the standard deviation of 19.11 and 5.04, respectively. Based on the adoption scores the respondents were classified into three categories: “low adoption” (up to 33), “medium adoption” (34 - 66), and “high adoption” (above 66). The distribution of respondents according to their adoption of pesticide use has been shown in Table 1. Data contained in Table 1 revealed that the highest proportion (48.3 percent) of project farmers fell under the low adoption category, 40.0 percent had medium adoption and 11.7 percent had high adoption while all (100 percent) of the NPFs were low adoption category. More than half (51.7 percent) of the project farmers had medium to high adoption category while no non- project farmers were in the medium to high adoption category. For clarity of understanding a bar diagram has been presented in Fig. 1.

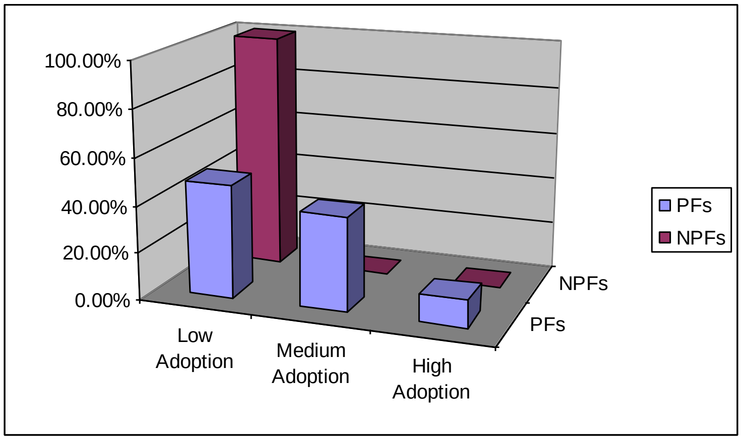

Fig.1. Farmers' adoption of modern sesame production technologies measured according to their extent of adoption.

Relationship between the selected growers's characteristics & other factors and their adoption of modern sesame production technologies

Relationship between the selected characteristics of sesame growers' & other factors and their adoption of modern sesame production technologies were ascertained by the Pearson's product moment coefficient of correlation and the summary of the result has been presented in Table 3. Out of sixteen factors of PFs, thirteen factors namely: education of the farmers, farm size of the farmers, Cropping intensity, family annual income , training exposure of the farmers, extension media contact, innovativeness, cosmopoliteness, agricultural knowledge on sesame cultivation, credibility of extension agents, risk orientation, suitability of technology, profitability of technology had significant and positive relationship with their adoption of modern sesame production technologies and rest of the factors (age, family size of the farmers, organizational participation) shown no significant relationship with their adoption. On the other hand, only three factors of NPFs, namely: farm size, innovativeness and suitability of technology had significant and positive relationship with their adoption and the rest variables shown no significant relationship with their adoption of modern sesame production technologies.

Table 3. Co-efficient of correlation of the selected characteristics of the respondents and their adoption of modern sesame production technologies

Selected characteristics of the farmers and others factors	Co-efficient of correlation ('r')	
	PFs	NPFs
Age	-0.131	-0.082
Education	0.493**	0.075
Family size	-0.191	0.002
Farm size	0.761**	0.375**
Cropping intensity	0.630**	0.083
Family annual income	0.405**	0.075
Training	0.624**	0.028
Extension media contact	0.638**	0.124
Innovativeness	0.281*	0.463
Cosmopoliteness	0.681**	0.247
Organizational participation	0.108	0.158
Knowledge on sesame cultivation	0.599**	0.142
Credibility of the extension agents	0.492**	0.126
Risk orientation	0.457**	0.091
Suitability of the technology	0.660**	0.336
Profitability of the technology	0.655**	0.013

***** = Correlation is significant at the 0.05 level (2-tailed); ****** = Correlation is significant at the 0.01 level (2-tailed); PFs: Project Farmers, NPFs: Non Project Farmers

Effect of project activities on some indicators related to agricultural development

A total of 16 factors were selected for this study in which some are constant and some are variable. Out of sixteen, seven variables were changed positively and significantly with the influences of project activities. Name of 7 variables with their changing percentage has been listed in Table 4.

Table 4. List of variables positively changed by the project activities

Indicators	Mean		% of mean difference of PFs over NPFs
	NPFs	PFs	
1. Family annual income	219.92	246.05	11.88
2.Training exposure	3.50	8.58	90.67
3. Extension media contact	20.05	30.48	52.02
4. Knowledge on sesame cultivation	26.13	32.90	25.91
5. Credibility of extension agents	21.88	24.93	13.94
6. Risk orientation	21.07	27.08	28.52
7. Profitability of technology	12.88	15.70	21.89

Family Annual Income: The behaviour of a farmer on a new technology may be influenced by his/her income. Farmers with higher income have a tendency to improve their farming behaviours on new innovation in order to increase their income. They also have more contact with various information sources and can invest more money to adopt new innovation. In this study family annual income of the project farmers had a positive and significant relationship with their adoption of modern sesame production technologies. Similar findings were also observed by Hussen (2001), Aurangozeb (2002) and Haque (2005). But in case of non-project farmers, income had no significant relationship with their adoption though their income was not far different (Table 2) from project farmers. Actually project farmers were more motivated than those of non-project farmers in adopting the modern sesame production technologies. For involvement with Project activities annual income of project farmers was increased 11.88 percent over non-project farmers.

