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EFFECT OF ROW SPACING AND DATES OF TRANSPLANTING ON YIELD PERFORMANCE OF ADVANCED RICE MUTANT (RM-40(C)-4-2-8) IN BORO SEASON OF BANGLADESH

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Abstract

Three experiments were conducted at BINA HQs farm Mymensingh and BINA sub-station Rangpur during boro season 2018-19 and 2019-20. The objective was to evaluate the mutant line at four different dates of transplanting and three levels of spacing. The mutant line, RM-40(c)-4-2-8 was compared with two check varieties Binadhan-18, BRRI dhan28 with four dates of transplanting were January 3, January 15, February 1 and February 15 and three row spacing were 20 cm × 15 cm, 20 cm × 20cm, 20 cm × 25 cm for both locations. The effect of date, variety and spacing's showed that transplanting date at January 15 the mutant RM-40(c)-4-2-8 produced maximum yield (5.88 t ha^{-1}) at 20 cm × 15 cm spacing during 2018-19 in Rangpur. The effect of dates of transplanting on grain yield showed that of January 15 transplanting produced the highest grain yield (5.82 t ha^{-1}) during 2019-20 at Mymensingh. Overall observation showed that mutant line RM-40(c)-4-2-8 yielded the best at 20 cm × 15 cm when transplanted on January 15 in Bangladesh.

Key words: Spacing; transplanting dates, grain yield, RM-40(c)-4-2-8, rice mutants

Introduction

Rice (*Oryza sativa* L.) is the most important cereal in Bangladesh. It is extensively cultivated throughout the year and also staple food crop in Bangladesh. The environmental condition of Bangladesh favourable for rice cultivation. Bangladesh earns about 13.02% of her gross domestic product (GDP) from crop (AIS, 2019). In Bangladesh, total cultivable land 11.77 million hectare and used for boro rice 20.18 million hectare and average yield 4.24 t ha^{-1} with a total production of about 38.7 million tons (AIS, 2019). In Bangladesh rice yield is lower than other countries like China, Japan, Egypt and Korea where yield is 7.5, 5.9,7.3 and 7.5 t ha^{-1}, respectively (Choi, 2000). The yield of rice may be increased through improved agronomic manipulations such as proper spacing and transplanting dates. The growth, development, yield and yield components of rice in are highly influenced by date of transplanting. Generally boro rice is transplanted from early December to mid-March. Early transplantation of boro rice prolongs field duration due to low temperature and involves high cost of production, particularly for management practices including irrigation, while delayed transplanting reduces the yield in some cases (BRRI, 2004). Generally closer spacing

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hampers intercultural operations, increases competition among the plants for nutrients, air, light, which results in weaker plants, mutual shading thus favours more straw yield than grain yield and wider plant spacing reduces grain yield per unit area. The benefit in respect of rice yield can be obtained where planting is done with optimum spacing. Genotypes are the key components of produce higher yield of rice depending upon their differences in characters, input requirements and response, growth process and off course the prevailing environmental conditions during the growing season. The growth process of rice plants under a given agro-climatic condition differs with genotypes. Closer spacing results, plants become weaker and thinner and consequently, yield is reduced. Importance of determine optimum spacing for maximizing the yield of rice. Number of seedling hill^{-1} is another important factor that influences plant population unit^{-1} area (Islam *et al.*, 2002). Planting density in transplanted rice culture constitutes the number of seedlings hill^{-1}. Mizan 2010, found the highest yield at 25 cm × 15 cm spacing for transplanted boro rice. The number of tillers and their growth is greatly affected both qualitatively and quantitatively by number of seedlings hill^{-1}. Effect of row and hill spacing influence on yield performance of boro rice (cv. BRRI dhan45) (M. R. Sultana *et al.,* 2012). Optimum number of seedlings hill^{-1} may enable the rice plant to grow properly both in its aerial and underground parts by utilizing maximum solar energy, nutrients, space, water and also could reduce seedling cost of farmers (Azad, 2004). The introduced plant material should be need evaluation under the prevailing climatic conditions of Bangladesh in relation to morphological and physiological characteristics. The highest sterility of spikelet at closest spacing reflects the high competition among the tillers for resources (Rashid, 2009). The normal planting dates show the possibility of day-time heat stress. Adjustment of the planting date is currently limited because high temperature tolerant cultivars are not available in the study region. So, it is also necessary to standardize the optimum planting time and planting spacing for exploiting the potential yield of the advanced mutant line under Bangladesh climatic conditions. Therefore, the research was undertaken to analyze the yield performance of the advanced lines of RM-40(c)-4-2-8 (developed through carbon-ion beam irradiation) under different plant spacing and planting dates for growing under irrigated conditions in Bangladesh.

