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SCREENING OF COLD TOLERANT, SHORT DURATION AND HIGH YIELDING RICE LINES SUITABLE FOR NORTHERN PART OF BANGLADESH

S. Khanam[1*], M. Ali[2], M.S. Rahman[3], M.S. Haque[1], M.M.A. Noor[1] and M.M. Hasan[2]

Abstract

Rice, like many crops is lack of acclimatization ability to cold temperature that limits reducing crop yield worldwide. Three cold tolerant, long duration, and short bold grain (Manjusree-2, Komol-7 and Komol-9) exotic varieties were backcrossed with popular high yielding, short duration, long slender grain, Binadhan-17 to develop cold tolerant, short duration with fine grain quality rice varieties for ensuring stable yields over cold stress environments in Bangladesh. Eighteen BC_1F_4 backcross lines along with check variety were evaluated over three locations, *viz.* Nilphamari, BINA Sub-station Rangpur, and BINA HQs farm, Mymensingh at reproductive stage. Among them six lines of Manjusree-2, three lines of Kamol-7 and six lines of Kamol-9 showed cold acclimatization with high yield potential. Crop duration was 144-160 days depending on the locations and varieties. Although the plant height of these lines was tall but did not lodge. Yield attributing characteristics of these lines were found better than parents with higher number of effective tillers, filled grains, long panicle and higher yield. Therefore, these advanced lines could be released as cold tolerant rice varieties along with high yield for Northern cold prone areas of Bangladesh after further trials and following variety release procedure.

Keyword: Cold tolerant, short duration, high yield, rice

Introduction

In Bangladesh, around 2 million hectare of rice area becomes affected by low temperature during winter season causing seedling mortality in some years up to 90% and thereby increases cost of cultivation. The population is rising at 1.37 per cent annually but arable land is decreasing at 0.4 percent (BBS, 2019-20) in Bangladesh. In north-eastern haor areas of Bangladesh, the land remains submerged most of the time and around 1.26-million hectares of cultivable land are restricted to grow only boro paddy every year. Boro season usually begins in mid-November but many farmers start sowing in late October to avoid flash floods. As a result, the harvesting time fall sometime in January-February that triggers yield loss due to cold stress (Rashid and Yesmin, 2017). However, extreme climate change such as cold stress has already raised a radical change in northern regions and north-eastern haor regions in Bangladesh and threatened the productivity of the existing rice varieties (Hakim *et al*., 2014). Therefore, to utilize these areas for rice cultivation, development of suitable cultivars could be the best approach.

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Rice is widely cultivated around the world in both temperate and high-elevation (Andaya and Mackill, 2003) environments in tropical and subtropical areas as well as in irrigated areas which rely on the use of cold water (Ye *et al*., 2010). But low temperatures is a major limitation for rice production in those zones that can reduce up to 25% of the final yield in rice genotypes (Lima *et al*., 2012). Two types of cold stress observed in rice- at young vegetative stage: heading-delay type occur which results in low spikelet fertility and at reproductive stage, spikelet-sterility type occurs which result in poor grain filling of rice crop (Andaya and Tai, 2006). Although rice is sensitive to low temperature stress, a range of cold tolerance exists among rice cultivars (Lou *et al*., 2007) and it is reported that Indica rice is more sensitive to cold stress than Japonica rice (Lv *et al*., 2016) and the damage at reproductive stages is usually significantly greater than damage at the seedling stage (Pan *et al*., 2015). It has been shown that, spikelet sterility increases by up to 90% if reproductive stages exposed at 15˚C (day) and 10˚C (night) temperature and reduces grain eating quality (Jacobs and Pearson, 1999).

The objectives of this study were to screen rice lines showing high levels of cold stress tolerance, short duration and higher yield.

Materials and method

Thirteen genotypes (10 from cold prone area of Nepal and 3 from Bangladesh) of 21 day old seedlings were subjected to cold stress (10 ^{0}C) in a growth chamber for three weeks to evaluate their cold response. Three genotypes *viz*. Manjusree-2, Kamol-7 and Kamol-9) were selected based on their cold tolerant and hybridized with high yielding short duration variety Binadhan-17 to develop cold tolerant progeny. The F_1 seeds of each cross progenies were backcrossed with Binadhan-17 as the selected exotic genotypes were low yielding and long duration varieties. This study was carried out at the pot (crossing), laboratory (molecular) and the experimental field of Bangladesh Institute of Nuclear Agriculture (BINA) Headquarters, Mymensingh, BINA Sub-station Rangpur and farmer's field Nilphamari. The pot experiments were set to produce F_1 and backcross generations since 2018. Crossing materials were grown at BINA HQs farm Mymensingh to advance the generation and their performance was evaluated. Based on yield and yield attributing characters preliminary screening was done from $BC_1F_{1\text{-}3}$ generation at BINA Headquarters farm, Mymensingh. 120 lines from BC_1F_2 generation and 49 lines from BC_1F_3 generation were selected. Next year further evaluation was done from BC_1F_4 generation at two locations of the northern part of Bangladesh e.g. Rangpur and Nilphamari including BINA Headquarters, Mymensingh and the result was compiled accordingly. In experimental field, plant to plant and row to row distance was maintained by 20 cm and 15 cm, respectively. The experiment was followed by non-replicated design. A unit plot size was 2m × 1m. Recommended doses of nitrogen, phosphorus, potassium, sulphur and zinc were applied in the form of Urea, TSP, MoP, Gypsum and Zinc Sulphate. Cultural and intercultural practices were followed as and when necessary. The data of different parameters were taken from five plants of each plot and the average value was recorded. Statistical analysis was done by t-test. The yield data were recorded according to plot basis. Two cold responsive genes ICE and DREB were survey to investigate the cold tolerant gene introgression into the BC_1F_4 population from exotic variety. Genomic DNA was isolated according to CTAB method (Doyle and Doyle, 1987). PCR analysis was performed in 10 µl reaction sample containing 50 ng of DNA template of 2 µl, 5 µl of master mix, 2 µl nuclear free water, 1 µl each of 10 µM forward and reverse primers using Biometra T_3 thermal cycler with single 96-well. After initial denaturation for five minutes at 94ºC, each cycle comprised one minute denaturation at 94ºC, one min annealing at 55ºC, and two min extension at 72ºC with a final extension for 7 min at 72ºC at the end of 35 cycles. The PCR products were analyzed by electrophoresis on 8% polyacrylamide gel using mini vertical polyacrylamide gels for high throughput manual genotyping (CBS Scientific Co. Inc., CA, USA). Two µl of amplification products were resolved by running gel in 1X TBE buffer for 2-2.5 hrs depending upon the allele size at around 80 volts and 400 mA current. The gels were stained in 0.5 mg ml^{-1} ethidium bromide and were documented using Whatman Biometra Gel Documentation System (prod nr: 1603209).

Result and discussion

From previously harvested 49 lines of BC_1F_3 generation (data not shown) was grown at BINA HQs, Mymensingh in boro season 2019-2020. Based on yield performance the best lines were selected for further evaluation. During 2020-2021 a non-replicated experiment was conducted with selected 18 lines of BC_1F_4 generation for each three locations. Almost all locations, plant height was observed taller for all lines compared to Binadhan-17 but lodging was not found in any location. It has been reported that although plant height is the major contributor to the lodging tolerance but not only genetic gain in lodging tolerance can be obtained, also long with strong culm resists lodging that is independent of plant height (Navabi *et al*., 2006: Nomura *et al*., 2019).

From BC_1F_3 generation, 21 lines of Monjusree-2, ten lines of komol-7, and 18 lines of komol-9 have been selected according to the higher tiller numbers, longer panicle length, maximum filled grains $plant^{-1}$ and yield $hill^{-1}$. Among them 18 (seven from Monjusree-2, five from komol-7 and six from komol-9) promising lines from BC_1F_4 generation were transplanted in BINA Hqs farm, Mymensingh, Sub-station farm, Rangpur and farmer's field, Nilphamari.

Crop duration was observed medium in all population and significant variation was observed in no. of effective tillers comparing to the both parents (Table 1). At Mymensingh, M2-P-15, M2-P-16 produced higher number of effective tillers $plant^{-1}$. Longer panicle length (25-27 cm) was observed in M2-P-5, 8, 10 and 15. M2-P-10 exhibited highest no. of filled grains (208.2) and less no. of unfilled grain $panicle^{-1}$ (26.4) comparing to the both parents and gave higher yield $plant^{-1}$ comparing to the recipient parent (Table 1). Considering the agronomic performance including yield, M2-P-5, 8, 10, 15 and 16 were the best. The superior performance of backcross lines may have resulted from breakage of undesirable linkages or loss of negative interactions as it went through one round of backcrossing and advancement. The field based phenotypic selections based on different agro-morphological characters at each generation helped in identification of lines with superior performance over recurrent parent in terms of quality and abiotic stress tolerance (Kush and Zena, 2009).

At BINA Sub-station, Rangpur crop duration and no. of effective tillers plant^{-1} were higher than Mymensingh. The range of no. of effective tillers was 11.8 to 18.8 per plant. Longer panicle was observed in M2-P-5. The highest no. of filled grains was observed in M2-P-5 and M2-P-16 than the both parent (Table 1). The lines M2-P-5, M2-P-8, M2-P-10, M2-P-14, M2-P-15 and M2-P-16 produced higher yield comparing to the both parent (Table 1). These seven lines can be evaluated for the next trial for Rangpur region where even small amounts of temperature fluctuation lead to decline a large amount of rice yield and Cold tolerant lines would be best possible solution of higher rice production (Rokonuzzaman *et al*., 2018).

Table 1. Evaluation of BC_1F_4 generation of Monjusree-2 based on grain yield and yield components during boro season 2020-21 at three locations

Location	Variety/Line	Duration (days)	Plant height (cm)	Effective tiller plant^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Yield (t ha^{-1})
Mymensingh	M2-P-5	146±0.71	102.6±1.88	7±0.45	26.6±0.32	163.6±4.82	7.5±0.34
	M2-P-8	145±0.71	110.2±1.88	6.8±0.45	27.4±0.32	146.8±4.82	6.6±0.34
	M2-P-10	147±0.71	122.4±1.88	7±0.45	25.4±0.32	208.2±4.82	7.6±0.34
	M2-P-14	147±0.71	99.6±1.88	7.8±0.45	23.2±0.32	137.8±4.82	5.1±0.34
	M2-P-15	146±0.71	112.2±1.88	10.4±0.45	25.8±0.32	149.4±4.82	7.5±0.34
	M2-P-16	148±0.71	107.4±1.88	8.6±0.45	24±0.32	159.4±4.82	7.2±0.34
	M2-P-19	150±0.71	102.6±1.88	7.6±0.45	23.6±0.32	136.2±4.82	3.4±0.34
	Monjusree 2 (P)	150±0.71	117.8±1.88	7.6±0.45	22.6±0.32	148.2±4.82	3.2±0.34
	Binadhan-17 (P)	158±0.71	98.4±1.88	13.8±0.45	23.0±0.32	156.8±4.82	7.1±0.34
Rangpur	M2-P-5	157±0.92	124.4±6.59	15±0.91	24.82±0.87	145.4±9.34	8.3±0.65
	M2-P-8	156±0.92	137±6.59	14.6±0.91	22.8±0.87	94.4±9.34	9.7±0.65
	M2-P-10	157±0.92	135.8±6.59	16.6± 0.91	22.2±0.87	107.8±9.34	8.1±0.65
	M2-P-14	157±0.92	85.4±6.59	16±0.91	19.7±0.87	115.2±9.34	8.5±0.65
	M2-P-15	157±0.92	131.2±6.59	11.8±0.91	16±0.87	121±9.34	8.5±0.65
	M2-P-16	157±0.92	141.8±6.59	18.8±0.91	22.9±0.87	182.8±9.34	9.9±0.65
	M2-P-19	157±0.92	101.6±6.59	12.2±0.91	22±0.87	116.4±9.34	6.2±0.65
	Monjusree 2 (P)	151±0.92	115.2±6.59	9.8±0.91	22.6±0.87	148.2±9.34	4.6±0.65
	Binadhan-17 (P)	162±0.92	99.5±6.59	14.1±0.91	23.8±0.87	156.8±9.34	7.0±0.65
Nilphamari	M2-P-5	160±0.82	103.6±6.13	19.8±1.27	21.7±0.43	148±10.93	8.9±0.59
	M2-P-8	159±0.82	130.2±6.13	14.2±1.27	22.6±0.43	97.2±10.93	9.3±0.59
	M2-P-10	160±0.82	135.4±6.13	16.2±1.27	23.3±0.43	81±10.93	9.6±0.59
	M2-P-14	159±0.82	84.8 ±6.13	13±1.27	19.4±0.43	118.2±10.93	9.5±0.59
	M2-P-15	159±0.82	129.2±6.13	11.8±1.27	21.6±0.43	133.2±10.93	6.0±0.59
	M2-P-16	160±0.82	138.6±6.13	19.6±1.27	22.5±0.43	181.2±10.93	9.2±0.59
	M2-P-19	159±0.82	112±6.13	10.4±1.27	21±0.43	139±10.93	8.5±0.59
	Monjusree- 2 (P)	153±0.82	115±6.13	8.8±1.27	22.5±0.43	145.2±10.93	4.3±0.59
	Binadhan-17 (P)	162±0.82	98.7 ±6.13	14 ±1.27	23.7±0.43	160.18±10.93	6.1±0.59

At Nilphamari, crop duration was little higher than Rangpur. All the lines produced higher No. of effective tillers plant^{-1}, among them M2-P-5, M2-P-8, M2-P-10 and M2-P-16 had the highest no. of effective tillers^{-1} (Table 1). Panicle length was the same for all the populations comparing to the both parents. M2-P-16 had highest no. of filled grain panicle^{-1} (181.2) comparing to the both parents. The Backcross lines M2-P-5, M2-P-8, M2-P-10, M2-P-14, M2-P-16 and M2-P-19 produced higher yield compare to the recipient parent (Table 1). These lines can be evaluated for the next trial. Agriculture of Nilphamari district is highly vulnerable in weather patterns and is therefore extremely at risk from climate change in aspect of temperature fluctuation, dew point temperature and sunshine period that contribute to the spikelet sterility in cold susceptible rice either in vegetative and reproductive phase (Islam *et al*., 2021).

Five lines from BC_1F_4 generation of parent, Komol-7 were evaluated at all three locations. Maturity date was shorter in Mymensingh than in Northern part of Bangladesh. Total number of effective tillers plant^{-1} was observed higher than parent Komol-7 but lesser than Binadhan-17 in all locations (Table 2). The backcross lines K7-P-1, K7-P-2, K7-P-3, K7-P-4, K7-P-7 and K7-P-9 had longer panicle (24.2 cm to 26.6 cm) than the recipient (23.4) and donar parent (23.8) at Mymensingh but had the similar length at Rangpur and

Table 2. Evaluation of BC_1F_4 generation of Komol-7 based on grain yield and yield components during boro season 2020-21 at three locations

Location	Variety/Line	Duration (days)	Plant height (cm)	Effective tillers plant^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Yield (t ha^{-1})
Mymensingh	K7-P-1	149±1.16	138.4±4.63	7.6±0.74	26.6±0.49	176.4±7.95	6.8±0.25
	K7-P-2	148±1.16	121.2±4.63	7.8±0.74	24.2±0.49	180±7.95	7.5±0.25
	K7-P-3	150±1.16	146±4.63	6.2±0.74	26.6±0.49	229.4±7.95	7.2±0.25
	K7-P-5	149±1.16	128±4.63	6.4±0.74	21.8±0.49	213.4±7.95	7.1±0.25
	K7-P-9	153±1.16	129.6±4.63	7.4±0.74	25.8±0.49	224±7.95	8.9±0.25
	Komol-7(P)	157±1.16	113.2±4.63	5.6±0.74	23.4±0.49	170.8±7.95	5.3±0.25
	Binadhan-17(P)	158±1.16	98.4±4.63	13.8±0.74	23.8±0.49	156.8±7.95	7.2±0.25
Rangpur	K7-P-1	152±1.16	116.4±4.63	7.8±0.71	22±0.49	131.2±7.95	6.0±0.25
	K7 -P-2	158±0.24	140.2±9.23	12.2±1.25	24.2±0.31	164.8±11.28	9.4±0.74
	K7-P-3	148±1.16	121.2±4.63	6±0.72	20.2±0.49	180 ±7.95	5.3±0.25
	K7-P-5	157±0.24	151.6±9.23	11.6±1.25	22.4±0.31	141.4±11.28	9.1±0.74
	K7-P-9	157±0.24	131.8±9.23	11.6±1.25	23.4±0.31	118.6±11.28	9.4±0.74
	Komol-7(P)	157±0.24	115.1±9.23	6.4±1.25	23.5±0.31	175.1±11.28	5.2±0.74
	Binadhan-17(P)	158±0.24	99.4 ± 9.23	13.8±1.25	23.9±0.31	160.3±11.28	6.5±0.74
Nilphamari	K7-P-1	155±1.16	118.4±4.63	7.8±0.31	22±0.49	139.2±7.95	6.3±0.25
	K7-P-2	160±0.37	135±7.11	11.4±1.21	22.6±0.25	146.6± 9.74	9.2±0.74
	K7-P-3	157±1.16	129.2±4.63	8±0.72	20.2±0.49	140±7.95	5.2±0.45
	K7-P-5	159±0.37	135.8±7.11	11.6±1.21	23.9±0.25	154.8±9.74	9.3±0.74
	K7-P-9	160±0.37	132.2±7.11	10.8±1.21	23.8±0.25	116.4±9.74	8.8±0.74
	Komol-7(P)	159±0.37	115.1±7.11	6.4±1.21	23.5±0.25	175.1±9.74	5.3±0.74
	Binadhan-17(P)	160±0.37	99.4±7.11	13.8±1.21	23.9±0.25	160.34±9.74	6.3±0.74

Nilphamari. All backcross lines had significantly higher no. of filled grains panicle^{-1} (176-229) than both parent but this result was not found similar at Rangpur and Nilphamari (Table 2) as cold temperature prevail more at Northern part than Mymensingh (Table 4) which hinder grain filling properly by incomplete panicle exertion, spikelet abortion along with late and incomplete grain (Satake and Hayase, 1970). Although yield, the most important and complex traits in rice is regulated by QTLs and influenced by external environmental factors (Wang *et al*., 2012; Zeng *et al*., 2017) three lines e.g. K7-P-2, K7-P-5 and K7-P-9 were selected from three locations as high yielding than the recipient parent.

Six lines from BC_1F_4 generation of parent, Komol-9 were also evaluated at all three locations. At Mymensingh, K9-P-17-17 line was observed short duration and plant height than other lines. Most of the backcross lines had significantly higher number of effective tillers plant^{-1} than the recipient parent (7.8). K9-P-16-3, K9-P-16-16 and K9-P-18 exhibited longer panicle (25.4 cm, 25.8 cm, and 25.4 cm) than the both parents. The number of filled grains panicle^{-1} was similar with both parents. K9-P-16-3 line produced higher yield comparing to the recipient parent (Table 3). At Rangpur Sub-station, all the back cross lines had taller plant height comparing to the donor parent (Table 3).

Table 3. Evaluation of BC_1F_4 generation of Komol-9 based on grain yield and yield components during boro season 2020-21 at three locations

Location	Variety/Line	Duration (days)	Plant height (cm)	Effective tiller plant^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Yield (t ha^{-1})
Mymensingh	K9-P-11	155±1.02	136.2±6.45	13±0.74	24.8±0.41	136.8±8.96	6.9±0.35
	K9-P-12	149±1.02	117.8±6.45	8.8±0.74	23.2±0.41	166.4±8.96	5.7±0.35
	K9-P-16-3	151±1.02	145.6±6.45	6.8±0.74	25.4±0.41	163.8±8.96	7.4±0.35
	K9-P-16-16	153±1.02	140.2±6.45	8.8±0.74	25.8±0.41	183±8.96	6.4±0.35
	K9-P-17-17	146±1.02	91.2±6.45	10.8±0.74	21.4±0.41	153.4±8.96	4.0±0.35
	K9-P-18	156±1.02	145.6±6.45	6.2±0.74	25.4±0.41	101±8.96	4.8±0.35
	K9 (P)	155±1.02	135.4±6.45	7.8±0.74	24.6±0.41	183.8±8.96	5.1±0.35
	Binadhan-17 (P)	158±1.02	98.4±6.45	13.8±0.74	23.8±0.41	156.8±8.96	7.2±0.35
Rangpur	K9-P-11	155±0.32	104.8±5.98	13.8±0.61	22.1±0.34	155.2±12.29	9.7 ±0.53
	K9-P-12	157±0.32	138.4±5.98	12.2±0.61	24.8±0.34	145.4±12.29	9.8±0.53
	K9-P-16-3	157±0.32	111.5±5.98	13.2±0.61	24.4±0.34	152.8±12.29	8.3±0.53
	K9-P-16-16	156±0.32	126±5.98	13.2±0.61	25±0.34	190.8±12.29	10.4±0.53
	K9-P-17-17	156 ±0.32	108±5.98	15.2±0.61	24.6±0.34	92±12.29	8.7±0.53
	K9-P-18	157 ±0.32	141.2±5.98	11±0.61	23.4±0.34	107±12.29	9.3±0.53
	K9 (P)	157 ±0.32	136.4±5.98	9.8±0.61	24.6±0.34	185.1±12.29	5.6±0.53
	Binadhan-17 (P)	158 ±0.32	98.4±5.98	13.8±0.61	23.6±0.34	167.1±12.29	8.1±0.53
Nilphamari	K9-P-11	158 ±0.38	97±5.74	13.4±0.55	23.7±0.39	163 ±11.43	7.7±0.45
	K9-P-12	159±0.38	112.6±5.74	11±0.55	22.7±0.39	110.6±11.43	9.4±0.45
	K9-P-16-3	160±0.38	111±5.74	12.2±0.55	24.7±0.39	180.4±11.43	9.2±0.45
	K9-P-16-16	159±0.38	121.8±5.74	12.4±0.55	22.0±0.39	148.4±11.43	8.5±0.45
	K9-P-17-17	159±0.38	104.2±5.74	14.6±0.55	22.8±0.39	94±11.43	9.3±0.45
	K9-P-18	160±0.38	139.6±5.74	11.6±0.55	21.7±0.39	148±11.43	8.6±0.45
	K9 (P)	157±0.38	136.4±5.74	9.8±0.55	24.6±0.39	185.1±11.43	5.5±0.45
	Binadhan-17 (P)	160±0.38	98.4±5.74	13.8±0.55	23.6±0.39	167.1±11.43	7.0±0.45

All had higher number of effective tillers than the recipient parent (9.8). RM-K9-P-16-16 had longer panicle (25cm) and maximum filled grain panicle^{-1} (190.8) hence yield was highest among the lines. All backcross lines showed higher yield than the both parents. Although scientists have tried to explore the mechanism of cold tolerance in rice for a long time, its genetic mechanism is still not well understood. Both additive and non-additive gene interaction are known to be present for controlling the attributes that directly or indirectly influence on yield and cold susceptibility (Chen *et al*., 2006).

At Nilphamari, K9-P-11 had shorter plant height (97 cm), K9-P-17-17 had higher no. of effective tiller (14.6), K9-P-11, K9-P-16-3 had longer panicle length (23.7cm and 24.7 cm) comparing to the both parent (Table 3). All six lines were showed higher yield than the both parents among them K9-P-12, K9-P-16-3, K9-P-16-16, K9-P-17-17 and K9-P-18 produced higher yield comparing to the recipient parent. Molecular analysis revealed that all selected 18 lines responded positively with the survey of two cold responsive genes ICE and DREB (Fig.1).

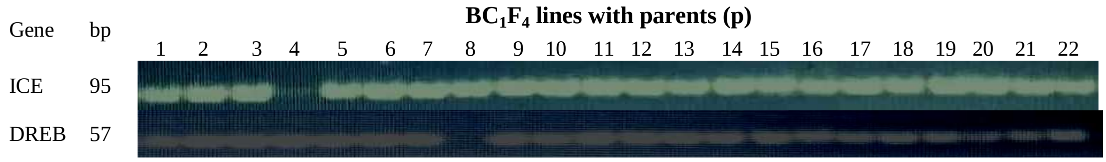

Fig 1: Two cold responsive genes (ICE and DREB) survey among 22 genotypes: Lane = Monjusree-2 (P); Lane2=Komol-7 (P); Lane3=Komol-9 (P); Lane4 = Binadhan-17 (P); Lane5-11= Monjusree-2 (BC_1F_4); Lane12-16 = Komol-7 (BC_1F_4); and Lane17-22 = Komol-9 (BC_1F_4)

Table 4. Monthly average temperature (°C) of three experimental districts

District	Temperature (^{0}C)	Month							
		Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	March-21	April-21	May-21
Mymensingh	Day	31	28	25.8	29	32	35	35	35
	Night	24	17	13.5	17	19	22	25	26
Rangpur	Day	33.1	29.5	25.1	22.7	24.1	31	33.3	31.8
	Night	24.8	17.9	13.7	12. 2	14	19	22.3	23.9
Nilphamari	Day	30.5	32.2	30	25.1	21.8	24.1	28.6	32
	Night	22.7	21.2	15	13	11.2	12.6	16.6	23.7

Source: Weather office, Mymensingh, Rangpur and Nilphamari

The day night temperature was different in Mymensingh region and the average night temperature was higher comparing to the northern part of Bangladesh (late Dec. to early March). However, the mean minimum temperature in Northern part at reproductive stage was recorded <20 ^{0}C (Table 4) in mid-February to mid-March that enhance spikelet sterility if below 20^{0}C prevails 5-6 days (Biswas *et al*., 2011). The reported genotypes could escape the cold injury due to having cold tolerance gene (Rahman *et al.,* 2020) which was supported by molecular analysis (Fig. 1). So, the Selected 15 lines [6 (Monjushree)+3(K7)+6(K9)] from Rangpur and Nilphamari would be the good material as cold-tolerant variety for North area of Bangladesh through further trials.

Conclusion

From the different sets of backcross population of BC_1F_4 generations 15 lines were acclimatized with low temperature without compromise the yield than their both parents. At all three locations, nine lines e.g. three (RM-M2-P-5, RM-M2-P-8, RM-M2-P-16) from Manjusree-2, three (RM-K7-P-2, RM-K7-P-5, RM-K7-P-9) from Komol-7 and three (RM-K9-P-11, RM-K9-P-12, RM-K9-P-16-3) from Komol-9 were performed better based on yield and yield contributing traits. Crop duration of the selected lines was 144-160 days that might be fitted at Northern cold prone area of Bangladesh and lodging tolerant gene might be involved these lines as lodging was not observed during the experimental period though the plant height is taller.

Acknowledgement

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IN VITRO DEVELOPMENT OF DROUGHT TOLERANT RICE THROUGH POLYETYLENE GLYCOL (PEG) USING EMBRYOGENIC CALLI

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Abstract

Selection for drought resistance is gaining more importance in rice (*Oryza sativa* L.) but selection under natural field conditions is tiresome due to low heritability and time required. Selection in tissue culture is thought to be the preferred way to accelerate selection efficiency. Several parameters such as seed germination percentage, callus induction, shoot regeneration and root induction was studied under drought stress imposed by polyetylene glycol (PEG 6000). Rice varieties Binadhan-19 and Binadhan-17 showed significant callus induction. Callus induction was significantly higher under dark condition (85.2%) than light condition (75.83%). After callus induction, drought stress was created by increased levels of PEG (0%, 5%, 8% and 10%). The highest and the lowest percentage of plant regeneration were found in both varieties at 0% and 10% PEG. The variety Binadhan-19 performed best at 5.0% PEG for shoot regeneration (64%) and root induction (60%) followed by 8% and 10% PEG. At 8% PEG level, shoot regeneration was 56% in Binadhan-19 and 40% in Binadhan-17 and root induction was 40% in Binadhan-19 and 30% in Binadhan-17. At 10% PEG level, shoot regeneration was 40% in Binadhan-19 and 32% in Binadhan-17 and root induction was 30% in Binadhan-19 and 20% in Binadhan-17. The variety Binadhan-19 performed better against drought stress than Binadhan-17. These results emphasize that, selection of drought tolerant rice plants *in vitro* by creating artificial water stress using PEG in culture media is feasible. The information gained from the study could be helpful in developing rice varieties *in vitro* for drought tolerance.

Key Words: Callus Induction, Drought Stress, Plant Regeneration, PEG.

Introduction

Drought is one of the major abiotic stresses that severely affects and reduces the yield and productivity of food crops worldwide up to 70% (Kaur *et al*., 2008; Thakur *et al.*, 2010; Akram *et al.*, 2013). The response of plants to drought stress is complex and involves changes in their morphology, physiology and metabolism. Drought stress is characterized, among others by the reduction of water content, closure of stomata and limitation of gas exchange. Much more extensive loss of water can lead to accumulation of reactive oxygen species (ROS), which disrupts metabolism and cell structure and eventually the enzyme-catalyzed reactions and finally may result in the death of plant (Jaleel *et al*., 2008; Phung *et al*., 2011).

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Rice (*Oryza sativa* L.), the world's most important cereal crop, is the primary source of food and calories for about half of mankind (Khush, 2005). Rice provides as much as 80% of the dietary calories in some Asian countries. The demand for increase in rice production is increasing to meet the needs of increasing world population. The demand for rice is constantly rising in Bangladesh with nearly 2.7 million people being added each year to its population of about 143 million (FAO, 2003). About 77.69% of total cultivable land in Bangladesh is being used for rice production, which contributes 21.22% of total agricultural production and engages about 48% of total agricultural labor forces (BBS, 2007). Rice constitutes the most important economic activity and the primary source of income and employment for more than 100 million households in Asia and Africa (FAO, 2004). The predominantly rice-growing areas in Asia (130 million hectares, more than 85% of the total world rice production) are often threatened by severe abiotic stresses. Bangladesh is facing rice production constraints such as drought, lack of irrigation facilities, flooding, and salinity of soils, coupled with fluctuation of commercial prices.

Binadhan-19 was developed by the Bangladesh Institute of Nuclear Agriculture (BINA), from NERICA-10 through radiation. It is a high yielding and drought tolerant rice variety which can be cultivated both in Aus and T. aman season. Binadhan-19 is long and slender and also cost effective as it requires less irrigation and fertilization. It is a short-duration variety which can be harvested within 90 to 95 days. While other Aus varieties take 110 to 115 days.

Binadhan-17 is a new highly yielding green super rice variety of T. aman developed by Bangladesh Institute of Nuclear Agriculture (BINA). The yield of Binadhan-17 is at least 33 percent higher than that of other varieties of T. aman Rice and production cost is around one-third lower. Binadhan-17 is harvested one-month earlier than other varieties of T. aman allowing cultivation of different winter crops. Polyethylene glycol (PEG) is known to cause osmotic stress *in vitro* which alters the osmotic potential of the cell and hence these serve as useful selection agents for drought tolerance. PEG with molecular mass of 6000 and above are non-ionic, non-toxic, water soluble polymers which do not penetrate intact plant tissues rapidly. It forms hydrogen bonds with water, decreasing the water potential of culture medium and finally inhibits both water and mineral uptake by roots. Thus, such an osmotic agent acts in lowering the water potential in a way similar to soil drying.

Drought is considered as one of the major abiotic stresses limiting rice production worldwide. Therefore, development of drought tolerant rice varieties has been considered as one of the strategies to increase rice production in drought prone areas. The main objective was to study *in vitro* callus induction and regeneration ability of Binadhan-19 and Binadhan-17 under drought stress.

Materials and methods

The experiment was carried out during the period from June to December 2021 in the Tissue culture laboratory at Biotechnology Division in Bangladesh Institute of Nuclear

Agriculture, Mymensingh, Bangladesh. Seeds of two rice varieties viz. Binadhan-17 and Binadhan-19 were collected from Plant Breeding Division, BINA, Mymensingh.

Surface sterilization of mature seed was carried out under laminar air flow cabinet. After collection of seeds following washed by sterilize water for 3 to 5 minutes to reduce the level of surface organism. The floating seeds were discarded. Later, they were rinsed in 70% ethyl alcohol for 2 minutes, followed by washing with sterile distilled water for 3 times. Finally, inside the cabinet, surface disinfection was done with 0.1% $HgCl_2$ for 2 minutes and during this period the sterilant was occasionally agitated. The seeds were then washed 5 times with sterilized distilled water to remove the sterilant. To ensure aseptic condition under *in vitro*, all instruments, glassware and culture media were sterilized by autoclaving with 15 PSI pressure at 121°C for 20 minutes. All inoculation and aseptic manipulations were carried out in a laminar air flow cabinet. The cabinet was exposed to the UV light for 30 minutes before use and cleaned with 70% ethyl alcohol to eliminate the chance of contaminations.

The MS medium formulated by Murashige and Skoog (1962) with vitamins (Duchefa, Netherlands) was used in the study. To test the embryo survivability, MS medium supplemented with NAA at 1.0 mgl^{-1}, BAP and Kinetin at 2.0 mgl^{-1} and different concentrations of (PEG) (6000) (0%, 5%, 8%, 10%). Sterilized mature seeds of two varieties of rice were inoculated into petridish with forceps each containing 25-30 ml MS medium with PEG at different concentrations viz. To = 0% (control/no PEG), T_1 = 5% PEG, T_2 = 8% PEG, T_3 = 10% PEG with three replication. Cultures were maintained at (25$\pm$2) ^{o}C temperature under both light and dark condition. The data on germination percentage, percentage of callus induction, percentage of embryogenic callus induction, percentage of shoot and root regeneration and finally percentage of established plant was recorded.

Statistical Analysis: The recorded data were statistically analyzed using Statistix 10 program and Microsoft Excel wherever applicable. The experiment was arranged in Completely Randomized Design (CRD) with three replications and the collected data were analyzed statistically following analysis of variance (ANOVA) technique and the mean differences were compared by DMNRT (Ducan's Multiple New Range Test) and the ranking was indicated by letters.

Results and discussion

Callus induction capacity from mature embryos

The rice varieties (Binadhan-19 and Binadhan-17) were cultured in MS medium supplemented with different concentrations and combinations of plant growth regulators. The mature embryos were inoculated on MS medium supplemented with 2, 4-D (2.0 mgl^{-1}) to observe the callus formation response. Callus formation invariably occurred from the embryo region of the seeds and was visible within 14 days. There were two different photoperiod conditions. One was under 24 hour dark condition and another one was under 24 hour light using 3000 lux intensity.

Table 1. Effect of dark and light condition on callus induction and embryogenic callus induction of Binadhan-17 and Binadhan-19

Sl. No.	Effect of dark condition				Effect of light condition			
	callus induction (%)		Embryogenic callus induction (%)		callus induction (%)		Embryogenic callus induction (%)	
	Bina dhan-17	Bina dhan-19	Bina dhan-17	Bina dhan-19	Bina dhan-17	Bina dhan-19	Bina dhan-17	Bina dhan-19
1.	83.87	87.09	63.22	67.74	77.41	80.64	52.9	56.77
2.	83.33	86.66	58.78	64	76.67	76.67	49.34	60
3.	82.75	88.27	63.44	75.86	75.86	82.75	52.41	57.93
4.	78.57	89.28	61.42	70	64.28	80	48.57	67.14
5.	85.18	85.92	60.74	68.15	68.14	81.48	51.85	57.77
6.	80.76	90.76	53.84	68.46	63.07	80.76	46.15	63.07
Mean	82.41	87.99	60.22	69.03	70.90	80.38	50.20	60.45

Under dark condition the average percentage of callus induction was obtained in the variety Binadhan-19 (87.99%) which was significantly different from the variety Binadhan-17 (82.41%).