Training experiences: Training experiences is an important factor which enhances knowledge and improves skills on various aspects of agricultural technologies of the farmers. Training promoted farmers in a broad spectrum to access in various information sources to gain knowledge, skills and attitude towards new technology. Training program under the project had a great role to increase the adoption. As a result, training received of the project farmers had a highly significant relationship with their adoption of modern sesame production technologies which was not significant in case of non-project farmers. Training experiences of project farmers was increased 90.67 percent over non-project farmers.

Extension media contact: The extension media contact of farmers had a significant relationship with their adoption. The more extension media contact the farmers had, the more was their adoption. The extension contact strengthened the base of their knowledge. When people come contact with various extension personnel, print media, exhibition, demonstration, field day and other motivational programs, it contributes significantly to increase their knowledge, skills and attitude towards adoption In this study extension media contact of the farmers had a positive and highly significant relationship with their adoption of modern sesame production technologies. Hussen (2001), Chowdhury (1997) also found the similar findings. These opportunity was lacking in non-project farmers and therefore, their knowledge, skill and attitude towards adoption did not raise up. So the relationship between extension media contact and their adoption was non-significant. Extension media contact of the project farmers was increased 52.02 percent over non-project farmers.

Agricultural knowledge on sesame cultivation: Agricultural knowledge on sesame cultivation of the project farmers had a positive and highly significant relationship with their adoption of modern Sesame production technologies. Similar findings were observed by Haque (2003) and Haque (2005). This is so as favourable attitude have formed mostly by knowledge, of the respondents therefore, it is quite logical that knowledge played a significant role in the adoption of modern sesame production technologies. Bangladesh Institute of Nuclear Agriculture (BINA) established some demonstration in the study areas on modern sesame production which was very effective to develop knowledge of project farmers on modern sesame production technologies. BINA also conducted some training on this issue from which the farmers became knowledgeable on modern sesame production technologies. Moreover, field day observation, frequent motivational field visit of project personnel and face to face discussion with farmers in their field, regular mobile contact, supplied printed materials etc which also enhanced their knowledge. The non-project farmers were out of these so that they could not get these opportunities and for that way their relationship was not significant. Agricultural knowledge on sesame cultivation of the project farmers was increased 25.91 percent over non-project farmers.

Credibility of extension agents: Credibility of extension agents is an important factor to the farmers in adopting new technologies. The effectiveness of sources in communicating developmental information to the rural people depends on the people's perception of the credibility of the sources. As the extension media contact of non-project farmers was low, their credibility of extension agents was also low. In this study, Credibility of extension agents to the project farmers had a positive and highly significant relationship with their adoption of modern Sesame production technologies but in case of non-project farmers it was non-significant. For involvement of project farmers with project activities, credibility of extension agents was increased 13.94 percent.

Risk Oriented: Higher risk oriented farmers have the ability to combat the risk by using proper ideas and practices and to get involved in various agricultural operations in their fields. As a result a large proportion of project farmers were high risk oriented due to self-confidence, awareness, higher income, large farm size and similar other traits. Due to project activities project farmers achieved to take high risk which made them courageous in respect of adopting modern sesame production technologies. In this study risk orientation of the project farmers had a positive and significant relationship with their adoption of modern sesame production technologies while non-project farmers had no significant relationship. This means that the farmers with higher risk orientation having higher ability to adopt new technologies than those of lower risk orientation. Project activities increased 28.52 percent risk taking capacity of project farmers over non-project farmers.

Profitability of technology: Profitability of technology is a matter of farmers' own perception. The perception about the profitability of technologies is important because a strong incentive and reward for any new act generally motivate the farmers. When they embank on the very high yield and profit given modern sesame varieties and package of practices might served as a strong force to convince the farmers and motivate them to go for these varieties and technologies. The perception level on the profitability of modern sesame cultivation of the project farmers was increased by the various project activities. The non-project farmers were out of these activities and that is way their perception on profitability of technology was comparatively low and their relationship with adoption was not significant. Profitability of technology of the project farmers had a positive and highly significant relationship with their adoption of modern sesame production technologies. It means the technologies with higher profitability had higher adoption of modern sesame production technologies. Pathak and Majumdar (1985) study supports this findings. In this study, perception on profitability of technology of project farmers was increased 21.89 percent over non-project farmers.

Conclusion

The findings of the study indicate that there were significant difference between project farmers and non-project farmers with respect to their adoption of modern sesame production technologies. The highest proportion (48.3 percent) of project farmers fell under the low adoption category, 40.0 percent had medium adoption and 11.7 percent had high adoption with an average adoption quotient was 37.11 while all (100 percent) of the non-project farmers were low adoption category with an average adoption quotient was 9.07. Half (51.7 percent) of the project farmers had medium to high adoption category while no non-project farmers were in the medium to high adoption category. Such facts lead to the conclusion that adoption of the project farmers significantly increased than those of non-project farmers due to different project activities such as demonstration, training on this issue, printed materials, field day observation, frequent motivational field visit of project personnel and face to face discussion with the project farmers in their fields and regular mobile contact. The non-project farmers were out of these so that they could not get these opportunities and for that way their adoption was not encouraging and considerable. The findings of the study demonstrate that the project farmers and non-project farmers varied significantly with the variation of their family size, annual income, training exposure, extension media contact, knowledge on sesame cultivation, credibility of extension agents, risk orientation, profitability of technology and their variation were 11.88%, 90.67%, 52.02%, 25.91%, 13.94%, 28.52% and 21.89%, respectively. These findings lead to conclude that access of project farmers to training as well as other extension methods under project activities, these desirable attributes of the project farmers had significantly increased than those of non-project farmers. Project activities played a pioneer role to increase these desirable traits of the project farmers.