Materials and methods

Experiments were carried out at the Agronomy field of BINA HQs farm, Mymensingh during boro season 2018-19 in Mymensingh and Rangpur 2019-20 in Mymensingh. The experiment was laid out in split split plot design with three replications. The experimental site was situated between 24.6°N and 90.5°E latitude and at 18 m high from the sea level. The soil of the experimental field was sandy loam type and belonged to the Old Brahmaputra Flood Plain Alluvial Tract in Mymensingh. The advanced mutant lines RM-40(c)-4-2-8 was collected from plant breeding division of BINA and the check variety was Binadhan-18 and BRRI dhan28 with three levels of spacing, viz. 20 cm × 15 cm, 20 cm × 20 cm and 20 cm × 25 cm having four dates of transplanting. The fertilizer doses applied for the experiment were 120 kg N ha^{-1}, 80 kg P ha^{-1}, 100 kg K ha^{-1}, 20 kg S ha^{-1} and 5 kg Zn ha^{-1}. Nitrogen, phosphorus, potassium, sulphur and zinc were supplied from urea, TSP, MoP, gypsum and zinc sulphate monohydrate respectively while urea was applied in three equal splits. Twenty five days old seedlings were transplanted in a randomized complete block design with three replications with single seedling hill^{-1}. The unit plot size was 3m × 4m. The crop was harvested and data on yield and yield components were recorded and analyzed statistically, and the means were compared with LSD (Gomez, K. A. and Gomez A. A. 1984). The advanced mutant lines RM-40(c)-4-2-8 was evaluated with check variety (Binadhan-18) during 2019-20 with three transplanting dates January 15, February 1 and February 15 in Mymensingh were assigned for comparing the performance of advanced mutant line. The application of herbicide (Bensulfuron methyl 4% + Acetachlor 14%) was necessary to keep the field weed free throughout the growing period along with hand weeding at 35 DAT. Furtera 5 G @ 10 kg ha^{-1} was applied to control the infestation of stem borer. The experiment was done under irrigated condition. After attaining 80% physiological maturity the crop was harvested for first, second, third and fourth dates of transplanting respectively. The harvested plants were threshed, cleaned, and processed, and then yield and yield contributing characters were recorded in agronomy laboratory. Weather parameters were also recorded for understanding the growing environment of the crop.

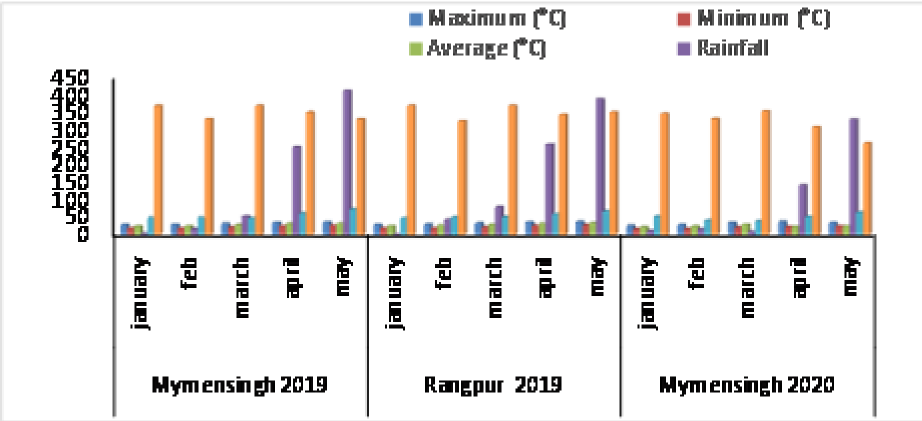

Fig. 1. Weather parameters during experimental period of 2019 in Mymensingh and Rangpur and 2020 in Mymensingh.

Results and discussions

Mymensingh

There was a statistically significant difference in plant height among different spacing. The highest plant height 106.8 cm was observed at (20 cm × 25 cm) spacing and the lowest plant height 105.8 cm at (20 cm × 15 cm) spacing (Table 1). The highest plant height 119.3 was obtained at interaction of mutant RM-40(c)-4-2-8 at spacing (20 cm × 25 cm) and mutant RM-40(c)-4-2-8 at spacing (20 cm × 15 cm) and lowest plant height 97.1 cm at variety BRRI dhan28 (Table 2).

There was a statistically significant difference of total tillers hill^{-1} among spacing. The highest number of total tillers hill^{-1}13.2 was observed at (20 cm × 25 cm) spacing and the lowest number of total tillers hill^{-1}11.5 at (20 cm × 15 cm) spacing (Table 1). There was a statistically significant difference of total tillers hill^{-1} among spacing and genotypes interaction (Table 2). The highest number of total tillers hill^{-1} 13.4 was obtained at interaction of variety Binadhan-18 and spacing (20 cm × 25 cm), mutant RM-40(c)-4-2-8 and spacing (20 cm × 15 cm) and the lowest number of total tillers hill^{-1} 10.8 was at mutant RM-40(c)-4-2-8 at spacing (20 cm × 15 cm) (Table 2).

There was a statistically significant difference of effective tillers hill^{-1} among different spacing. The highest number of effective tillers hill^{-1} 11.7 was observed at (20 cm × 25 cm) spacing and the lowest number of effective tillers hill^{-1} 10.1at (20 cm × 15 cm) spacing (Table 1). Among genotypes the highest number of effective tillers hill^{-1} 11.1 was observed at BRRI dhan28 and the lowest number of effective tillers hill^{-1} 10.6 at genotype RM-40(c)-4-2-8. The highest number of effective tillers hill^{-1} 12 was obtained at interaction of variety Binadhan-18, spacing (20 cm × 25 cm) and lowest number of effective tillers hill^{-1} 9.7 at variety RM-40(c)-4-2-8, spacing (20 cm × 15 cm) (Table 2).

There was a statistically significant difference in panicle length among genotypes the highest panicle length 27.2 cm was recorded inRM-40(c)-4-2-8 and the lowest panicle length 22.4 cm at mutant BRRI dhan28.There was a statistically significant difference of panicle length among spacing and genotype interaction. The highest panicle length 27.3 cm was obtained at interaction of mutant RM-40(c)-4-2-8, spacing (20 cm × 15 cm) and lowest panicle length 22.3 cm at variety BRRI dhan28 at spacing (20 cm × 22 cm) (Table 2).