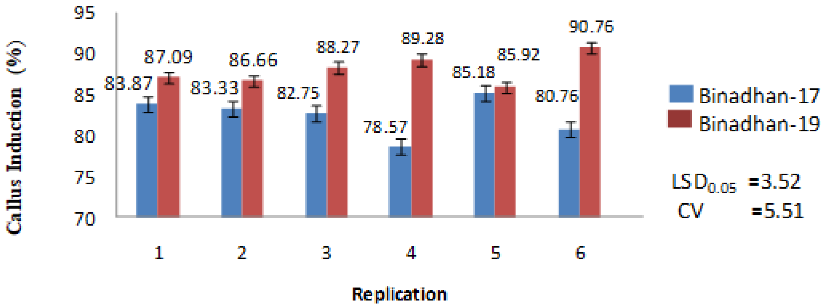

Fig. 1: Effect of dark condition on callus induction (%) of two rice varieties. (Data were recorded after 14 days of inoculation**)**

Under light condition average percentage of callus induction was obtained from the variety Binadhan-19 (80.38%) which was significantly different from the variety Binadhan-17 (70.90%)

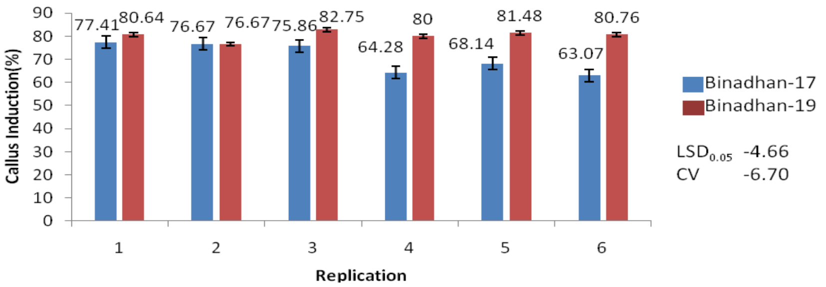

Fig. 2: Effect of light condition on callus initiation (%) of two rice varieties. (Data were recorded after 14 days of inoculation**)**

From the recorded data, it was clearly observed that dark condition was more effective than light condition for callus initiation.

Embryogenic callus induction from mature embryos

The mean squares of varieties for the percentage of callus induction are highly significant indicating the presence of adequate variability between the varieties for this parameter. The average percentage of embryogenic callus induction in dark condition was obtained from the variety Binadhan-19 (69.03%) which was significantly different from Binadhan-17 (60.22%).

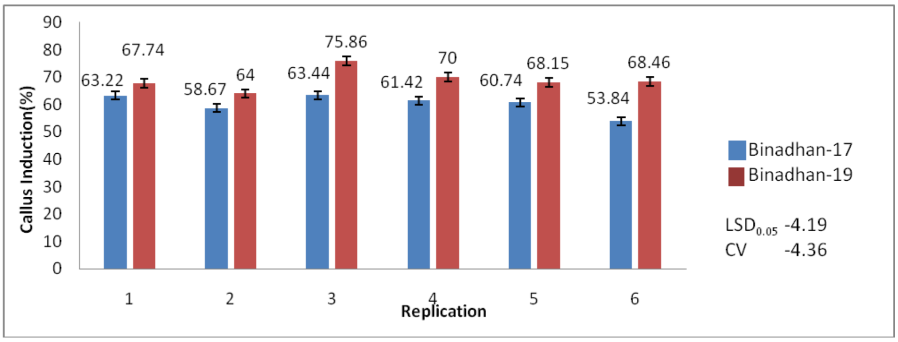

Fig. 3: Effect of interaction between varieties on percentage of embryogenic callus induction in the dark condition.

The higher average percentage of embryogenic callus induction in light condition was obtained from Binadhan-19 (60.45%) which was significantly different from Binadhan-17 (50.20%).

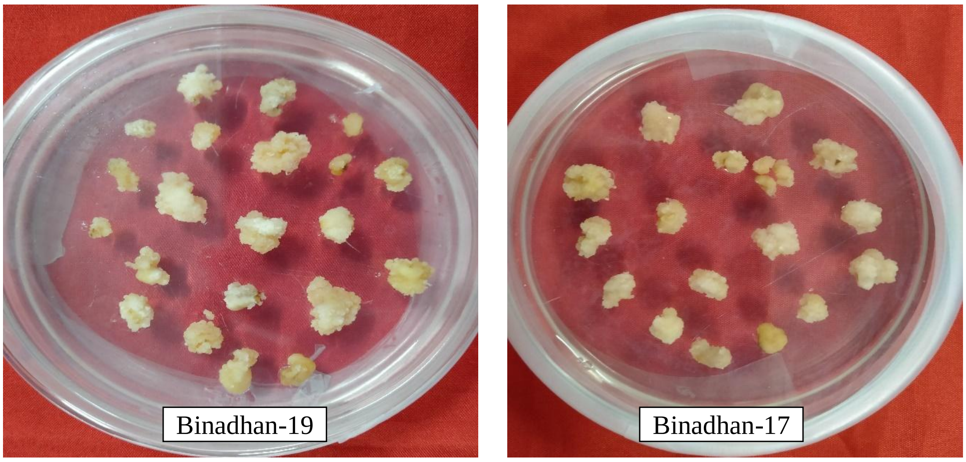

Fig. 4: Embryogenic Callus initiation of two rice varieties cultured on MS medium supplemented with 2, 4-D in dark condition.

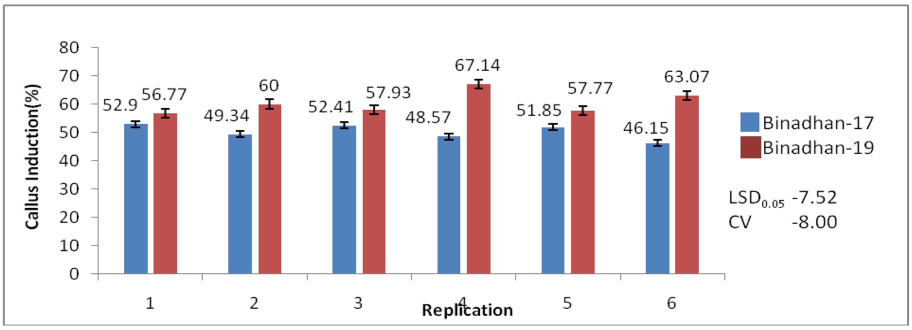

Fig. 5: Effect of interaction between varieties on percentage of embryogenic callus induction in the light condition.

In Vitro shoot regeneration from embryogenic calli response to polyethylene glycol (PEG)

Embryogenic calli of two rice varieties were cultured in MS medium with different plant growth regulators NAA 1.0 mgl^{-1}, BAP and Kn both at 2.0 mgl^{-1}. To induce drought stress, different concentrations of PEG (0%, 5%, 8% and 10%) were added in the culture medium. After 14 days, it was clearly observed that the extent of regeneration ability varied from different PEG concentration. In the two varieties, regeneration percentage was found higher in control. Growth rate and regeneration capacity were decreased with increasing levels of PEG concentration. Among the different concentrations of PEG, The lowest value was recorded for 10% PEG in both the varieties Binadhan-17 (32%) and Binadhan-19 (40%). At 5% PEG, the highest value 48% was recorded in Binadhan-17 and 64%in Binadhan-19.

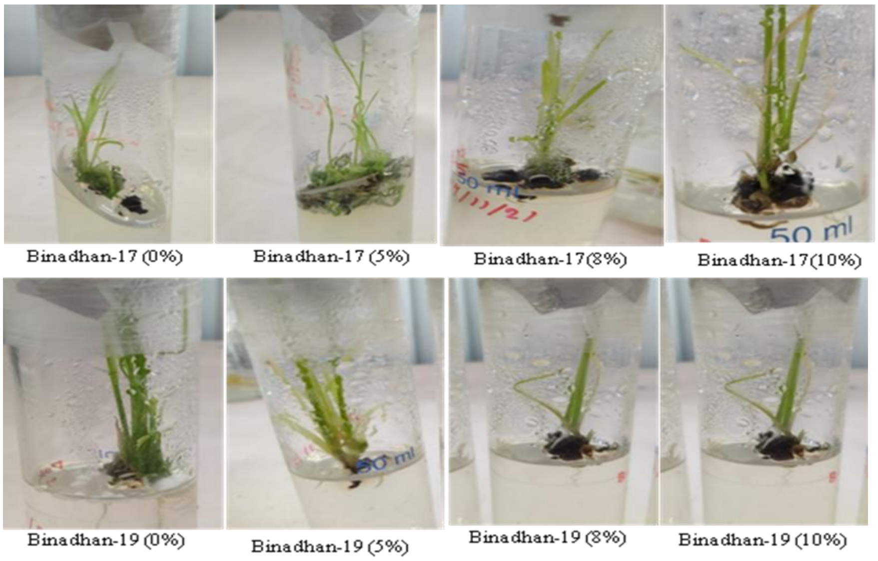

Fig. 6: Shoot regeneration of rice varieties cultured on different concentration of PEG (0%, 5%, 8% and 10%) respectively.

Table 2. Effect of different concentrations of PEG on shoot regeneration ability

Varieties	PEG (%)	No. of calli inoculated	No. of calli showing shoot initiation	Shoot regeneration %
Binadhan-17	$T_0 = 0$	25	19	76
	$T_1 = 5$	25	12	48
	$T_2 = 8$	25	10	40
	$T_3 = 10$	25	8	32
Binadhan-19	$T_0 = 0$	25	20	80
	$T_1 = 5$	25	16	64
	$T_2 = 8$	25	14	56
	$T_3 = 10$	25	10	40

Here, T_0 = MS Media + 0% PEG + NAA 1.0 mgl^{-1}, BAP & Kin at 2.O mgl^{-1}
T_1 = MS Media + 5% PEG + NAA 1.0 mgl^{-1}, BAP & Kin at 2.0 mgl^{-1}
T_2 = MS Media + 8% PEG + NAA 1.0 mgl^{-1}, BAP & Kin at 2.0 mgl^{-1}
T_3 = MS Media +10% PEG + NAA 1.0 mgl^{-1}, BAP & Kin at 2.0 mgl^{-1}

In Vitro root induction from regenerated shoot in presence of Polyethylene glycol (PEG)

Half strength of MS media supplemented with different concentrations of PEG (0%, 5%, 8% and 10%) were used to see the rooting response of the regenerated shoots. MS medium supplemented with different concentrations of PEG and no growth regulator hormones was found most effective for root induction. The lowest value was recorded for the concentration of 10% PEG in both the varieties Binadhan-17 (20%) and Binadhan-19 (30%) respectively. The highest value at 5% PEG was recorded in Binadhan-17 (50%) and Binadhan-19 (60%) respectively.

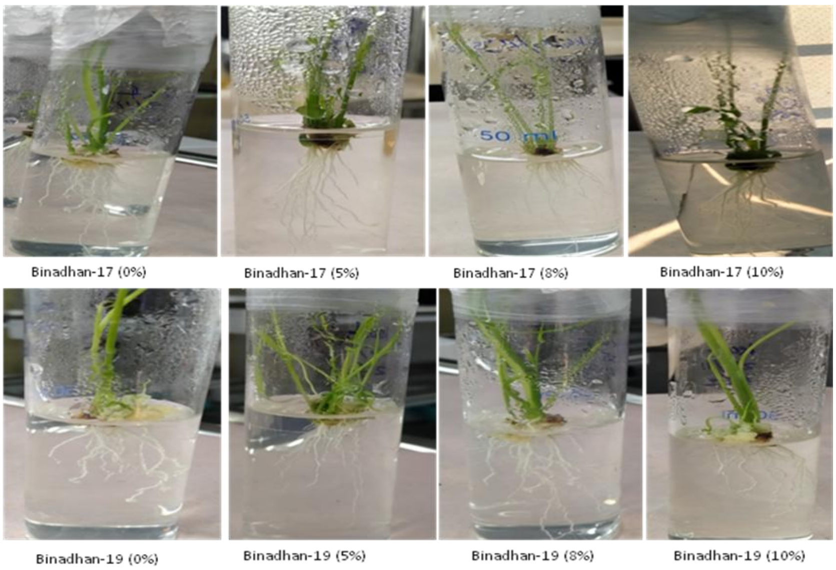

Fig.7: Root induction of two rice varieties cultured on half strength of MS medium supplemented with different concentrations of PEG (0%, 5%, 8% and 10%) respectively.

Table 3. Effect of MS medium (Half strength) supplemented with different concentration of PEG on root induction

Varieties	PEG (%)	No. of shoot inoculated	No. of shoot showing root induction	Root induction %
Binadhan-17	$T_0 = 0$	10	7	70
	$T_1 = 5$	10	5	50
	$T_2 = 8$	10	3	30
	$T_3 = 10$	10	2	20
Binadhan-19	$T_0 = 0$	10	7	70
	$T_1 = 5$	10	6	60
	$T_2 = 8$	10	4	40
	$T_3 = 10$	10	3	30

Here, T_0 (Control) = Half strength of MS media + 0% PEG
T_1 = Half strength of MS media + 5% PEG
T_2 = Half strength of MS media + 8% PEG
T_3 = Half strength of MS media + 10% PEG

Establishment of plants

The small plantlets that attained good shoot development and produced sufficient roots were transfer to pots containing 50% soilrite (1:1:1 ratio of vermiculite, perlite and Sphagnum moss) mixed with soil for hardening. Excess agar around the roots was washed off by tap water to prevent microbial infection. Then the pots were kept in a humid chamber for 3-5 days in the culture room under 16h light and 8h dark cycle at 28^{o}C and then in green house at (28$\pm$2)^{o}C. Establishment of regenerated plants lead to regeneration of a complete plant on the medium. When the plants grew up to a height of above 10cm and sufficient roots were proliferated, those were transferred to the earthen pot. Tillering capacity and survival rate of plants in the pots were satisfactory. Many studies suggest that MS medium supplemented with just 2, 4-D can produce more calli (Shahsavari *et al*., 2010). However, Mohd Din *et al*. (2016) found high level of callus induction in medium supplemented with 2, 4-D and combination of BAP or NAA. Embryogenic callus grown on MS medium supplemented with four different concentrations of PEG viz. 0% (control), 5%, 8% and 10% PEG, created different osmotic stress condition on the media. Wani *et al*. (2010) showed both reduced callus induction and shoot regeneration of rice varieties PAU 201 and PR116 in medium supplement with different concentrations of PEG. Tripathy (2015) also found similar reduction in regeneration frequency with increased concentration of PEG in upland rice. Further, variety depended responses with PEG have also been observed. Akter *et al*. (2016) found that rice variety Binadhan-10 performed the best against PEG compared to Binadhan-4, Binadhan-5, Binadhan-6 and Iratom-24.In this study, under difference PEG levels Binadhan-19 performed better than Binadhan-17. Shoot regeneration and root induction was higher in Binadhan-19 than Binadhan-17. Both the varieties show reduction in callus induction with increased levels of PEG. The highest percentage of callus induction was recorded in Binadhan-19 under control condition (0% PEG). Considering all the parameters, the two varieties when raised *in vitro* up to the seedling stage without any drought stress (0% PEG), Binadhan-19 showed better performance than Binadhan-17. Similarly, the variety Binadhan-19 performed better at 5% concentration of PEG under drought stress. These findings suggested that the variety Binadhan-19 could be considered as more tolerant against drought condition than Binadhan-17.

Conclusion

Crop genetic improvement for drought stress at the molecular and physiological level is very complex and challenging. The results of this study indicate that, the two rice varieties Binadhan-17 and Binadhan-19 have good callus induction ability as well as inherent tolerance to drought. We suggest that, *in vitro* screening with the induction of chemical drought by using PEG 6000 to modulate drought tolerance would be a feasible strategy to develop drought tolerant lines of rice. The above study will be the base line for future screening experiments.

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SCREENING OF BRINJAL GENOTYPES TO IDENTIFY GENETIC RESOURCES WITH HIGHER YIELD AND YIELD ATTRIBUTES

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Abstract

The present study was conducted for morphological evaluation of 65 brinjal genotypes at the research field of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Morphological characterization, performed as per the minimum descriptors as prescribed by IBPGR, revealed wide and significant variations for most of the traits investigated. In terms of individual fruit weight, the heaviest fruits were obtained from the genotype SM17 (251.78 g) followed by SM6 (221.56 g), whereas the lightest fruits were found in genotype SM58 (50.78 g). At 120 days of planting (DAP), the longest and shortest plants were recorded from the genotypes SM44 (73.67 cm) and SM24 (31.22 cm), respectively. Most importantly, the highest yield (58.34 t ha^{-1}) was recorded from the genotype SM28 followed by SM6 (56.95 t ha^{-1}). By contrast, the genotype SM46 yielded the lowest (8.36 t ha^{-1}). Among the 65 genotypes studied, 13 promising genotypes (SM1, SM5, SM6, SM7, SM11, SM16, SM17, SM21, SM28, SM33, SM42, SM54 and SM56) were selected based on yield and other quality attributes, namely colour, shape, size, texture and glossiness.

Key words: Brinjal, eggplant, genotype screening, yield, yield attributes.

Introduction

Brinjal (*Solanum melongena* L.) also known as eggplant or aubergine, is an important solanaceous vegetable crop grown widely in the central, south and south-east Asian countries, and in a number of African countries of the world (Kalloo, 1993; Alam *et al*., 2003; Kumar *et al*., 2003; Shaukat *et al*., 2009). Brinjal is believed to have been originated in India, as the people of this subcontinent were reported to grow brinjal since last 4000 years (Dunlop, 2006). It occupies a distinct place in the realm of vegetable crops globally. The current global production of brinjal is estimated as 54.08 million tons of which 93% is contributed by the Asian countries (FAO, 2020). In terms of production, China ranked the top (45% of world output) followed by India (24%) (FAO, 2020). Brinjal is one of the most nutritious and culturally important vegetables and is a good source of minerals and vitamins. It is also one of the most common, popular and principal vegetables grown both in summer and winter seasons in Bangladesh. To meet domestic demand Bangladesh produces substantial amounts brinjal every year. During 2019-20, 558 thousand metric tons of brinjal were produced from 53.44 thousand hectare of land (BBS, 2021).

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Numerous species of the genus *Solanum* are available in nature of which most of them are wild and few are cultivated like *S. melongena* L. and *S. tuberosum* L. There exist numerous cultivars with considerable morphological and genetic variability required for varietal improvement of brinjal. Different morphological studies are very much important for characterization and classification of germplasm (Agdagwa and Nadukwa, 2004; Sudre *et al*., 2010). The seeds of different varieties or cultivars of brinjal in our country are readily available and cheap and could be preserved by the farmers themselves thus reducing their cost of production. Many local varieties are well known among the farmers but their improvement is needed. So characterization of genotypes based on yield and yield attributes is helpful for identification of superior genotypes for breeding programme. For sustainable improvement of any vegetable crop, judicious and effective use of genotypes is a must for the advancement of agronomic characters coupled with resistant ability against biotic and abiotic stresses. So, keeping in the view the vast opportunity for improvement of brinjal, the present research was undertaken to perform morphological characterization of brinjal genotypes with desired yield and yield attributes.

Materials and methods

The experiment was conducted at the research field of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh with 65 brinjal genoypes were collected from IPM Lab of Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh Agriculture Research Institute (BARI), Gazipur and BINA, Myemensingh. The collected genotypes were assigned to accession numbers starting from SM1-SM65 (Table 1). The seeds were sown and seedlings of 35 days old were planted in the prepared land flowing randomized complete block design (RCBD) with three replications. One genotype represented one treatment and 5 plants of one genotype represented one replication. Plant to plant and row to row distances were 80 and 60 cm, respectively. The plot size was 6.0 × 5.6 m. Fifty centimeters drain was kept between two adjacent plots to facilitate drainage of excess water. Fertilizers were applied as per Fertilizer Recommendation Guide (BBS, 2011). Middle three plants in a row were selected for observations in each replication per genotype. Data were recorded on various yield attributers (e.g. plant height, number of primary branches, canopy area, individual fruit weight and number of fruits per plant) and yield. Statistical analyses of the reorded data were performed through descriptive statistics (percentage, mean, standard error of mean) and analysis of variance (ANOVA) was performed using computer package MStat C to find out the statistical significance of the treatments (genotypes). The mean separation was done least significance difference (LSD) test (Gomez and Gomez, 1984).

Table1. List of brinjal genotypes along with sources used in the experiment (information provided in the parentheses indicate original source of the genotypes)

Sl. No.	Accession No.	Local name	Sources of collection
1.	SM1	Zhumki	IPM Lab, BAU, Mymensingh (Nandina, Jamalpur)
2.	SM2	ISD-006	IPM Lab, BAU, Mymensingh (BARI, Joydebpur, Gazipur)
3.	SM3	Laffa-M	IPM Lab, BAU, Mymensingh (Marichar Char, Mymensingh)
4.	SM4	Laffa-G	IPM Lab, BAU, Mymensingh (Gaffargoan, Mymensingh)
5.	SM5	Laffa-B	IPM Lab, BAU, Mymensingh (Rupgonj, Narayangonj)
6.	SM6	Laffa-S	IPM Lab, BAU, Mymensingh (Sherpur)
7.	SM7	Volanath-M	IPM Lab, BAU, Mymensingh (Marichar Char, Mymensingh)
8.	SM8	Thamba	IPM Lab, BAU, Mymensingh (Marichar Char, Mymensingh)
9.	SM9	Dohazari Red	IPM Lab, BAU, Mymensingh (Dohazari, Chittagong)
10.	SM10	Dohazari-G	IPM Lab, BAU, Mymensingh (Dohazari, Chittagong)
11.	SM11	Borka	IPM Lab, BAU, Mymensingh (Notun Bazar, Mymensingh)
12.	SM12	Khatkhatia-B	IPM Lab, BAU, Mymensingh(Bhurungamari, Kurigram)
13.	SM13	Khatkhatia	IPM Lab, BAU, Mymensingh (BAU, Mymensingh)
14.	SM14	Kaikka-N	IPM Lab, BAU, Mymensingh (Nandina, Jamalpur)
15.	SM15	Kaikka-G	IPM Lab, BAU, Mymensingh (Gaffargoan, ymensingh)
16.	SM16	Islampuri-BADC	IPM Lab, BAU, Mymensingh (BADC, Mymensingh)
17.	SM17	Jessore-L	IPM Lab, BAU, Mymensingh (Manirampur, Jessore)
18.	SM18	Dharala	IPM Lab, BAU, Mymensingh (Betila, Manikgonj)
19.	SM19	Uttara	IPM Lab, BAU, Mymensingh (BARI, Joydebpur, Gazipur)
20.	SM20	Kazla	IPM Lab, BAU, Mymensingh (BARI, Joydebpur, Gazipur)
21.	SM21	BL-118	IPM lab, BAU, Mymensingh (BARI, Joydebpur, Gazipur)
22.	SM22	Dundhul	IPM Lab, BAU, Mymensingh (Gaffargoan, Mymensingh)
23.	SM23	EG-190	IPM Lab, BAU, Mymensingh (AVRDC, Taiwan)
24.	SM24	China oblong	IPM Lab, BAU, Mymensingh (Paba, Rajshahi)
25.	SM25	Ishurdi-WS	IPM Lab, BAU, Mymensingh (Ishurdi, Pabna)
26.	SM26	Ishurdi-BS	IPM Lab, BAU, Mymensingh (Ishurdi, Pabna)
27.	SM27	Putabegun	IPM Lab, BAU, Mymensingh (Chittagong)
28.	SM28	Longla Long	IPM Lab, BAU, Mymensingh (Longla Moulvibazar)
29.	SM29	Shingnath-S	IPM Lab, BAU, Mymensingh (BAU, Mymensingh)
30.	SM30	Longla Talbegun	IPM lab, BAU, Mymensingh (Longla Moulvibazar)
31.	SM31	Islampuri	IPM Lab, BAU, Mymensingh (Islampur, Jamalpur)
32.	SM32	Thapara	IPM Lab, BAU, Mymensingh (Gabtoli, Bogra)
33.	SM33	Menter	IPM Lab, BAU, Mymensingh (Gabtoli, Bogra)
34.	SM34	Salta	IPM lab, BAU, Mymensingh (Burirhut, Rangpur)
35.	SM35	Iribegun	IPM Lab, BAU, Mymensingh (Betila Manikgonj)
36.	SM36	Eye-red	IPM Lab, BAU, Mymensingh (Betila Manikgonj)
37.	SM37	Deembegun	IPM lab, BAU, Mymensingh (BAU, Mymensingh)
38.	SM38	Comilla-L	IPM Lab, BAU, Mymensingh (Comilla)
39.	SM39	Chega	IPM Lab, BAU, Mymensingh (Jessore)

Table 1. (Continued)

Sl. No.	Accession No.	Local name	Sources of collection
40.	SM40	BARI Begun-1 (Uttara)	BARI, Joydebpur, Gazipur
41.	SM41	BARI Begun-4 (Kazla)	BARI, Joydebpur, Gazipur
42.	SM42	BARI Begun-5 (Nayantara)	BARI, Joydebpur, Gazipur
43.	SM43	BARI Begun-6 (Ishurdi local)	BARI, Joydebpur, Gazipur
44.	SM44	BARI Begun-7 (Singnath)	BARI, Joydebpur, Gazipur
45.	SM45	BARI Begun-9 (Dohazari)	BARI, Joydebpur, Gazipur
46.	SM46	BARI Begun-10 (Bholanath)	BARI, Joydebpur, Gazipur
47.	SM47	BAU Begun-1	BINA, BAU campus, Mymensingh
48.	SM48	Indian-1	BINA, BAU campus, Mymensingh
49.	SM49	Pahuza-1	BINA, BAU Campus, Mymensingh
50.	SM50	Pahuza-2	BINA, BAU Campus, Mymensingh
51.	SM51	Magura Local	BINA, BAU Campus, Mymensingh
52.	SM52	Long Lived High Plant	BINA, BAU Campus, Mymensingh
53.	SM53	Purple Long	BINA, BAU Campus, Mymensingh
54.	SM54	Kansant Local	BINA, BAU Campus, Mymensingh
55.	SM55	Laffa-BAU	IPM Lab, BAU, Mymensingh (BAU, Mymensingh)
56.	SM56	Katabegun-WS	IPM Lab, BAU, Mymensingh (Paba, Rajshahi)
57.	SM57	Marich Begun-S	IPM Lab, BAU, Mymensingh (Sherpur)
58.	SM58	Marich Begun-E	IPM Lab, BAU, Mymensingh (Sherpur)
59.	SM59	Natore Local (Long)	BINA, BAU Campus, Mymensingh
60.	SM60	Apple Begun	BINA, BAU Campus, Mymensingh
61.	SM61	Natore Local (Round)	BINA, BAU Campus, Mymensingh
62.	SM62	China Round	BINA, BAU Campus, Mymensingh
63.	S M63	BAU Begun-2	BINA, BAU Campus, Mymensingh
64.	SM64	Kansat-1	BINA, BAU Campus, Mymensingh
65.	SM65	Kansat-2	BINA, BAU Campus, Mymensingh

Results and discussion

Plant height

Plant height widely varied among the collected 65 brinjal genotypes during the entire period of investigation (Table 2). Plant height gradually increased over time. Plant heights ranged from 4.44-19.44, 24.11-56.22, 31.44-69.67 and 31.22-73.67 cm at the 40. 70, 100 and 120 DAP, respectively (Table 2). At the 120th DAP, the longest and shortest plants were recorded from the genotypes SM44 (73.67 cm) and SM24 (31.22 cm), respectively (Table 2). Other comparatively taller genotypes included SM15, SM16, SM21, SM25, SM36, SM49 and SM62. The genotype SM24 was found to be the shortest (31.22 cm) followed by SM30 (38.44 cm) at the same day of observation. The observed variation was possibly attributed to the genetic factor. Similar trend was also observed by Kumar *et al.* (2011), Ahmed *et al.* (2014).

Number of primary branches plant^{-1}

Branching is an important character of brinjal plants since fruiting and yield depend greatly on profuse benching. Number of primary branches plant^{-1} varied significantly among the genotypes at all the days of investigations (40, 70, 100 and 120 days after transplanting). Number of primary branches plant^{-1} increased with the advancement of plant growth. At the 40th DAP, plants of some genotypes had zero (SM7, SM16, SM17, SM61 and SM62) to 3.11 primary branches (Table 2). Number of primary branches pant^{-1} ranged from 0-3.11, 0.11-8.33, 3.56-12.22 and 4.11-12.22 at the 40, 70, 100 and 120 DAP, respectively. The highest number of primary branches plant^{-1} were recorded in the genotype SM42 (12.22) followed by SM58 (9.33), SM51 (9.11) and SM6 (9.00) (Table 2). The least number of primary branches plant^{-1} was recorded in the plants of the genotype S10 (4.11) followed by SM9 (4.44); SM45, SM62 & SM64 (4.67); SM47 & SM55 (4.89). The rest of the genotypes had moderate branching (Table 2). The variation was very wide and was due to difference in genetic constituents.

Canopy area

Highly significant variations were observed among the collected genotypes in terms of canopy area during the entire period of investigation. Irrespective of the genotypes, canopy area trended to increase as the time after planting advanced. However, the rates of increase were higher until the 100th DAP, and reduced afterwards. Canopy areas ranged from 83.04 (SM64) to 575.10 (SM16); 718.97 (SM62) to 2704.94 (SM26); 1384.39 (SM30) to 4205.42 (SM20); and 1529.18 (SM62) to 4264.82 (SM20) cm^2 at the 40, 70, 100 and 120 DAP, respectively (Table 2). At the 120th DAP, the genotype with the largest canopy area was SM20 (4264.82 cm^2) followed by SM42 (4006.99 cm^2), SM33 (3913.31 cm^2) and SM46 (3840.57 cm^2) (Table 2). On the contrary, the genotype with the smallest canopy was SM62 (1529.18 cm^2) followed by SM53 (1832.10 cm^2) and S24 (1695.86 cm^2). The rest of the genotypes had moderate canopy area at the 120 days after transplanting. Similar trends of canopy area for the collected genotypes were also manifested at the 40, 70 and 100 DAP (Table 2).

Individual fruit weight

There were marked variation in fruit weight among the collected 65 brinjal genotypes. Individual fruit weight ranged from 50.78 (SM58) to 251.78 g (SM17). The heaviest fruit was obtained from the genotype SM17 (251.78g) followed by SM6 (221.56g) and SM47 (194.78 g), whereas the lightest fruits were obtained from the genotype SM58 (50.78 g) followed by SM57 (67.00 g) and SM23 (86.78 g) (Table 3).

Fruit length

Fruit length and diameter significantly differed among the genotypes. Length of fruit ranged from 6.78 (SM60) to 30.40 cm (SM45). The longest fruit was harvested from the genotype SM45 (30.40 cm) followed by SM44 (27.24 cm) and SM50 (19.22 cm), while the shortest was recorded in the genotype SM60 (6.78 cm) followed by SM24 (7.04 cm) and SM39 (7.26 cm) (Table 3). Variation of fruit length has also been reported by Gavade and Ghadge (2015), Vandana *et al.* (2014), Kumer *et al.* (2011).

Fruit diameter

Significant variation was also observed among the genotypes in case of fruit diameter. Similar to fruit length, fruit diameter also varied among the genotypes. Fruit breadth ranged from 2.50 (SM13) to 8.66 cm (SM29). The widest fruit was obtained from the genotype SM29 (8.66 cm) followed by SM45 (8.40 cm) and SM56 (8.38 cm). By contrast, the narrowest fruits were obtained from the genotype SM13 (2.50 cm) followed by SM49 (2.52 cm) and SM53 (2.52 cm). Considering both length and diameter, the genotype SM45 had the largest fruit (Table 3). This result is supported by Ahmed *et al.* (2014), Begum *et al*. (2013) and Kumer *et al.* (2011).

Length of fruit peduncle

Fruit peduncle length varied significantly among the collected genotypes. The fruit of genotype SM27 had the longest peduncle (11.42 cm) followed by SM46 (9.66 cm) and SM44 (9.42 cm). On the other hand the fruits of the genotype SM16 had the shortest peduncle (2.52 cm) followed by SM16 (2.71 cm) and SM34 2.76 cm) (Table 3).

Number of fruits plant^{-1}

Total number of fruits plant^{-1} varied significantly among the genotypes. Number of fruits plant^{-1}ranged from 4.33 to 18.89. The maximum number of fruits were harvested from the genotype SM25 (18.89 plant^{-1}), which was closely followed by the genotypes SM51 (18.56 plant^{-1}), SM28 (17.78 plant^{-1}) and SM40 (17.67 plant^{-1}). In contrast, the lowest number of fruits were recorded in genotype SM46 (4.33 plant^{-1}) followed by the genotypes SM43 (5.00 plant^{-1}), SM35 (5.67 plant^{-1}) and SM59 (5.89 plant^{-1}) (Table 3).

Weight of fruits plant^{-1}

Total weight of fruits per plant differed significantly amongst the collected brinjal genotypes. Average weight of brinjal fruits per plant was in the range from 401.33 to 2800.33 g. The highest amount of fruits was obtained from the genotype SM28 (2800.33 g), which was closely followed by the genotypes SM6 (2733.44 g) and SM7 (2595.56 g). On the other hand, the lowest amount of fruits were harvested from the genotype SM46 which yielded only 401.33 g fruit per plant and was followed closely by the genotypes SM64 (715.22 g per plant) and SM58 (852.78 g per plant) (Table 3). Ahmed *et al.* (2014) found a result as high as 5320 g plant^{-1}. Lower yield per plant for some genotype may be because of non-favourable environment.

Yield of brinjal

Yield is the most important parameter in respect of crop improvement. Yield of brinjal varied markedly and significantly among the collected 65 genotypes, and which ranged from 8.36 to 58.34 t ha^{-1}. The highest yield of 58.34 t ha-^{1} was recorded from the genotype SM28 that was closely followed by the genotypes SM6 (56.95 t ha^{-1}) and SM7 (54.07 t ha^{-1}). By contrast, the lowest yielding genotype was SM46 that yielded only 8.36 t ha^{-1} and was closely followed by the genotypes SM64 (14.90 t ha^{-1}) and SM58 (17.77 t ha^{-1}). This result is in support of Kumer *et al.* (2014) and Sanas *et al.* (2014). Lower yield were found of some genotypes due to may be genetical and environmental effect. As per BBS (2020), average yield of rabi brinjal is 12.25 t ha^{-1}. The average yield of BARI released varieties ranges from 45-55 t ha^{-1} (Krishi Projukti Hatboi, 2020). Among the 65 genotypes, 13 promising genotypes (SM1, SM5, SM6, SM7, SM11, SM16, SM17, SM21, SM28, SM33, SM42, SM54 and SM56) were selected based on yield (equal or higher than BARI released varieties) and other quality attributes, namely cooler, shape, size, texture and glossiness (Fig. 1).

Fig. 1. Selected 13 high yielding brinjal genotypes.