Based on the above findings the following recommendations put forward for maximize production of modern sesame:

- Training exposure and extension media contact of the sesame growers showed high significant and positive relationship with their adoption of modern sesame production technologies. Farmers' level of knowledge should be increased through training, extension contact and other extension methods, in order to develop clear understanding about the use and benefit of technologies.

- Frequent contact with extension media can makes farmers more innovative and cosmopolitan which will ultimately lead to their adoption of modern sesame production technologies. Hence, the concern authorities should take cognizance of these facts and take necessary steps to increase the frequency of extension contact of the farmers and to provide necessary training sessions to the farmers.
- Increased adoption rate of modern sesame production technologies are important for meeting the national demand of edible oil. To achieve higher degrees of adoption of modern sesame production technologies, the farmers' knowledge, attitude and perception have to be increased. Henceforth, DAE and other extension service providing organizations should be given more emphasis to take necessary steps to increase knowledge and perception level of farmers for dissemination and adoption of modern sesame production technologies. For this regard Government and non-government organizations should provide effective training program on modern sesame production packages for the farmers at regular intervals to build their farming skills.
- DAE should strengthened the field level services by the field workers (SAAOs) to give farmers proper information, suggestions and advice regarding adoption of modern sesame production technologies.

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Short Communication

PHOTOSYNTHESIS, DRY MATTER PRODUCTION AND YIELD PERFORMANCE OF LENTIL VARIETIES UNDER HIGH TEMPERATURE

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Abstract

Climate is changing and air temperature is rising due to increasing concentration of CO_2 and other atmospheric greenhouse gases. The rise in atmospheric temperature causes detrimental effects on growth, yield, and quality of the crop varieties by affecting their phenology, physiology, and yield components. A pot experiment was carried out with ten high yielding lentil varieties to assess the effects of high temperature (34^0C) on physiological parameters yield attributes and yield and to find out temperature stress tolerant varieties. Temperature treatments *viz.* (i) Ambient, (ii) 34^oC at flower initiation stage and (iii) 34^oC at pod filling stage of the 10 lentil varieties *viz.* Binamasur-2, Binamasur-3, Binamasur-4, Binamasur-5, Binamasur-6, Binamasur-7, Binamasur-8, Binamasur-9, Binamasur-10 and BARI masur-5 were imposed separately for 7 days in plant growth chamber. Photosynthesis, chlorophyll content in leaves, total dry matter and yield attributes decreased under high temperature. Temperature imposed at pod growth stage had greater negative effect. The higher yield reduction was recorded in Binamasur-2 and Binamasur-3. But the yield loss under high temperature was less in two varieties *viz.* Binamasur-6 and Binamasur-8.

Key words: Dry matter, high temperature, photosynthesis, yield, lentil

Lentil (*Lens esculenta* Medik.) is an important pulse crop with high protein content, has the potential capacity to combat nutritional deficiencies in developing regions and countries. High temperature and water stress are significant abiotic stresses that limit production worldwide (Sehgal*et al*. 2017; Gaur *et al*. 2015). High temperature affects crops through either: (i) above-optimum temperatures for an extended period, which increases supply of assimilates but reduces grain filling period and yield; or (ii) heat wave responses, which is a short period of high temperature (>32^oC) that causes non-recoverable reduction in grain set and yield potential (Vadez*et al*. 2012). Together these abiotic stresses, estimated to cause up to 50% yield loss per annum in pulse crops globally (Gaur *et al*. 2014). Lentil requires low temperatures during vegetative growth, while at maturity, warm temperatures required; the optimum temperature for its best growth has been reported to be 18-30^oC (Roy *et al*. 2012). Lentil is particularly sensitive to high temperature (>30^oC) during the reproductive phase, causing pod and flower abortion and significant reduction in grain yield and quality ((Sita*et al*. 2017). Yield was reduced by 87% for lentils grown in pots under field conditions with high temperature during the reproductive phase (38^oC day time, 23^oC night) (Bhandari*et al*. 2016), and grain set was observed to be the most sensitive yield component (Bhandari*et al*. 2016; Gaur *et al*. 2015). In Bangladesh, lentil sowings occasionally get postponed because of the delayed harvest of the preceding crop, mostly T. Aman rice. The lentil crop is then adversely affected by the high approaching summer temperatures, leading to low grain yields and poor grain quality (Tickoo*et al*. 2005). Efforts can be made to increase area as well as yield of lentil crops by the use of temperature stress tolerant varieties. So the experiment was conducted to evaluate ten high yielding lentil varieties to observe the effect of high temperature and to find out temperature tolerant varieties.