Among genotypes the highest number of filled grains panicle^{-1} 140.9 was recorded at mutant RM-40(c)-4-2-8 and the lowest number of filled grains panicle^{-1} 117.2 at mutant RM-40(c)-4-2-8. There was a statistically significant difference of filled grain panicle^{-1} among spacing and genotype interaction. The highest number of filled grains panicle^{-1} 145.3 was obtained at interaction of variety RM-40(c)-4-2-8, spacing (20 cm × 20 cm) and lowest number of filled grains panicle^{-1} 116.3 at BRRI dhan28, spacing (20 cm × 25 cm) (Table 2).

Among genotypes the highest number of unfilled grains panicle^{-1} 9 was recorded at mutant Binadhan-18 and the lowest number of unfilled grains panicle^{-1} 30.7 at variety BRRI dhan28.There was a statistically significant difference of unfilled grain panicle^{-1}among spacing and genotype interaction. The highest number of unfilled grains panicle^{-1} 34.2 was obtained at interaction of Binadhan-18, spacing (20 cm × 15 cm) and lowest number of unfilled grains panicle^{-1} 29.4 at mutant RM-40(c)-4-2-8, spacing (20 cm × 25 cm) (Table 2).

Among genotypes, the highest thousand seed weight 22.5g was recorded at variety BRRI dhan28 and the lowest thousand seed weight 19.7gat mutant RM-40(c)-4-2-8. The highest thousand seed weight 22.9 g was obtained at interaction of variety BRRI dhan49, spacing (20 cm × 25 cm) and lowest thousand seed weight 22.1 g at mutant RM-40(c)-4-2-8, spacing (20 cm × 25 cm) (Table 2).

There was a statistically significant difference of grain yield among spacing. The highest grain yield 5.45 t ha^{-1} was recorded at (20 cm × 15 cm) spacing and the lowest grain yield 4.69 t ha^{-1} was at (20 cm × 25 cm) spacing (Table 1). Among the genotype, the highest grain yield 5.67 t ha^{-1} was recorded at mutant RM-40(c)-4-2-8 and the lowest grain yield 4.23 t ha^{-1} at variety Binadhan-18 (Table 1). The highest grain yield 5.86 t ha^{-1} was obtained at interaction of mutant RM-40(c)-4-2-8, spacing (20 cm × 15 cm) and lowest grain yield 3.88 t ha^{-1} at variety Binadhan-18, spacing (20 cm × 25 cm). It might be due to the number of tillers m^{-2}, filled grains $panicle^{-1}$, panicle length was the highest at 20 cm × 15 cm spacing. Optimum (20 cm × 15 cm) spacing for mutant RM-40(c)-4-2-8 proper growth, more effective tiller, panicle initiation, formation of filled grains $panicle^{-1}$ and thousand grain weight and yield was the maximum (Table 1 and Table 2). Optimum plant spacing ensures the plant establishment rates to grow properly with their aerial and underground parts by utilizing more solar radiation interception and nutrients uptake (Miah *et al.,* 1990).

Table 1. Effect of date of transplanting and spacing on yield contributing characters of rice mutant in BINA HQs farm Mymensingh during boro season

Treatments	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	1000 seed wt. (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Dates of transplanting									
January 15 (D_1)	111.8	12.7	11.2	25.2	127.3	32.4	21.4	5.13	6.35
February 01 (D_2)	109.0	13.3	11.7	25.3	127.9	32.4	21.4	5.06	6.62
February 15 (D_3)	98.0	11.0	9.9	24.6	120.9	30.0	21.4	4.61	6.54
$LSD_{0.05}$	3.3	1.2	1.3	0.6	NS	NS	NS	NS	NS
Genotypes (mutant/varieties)									
RM-40(c)-4-2-8 (V_1)	118.8	11.8	10.6	27.2	140.9	30.9	19.7	5.67	7.35
Binadhan-18 (V_2)	102.3	12.7	11.0	25.5	118.0	33.2	22.1	4.23	5.91
BRRI dhan28 (V_3)	97.7	12.5	11.1	22.4	117.2	30.7	22.5	5.26	6.25
$LSD_{0.05}$	1.8	1.2	NS	0.4	8.0	NS	0.2	0.23	0.38
Spacings									
20 cm × 15 cm (S_1)	105.8	11.5	10.1	25.2	123.4	32.7	21.4	5.45	6.87
20 cm × 20 cm (S_2)	106.2	12.4	10.9	24.9	128.4	31.8	21.5	5.01	6.51
20 cm × 25 cm (S_3)	106.8	13.2	11.7	25.0	124.4	30.3	21.3	4.69	6.13
$LSD_{0.05}$	NS	1.3	0.3	NS	4.5	NS	NS	0.07	0.17

Among genotypes the highest straw yield 7.35 t ha^{-1} was recorded at variety RM-40(c)-4-2-8 and the lowest straw yield 5.91 t ha^{-1}at Binadhan-18. There was a statistically significant difference of straw yield among spacing and genotype interaction. The highest straw yield 7.76 t ha^{-1} was obtained at variety RM-40(c)-4-2-8, spacing (20 cm × 15 cm) and lowest straw yield 5.8 t ha^{-1} at BRRI dhan28, spacing (20 cm × 25 cm) (Table 2). Out of three transplanting dates transplanted on January 15, 2018 produced the highest yield (5.13 t ha^{-1}), whereas that of Feb. 15 transplanting produced the lowest grain yield (4.61 t ha^{-1}). It might be due to the highest plant height, highest panicle length and more filled grains $panicle^{-1}$ (127.3) were produced on January 15 transplanting (Table 1). Available data regarding the effect of spacing in conventionally transplanted rice cultivation in boro season