Table 2. Variation in plant height, number of primary branches plant^{-1} and canopy area among 65 brinjal genotypes at different days after planting (DAP)

Genotypes	Plant height (cm) at different DAP				Number of primary branch plant^{-1} at different DAP				Canopy area (cm^2) at different DAP			
	40	70	100	120	40	70	100	120	40	70	100	120
SM1	14.56	40.11	57.78	56.33	0.44	3.56	5.22	5.33	508.24	1676.06	2562.33	2642.66
SM2	8.56	27.00	47.22	50.00	0.83	3.28	5.89	6.17	335.98	1264.20	3281.83	3416.15
SM3	8.56	30.44	44.33	47.56	0.11	3.00	5.11	5.44	367.29	1795.73	3069.09	3279.47
SM4	11.06	32.56	49.44	51.89	0.56	6.56	6.22	6.44	597.04	2081.56	3237.69	3361.72
SM5	12.67	37.67	53.22	55.78	0.22	3.33	4.56	5.11	362.15	1837.08	3064.20	3234.20
SM6	11.56	39.78	55.11	57.33	0.78	5.56	8.89	9.00	547.36	1954.91	3416.06	3576.72
SM7	12.67	40.89	53.89	57.11	0.00	5.00	7.22	7.44	592.15	2206.98	3100.92	3200.18
SM8	9.00	25.56	40.56	42.89	0.33	3.22	6.56	6.89	456.87	1789.45	3093.68	3284.79
SM9	7.44	26.44	34.56	44.89	0.56	3.56	4.33	4.44	312.52	2187.88	3329.62	3438.13
SM10	11.22	35.67	41.00	46.67	0.22	3.44	3.56	4.11	312.69	1824.17	2578.46	2634.72
SM11	15.22	26.56	34.89	46.78	0.56	3.33	4.78	6.44	411.34	1087.31	2203.58	3038.12
SM12	11.67	34.67	50.56	52.67	0.11	5.00	5.89	6.11	299.74	1146.89	1744.62	2015.71
SM13	17.11	36.89	48.22	53.56	0.78	5.44	6.78	7.00	435.42	1973.32	2749.51	3037.08
SM14	8.00	27.44	40.89	46.33	0.22	4.00	4.56	4.89	323.46	1225.99	1917.06	2040.65
SM15	11.11	33.00	50.89	72.22	0.11	3.89	5.22	6.56	418.84	1319.50	1915.92	3510.00
SM16	19.44	53.56	69.56	70.89	0.00	2.56	4.44	4.67	575.10	2210.47	3419.20	3491.68
SM17	11.11	31.33	45.89	49.89	0.00	0.11	4.00	5.22	370.35	1664.55	2851.03	3083.40
SM18	23.44	37.00	46.00	56.33	0.22	3.33	4.67	6.44	428.52	1301.71	2177.59	3829.23
SM19	12.78	27.11	36.89	42.33	0.44	6.44	8.33	8.33	387.09	2257.05	3539.48	3773.75
SM20	13.89	30.11	48.11	49.44	1.33	6.33	6.00	6.33	336.33	2168.17	4205.42	4264.82
SM21	15.78	43.22	59.33	63.00	1.22	6.22	7.11	7.22	480.07	2190.41	2971.66	3164.77
SM22	11.89	29.33	43.78	48.78	0.89	4.11	6.11	6.22	249.50	1991.37	2627.40	2762.24
SM23	12.78	27.56	37.11	43.56	0.11	4.56	5.89	5.78	283.82	1241.09	1783.78	2036.38
SM24	10.11	25.22	29.33	31.22	0.11	2.33	3.67	4.44	193.99	1177.15	1656.78	1695.86
SM25	12.78	38.89	52.56	63.11	0.22	3.78	4.78	6.11	526.47	1552.91	2673.54	2554.39
SM26	14.78	30.78	40.11	43.22	0.22	6.33	7.22	7.22	446.49	2704.94	3948.64	3950.99
SM27	19.44	42.89	55.33	57.89	1.56	4.11	5.44	5.67	426.26	2088.80	2803.06	2893.34
SM28	14.67	36.22	47.78	48.44	0.22	4.22	6.67	7.11	338.25	1718.63	2429.31	2476.06
SM29	13.67	33.22	44.22	45.00	0.89	5.44	5.89	6.00	421.24	1421.98	1987.10	1993.90
SM30	13.67	24.56	31.44	38.44	0.78	3.33	4.67	6.78	318.45	769.82	1384.39	1975.84
SM31	11.44	32.00	42.44	47.11	0.22	4.56	5.89	6.22	584.22	2336.68	2959.27	3071.79
SM32	10.78	32.89	51.67	55.22	0.78	3.33	5.00	5.67	188.40	1676.06	2562.33	2642.66
$LSD_{0.05}$	6.07	10.54	10.65	10.77	1.31	2.53	2.28	2.19	257.15	704.64	1161.61	1180.83
$LSD_{0.01}$	7.98	13.85	13.99	14.15	1.72	3.32	3.00	2.87	337.97	926.10	1526.69	1551.94
Level of sig.	**	**	**	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability

Table 2 (Contd.)

Genotypes	Plant height (cm) at different DAP				Number of primary branch plant $^{-1}$ at different DAP				Canopy area (cm^2) at different DAP			
	40	70	100	120	40	70	100	120	40	70	100	120
SM33	9.22	37.33	47.44	50.22	1.22	5.56	6.11	6.22	364.50	2398.96	3562.59	3913.31
SM34	10.39	28.00	50.89	54.22	0.33	2.22	4.56	4.78	316.49	1338.43	2655.74	2753.34
SM35	8.00	27.33	44.56	47.56	0.22	3.33	4.78	5.11	399.26	2055.48	3507.21	3542.44
SM36	17.44	43.33	61.33	68.22	0.22	5.22	6.56	7.00	591.45	2215.27	3595.91	3733.11
SM37	13.67	29.89	47.00	50.22	0.67	4.00	5.11	5.33	475.45	2217.19	2930.84	3070.05
SM38	20.22	39.00	51.33	52.56	0.44	3.56	4.56	5.22	219.28	1844.92	2499.27	2581.95
SM39	16.00	32.67	44.89	48.89	0.67	3.33	4.44	5.11	446.84	1940.78	2723.86	2869.52
SM40	15.11	34.89	46.89	49.78	0.89	6.11	5.44	5.78	361.01	2163.02	3054.79	3167.13
SM41	11.33	36.89	51.00	55.44	0.89	5.56	8.00	8.11	305.71	1690.54	2621.55	2757.62
SM42	13.33	38.22	51.44	56.00	1.22	8.33	12.22	12.22	346.10	2250.59	3872.93	4006.99
SM43	7.67	22.56	56.44	59.44	0.33	3.33	5.89	6.11	350.90	1658.97	3018.59	3266.91
SM44	13.67	56.22	69.67	73.67	1.56	5.89	6.33	6.78	480.77	2146.19	2727.96	2893.16
SM45	14.11	54.00	65.11	66.67	0.22	3.00	4.33	4.67	223.20	1698.22	2818.85	2988.58
SM46	15.22	34.11	47.22	57.89	1.44	4.33	5.33	5.89	366.51	2580.56	3651.30	3840.57
SM47	12.00	30.11	47.22	49.56	0.44	3.56	4.56	4.89	404.19	1638.90	3136.43	3254.18
SM48	11.11	38.44	54.67	58.33	1.00	6.33	7.00	7.11	400.22	1855.74	2561.98	2904.94
SM49	14.78	45.33	60.78	65.33	1.33	5.89	7.33	7.56	446.12	2034.46	3102.58	3436.03
SM50	15.33	33.11	48.44	52.11	3.11	6.33	6.89	6.89	443.35	1730.14	2945.76	2993.38
SM51	13.67	38.00	52.44	56.00	2.11	8.67	9.11	9.11	439.86	2063.16	2903.63	3006.38
SM52	14.89	40.22	61.33	72.00	1.00	4.33	5.11	5.78	763.20	2102.23	3393.47	3823.04
SM53	10.44	34.33	47.11	49.00	1.78	7.11	7.67	7.78	142.09	1221.63	1689.76	1832.10
SM54	18.56	39.00	53.56	55.78	1.44	5.11	5.67	6.11	568.34	1936.33	2863.68	3032.19
SM55	12.33	27.00	44.11	45.44	0.00	2.22	4.11	4.89	506.41	2041.35	2799.92	2913.05
SM56	12.33	33.00	47.00	52.44	1.44	4.44	6.22	6.22	597.30	1892.20	2587.19	3003.23
SM57	8.50	27.89	38.56	55.11	1.89	2.56	4.67	6.33	228.70	1458.09	2672.84	4316.72
SM58	12.00	30.00	53.67	53.67	1.44	8.89	9.22	9.33	437.51	2727.35	3877.81	3875.63
SM59	7.11	24.11	40.56	45.78	0.33	3.56	5.78	6.22	186.53	960.84	1945.23	2594.34
SM60	6.67	24.33	37.56	49.44	0.00	3.22	4.56	5.56	145.18	1328.13	2629.14	2664.64
SM61	6.89	30.00	48.44	55.22	0.56	3.89	4.78	5.11	111.08	1277.80	1954.13	1966.16
SM62	8.83	32.78	61.11	61.67	0.00	1.89	4.00	4.67	88.15	718.97	1429.57	1529.18
SM63	4.44	30.00	47.89	53.56	0.67	4.22	5.00	5.44	200.09	946.62	2915.23	3049.29
SM64	5.22	28.67	47.11	46.89	0.11	3.00	3.78	4.67	83.04	1020.85	2397.56	2489.84
SM65	9.56	30.78	46.78	49.67	0.89	4.78	5.56	5.89	197.91	1653.82	3323.34	3822.08
$LSD_{0.05}$	6.07	10.54	10.65	10.77	1.31	2.53	2.28	2.19	257.15	704.64	1161.61	1180.83
$LSD_{0.01}$	7.98	13.85	13.99	14.15	1.72	3.32	3.00	2.87	337.97	926.10	1526.69	1551.94
Level of sig.	**	**	**	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability

Table 3. Important yield attributes (fruit characters) of the 65 genotypes at commercial maturity

Genotypes	Fruit length (cm)	Fruit breadth (cm)	Peduncle length (cm)	Number of fruit plant^{-1}	Individual fruit wt. (g)	Wt. of fruits plant^{-1} (kg)
SM1	18.22	3.48	5.32	16.67	130.89	2.17
SM2	14.56	4.41	3.52	11.78	99.56	1.16
SM3	15.52	5.18	4.98	9.89	189.44	2.03
SM4	11.96	4.90	5.50	11.00	167.33	1.87
SM5	16.10	4.46	4.24	14.33	159.78	2.26
SM6	17.13	5.32	6.56	12.22	221.56	2.73
SM7	17.59	5.81	4.80	14.00	187.22	2.60
SM8	11.50	4.45	4.22	8.89	123.89	1.08
SM9	12.06	6.60	3.80	6.11	167.67	1.02
SM10	12.46	6.64	5.34	9.78	178.67	1.81
SM11	11.62	7.07	4.48	13.78	184.00	2.57
SM12	14.36	3.30	3.80	13.78	87.11	1.19
SM13	20.61	2.50	4.86	15.11	101.78	1.51
SM14	11.94	4.76	5.10	9.44	149.11	1.44
SM15	16.45	4.00	3.30	14.89	108.44	1.57
SM16	8.53	8.11	2.71	15.33	167.78	2.57
SM17	12.30	8.16	2.52	9.00	251.78	2.25
SM18	9.32	6.42	3.71	10.89	169.44	1.85
SM19	10.96	6.00	4.54	15.89	134.22	2.13
SM20	10.25	5.12	3.97	15.11	101.67	1.53
SM21	15.53	4.08	6.86	16.33	134.11	2.19
SM22	17.32	4.96	9.08	12.56	151.89	1.94
SM23	14.10	3.76	6.26	19.11	86.78	1.67
SM24	7.04	4.87	4.71	10.78	92.56	0.99
SM25	15.04	4.37	5.42	18.89	90.89	1.74
SM26	8.39	5.16	4.16	14.56	115.22	1.70
SM27	7.28	6.09	4.83	13.89	129.67	1.82
SM28	17.21	4.35	11.42	17.78	157.89	2.80
SM29	17.50	8.66	5.35	14.78	149.56	2.22
SM30	15.41	3.73	4.52	12.67	140.22	1.77
SM31	10.70	6.78	5.79	10.44	197.00	2.08
SM32	10.31	5.82	3.80	8.89	187.78	1.69
SM33	9.74	6.32	3.64	14.00	167.33	2.34
SM34	13.44	3.45	2.76	13.00	107.78	1.39
SM35	9.12	7.22	3.01	5.67	194.56	1.06
SM36	11.86	3.31	7.53	13.00	107.56	1.37
SM37	9.15	5.85	3.32	8.33	123.00	1.03
SM38	8.44	6.75	3.62	10.44	154.22	1.62
SM39	7.26	6.87	3.23	8.00	175.78	1.41
SM40	13.15	3.87	3.52	17.67	102.00	1.82
SM41	13.75	3.96	2.77	13.00	140.33	1.53
SM42	8.70	6.82	3.90	13.78	156.89	2.19
SM43	8.50	5.51	6.68	5.00	182.56	0.94

Table 3. (Contd.)

Genotypes	Fruit length (cm)	Fruit breadth (cm)	Peduncle length (cm)	Number of fruit plant^{-1}	Individual fruit wt. (g)	Wt. of fruits plant^{-1} (kg)
SM44	27.24	2.81	9.42	12.00	107.67	1.26
SM45	30.40	8.40	4.49	12.11	133.00	1.62
SM46	16.78	2.95	9.66	4.33	92.56	0.40
SM47	7.60	7.56	4.52	7.44	194.78	1.46
SM48	12.46	4.62	5.82	11.33	138.33	1.56
SM49	18.54	2.52	4.10	17.22	95.56	1.69
SM50	19.22	3.15	4.92	16.78	98.44	1.65
SM51	14.21	4.56	4.10	18.56	100.44	1.88
SM52	15.22	5.88	3.82	8.78	193.22	1.63
SM53	18.06	2.54	5.68	12.11	107.11	1.25
SM54	15.14	4.66	5.44	15.67	137.78	2.16
SM55	10.32	5.94	4.14	10.22	181.78	1.89
SM56	10.36	8.38	3.30	14.22	161.56	2.30
SM57	9.16	3.06	3.93	16.67	67.00	1.11
SM58	8.49	2.74	3.32	16.56	50.78	0.85
SM59	11.22	2.64	3.34	5.89	176.44	1.03
SM60	6.78	7.31	3.26	9.00	166.89	1.50
SM61	9.62	5.05	3.28	11.67	153.67	1.80
SM62	8.52	7.46	3.53	6.67	148.56	0.99
SM63	11.18	6.26	5.33	8.89	161.11	1.44
SM64	14.49	3.33	4.86	6.56	108.44	0.72
SM65	12.45	5.73	6.75	6.56	168.67	1.08
$LSD_{0.05}$	2.02	2.06	1.33	2.59	33.63	0.55
$LSD_{0.01}$	2.65	2.71	1.74	3.40	44.20	0.72
Level of sig.	**	**	**	**	**	**

** = Significant at 1% level of probability

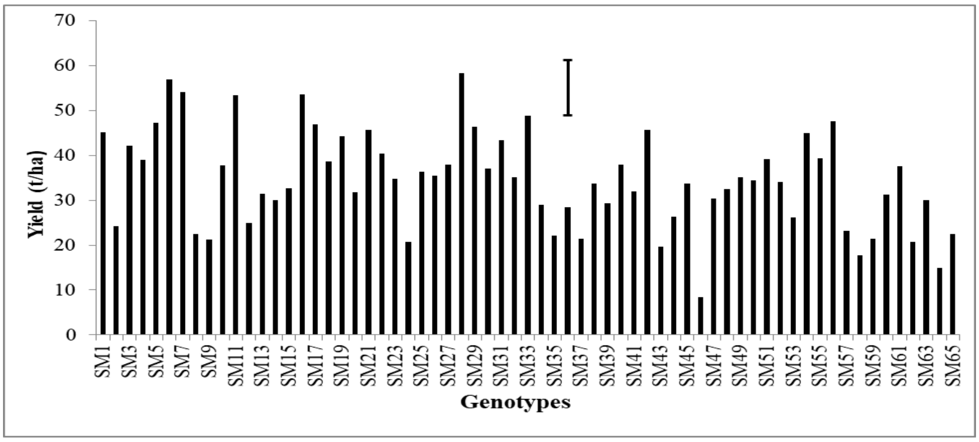

Fig. 1. Genotypic difference in yield of brinjal among the 65 genotypes at their commercial maturity. The vertical bar represents LSD at the 5% level of significance.

Conclusion

The genotypes of brinjal differed significantly for most of the yield attributing characters. Characterization plays a vital role to maintain genetic purity of a genotype. The highest yield of 58.34 t ha^{-1} was recorded from the genotype SM28 followed by SM6 (56.95 t ha^{-1}). The promising genotype(s) with desirable yield attributes and other horticultural characteristics can be utilized in crop breeding programme for development of superior genotypes with high yield and optimal quality. The outputs of the present research would be useful to the brinjal researchers in Bangladesh.

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INTEGRATED NUTRIENT AND CROP MANAGEMENT PRACTICES FOR INCREASED CROP PRODUCTION IN WHEAT-FALLOW-T.AMAN RICE CROPPING PATTERN WITH MUNGBEAN INCLUSION

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Abstract

Integrated use of fertilizers and manures can ensure higher crop yield maintaining soil productivity for sustainable production. An experiment was conducted at Bangladesh Institute of Nuclear Agriculture (BINA) Sub-station Ishwardi, Pabna for consecutive two years (2013-2014 and 2014-2015) with integrated use of organic, inorganic fertilizers and mungbean residue in the Wheat-Mungbean-T.aman rice cropping pattern. The experiment comprised of seven treatments arranged in a randomized complete block design with three replications. Collected soil samples (initial and after completion of two years cropping pattern) were analyzed in the laboratory for different parameters following standard methods. The highest grain yield of wheat was recorded in the treatment T_2 ($N_{120}P_{30}K_{45}S_{20}Zn_4B_2$ kg ha^{-1}) which was statistically identical with T_7 (4.47 t ha^{-1}), T_6 (4.40 t ha^{-1}) and T_4 (4.43 t ha^{-1}). The highest mungbean seed yield 1.45 tha^{-1} was recorded in the treatment T_2 ($N_{10}P_{15}K_{10}S_5$ kg ha^{-1}) along with residual effect of applied fertilizer during rabi season. It was noted that the treatment T_2 (1.45 t ha^{-1}) produced statistically identical yield with the treatment T_4 (1.38 t ha^{-1}), T_5 (1.20 t ha^{-1}) T_6 (1.30 t ha^{-1}) and T_3 (1.17 t ha^{-1}). The results indicated that grain and straw yields of T. Aman rice had positively influenced when inorganic fertilizers were applied along with incorporation of mungbean stovers before transplanting of T. Aman rice. The highest marginal rate of return (MRR) 634% in the treatment T_5 followed by 568% and 410% in the treatments T_6 and T_4. Uptake of different nutrients of the cropping pattern follow the order: N>K>P>S. Incorporation of mungbean stover as brown manuring into the soil before transplanting of Aman rice had significantly increased the yield of rice which minimized 1/3 of recommended N fertilizer and improved soil fertility.

Key wards: Crop management, Mungbean, Brown manure, Nutrient uptake and Soil fertility.

Introduction

Rice is the key staple food for the world's poorest and undernourished people living in Asia and Africa as they cannot afford or do not have access to nutritious foods (Bin *et al,*. 2022) and influences the livelihoods and economies of several billion people. In Bangladesh, Rice-Rice and Rice-Wheat are widely practiced cropping patterns among which Rice-Wheat cropping pattern covers an area of 6,50,000 ha (Bhuiyan *et al.*, 2010). Again, Rice-wheat cropping pattern further has become more popular with the increasing area under high yielding varieties of rice and wheat cultivation. The national average rice yield (3.01 t ha^{-1}) is much lower than that of other rice growing countries (BBS, 2020).

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Modern varieties obviously require higher amount of nutrients to attain higher crop yields. Rice-Wheat cropping system has a capacity to produce more than 8 tons of cereal grain ha^{-1} $year^{-1}$ which removed 400-700 kg ha^{-1} nutrients from soil against the application of 440 kg ha^{-1} nutrients (Bhuiyan *et al.*, 2010). Most of the farmers in Bangladesh do not use balanced doses of fertilizers. Practicing the crop rotations with inadequate and disproportionate amount of fertilizers have created system productivity stagnation, nutrient and water imbalance and soil organic matter depletion (Zia *et al.*, 1992). Rice productivity and total rice production in Bangladesh still have scope to increase if the proper crop management systems are followed (Shelley *et al*., 2015). Grain yield of rice was significantly increased due to application of green manure prior to T aman rice (Irin *et. al.,* 2020). A sustainable agriculture is ecologically sound, economically viable and socially acceptable. These four goals for sustainability can be applied to all aspects of any agricultural system. Basic concepts of sustainable systems are to maintain or improve soil quality and fertility, improve internal nutrient cycles on the farm which will reduce the dependence on external use of chemical fertilizers (Rana and Rana, 2011).

The low organic matter content, higher cropping intensity, improper cropping sequence, and faulty management practices are the major causes of depletion of soil fertility. Proper identification and management of soil fertility problems are pre-requisite for boosting crop production and sustaining higher yields over a long period of time. A suitable combination of organic and inorganic sources of nutrients is necessary for a sustainable agriculture that will provide food with good quality and maintain a sound environment (Mollah *et al.*, 2011). Growing a legume in the cropping sequence has special significance in the maintenance of soil fertility and crop productivity because of its unique ability of fixing and utilizing atmospheric nitrogen (Rahman *et al*., 2013). The rural people has little chance to add organic residues to the soil through farmyard manure, composts or organic residues as a major portion of these materials are being used as fuel. Inclusion of legume crop in between cereals may contribute to maintaining or increasing soil organic matter. Soil N loss may be minimized by using effective legume crops which can supply sufficient BNF (Biological nitrogen fixation) input to enhance soil N by improved recycling of N through plant residues (Cazzato *et al.*, 2012). Growing a legume in the cropping sequence has special significance in the maintenance of soil fertility and crop productivity because of its unique ability of fixing and utilizing atmospheric nitrogen and crop productivity because of its unique ability of fixing and utilizing atmospheric nitrogen (Rahman *et al.*, 2013). Mungbean is the most common grain legume grown in the summer to utilize the gap between winter and rainy season crops (Bhuiyan, 2010). Rice-Wheat cropping systems became important due to consumptions of wheat in many ways like human diets, cattle feed etc. Most of the wheat growing farmers of the country are growing wheat in Wheat-Fallow-T.Aman rice cropping pattern. There is scope of introducing mungbean in fallow period after wheat and a few farmers already started growing mungbean in Kharif-I season. In addition mungbean seed yield added some return for the farmers as well as additional nutrients supply from mungbean brown manuring (Rahman *et al.,* 2013).

The inclusion of leguminous crops into cereal farming system is important for their residues which caused long-term sustainability. In tropical areas like Bangladesh, mungbean can easily be grown as a short duration summer pulse crop between wheat and rice. Mungbean should receive attention for evaluating the sources of organic matter, nutrient supply and to produce certain amount of grains in the cropping system (Sarker *et al.,* 2011). It is used as whole or split seeds as soup (Dal) but in other countries sprouted seeds are widely used as vegetables. It is important source of high quality protein (26%), carbohydrates (51%), moisture (10%), mineral (4%) and vitamins (3%) (Jahan *et al.,* 2014).

The imbalanced use of fertilizers and the traditional cereal-cereal cropping system has not been able to restore the natural fertility of the soils. To increase the crop production and farm income on sustainable basis, these lands require careful handling and land management should scientific manners (Ahmad *et al.,* 2010). Assessment of the nutrient requirement of different crops for desired yield levels in a cropping sequence is the first step in developing sound fertilizer management practices. Inclusion of legumes in crop rotations protect the fragile soil surface and may even counteract erosive forces by restoring the organic matter content and organic fertility of the soils. This would also help to restore the natural fertility of the soils (Ahmad *et al.,* 2010). Therefore, in order to sustain agricultural production it is necessary to introduce mungbean green manuring crops in cropping pattern to maintain and improve soil fertility.

Material and Methods

An experiment was conducted at BINA Sub-station Ishwardi, Pabna for two years (2013-2014 to 2014-2015) with integrated use of organic, inorganic fertilizers and crop residue management using Wheat-Mungbean-T.Aman rice cropping pattern where the existing pattern is Wheat-Fallow-T.Aman rice. The experiment was laid out in a Randomized Complete Block Design (RCBD) having unit plot size of 4m x 5m and replicated thrice. Treatments were T_1 = Control (without fertilizer), T_2 = 100% chemical fertilizers (recommended rate for high yield goal) to each major crop, T_3 = 70% chemical fertilizers in each major crop + cowdung (5 t ha^{-1}), T_4 = 100% chemical fertilizers for the first major crop (only N fertilizer in T. Aman rice), T_5 = 70% chemical fertilizers to each major crop, T_6 = 100% chemical fertilizers for the first crop + 50% chemical fertilizers for T. Aman rice and T_7 = 100% chemical fertilizers for the first crop + 50% chemical fertilizers for T.Aman rice but no mungbean crop in the system. Composite soil samples were collected at 0-15 cm depth from the experimental site. Collected soil samples were analyzed in the laboratory for different parameters following standard methods. The initial soil of experimental field contained pH 8.1, organic matter 1.22%, total N 0.10%, available P, S, Zn and B were 11, 16, 1.05 and 0.35 ppm, respectively. The exchangeable cations were K, Ca Mg 0.20, 4.75 and 1.56 me%. Wheat (cv. Gourav) was sown at the rate of 120 kg seed ha^{-1} with a line to line spacing of 20 cm. The crop cycle was started by sowing of wheat during Rabi season followed by summer mungbean (cv. Binamoog-5) in Kharif-1 season and T.Aman rice (cv. Binadhan-7) in Kharif-II season. Treatment combinations with 100%

and 70% fertilizers used used in the experiment is given in the Table 1. For wheat full dose of cowdung, P, K, S, Zn B and 1/3 of N from urea were applied at the time of final land preparation. Remaining N was applied in two equal splits i.e. at CRI and panicle initiation stages. Irrigation was done as and when necessary. For mungbean, a basal application of recommended dose of N, P, K and S were applied at the time final land preparation. After final harvest seed and stover yields of mungbean were recorded and the stover was incorporated in the respective plots. For T.Aman rice all the fertilizers except urea were applied at the time of final land preparation. Urea was applied in two equal splits at 10 and 45 days after transplanting (DAT). Grain and straw yields were recorded per plot basis at 14% moisture level and the required amount of grain and straw samples were kept for determination of N, P, K and S content. Economic analysis (BCR, MBCR and MRR) of the product was done as described by Perrin *et. al.* (1979). After completion of two cycles soil samples were collected from each plot and analyzed for pH, organic matter, total N and available P, K, S and Zn to monitor the nutritional status of the soils.

Table 1. Treatment combinations with 100% & 70% fertilizers used for Wheat-Fallow-T.Aman rice cropping pattern

Treatment	Nutrient added (kg ha^{-1})										
	Wheat (cv. Gourav)							T. Aman (Binadhan-7) rice			
	N	P	K	S	Zn	B	CD t/ha	N	P	K	S
T_1	-	-	-	-	-	-	-	-	-	-	-
T_2 (100%)	120	30	45	20	04	02	-	80	20	30	08
T_3 (70%)	84	21	32	14	03	01	05	56	14	21	06
T_4 (100%)	120	30	45	20	04	02	-	80	-	-	-
T_5 (70%)	84	21	32	14	03	01	-	56	14	21	06
T_6 (100%)	120	30	45	20	04	02	-	80	10	15	04
T_7 (100%)	120	30	45	20	04	02	-	80	10	15	04

For mungbean (Binamoog-5) a basal recommended dose $N_{20}P_{15}K_{10}S_5$ kg ha^{-1} was used during final land preparation.

Results

Yield of crops

Wheat: Application of different doses of fertilizers treatments increased grain and straw yields of wheat (cv. Gourav) significantly over the absolute control treatment (Table 2). Grain and straw yields of wheat ranged from 0.74-4.55 and 1.52-6.61 t ha^{-1}, respectively. The highest grain yield of 4.55 t $ha^{-1}$was recorded from the treatment T_2 ($N_{120}P_{30}K_{45}S_{20}Zn_4$ and B_2 kg ha^{-1}) which was statistically identical with the treatment T_7 (4.47 t ha^{-1}), T_6 (4.40 t ha^{-1}) and T_4 (4.43 t ha^{-1}). However, treatment T_3 which received 70% chemical fertilizer of T_2 along with cowdung 5 t ha^{-1} produced statistically identical yield (3.87 t ha^{-1}) with treatment T_5 (3.50 t ha^{-1}) (70% chemical fertilizer of T_2 only). Like grain yield the straw yields followed the same trends (Table-2).

Mungbean: Grain and stover yields of mungbean (cv. Binamoog-5) increased significantly due to treatments over control (Table 2). The highest grain yield of 1.45 t ha^{-1} was recorded in treatment T_2 ($N_{10}P_{15}K_{10}$ & S_5 kg ha^{-1}) along with residual effect of fertilizer applied during rabi season. It is noted that treatment T_2 produced statistically identical yield (1.45 t ha^{-1}) with the treatment T_4 (1.38), T_5 (1.20) T_6 (1.30) and T_3 (1.17), t ha^{-1}.

T.Aman: The results indicated that grain and straw yields of T.Aman rice had positive effect when inorganic fertilizers were applied along with incorporation of mungbean stovers before transplanting of aman rice (Table 2). The highest grain yield 4.55 t ha^{-1} was recorded in treatment T_2 ($N_{70}P_{15}K_{30}$ and S_6 kg ha^{-1}) which was statistically identical with treatment T_5 (4.34 t ha^{-1}), T_7 (4.21 t ha^{-1}), T_6 (4.14 t ha^{-1}), and T_3 (4.17 t ha^{-1}). On the other hand, treatment T_4 (3.50 t ha^{-1}) produced 2nd lowest yield compared to others. Like grain yield, the straw yield also followed the same trend (Table 2).

Table 2. Effect of different fertilizer doses on grain/seed and straw/stover yield (t ha^{-1}) of Wheat-Fallow-T.Aman rice

Treatments	Wheat (cv. Gourab)			Mungbean (cv. Binamoog-5)			T.aman rice (cv. Binadhan-7)		
	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean
				Grain/Seed					
T_1	0.75d	0.72c	0.74	1.04c	1.25c	1.15	1.98c	1.60c	1.79
T_2	4.60a	4.50a	4.55	1.34a	1.55a	1.45	4.58a	4.52a	4.55
T_3	3.94b	3.80b	3.87	1.14b	1.20ab	1.17	4.24ab	4.10ab	4.17
T_4	4.39a	4.47a	4.43	1.32a	1.43a	1.38	3.50b	3.50b	3.50
T_5	3.66c	3.33b	3.50	1.10bc	1.30ab	1.20	4.42a	4.25ab	4.34
T_6	4.32a	4.48a	4.40	1.34a	1.25ab	1.30	4.13ab	4.15ab	4.14
T_7	4.38a	4.55a	4.47	*	*	*	4.21ab	4.20ab	4.21
				Straw/Stover					
T_1	1.62a	1.42c	1.52	2.37	2.13c	2.25	3.67d	3.65c	3.66
T_2	6.09ab	6.40a	6.25	3.46	3.21bc	3.34	6.46a	6.40a	6.43
T_3	5.68c	5.15b	5.42	2.69	3.39ab	3.04	6.25ab	6.20a	6.23
T_4	6.84a	6.37a	6.61	3.38	2.86d	3.12	5.13c	5.15ab	5.14
T_5	5.31c	5.95a	5.63	2.42	2.99cd	2.71	5.50bc	5.50ab	5.50
T_6	6.29a	6.58a	6.44	3.31	3.58a	3.45	6.55a	6.35a	6.45
T_7	6.21a	6.40a	6.31	*	*	*	6.77a	6.25a	6.51

* As per treatment plan, there was no green manuring/mungbean crop in T_7 treatment

Economics of Fertilizer Uses

Economics of fertilizer uses have been calculated on the total products of two cropping cycles following partial budget analysis and marginal analysis as described by Perrin *et. al*. (1979). The results of economic analysis for Wheat-Fallow-T.Aman rice cropping pattern (Table 3) indicated that the highest net benefit (Tk. 1,21,458 ha^{-1}) was obtained in treatment T_2 followed by T_6 (Tk. 1,16,149 ha^{-1}), T_4 (Tk. 1,12,501 ha^{-1} and T_3 (Tk. 1,05,982 ha^{-1}). Marginal analysis of undominated fertilizer response data (Table 4) showed the highest marginal rate of return (MRR) in treatment T_5 followed by the treatments T_6 and T_4.

Table 3. Economics of fertilizer use in crop production under Wheat-Fallow-T.Aman rice cropping pattern

Treatments	Economic Yield		Gross Profit			Variable money cost (Fertilizer)	Variable opportunity cost	Total variable cost	Net benefit
	Grain	Straw	Grain	Straw	Total				
	($t\ ha^{-1}$)		($Tk.\ ha^{-1}$)			($Tk.\ ha^{-1}$)			
T_1	3.68	7.43	50,470	7,430	57,900	-	-	-	57,900
T_2	10.55	16.02	1,16,650	16,020	1,32,670	10,612	600	11,212	1,21,458
T_3	9.19	14.69	1,00,400	14,690	1,15,090	9,478	450	9,928	1,05,162
T_4	9.31	14.87	1,06,800	14,870	1,21,670	8,719	450	9,169	1,12,501
T_5	9.04	13.48	99,720	13,840	1,13,560	6,978	600	7,578	1,05,982
T_6	9.84	16.34	1,09,620	16,340	1,25,960	9,211	600	9,811	1,16,149
T_7	8.68	12.82	78,300	12,820	91,120	7,616	450	8,066	83,054

Price of N as urea= Tk. 13.0 kg^{-1}; P as TSP= Tk. 75.0 kg^{-1}; K as MP= Tk. 20.0 kg^{-1}; S as gypsum= Tk. 28 kg^{-1}; Zn as ZnO= Tk. 111 kg^{-1}; B as Borax= Tk. 250 kg^{-1} and CD=Tk. 500 t^{-1}; Price of rice grain=Tk. 8.00 kg^{-1}; straw=Tk. 1000 t^{-1}; Mungbean seed = Tk. 25.0 kg^{-1}; stover = Tk. 1000 t^{-1}; wheat grain = Tk. 10.0 kg^{-1} and straw = Tk. 1.00 kg^{-1}.

Table 4. Marginal analysis of undominated fertilizer response data

Net benefit ($Tk.\ ha^{-1}$)	Treatments	Variable cost ($Tk.\ ha^{-1}$)	Changes from next highest		
			Marginal increase in net benefit ($Tk.\ ha^{-1}$)	Marginal increase in variable cost ($Tk.\ ha^{-1}$)	MRR (%)
1,21,458	T_2	11,212	5,309	1,401	3.79
1,16,149	T_6	9,811	3,648	642	5.68
1,12,501	T_4	9,169	6,519	1,591	4.10
1,05,982	T_5	7,578	48,082	7,578	6.34
57,900	T_1	-	-	-	-

Nutrient Uptake

The amounts of N, P, K and S absorbed by Wheat-Mungbean-T.Aman cropping pattern as affected by different doses of nutrients, organic matter and crop residue management are presented in Table 5. Total nutrient uptake increased with the increase of yield. Total nutrient uptake ranged from N (71-230), P (11-53), K (84-254) and S (11-36), kg ha^{-1}, respectively. Nutrient uptake of the cropping pattern found to follow the order: K>N>P>S.

Table 5: Nutrient uptake (kg ha^{-1}) of Wheat-Fallow-T.Aman rice cropping pattern as affected by different treatment combinations

Treatments	N	P	K	S
T_1	71	16	84	11
T_2	230	51	240	34
T_3	165	38	206	28
T_4	198	45	213	29
T_5	152	36	174	25
T_6	228	53	254	36
T_7	194	33	193	27
Range	71-230	11-53	84-254	11-36

Soil Fertility Status

The changes in soil pH, organic matter, total N and available P, K and S of initial soil as well as post-harvest soil of Wheat-Mungbean-T.Aman rice cropping pattern are furnished in Table 6. Incorporation of mungbean stover into soil in between two cereal crops has brought no appreciable changes of nutrients in the post-harvest soil during the period of the study. There were considerable decreases in pH and organic matter content appeared in most cases. However, available P and S were slightly increased but there were considerable depressing on exchangeable K in soils resulted from the two years of cropping. On the other hand, the amount of K removal far exceeding that replenished through fertilization.

Table 6: Changes in soil nutrient status due to fertilizer doses under Wheat-Fallow-T.Aman rice cropping pattern after two cropping cycles

Treatment	pH	Organic matter (%)	Total N (%)	Available Nutrients (ppm)				Exchangeable Cations (me%)		
				P	S	Zn	B	K	Ca	Mg
Initial soil										
	8.1	1.22	0.10	11	16	1.05	0.35	0.20	4.75	1.56
Post harvest soil										
T_1	8.0	1.19	0.08	10	14	1.01	0.37	0.16	4.70	1.66
T_2	7.8	1.20	0.09	12	14	1.00	0.36	0.17	4.71	1.60
T_3	8.0	1.16	0.09	11	12	1.04	0.38	0.15	4.80	1.53
T_4	7.9	1.18	0.10	14	13	1.04	0.35	0.18	4.72	1.58
T_5	8.0	1.19	0.08	11	15	1.00	0.37	0.15	4.70	1.58
T_6	7.6	1.17	0.09	12	15	1.06	0.33	0.16	4.70	1.59
T_7	8.0	1.18	0.08	11	16	1.04	0.34	0.17	4.70	1.55

Discussion

Increased crop productivity from the shrinking land resources is the urgent need to meet the increased food demand of the swelling population in Bangladesh (Islam *et al.*, 2002). Application of different doses of fertilizers treatments increased grain and straw yields of wheat (cv. Gourav) significantly over the absolute control treatment. Treatment received 100% chemical fertilizer produced higher yield than treatments received 70% chemical fertilizer. However, treatment T_3 which received (70% chemical fertilizer of T_2 + cowdung 5 t ha^{-1}) produced the statistically identical yield with treatment T_5 (70% chemical fertilizer of T_2 only). That is the treatment received 70% chemical nutrient along with cowdung 5 t ha^{-1} had some positive effect on grain yield over the treatment received 70% chemical fertilizer only. Rahman *et al.* (2013) reported highest grain yield from 100% fertilizer application which was comparable with 75% inorganic fertilizer along with legume residue incorporation. Genetic biofortification coupled with agronomic approach (fertilization) would help to develop of new cultivars of wheat that would have ability to accumulate Zn and Fe in grain (Khan *et al*., 2021).