A pot experiment was carried out with ten high yielding lentil varieties cultivating by the farmers to assess the effects of high temperature (34^0C) on photosynthesis, chlorophyll content (SPAD reading) in leaves, dry mass production, yield attributes and yield and to find out temperature stress tolerant varieties. The experiment was conducted during November 2017 to March 2018 at BINA, Mymensingh, Bangladesh. Seeds were sown in pots on 21 November 2017. Each pot contained 8 Kg of soils (Silty loam, organic matter 1.05%, total N 0.07%, available P 14.3 ppm, exchangeable K 0.25 meq.per 100g soil, available S 13.2 and soil pH 6.67). The experiment was laid out in a Complete Randomized Design with three replications. Recommended dose of fertilizers was applied and other cultural practices were followed as and when required. Temperature treatments *viz*. (i) Ambient, (ii) 34^oC at flower initiation stage and (iii) 34^oC at pod filling stage of the lentil varieties *viz.* Binamasur-2, Binamasur-3, Binamasur-4, Binamasur-5, Binamasur-6, Binamasur-7, Binamasur-8, Binamasur-9, Binamasur-10 and BARI Masur-5 were imposed separately for 7 days in controlled plant growth chamber (RH 80%, CO_2 330 ppm). The nitrate reductase activity, chlorophyll content and photosynthetic rate of leaves were

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determined during temperature imposed. At harvest, total dry matter, seed yield and yield related parameters were recorded. Photosynthetic rate was recorded using *Portable Photosynthesis System LI-6400XT, LI-COR Inc.*, Lincoln, NE, USA. Statistical analysis was done as per design used with the help of MSTAT computer packages.

Results indicated that high temperature imposed either at flower initiation stage or pod growth stage had high significant negative influence on plant parameters (Table 1). But temperature imposed at pod development stage had greater negative influence on morpho-physiological parameters as well as seed yield than temperature imposed at flowering stage. The results agreewith Bhandary*et al*. (2016), Kumar *et al*. (2016) and Delahunty*et al*. (2018) who stated that morpho-physiological parameters of lentil decreased under high temperature. Binamasur-6, Binamasur-8 and Binamasur-10 showed taller plants, Binamasur-7 showed higher photosynthetic rate, and BARI Masur-5 and Binamasur-9 had higher seed yield and harvest index under high temperature (Table-2). But seed yield drastically reduced under high temperature in all varieties at any growth stage (Fig. 1). Higher yield reduction was recorded in Binamasur-2 and Binamasur-5 (Fig. 1). Yield loss under high temperature was less in two varieties *viz*. Binamasur-6 and Binamasur-8 and showed tolerance to high temperature.

Table 1. Growth stages on morpho-physiological parameters and yield traits of lentil varieties as affected by high temperature

34 ^{0}C imposed at	Plant height (cm)	Photo-synthesis rate (µmolCO_2 $m^{-2}S^{-1}$)	Chloro-phyll content ($mgg^{-1}fw$)	Nitrate reductase (µ mol NO_2/gfw/h)	Total dry mass plant^{-1} (g)	Pods plant^{-1} (no.)	Seeds plant^{-1} (no.)	Seed weight plant^{-1} (g)	Harvest index (%)
Control	29.5a	32.36 a	2.85 a	2.84a	8.53 a	230 a	249.1 a	6.49 a	40.33 a
Stages:									
Flowering	27.0c	27.66 b	2.29 b	0.78b	3.16 c	197 b	84.21 b	1.81 b	36.41 b
Pod filling	28.2 b	25.05 b	2.14 b	1.52c	3.13 b	181 c	15.91 c	0.74 c	19.12 c
F-test	**	**	**	**	**	**	**	**	**

In a column, figure (s) with same letter do not differ significantly at P ≤ 0.05 by DMRT; ** indicates significant at 1 % level of probability

Table 2. Variation in morpho-physiological parameters, seed yield and yield attributes of 10 lentil varieties under high temperature

Varieties	Plant height (cm)	Photo-synthesis rate (µmolCO_2 $m^{-2}S^{-1}$)	Chloro-phyll content ($mgg^{-1}fw$)	Nitrate reductase (µ mol NO_2/gfw /h)	Total dry mass plant^{-1} (g)	Pods plant^{-1} (no.)	Seeds plant^{-1} (no.)	Seed weight plant^{-1} (g)	Harvest index (%)
Binamasur-2	27.6 b	32.66 bc	2.42bcd	1.62 cd	3.75 cd	88.2 b	133.8 b	3.18 bc	38.12 bc
Binamasur-3	28.1 b	26.94 f	1.96e	1.96 a	3.84 bc	75.9 e	116.7 c	3.21 bc	37.05 c
Binamasur-4	25.0 c	30.07 d	2.26cde	1.61 cd	3.45 e	71.0 f	111.1 d	3.04 bc	38.72 b
Binamasur-5	27.4 b	28.56 e	2.81ab	1.87 ab	4.00 ab	78.9 d	119.8 c	3.21 bc	37.21 c
Binamasur-6	30.7 a	32.06 c	2.53bc	1.44 d	3.59 de	69.7 g	103.1 e	2.28 de	33.88 d
Binamasur-7	26.5 bc	36.65 a	2.39cd	1.79abc	3.64 d	75.1 e	110.5 d	2.87 c	37.24 c
Binamasur-8	30.8 a	30.16 d	2.50bc	1.42 d	3.66 d	53.9 h	76.44 f	1.89 e	26.21 f
Binamasur-9	27.6 b	29.61 de	2.07de	1.76abc	4.05 ab	85.8 c	132.4 b	3.59 ab	39.19 ab
Binamasur-10	32.3 a	33.35 b	3.00a	1.71 bc	4.15 a	71.4 f	109.4 d	2.57 cd	31.18 e
BARI Masur-5	26.3 bc	26.81 f	2.34cde	1.98 a	4.17 a	98.2 a	150.9 a	3.94 a	41.92 a
F-test	**	**	**	**	**	**	**	**	**