(Rahman *et al.*, 2008). Among the genotypes, RM-40(c)-4-2-8 produced the highest grain yield (5.67 t ha^{-1}). It might be due to highest plant height, panicle length, more filled grains $panicle^{-1}$ (140.9) produced by mutant line RM-40(c)-4-2-8 (Table 1). Genotypes are the key components of produce higher yield of rice depending upon their differences in characters, input requirements and response, growth process and off course the prevailing environmental conditions during the growing season.

Table 2. Two factor effect on the yield and yield contributing characters of rice mutant/varieties at BINA HQs farm Mymensingh during boro season

Treatments	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Dates × Varieties									
D_1V_1	120.9	12.7	11.2	27.1	148.5	29.0	19.4	5.87	7.65
D_1V_2	111.7	11.8	10.5	25.6	117.6	36.8	22.4	3.97	5.46
D_1V_3	102.7	13.7	11.8	22.9	116.0	31.4	22.5	5.12	5.92
D_2V_1	121.2	13.1	12.0	27.3	142.5	33.7	19.6	5.74	7.56
D_2V_2	103.3	13.8	11.3	25.7	121.2	32.9	22.1	4.35	5.89
D_2V_3	102.6	13.0	11.8	22.7	120.0	30.6	22.5	5.11	6.41
D_3V_1	114.4	9.7	8.6	27.0	131.8	30.0	20.0	5.56	6.84
D_3V_2	91.9	12.4	11.1	25.1	115.2	29.9	21.7	4.36	6.36
D_3V_3	87.8	10.9	9.8	21.8	115.7	30.0	22.5	4.96	6.43
$LSD_{0.05}$	3.1	0.8	1.3	0.7	13.8	NS	0.4	0.39	0.65
Dates × Spacings									
$D_1 S_1$	111.2	11.9	10.2	25.4	128.0	34.6	21.5	5.61	6.81
$D_1 S_2$	112.2	12.7	11.3	25.0	128.2	32.8	21.6	5.06	6.42
$D_1 S_3$	111.9	13.6	11.9	25.1	125.8	29.9	21.2	4.72	5.80
$D_2 S_1$	108.9	12.4	10.8	25.7	124.6	32.0	21.4	5.41	6.94
$D_2 S_2$	109.0	13.3	11.6	25.0	131.4	33.7	21.6	4.99	6.59
$D_2 S_3$	109.1	14.2	12.7	25.1	127.8	31.6	21.2	4.80	6.33
$D_3 S_1$	97.2	10.1	9.3	24.5	117.6	31.5	21.5	5.34	6.87
$D_3 S_2$	97.6	11.1	9.8	24.7	125.5	28.8	21.2	4.98	6.52
$D_3 S_3$	99.3	11.8	10.5	24.8	119.6	29.6	21.5	4.56	6.25
$LSD_{0.05}$	1.0	0.2	0.5	0.7	7.8	NS	NS	0.12	0.29
Varieties × Spacings									
$V_1 S_1$	118.2	10.8	9.7	27.1	138.4	32.4	19.7	5.86	7.76
$V_1 S_2$	118.9	11.9	10.8	27.1	145.3	31.0	19.8	5.63	7.35
$V_1 S_3$	119.3	12.8	11.3	27.3	139.1	29.4	19.5	5.51	6.93
$V_2 S_1$	102.0	11.9	10.1	26.0	113.7	34.2	22.2	4.56	6.21
$V_2 S_2$	102.1	12.7	10.8	25.3	122.4	33.8	22.1	4.24	5.86
$V_2 S_3$	102.8	13.4	12.0	25.2	117.8	31.6	21.9	3.88	5.64
$V_3 S_1$	97.1	11.7	10.4	22.6	118.0	31.4	22.4	5.65	6.64
$V_3 S_2$	97.8	12.5	11.1	22.3	117.3	30.5	22.5	5.06	6.32
$V_3 S_3$	98.3	13.4	11.8	22.5	116.3	30.1	22.5	4.69	5.80
$LSD_{0.05}$	NS	0.4	0.5	0.7	7.8	NS	0.4	0.12	0.29
CV%	4.1	10.6	11.4	7.2	10.7	9.4	2.1	7.5	9.7

D_1 = January 15, D_2 = February 01, D_3 = February 15, S_1= 20 cm × 15 cm, S_2 = 20 cm × 20 cm
S_3 = 20 cm × 25 cm, V_1= RM-40(c)-4-2-8, V_2 = Binadhan-18, V_3 = BRRI dhan28.

The grain yield of (20 cm × 15 cm) spacing was the highest (5.45 t ha^{-1}), whereas that of (20 cm × 25 cm) was the lowest (4.69 t ha^{-1}). It might be due statue of the plant and highest panicles m^{-2} in (20 cm × 15 cm) spacing congenial for growth and yield of the mutant (Table 1).