Grain and stover yields of mungbean (cv. Binamoog-5) increased significantly due to treatments over control. The highest grain yield of 1.45 t ha^{-1} was recorded in the treatment T_2 along with residual effect fertilizer applied during rabi season. It is noted that the treatment T_2 produced the statistically identical yield with the treatments T_4, $T_{5,}$ T_6 and T_3. Soil test based fertilizer recommendation with some additional nutrients would increase the yield in Wheat-Mungbean-T.Aman rice cropping pattern (Das *et al.*, 2018). The lowest grain yield of 1.15 t ha^{-1} was obtained in the control treatment. Considering amount of residue after harvesting legume crops with narrower C:N ratio is left in the soil which upon decomposition improves the physical condition and fertility of soil. Further supply of nitrogen by introducing legume crop in the cropping sequence involves no extra input and risk but may be a better substitute partly for chemical nitrogen (Pokhrel and Pokhrel, 2013).

The results of grain and straw yields of T. Aman rice (cv. Binadhan-7) under Wheat-Fallow-T. Aman cropping pattern are indicated that grain and straw yields of T.aman rice had positive influenced when inorganic fertilizers were applied along with incorporation of mungbean stovers before transplanting of T. Aman rice. The highest grain yield was recorded in the treatment T_2 which was statistically identical with the treatments T_5, T_7, T_6, and T_3. Grain yield of rice was significantly increased due to application of green manure prior to T aman rice (Irin et. al, 2020). According to Haque et al. (2002), nutrient deficiencies have resulted in the decline of yields of rice or/and wheat as well as a reduction in factor productivity at a number of locations where long-term trials have been conducted.

Incorporation of mungbean stover into soil in between two cereal crops has brought no appreciable changes in the post-harvest soil during the period of the study. There were considerable decreases in pH and organic matter content appeared in most cases. However, available P and S were slightly increased but there were considerable depressing on exchangeable K in soils resulted from the two years of cropping. On the other hand, the amount of K removal far exceeding that replenished through fertilization.

Now it is important to pay attention to net benefits rather than yields. Proper fertilization effectively improves quality and yield of crops, reduces cost as well as increase farmers income.

Economic analysis for Wheat-Mungbean-T.aman rice cropping pattern showed highest net benefit of Tk. 1,21,458 ha^{-1} in treatment T_2. All the treatments with mungbean produced higher net benefit than the treatment with no mungbean. The legume base cropping system found appropriate on farm, from the quantitative and qualitative production point of view which is not only ecologically and environmentally sound, but also it is economically viable recommendations and fittest for sustainable soil management (Pokhrel and Pokhrel, 2013). Marginal analysis of undominated fertilizer response data recorded the highest MRR in the treatment T_5 followed by the treatments T_6 and $T_{4,}$ respectively.

Conclusion

For yearly cropping sequences the residual effect of P & S fertilizers applied to the first crop should be evaluated and considered in formulating fertilizer recommendations for the subsequent crop. Incorporation of mungbean stover as brown manuring in soil before transplanting of aman rice may significantly increase the yield of rice as well as minimize 1/3 of recommended N fertilizer. Considering crop yield, economic return and soil fertility, inclusion of mungbean as a green manure could be recommended for the Wheat-Fallow-T. Aman rice cropping pattern.

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DETERMINATION OF OPTIMUM SEED RATE ON GROWTH, YIELD AND YIELD CONTRIBUTING CHARACTERS OF LENTIL MUTANTS AT DIFFERENT AEZS IN BANGLADESH

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Abstracts

Lentil is the most popular pulse crop in terms of both area and consumer choice in Bangladesh. However, the lack of situation and cultivar specific seed rate recommendations are among the problems that constrain its productivity. Therefore, a field experiment was conducted during 2020 to determine the optimum seed rate for sowing of lentil mutants/varieties on the growth and yield contributing characters of advanced lentil lines/variety developed by Bangladesh Institute of Nuclear Agriculture (BINA). The study looked at four seeding rates: 25 kg ha^{-1}, 30 kg ha^{-1}, 35 kg ha^{-1} and 40 kg ha^{-1} on three advanced lentil mutants viz. LM-99, LM-118, LM-206-5 in comparison with one checked variety Binamasur-8. In all three locations, the seed yield of lentil mutant was notably different, with Ishurdi producing the highest seed production (2.09 t ha^{-1}). The mutant LM-99 generated the maximum seed yield (1.66 t ha^{-1}) among the several advance mutants/variety, followed by LM-118 (1.58 t ha^{-1}). Among the various seed rates, 35 kg ha^{-1} produced the highest seed yield (1.64 t ha^{-1}) in the 2020 season. The findings suggest that when another management techniques were followed correctly, the mutant line LM-99 produced the maximum yield at a seed rate of 35 kg ha^{-1}.

Key words: lentil, variety, seed rate, yield, yield components.

Introduction

Lentil (*Lens culinaris* Medik) is the second most important pulse crop based on cultivating area and production in Bangladesh but stands first in the consumer's preference in Bangladesh (Uddin *et al.,* 2008). It is an inexpensive source of protein, calories, and certain vitamins (Nourin *et al.,* 2019). It is also a main source of vegetable proteins in human diet. The protein content of lentil seeds, on an average, is around 22-34.6% while 100 g of dried lentil seeds have 340-346 calories and it is considered as poor man's meat as well as cheapest source of protein for under privileged group of people. Moreover, lentil is also a cheap source of fiber, as well as micronutrients (Crook *et al.,* 1999). Lentil being a legume crop can fix atmospheric nitrogen through root nodules by Rhizobium bacteria, which may reduce the pressure of nitrogenous fertilizer application to the crop. It is evident that pulse containing cropping pattern helped to increase the organic matter in the soil (Islam, 1988). The lentil genotypes have inbuilt potential to provide relatively good production even in stress conditions i.e., drought, frost and water logging.

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The main problem for this crop are cultivation in soils with low fertility and also have a variety of environmental stresses, such as drought, salinity, and high and low temperatures, major problem in cultivating a crop in this condition is related to the poor germination and establishment of the crop '(BARC, 1999). Some other causes responsible for low yield of lentil are use of traditional local cultivars, low plant density per unit area and poor crop management practices constituting the major ones. Use of the modern lentil cultivars and maintenance of proper plant density per unit area would thus help in increasing the yield from unit per area (Bhuiyan, 1976). It is also to be noted that the response to plant density varies among lentil genotypes/varieties depending on the seed size and growth habit of the specific cultivars (Nigussie *et al.*, 2009). Optimum plant population density is an important factor to realize the potential yields as it directly affects plant growth and development. It varies with the small to medium seed varieties (microsperma group) might be too low to obtain optimal yield. Many studies show that lentil yields are remarkably stable over a wide range of population densities. The plants are able to fill available space by initiating lateral branches and thus can compensate for poor emergence and grain yield (Selim, 1999). On the other hand, low and scattered plant populations are unable to utilize the resources efficiently and often produce low yields. As a result, it is necessary to determine the economically optimum seed rate for a broadcast sowing of lentil varieties. The aim of the present study was to investigate the effect of different treatments of seed rate on growth and yield of different genotypes of lentil under rainfed and supplemental irrigation conditions.

Materials and methods

The experiment was carried out at the Field of the BINA Sub-station, Ishurdi, Chapainawabganj and Magura during 2020-21. The edaphic and climatic conditions play a key role for the achievement of elevated production and enhanced seed quality. The climatic parameters during the growing period of lentil in different time and location are presented in Figure 1. The land is medium high having sandy loam texture soil under non-calcareous dark gray flood plain soil type with soil pH 6.7 (UNDP and FAO, 1998). The experiment was laid out in split- plot design with three replications. The study looked at four seeding rates: 25 kg ha^{-1}, 30 kg ha^{-1}, 35 kg ha^{-1} and 40 kg ha^{-1} on three advanced lentil mutants viz. LM-99, LM-118, LM-206-5 in comparison with one check variety Binamasur-8. The unit plot size was 4 m × 3 m. Row spacing is maintained in 30 cm and following continuous line sowing. The crop was sown on 16 November and harvested on last week of February in both the year. The treatments were randomly distributed to the plots within a block.

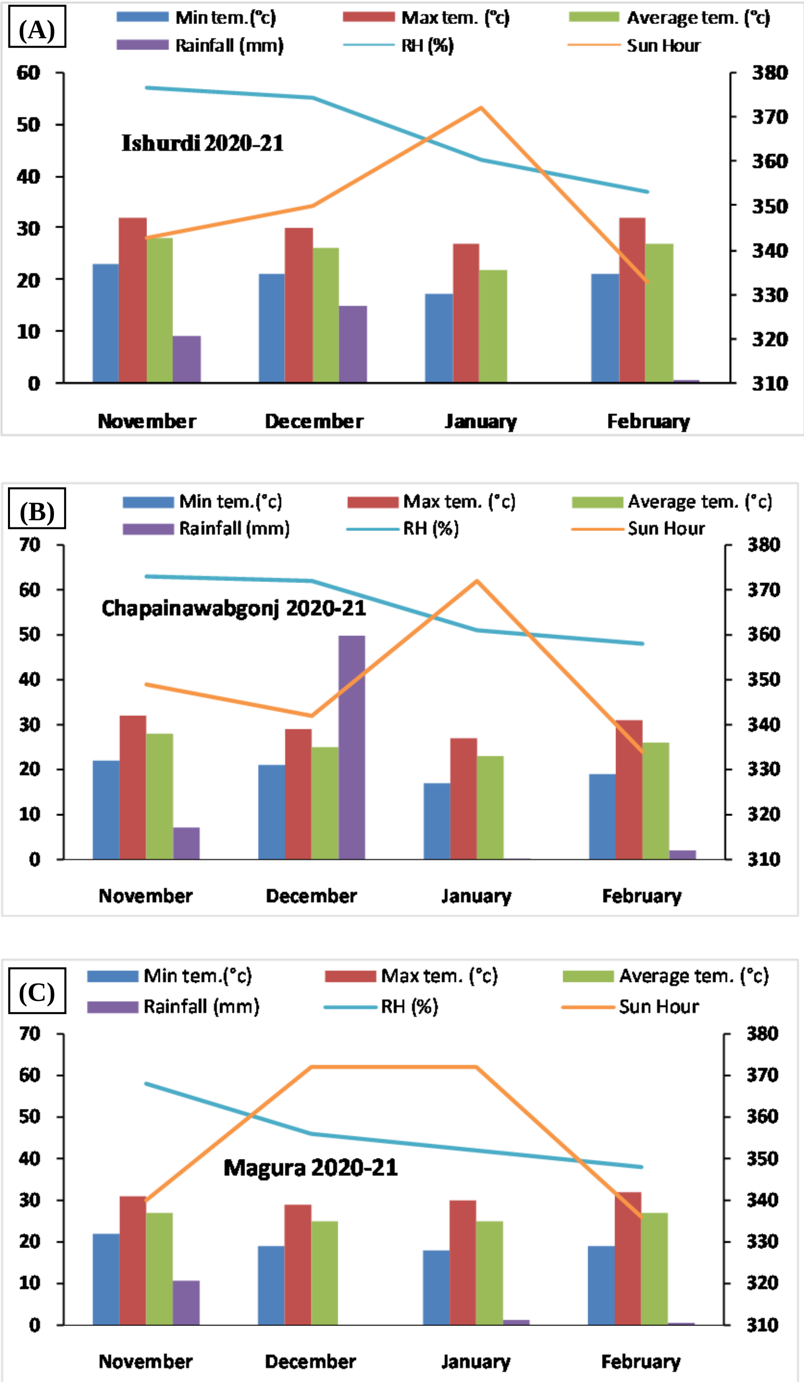

Fig. 1. The climatic parameters during the growing period of lentil in Ishurdi (a), Chapainawabganj (b) and Magura (c).

Field preparation, fertilization, sowing and intercultural operation

The experimental land was first opened on October with a power tiller. Later on, the land was ploughed and cross-ploughed two times by power tiller followed by laddering to desirable tilth. All the weeds and stubble were removed and fertilizers such as urea, muriate of potash (MOP), triple super phosphate (TSP) and zinc sulphate were applied following the BINA recommended doses @ 50, 40, 40 and 10 kg ha^{-1} respectively. Seeds with 92% germination capacity were sown in line continuously having line to line maintain the distance 30 cm. Weeds were controlled by two hands weeding with niri. The stem phylum blight disease was controlled by spraying of Amister top 250 EC @ 20 ml per 5 decimal lands. The crop was harvested at full maturity on last week of February.

The observations on crop growth and yield characters were recorded at harvest and the following parameters were population m^{-2}, plant height (cm), branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, 1000 seed weight (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}) and crop duration. The yield contributing characters were recorded from 5 randomly selected plants in each plot and their mean values were determined. The yields were taken plot-wise by harvesting central 10 m^2 area of each plot and then it was converted to hectare basis.

The recorded data were subjected to split-plot design of analysis of variance (ANOVA) under linear models of statistics using software statistics 10 version 8.1. Further Least Significant Difference (LSD) test was also employed to test the level of significance among different combination means (Gomez and Gomez, 1984).

Results and discussions

Effect of location

Location showed significant effect on plant population and yield. The main cause of variation of growth and yield of lentil was greatly influenced by locational effect. In the present study, the Populations m^{-2} (78.3), plant height (42.6 cm), pods $plant^{-1}$ (208.6) and seed yield was highest in Ishurdi (2.09 t ha^{-1}) followed by Magura, plant height (35.7 cm), pods $plant^{-1}$ (121.2) and seed yield (1.44 t ha^{-1}) but the branches $plant^{-1}$ (7.6) was highest in Chapainawabganj (Table 1). The result in accordance with the findings of Vlachostergios *et al*., (2021) who stated that the location effect was the main source of variation in lentil yield. Different locations were found to be suitable for each traits and breeding must be applied in locations that are characterized by a high discriminating ability and representativeness.

Effect of mutant/variety

Differential performance by the different lentil varieties may be due to genetic variability adapt ability, morphological features, and physiological factors during the cropping period. The lentil genotype LM-99 showed the highest seed yield (1.66 t ha^{-1}) and pod $plant^{-1}$ (150.6) among the mutants/variety followed by LM-118 (1.58 t ha^{-1}) but pod $plant^{-1}$ (146.9) was second highest in LM- 206-5 (Table 1). The growth duration (120 days) was shorter in all mutants compare to check Binamasur-8 (Table 1). Similar findings of higher seed yield in lentil genotypes were reported by Singh *et al*., (2011) and Rahman *et al*., (2013) who stated that different genotypes varied in yield and yield contributing characters due to their genetic makeup yield parameters and higher growth duration.

Effect of seed rate

Optimum plant population density is an important factor to realize the potential yields as it directly affects plant growth and development. Higher plant density may lead to severe competition between plants (Singh and Singh, 1994) and increase risk of disease and lodging of the crop, resulting in reduced grain yield (Selim, 1999). On the other hand, low and scattered plant populations are unable to utilize the resources efficiently and often produce low yields. In the present study, the seed rate 35 kg ha^{-1} produced the highest grain yield (1.64 t ha^{-1}) followed by 25 kg ha^{-1} but pod plant^{-1} was highest in 25 kg ha^{-1} and lowest in 35 kg ha^{-1} among the four different seed rates (Table 1). The result was supported by Saleem *et al*., 2012 who stated that the response of lentil to various plant densities has been variable depending upon genotype, planting time and growing conditions and showed that grain yield kept on increasing up to a seed rate of 40 kg ha^{-1} and remained static thereafter with a non-significant difference for any further increase in seed sown. Barua, (2011) reported that increasing seeding rates had a negative effect on 100-seed weight and hence on seed yield.

Table 1. Mean values of different crop characteristics as affected by locations, varieties and seed rate during 2020-2021.

Treatments	Populations m^{-2} (no.)	Plant height (cm)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Crop duration (days)
Location(s):									
Ishurdi (L_1)	78.3	42.6	2.3	208.6	1.7	21.40	2.09	4.54	
C.nawabgang (L_2)	69.4	28.8	7.6	106.4	1.7	19.83	1.24	4.90	
Magura (L_3)	60.7	35.7	4.7	121.2	1.6	22.03	1.44	4.54	
$LSD_{0.05}$	2.9	1.5	0.6	32.7	0.1	0.39	0.16	0.26	
Mutants/Variety:									
LM-99 (V_1)	69.9	35.8	4.8	150.6	1.6	21.36	1.66	4.56	120
LM-118 (V_2)	71.2	35.0	4.9	145.4	1.7	20.74	1.58	4.72	120
LM-206-5 (V_3)	67.7	36.2	5.0	146.9	1.6	21.49	1.55	4.60	120
Binamasur-8 (V_4)	69.0	35.8	4.8	138.5	1.7	20.76	1.51	4.76	123
$LSD_{0.05}$	6.9	1.5	0.6	15.0	0.1	0.39	0.17	0.22	
Seed rate:									
25 kg ha^{-1} (S_1)	59.1	35.9	4.9	152.3	1.7	21.17	1.60	4.61	
30 kg ha^{-1} (S_2)	65.9	36.1	4.8	144.4	1.7	21.10	1.58	4.71	
35 kg ha^{-1} (S_3)	72.3	35.6	4.9	138.9	1.7	21.12	1.64	4.59	
40 kg ha^{-1} (S_4)	80.6	35.1	4.9	146.0	1.7	20.96	1.55	4.73	
$LSD_{0.05}$	3.3	1.1	0.4	10.3	0.1	0.20	0.07	0.16	

Two way interaction effect of locations, mutant and seed rates

The interaction of variety and location showed significant differences on total plant population and growth, yield contributing characters such as plant height, branches plant^{-1}, pods plant^{-1} and 1000 seed weight. The highest seed yield (2.20 t ha^{-1}) produced with Binamasur-8 followed by LM-99 (2.09 t ha^{-1}) in Ishurdi and lowest yield was produced by Binamasur-8 in Chapainawabganj (Table 2). The findings agreed with the results of Yadav *et al.,* (2007) who observed that productivity of lentil varies greatly from location to location and wide gaps between the locations due to facing the challenges of biotic and abiotic stresses which are responsible for the low productivity and stagnation in the production. Such gaps in the productivity can be minimize with the introduction of modern techniques. The interaction results of mutant/variety and seed rate revealed that the seed yield of LM-118 was the highest (1.77 t ha^{-1}) at the seed rate of 35 kg ha^{-1} followed by 40 kg ha^{-1}. The lowest yield was observed in LM-206-5 (1.36 t ha^{-1}) at 40 kg ha^{-1} seed rate (Table 2). The better performance per plant was due to better utilization of resources. The results are in conformity with the findings of Singh *et al.,* (2005); Praveen and Bhuiya, (2010) and Ilinger, (2017). The response of lentil to various plant densities has been variable depending upon genotype, planting time and growing conditions. The interaction of seed rates and location showed significant differences in the yield and related attributes. The seed yield of lentil was highest in Ishurdi at the seed rate of 25 kg ha^{-1} (2.12 t ha^{-1}) followed by 30 kg ha^{-1} (2.01 t ha^{-1}) compared to other seed rates and the yield was the lowest in Chapainawabganj at the seed rate of 30 kg ha^{-1} (1.19 t ha^{-1}) (Table 2). Despite of significantly higher growth and yield parameters plant^{-1}, the reduction in seed yield compared to higher seed rate of 35 kg ha^{-1} was mainly due to lower plant population per unit area. The results are in conformity with the findings of Saleem *et al.*, (2012) who reported positive correlation of seed yield with seed rate in appropriate area of cultivation.

Table 2. Interaction effect of location and mutants/variety, mutants/variety and seed rate, seed rates and location on yield of lentil lines in different locations.

Treatments	Populations m^{-2} (no.)	Plant height (cm)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Location × Mutant/Variety:								
L_1V_1	72.6	43.1	2.3	209.6	1.7	21.86	2.09	4.45
L_1V_2	85.0	40.8	2.3	219.5	1.7	20.80	1.81	4.60
L_1V_3	75.9	44.6	2.5	213.0	1.7	21.67	1.97	4.47
L_1V_4	79.7	41.9	2.2	192.2	1.7	21.28	2.20	4.64
L_2V_1	74.0	29.1	7.4	110.4	1.7	20.26	1.43	4.76
L_2V_2	65.2	28.4	7.6	102.5	1.7	19.36	1.36	4.96
L_2V_3	66.6	28.3	7.6	105.3	1.7	20.79	1.16	4.86
L_2V_4	71.9	29.5	7.8	107.4	1.7	18.93	1.02	5.01
L_3V_1	63.2	35.1	4.7	132.0	1.6	21.96	1.45	4.45
L_3V_2	63.6	35.8	4.8	114.3	1.6	22.06	1.49	4.60
L_3V_3	60.6	35.8	4.9	122.3	1.6	22.02	1.53	4.47
L_3V_4	55.3	36.0	4.4	116.1	1.7	22.06	1.31	4.64
$LSD_{0.05}$	11.9	2.7	1.0	25.9	0.1	0.67	0.29	0.38

Table 2. Continued

Treatments	Populations m^{-2} (no.)	Plant height (cm)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Mutants/Variety × Seed rate:								
$V_1 S_1$	56.7	36.5	5.0	165.5	1.6	21.62	1.65	4.56
$V_1 S_2$	66.4	35.7	4.8	154.3	1.7	21.54	1.64	4.47
$V_1 S_3$	74.8	35.7	4.5	135.5	1.6	21.36	1.67	4.38
$V_1 S_4$	81.7	35.3	4.8	147.3	1.6	20.91	1.66	4.81
$V_2 S_1$	61.6	35.9	4.9	146.0	1.7	20.71	1.56	4.65
$V_2 S_2$	65.8	35.9	4.5	143.7	1.7	20.58	1.54	4.75
$V_2 S_3$	74.4	34.2	5.2	140.7	1.7	20.80	1.77	4.65
$V_2 S_4$	83.3	33.9	5.0	151.3	1.7	20.87	1.73	4.84
$V_3 S_1$	54.0	36.7	4.8	151.3	1.6	21.41	1.65	4.60
$V_3 S_2$	64.4	35.8	4.7	140.4	1.6	21.43	1.65	4.54
$V_3 S_3$	72.9	36.6	5.2	146.2	1.7	21.70	1.55	4.63
$V_3 S_4$	79.4	35.7	5.2	149.6	1.7	21.42	1.36	4.63
$V_4 S_1$	64.3	34.4	4.7	146.4	1.7	20.92	1.54	4.64
$V_4 S_2$	66.9	37.1	5.0	139.0	1.7	20.82	1.49	5.05
$V_4 S_3$	67.1	36.1	4.7	133.1	1.7	20.64	1.55	4.71
$V_4 S_4$	77.7	35.6	4.7	135.6	1.7	20.64	1.45	4.64
$LSD_{0.05}$	6.6	2.3	0.7	20.6	0.1	0.40	0.14	0.32
Seed rates × location:								
S_1L_1	62.5	43.2	2.3	224.0	1.7	21.40	2.12	4.55
S_1L_2	71.7	43.7	2.4	199.9	1.7	21.47	1.81	4.58
S_1L_3	82.5	42.8	2.4	194.3	1.8	21.49	1.97	4.46
S_2L_1	96.6	40.7	2.2	216.0	1.6	21.24	2.01	4.58
S_2L_2	57.4	28.5	7.5	106.8	1.7	19.88	1.19	4.75
S_2L_3	62.8	29.1	7.2	107.8	1.7	19.91	1.22	4.96
S_3L_1	74.6	28.6	7.8	104.5	1.7	19.92	1.41	4.86
S_3L_2	82.9	29.2	8.0	106.4	1.7	19.63	1.16	5.02
S_3L_3	57.6	36.0	4.8	126.1	1.6	22.22	1.46	4.55
S_4L_1	63.1	35.6	4.8	125.4	1.6	21.91	1.40	4.58
S_4L_2	59.8	35.5	4.6	117.7	1.6	21.96	1.44	4.46
S_4L_3	62.2	35.5	4.6	115.5	1.7	22.01	1.48	4.58
$LSD_{0.05}$	5.7	2.0	0.6	17.8	0.1	0.35	0.12	0.28

L_1 = Ishurdi; L_2 = Chapainawabganj; L_3 = Magura; V_1 = LM-99-8; V_2 = LM-118-9; V_3 = LM- 206-5; V_3 = Binamasur-8; S_1 = 30 kg ha^{-1}; S_2 = 35 kg ha^{-1}; S_3 = 40 kg ha^{-1} and S_4 = 45 kg ha^{-1}

Cumulative interaction effect of locations, mutant and seed rates

The interaction of location, varieties and seed rate effect seriously on yield and growth attribute of lentil. The maximum seed yield (2.18 t ha^{-1}) was obtained from the location Ishurdi with the mutant LM-138-3 (V_1) at seed rate of 30 kg ha^{-1} followed by Chapainawabganj with LM-99 at the seed rate 30 kg ha^{-1} (2.10 t ha^{-1}). The lowest seed yield (0.63 t ha^{-1}) was observed in Ishurdi with the mutant LM-206-5 at the seed rate of 30 kg ha^{-1} (Table 3). This might be due to optimum combination of location, genotype and higher seed rate (plant population). The significantly higher performance of individual effect of locations, genotype and seed rate also contributed significantly to the higher yield. These findings are in agreement with the results of Choubey *et al.*, (2013) and Ouji *et al.*, (2016) who found that the seed rate of 120 seeds/m^2 was found to be the best for lentil production.

Table 3. Interaction effect of location, mutants/variety and seed rate on yield of lentil in different locations.

Treatments	Populations m^{-2} (no.)	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Seeds pod^{-1} (no.)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Location× Mutants/Variety × Seed rates:								
$L_1V_1S_1$	61.9	44.7	2.3	256.3	1.7	21.84	1.91	4.51
$L_2V_1S_1$	67.0	43.3	2.7	194.7	1.7	21.99	1.97	4.36
$L_3V_1S_1$	75.0	43.0	2.4	175.7	1.8	21.94	1.87	4.29
$L_1V_1S_2$	86.5	41.3	1.8	211.7	1.5	21.65	2.01	4.65
$L_2V_1S_2$	67.3	43.3	2.6	213.3	1.6	20.66	2.10	4.57
$L_3V_1S_2$	76.0	41.7	2.1	213.7	1.8	20.83	2.05	4.64
$L_1V_1S_3$	91.3	39.7	2.5	210.0	1.8	21.23	2.01	4.51
$L_2V_1S_3$	105.3	38.3	2.2	241.0	1.6	20.48	2.07	4.69
$L_3V_1S_3$	57.7	46.0	2.1	217.0	1.6	21.70	2.05	4.55
$L_1V_1S_4$	72.7	45.0	2.3	197.7	1.7	21.62	2.01	4.38
$L_2V_1S_4$	80.3	45.3	2.7	208.3	1.7	21.76	1.73	4.47
$L_3V_1S_4$	93.0	42.0	2.7	229.0	1.7	21.59	1.77	4.50
$L_1V_2S_1$	63.0	38.7	2.1	209.3	1.7	21.40	2.02	4.54
$L_2V_2S_1$	71.0	44.7	2.5	193.7	1.6	21.44	2.01	4.93
$L_3V_2S_1$	83.3	43.3	1.9	183.3	1.7	21.04	2.07	4.58
$L_1V_2S_2$	101.5	41.0	2.2	182.3	1.7	21.24	2.18	4.50
$L_2V_2S_2$	48.7	29.5	7.7	110.0	1.7	20.98	1.39	4.65
$L_3V_2S_2$	65.3	29.7	7.1	111.7	1.7	20.60	1.42	4.70
$L_1V_2S_3$	87.3	28.7	6.7	112.0	1.6	20.29	1.44	4.57
$L_2V_2S_3$	94.7	28.6	7.9	107.7	1.7	19.17	1.46	5.11
$L_3V_2S_3$	57.3	28.3	7.5	103.7	1.8	19.03	1.17	4.82
$L_1V_2S_4$	55.0	29.7	6.3	104.1	1.7	19.11	1.27	4.98
$L_2V_2S_4$	68.7	26.6	8.4	100.3	1.7	19.27	1.51	4.92
$L_3V_2S_4$	79.7	29.0	8.1	101.8	1.7	20.03	1.50	5.14

Table 3. Continued

Treatments	Populations m^{-2} (no.)	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Seeds pod^{-1} (no.)	1000 seed wt. (g)	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)
$L_1V_3S_1$	52.3	27.5	7.6	104.9	1.7	20.70	1.27	4.71
$L_2V_3S_1$	57.3	26.9	7.2	104.3	1.7	20.85	1.35	4.88
$L_3V_3S_1$	76.0	29.6	7.7	105.3	1.7	21.19	1.40	4.95
$L_1V_3S_2$	80.7	29.1	7.9	106.8	1.8	20.41	0.63	4.89
$L_2V_3S_2$	71.3	28.5	7.1	108.5	1.7	18.80	0.94	4.82
$L_3V_3S_2$	73.3	30.1	7.9	111.0	1.7	19.08	0.83	5.30
$L_1V_3S_3$	66.3	29.3	8.3	100.5	1.7	18.94	1.27	4.98
$L_2V_3S_3$	76.7	30.0	8.0	109.3	1.8	18.89	1.03	4.93
$L_3V_3S_3$	59.6	35.3	5.1	130.1	1.4	22.04	1.41	4.51
$L_1V_3S_4$	67.0	34.0	4.6	156.4	1.7	22.04	1.40	4.36
$L_2V_3S_4$	62.1	35.4	4.5	118.8	1.5	21.85	1.46	4.29
$L_3V_3S_3$	64.1	35.8	4.7	122.5	1.7	21.91	1.51	4.65
$L_1V_4S_1$	60.0	36.2	4.7	121.1	1.7	22.45	1.43	4.57
$L_2V_4S_1$	66.3	36.5	5.2	113.3	1.6	21.80	1.30	4.64
$L_3V_4S_1$	63.1	36.3	4.7	111.7	1.6	21.90	1.62	4.51
$L_1V_4S_2$	64.9	34.5	4.7	111.2	1.7	22.09	1.61	4.69
$L_2V_4S_2$	52.1	36.6	4.6	131.9	1.7	21.83	1.43	4.55
$L_3V_4S_2$	63.1	35.5	4.7	119.3	1.4	21.83	1.50	4.38
$L_1V_4S_3$	62.5	35.0	5.2	124.9	1.6	22.16	1.53	4.47
$L_2V_4S_3$	64.7	36.0	5.1	113.1	1.5	22.26	1.67	4.50
$L_3V_4S_3$	58.6	36.1	4.9	121.3	1.6	22.57	1.55	4.54
$L_1V_4S_4$	56.3	36.6	4.6	112.5	1.7	21.95	1.41	4.93
$L_2V_4S_4$	51.5	35.6	3.9	115.5	1.8	21.93	1.13	4.58
$L_3V_4S_4$	55.0	35.7	4.0	115.0	1.7	21.80	1.14	4.50
$LSD_{0.05}$	5.7	4.0	1.3	35.7	0.2	0.70	0.25	0.55
CV%	7.5	8.8	5.8	7.1	9.7	3.23	9.56	7.25

L_1 = Ishurdi; L_2 = Chapainawabganj; L_3 = Magura; V_1 = LM-99-8; V_2 = LM-118-9; V_3 = LM- 206-5; V_3 = Binamasur-8; S_1 = 30 kg ha^{-1}; S_2 = 35 kg ha^{-1}; S_3 = 40 kg ha^{-1} and S_4 = 45 kg ha^{-1}

Conclusions

It was concluded that the LM-99 advanced mutant/varieties produced the highest seed yield in Ishurdi station among the several advance mutants with a seed rate of 35 kg ha^{-1}. In terms of yield and duration, it has outperformed the check variety in all three locations. The two remaining mutants LM-118 and LM-206-5 also performed better than check Binamashur-8 in case of yield and the location Magura performed better after the Ishurdi in Bangladesh. The development of new commercial lentil varieties for the lentil favored area particularly in Ishurdi and Magura, could be aided by the promising mutant LM-99.

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EVALUATION OF LATE SOWING POTENTIALS OF RAPESEED VARIETIES ON SEED YIELD AND YIELD CONTRIBUTING CHARACTERS IN MYMENSINGH

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Abstract

Rapeseed mustard are an important oilseed in Bangladesh. The yield performance and crop geometry of Bangladesh Institute of Nuclear Agriculture (BINA) newly released mustard variety is still under question in lately sowing potentiality after harvesting Aman rice. The first experiment was conducted with four varieties viz. Tori-7, BARI Sarisha-14, Binasarisha-7 and Binasarisha-9 for the sowing date on 13 December with split plot design. The next experiment conducted with six variety viz. Binasarisha-4, Binasarisha-8, Binasarisha-9, Binasarisha-10, BARI Sarisha-14 and BARI Sarisha-17 for two dates of sowing i.e. 30 November & 10 December with split plot design at the research field of BINA during Rabi season of 2019-20 and 2020-21 to observe their late sowing potentialities. In 13 December sowing, Binasarisha-9 produced the highest seed yield. In 2020-21, seed yield was highest on sowing dates 30 November where Binasharisha-9 performed the best both in seed yield and yield contributing characters which indicates that Binasarisha-9 has the late sowing potential among the six tested varieties.

Key words: Mustard, late potential, seed yield, variety

Introduction

Rapeseed mustard are the third most important source of edible oil crops and at present, is the third largest source of vegetable oil all over the world next to soybean (*Glycine max*) and palm (*Elaeis guineensis* Jacq.). It is grown in certain tropical and subtropical regions as a cold season crop (Shekhawat *et al.*, 2012). Rapeseed mustard seed in general, contains 30-43% oil, 17-25% proteins, 8-10% fibers, 6-10% moisture, and 10-12% extractable substances (Pandey *et al.*, 2013). In Bangladesh context, rapeseed mustard (*Brassica spp.)* are popular edible oil in rural area and accounts about 72% of total oilseed production in the country. This oil is important for improving the taste of a number of food items (Aziz *et al.,* 2011). The total rapeseed mustard oil production was 3,11,740 metric ton occupying 6,67,242 acres area which is about 62.5% of the total oilseed area in the year of 2018-19 (BBS, 2019). The overall production of mustard and rape was declining due to a decrease in the covered area and it was recorded 352 thousand ton in 2018 which declining to 312 thousand ton in 2019 (www.ceicdata.com). Demand of edible oil has been increased with increasing population and improvement in the living standard of the people, resulting thereby in short supply of edible oils which is being met with imports. Thus, there is need to boost the oilseed production through area expansion and productivity enhancement.

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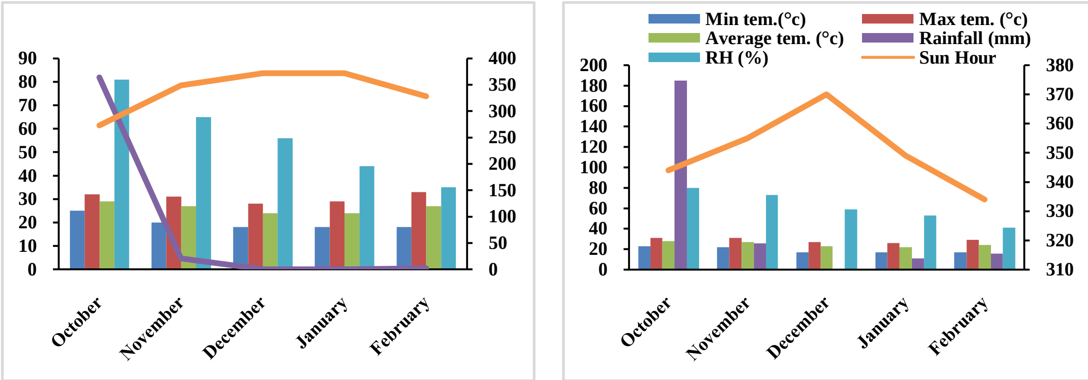
Different sowing dates provide variable environmental conditions within the same location for growth & development of crop (Panda *et al.,* 2004). The late sowing of mustard decreased seed yield through synchronization of siliqua filling period with high temperatures, the decrease in assimilates production, drought stress occurrence, shortened siliqua filling period and acceleration of plant maturity (Mendham *et al.,* 1981) as it is a thermo sensitive as well as photosensitive crop (Angrej *et al.,* 2002). Cultivation of low yielder local varieties in late sowing are the major causes for poor yield of rapeseed mustard in the country (Alam and Rahman, 2006). High yield with late potential of a variety is the prerequisite for increasing the production of a crop. In the recent years, Bangladesh Agricultural Research Institute (BARI) and BINA have developed a number of high yielding with late potential rapeseed mustard varieties with high seed yield potentiality up to 2.5 t ha^{-1}. To this point of view, genotypes play an important role in crop production and the potential yield of a genotype within the genetic limit is determined by its environment (Iraddi, 2008). The release of high yielding varieties has contributed a great deal towards the improvement of Mustard yields. The yield potential of these high yielding varieties can be further exploited through better agronomic practices involving many physiological changes. Therefore the present study was undertaken to identify rapeseed mustard varieties having suitable late sowing potential for the expansion of cultivation area in Bangladesh.