In a column, figure(s) with same letter do not differ significantly at P ≤ 0.05 by DMRT; ** indicates significant at 1 % level of probability

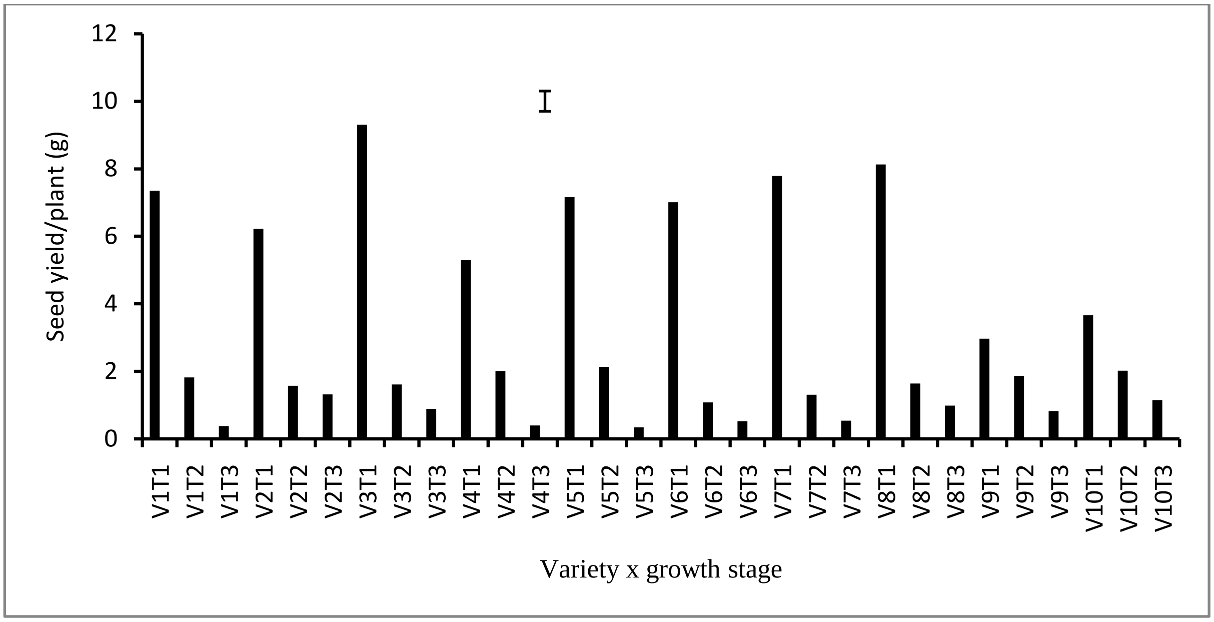

Fig. 1. Interaction effect of high temperature between variety and growth stage on seed yield in lentil

Vertical bar represents $Lsd_{0.05}$. V1 = Binamasur-2, V2= Binamasur-4, V3= BARI Masur-5, V4= Binamasur-10, V5= Binamasur-5, V6= Binamasur-7, V7= Binamasur-3, V8= Binamasur-9, V9= Binamasur-8, V10= Binamasur-6; T1= Control, T2= 34 ^{0}C temperature imposed at flowering stage, T3= 34 ^{0}C temperature imposed at pod growth stage

High temperature at flowering or grain filling stage severely affected yield and attributes of the lentil varieties. But temperature imposed at grain filling stage had greater negative influence. Among ten lentil varieties, Binamasur-6 and Binamasur-8 had some tolerance to high temperature.

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Short communication

BINATIL-2: A GAMMA RAYS INDUCED MUTANT VARIETY OF SESAME

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Abstract

Seeds of local sesame variety T-6 were irradiated with gamma rays and grown as M_1 during Kharif-I 2002. The yield potential of two M_6 mutants, SM-5 and SM-12 was evaluated through different trials in some sesame growing areas of the country during 2007 to 2009. Results showed that mutant SM-12 produced the highest seed yield in all the locations and years. Mutant SM-12 also produced the highest number of capsules/plant. Average seed yield of SM-12 over the locations and years was 1531 kg/ha which was 6.2 and 11.2% higher than two popular check varieties, Binatil-1 and BARI Til-2, respectively. Binatil-1 and BARI Til-2 produced the seed yield of 1446 and 1377 kg/ha, respectively. Results of yield trials carried out across the country indicated SM-12 was found suitable and thus National Seed Board of Bangladesh registered SM-12 as Binatil-2 in 2011 for commercial cultivation in Bangladesh.