The effect of date and variety showed that RM-40(c)-4-2-8 produced the maximum yield (5.87 t ha^{-1}) when transplanted on January 15 (Table 3). There is a statistically significant different on effect of date and variety the highest filled grains panicle^{-1} (148.5) and lowest (29.4) unfilled grains panicle^{-1} produced on January 15 by RM-40(c)-4-2-8 (Table 2). Transplanting on January 15 produced the maximum yield (5.61 t ha^{-1}) at (20 cm × 15 cm) spacing (Table 2). It might be due to the highest genetic expression for the mutant line in Mymensingh region when the raising of seedling, seedling transplanting. Nonetheless, the bright sunshine at reproductive development phase was also congenial for optimum yield of the mutant line (Table 2). Effect of variety and spacing showed that RM-40(c)-4-2-8 produced maximum yield (5.86 t ha^{-1}) at (20 cm × 15 cm) spacing. It might be due to (20 cm × 15 cm) spacing congenial for suitable growth and development for more panicles produced m^{-2} highest for the mutant RM-40(c)-4-2-8and found maximum yield (Table 2).

Table 3. Combine interaction effect of date of transplanting, mutants and spacing on yield contributing characters of rice mutant at BINA HQs farm Mymensingh during boro season

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Dates × Varieties × Spacings									
$D_1V_1S_1$	121.1	11.9	10.3	27.2	151.7	33.7	19.3	6.12	8.06
$D_1V_1S_2$	121.1	12.6	11.5	26.9	145.7	26.0	19.6	5.70	7.84
$D_1V_2S_3$	120.4	13.5	11.7	27.3	148.1	27.3	19.4	5.48	7.06
$D_1V_2S_1$	110.5	11.1	9.4	26.4	116.7	40.7	22.7	4.51	6.07
$D_1V_2S_2$	112.5	11.9	10.7	25.4	121.7	37.1	22.4	3.89	5.48
$D_1V_2S_3$	112.2	12.6	11.5	25.1	114.3	32.7	22.0	3.50	4.84
$D_1V_3S_1$	102.1	12.7	10.9	22.7	115.7	29.4	22.4	5.50	6.31
$D_1V_3S_2$	102.9	13.6	11.8	22.8	117.3	35.2	22.7	5.17	5.94
$D_1V_3S_3$	103.2	14.7	12.5	23.1	115.0	29.7	22.3	4.68	5.52
$D_2V_1S_1$	120.1	11.9	10.9	27.4	140.2	34.3	19.5	5.92	8.02
$D_2V_1S_2$	121.3	13.2	12.0	27.3	147.1	34.5	20.0	5.58	7.48
$D_2V_2S_3$	122.1	14.2	13.3	27.3	140.2	32.3	19.3	5.32	7.19
$D_2V_2S_1$	103.2	13.2	10.6	26.5	110.2	32.3	22.3	4.51	6.16
$D_2V_2S_2$	102.8	13.7	10.9	25.3	129.7	35.3	22.3	4.35	5.78
$D_2V_2S_3$	103.8	14.4	12.3	25.4	123.7	31.0	21.7	4.19	5.75

Table 3. Continued

Treatments	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
D_2V_3 S_1	103.5	12.0	11.0	23.3	123.3	29.3	22.4	5.40	6.65
D_2V_3 S_2	102.9	13.1	11.9	22.3	117.3	31.3	22.4	5.04	6.53
D_2V_3 S_3	101.5	13.9	12.4	22.5	119.3	31.3	22.7	4.88	6.05
D_3V_1 S_1	113.5	8.6	8.0	26.7	123.3	29.3	20.4	5.94	7.21
D_3V_1 S_2	114.3	9.9	8.9	27.1	143.1	32.3	19.8	5.50	6.74
D_3V_2 S_3	115.5	10.7	9.1	27.2	128.8	28.5	19.8	5.24	6.56
D_3V_2 S_1	92.3	11.5	10.4	25.0	114.3	29.7	21.7	4.67	6.41
D_3V_2 S_2	90.9	12.5	10.9	25.2	116.0	29.0	21.5	4.47	6.33
D_3V_2 S_3	92.3	13.2	12.1	25.2	115.3	31.0	22.0	3.93	6.34
D_3V_3 S_1	85.7	10.3	9.4	21.7	115.0	35.5	22.3	5.41	6.97
D_3V_3 S_2	87.5	10.9	9.7	21.7	117.3	25.1	22.4	4.98	6.48
D_3V_3 S_3	90.1	11.5	10.4	22.0	114.7	29.3	22.7	4.49	5.84
$LSD_{0.05}$	1.7	0.6	0.9	5.2	13.5	10.2	0.7	0.20	0.50
CV%	4.1	10.6	11.4	7.2	10.7	9.4	2.1	7.5	9.7

D_1 = January 15, D_2 = February 01, D_3 = February 15, S_1 = 20 cm × 15 cm, S_2 = 20 cm × 20 cm
S_3 = 20 cm × 25 cm, V_1 = RM-40(c)-4-2-8, V_2 = Binadhan-18, V_3 = BRRI dhan28.

The interaction effect of date, variety and spacing showed that the mutant line, RM-40(c)-4-2-8 produced maximum yield (6.12 t ha^{-1}) at (20 cm × 15 cm) spacing in Jan. 15 transplanting dates (Table 3).