Material and methods

The field experiment was conducted at the Field Laboratory of the BINA HQ farm, Mymensingh during the period from during Rabi season (November to March) of 2019-20 and 2020-21 in two consecutive years. Geographically, the research field is located at 24.74° N latitude and 90.42° E longitudes. Mymensingh district falls under the sub-tropical climate, which is characterized by high temperature and high humidity in Kharif season and the Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February. The climatic parameters during the growing period of rapeseed mustard in Mymensingh are presented in Figure 1.

Soil characteristics in the study areas were silt loam to silty clay having pH value range from 5.2 to 7.8. The first experiment was consisted with only single sowing time (December 13), in 2019-20 with Tori-7 (V_1), BARI Sarisha-14 (V_2), Binasarisha-7 (V_3) and Binasarisha-9 (V_4) with split plot design. In the next year the experiment consisted with two sowing time 30 Nov. (D_1) and 10 Dec. (D_2) in 2020-21 with six rapeseed mustard variety viz, Binasarisha-4 (V_1), Binasarisha-8 (V_2), Binasarisha-9 (V_3), Binasarisha-10 (V_4), BARI Sarisha-14 (V_5) and BARI Sarisha-17 (V_5) with split plot design where sowing time was placed in the main plot and varieties was placed in the sub-plot. Three replications were maintained in both years. The size of each unit plot was 4 m × 3 m where line to line and plant to plant distances were 30 and 6 cm, respectively. All the weeds and stubbles were removed after proper ploughing and the land was laid out as per the experimental design. Fertilizers were applied at the rate of 70, 30, 50, 90 and 3 kg/acre urea, muriate of potash

(MOP), triple super phosphate (TSP), gypsum and Zinc sulphate, respectively at final land preparation (Fertilizer Recommended Guide, BARC, 2018). The *Alternaria* blight disease was controlled by spraying of propiconazol 250 EC @ 20 ml per 5 decimal lands. Weeds were controlled by two hands weeding.



(a) (b)

(www.Worldweatheronline.com/Mymensingh)

Figure 1. Meteorological condition during the *Rabi* season in Mymensingh for two consecutive years 2019-20 (a) and 2020-21 (b).

The crop was harvested at full maturity and the harvested crop was brought to the threshing floor and was dried for three days. The yield of seed was adjusted at 10% moisture level. Data on yield contributing characters were recorded at harvest. The yield contributing characters were recorded from 10 randomly selected plants in each plot and their mean values were determined. The yields were taken plot-wise by harvesting central 10 m^2 area of each plot and then it was converted to hectare basis. The collected data was on plant height (cm), population m^{-2}, no. of branches $plant^{-1}$, no. of siliqua $plant^{-1}$, no. of seeds $Siliqua^{-1}$, siliqua length (cm), 1000 seed weight (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}) and maturity period. The collected data were analyzed using statistical computer package Statistics 10 and mean differences were adjudged by using LSD (Gomez and Gomez, 1984).

Results and discussion

Effect of variety on growth and yield of rapeseed

All the varieties used **i**n the experiment were differed in respect of seed yield and yield contributing characters and it was considered from least significance difference (LSD) value. The result of the first experiment during 2019-20 showed that the silique length (7.1 cm), seed yield (1.3 t ha^{-1}), maturity duration (81 days) was the highest in Binasarisha-9 but plant height (47.7 cm) was lowest where the Tori 7 exhibited the highest plant height (64.7 cm), branches $plant^{-1}$ (4.4), silique $plant^{-1}$ (43.9), 1000 seed weight (3.5) and also showed least maturity duration (66 days) (Table 1). On the other hand, the experiment conducted in

2020-21 exhibited that all the varieties differed in their yield and yield components (Table 2). The Binasarisha-4 exhibited the highest numbers of seeds silique^{-1} (32.9) and 1000 seed weight (3.5g) but lowest in maturity duration (66 days). The plant height (104.4 cm), branches plant^{-1} (101.9) and 1000 seed weight (3.5g) was observed maximum in Binasarisha-8. Eventually the Binasarisha-9 showed the highest seed yield (1.4 t ha^{-1}) due to the highest siliqua length (7.2 cm) and numbers of seed silique^{-1} (29.9). The BARI Sarisha 17 produced the highest branches plant^{-1} (5.5), stover yield (3.8) and maturity duration (82 days) (Table 2). This result is in agreement with the findings of Al-Juheishy and Ghazal, (2017) investigated growth and yield performance of rapeseed including two varieties of rapeseed (Pactol and Srew) with four seed rates (4, 6, 8, 10 kg ha^{-1}). The Srew variety significantly exceeded the highest mean of the trait of the number of branches plant^{-1}, number of siliqua plant^{-1}, the weight of 1000 seeds, seed yield, while the Pactol variety scored the highest mean for plant height and the number of seeds silique^{-1} respectively.

Table 1. Effect of rapeseed mustard varieties on seed yield and yield contributing characters during 2019-2020 (13 December)

Varieties	Plant height (cm)	Branches plant^{-1} (no.)	Silique plant^{-1} (no.)	Seeds Siliqua^{-1} (no.)	Silique length (cm)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Maturity duration (days)
Tori 7	64	4.4	43.9	23.7	5.4	3.5	1.1	2.9	66
BARI Sarisha-14	60	3.0	31.5	34.2	5.0	3.5	1.3	3.1	74
Binasarisha-7	55	2.7	39.0	26.0	4.8	3.3	1.0	2.9	78
Binasarisha-9	47	2.7	31.9	28.4	7.1	3.4	1.3	2.9	81
$LSD_{0.05}$	3.7	0.5	2.4	4.4	0.6	0.3	0.2	0.1	3.1

Table 2. Effect of rapeseed mustard varieties on seed yield and yield contributing characters in 2020-2021

Varieties	Plant height (cm)	Branches plant^{-1} (no.)	Silique plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	Silique length (cm)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Maturity duration (days)
Binasarisha-4	87	3.3	40.8	32.9	7.1	3.5	1.3	2.9	66
Binasarisha-8	104	3.8	101.9	11.3	3.7	3.5	1.2	3.1	74
Binasarisha-9	86	4.1	46.6	29.9	7.2	3.3	1.4	2.9	78
Binasarisha-10	74	4.6	91.1	18.1	4.3	3.4	1.2	3.0	81
BARI Sarisha-14	74	5.4	42.5	29.9	4.1	3.4	1.3	2.9	79
BARI Sarisha 17	83	5.5	46.5	28.5	3.9	3.3	1.3	3.8	82
$LSD_{0.05}$	7.1	0.2	4.4	1.8	0.5	0.3	0.1	1.1	2.13

Effect of sowing dates on growth and yield of rapeseed

The effect of different sowing dates significantly affected on plant height, number of plant population m^{-2}, number of branch plant^{-1}, number of siliqua plant^{-1}, number of seed siliqua^{-1}, siliqua length 1000 weight, seed yield and stover yield are presented in Table 3. The yield and yield contributing characters such as plant height (92.7 cm), branches plant^{-1}

(4.26), seeds siliqua^{-1} (27.4), 1000 seed weight (3.40) was recorded highest in 10 December and it was significantly different from the all other treatments. On the other hand, the traits population m^{-2} (114.47), siliqua plant^{-1} (67.68), seed yield (1.27) and stover yield (3.11) showed highest in 30 November. These results are in agreement with the result of Rahman *et al.*, (2007) who stated that plant height differed significantly among the studied mustard varieties. The results of present study were also supported by the results of Tripathi *et al.*, (2021) in mustard who observed the three sowing dates (15 Oct., 10 Nov. and 05 Dec.) and stated that the 10 November was superior compare to rest of the planting dates and showed effectively increasing the growth, oil content and oil yield. On the other hand the lowest yield recorded under dates at 15 October.

Table 3. Effect of sowing dates of mustard varieties on yield and yield contributing characters in 2020-2021

Treatment	Plant height (cm.)	Popula. m^{-2} (no.)	Branches plant^{-1} (no.)	Silique plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	Siliqua length (cm)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Dates of sowing:									
November 30 (D_1)	77	114.5	4.3	67.7	22.8	4.8	3.3	1.3	3.1
December 10 (D_2)	92	103.1	4.6	55.4	27.4	5.3	3.4	1.2	2.9
Significance level	*	*	NS	**	**	*	NS	NS	NS

Interaction effect of sowing dates and variety

The interaction of sowing dates (30 November and 10 December) and varieties (Binasarisha-4, Binasarisha-8, Binasarisha-9, Binasarisha-10, BARI Sarisha 14, BARI Sarisha 17) had significant effect on yield and yield contributing characters (Table 4). Results showed that the Binasarisha-8 (V_2) exhibited the highest plant height (116.27 cm) where the seed yield (1.6 t ha^{-1}) was observed in Binasarisha-9 (V_3) at December 10 (D_2). The seeds siliqua^{-1} also observed highest at 10 December (D_2) in Binasarisha-4 (V_1). On the other hand, Binasarisha-10 (V_4) exhibited maximum siliqua plant^{-1} (131.4) and siliqua length (7.4 cm) was highest in Binasarisha-9 (V_3) at the sowing dates November 30 (D_1). The findings were complied with Aziz *et al.*, (2011) who stated that sowing time is an important factor for seed yield and quality in rapeseed and the highest grain yield (1.94 t ha^{-1}) was recorded from the treatment combination of the variety Binasarisha-5 at 30 November sowing and the lowest (1.08 t ha^{-1}) in delay sowing at 15 January with Binasarisha-9. These results are also in conformity with the findings of Akhter *et al.*, (2015) who observed that the variety P-3 sown on 1st October recorded significantly higher seed yield of 19.13 q ha^{-1}. The higher seed yield in this interaction might be due to significantly higher number of primary and secondary branches per plant, higher number of siliqua per plant and 1000 seed weight.

Table 4. Interaction effect of sowing dates and variety on yield and yield contributing characters of rapeseed mustard during 2020-2021

Treatment	Plant height (cm.)	Branches plant^{-1} (no.)	Silique plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	Silique length (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
$D_1 V_1$	81	3.2	36.5	29.9	7.0	3.5	1.4	3.0
$D_1 V_2$	92	4.1	104.8	11.8	3.6	3.3	1.3	3.2
$D_1 V_3$	83	4.9	50.2	26.4	7.4	3.4	1.2	3.5
$D_1 V_4$	69	4.6	131.4	17.7	3.7	3.4	0.8	2.9
$D_1 V_5$	65	4.5	41.5	25.3	3.8	3.3	1.5	3.0
$D_1 V_6$	72	4.2	41.7	25.6	3.6	3.5	1.4	3.9
$D_2 V_1$	93	3.4	45.1	35.9	7.2	3.3	1.3	3.3
$D_2 V_2$	116	3.4	99.1	10.8	3.8	3.4	0.9	3.4
$D_2 V_3$	90	3.2	42.9	33.5	7.1	3.4	1.6	3.1
$D_2 V_4$	79	4.5	50.9	18.4	5.0	3.3	1.4	4.0
$D_2 V_5$	83	6.4	43.4	34.6	4.3	3.5	1.1	3.6
$D_2 V_6$	94	6.7	51.3	31.4	4.3	3.3	0.9	3.9
$LSD_{0.05}$	10.1	0.6	6.1	2.6	0.7	3.4	0.10	3.9
CV%	7.8	8.2	4.3	3.9	8.2	3.5	6.4	8.1

N.B: D_1, November 30; D_2, December 10; V_1, Binasarisha-4; V_2, Binasarisha-8; V_3, Binasarisha-9; V_4, Binasarisha-10; V_5, BARI Sarisha 14; V_6, BARI Sarisha 17.

Conclusion

From the results it may be concluded that the maximum late sowing seed yield potentiality explored by the variety Binasarisha-9 supported the better seed yield and yield contributing characters compared to other tested varieties in Mymensingh district of Bangladesh.

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EFFECT OF HIGH TEMPERATURE ON PHOTOSYNTHESIS, STOMATAL CONDUCTANCE, TRANSPIRATION AND YIELD OF BORO RICE VARIETIES UNDER DIFFERENT SOIL MOISTURE REGIMES

M.T. Islam

Abstract

Climate is changing and air temperature is rising due to increasing concentration of CO_2 and other atmospheric greenhouse gases. The flowering stage of rice is important for high temperatures. An experiment was carried out at Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh during December 2020 to May 2021 with three Boro rice varieties to find out proper soil moisture level at flowering stage to reduce high temperature effect. Binadhan-8, Binadhan-10 and Binadhan-14 were grown in pots each of 8 kg soil in ambient temperature. During flowering stage the plants were kept in plant growth chamber at 38 ^{0}C for 24 hrs under different soil moisture levels (standing water of 2 inches, 100% FC and 80% FC) in pot soil. Then all the plants were allowed to complete the maturity under sufficient soil moisture at ambient temperature. The experiment was conducted in RCBD with three replications. The results revealed that under high temperature photosynthesis, transpiration rate and yield significantly decreased but leaf temperature (^{o}C) and water use efficiency increased at 80% FC. Transpiration maintained leaf temperature of 33.17-34.87°C during air temperature of 3°C. Binadhan-8 and Binadhan-10 maintained lower leaf temperature and Binadhan-14 had better water use efficiency at 80% FC. Higher yield was found in 100% FC and standing water of 2 inches compared to 80% FC. So, maintaining 100% FC or standing water of 2 inches at flowering stage of Boro rice varieties can reduce high temperature effect.

Key words: High temperature, photosynthesis, stomatal conductance, transpiration, yield.

Introduction

Changing climate rises air temperature 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 (Rawson, 1992; Kumar, 2020). The economic yield of a plant depends mainly on leaf photosynthesis. Stomata can function as valves to control the balance of water loss and carbon gain in plants (Huang *et al*., 2021). The climate changes that are currently occurring make it necessary to understand the effects of temperature on photosynthesis. Models based on large-scale observations indicate that, in the absence of agronomic adaptation, the decrease in crop yields can reach 17% for each 1°C increase in the temperature of the growing season (Yamori *et al*., 2014). Climate model predicts 33%

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rice yield decrease in 2100 (Karim *et al*., 2012). Boro rice is transplanted in January-February and usually faces high temperature (36-39 °C) at its reproductive stage in April-May (Islam 2021a). Flowering stage of rice is very important for high temperature (Islam, 2011 and Islam, 2013). High temperature may cause drying of pollen and stigma and ceasing pollen tube development unsuitable for fertilization. As a result, unfilled grains are produced. Rice grain dry weight increased from fertilization to 18-24 days and water stress decreased the rate of accumulation and finally produced decreased grain weight (Islam and Gretzmacher, 2001; Islam 2010; Hafiz *et al*., 2015; Moonmoon *et al*., 2020a). The yield of rice is an integrated result of various processes including canopy photosynthesis, conversion of assimilates to biomass, and partitioning of assimilates to grains (Jeng *et al*., 2006). Drought stress affects plant growth and development, and ultimately reduces grain yield of rice (Islam *et al*., 1994b; Islam *et al*., 2005a; Zohora *et al*. 2016; Moonmoon *et al*., 2017; Moonmoon *et al*., 2020b). Response of rice yield to drought varies with growth stage being most sensitive at booting followed by flowering and or grain filling stage (Islam *et al*., 1994a). The early reproductive growth period, encompassing tetrad-formation stage of miosis (i.e., about 10-15 d prior to heading), was found to be the most sensitive and critical to water deficit resulting in up to 59% grain sterility that caused similar magnitude of yield reduction (Singh *et al*., 2010). As the grain formation progressed further, the early period of grain-filling was found to be more vulnerable to water stress than the late-milk stages (Singh *et al*., 2010). For stress condition, reproductive stages are critical than vegetative stages and booting to early grain filling stages are more critical (Moonmoon and Islam, 2017; Islam *et al*., 2005b; Rahman *et al*., 2002). So, the experiment was conducted to find out proper soil moisture level at flowering stage of Boro rice varieties to reduce high temperature effect.

Materials and Methods

An experiment was conducted with three rice genotypes *viz*. Binadhan-8, Binadhan-10 and Binadhan-14 at pot yard and in plant growth chamber of Bangladesh Institute of Nuclear Agriculture (BINA) during December, 2020 to May, 2021 to assess the effect of high temperature under different soil moisture levels. The soils of the experiment were collected from the field of BINA Farm. The top soil was non-calcareous Dark Grey Floodplain with loamy texture belonging to the AEZ Old Brahmaputra Floodplain. The collected soil was pulverized, inert materials, visible insect pest and plant propagules were removed. Pots are filled with top soils. The soil moisture stresses were calculated based on field capacity (FC). Gravimetric Method determined FC. Each pot contained 8 kg soil. All soils pots were fertilized with urea, TSP, MP and gypsum @ 2.08, 0.32, 0.41 and 0.21g pot^{-1} corresponding 260, 125, 180 and 80 kg ha^{-1} Urea, TSP, MoP and Gypsum, respectively. All TSP, MoP, Gypsum and one-third of the urea were applied as basal dose. The remaining two-thirds of the urea were applied in two equal splits in each pot at 25 and 45 days after transplanting (DAT). One seedling was transplanted in a puddled pot. For gap filling there were extra seedlings preserved. All necessary intercultural operations, mainly weeding, and irrigation was done as and when necessary. The experiment was set in a two factorial RCBD with three replications. The first factor was rice genotypes and the second factor was irrigations: standing water of 2 inches, 100% FC, 80% FC and in pot soil. Plants were grown in ambient temperature and during flowering stage those were kept in plant growth chamber at 38^0C for 24 hours under different soil moisture levels (standing water of 2 inches, 100% FC, 80% FC). Then all the plants were allowed to complete the maturity in ambient temperature. Data on photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance, transpiration, leaf temperature and water use efficiency were recorded during stress imposition using Portable Photosynthesis System (Li-6800, LICOR, USA) and yield and yield attributes were recorded at maturity. Data were analyzed statistically and DMRT was used to compare the means.

Results and Discussion

Photosynthesis gradually decreased but Tleaf (^{o}C) increased with decreasing soil moisture levels (Table 1). The results agree with Yang *et al*. (2020) who opined that photosynthesis is highly sensitive to high temperature stress. Higher value of Fv/Fm was found at standing water of 2 inches compared to other soil moisture levels. Stomatal conductance and transpiration rate was decreased only at 80% FC. Stomata can function as valves to control the balance of water loss and carbon gain in plants (Huang *et al*., 2021). Transpiration maintained Tleaf (^{o}C) of 33.17-34.87°C during air temperature of 38°C (Table 2). The results agree with Islam 2021b and Moonmoon *et al*., 2020c. In photosynthesis system, CO_2 enters the leaf where its reduction in the chloroplasts is accompanied by O_2 production (Cornic, 2021). Its entry is almost exclusively through the stomata. For each molecule of CO_2 absorbed, 50 to 300 molecules of water are transpired from the leaves, depending on the plant (Cornic, 2021). This water allows, among other things, the cooling of the leaf. The leaf is a converter of solar energy into chemical energy and, like any energy converter, requires a permanent cooling system. Binadhan-8 showed higher photosynthesis, stomatal conductance, transpiration but lower water use efficiency and Tleaf (^{o}C) (Tables 1 and 2). On the other hand Binadhan-14 had lower photosynthesis, stomatal conductance, transpiration but higher water use efficiency and Tleaf (^{o}C). Binadhan-10 was intermediate in those parameters. The rice varieties did not vary in Fv/Fm.

Number of panicles plant^{-1}, grains panicle^{-1}, 1000-grain weight and yield were decreased only at 80% FC (Table 3). Number of unfilled grains panicle^{-1} gradually increased with the decrease of soil moisture levels. Better yield was found in 100% FC and standing water of 2 inches compared to 80% FC. The results are in conformity with many researchers (Islam 2001; Islam *et al*., 2005c; Islam *et al*., 2012; Hazra *et al*., 2016). Binadhan-8 showed higher number of grains panicle^{-1}, 1000-grain weight and yield. Binadhan-10 had higher number of panicles plant$^{-1,}$ medium unfilled grains panicle^{-1}, 1000-grain weight and yield (Tables 3 and 4). Whereas Binadhan-14 showed higher number of unfilled grains panicle^{-1} and lower number of panicles plant^{-1}, number of grains panicle^{-1}, 1000-grain weight and yield.

Under high temperature most of the gas exchange parameters significantly decreased at 80% FC compared to 100% FC or standing water of 2 inches in pot soil. The rice varieties had sufficient soil moisture at 100% FC or standing water of 2 inches. Under the treatment, physiological parameters like photosynthesis, stomatal conductance and transpiration were affected at 80% FC. Although 80% FC was mild water stress but combined effect of high temperature and 80% FC had negative effect on physiological parameters, yield attributes and yield. So, soil moisture at 100% FC or standing water of 2 inches at flowering stage of the rice varieties can reduce high temperature effect.

Table 1. Effect of soil moisture levels on photosynthetic parameters of rice varieties under high temperature

Treatment	Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)	Fv/Fm	Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$)	Transpiration ($mmolH_2Om^{-2}s^{-1}$)	Water use efficiency	Tleaf (^oC)
T1	22.30 a	0.90 a	0.64 a	8.21 a	2.72 b	33.48 c
T2	21.56 b	0.78 b	0.63 a	8.11 a	2.66 b	33.79 b
T3	18.27 c	0.75 b	0.43 b	5.53 b	3.34 a	34.03 a
CV (%)	2.81		1.95	2.74	3.66	0.46
Varieties						
V1	21.91 a	0.83 a	0.58 a	7.70 a	2.86 b	33.32 c
V2	20.47 b	0.82 a	0.56 b	7.36 b	2.83 b	33.61 b
V3	19.74 c	0.79 a	0.56 b	6.80 c	3.01 a	34.37 a
CV (%)	2.81	4.74	1.95	2.74	3.66	0.46

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Here, V1: Binadhan-8, V2: Binadhan-10 and V3: Binadhan-14; T1: Standing water of 2 inches, T2: 100% FC and T3: 80% FC.

Table 2. Interaction effect of variety and soil moisture level on photosynthetic parameters of rice varieties under high temperature

Variety×Soil moisture	Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)	Fv/Fm	Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$)	Transpiration ($mmolH_2Om^{-2}s^{-1}$)	Water use efficiency	Tleaf (^oC)
V1T1	23.60 a	0.93 a	0.66 a	8.47 a	2.79 d	33.23 c
V1T2	23.17 a	0.78 c	0.66 a	8.40 ab	2.76 de	33.17 c
V1T3	18.97 d	0.76 c	0.44 de	6.23 e	3.05 c	33.57 b
V2T1	21.57 bc	0.92 ab	0.63 bc	8.23 abc	2.62 de	33.57 b
V2 T2	20.83 bc	0.78 c	0.61 c	8.07 bcd	2.58 e	33.60 b
V2T3	19.00 d	0.76 c	0.44 d	5.77 f	3.30 b	33.67 b
V3T1	21.73 b	0.86 b	0.64 ab	7.93 cd	2.74 de	33.63 b
V3T2	20.67 c	0.77 c	0.63 bc	7.87 d	2.63 de	34.60 a
V3T3	16.83 e	0.74 c	0.42 e	4.60 g	3.67 a	34.87 a
CV (%)	2.81	4.74	1.95	2.74	3.66	0.46

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Here, V1: Binadhan-8, V2: Binadhan-10 and V3: Binadhan-14; T1: Standing water of 2 inches, T2: 100% FC and T3: 80% FC.

Table 3. Effect of soil moisture levels on yield and yield components of rice varieties under high temperature

Treatment	Panicle plant^{-1} (no.)	Grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain wt. (g)	Yield plant^{-1} (g)
T1	10.56 a	131.33 a	23.67 c	24.14 a	33.42 a
T2	10.56 a	131.11 a	31.89 b	23.88 a	33.00 a
T3	10.00 b	111.89 b	54.33 a	22.61 b	25.32 b
CV (%)	4.50	2.01	6.78	2.20	3.58
Varieties					
V1	10.00 b	131.56 a	37.00 b	24.99 a	32.99 a
V2	10.89 a	118.33 c	50.89 a	23.36 b	30.11 b
V3	10.22 b	124.44 b	22.00 c	22.29 c	28.64 c
CV (%)	4.50	2.01	6.78	2.20	3.58

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

Here, V1: Binadhan-8, V2: Binadhan-10 and V3: Binadhan-14; T1: Standing water of 2 inches, T2: 100% FC and T3: 80% FC.

Table 4. Interaction effect of variety and soil moisture level on yield and yield attributes of rice varieties under high temperature

Variety×Soil moisture	Panicle plant^{-1} (no.)	Grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain wt. (g)	Yield plant^{-1} (g)
V1T1	10.33 ab	138.00 a	16.00 f	25.30 a	36.06 a
V1T2	10.33 ab	135.67 a	20.00 ef	25.17 a	35.27 a
V1T3	9.33 c	121.00 b	75.00 a	24.50 ab	27.64 c
V2T1	11.00 a	121.00 b	44.67 c	23.80 bc	31.68 b
V2T2	11.00 a	122.33 b	52.00 b	23.17 c	31.16 b
V2T3	10.67 ab	111.67 c	56.00 b	23.10 c	27.49 c
V3T1	10.33 ab	135.00 a	10.33 g	23.33 c	32.53 b
V3T2	10.33 ab	135.33 a	23.67 e	23.30 c	32.56 b
V3T3	10.00 bc	103.00 d	32.00 d	20.23 d	20.84 d
CV (%)	4.50	2.01	6.78	2.20	3.58

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

Here, V1: Binadhan-8, V2: Binadhan-10 and V3: Binadhan-14; T1: Standing water of 2 inches, T2: 100% FC and T3: 80% FC.

Conclusion

Under high temperature photosynthesis, transpiration rate and yield of the Boro rice varieties were significantly decreased at 80% FC compared to 100% FC or standing water of 2 inches in pot soil. So, maintaining soil moisture at 100% field capacity or standing water of 2 inches appears to reduce the high-temperature effect of Boro rice varieties at flowering stage.

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GROWTH AND SEED YIELD RESPONSE OF SESAME VARIETIES TO SOWING DATES

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Abstract

An experiment was conducted at the Agronomy Field of Bangladesh Agricultural University, Mymensingh, during February to June 2014 to investigate the effect of dates of sowing on morphological characters, yield attributes and seed yield of sesame. The experiment comprised of three sesame varieties *viz.,* Binatil-1, BARI Til-2 and BARI Til-3 and five dates of sowing *viz*., 26 February, 13 March, 28 March, 12 April and 27 April. The experiment was laid out in a split-plot design with three replications. Results revealed that plant height, branch, leaf and node number plant^{-1}, stem, stover weight plant^{-1} and harvest index, yield attributes *viz.*, capsule number plant^{-1}, capsule length, seed number capsule^{-1}, 1000-seed weight and yield decreased with delay in sowing and yield became zero when sown in April due to death of plants at early stages due to heavy rainfall in May and June. The highest seed yield was observed when seeds were sown in 26 February due to attributed higher number of capsules plant^{-1} and seeds capsules^{-1}. The lowest seed yield was recorded in 28 March sowing. Among the cultivars, the highest seed yield was recorded in Binatil-1 (900 kg ha^{-1}). Results indicated that higher seed yield can be obtained by sowing of Binatil-1 and BARI Til-3 on 26 February while BARI Til-2 on 13 March. In contrast, the lowest seed yield was obtained in BARI Til-2 and BARI Til-3 with 28 March sowing (385 and 383 kg ha^{-1}, respectively).

Key words: Sesame, morphological characters, yield attributes.

Introduction

Sesame (*Sesamum indicum* L.) is an important oilseed in Bangladesh and is grown almost all regions in the country. It is the third largest source of edible oil in the country. Among the areas of oil crops, rapeseed/mustard, groundnut and sesame occupied 70, 18 and 12%, respectively of the total cropped area (MOA, 2015). The crop is grown both in summer and winter seasons in Bangladesh. The summer sesame covers about two-third of the total cropped area. The seeds of sesame contain 44-56% oil, 18-22% protein and 15-20% carbohydrate (Weiss, 1983). Sesame oil is mainly used for cooking and also used in the manufacture of perfumes, pharmaceuticals and insecticides (Sarker *et al.*, 2007). Hulled seed is used in baking industries. Sesame oil cake contains protein of high biological value and appreciable quantities of calcium and phosphorus and is used as animal feed and fertilizer. Oil crops play a vital role in human diet but the consumption rate is far below the balanced diet. To fulfil the requirement, the country has to increase its production to meet its internal demand. The area under oil crop may be increased for boasting its production with the adoption of appropriate technologies.

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Despite its versatile use and wide adaptability to the agro-environmental conditions of Bangladesh, the crop is still neglected both in the research and farmers levels. The climate and edaphic conditions of Bangladesh are quite suitable for its cultivation but contribution of sesame to total production is lesser due to its lower seed yield (680 kg ha^{-1}; MOA, 2015). The low yield of sesame is primarily due to poor management practices (Shubha, 2006). Successful production of the crop depends on quality seed and appropriate management practices. Among the various management practices, time of sowing is the single most important factor influencing the seed yield. Reports reveal that seed yield decreases both with delay or early planting than optimum date (Sivagamy and Rammohan, 2013). However, optimum planting time varies in different regions of Bangladesh depending upon onset of monsoon and specific photo-thermal requirement (Mondal, 2004). Research works on the effect of time of sowing on sesame are scanty. Sarkar *et al.* (2007) reported that last week of February sowing is best suited for getting maximum yield in sesame. On the other hand, Shubha (2006) reported that March sowing gave the highest seed yield in sesame. So, further research work is necessary to find out appropriate sowing date of sesame in Bangladesh. Considering the above background, the present study was undertaken to find out the effect of date of sowing on morphological characters, yield and yield attributes of sesame; and to observe the interaction effect of sowing dates and cultivars on morphological characters, yield and yield attributes of sesame.

Materials and Methods

The experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from 26 February to 17 June 2014. The experimental field was a medium high belonging to the Sonatola Soil Series of Grey Floodplain soil under the Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9). The soil was silty loam. The experimental field is under subtropical climate characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March. The maximum, minimun and average temperature range during the experimental period (February to June) are presented in Table 1.

The experiment comprised of three sesame varieties *viz.*, Binatil-1, BARI Til-2 and BARI Til-3 and five dates of sowing *viz.*, 26 February, 13 March, 28 March, 12 April and 27 April. The experiment was laid out in a split-plot design with three replications. Date of sowing was assigned to main plot and variety to the sub-plot. The size of the unit plot was 3.0m × 3.0m. Plant to plant and row to row distances were maintained at 5 cm and 30 cm, respectively. Urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate were applied at 100, 130, 50, 100 and 5 kg ha^{-1} (BARI, 2014). Total amount of TSP, MoP, gypsum, borax and half of urea were applied as basal dose while remaining half urea was top dressed at 25 days after sowing. Only one weeding was done manually at 15 days after sowing for each date of sowing. Among the five dates of sowing, the later two sowing dates i.e. 12 and 27 April, the crop died before reaching harvesting stage due to waterlogging by heavy rain. At maturity, harvesting was done only for the sowing dates of 26 February, 13 March and 28 March. Ten plants were randomly selected from each plot and tagged for recording necessary data. After sampling, the whole plot was harvested at maturity. The harvested crop was threshed, cleaned and sun-dried to a moisture content of 14% to record the seed yields and straw plot-wise and converted into tons hectare^{-1}. The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C (Russell, 1986).

Results and Discussion

The crop sown on 26 February, 13 March and 28 March reached maturity stage but the crops sown on 12 April and 27 April did not because they died at their vegetative stage due to heavy rain combing waterlogged condition (Table 1).

Table 1. Monthly recorded of air temperature, rainfall, relative humidity and sunshine hours of the experimental site during the period from February to June 2014

Months		Air temperature (^{0}C)			Total rainfall (mm)	Average relative humidity (%)	Total sunshine (hrs)
		Maximum	Minimum	Average			
February	01-07	24.21	13.74	18.97	0.00	80.57	6.90
	08-15	26.56	15.96	21.26	00.0	76.86	7.20
	16-22	27.00	14.81	20.91	0.10	72.00	9.06
	23-28	27.34	15.46	21.40	0.00	71.43	9.57
March	01-07	28.40	17.80	23.10	0.00	69.86	8.51
	08-15	26.50	16.40	21.45	19.0	75.63	6.63
	16-23	28.50	18.45	23.48	2.10	76.75	7.39
	24-31	29.44	20.02	24.73	92.9	78.63	7.14
April	01-07	30.41	20.33	25.37	0.00	78.86	7.46
	08-15	32.84	23.01	27.93	22.0	78.12	8.86
	16-22	30.56	22.14	26.35	51.8	82.57	6.04
	23-30	31.56	22.62	27.09	61.4	81.00	6.91
May	01-07	31.54	23.73	27.64	39.0	85.57	3.54
	08-15	32.80	23.71	28.25	20.4	77.25	7.95
	16-23	32.84	23.34	28.09	102	79.75	7.99
	24-31	32.55	23.50	28.03	104	82.50	6.29
June	01-07	32.54	24.73	28.64	35.0	87.50	5.54
	08-15	33.40	24.31	28.85	20.4	87.27	6.95
	16-23	33.84	24.54	29.19	112	79.75	7.99
	24-30	33.25	24.20	28.73	124	82.51	6.69

Source: Weather Yard, Department of Irrigation and Water Management, BAU, Mymensingh

Effect of date of sowing on morphological characters:

Results indicated that the plant height decreased with delay in sowing of all varieties (Fig. 1). The pattern of increase of plant height for the first two sowing was almost similar (Fig. 1). Although delayed sowing decreased plant height, it was very much severe for the last three sowings. The highest plant height was recorded in 26 February sowing (101.8 cm) followed by 13 March sowing (95.4 cm). The lowest plant height was observed in 27 April sowing (27.8 cm). However, at early growth stages, increased plant growth was observed under delayed sowing and finally at harvest, the plant height was shorter compared to earlier sowing. This might be related to ambient temperature and available soil moisture for plant growth and development during April sowing. It was observed that air temperature and soil moisture increased from February to May followed by no significant changes in June (Table 1). So, April sowing plants got higher air temperature and soil moisture at early growth stages compared to February and March sowing which enhanced plant growth and development. Mentionable that 12 and 27 April sowing plants died before fruit setting due to heavy rainfall causing waterlogged (Table 1). Similar result was also reported by Sarkar *et al.* (2007) in sesame where sesame plant height decreased with delayed sowing.

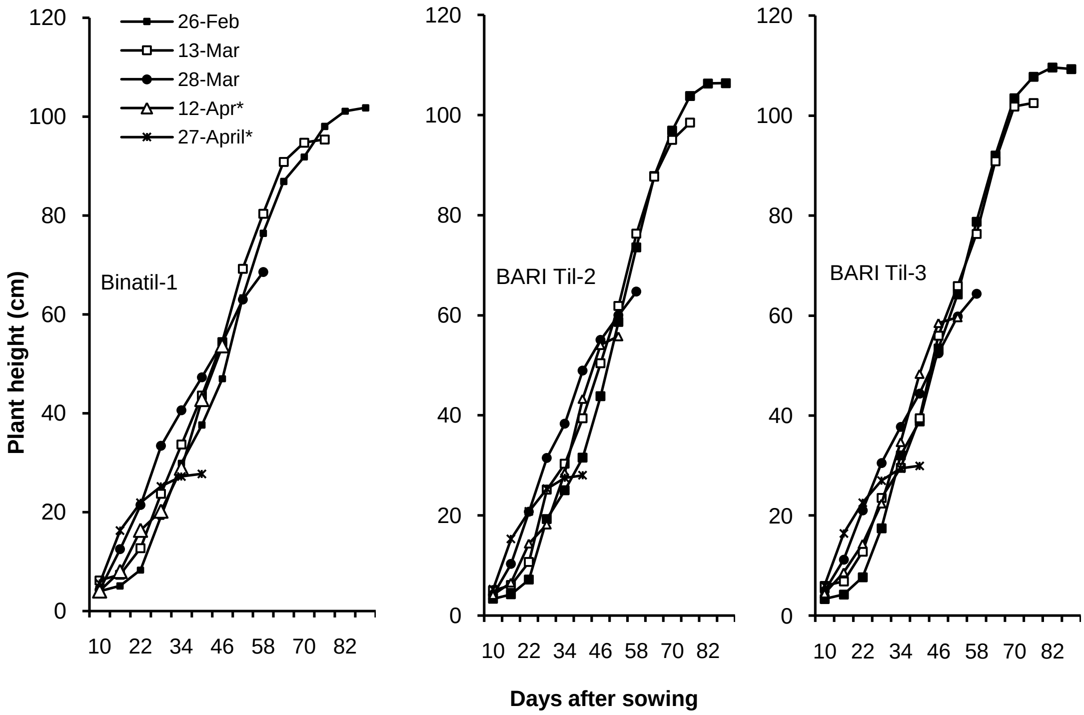

Fig. 1. Seasonal pattern of plant height of three sesame varieties *viz.*, Binatil-1, BARI Til-2 and BARI Til-3 under five date of sowing. (The crop sown on 12 and 27 April died at about 40 and 60 days after sowing, respectively).