Bangladesh is deficient in edible oil production. The domestic production of edible oil including rice bran oil can hardly meet 20% demand of the country. Therefore, it is urgently needed to expedite efforts for increasing the local production of oilseeds. In Bangladesh, among the oilseed crops, sesame is cultivated on 35.65 thousand hectares of land with a production of 34.00 thousand tons with seed yield of 954 kg/ha (BBS 2017). There are many factors responsible for its low yield per unit area but the most important is the non-availability of high yielding varieties. It is therefore, imperative to develop high yielding varieties of sesame for higher production.

The main objective for plant breeding is to increase genetic diversity and induction of variability for the selection of high yielding varieties. Among the different breeding methods, induced mutation has been extensively and successfully used for genetic improvement of any yield attributes either qualitative or quantitative in nature for sesame and other crops (Das *et al*. 1999 & 2004; Ahloowalia *et al.*, 2004, Khatri *et al.* 2005, Sarwar *et al.*, 2008 & 2010, Uddin *et al.* 2007, Naeem et al., 2009, Malek & Monshi 2010, Malek, *et al.*, 2012a & 2012b; Ghanei *et al*., 2013; Ambavane *et al*., 2015; Begum *et. al.*, 2015; Aristya *et al*., 2018). It is notable that using this technique, a large number of mutant varieties of different crops with improved traits have been developed and released worldwide, many of which have substantial economic values (Maluszynski *et al.*, 2000). Over 3275 mutant varieties in more than 220 plant species have to-date been officially released worldwide (see http://mvd.iaea.org/). The commercial utilization of mutant-induced and mutant-derived varieties strongly shows that mutation breeding is a useful tool for generating new germplasm for crop improvement (Ishige, 2009). The present research was therefore, carried out to evolve sesame variety(s) having suitable plant type, heavy bearing and high seed yield potential through treating seeds of local sesame variety, T-6 with gamma rays.

Seeds of local sesame variety T-6 were exposed to gamma rays in 2002 to induce genetic variability for the selection of improved mutant genotypes. The treated seeds were sown to obtain M_1 generation along with mother check at the experimental field of BINA head quarters, Mymensingh. Seeds from five selected capsules from the lower part of the rachis of each M_1 plant were harvested. The M_2 seeds from each individual M_1 plants were grown along with mother check in plant-progeny-row in 2003. In M_2 population, all the plants were carefully observed and plants appearing different from mother variety for one or more morphological traits were harvested separately. From first segregation M_2 population, a total of 265 mutant variants appearing different form from the mother variety for one or more morphological traits were selected and M_3 seeds from 265 individual mutant variants were collected separately. Then M_3 seeds from 265 individual mutant variants were grown in plant-progenies row along with mother variety in 2004. A total of 47 mutant variants were selected from M_3 population. For the observation trial M_4 seeds of selected 47 mutant variants were grown following plant-progeny row along with mother variety. From the observation trial of M_4 generation a total of 25 individual mutant variants were selected. M_5 seeds of 25 individual plants were grown in 2006 following plant-progeny row along with mother variety and were found to breed true. Among the 25 true breeding mutants, two most promising M_6 mutants (SM-5 and SM-12) for having their desirable morphological traits and yield attributes

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compared to their mother variety T-6 were selected from 700Gy during observation trial (non-replicated) and were put into extensive trial in different sesame growing areas of the country during 2007 to 2009. Considering the better performance of SM-5 and SM-12, advanced yield trial (AYT) was conducted in the farms of BINA sub-stations at Magura, Satkhira and Ishurdi during Kharif-I 2007. In Kharif-I 2008, on-station and on-farm trials were carried out in the farms of BINA sub-stations at Magura and Ishurdi, and in the farmers' field at Nachole of Chapainawabganj and Tetulia of Panchagor districts. In Kharif-I 2009, again on-station and on-farm trials were carried out in the farms of BINA sub-stations at Magura and Ishurdi, and in the farmers' field at Atgharia of Pabna and Sadar of Jhenaidah, Jashore and Satkhira districts. AYT conducted in 2007 was laid out in a randomized complete block design with three replicates and, On-station and on-farm yield trials conducted during 2008 and 2009 were also laid out following the same design with three replicates. Unit plot size was maintained $15m^2$ (5m × 3m) for AYT, $16m^2$ (4m × 4m) for on-station and on-farm trial conducted in 2008 and $25m^2$ (5m × 5m) for on-station and on-farm trial conducted in 2009. Recommended fertilizer doses were applied. Seeds were sown within the 2^{nd} week of March of each year. Row to row distance was maintained 30cm. Different intercultural operations were followed as and when necessitated for proper growth and development of the plants of each plot. Two popular sesame varieties, Binatil-1 and BARI Til-2 were included in all trials as check for comparative assessment in respect of seed yield, maturity period, plant height, number of branches and capsules/plant, number of seeds/capsule etc. The data were analyzed statistically following Gomez and Gomez (1984) and the mean values were compared by DMRT at 5% level of significance.

Gamma rays irradiated seeds of T-6 were grown as M_1 during 2002. Selection of desirable individuals was made from M_2 during 2003 and true breeding nature was confirmed in M_5 generation in 2006. A total of 25 mutants having high seed yield and other yield attributes were selected from M_5 generation. Two promising M_6 mutants (SM-5 and SM-12) with desirable morphological characters and yield attributes compared to the mother variety (T-6) and check varieties were selected from 700Gy from observation trial (non-replicated) conducted in Kharif-I of 2006 (data not shown). The selected two mutants were evaluated though extensive trials in different sesame growing areas of the country during 2007 to 2009.