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Transplanting on January 15 gave the highest grain yield (5.98 t ha^{-1}) whereas Feb. 15 transplanting date produced the lowest grain yields (4.07 t ha^{-1}) (Table 4). Among the mutant lines/varieties, the mutant RM-40(c)-4-2-8 produced the highest grain yield (4.88 t ha^{-1}) followed by Binadhan-18 (4.81 t ha^{-1}) (Table 4). The grain yield of (20 cm × 15 cm) spacing was the highest (4.94 t ha^{-1}), whereas that of (20 cm × 25 cm) was the lowest (4.66 t ha^{-1}) (Table 4). It might be due statue of the plant and highest panicles m^{-2} in (20 cm × 15 cm) spacing congenial for growth and yield of the mutant (Table 4).

The interaction effect of date and variety showed that the variety BRRI dhan28 produced the maximum yield (6.2 t ha^{-1}) at January 15 followed by the mutant RM-40(c)-4-2-8 (5.48 t ha^{-1}) (Table 5). The interaction effect of spacing and transplanting at January 15 produced the maximum yield (6.06 t ha^{-1}) at (20 cm × 15 cm) which is followed by same transplanting date produced (5.74 t ha^{-1}) at (20 cm × 20 cm) (Table 5). The interaction effect of variety and spacing the mutant RM-40(c)-4-2-8 produced maximum yield (5.09 t ha^{-1} followed by Binadhan-18 (4.98 t ha^{-1}) at same spacing 20 cm × 15 cm (Table 5).

Table 4. Effect of date of transplanting, genotypes and spacing on the yield and yield contributing characters of rice mutant/varieties at different spacings at BINA Sub-station, Rangpur during boro season

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Dates of transplanting									
January 3 (D_1)	104.4	11.4	10.4	24.0	142.0	23.3	21.3	4.84	6.00
January 15 (D_2)	112.8	13.6	11.8	25.4	153.2	13.5	21.5	5.98	7.01
February 1 (D_3)	110.8	12.2	10.7	24.2	129.2	16.9	21.5	4.22	5.70
February 15 (D_4)	113.1	11.1	9.8	25.2	145.1	20.6	21.4	4.07	5.32
$LSD_{0.05}$	NS	0.7	0.7	0.7	5.9	9.2	NS	0.22	0.19
Mutants/Variety									
RM-40(c)-4-2-8 (V_1)	118.1	11.6	10.4	26.8	166.6	15.4	19.7	4.88	6.10
Binadhan-18 (V_2)	107.0	11.9	10.6	24.5	125.0	22.0	22.2	4.81	6.00
BRRI dhan28 (V_3)	105.8	12.7	11.2	22.8	135.6	18.4	22.4	4.60	5.93
$LSD_{0.05}$	NS	0.8	0.6	0.7	7.5	4.1	NS	0.18	NS
Spacings									
20 cm × 15 cm (S_1)	109.7	10.8	9.7	24.6	143.7	18.8	21.4	4.94	6.15
20 cm × 20 cm (S_2)	110.8	12.3	11.0	24.6	142.1	18.3	21.4	4.74	5.96
20 cm × 25 cm (S_3)	110.4	13.0	11.4	24.9	141.3	18.6	21.5	4.66	5.92
$LSD_{0.05}$	NS	0.7	0.5	NS	NS	NS	NS	0.35	0.19

Table 5. Two factor effect on the yield and yield contributing characters of boro rice mutant/ varieties at BINA sub-station Rangpur

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Dates × Mutants/Variety									
D_1V_1	116.1	10.8	9.8	25.2	168.1	22.5	19.5	5.48	6.43
D_1V_2	100.3	11.3	10.4	25.5	121.3	27.1	22.2	5.33	6.27
D_1V_3	96.9	12.0	10.9	21.3	136.7	20.5	22.2	3.80	5.30
D_2V_1	119.9	14.3	12.4	27.4	179.0	8.2	19.8	5.59	6.74
D_2V_2	108.5	12.7	11.2	25.2	138.7	14.7	22.3	5.68	7.15
D_2V_3	110.1	13.7	11.9	23.4	141.8	17.6	22.5	6.20	7.15
D_3V_1	115.8	9.6	9.0	25.8	144.9	15.1	19.9	4.17	5.61
D_3V_2	110.4	14.0	11.7	23.9	117.5	20.1	22.2	4.06	5.42
D_3V_3	106.2	13.1	11.4	23.0	125.2	15.4	22.4	4.44	6.08
D_4V_1	120.5	11.6	10.2	28.8	174.3	15.8	19.5	4.38	5.62
D_4V_2	108.7	9.8	8.9	23.5	122.3	26.0	22.3	3.88	5.15
D_4V_3	110.1	11.9	10.4	23.4	138.6	20.1	22.3	3.96	5.21
$LSD_{0.05}$	2.7	1.5	1.1	1.4	15.0	8.0	0.5	0.17	0.65