The number of leaves plant^{-1} increased slowly until 34 days after sowing (DAS) then increased rapidly up to 76-80 DAS and followed by declined at maturity (Fig. 2) due to leaf shedding. The number of leaves plant^{-1} decreased with delay sowing in all the cultivars. In Binatil-1, the highest number of leaves was recorded in 13 March sowing followed by 26 February. On the other hand, in BARI Til-2 and BARI Til-3, the highest number of leaves was recorded in 26 February sowing followed by 13 March. The lowest number of leaves plant^{-1} was observed in 27 April sowing in all the varieties. However, at early growth stages, increased leaf number was observed under late sowing compared to earlier sowing. This is because of higher plant growth and development for late sowing (Fig. 1). Similar result was also reported by Ali *et al.* (2005) in sesame.

Number of nodes plant^{-1} increased over the growing period. The highest number of nodes plant^{-1} was found in 26 February sowing then decreased with delay in sowing due to shorter plant height (Fig. 3). The highest number of nodes plant^{-1} was observed in 26 February sowing in all varieties due to production of taller plant. In contrast, the lowest number of nodes plant^{-1} was recorded in plants from 27 April sowing in all the varieties. The lower number of nodes plant^{-1} was observed in delayed sowing that might be due to its growth retardation by the heavy rainfall that might have caused root rott under saturated field condition (Sarkar *et al*., 2007). Similar result was also reported by Ghosh and Bagdi (1986) in sesame.

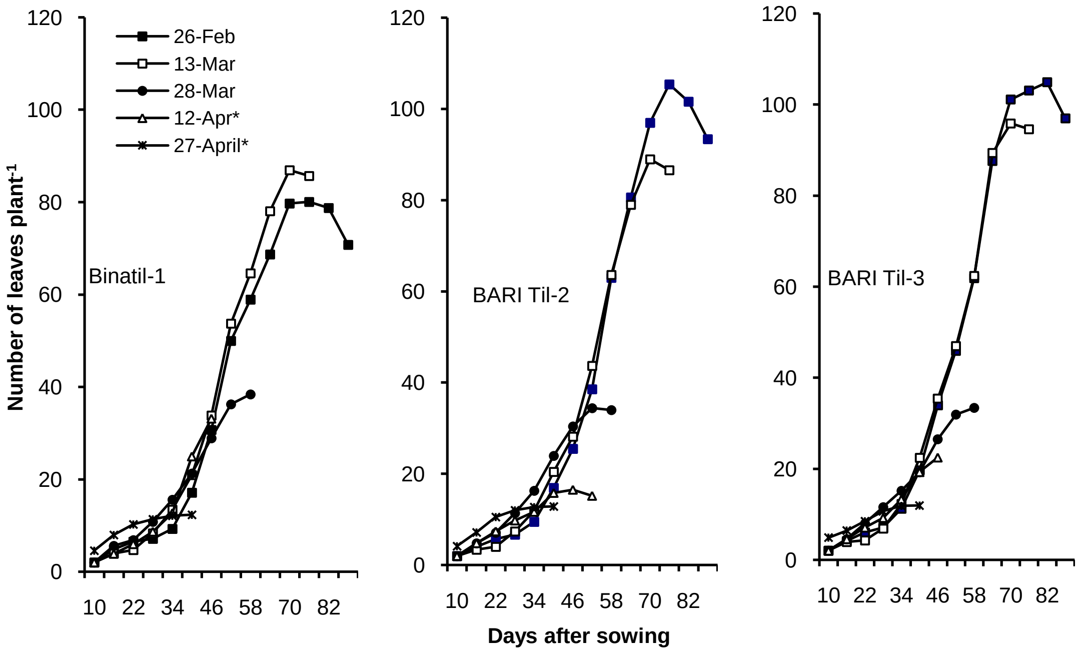

Fig. 2. Seasonal pattern of leaf production of three sesame varieties *viz*., Binatil-1, BARI Til-2 and BARI Til-3 under five date of sowing. (The crop sown on 12 and 27 April died at about 40 and 60 days after sowing, respectively).

The effect of date of sowing on stem, shell and stover weight was significant except harvest index (Table 2). Results indicated that stem, shell and stover weigh decreased with delay sowing. The highest number of branches and nodes plant^{-1} (23.55), the highest stem and stover weight was observed in 26 February sowing and the lowest was recorded in 28 March sowing (14.84) (Table 2).

Table 2. Effect of sowing date and cultivar on morpho-physiological characters of sesame

Treatments	Plant height (cm)	Nodes plant^{-1} (no.)	Branches plant^{-1} (no.)	Stem wt. plant^{-1} (g)	Shell wt. plant^{-1} (g)	Stover weight (t ha^{-1})	Harvest index (%)
Sowing date							
26 February	102.4 a	23.55 a	2.91 a	7.61 a	1.00 a	8.61 a	15.23
13 March	103.6 a	19.16 b	2.53 b	7.20 b	1.03 a	8.23 a	14.75
28 March	70.59 b	14.84 c	2.87 ab	3.11 c	0.43 b	3.54 b	13.63
Level of significance	**	**	*	**	**	**	NS
Variety							
Binatil-1 (V_1)	91.14	16.76 b	0.40 c	5.74 b	0.73 b	6.47	15.26 a
BARI Til-2 (V_2)	93.54	20.53 a	4.82 a	6.50 a	0.81 b	7.31	13.59 b
BARI Til-3 (V_3)	91.92	20.27 a	3.09 b	5.68 b	0.91 a	6.59	14.77 a
Level of significance	NS	**	**	**	**	NS	**
CV (%)	2.78	7.37	11.31	7.97	9.89	9.59	6.62

In a column, figure (s) having same letter do not differ significantly at 5% level as per DMRT;
*, ** indicate significant at 5% and 1% level of probability, respectively;
NS = Not significant; †: 12 and 27 April sowing plants died at early growth stages due to heavy rainfall.

Effect of variety on morphological characters:

The variation in number of branches and nodes plant^{-1}, stem and shell weight, and harvest index among the varieties was statistically significant except plant height and stover weight (Table 2). The highest number of nodes and branches plant^{-1}, the highest plant height, stem, stover weight was recorded in BARI Til-2 followed by BARI Til-3. The lowest number of branches and nodes plant^{-1} was observed in Binatil-1. Variation in number of nodes and branches plant^{-1} could be related to varietal characteristics. Binatil-1 produced fewer number branches plant^{-1} (Table 2) which resulted lower number of nodes plant^{-1}. Less or no branch producing plant is desirable in sesame because unicum plant has the capacity to show synchrony capsules maturation. On the other hand, branched plant shows asynchrony in capsule maturity. This is because of branches starts flowers after 70-80 % finishing of flowering by the main stem. In that context, Binatil-1 is the best variety for synchronous pod maturity. Further, harvest index indicating the efficiency of dry matter partitioning to economic yield. In the present experiment, the highest harvest index was observed in Binatil-1 which means that Binatil-1 has the better capacity to dry matter partitioning to economic yield which is the desirable character.

Effect of date of sowing on yield contributing characters and yield:

Significant effect of date of sowing was also found on seed yield and related traits (Table 3). Results revealed that total, fertile and unfertile capsule number, capsule length, number of filled and unfilled seeds capsule^{-1}, 1000-seed weight and seed yield decreased with delay sowing. The highest yield and related traits was recorded in 26 February sowing followed by 13 March sowing. In contrast, the lowest yield attributes was recorded in 28 March sowing. Mentionable that plant died when sown April or later due to heavy rainfall. Reduced number of capsules plant^{-1} under delay sowing condition might be due to production of lower number of nodes plant^{-1} (Fig. 3). Similar result was also reported by many researcher (Suryavanshi *et al*., 1990; Sukhadi and Dhoble, 1990; Suryavanshi *et al*., 1993; Tiwari *et al*., 1994; Ali *et al*., 2005). They observed that capsule number plant^{-1} decreased with delay in sowing. The capsule length decreased with delay sowing might be due to the fact that late sown plants get less time for growth and development and had less assimilate available for capsule growth (Figs. 1-3). Here, early sown plants produced more seeds capsule^{-1} than the later sowing plants indicating early sowing helped plants to produce more assimilates which helped to set more fertile seeds capsule^{-1}. It is possible because of early sown plant has capacity to produce more leaves than the delay sowing plants (Fig. 2).

Table 3. Effect of sowing date and cultivar and their interaction on yield and related traits in sesame

Treatments	Total capsules plant^{-1} (no.)	Fertile capsules plant^{-1} (no.)	Unfertile capsules plant^{-1} (no.)	Capsule length (cm)	Filled seeds capsule^{-1} (no.)	Unfilled seeds capsule^{-1} (no.)	1000-seed weight (g)	Seed yield plant^{-1} (g)	Seed yield (kg ha^{-1})
Sowing date									
26 February (D_1)	64.71 a	46.00 a	18.71 a	2.75 a	52.09 a	22.72 a	2.60 a	4.46 a	1059.4 a
13 March (D_2)	56.13 b	46.07 a	10.98 b	2.82 a	50.00 a	16.24 b	2.32 b	3.70 b	986.94 c
28 March (D_3)	28.02 c	17.29 b	10.07 b	1.53 b	25.37 b	11.89 b	2.11 c	2.04 c	456.44 d
Variety									
Binatil-1 (V_1)	48.00 b	33.31 c	13.84 a	2.70 a	43.24 b	16.81 b	2.71 a	3.27	900.2 a
BARI Til-2 (V_2)	49.91 ab	36.44 b	13.47 a	2.54 b	49.52 a	19.49 a	2.10 b	3.53	779.1 c
BARI Til-3 (V_3)	51.04 a	40.60 a	11.44 b	1.87 c	35.70 c	14.55 c	2.21 b	3.40	823.5 c
Interaction									
D_1V_1	63.60 ab	43.33 b	20.27 a	3.52 a	55.62 bc	22.43 b	2.78	4.51 a	1141.2 a
D_1V_2	67.00 a	46.33 a	20.67 a	2.87 b	58.83 ab	26.32 a	2.41	4.43 a	890.3 c
D_1V_3	63.53 ab	49.33 a	14.20 b	1.85 d	42.81 d	19.42 c	2.54	4.43 a	1146.7 a
D_2V_1	54.40 c	42.13 b	12.00 b	2.79 b	50.15 c	15.57 d	2.74	3.55 b	957.8 c
D_2V_2	59.27 bc	49.27 a	10.00 c	3.47 a	61.49 a	18.81 c	2.05	3.84 b	1062.5 b
D_2V_3	54.73 c	47.80 a	9.93 c	2.19 c	39.37 d	14.33 de	2.17	3.70 b	940.5 c
D_3V_1	25.73 e	14.47 d	9.27 c	1.75 d	23.95 e	12.43 ef	2.59	1.75 d	601.7 d
D_3V_2	23.47 e	13.73 d	9.73 c	1.28 e	28.25 e	13.33 de	1.83	2.31 c	384.5 e
D_3V_3	34.87 d	24.67 c	10.2 c	1.57 de	24.92 e	9.92 f	1.92	2.07cd	383.2 e
CV (%)	5.34	5.58	8.08	7.90	8.03	8.81	6.27	6.77	4.93

In a column, same figure(s) do not differ significantly at $P \leq 0.05$ as per DMRT;
†: The crop sown on 12 and 27 April died at about 40 and 60 DAS due to heavy rainfall causing waterlogged condition.

This result is consistent with the result of Ali *et al*. (2005) in sesame who reported that number of filled seeds capsule^{-1} decreased with delay in sowing. Reduced 1000-seed weight for delay in sowing might be due to lower amount of assimilates translocation from leaf to capsule. Similar result was also reported by many researchers (Chimanshette and Dhoble, 1992; Sarker *et al.,* 2007; Ogundare *et al.,* 2015).

Yield was zero in April sowing due to plant died before setting capsule for heavy rainfall (Appendix II). Reduced seed weight plant^{-1} as well as seed yield (kg ha^{-1}) under late sowing condition due to lower number of capsules plant^{-1} (Table 3). Similar result was also reported by Sarker *et al*. (2007) in sesame.

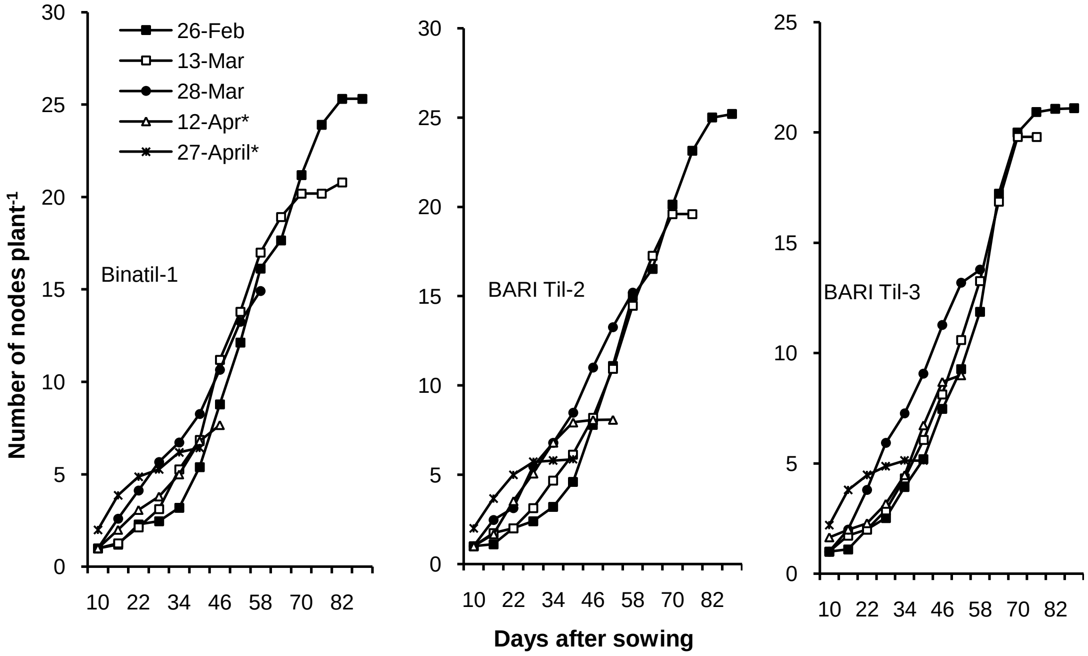

Fig. 3. Effect of date of sowing on node number at different growth stages of sesame cultivars *cv*. Binatil-1, BARI Til-2 and BARI Til-3. (The crop sown on 12 and 27 April died at about 40 and 60 days after sowing, respectively).

Effect of variety on yield contributing characters:

The effect of varieties on yield attributes and seed yield was significant except seed weight plant^{-1} (Table 3). The highest number of fertile capsules plant^{-1} was observed in BARI Til-3 with lowest number of seeds capsule^{-1} while the highest filled seeds capsule^{-1} was recorded in BARI Til-2. It is mentionable that although Binatil-1 performed inferiority in yield attributes except seed size but showed the highest seed yield per unit area basis due to greater number of plants accommodation within a unit area for its unicum canopy stature compared to BARI Til-2 and BARI Til-3. The lowest seed yield per unit area was recorded in BARI Til-2 due to smaller size seeds.

Interaction between variety and date of sowing on yield attributes and seed yield:

Interaction of sowing dates and varieties had significant effect on all yield attributes except seed size (Table 3). The highest seed weight plant^{-1} and seed yield ha^{-1} was observed in Binatil-1 when sown on 26 February (4.51 g plant^{-1} and 1141 kg ha^{-1}) which was statistically similar to BARI Til-3 × 26 February sowing (4.43 g plant^{-1} and 1137 kg ha^{-1}). In contrast, the lowest seed yield was observed in BARI Til-2 and BARI Til-3 with 28 March sowing (385 and 383 kg ha^{-1}, respectively). Results further revealed that Binatil-1 performed the best in seed yield under late sowing condition indicating Binatil-1 was more stable in producing seed yield than BARI Til-2 and BARI Til-3 under different dates of sowing from February to March.

From the results, it could be concluded that all the three varieties performed better in early sowing i.e. last week of February or first week of March followed by a decline and yield was near to zero in April sowing. Among the studied varieties, higher yield can be obtained by sowing of Binatil-1 and BARI Til-3 at 26 February while BARI Til-2 at 13 March.

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EFFECT OF DROUGHT STRESS ON PHOTOSYNTHESIS, STOMATAL CONDUCTANCE, TRANSPIRATION AND YIELD OF MUNGBEAN GENOTYPES UNDER HIGH TEMPERATURE

M. T. Islam

Abstract

Climate is changing and air temperature is rising due to increasing concentration of CO_2 and other atmospheric greenhouse gases. Drought is one of the most prevalent forms of abiotic environmental stress that reduce crop productivity. An experiment was conducted with six mungbean (*Vigna radiata* L. Wilczek) mutants *viz*., MI-12, MM-1, MM-11, MM-2, MM-5, MM-8 along with Binamoog-8 at Bangladesh Institute of Nuclear Agriculture during March-May, 2021 to assess the effect of drought at flowering stage of the mungbean genotypes under high temperature. Plants were grown in ambient temperature and during flowering stage those were kept in plant growth chamber at 38 ^{0}C for 24 hrs under different soil moisture levels (80, 60 and 40% FC) in pot soil. After high temperature treatment, the plants were allowed to complete the maturity under sufficient soil moisture (80% FC) at ambient temperature. The experiment was laid out in a randomized complete block design with three replications. Data on photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance, transpiration were recorded during stress imposition and yield and yield attributes were recorded at maturity. Under the temperature treatment photosynthesis, Fv/Fm, stomatal conductance, transpiration rate, water use efficiency and yield decreased significantly with the decrease of soil moisture levels. Photosynthesis, Fv/Fm, stomatal conductance, transpiration rate water use efficiency and yield decreased 10.10, 2.35, 7.40, 3.24, 7.16 and 34.87, respectively at 60% FC and 14.35, 7.05, 18.51, 10.81, 15.30 and 62.73%, respectively, at 40% FC compared to control. The mutants MM-5 and MM-8 showed better performance under drought and high temperature.

Key words: Drought, temperature, photosynthesis, Fv/Fm, stomatal conductance, transpiration, water use efficiency, mungbean yield

Introduction

Drought is a multidimensional complex stress, simultaneously disturbing the physiological, morphological, biochemical, and molecular states which control the growth and quality of the crop and ultimately crop productivity (Basu *et al*., 2016). This situation has been aggravated worldwide as drought-stressed areas are expanding rapidly due to uneven rainfall, limited water sources, and other rapid and drastic changes in global environmental conditions (Fahad *et al*., 2017). Mungbean (*Vigna radiata* L. Wilczek) is one of the most important crops of global economic importance. The raw and mature seeds are rich in nutrients including carbohydrates, protein, fibers, minerals, antioxidants

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like flavonoids (Quercetin-3-Oglucoside), and phenolics (Guo *et al*., 2012). In addition to being the prime source of human food and animal feed, it plays an important role in maintaining the soil fertility by enhancing the soil physical properties and fixing atmospheric nitrogen (Naik *et al*., 2020). Despite being an economically important crop, overall production of mungbean is low (838 kg ha^{-1}) (BBS, 2021) due to abiotic and biotic stresses (Islam *et al*., 2006; Bangar *et al*., 2018). It has raceme type of inflorescence with asynchronous flowering. The number of fruits with developing seeds increases after fruit setting stage and reaches to maximum seed growth stage but during this period the plant is still growing vegetative. Therefore, developing reproductive sinks are competing for assimilates with vegetative sinks. Number of fruits and seeds is related with photosynthetic rate that determines through leaf area and dry matter production (Islam and Razzaque, 2010). Per cent solar radiation interception and rate of dry matter production increased with leaf area development (Hamid *et al*., 1990). Mungbean yield is predetermined by the potential of a given variety and the environment. Pulse crops are generally cultivated during the dry season, when water deficit or unavailability of soil moisture is a common occurrence (Islam *et al*., 2005; Islam and Razzaque, 2007). Soil moisture is an essential requirement which regulates physiological growth processes and yield of plants. However, different crop cultivars have different ability to respond to drought conditions in terms of growth and development. Amelioration of drought environment through management practices like irrigation, mulching etc. are costly involvement and sometimes quite impossible for the poor economic conditions of the farmers. The best alternative is thus developing/screening of drought tolerant cultivars for the moisture deficit areas of the country. However, mungbean varieties respond variably to drought stress depending on stress duration, growth stage, and variety of the crop. Optimum temperature for potential yield of mungbean lies between 28-30^{o}C (Poehlman l99l). High temperature (36^{o}C) at pre-flowering and flowering stages decreases photosynthetic rate, biomass and yield in mungbean (Islam 2018 and Islam 2015). Increases in temperature resulted in changes in the fluorescence parameters in two varieties of beans, but to a different extent (Pastenes and Horton 1996). In Bangladesh, summer mungbean is generally cultivated in March-May and high temperature (34-38 ^{o}C) often affects its growth and yield. But information regarding their tolerance to high temperature is less. When physiological basis of yield and yield-forming components under drought and temperature stress are understood, it is possible to improve yields of a mungbean crop. So, effect of drought on seven mungbean genotypes under high temperature was investigated with respect to photosynthetic related parameters and yield.

Materials and methods

A pot experiment was conducted at the pot yard of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. The experimental site falls under the AEZ (Agro-Ecological-Zone)-9 (Old Brahmaputra Floodplain) of Bangladesh and situated at latitude 24.75°N and longitude of 90.50°E. The soils of the experiment were collected from the field of BINA Farm. The top soil was non-calcareous Dark Grey

Floodplain with loamy texture belonging to the AEZ Old Brahmaputra Floodplain. The collected soil was pulverized, inert materials, visible insect pest and plant propagules were removed. Pots are filled with top soils. The pot was 25 cm deep with 27 cm diameter at the top. The soil moisture stresses were calculated based on field capacity (FC). Gravimetric Method determined FC. FC of the soil was treated as 100% FC and 80% of FC (control), 60 and 40% were used as drought stress. Each pot contained 12 kg soil. All soils pots were fertilized with Urea, TSP and MoP @ 0.40, 0.70 and 0.40 g pot^{-1} corresponding @ 40, 70 and 40 kg ha^{-1}, respectively. All fertilizers were applied as basal dose. The experiment was carried out with six mutants *viz*., MI-12, MM-1, MM-11, MM-2, MM-5, MM-8 along with Binamoog-8 of mungbean. Seeds were sown in pots on first March 2021. Five seeds were sown in each pot and finally one plant was allowed to grow for treatment imposition and data collection. The experiment was set in a two factorial RCBD with three replications. The first factor was mungbean genotypes and the second factor was irrigations: control (80% FC) and drought (60 and 40% FC) stress treatments. Cultural practices were followed as and when required. Plants were grown in ambient temperature and during flowering stage those were kept in plant growth chamber at 38 ^{0}C for 24 hrs under different soil moisture levels (80, 60 and 40% FC) in pot soil. Then all the plants were allowed to complete the maturity under sufficient soil moisture (80% FC) at ambient temperature. Data on photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance and transpiration and water use efficiency were recorded from 9 plants of each genotype during stress imposition using Portable Photosynthesis System (Li-6800, LI-COR, USA). At maturity, data on plant height, pods plant^{-1}, seeds pod^{-1}, 1000-seed weight and seed weight plant^{-1} were recorded. Statistical analysis was done and DMRT test adjusted the means.

Results and Discussion

Results revealed that photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance, transpiration rate and water use efficiency of mungbean genotypes decreased with the decrease of soil moisture levels under high temperature at flowering stage (Table 1-2). Under the temperature treatment photosynthesis, Fv/Fm, stomatal conductance, transpiration rate and water use efficiency decreased 10.10, 2.35, 7.40, 3.24 and 7.16%, respectively at 60% FC and 14.35, 7.05, 18.51, 10.81 and 15.30% respectively, at 40% FC compared to control. The results are in consistent with Islam 2018 and Islam 2015. The highest values of plant height, yield and yield attributes were found in control condition (80 %FC) and those were gradually decreased at 60 and 40 %FC (Table 3-4). Under the temperature treatment plant height, pods plant^{-1}, seed pod^{-1}, 1000-seed weight and seed yield plant^{-1} decreased 7.31, 5.65, 20.72, 15.28 and 34.87%, respectively at 60% FC and 19.11, 27.38, 37.07, 20.93 and 62.73%, respectively at 40% FC compared to control. The results revealed that yield and yield contributing characters decreased severely with the increasing level of water stress. The results are in conformity with Singh and Singh 2011; Pooja *et al*. 2019; Kumar *et al*. 2020. The seed yield of mungbean crop is a function of cumulative effect of various yield components, which are influenced by the genetic make-up of variety, various agronomic practices, and environmental conditions (Yuliasti and Reflinur, 2015). Drought stress is considered as one of the most devastating environmental stresses affecting crop production globally. Mungbean grows mainly in rain-fed conditions at high temperatures (27-30 ^{o}C), with low humidity and moderate rainfall from 60 to 80 cm (Kumar *et al*. 2020). Due to this, it faces stress at different development stages and it thrives under drought conditions. Morpho-physiological parameters, yield attributes and yield of mungbean genotypes significantly decrease with drought stress (Islam *et al*. 2005; Islam *et al*. 2006; Sunayana *et al*. 2016). High temperature disrupts water, ion and organic solute movement across plant membranes which interfere with photosynthesis and respiration. High temperature stress causes direct negative impact on flower retention in mungbean (flower shading up to 79%) and consequently on pod formation (Kumari and Verma, 1983). Photosynthesis, stomatal conductance, stem weight, total dry matter production and yield decrease with high temperature (36^{o}C) at pre-flowering, flowering and pod filling stage of mungbean genotypes (Islam, 2015; Islam, 2018). Although mungbean yield is not always directly related with photosynthesis, however, related with leaf area and total dry matter production and high yielding mutants may have higher photosynthesis with higher water use efficiency (Islam and Razzaque, 2010). Decreased plant height under stress might be due to lower cell division under stress condition. The highest yield in control was due to higher number of pods plant^{-1}, seeds pod^{-1} and seed size (1000-seed weight). The mungbean genotypes responded variably to drought stress. The genotypes MM-8 and MM-5 had higher values in most of the photosynthetic parameters and yield.

Table 1. Effect of water stress on photosynthesis, Fv/Fm, stomatal conductance, transpiration and water use efficiency of mungbean genotypes under high temperature

Treatment	Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)	Fv/Fm	Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$)	Transpiration ($mmolH_2Om^{-2}s^{-1}$)	Water use efficiency
Control	26.33 a	0.85 a	0.27 a	3.70 a	7.12 a
60 %FC	23.67 b	0.83 b	0.25 b	3.58 b	6.61 b
	(10.10)	(2.35)	(7.40)	(3.24)	(7.16)
40 %FC	19.95 c	0.79 c	0.22 c	3.30 c	6.03 c
	(14.35)	(7.05)	(18.51)	(10.81)	(15.30)
CV (%)	4.20	2.60	2.78	0.77	4.04
Genotype					
Binamasur-8	22.67 cd	0.80 b	0.25 b	3.51 c	6.43 cd
MI-12	22.00 d	0.80 b	0.23 d	3.47 d	6.32 d
MM-1	23.22 c	0.82 b	0.24 bc	3.50 c	6.61 c
MM-11	21.89 d	0.80 b	0.24 cd	3.52 c	6.19 d
MM-2	22.00 d	0.81 b	0.24 bc	3.47 d	6.32 d
MM-5	24.67 b	0.87 a	0.26 a	3.59 b	6.86 b
MM-8	26.78 a	0.85 a	0.27 a	3.63 a	7.38 a
CV (%)	4.20	2.60	2.78	0.77	4.04

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Figures within parenthesis indicate % decrease at 60 and 40% FC compared to control.

Table 2. Combined effect of water stress and mungbean genotypes on photosynthesis, Fv/Fm, stomatal conductance, transpiration and water use efficiency under high temperature

Genotype×Treatment	Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)	Fv/Fm	Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$)	Transpiration ($mmolH_2Om^{-2}s^{-1}$)	Water use efficiency
Binamasur-8×Control	26.00 bcd	0.82 efg	0.27 bc	3.70 bc	7.03 cd
Binamasur-8×60% FC	23.00 ghi	0.82 efg	0.25 efg	3.58 ef	6.42 ef
	(11.53)	(0)	(7.40)	(3.24)	(8.67)
Binamasur-8×40% FC	19.00 jk	0.76 i	0.22 i	3.25 i	5.85 ghi
	(26.92)	(7.31)	(18.51)	(12.16)	(16.78)
MI × Control	25.33 de	0.82 efg	0.26 def	3.66 cd	6.93 cd
MI-12 × 60% FC	22.33 hi	0.81 efg	0.24 h	3.53 g	6.33 ef
	(11.84)	(1.21)	(7.69)	(3.55)	(8.65)
MI-12 × 40% FC	18.33 jk	0.77 hi	0.21 i	3.22 i	5.69 hi
	(27.63)	(6.09)	(19.23)	(12.02)	(17.89)
MM-1 × Control	26.33 bcd	0.87 bc	0.27 bcd	3.70 bc	7.12 bc
MM-1 × 60% FC	23.67 fgh	0.81 efg	0.25 fgh	3.55 fg	6.66 de
	(10.10)	(6.89)	(7.40)	(4.05)	(6.46)
MM-1 × 40% FC	19.67 j	0.77 hi	0.22 i	3.26 i	6.04 fgh
	(25.29)	(11.49)	(18.51)	(11.89)	(15.16)
MM-11 × Control	25.67 cde	0.81 efg	0.26 cde	3.71 b	6.92 cd
MM-11 × 60% FC	22.00 i	0.82 efg	0.24 gh	3.59 ef	6.13 fg
	(14.29)	(0)	(7.69)	(3.23)	(11.41)
MM-11 × 40% FC	18.00 k	0.77 hi	0.21 i	3.26 i	5.52 i
	(29.87)	(4.93)	(19.23)	(12.12)	(20.23)
MM-2 × Control	25.33 de	0.83 def	0.27 bcd	3.65 d	6.94 cd
MM-2 × 60% FC	22.33 hi	0.82 efg	0.25 fgh	3.51 g	6.36 ef
	(11.84)	(1.20)	(7.40)	(3.83)	(8.35)
MM-2 × 40% FC	18.33 jk	0.79 ghi	0.22 i	3.24 i	5.65 hi
	(27.63)	(4.81)	(18.51)	(11.23)	(1.29)
MM-5 × Control	27.00 bc	0.91 a	0.28 ab	3.70 b	7.29 abc
MM-5 × 60% FC	25.00 def	0.86 cd	0.27 bcd	3.63 de	6.89 cd
	(7.40)	(5.49)	(3.57)	(1.89)	(5.48)
MM-5 × 40% FC	22.00 i	0.84 cde	0.25 fgh	3.43 h	6.41 ef
	(18.51)	(7.69)	(10.71)	(7.29)	(12.07)
MM-8 × Control	28.67 a	0.90 ab	0.28 a	3.77 a	7.60 a
MM-8 × 60% FC	27.33 ab	0.86 bcd	0.27 ab	3.65 d	7.49 ab
	(4.67)	(4.44)	(3.57)	(3.18)	(1.44)
MM-8 × 40% FC	24.33 efg	0.80 fgh	0.25 efg	3.46 h	7.03 cd
	(15.13)	(11.11)	(10.71)	(8.22)	(7.50)
CV (%)	4.20	2.60	2.78	0.77	4.04

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Figures within parenthesis indicate % decrease at 60 and 40% FC compared to control.

Table 3. Effect of water stress on yield and yield components of mungbean genotypes under high temperature

Treatment	Plant height (cm)	Pods plant^{-1}	Seed pod^{-1}	1000-seed wt. (g)	Seed wt. plant^{-1} (g)
Control	47.04 a	15.74 a	10.52 a	39.27 a	6.28 a
60% FC	43.60 b	14.85 b	8.34 b	33.31 b	4.09 b
	(7.31)	(5.65)	(20.72)	(15.28)	(34.87)
40% FC	38.05 c	11.43 c	6.62 c	31.05 c	2.34 c
	(19.11)	(27.38)	(37.07)	(20.93)	(62.73)
CV (%)	6.30	9.06	5.29	1.96	10.21
Genotypes					
Binamasur-8	43.62 b	12.08 c	9.14 b	30.26 f	3.46 c
MI-12	48.69 a	13.20 c	8.07 cd	38.96 b	4.40 b
MM-1	44.33 b	14.42 b	7.48 e	39.78 a	4.37 b
MM-11	42.62 b	10.76 d	8.36 c	35.06 d	3.37 c
MM-2	36.64 c	12.56 c	7.80 de	33.38 e	3.47 c
MM-5	42.33 b	14.56 b	9.76 a	38.01 c	5.49 a
MM-8	42.02 b	20.49 a	8.87 b	26.38 g	5.09 a
CV (%)	6.30	9.06	5.29	1.96	10.21

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Figures within parenthesis indicate % decrease at 60 and 40% FC compared to control.

Table 4. Combined effect of water stress on yield and yield attributes of mungbean genotypes under high temperature

Interaction	Plant height (cm)	Pods plant^{-1}	Seed pod^{-1}	1000-seed weight (g)	Seed weight plant^{-1} (g)
Binamasur-8 × Control	47.87 bc	13.07 ef	11.10 ab	32.97 ij	4.78 ef
Binamasur-8 × 60% FC	44.00 cde	13.07 ef	9.00 efg	30.17 lm	3.54 gh
	(8.08)	(0)	(18.91)	(8.49)	(25.94)
Binamasur-8 × 40% FC	39.00 fghi	10.10 gh	7.33 j	27.63 n	2.05 jk
	(18.52)	(22.72)	(39.96)	(16.19)	(57.11)
MI × Control	54.73 a	14.87 cde	9.87 cd	44.97 a	6.59 c
MI-12 × 60% FC	48.67 b	14.87 cde	8.00 hik	37.57 ef	4.46 f
	(11.07)	(0)	(18.94)	(16.45)	(32.32)
MI-12 × 40% FC	42.67 defgh	9.87 h	6.33 k	34.33 gh	2.14 jk
	(22.03)	(33.62)	(35.86)	(23.66)	(67.52)
MM-1 × Control	49.13 b	13.40 def	9.70 cde	45.50 a	5.90 cd
MM-1 × 60% FC	46.20 bcd	16.20 c	7.73 ij	38.40 de	4.79 ef
	(5.96)	(0)	(22.30)	(15.60)	(18.81)
MM-1 × 40% FC	37.67 i	13.67 def	5.00 l	35.43 g	2.42 ij
	(23.32)	(0)	(48.45)	(22.13)	(58.98)
MM-11 × Control	46.87 bcd	12.07 fg	10.40 bc	41.07 c	5.17 ef
MM-11 × 60% FC	43.33 def	12.07 fg	8.33 ghi	33.27 hi	3.35 gh
	(7.55)	(0)	(19.90)	(18.99)	(35.20)

Table 4. Continued.