Combined means of quantitative characters of the mutants and check varieties for advanced yield trial conducted during 2007 are presented in Table 1 and, on-station and on-farm trials conducted during each of 2008 and 2009 are presented in Table 2 and Table 3, respectively. Results of advanced yield trial showed that on an average of three locations, mutant SM-12 produced the highest plant height of 104cm followed by BARI Til-2 (90cm) while SM-5 had the shortest height of 81cm. Binatil-1 produced the highest number of 75 seeds/capsule followed by SM-12 which produced 68 seeds/capsule. Mutant SM-12 produced the highest number of 52 capsules/plant and gave the highest seed yield of 1444 kg/ha and two checks, Binatil-1 and BARI Til-2 produced 1331 and 1317 kg/ha seed yield, respectively (Table 1). On-station trial of 2008 (Table 2) showed that SM-12 produced highest number of 3.3 branches/plant and highest seed yield of 1870 kg/ha. On-farm trial during 2008 (Table 2) showed that BARI Til-2 and SM-12 produced the significantly higher number of branches than Binatil-1 and SM-5. Binatil-1 produced the highest seed yield of 1345 kg/ha followed by SM-12 (1276 kg/ha). Mutant SM-5 and check variety BARI Til-2 produced statistically lower seed yield (1203 and 1154 kg/ha, respectively)

Table 1. Mean of two mutants and checks for different yield attributing characters in AYT during Kharif-I, 2007

Locations	Mutants/ check	Days to maturity	Plant height (cm)	Branches $plant^{-1}$ (no.)	Capsules $plant^{-1}$ (no.)	Seeds $Capsule^{-1}$ (no.)	Seed yield ($kgha^{-1}$)
Magura	SM-5	76d	93c	0.0c	42.3	68b	1293b
	SM-12	91a	110a	1.9b	44.3	66b	1570a
	Binatil-1	82c	104b	0.0c	42.0	83a	1383b
	BARI Til-2	85b	107ab	2.6a	43.0	64b	1430ab
Satkhira	SM-5	83d	75b	0.00b	47b	68b	1258c
	SM-12	100a	100a	3.2a	60a	73a	1445a
	Binatil-1	87c	80b	0.00b	51b	74a	1370ab
	BARI Til-2	96b	76b	3.2a	49b	68b	1295b
Ishurdi	SM-5	84d	75c	0.0b	42b	63c	1085b
	SM-12	99a	101a	3.8a	51a	66b	1313a
	Binatil-1	91c	83b	0.0b	44b	69a	1238a
	BARI Til-2	94b	86b	3.5a	49a	61c	1225a
Combined means over three locations	SM-5	81d	81c	0.0b	44c	66c	1212c
	SM-12	97a	104a	2.9a	52a	68b	1444a
	Binatil-1	86c	89b	0.0b	46bc	75a	1330b
	BARI Til-2	91b	90b	3.1a	47b	65c	1317b

In a column, values with same letter(s) for individual location/combined means do not differ significantly at $p \leq 0.05$ by DMRT.

than Binatil-1 and SM-12. In Table 3, on-station trial conducted during 2009 showed that mutant SM-12 produced the highest seed yield of 1623 kg/ha while two checks Binatil-1 and BARI Til-2 produced the seed yield of 1498 and 1458 kg/ha, respectively. On-farm trial conducted during 2009 showed that mutant SM-12 also produced the highest seed yield of 1440 kg/ha and two checks Binatil-1 and BARI Til-2 produced the seed yield of 1272 and 1281 kg/ha, respectively (Table 3).

Table 2: Mean of two mutants and checks for different yield attributing characters in on-station and on-farm trials during Kharif-I, 2008

Locations	Mutants/ Checks	Days to maturity	Plant height (cm)	Branches $plant^{-1}$ (no.)	Capsules $Plant^{-1}$ (no.)	Seeds $Capsule^{-1}$ (no.)	Seed yield (kg ha^{-1})
On-station trial							
Magura	SM-5	71c	100c	0.0b	49b	80ab	1761c
	SM-12	76b	122a	2.9a	52b	73bc	2047a
	Binatil-1	77b	126a	0.0b	63a	86a	2004ab
	BARI Til-2	79a	113b	3.1a	44b	70c	1913b
Ishurdi	SM-5	91c	96c	2.5b	58	62b	1116c
	SM-12	96a	105b	3.2a	65	61b	1692a
	Binatil-1	93b	113a	0.0c	60	75a	1563ab
	BARI Til-2	95a	105b	3.1a	64	61b	1438b
Combined means over two locations	SM-5	81d	98d	1.2b	54	71b	1439c
	SM-12	86b	114b	3.1a	58	67bc	1870a
	Binatil-1	85c	120a	0.0c	62	80a	1783a
	BARI Til-2	87a	109c	3.1a	54	65c	1675b
On-farm trial							
Nachole, Chapainawabgonj	SM-5	87c	83c	0.6b	46	79b	1136c
	SM-12	97a	97b	3.3a	50	71c	1240b
	Binatil-1	91b	108a	0.0b	54	85a	1302a
	BARI Til-2	97a	97b	3.5a	53	70c	1115c
Tetulia, Pachagar	SM-5	86c	85b	0.5b	48ab	63b	1271bc
	SM-12	96a	85b	3.3a	52a	61bc	1313b
	Binatil-1	91b	97a	0.0b	49a	75a	1388a
	BARI Til-2	96a	88b	2.9a	44b	57c	1194c
Combined means over two locations	SM-5	86c	84c	0.5b	47	71b	1203c
	SM-12	96a	91b	3.3a	51	66c	1276b
	Binatil-1	91b	102a	0.0c	52	80a	1345a
	BARI Til-2	96a	92b	3.2a	48	64d	1154c

In a column, values with same letter(s) for individual location/combined means do not differ significantly at $p \leq 0.05$ by DMRT.