Table 5. Continued

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Dates × Spacing									
$D_1 S_1$	103.3	9.6	8.9	24.4	145.4	22.5	21.2	4.94	5.86
$D_1 S_2$	104.0	11.6	10.7	23.6	142.0	23.6	21.3	4.69	6.07
$D_1 S_3$	106.0	12.8	11.6	24.1	138.6	24.0	21.4	4.58	6.07
$D_2 S_1$	112.2	13.0	11.4	25.5	156.7	13.5	21.5	6.06	7.24
$D_2 S_2$	113.3	13.5	11.8	25.4	152.9	13.6	21.6	5.74	6.81
$D_2 S_3$	113.0	14.2	12.3	25.1	149.9	13.4	21.6	5.17	6.99
$D_3 S_1$	110.2	10.9	9.7	23.6	127.8	19.7	21.6	4.59	5.93
$D_3 S_2$	111.8	12.6	11.2	24.3	131.2	14.5	21.2	4.16	5.65
$D_3 S_3$	110.4	13.1	11.2	24.8	128.6	16.4	21.6	3.92	5.53
$D_4 S_1$	113.1	9.7	8.9	24.9	144.7	19.6	21.2	4.42	5.58
$D_4 S_2$	113.9	11.6	10.3	25.1	142.5	21.7	21.4	4.12	5.30
$D_4 S_3$	112.3	11.9	10.4	25.8	148.1	20.6	21.5	3.67	5.09
$LSD_{0.05}$	2.8	1.4	0.9	0.8	12.0	4.4	0.5	0.16	0.39
Mutants/Variety × Spacing									
$V_1 S_1$	118.0	10.7	9.7	26.8	170.5	14.3	19.5	5.09	6.29
$V_1 S_2$	117.8	11.4	10.3	26.2	164.6	15.9	19.7	4.75	5.97
$V_1 S_3$	118.5	12.6	11.1	27.4	164.7	16.0	19.8	4.79	6.05
$V_2 S_1$	106.0	10.6	9.5	24.4	128.2	22.4	22.2	4.98	6.21
$V_2 S_2$	107.2	12.4	10.9	24.4	124.6	20.9	22.2	4.91	5.96
$V_2 S_3$	107.8	12.8	11.3	24.8	122.2	22.5	22.4	4.69	5.82
$V_3 S_1$	105.2	11.2	9.9	22.6	132.3	19.8	22.4	4.74	5.96
$V_3 S_2$	107.3	13.2	11.7	23.2	137.3	18.2	22.2	4.57	5.94
$V_3 S_3$	105.0	13.6	11.8	22.6	137.1	17.3	22.5	4.49	5.90
$LSD_{0.05}$	2.4	1.2	0.8	0.7	10.0	3.8	0.4	0.28	0.34

D_1 = January 3, D_2 = January 15, D_3 = February 01, D_4 = February 15, S_1 = 20 cm ×15 cm, S_2 = 20 cm × 20 cm S_3 = 20 cm × 25 cm, V_1= RM-40(c)-4-2-8, V_2 = Binadhan-18, V_3 = BRRI dhan28.

The interaction effect of date, variety and spacing showed that transplanting date at January 15 the mutant RM-40(c)-4-2-8 produced maximum yield (5.88 t ha^{-1}) at 20 cm × 15 cm spacing. The lowest (3.40 t ha^{-1}) yield was reduced in all interaction at D_4V_2 S_3 (Table 6).

The effect of dates of transplanting on grain yield showed that of Jan. 15 transplanting produced the highest grain yield (5.82 t ha^{-1}) whereas Feb. 15 transplanting date produced the lowest grain yield (5.49 t ha^{-1}) (Table 7). Between two genotypes, Binadhan-18 produced the highest grain yield (5.67 t ha^{-1}) (Table 7). The interaction effect of date and variety showed that Binadhan-18 produced the maximum yield (6.39 t ha^{-1}) at January 15 transplanting followed by Feb. 1 (6.29 t ha^{-1}) (Table 7).

Table 6. Combine interaction effect of date of transplanting and row spacing on the yield and yield contributing characters of boro rice mutant/varieties at BINA Sub-station Rangpur