Interaction	Plant height (cm)	Pods plant^{-1}	Seed pod^{-1}	1000-seed weight (g)	Seed weight plant^{-1} (g)
MM-11 × 40% FC	37.67 i	8.13 h	6.33 k	30.83 kl	1.60 k
	(19.62)	(32.64)	(39.13)	(24.93)	(69.05)
MM-2 × Control	40.27 efghi	13.73 def	10.07 cd	39.10 d	5.36 de
MM-2 × 60% FC	37.33 i	13.93 def	8.00 hij	31.93 jk	3.52 gh
	(7.30)	(0)	(20.55)	(18.33)	(34.32)
MM-2 × 40% FC	32.33 j	10.00 gh	5.33 l	29.10 m	1.53 k
	(19.71)	(27.16)	(47.07)	(25.57)	(71.45)
MM-5 × Control	45.33 bcd	15.33 cd	11.27 a	43.73 b	7.54 b
MM-5 × 60% FC	43.00 defg	15.33 cd	9.33 def	36.70 f	5.24 de
	(5.14)	(0)	(17.21)	(16.07)	(30.50)
MM-5 × 40% FC	38.67 ghi	13.00 ef	8.67 fgh	33.60 hi	3.67 g
	(14.69)	(15.19)	(23.07)	(23.16)	(51.32)
MM-8 × Control	45.07 bcd	27.73 a	11.27 a	27.53 no	8.59 a
MM-8 × 60% FC	42.67 defgh	18.50 b	8.00 hij	25.17 p	3.72 g
	(5.32)	(33.28)	(29.01)	(8.57)	(56.69)
MM-8 × 40% FC	38.33 hi	15.23 cd	7.33 j	26.43 o	2.95 hi
	(14.95)	(45.07)	(34.96)	(3.99)	(65.65)
CV (%)	6.30	9.06	5.29	1.96	10.21

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Figures within parenthesis indicate % decrease at 60 and 40% FC compared to control.

Conclusion

Photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance, transpiration rate, water use efficiency and yield of mungbean genotypes decreased with the decrease of soil moisture levels under high temperature at flowering stage. Among the mungbean genotypes, MM-5 and MM-8 showed better performance under drought and high temperature. So, these two mutants may be used for cultivation under drought and high temperature stress.

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GROWTH AND YIELD PERFORMANCE OF SEVEN RICE VARIETIES UNDER MODERATE SALINITY STRESS

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Abstract

Salinity is a major problem in the Southern part of Bangladesh that reduces the country's rice production. The present investigation was carried out at Bangladesh Institute of Nuclear Agriculture (BINA) Sub-station, Satkhira during Boro season (December-April) of 2020-21to evaluate five hybrid and two inbred salt tolerant rice varieties under moderatesalinity stress . Ontogenetic growth study revealed that all the rice varieties produced the highest number of leaves and tiller at 78 and 64 DAT (Days after Transplanting), respectively. Based on the morphological performance, hybrid rice namely Hira-2 followed by Tejgold and HYV rice namely Binadhan-10 produced the highest grain yield due to increased seed width, 1000 seed weight and total dry matter production. In addition, the seed width showed strong positive correlations with the grain yield and 1000-grain weight indicated an important trait for higher grain yield production in rice. Therefore, further studies are needed in different level of saline areas to identify the potential saline tolerant high yielding rice variety in boro season.

Key words: Morphological parameters, growth, salinity and Bororice.

Introduction

For being a staple food, its production is considered as the key factor for food security in Bangladesh. In the last 30 years, Rice production has doubled with the development of high yielding, short duration, stress-tolerant, resource responsive and semi-dwarf varieties (Chowhan *et. al.,* 2021). However, the threat of a food crisis remains because of increasing population, water insufficiency, shortage of labor, global climate change, pest/diseases infestation, increasing incidences of salinity, uneven distribution of rainfall, soil erosion, soil degradation etc. Above all, salinity is a major problem that hindering the rice production in the world especially in southern part of Bangladesh.

Salinity is most important abiotic stress that directly regulates the plant growth and affects grain yield production in rice. The coastal zone of Bangladesh covers nearly 20% of the total land and over 30% of the cultivable lands of the country and about 53% of coastal soils are salt-affected (Hasan *et. al.,* 2019). However, rice is very sensitive to salinity stress and is currently listed as the most salt sensitive cereal crop with threshold of 3 dSm^{-1} for most of the cultivated varieties (USDA, 2013). In Bangladesh, about 1.06 million hectares of arable lands are affected by soil salinity (SRDI, 2010). Salinity is a year-round problem in the coastal region for agricultural production; it is increasing rapidly in Khulna, Bagerhat and Satkhira districts of Bangladesh (Hasan *et. al.,* 2019).

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The yield performance of the cultivars could be influenced by the environments and to a point by genotype and environment (GE) interaction (Rasyad *et al.*, 2012). Therefore, Rabi crops and Boro rice are mostly affected within the coastal area due to salinity stress. Grain yield is the result of several components that are seriously affected by soil salinity and threatening country's food security (Abbas *et al.,* 2013). Grain yield losses may occur as a result of decreased growth of the vegetative parts and/or as a result of abnormalities in the reproductive process (Reddy *et al.,* 2017; Devi *et al.,* 2022). The degree of the response depends on stress severity and climatic conditions, as well as on the degree of genotype to salinity tolerance. Modern and high-yielding rice cultivars haven't been widely adopted in saline-prone areas where traditional varieties are still being cultivated by farmers because the cultivars can partly stand in waterlog and salt stress conditions; but they're low-yielding, photoperiod sensitive with long duration (Islam *et al.*, 2013).

Rice is moderately susceptible to salinity, since most rice plants are severely injured at an EC 8-10 dSm^{-1}. Yield losses due to salinity are amounted to 30-50 percent and our farmers normally grow local varieties due to unavailability of salt tolerant high yielding varieties (HYV). Therefore, to keep pace with the population growth and food productions, the yield per unit area needs to be increased for minimizing the yield gap. Appropriate salt tolerant high yielding varieties that can fit into the rice-growing ecosystem in the coastal areas of Bangladesh will boost up the country's rice production. Hybrid rice cultivars are getting popular across the coastalarea probably due to the homeostasis effect; earliness and better productivity which made them attractive to farmers; thus, growers became curious about crop diversification to extend their financial gain (Virmani and Kumar, 2004).

In Bangladesh, hybrid rice had higher productivity (20–25%) than HYV rice (Anwar *et al.,* 2021). Higher productivity of hybrid rice can render Bangladesh self-sufficient in rice (Yuan, 2012). Besides, the prices of hybrid rice are 5–10% lower, which resulted in lower profits than HYVvarieties. The farmers stated that the reasons for the decrease in hybrid rice areas were higher seed prices, greater vulnerability to insect infestation, lower market demand, and inferior quality of grain (Anwar*et al.,* 2021). So, farmers are interested to cultivate inbreed varieties that they preserve their seeds and cultivate further season.

The use of tolerant varieties can alleviate salinity problems in salt-affected rice-growing areas but this must be combined with other crop management technologies such as a suitable cropping schedule (Plaut *et al.,* 2013). Thus, it is urgent for the researchers and policy makers to search alternative techniques for better utilization of stress-prone areas, like screening of salt tolerant cultivars might be the best approach to bring salinity prone areas under cultivation and will ensure the country's food security. Moreover, little is known about varietal differences that can be exploited to improve salinity tolerance, especially in rice cropping systems. Screening of salinity tolerance based on agronomical parameters such as growth, yield and yield components has become a reliable method worldwide (Moradi and Ismail, 2007; Cha-Um *et al.,* 2010; El-Hendawy *et al.,* 2009). Thus, this experiment was carried out under moderate saline condition to know the morphological causes of yield variation and select boro rice varieties for higher grain yield production in the southern part of Bangladesh.

Materials and Methods

A field experiment was conducted at the saline prone area, BINA Sub-station farm, Binerpota, Satkhira (22^0 45' N and 89^0 6' E) under natural growth condition during Boro season in 2020-2021. There were7 rice varieties *viz*. 5 Hybrids-SL-8, Syngenta-1203, Hira-2, Tejgold, BRAC Hybrid-777; and 2 HYVs-Binadhan-10 and BRRI dhan67. Salinity level was taken randomly and 3 times in a month using EC meter (ECTestr11+, Spectrum Technologies, Inc.), then the average value was calculated.

The experiment was laid out in a randomized complete block design (RCBD) with 3 replications. The unit plot size was 4m × 3m. The varieties were randomly distributed among the plots. Seeds of all varieties were soaked in water for 24 hours and kept in dark condition for 48 hours. Seedling nurseries for each variety were prepared by pudding the soil. Finally, the sprouted seeds were sown on a well-prepared wet nursery bed on 20 December 2020. The land was prepared by two times ploughing with a power tiller and then all kind of weeds, stubbles and crop residues were removed from the field. The fertilizers were measured and applied according to the fertilizer recommendation guide of BARC (2018). During the final land preparation, the land was fertilized with full dose of TSP, Muriate of potash (MP), Gypsum and Zinc Sulphate. Urea was applied as top-dressing in three equal splits after 20, 35 and 50 days of transplanting. Finally, the forty days old seedlings of all tested varieties were uprooted and then transplanted in the experimental field following the layout. The height was measured from the five randomly selected seedlings of each variety using measuring scale. The single seedling per hill with spacing 20cm × 15cm was used for transplanting. Intercultural operations were done when necessary for ensuring rice growth and development.

The plot was observed regularly and the leaves and tillers number per plant were recorded with 7 days intervals at 50 DAT, 57 DAT, 64 DAT, 71 DAT, 78 DAT and 85 DAT from each experimental plot. For TDM, the single plant of each tested variety was collected from each experimental plot and then corresponding dry weights were recorded after oven drying at 80 ± 2 ºC for 72 hours.Finally, the crops were harvested on 09 May 2021 at 90% of the seeds attained yellow color. Prior to harvesting 5 randomly selected plants per plot excluding border rows were taken from each plot to collect data on yield contributing characters and then the rice of the full plot was harvested. Plot yield was recorded after threshing by a thresher and drying in the sun properly excluding the grains of sample plants. The rice yield adjusted to 14% moisture content and converted to t ha^{-1}. From the randomly harvested five hills, the following data were recorded plant height, total tillers $hill^{-1}$, flag leaf length, flag leaf width, panicle length, filled grainspanicle^{-1}, unfilled grains panicle^{-1}, seed length, seed width, 1000-seed weight and grain yield (t ha^{-1}).

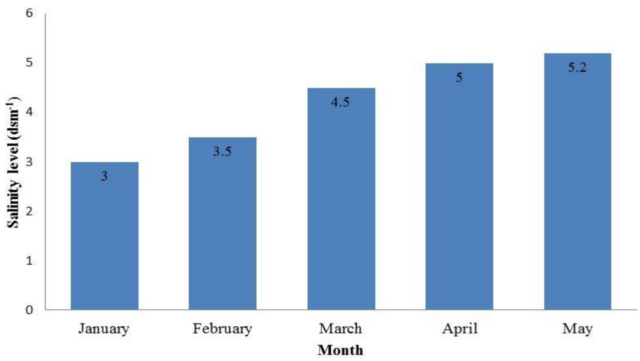

Fig. 1. Level of salinity during crop growing season

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjusted using the statistical computer package program Statistix10 at 5% level of significance was used to compare mean differences among the treatments (Gomez & Gomez, 1984).

Results and discussion

Seedling age and height has important role in the grain yield and yield contributing characters of rice. The seedling height was measured at forty days old and then transplanted in the experimental field. There was a significant difference among the seedling height but apparently the highest seedling height was recorded in BRAC Hybrid-777 followed by Binadhan-10. Besides, the shortest seedling height was observed in Hira-2 (Fig. 2). Similar results were reported by Aslam *et al.*, (2015).

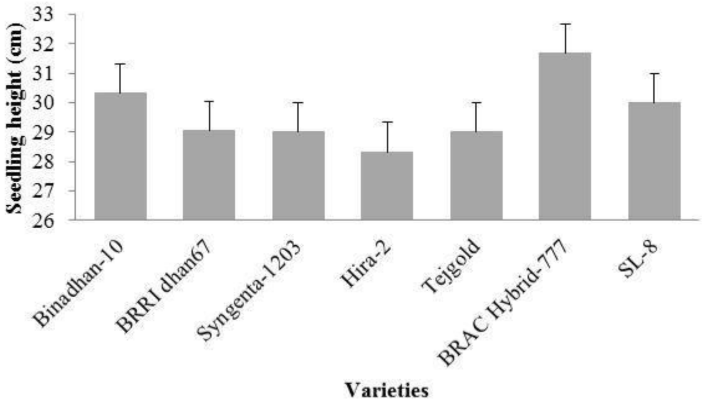

Fig. 2. Seedling height of cultivated varieties

Results indicated that leaves number plant^{-1} increased with age until 78 days after transplanting followed by a decline (Fig. 3). The highest number of leaves was produced at 78 days after transplanting in most of the studied genotypes. Finally, BRAC Hybrid-777 and

Binadhan-10 produced the highest number of leaves compared to other studied cultivars (Fig. 3.). Dissimilarities in leaf numbers may shape individual varietal growth, nutrient use efficiency and genetic traits (Chowan *et. al.,* 2021). This suggests that variations in leaf numbers were noted among the studied varieties at harvest which direct contribute in rice grain yield production (Akter *et al.,* 2019).

The effect of variety on tiller production at 6 growth stages was significant (Fig. 4). The number of tillers was increased with age up to 64 DAT followed by a decline with age due to asynchronous non-effective side tiller mortality. Similarly, Patra and Haque (2011) reported that the lowest number of panicles bearing tillers was found due to non-effective side tiller mortality. However, Binadhan-10 and BRRI dhan67 produced higher number of tillers hill^{-1} and Syngenta-1203 and BRAC Hybrid-577 produced lower number of tillers at harvest (Fig. 4.).

The grain yield-related traits are positively associated with flag leaf area (Ashrafuzzaman, *et al.*, 2009) because it is the most important source of photosynthetic energy during reproduction and grain filling (Rahman *et al.*, 2013). All the varieties had shown significant difference in flag leaf length and width. The longest flag leaf was found in Binadhan-10 followed by Syngenta-1203 andthe shortest in Hira-2. In addition, the highest flag leaf width was noted in Hira-2 and on the other hand, Tejgold produced the lowest flag leaf width (Table 1). In the present study, Syngenta-1203 had the long and narrow leaves that might help in capturing resource and producing sufficient assimilates.

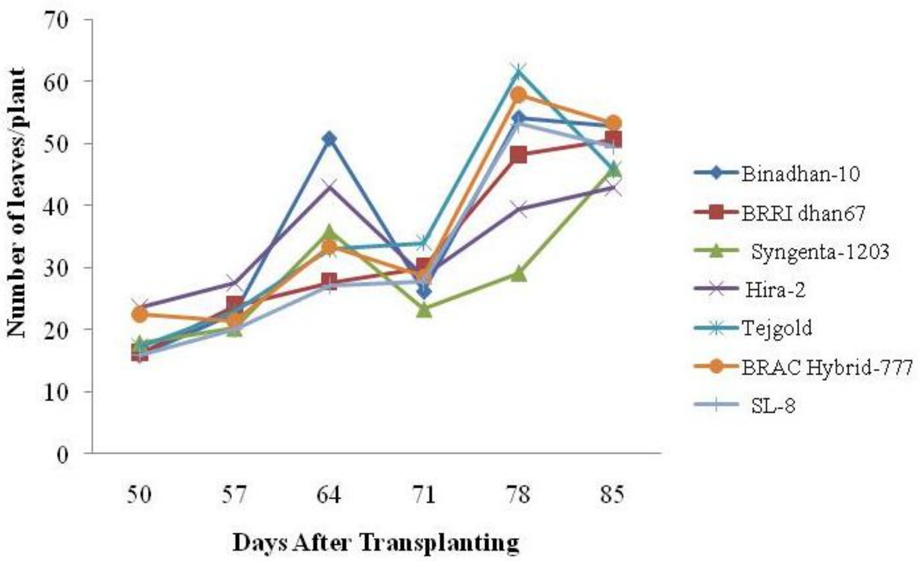

Fig. 3. Leaves production pattern of seven rice varieties in boro season.

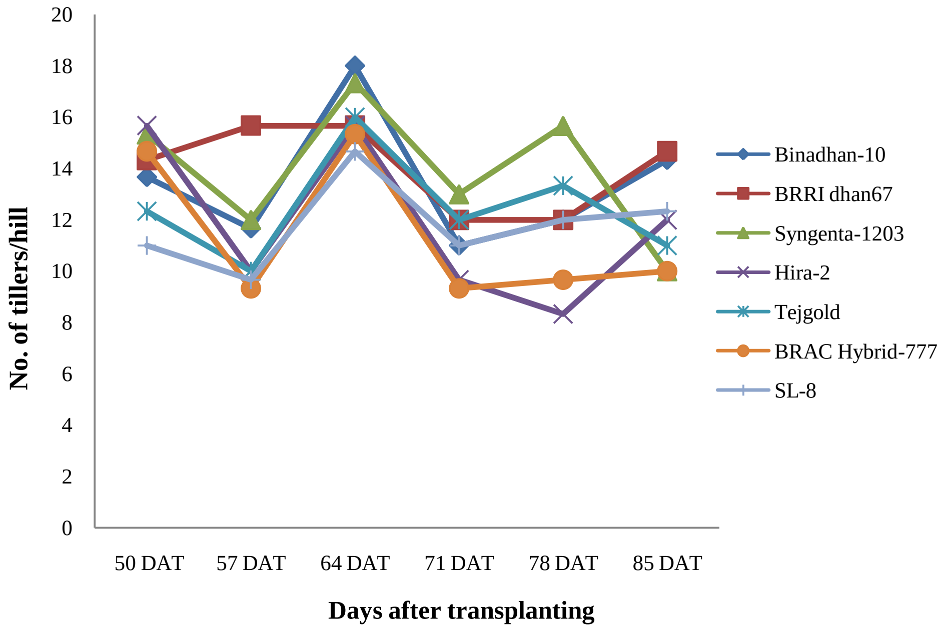

Fig. 4. On to genetic tillering pattern of seven rice varieties in Boro season.

Considering the yield and yield contributing characters; it was observed that the majority of the studied traits showed significant difference among the tested varieties (Table 1). Results revealed that BRAC Hybrid-777 produced the tallest plants (121.6 cm) followed by Binadhan-10 (120.8 cm) and BRRI dhan67 (119.9 cm) with same statistical rank. In contrast, Hira-2 and SL-8 exhibited shorter plant. Plant height is directly affected by genotype and it is an important to nitrogenous fertilizer responses and lodging. Generally, hybrid rice varieties are shorter than inbred HYV varieties and contribute in grain yield (Awal *et al.*, 2007). The number of tillers has a positive association with plant biomass and economic yield in rice (Deng *et al.*, 2015). The highest effective tillers hill^{-1}was recorded in BRRI dhan67 (11.6) followed by Binadhan-10 (11.1) and Syngenta (10.8) with same statistical rank. The lowest number of effective tillers hill^{-1} was observed in BRAC Hybrid-777 (9.0).

Panicle length is an important character which contributes in grain yield production of rice. The highest panicle length (29.0 cm) was recorded in Binadhan-10 followed by BRAC Hybrid-777 (28.8 cm) and the lowest (24.0 cm) was found in SL-8. The other studied varieties showed insignificant difference in panicle length themselves. Gravois and Hilms (1992) reported that the effect of filled grains per panicle and rice yield was positively correlated. The maximum filled grains per panicle (260.2) were counted in Syngenta-1203 and the lowest (163.8) in Binadhan-10. In addition, the highest number of unfilled grains per panicle (35.9) was also found in Syngenta-1203 and the lowest (5.8) in Hira-2 followed by Binadhan-10 (7.4).

Seed size is one of the crucial indicators of seed quality that considered in a crop improvement program. The longest seed was found in BRAC Hybrid-777 (10.3 mm) and the shortest in BRRI dhan67 (8.5 mm) followed by Binadhan-10 (8.7 mm). Besides, the highest seed width was exhibited in Hira-2 (2.8 mm) followed by Binadhan-10 (2.7 mm) and the lowest in BRRI dhan67 (2.1 mm). Considering the grain yield production, Hira-2 produced the maximum grain yield (8.9 t ha^{-1}) followed by Tejgold (8.3 t ha^{-1}), Binadhan-10 (7.9 t ha^{-1}) and BRRI dhan67 produced the lowest grain yield (6.6 t ha^{-1}). The highest 1000-seed weight was recorded in SL-8 (30.9 g) followed by Hira-2 (28.2 g) and lowest was in BRRI dhan67 (21.0 g). These data suggests that the yield can be increased with the increased grains per panicle with bolder grain size in rice which is supported by our previous report (Akter *et al.,* 2019).

Table 1: Yield and yield contributing characters of seven rice cultivars

Variety	Plant height (cm)	Effective tillers $hill^{-1}$ (no.)	Flag leaf length (cm)	Flag leaf width (cm)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)
Binadhan-10	120.8a	11.1ab	41.4a	1.7ab	29.0a	163.8c
BRRI dhan67	119.9a	11.6a	35.0c	1.6b	26.9b	191.7bc
Syngenta-1203	111.7bc	10.8abc	40.9a	1.6b	26.4b	260.2a
Hira-2	107.7c	9.8bcd	29.3d	1.8a	26.2b	192.4bc
Tejgold	116.9ab	9.2cd	36.3bc	1.5b	26.6b	214.2ab
BRAC Hybrid-777	121.6a	9.0d	39.3ab	1.7ab	28.8a	235.1ab
SL-8	108.3c	9.7bcd	38.3abc	1.7ab	24.0c	215.0ab
CV (%)	3.58	9.46	6.09	6.24	3.50	13.05

Variety	Unfilled grains $panicle^{-1}$ (no.)	Seed length (mm)	Seed width (mm)	1000- grain weight (g)	Grain yield (t ha^{-1})
Binadhan-10	7.4cd	8.7cd	2.7ab	27.6abc	7.9b
BRRI dhan67	9.0c	8.5d	2.1e	21.0d	6.6d
Syngenta-1203	35.9a	8.8c	2.4cd	23.1cd	6.9cd
Hira-2	5.8d	8.8c	2.8a	28.2ab	8.9a
Tejgold	16.3b	9.8b	2.4cd	24.3bcd	8.3b
BRAC Hybrid-777	34.0a	10.3a	2.2de	23.3cd	7.0cd
SL-8	7.4cd	9.6b	2.5bc	30.9a	7.2c
CV (%)	9.52	2.10	5.30	10.45	3.44

The grain yield is positively associated with the grain size, which is determined by the grain length, grain width, and grain shape (Duan *et al.,* 2014). All the studied agronomical traits among the varieties were significantly different and showed a varied degree of correlation in either positive or negative direction (Fig. 5). In this present study, grain yield strongly and positively correlated with grain size [width (r = 0.72***) and 1000-seed weight (r = 0.56**)] and the flag leaf length revealed a negative correlation with the grain yield (r = -0.55**) which are supported by our previous study (Akter *et al.,* 2022).

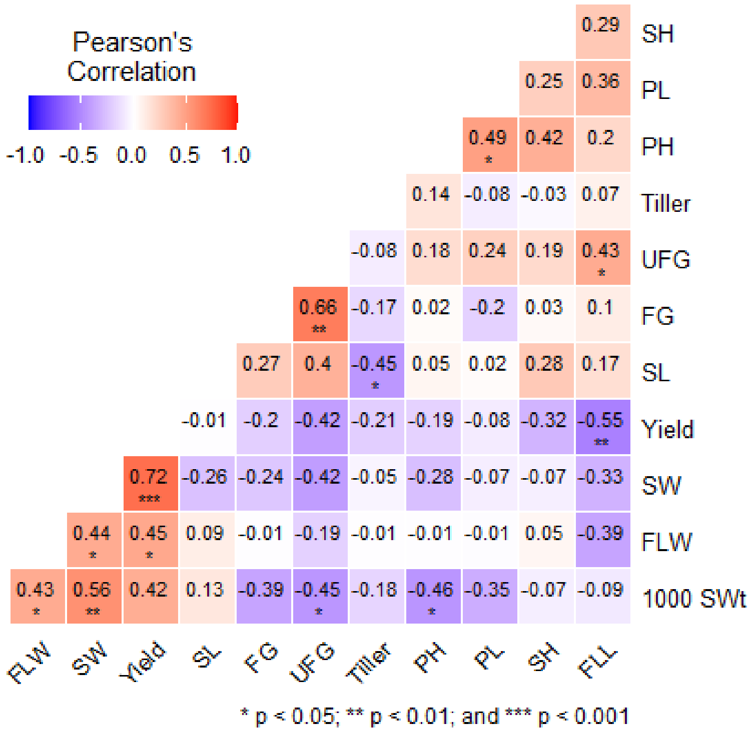

Fig. 5. Correlation among the agronomical parameters of seven rice varieties; where FLW flag leaf width, SW seed width, SL seed length, FG filled grain, UFG unfilled grain, PH plant height, PL panicle length, SH, FLL flag leaf length.

Dry matter accumulation reflects growth and metabolic efficiency of a plant, which ultimately influences the economic yield. Total dry matter production by rice plants increased progressively with the advancement of growth stages and important for higher grain yield in rice. In this present study, total dry matter (TDM) production at various crop growth stages of rice was significantly influenced by different varieties. Most of the studied varieties showed the maximum TDM at 78 DAT. Finally, BRAC Hybrid-777 produced the highest TDM and the lowest TDM was found in Hira-2 (Fig. 6) indicated that good dry matter partitioning of assimilates to the grain in rice. The poor grain filling might be related to poor partitioning of assimilates to the grain in rice (Puteh *et al.*, 2014).

The grain yield increased with increased total dry matter production and grain yield strongly correlated with total dry mass production (Akter *et al.*, 2019) and higher dry matter production during grain filling is helpful for grain filling in rice as previously reported by Yang *et al.* (2002). Results indicated that positive correlation was observed between grain yield and total dry mass production (Fig. 7). The results indicated that higher dry matter production during grain filling is important for grain yield production in rice that supported by (Deng *et al.*, 2015; Bidgoli *et al.*, 2006).

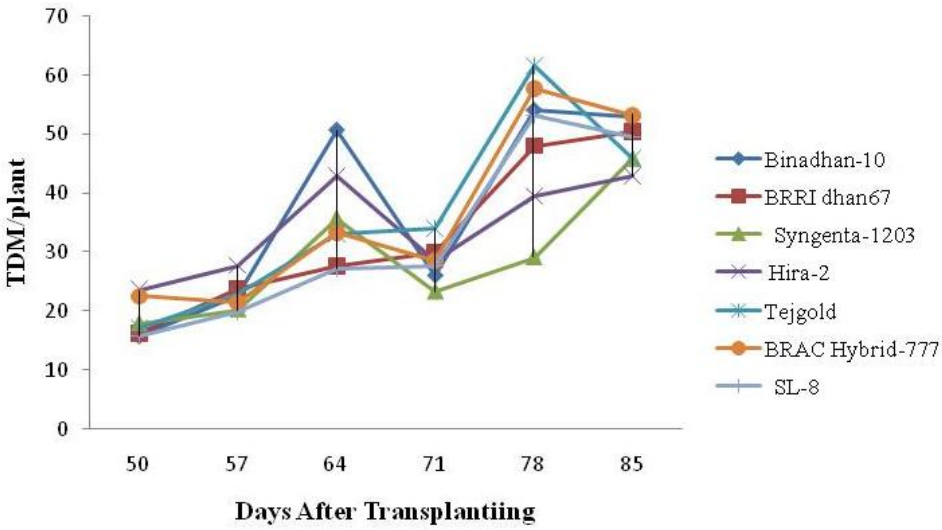

Fig. 6. Total dry mass production (TDM) at different growth stages in seven rice varieties.

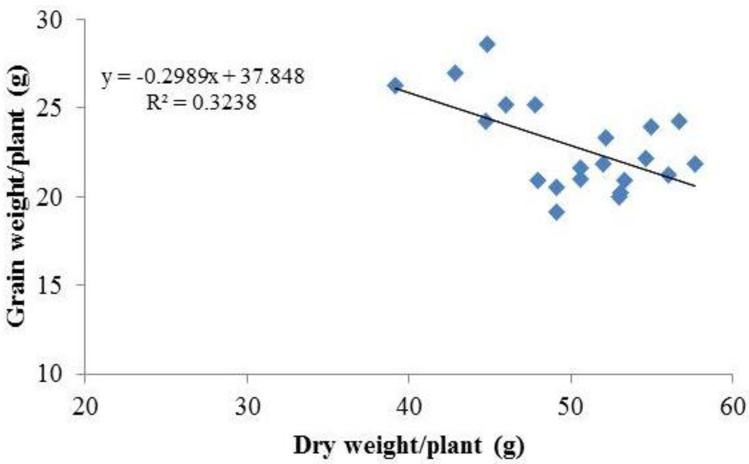

Fig. 7. Relationship between total dry matter (TDM) production and grain weight per plant.

Conclusion

Amongst the studied varieties; hybrid rice Hira-2 followed by Tejgold; and HYV rice Binadhan-10 produced higher grain yield for bolder seed size. Positive correlation between TDM and yield indicated that good dry matter partitioning of assimilates to the grain in rice. Therefore, further studies are needed including varied level of saline areas to identify the highly saline tolerant high yielding rice variety in Boro season.

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ECONOMIC STUDY OF BINADHAN-14 PRODUCTION IN SOME SELECTED AREAS OF BANGLADESH

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Abstract

This study was conducted to analyze the profitability of Binadhan-14 producing farmers in Mymensingh, Rangpur, Cumilla and Magura districts of Bangladesh. This study was based on primary data which were collected from 160 Binadhan-14 producing farmers. In the sampled areas data were collected through pre-designed interview schedule from May-June, 2018 for achieving the purpose. The cultivation of Binadhan-14 was profitable from the point of view of the farmers. The average net return per hectare was Tk. 36666. Benefit cost ratio was at 1.45 and 2.02 on full cost and variable cost basis implying that the Binadhan-14 cultivation at farm level was profitable. Cobb-Douglas production function was chosen to determine the factor affecting gross return of Binadhan-14 production. Most of the factors namely, human labour cost, power tiller cost, seed cost, fertilizer cost, irrigation cost and insecticides cost were statistically significant and positive. The farmers in the study areas encountered some constraints to Binadhan-14 production. The first ranked constraint was unavailability of seeds in all areas (87%). Other constraints were shattering problem (67%), lack of training (37%), lack of technical know-how (31%), lack of capital (26%) and low education level of farmers (15%). The economic return of Binadhan-14 production was encouraging to the farmers for more cultivation of the variety.

Key words: Binadhan-14, Profitability, Factors affecting, Cobb-Douglas production function.

Introduction

Rice is one of the dominant cereal dietary items of almost 15 million farm families (BBS, 2015) of Bangladesh. It provides one-sixth of rural household income, nearly 48%, of the rural employment two-thirds of per capita daily calorie intake, and half of per capita daily protein intake (Rahman *et al.*, 2016). About 81 percent of the total cropped area and over 80 percent of the total irrigated area is planted to rice. Approximately 96 percent share of the total cereal supply comes from rice alone (Alam *et al.*, 2013). Rice contributes almost o the GDP and recruites about 40% of the labor force of the country (BBS, 2020). There are three concurrent crop seasons in Bangladesh, where paddy is grown in about 42% of the land during Boro season and it accounts for the production of 19.56 million tons of clean rice, which is around 54% of the total production of the country (BBS, 2020). Although, the country already attained self-sufficiency in rice production (Jalilov *et al.,* 2019).

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It has serious deficit in edible oil producing crops which to be met or at least to be reduced under the challenges like limited and scattered land holdings, natural hazards, increasing temperatures, irregular and unpredictable rainfall, winter shortening, rising sea level, rice mono-cropping, and low profitability in rice cultivation (Mondal *et al.,* 2012).

Binadhan-14 is a late transplanting potential Boro which is commonly known as Braus rice variety allows Boro rice transplantation even up to last week of March and produces average yield of 6.9 t ha^{-1} in 105-125 days under proper management practices. This variety allows of any duration in the cropping pattern of short duration T. Aman rice-mustard/rapeseed-Boro rice keeping the Boro yield unaffected. It has long-fine grains with palatable to eat. This variety contributes significantly in increasing area under mustard/ rapeseed, pulses, potato and even winter vegetables and thus increased farmer's income, more employment and meets the challenges of self-sufficiency in food production.

There are some studies about the profitability of rice production in Bangladesh (Anik, 2003; Ismail *et al.,* 2010; Khan, 2005; Tasnoova *et al..* 2006; Rahman *et al.,* 2015; Noonari *et al.,* 2015; Islam *et al.*, 2017; and Bwala *et al.*, 2018). The present study is important for rice production in the late Boro/Braus season in Bangladesh which accommodates one more crop in the existing cropping system. The study not only analyses the profitability but also identify factors affecting gross return and the farmer's major constraints about rice productions in late Boro season. Therefore, the findings of this study would guide the policy makers in designing policies that can contribute to the measures needed to improve the nation's potential for food (rice, edible oil, pulse, winter vegetables including potato) production efficiently. The specific objectives of the study were i) to determine the profitability of Binadhan-14 growers, ii) to assess the factors affecting gross return of Binadhan-14 and iii) to determine the resource allocation efficiency in Binadhan-14 rice production and (iv) to identify the major constraints to Binadhan-14 cultivation.

Materials and Methods

Selection of the study area, sample size and sampling technique:

This study was conducted in four districts of Bangladesh, viz., Mymensingh, Rangpur, Cumilla and Magura. One hundred and sixty Binadhan-14 growers, taking 40 randomly from each district were selected with the help of Department of Agricultural Extension (DAE) personnel for interview. Field investigators under the direct supervision of the researchers, collected field level cross sectional data using pre-tested interview schedule.

Method of data collection and period of study:

Data were collected from sampled Binadhan-14 growers through face to face interview method using the interview schedule mentioned, above. Field level primary data were collected by the researcher with the help of trained enumerators for the period of May-June, 2018.

Analytical techniques:

Collected data were edited, summarized, tabulated and analyzed to fulfill the objectives of the study. The data were analyzed with the help of suitable statistical measures like frequencies, percentages, mean and standard deviation. Descriptive statistics were also used to analyze and compare the socioeconomic characteristics. The total cost was composed of total variable costs (TVC) and total fixed costs (TFC). The gross return (GR) was computed as total output multiplied by the market price of Binadhan-14. Profits or gross margin (GM) was defined as GR-TVC, whereas the net return (NR) was defined as GR-TC. Finally, the Benefit Cost Ratio (BCR) was computed as GR/TC.

Statistical Analysis:

The following Cobb-Douglas type production function was used to estimate the parameters. The functional form of the Cobb- Douglas multiple regression equation was as follows:

$$Y= AX_1^{b1}X_2^{b2}..................X_n^{bn}e^{ui}$$

The production function was converted to logarithmic form so that it could be solved by least square method i.e.

$$\ln Y= a+b_1\ln X_1 + ... + b_n\ln X_n +e^{ui}$$

The empirical production function was the following:

$$\ln Y= a + b_1\ln X_1+ b_2\ln X_2+b_3\ln X_3+b_4\ln X_4+b_5\ln X_5+b_6\ln X_6+Ui$$

Where,

Y = Yield/Gross return (kg ha^{-1})

X_1 = Human labor (Man days ha^{-1})

X_2 = Power tiller (Tk. ha^{-1})

X_3 = Seed (kg ha^{-1})

X_4 = Fertilizer (kg ha^{-1})

X_5 = Irrigation (Tk. ha^{-1})

X_6 = Insecticides (Tk. ha^{-1})

a = Constant value b_1 b_2 .... b_6= Co-efficient of the respective variables and

U_i= Error term.

Results and Discussion

Economic profitability of Binadhan-14 production

Profitability is one of the major criteria for determination of acceptance of a crop. The cost of Binadhan-14 production, gross return, gross margin, net return and the benefit cost ratio (BCR) for Binadhan-14 cultivation are being discussed in the following sections (Table 1 and Table 2).

Cost of Binadhan-14 cultivation

The cost of human labour, land preparation, power tiller, seed, fertilizers, pesticides and irrigation cost were taken into consideration in calculating cost of Binadhan-14 production. Beside this, interest on operating capital was also considered as the cost of Binadhan-14 production. Total cost consists of variable cost and fixed cost that covered 72% and 28% of total cost for Binadhan-14 production (Table 1).

The average cost of Binadhan-14 cultivation was Tk. 80824 and Tk. 58158 per hectare on full cost and cash cost basis, respectively. The highest production cost was attributed to human labour (50.9%), followed by irrigation (10.8%), power tiller (7.8%), and land use (7.7%). The cost of Binadhan-14 cultivation was found the highest in Cumilla (Tk. 85764/ha) followed by that in Magura (Tk. 83344/ha), Mymensingh (Tk. 80874/ha) and Rangpur (Tk. 73314/ha), respectively (Table 1).