Average of all the quantitative characters of mutant SM-12 along with two checks over three years trials are presented in Table 4. Results revealed that mutant SM-12 produced the seed yield of 1531 kg/ha followed by two checks Binatil-1 and BARI Til-2 with seed yield of 1446 and 1377 kg/ha, respectively. It was also estimated that promising mutant SM-12 produced 6.2 and 11.2% higher seed yield than the two checks Binatil-1 and BARITil-2, respectively.

Generation of new plant type with improvement in yield attributes leading to produce high yield is the main plant breeding objective. Gamma-rays induced mutations have been instrumental in creating useful genetic variability in characters of economic importance in sesame cultivars, which led to the development of improved mutant varieties. SM-12 showed superiority to control varieties in seed yield in all the trials. Important factors responsible for an increase in the productivity in sesame are the number of branches and capsules/plant, seeds/capsule and an increase in seed weight. SM-12 produced not only the higher number of primary branches, but also produced the higher number of capsules/plant though it had lower number of seeds/capsule. Number of seeds/capsule was lower in SM-12. Mutant genotypes with higher number of branches, capsules/plant and finally in seed yield have also been reported in sesame (Das *et al.*, 1999; Malek & Monshi, 2010; Sarwar *et al*., 2010; Begum *et al*., 2015; Aristya *et al*., 2018) as a consequence of mutagenesis.

It was concluded that the performance of mutant SM-12 for seed yield and yield components was superior to the two check varieties, Binatil-1 and BARITil-2. Mutant SM-12, because of its high yield potential, held promise for selection and National Seed Board of Bangladesh (NSB) registered the mutant SM-12 as Binatil-2 in 2011 for commercial cultivation in the farmers' field of Bangladesh.

Table 3: Means of one mutant and two check varieties for different yield attributing characters in on-station and on-farm trials during Kharif-I, 2009

Locations	Mutant/ Varieties	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Capsules plant^{-1} (no.)	Seeds capsule^{-1} (no.)	Seed yield (kgha^{-1})
On-station trial							
Magura	SM-12	92b	115	2.5a	42a	64b	1620a
	Binatil-1	88c	113	0.0b	37ab	76a	1488b
	BARItil-2	94a	116	2.3a	33b	66b	1470b
Ishurdi	SM-12	96b	92	3.4a	65a	68b	1625a
	Binatil-1	91c	91	0.0b	41b	76a	1508b
	BARItil-2	100a	89	3.3a	59a	67b	1445c
Combined means over two locations	SM-12	94b	104	2.9a	54a	66b	1623a
	Binatil-1	89c	102	0.0b	39c	76a	1498b
	BARItil-2	97a	103	2.8a	46b	66b	1458b
On-farm trial							
Atgharia, Pabna	SM-12	93a	103	3.4a	62a	64b	1383a
	Binatil-1	90b	107	0.0b	56b	75a	1265b
	BARItil-2	94a	108	3.5a	61a	64b	1250b
Jhenaidah Sadar	SM-12	95a	112a	2.7a	46a	68b	1440a
	Binatil-1	89b	106b	0.0b	37b	78a	1241b
	BARItil-2	95a	113a	2.4a	42a	66b	1280b
Satkhira Sadar	SM-12	92b	121	2.7a	63a	65b	1431a
	Binatil-1	85c	116	0.0b	46c	80a	1258b
	BARItil-2	95a	121	2.4a	57b	65b	1250b
Jashore Sadar	SM-12	95a	90b	3.4a	51a	67b	1508a
	Binatil-1	89b	88b	0.0b	42b	78a	1325b
	BARItil-2	95a	95a	3.4a	45b	65b	1343b
Combined means over four locations	SM-12	94a	106ab	3.1a	55a	66b	1440a
	Binatil-1	88b	104b	0.0b	45c	77a	1272b
	BARItil-2	95a	109a	2.9a	51b	65b	1281b

In a column, values with same letter(s) for individual location/combined means do not differ significantly at $p \leq 0.05$ by DMRT.

Table 4. Means (average of three years trial) of mutant SM-12 and two check varieties Binatil-1 and BARI Til-2 for morphological characters, yield attributes and yield

Mutant/check varieties	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Capsules Plant^{-1} (no.)	Seeds Capsule^{-1} (no.)	Seed yield (kgha^{-1})	Seed yield increased over check varieties
SM-12	93	104	3.1	54	67	1531	6.2% over Binatil-1 11.2% over BARI Til-2
Binatil-1	88	103	0.0	49	78	1446	-
BARI Til-2	93	101	3.0	49	65	1377	-

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