Treatments	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	1000 seed weight (g.)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
Dates × Mutants/Variety× Spacing									
$D_1V_1 S_1$	116.5	8.9	8.4	25.5	174.0	18.7	19.1	5.82	6.03
$D_1V_1 S_2$	113.6	10.7	9.7	23.0	156.9	24.7	19.6	5.67	6.72
$D_1V_2 S_3$	118.1	12.8	11.3	27.1	173.4	24.1	19.7	5.32	6.53
$D_1V_2 S_1$	99.3	9.3	8.5	25.4	124.3	27.4	22.1	5.27	6.40
$D_1V_2 S_2$	100.6	11.8	10.9	25.5	122.9	24.8	22.3	5.37	5.91
$D_1V_2 S_3$	101.0	12.8	11.9	25.5	116.7	29.0	22.2	5.37	6.50
$D_1V_3 S_1$	94.2	10.7	9.7	22.1	137.9	21.4	22.3	4.00	5.14
$D_1V_3 S_2$	97.8	12.5	11.5	22.1	146.3	21.2	22.1	3.80	5.58
$D_1V_3 S_3$	98.8	12.9	11.7	19.7	125.8	18.8	22.2	3.60	5.18
$D_2V_1 S_1$	118.9	14.1	12.3	27.5	182.3	9.3	19.8	5.88	7.13
$D_2V_1 S_2$	120.2	13.7	12.2	27.4	179.3	7.9	20.2	4.97	6.25
$D_2V_2 S_3$	120.6	15.1	12.9	27.2	175.3	7.5	19.6	5.53	6.83
$D_2V_2 S_1$	106.9	11.7	10.5	25.3	145.3	15.3	22.2	5.37	7.16
$D_2V_2 S_2$	109.0	13.2	11.3	25.1	141.3	14.9	22.1	5.67	7.14
$D_2V_2 S_3$	109.5	13.2	11.9	25.4	129.5	13.9	22.5	5.30	7.16
$D_2V_3 S_1$	110.9	13.2	11.4	23.8	142.5	16.1	22.5	5.70	7.43
$D_2V_3 S_2$	110.7	13.6	12.0	23.7	137.9	17.9	22.4	5.78	7.03
$D_2V_3 S_3$	108.7	14.2	12.2	22.8	144.9	18.8	22.7	5.67	6.98
$D_3V_1 S_1$	115.2	10.3	9.4	25.9	149.8	17.3	20.2	4.67	5.89
$D_3V_1 S_2$	116.6	9.4	9.1	25.9	143.9	13.0	19.5	4.03	5.43
$D_3V_2 S_3$	115.7	9.1	8.6	25.7	141.1	15.1	19.9	3.80	5.52
$D_3V_2 S_1$	109.3	11.9	10.1	23.9	118.9	19.7	22.3	4.33	5.77
$D_3V_2 S_2$	110.1	14.5	12.2	23.3	115.5	19.1	22.2	4.13	5.65
$D_3V_2 S_3$	111.9	15.5	12.8	24.5	118.1	21.5	22.3	3.70	4.83
$D_3V_3 S_1$	106.1	10.5	9.6	21.1	114.9	22.1	22.4	4.77	6.14
$D_3V_3 S_2$	108.7	14.0	12.2	23.6	134.1	11.3	22.0	4.30	5.85
$D_3V_3 S_3$	103.7	14.7	12.3	24.1	126.6	12.6	22.7	4.27	6.24
$D_4V_1 S_1$	121.1	9.3	8.7	28.3	176.0	12.0	19.1	5.03	6.09
$D_4V_1 S_2$	120.9	11.9	10.3	28.5	178.1	18.0	19.7	4.33	5.46
$D_4V_2 S_3$	119.6	13.4	11.4	29.7	168.9	17.4	19.7	3.77	5.30
$D_4V_2 S_1$	108.5	9.6	8.8	23.1	124.1	27.4	22.2	4.37	5.50
$D_4V_2 S_2$	109.1	10.0	9.3	23.6	118.5	24.8	22.2	3.87	5.15
$D_4V_2 S_3$	108.6	9.8	8.7	23.8	124.3	25.7	22.5	3.40	4.79
$D_4V_3 S_1$	109.5	10.3	9.1	23.3	133.9	19.4	22.2	3.87	5.14
$D_4V_3 S_2$	111.9	12.9	11.3	23.2	130.8	22.2	22.4	4.17	5.31
$D_4V_3 S_3$	108.8	12.5	10.9	23.8	151.1	18.8	22.4	3.83	5.18
$LSD_{0.05}$	4.8	2.4	1.6	1.5	21.0	7.7	0.8	0.56	0.68
CV%	5.4	12.3	9.2	5.7	10.6	25.2	2.2	7.43	10.96

D_1 = January 3, D_2 = January 15, D_3 = February 01, D_4 = February 15, S_1 = 20 cm × 15 cm, S_2 = 20 cm × 20 cm S_3 = 20 cm × 25 cm, V_1= RM-40(c)-4-2-8, V_2 = Binadhan-18, V_3 = BRRI dhan28.

Table 7. Effect of and dates of transplanting, genotypes and spacing on yield contributing characters of RM-40(c)-4-2-8rice mutant during boro season 2019-20

Treatments	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Crop duration (days)
Dates of transplanting										
January 15 (D_1)	107.4	10.2	9.4	26.2	106.1	26.7	21.2	5.82	6.77	
February 01 (D_2)	107.8	10.0	8.9	25.3	111.4	25.8	21.2	5.72	6.76	
February 15 (D_3)	106.6	10.3	9.2	25.3	96.7	27.7	20.5	5.49	6.65	
$LSD_{0.05}$	2.5	1.1	1.2	0.9	8.1	3.6	0.7	0.17	0.15	
Mutant/Varieties										
RM-40(c)-4-2-8 (V_1)	99.9	10.6	9.7	24.3	81.3	21.9	23.0	5.12	6.18	142
Binadhan-18 (V_2)	114.7	9.7	8.6	27.0	128.2	31.6	19.0	6.23	7.28	145
T value	1.8	1.2	NS	0.4	8.0	NS	0.2	0.23	0.38	
Dates × Varieties										
D_1V_1	100.5	10.8	10.0	25.4	81.1	19.5	23.1	5.25	6.30	
D_1V_2	114.4	9.5	8.7	27.0	131.2	33.9	19.2	6.39	7.25	
D_2V_1	100.3	10.1	8.8	23.6	91.2	20.6	23.5	5.15	6.13	
D_2V_2	115.3	9.9	8.9	27.0	131.7	30.9	19.0	6.29	7.39	
D_3V_1	98.9	11.0	10.3	23.8	71.7	25.6	22.3	4.98	6.11	
D_3V_2	114.3	9.5	8.1	26.9	121.6	29.9	18.7	6.00	7.20	
$LSD_{0.05}$	2.6	2.0	1.9	1.0	12.4	3.0	0.8	0.16	0.49	
CV (%)	2.9	7.0	8.1	2.2	5.9	8.5	2.2	1.91	3.62	

Conclusion

It was concluded from the findings that grain yield at 20 cm × 15 cm, spacing, the mutant RM-40(c)-4-2-8 produced maximum yield 5.88 t ha^{-1} in Rangpur followed by 5.86 t ha^{-1} in Mymensingh when transplanted on January 15. To ensure satisfactory yield of mutant line of RM-40(c)-4-2-8 might be express full potentialities in boro season at 35 days age seedling, if edaphic condition, favorable weather parameters and management practices of 20 cm × 15 cm spacing on January 15 transplanting.

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