Table 1. Cost of Binadhan-14 production at different locations

Cost Component	Cost of production (Tk. ha^{-1})				All areas	% of total cost
	Mymensingh	Rangpur	Cumilla	Magura		
Variable Cost	58654	52918	60613	60445	58158	72.0
Hired labour (Man days)	24676	23342	26065	24945	24757	30.6
Power tiller	6669	5558	7040	5928	6299	7.8
Seed	2408	2223	2149	2594	2344	2.9
Fertilizers:						
Urea	2371	2223	2594	2668	2464	3.0
TSP	2445	2668	2490	2816	2605	3.2
MP	1667	1853	1890	2038	1862	2.3
Cow dung	5669	5299	5328	5817	5528	6.8
Pesticides	2297	1853	2223	2075	2112	2.6
Irrigation	8892	6669	9114	10374	8762	10.8
Int. on operating capital	1560	1230	1720	1190	1425	1.8
Fixed Cost	22220	20396	25151	22899	22667	28.0
Family labour	15784	14895	18323	16724	16432	20.3
Land use cost	6436	5501	6828	6175	6235	7.7
Total Cost (A+B)	80874	73314	85764	83344	80824	100

Source: Field survey, 2018

Return from Binadhan-14 production

The average return from Binadhan-14 production at different locations is shown in Table 2. The average yield of Binadhan-14 was 5631 kg ha^{-1}. The yield was highest at Magura (6378 kg ha^{-1}) followed by Cumilla (5962 kg ha^{-1}), Mymensingh (5442 kg ha^{-1}) and Rangpur (4741 kg ha^{-1}). The total return from Binadhan-14 production consists of the values of Binadhan-14 and straw.

The average gross margin was found Tk. 59332/ha on variable cost basis. Gross margin was highest in Magura (Tk. 69680/ha) followed by Cumilla (Tk. 61079/ha), Rangpur (Tk. 53712/ha) and Mymensingh (Tk. 52857/ha) (Table 2). The average net return per hectare was Tk. 36666. The net return was highest in Magura (Tk. 46781/ha) followed by Cumilla (Tk. 35928/ha), Rangpur (Tk. 33316/ha) and Mymensingh (Tk. 30637/ha), respectively. Benefit cost ratio was estimated at 1.45 and 2.02 on full cost and variable cost basis, respectively, implying that the Binadhan-14 cultivation at farm level was profitable.

Table 2. Profitability of Binadhan-14 cultivation in different locations

Type	Study areas				All areas
	Mymensingh	Rangpur	Cumilla	Magura	
Yield from Binadhan-14 (kg ha^{-1})	5442	4741	5962	6378	5631
Return from Binadhan-14 (Tk. ha^{-1})	109112	103780	119538	127560	114998
Return from straw (Tk. ha^{-1})	2399	2850	2154	2565	2492
Total return (Tk. ha^{-1})	111511	106630	121692	130125	117490
Total variable cost (Tk. ha^{-1})	58654	52918	60613	60445	58158
Total Cost (Tk. ha^{-1})	80874	73314	85764	83344	80824
Gross margin (Tk. ha^{-1})	52857	53712	61079	69680	59332
Net return (Tk. ha^{-1})	30637	33316	35928	46781	36666
Rate of return (BCR)					
BCR on full cost	1.38	1.45	1.42	1.56	1.45
BCR on variable cost	1.90	2.02	2.01	2.15	2.02

Source: Field survey, 2018

Factors affecting gross return of Binadhan-14 production

To determine the effects of the explanatory variables, linear and Cobb-Douglas model were initially estimated for Binadhan-14 rice production. Some of the key variables are explained below.

Human labour cost (X_I)

In Table 3 most of the parameters are statistically significant and positive. The regression coefficients for Binadhan-14 under Mymensingh, Rangpur, Cumilla and Magura districts were positive and significant. The coefficient of Mymensingh, Rangpur and Cumilla districts were significant at 5% level implying that the 1 percent increases in the labour use cost increase the gross return from rice by 0.080, 0.302 and 0.399 percent, respectively. The coefficient of Magura districts was significant at one percent level and it was 0.225 percent. This indicated that 1 percent increase in human labour cost keeping other factors constant, would increase the gross returns by 0.225 percent (Table 3).

Power tiller cost (X_2)

Table 3 showed that the coefficient of power tiller cost in Mymensingh and Magura districts was 0.020 and 0.010, which was found to be significant at 5 percent level. It indicates that 1 percent increase in power tiller cost keeping other factors constant would be able increase the gross returns by 0.020 and 0.010 percent, respectively. The coefficient of power tiller cost under Rangpur and Cumilla district was positive but not significant.

Seed cost (X_3)

The coefficient of seedling cost of the Binadhan-14 production was statistically significant at 1 percent level of significance for Magura district. The result implies that 1 percent increase in the seedling cost for Magura district, keeping other factors constant, would result in an increase in gross return from rice by 0.702 percent.

The coefficient of seedling cost of the rice production was statistically significant at 10 percent level of significance for Mymensingh, Rangpur and Cumilla districts were 0.690, 0.150 and 0.230. The result implies that 1 percent increase in the seedling cost for Mymensingh, Rangpur and Cumilla districts farming systems, keeping other factors constant, would result increase in gross return from rice by 0.690, 0.150 and 0.230 percent, respectively.

Fertilizer cost (X_4)

The coefficient of fertilizer cost was statistically significant at 10 percent level of significance for Cumilla district (Table 3). The result implies that 1 percent increase in the fertilizer cost for Cumilla district, keeping other factors constant, would result in an increase in gross return from rice by 0.780 percent. The coefficient of fertilizer cost under Mymensingh, Rangpur and Magura districts were positive but not significant.

Irrigation cost (X_5)

Table 3 showed that the coefficient of irrigation cost in Mymensingh and Rangpur districts was 0.020 and 0.050, which was found to be significant at 10 percent level. It indicates that 1 percent increase in irrigation cost keeping other factors constant would be able increase the gross returns by 0.020 and 0.050 percent, respectively. The coefficient of irrigation cost under Cumilla and Magura was positive but not significant.

Insecticides cost (X_6)

The coefficient of insecticides cost in Mymensingh and Magura districts were 0.257 and 0.580, which was found to be significant at 5 percent level (Table 3). It indicates that 1 percent increase in insecticides cost keeping other factors constant would be able increase the gross returns by 0.257 and 0.580 percent, respectively.

The coefficient of insecticides cost was statistically significant at 10 percent level of significance for Rangpur and Cumilla districts was 0.186 and 0.221. The result implies that 1 percent increase in the insecticides cost for Rangpur and Cumilla districts, keeping other factors constant, would result increase in gross return from rice by 0.186 and 0.221 percent, respectively (Table 3).

Table 3. Estimated values of regression co-efficient and related statistics of Cobb-Douglas production function for Binadhan-14 production

Explanatory variables	Study areas							
	Mymensingh		Rangpur		Cumilla		Magura	
	Estimated Co-efficient	T-values	Estimated Co-efficient	T-values	Estimated Co-efficient	T-values	Estimated Co-efficient	T-values
Intercept	2.558* (0.651)	4.070	2.528* (0.851)	4.010	4.950* (0.510)	9.78	4.170* (0.850)	4.890
Human labour cost (X_I)	0.080** (0.040)	1.710	0.302** (0.119)	2.995	0.399** (0.186)	3.861	0.225*** (0.086)	4.713
Power tiller cost (X_2)	0.020** (0.010)	2.550	0.312 (0.084)	2.845	0.059 (0.626)	2.192	0.010** (0.010)	1.980
Seed cost (X_3)	0.690* (0.050)	8.410	0.150* (0.080)	2.010	0.230* (0.160)	2.139	0.702*** (0.248)	4.379
Fertilizer cost (X_4)	0.287 (0.061)	4.713	0.250 (0.080)	2.930	0.780* (0.130)	5.820	0.054 (0.120)	2.182
Irrigation cost (X_5)	0.020* (0.300)	0.530	0.050* (0.040)	1.130	0.079 (0.122)	2.355	0.430 (0.198)	3.415
Insecticides cost (X_6)	0.257** (0.109)	3.139	0.186* (0.156)	1.456	0.221* (0.147)	2.889	0.580** (0.161)	4.879
Coefficient of multiple determination (R^2)	0.746		0.778		0.820		0.845	
F-value	8.436		9.336		10.114		11.238	
Returns to scale	1.020		1.056		1.078		1.088	

Source: Field survey, 2018

Note: *** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level (Figures in the parentheses indicates the standard errors)

Coefficient of multiple determination (R^2)

The coefficient of multiple determination (R^2) tells how well the sample regression line fits the data. It is evident from Table 3 that the values of R^2 were 0.746, 0.778, 0.820 and 0.845 for Mymensingh, Rangpur, Cumilla and Magura districts, respectively. This means that around 75, 79, 82 and 84 percent of the variations in gross return for Binadhan-14 rice, respectively were explained by the independent variables included in the model.

Return to Scale

The summation of all of the production coefficient indicates return to scale. The sum of elasticity coefficients was 1.020, 1.056, 1.078 and 1.088 in case of Binadhan–14 meaning increasing returns to scale. This means that, 1 percent increase in all inputs simultaneously would result on average 1.020, 1.056, 1.078 and 1.088 percent increase in gross return of Binadhan-14. This value being greater than 1 means that the farmers are operating at the region of increasing return to scale.

Major constraints to Binadhan-14 cultivation

Binadhan-14 was a profitable rice variety in the study areas. Farmers faced various constraints to Binadhan-14 cultivation. In Table 4, about 87% farmers opined unavailability of seed as a top ranked problem of Binadhan-14 cultivation. Other constraints were shattering problem (67%), lack of training (37%), lack of technical know-how (31%), lack of capital (26%) and low education level of farmers (15%).

Table 4. Major constraints to Binadhan-14 cultivation in the study areas

Sl. No.	Constraints	Percent of farmers responded					Rank
		Mymensingh	Rangpur	Cumilla	Magura	All areas	
1.	Unavailability of seed	88	94	89	76	87	1
2.	Shattering problem	60	65	70	74	67	2
3.	Lack of training	30	82	8	28	37	3
4.	Lack of technical know-how	30	25	53	15	31	4
5.	Lack of capital	17	50	12	25	26	5
6.	low education level of farmers	10	15	18	20	15	6

Source: Field survey, 2018

Conclusion

Binadhan-14 production is profitable in the study areas. All of the factors namely, human labour cost, power tiller cost, seed cost, fertilizer cost, irrigation cost and insecticides cost are very important for Binadhan-14 cultivation. Binadhan-14 farmers received high return on its investment. But some constraints and factors were influenced during the cultivation process. There is a need of proper guide to farmers about Binadhan-14 rice production in the study areas.

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Short Communication

IN VITRO CALLUS REGENERATION OF *BRASSICA SPP* THROUGH ANTHER CULTURE

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Abstract

Brassica is an important oil-yielding crop under Brassicaceae family. *Brassica* is the third most important vegetable oil crop in the world, after palm and soyabean oil. But it takes a long time to develop new Brassica cultivars. Haploid production of *Brassica* spp. through anther culture proved to be an important approach of tissue culture. The purpose of this study was to carry out a suitable protocol for happloid production of *Brassica spp.* and observe genotypic variation for callus induction. Three replications were used containing different concentration of 2, 4-D, BAP, Kiniten and NAA. The highest percentage of callus induction (56.2%) was found in CM 800 within minimum days (18 days) and the nature of callus was compact. It indicates totipotency capacity of cell was also influenced by radiation. Future study was necessary to shoot and root induction process for successful speed breeding program.

Keywords: Anther culture, callus, *In vitro* regeneration and *Brassica spp.*

The world is experiencing rising demands for crop as well as global agricultural production that need to be increased by 60-110% to meet the increasing demands and to ensure food security (FAO 2012). Crop improvement through breeding has been the major tool to stable global food supply. To adequately address these food security challenges, high yielding crop varieties need to be developed as a partial solution (Lenaerts *et al.,* 2019). Development of new varieties is time-consuming as it is dependent on generation period of a crop. Mustard (*Brassica napus*), a member of the Brassicaceae family is not out of this time frame. In biology (i.e. genetics) as breeding material is not genetically uniform or "stable" (i.e. plants are not homozygous) until at least 6 to 8 generations (i.e. self-pollination events). Breeders always use new methods and tools to develop new varieties, and accordingly, have long discussed the pros and cons of different breeding methods, especially with regard to the speed of breeding (Forster *et al.,* 2014). Speed breeding or accelerated plant breeding is an emerging strategy among plant breeders to develop new cultivars in short span of time. Basically it focused on most time consuming component of breeding program known as "line fixation" stage. Doubled haploid (DH) populations are produced by regenerating plants by the induction of chromosome doubling from pollen grains, which greatly shortens the line fixation stage because completely homozygous lines are produced immediately (Mishra *et al*., 2016). In oilseed rape, the doubled haploid method can reduce the time to develop a new cultivar by about 2-4 years compared to the traditional breeding procedures (Cardoza *et al*., 2006; Alam *et al*., 2009). Due to the recalcitrant nature of -

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Brassica tissue in vitro, it eluded any notable progress in this regard for a long time. Since the first report of haploid production in 1920s, the DH, both the range of species and efficiency of production, has been greatly improved and is routinely used in many crop breeding programs (Asif, 2013; Li *et al.,* 2013).

The regeneration of plants from tissue culture is an important and essential component of biotechnological research. Tissue culture techniques can play an important role for improvement of genetic variability by initiating variation (somaclonal variation) or mutation at an unusually high rate (Krishna *et al.,* 2016). Anther culture derived haploids have been used to produce homozygous diploids, which accelerate breeding programmes. Anther culture technique is the most viable and efficient method of producing homozygous doubled haploid plants within a short period (Ali *et al.,* 2021). Haploid embryos or doubled haploid plants can also be used in mutation, genetic engineering, biochemical and physiological studies (Razdan, 1993). Therefore, to harvest the diverse merits of anther culture, the present research work was planned to carry out a suitable and reproducible protocol for deals with the current status of primary knowledge on the production of haploids and DHs through mustard anther culture.

The experiment was carried out during January to March 2022 at the Biotechnology Division of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. *Brassica* genotypes viz., BARI Sarisha-18 with its two mutants obtained from 800 and 1000Gy (M_2 population) of ^{60}Co and first filial population of BARI Sarisha-18 × Tori-7 and Tori-7 were used as plant materials for this study. Flower buds were collected at the late uninucleate stage in the morning before 9:00 am from the research field of Plant Breeding Division of BINA, Mymensingh. Collected buds were surface sterilized by submerging them into 70% ethyl alcohol (MERCK, Germany) for two minutes then rinsed for three minutes by sterilized distilled water for three times. Anthers were aseptically removed from flower buds using fine tweezers and inoculated into 8 cm petridishes each containing 10 ml MS medium (Nitish and Nitish, Duchefa) supplemented with 4 mgl^{-1} 2, 4-D and 1 mgl^{-1} BAP. About fifty anthers of each genotype were inoculated into each replication. The whole procedure was carried out in laminar airflow cabinet. The cultured vessels were then marked with permanent marker to indicate treatment after sealing with parafilm. Cultures were maintained in plant growth incubator at 25^0±1°C temperature in complete dark condition for callus induction and checked to record the response. Callus size was measured by millimeter scale.

The research was operated in Completely Randomized Design (CRD) with three replications. Data were recorded on number of anthers showing callus, percent of callus induction and days to callus initiation and callus size and statistically analyzed to confirm the significance of the experimental results. The standard deviation, percentage of response and mean for all treatments were calculated by using MS Excel 2010. The significance and difference between means were evaluated by Duncan's Multiple Range Test (DMRT) at 5% significance level by Statistix 10 software.

Callus induction performances of all the materials are presented in Table1. Firstly considered trait was number of anthers able to initiate callus induction and it was ranged from 9 to 23. This ranged indicated the genotypic variation of the studied materials in terms of totipotency. Results showed that CM800 anthers cultured on medium supplemented with 4 mgl^{-1} 2, 4-D and 1 mgl^{-1} BAP exhibited the significantly highest response (23) for callus induction in minimum days (18) and the maximum percentage of callus (56.2) was also observed at the same supplement addition. Moreover, anthers of BARI Sarisha-18, Tori-7 and CM1000 responded statistically the same for callus induction (17, 16 and 15, respectively). On the other hand, the lowest response (9) was observed in BARI Sarisha-18 × Tori-7. The second parameter was the number of days required to complete callus induction and found significantly different response from studied genotypes. The callus induction days was ranged from 18 to 30 days. The maximum days required for callus induction was obtained from BARI Sarisha-18×Tori-7 followed by Tori-7. BARI Sarisha-18 × Tori-7 required 30 days whereas Tori-7 required 28 days and both of them are statistically similar. The CM100 required 22 days for callus induction which was statistically identical with BARI Sarisha-18 (23 days). The callus induction rate was faster in CM800, that was different from others and it required only 18 days.

Table 1. Response of varieties on callus induction for studied genotypes

Genotype	No. of anthers showing callus induction	Days of callus induction	Callus induction (%)	Nature of callus
CM800	23a	18c	56.2a	Compact
CM1000	15ab	22b	38.1bc	Compact
BARI Sarisha-18 × Tori-7	9b	30a	22.6c	Compact
BARI Sarisha-18	17ab	23b	43.5b	Compact
Tori-7	16ab	28a	40.0b	Compact

N.B: Mean values having common letter in the column are statistically identical and those having different letters are statistically different

The percentage of callus induction was the highest in CM800 (56.2%) followed by BARI Sarisha-18 (43.5), CM1000 (38.1%) and Tori-7 (40%). Callus induction was lowest in cross material of BARI Sarisha-18×Tori-7 (22.6%). It was found that irradiated materials CM1000 and CM800 showed comparatively good potentiality in number of callus growth than other genotypes. Comparatively lower potentiality in callus growth was observed in BARI Sarisha-18 × Tori-7 followed by Tori-7. This finding confirmed that of Javed and Hassan (1992) who noted that callus growth was better in *B. napus* genotype.

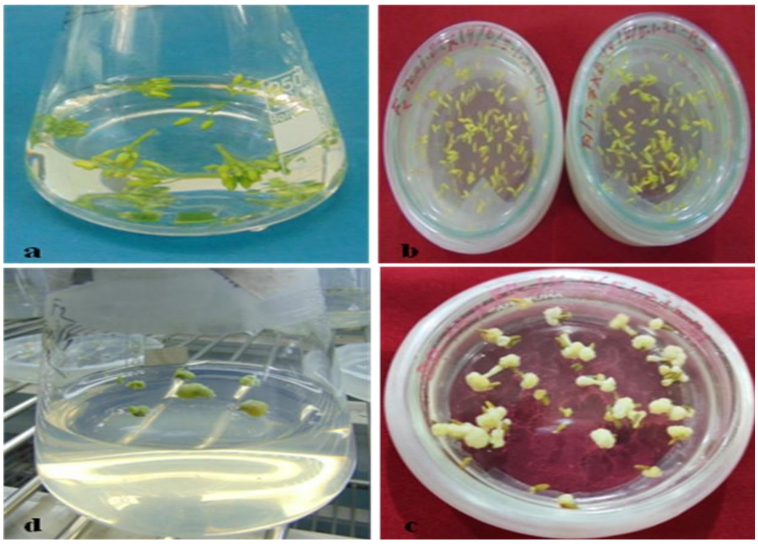

Fig. 1: Steps of anther culture of *Brassica sp*. (a) Collected buds, (b) Anthers on culture media, (c) Callus formation after 21-28 days and (d) Calli on regenerated media

Callus maintenance is essential to get regenerated plants. So MS medium supplemented with 4 mgl^{-1} BAP and 1 mgl^{-1} NAA was used. It was appeared from the study that the responses of calli of different genotypes were different. Among the genotypes, the callus size was found better and identical in CM800 and Tori-7. Callus size of BARI Sarisha-18 and CM1000 was 1.75 mm and 1.70 mm respectively. The lowest callus size was obtained from BARI Sarisha-18 × Tori-7 (1.3 mm).

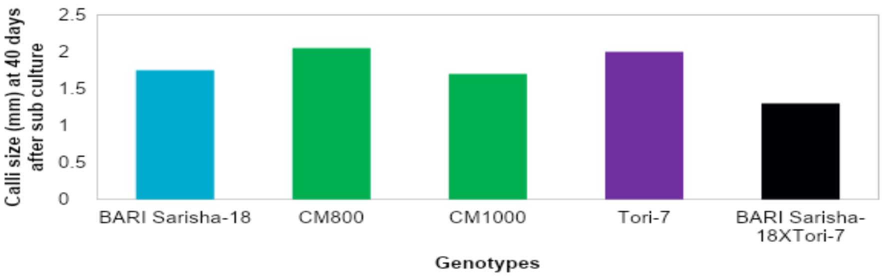

Fig. 2: Influence of genotype on callus proliferation after 45 days of sub culture.

From the above results it indicates that irradiation of *Brassica* genotyoes have positive role to influence the tot potency of calli to regenerate identical plant type. For haploid plant production it can be widely used after suitable optimization of media concentration. Here only two different doses of ^{60}Co were used, it will be better to used more doses for strong recommendation. If we consider the genotype then *B. napus* have more response than *B. campesties*.

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Short communication

GAMMA RAY INDUCED RADIOSENSITIVITY OF BLACK CUMIN GENOTYPE

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Mutagenesis using ionizing radiation has been widely used for the genetic variability with novel characteristics. To know the optimum dose in black cumin an experiment was carried out at Bangladesh Institute of Nuclear Agriculture, HQs farm, Mymensingh. Collected three germplasm (BC10861, BC10863 and BC10864) of black cumin seeds were irradiated with different doses of gamma radiation as 50 Gy, 100 Gy, 150 Gy, 200 Gy, 250 Gy and 300 Gy to determine the LD_{50} for development of desirable mutants. Maximum seed germination (94.5-97.1%) was found from the lowest dose (50 Gy) of gamma radiation, while the minimum germination (18.2-22.0%) was obtained from the highest dose (300 Gy) among the three germplasm BC10861, BC10863 and BC10864. The seedlings survivability was 45-49% at 150 Gy. After one month, in the later growth stage none of the seedlings survived at the dose of 250 Gy and 300 Gy. At lower dose of 50 Gy maximum numbers of leaves (6.12-7), number of roots per plant (7.13-8.05), root length (5.34-7.1 cm), shoots length (5.3-7.1 cm) and fresh weight per plant (0.25-0.29 g) were observed among the germplasm. The seed germination and seedlings survival decreased with the radiation dose increased. The seedling growth parameters like number of leaves, root length, shoot length and fresh weight per plant reduced around 50% at 150 Gy dose of gamma radiation. Among the six doses of irradiation the LD_{50} was close to 150 Gy which caused around 55-51% death of seedlings, 45-49% seedlings survival and around 50% reduction in plant growth. Hence, it is concluded that 150 Gy may be the optimum dose for creating useful mutation induction in black cumin.

Key words: Black cumin, gamma ray, irradiation, LD_{50}, mutagenesis.

Nigella sativa L., known as black cumin, belongs to the Ranunculaceae family and the order Ranales (Malhotra, 2004). Seed of black cumin contains about 21% protein, 35% carbohydrates and 35-38% plant fats and oils (Preussa *et al*., 2003). It contains all essential amino acids and rich source of vitamins and minerals (Sarada *et al*., 2015, Sastry *et al*., 2013). The seeds and its essential oil have been widely used in functional foods, nutraceutical and pharmaceutical products to treat different diseases. However, the production is not sufficient in accordance with demand in Bangladesh.

The physical mutagens like gamma rays are known to be the most popular mutagen because of their simple use, high penetration, reproducibility, high mutation frequency and less disposal problems (Chahal & Ghosal, 2002). After the discovery that physical mutagens can induce mutation, many plant breeders and geneticists started observing the use of radiation induced mutations for altering plant characters (Ahloowalia *et al*., 2004). During

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the last seventy years, more than 3402 mutant varieties have been officially released (Mutant Variety Database, IAEA, 2021). Mutation induced by radiation was the most commonly used method to develop direct mutant varieties (89%). Although mutations are beneficial for producing variability in populations, the treatments themselves can be detrimental and can cause a reduction in germination, growth rate, plant vigour and pollen and ovule fertility in a plant (Micke and Donini, 1993). If the variability is low in the population/germplasm, then it is necessary to create variability for crop improvement. The variability is created through recombination techniques in general, but it's difficult in black cumin, due to small flower size, lack of genetic variability and non availability of any type of sterility (Sastry and Anandaraj, 2013). There is immense need of high yielding varieties, which is not possible without generating variability in black cumin and also in other seeds species. Mutagenic effectiveness is a measure of the mutations induced per unit dose of a mutagen (time×concentration/dose), while mutagenic efficiency gives an idea of genetic damage (mutation) in relation to the total biological damage caused in M_1 generation (Ambavane *et al*., 2015). In addition response of plants to gamma radiation may vary with the genetic makeup of the crops, the tissue exposed, and the dose of irradiation (Sakamoto 2006). While the mutagenic effectiveness decreased with the increase in dose of mutagen that indicates negative relationship between effectiveness and number of mutagens.

However, for initiating mutation breeding programme in any crop to create the desired variability, the knowledge of optimum dose of mutagen is essential. The growth parameters including percent seed germination, seedling growth are some of the usually used criteria for determining mutagenic sensitivity in a particular crop and variety (Lal *et al*., 2009). Therefore, this experiment was conducted to determine the optimum dose of radiation for LD_{50} in black cumin.

The experiment was carried out at BINA HQs farm, Mymensingh. Dry black cumin seeds (200 no.) were irradiated with gamma rays at the doses of 50 Gy, 100 Gy, 150 Gy, 200 Gy, 250 Gy and 300 Gy by ^{60}Co source. The irradiated seeds along with non irradiated seeds were placed on blotting paper for percent seed germination. Following parameters related to determine LD_{50} were recorded:

Percent seed germination: Seed germination was recorded treatment wise on the day (14 day) when the control showed 100 percent germination. The emergence of plumule and radicle was considered as germination.

$$\text{Percent seed germination} = \frac{\text{No. of germinated seeds}}{\text{Total no. of seed}} \times 100$$

Percent seedling survival: The percent survival of seedling was calculated after 30 DAS using formula given below:

$$\text{Percent survival} = \frac{\text{No. of plant survived}}{\text{No. of seed sown}} \times 100$$

Seedling height (cm): Seedling height was recorded from15 randomly selected seedlings per replication after 30DAS.

Root length (cm): Root length of 15 randomly selected seedlings was recorded at 30 DAS for each replication.

Shoot length (cm): Shoot length was recorded from 15randomly selected seedlings per replication after 30 DAS.

Fresh weight of plants (g): Freshly uprooted seedlings were placed on blotting paper to soak the surface water and then weighted on an electronic balance and mean value was calculated for each treatment.

Number of Leaf per seedling: Leaves were counted manually from randomly selected 15 selected seedlings at 30 DAS for each replication.

Number of root per seedling: Roots were counted manually from randomly selected 15 selected seedlings at 30 DAS for each replication

Experiment was carried out in completely randomized design and each treatment was replicated thrice. All data were analyzed using the statistics following Gomez and Gomez (1984). The means were separated by Duncan Multiple Range Test (DMRT) at 5% level of significance.

The data pertaining to seed germination and seedling survival is presented in Figure 1 which revealed that as the irradiation doses increased, both percentage of seed germination and seedling survival decreased. The seed germination was 100% in non irradiated seeds, while after imposing irradiation the percent germination were 97 in 50 Gy, 96 in 100 Gy, 91 in 150 Gy, 76 in 200 Gy, 49 in 250 Gy and 19 in 300 Gy for BC10861 germplasm, 95 in 50 Gy, 93 in 100 Gy, 93 in 150 Gy, 73 in 200 Gy, 54 in 250 Gy and 18 in 300 Gy for BC10863 germplasm and 96 in 50 Gy, 97 in 100 Gy, 94 in 150 Gy, 76 in 200 Gy, 50 in 250 Gy and 22 in 300 Gy for BC10864 germplasm (Fig 1). Among the doses of irradiation, 250 Gy and 300 Gy were more lethal. The plumule and radical emerged at the dose 250 Gy and 300 Gy but in later growth stages failed to transform into complete seedling.

With regards to the survival of seedlings, the survival of seedlings decreased with increase in dose of gamma radiation. In control the 100% seedlings were survived but the irradiated seedlings reduced in its survivality after germination. The seedlings survival rate was 85.0 in 50 Gy, 65.0 in 100 Gy, 47.0 in 150 Gy, 38.0 in 200 Gy, 20.0 in 250 Gy and 5.0 in 300 Gy for BC10861 germplasm, 77.0 in 50 Gy, 73.0 in 100 Gy, 49.0 in 150 Gy, 37.0 in 200 Gy, 15.0 in 250 Gy and 3.0 in 300 Gy for BC10863 germplasm and 81.0 in 50 Gy, 67.0 in 100 Gy, 45.0 in 150 Gy, 33.0 in 200 Gy, 18.0 in 250 Gy and 2.5 in 300 Gy for BC10864 germplasm (Fig 1).

The decrease in seed germination induced by mutagenic treatments may be the result of damage of cell constituents at molecular level or altered enzyme activity (Khan and Goyal, 2009). Micco *et al*., (2011) have correlated seed germination with abnormalities in mitotic cycles and in metabolic pathways of the cells. The reduction in germination and survival may be due to absorption of ionizing radiation in biological materials, acting directly on critical targets in the cell (Kovacs and Keresztes, 2002). Bashir *et al*., (2013) also reported that the seed germination percentage and percent survival decreased with an increase in dose of the gamma irradiation. They concluded that lower treatment of gamma irradiation has influenced less biological damage and would be suitable for inducing desirable mutations. The present findings are in agreement with the above mentioned reports. Similar findings were also reported where in, higher doses of gamma radiation reduced germination percentage and survival in fennel (Verma *et al*., 2017) and coriander (Sarada *et al*., 2015).

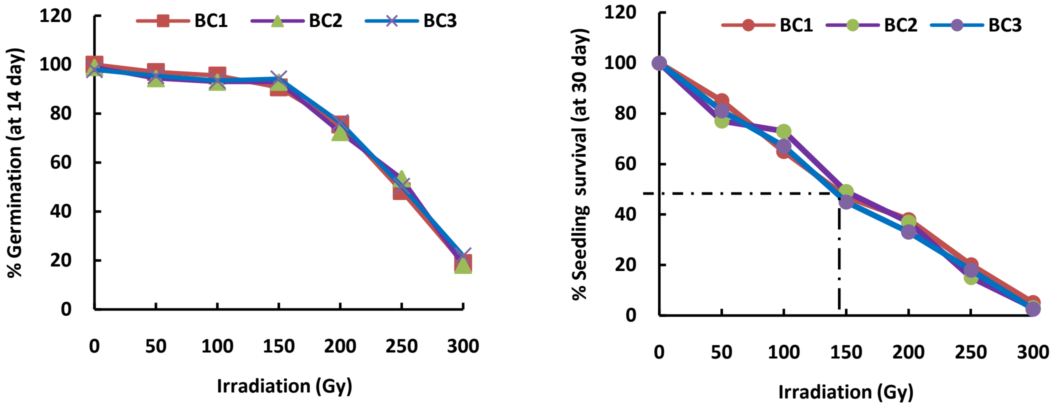

Fig. 1. Mutagenic effect of gamma rays on percent germination and percent seedling survival in black cumin (BC1 = BC10861, BC2 = BC10863 & BC3 = BC10864)

Fig. 2(a): Effect of different doses of gamma irradiation on growth of black cumin of BC-10861 germplasm

Fig. 2(b): Effect of different doses of gamma irradiation on growth of black cumin of BC-10863 germplasm

Fig. 2(c): Effect of different doses of gamma irradiation on growth of black cumin of BC-10864 germplasm

Table 1. Effect of acute exposure of different doses of gamma rays on growth characters of seedlings

Germplasm	BC10861					BC10863					BC10864				
Dose (Gy)	No. of leaves	No. of roots plant^{-1}	Root length (cm)	Shoot length (cm)	Fresh wt. plant^{-1} (g)	No. of leaves	No. of roots plant^{-1}	Root length (cm)	Shoot length (cm)	Fresh wt. plant^{-1} (g)	No. of leaves	No. of roots plant^{-1}	Root length (cm)	Shoot length (cm)	Fresh wt. plant^{-1} (g)
0 (Control)	7.53a	8.25a	7.31a	9.07a	0.37a	7.34a	7.53a	6.52a	8.70a	0.31a	6.87a	8.01a	6.43a	8.63a	0.33a
50	7.00ab	8.05a	7.10a	8.62ab	0.29b	6.94a	7.13a	5.54b	7.91b	0.25b	6.12b	7.52ab	5.34b	7.31b	0.28a
100	6.87b	7.57b	5.74b	7.93b	0.21c	5.85b	6.54b	5.33b	7.53b	0.24b	5.95bc	7.35b	5.11b	6.23c	0.21b
150	5.32c	6.43c	4.64c	5.72c	0.13d	5.35b	5.38c	3.51c	5.76c	0.14c	5.35c	5.95c	3.89c	4.93d	0.15c
200	4.24d	2.45d	3.24d	4.52d	0.07e	3.24c	2.19d	1.70d	3.74d	0.05d	3.62d	2.54d	2.60d	3.52e	0.08d
250	0.00e	0.00e	0.00e	0.00e	0.00f	0.00d	0.00e	0.00e	0.00e	0.00e	0.00e	0.00e	0.00e	0.00f	0.00e
300	0.00e	0.00e	0.00e	0.00e	0.00f	0.00d	0.00e	0.00e	0.00e	0.00e	0.00e	0.00e	0.00e	0.00f	0.00e
CV (%)	4.43	3.78	4.45	4.99	9.96	5.53	3.98	5.97	4.64	12.5	6.42	4.34	6.74	4.89	11.65
SE (±)	0.16	0.14	0.15	0.21	0.01	0.19	0.13	0.15	0.18	0.01	0.21	0.16	0.12	0.17	0.02

Highly significant differences were observed among the lower and higher doses of irradiation on number of leaves, root length, shoot length and fresh weight per plant in Fig. 2 (a, b and c). From the Table 1, The maximum number of leaves (7), number of roots per plant (8.05), root length (7.10 cm), shoots length (8.62 cm) and fresh weight per plant (0.29 g) were observed at lower dose 50 Gy and the minimum number of leaves (4.24), number of roots per plant (2.45), root length (3.24 cm), shoots length (4.52 cm) and fresh weight per plant (0.07 g) were observed at higher dose 200 Gy in BC10861 germplasm.

Again the maximum number of leaves (6.94), number of roots per plant (7.13), root length (5.54 cm), shoots length (7.91 cm) and fresh weight per plant (0.25 g) were observed at lower dose 50 Gy and the minimum number of leaves (3.24), number of roots per plant (2.19), root length (1.70 cm), shoots length (3.74 cm) and fresh weight per plant (0.05 g) were observed at higher dose 200 Gy in BC10863 germplasm.

Furthermore, the maximum number of leaves (6.12), number of roots per plant (7.52), root length (5.34 cm), shoots length (7.31 cm) and fresh weight per plant (0.28 g) were observed at lower dose 50 Gy and the minimum number of leaves (3.62), number of roots per plant (2.54), root length (2.60 cm), shoots length (3.52 cm) and fresh weight per plant (0.08 g) were observed at higher dose 200 Gy in BC10864 germplasm. On the other hand, no survivality was observed in case of all germinated seedlings at the gamma radiation doses 250 and 300 Gy (Table. 1). The high dose irradiation that caused growth inhibition could be described to the cell cycle arrest at G2/M phase during somatic cell division and/or various damages in the entire genome as reported by Preussa and Britta (2003). Similar results were obtained by Yadav and Ramkrishna, (2013) in *Cuminum cyminum*.

The results of the experiment indicated that high dose of gamma radiation reduced germination percentage, seedling survival, shoot length, root length, number of leaves and fresh weight of plant drastically. The high doses of 250 to 300 Gy gamma rays were more lethal. The 150 Gy of gamma radiation was found to cause near about 50% seedling survival and 50% reduction in root length, shoot length and fresh weight per plant. It is expected that 150 Gy of gamma ray would be the optimal dose for inducing useful mutation in black cumin which will help to develop desirable mutants.

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