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EVALUATION OF TWO ADVANCED GENERATION *BORO* RICE MUTANTS BASED ON MORPHO-PHYSIOLOGICAL CRITERIA

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Abstract

Experiments were performed at farmers' fields of five locations viz., Mymensingh, Sherpur, Jamalpur, Natore and Naogaon districts with two promising *Boro* rice mutants, RM-16(N)-8, RM-16(N)-10 and a check, BRRI dhan58 to evaluate some morpho-physiological features and its impact on grain yield. The experiment was setup in RCB design with three replications. Results revealed that high yielding genotypes, in general, showed superiority in morpho-physiological characters (leaf area, leaf area index, total dry mass production, absolute growth rate, relative growth rate, chlorophyll, total sugar and soluble protein content in leaves and harvest index) than the low yielding one. Results further indicated that genotype improvement efforts have achieved higher grain yield by higher growth rate at early growth stages and better assimilate partitioning to economic yield and short stature plants are unlikely to improve harvest index and resistant to lodging in rice. The mutant, RM-16(N)-10 had medium plant stature with greater biomass production capacity, superiority in growth and biochemical parameters and improve dry matter partitioning to economic yield which resulted higher number of grains panicle^{-1}, thereby grain yield. In contrast, RM-16(N)-8 showed inferiority in morpho-physiological characters and performed the lowest yield attributes and grain yield. This information may be used in future plant breeding programme.

Key Words: Growth, mutants, chlorophyll, photosynthesis, yield

Introduction

In Bangladesh, the yield potential of modern Boro rice varieties varies from 7.5 to 9.0 tons ha^{-1}. The domestic production of rice cannot entirely meet up the requirements of hungry millions of Bangladesh. To meet increasing demand of rice for the fast-growing population of Bangladesh, there need urgent attention to develop high yielding variety under sub-tropical environmental condition. To increase rice production, there is very little scope for horizontal expansion of rice area. Furthermore, the wide gap between achievable (8.4 t ha^{-1}) and average yield (4.96 t ha^{-1}) should be reduced. Now, the main strategy for development of rice in Bangladesh should be to develop lines having high yield potentials with short life span and high levels of resistance to major diseases. Due to the shortage of cultivable land, the scope of its extensive cultivation is very limited in this country.

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That is why special attention should be given for increasing the yield per unit area by developing improved varieties/technology and management practices.

It is evident that grains per unit area are related to canopy photosynthesis during flowering and grain set. Furthermore, canopy photosynthesis rate determines through leaf area index and crop growth rate. Important physiological attributes such as leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), specific leaf weight (SLW) and photo-assimilate production capacity and its efficient partitioning to economic yield etc. can address various constraints of a variety for increasing its productivity (Mondal *et al*., 2013). A plant with optimum LAI and NAR may produce higher biological yield. For optimum yield in rice, the LAI should be ranged from 6.0 to 7.0 (Asmamaw, 2017). Any reduction of leaf area or the amount/intensity of light may have an adverse effect on yield (Mondal *et al*., 2011). The dry matter accumulation may be the highest if the LAI attains its maximum value within the shortest possible time (Mondal *et al*., 2014). Not only TDM production, the capacity of efficient partitioning between the vegetative and reproductive parts may produce high economic yield (Mondal *et al*., 2011). It is suggested that high partitioning efficiency (harvest index) would be advantageous for high yield. Probably a better understanding of crop growth and yield parameters and the partitioning of assimilates into seed formation would help to expedite yield improvement of this crop. Keeping all those above in mind, the current research was undertaken to investigate variations in some growth, biochemical parameters and yield attributes for selection of important sources and sinks in two elite mutants and one variety of *Boro* rice.

Materials and Methods

The field experiment was performed at farmers' field of five locations under different agro-ecological zones in Bangladesh viz., Mymensingh, Sherpur, Jamalpur, Natore and Naogaon districts during December 2021 to May 2022. Two advanced mutants (RM-16 (N)-8 and RM-16 (N)-10) and one check variety (BRRI dhan58) of *Boro* rice were used as treatment in the experiment. The experiment was laid out in a Randomized Complete Block Design with 3 replications. The size of the unit plot was 5 m x 6 m. Plant to plant distance was 15 cm and row to row distance was 20 cm. Thirty five days old seedlings were transplanted on January 20, 2022. The land was fertilized with 220, 150, 130, 60 and 5 kg ha^{-1} of urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate, respectively (BARC, 2018). Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate were used as source of nitrogen, phosphorus, potassium, sulphur and zinc, respectively. One third urea and other fertilizers were incorporated with the soil at the final land preparation and rest of the urea was top dressed in two equal splits at 25 and 50 days after transplanting (DAT). Others standard cultural practices were followed to ensure the normal plant growth and development. The morpho-physiological parameters were recorded from the experiment that setup at farmer's field of Mymensingh district. For growth analysis, five hills were randomly sampled for growth analysis at Booting (60 DAT), heading (90 DAT) and physiological maturity (120 DAT) stages. The uprooted plants were separated into stem, leaves and roots and the corresponding dry weight were recorded after oven drying at 80 ± 2 ^{0}C for 72 hours. Leaf area was measured by LICOR leaf area meter (LI 3000A, USA) before drying. The growth analyses like AGR and RGR were carried out following the formulae of Hunt (1978). Photosynthesis was measured at tillering, booting, heading and physiological maturity stages by portable photosynthesis meter (LI- 6800XT, USA). Leaf chlorophyll was determined at tillering, booting, heading and two weeks after heading stages by following the method of Yoshida., *et al*. (1976). Total sugar was determined at tillering, booting, heading and two weeks after heading stages following the method of Dubois., *et al*. (1956).

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

Results and Discussion

Morphological and phenological characters

Plant height, number of tillers hill^{-1}, leaf area (LA) and internode length varied significantly among the mutants/variety (Table 1). The tallest plant was recorded in BRRI dhan56 (109.1 cm) while the shortest plant was recorded in RM-16 (N)-8 (92.5 cm) followed by the mutant RM-16 (N)-10 with same statistical rank (94.2 cm). Results showed that two mutants, RM-16 (N)-8 and RM-16 (N)-10 were shorter than the control variety BRRI dhan58. There had no high difference for tiller production and leaf area among the mutants/variety (Table 1). However, two mutants, RM-16 (N)-8 and RM-16 (N)-10 produced higher number of tillers hill $^{-1}$ with being the highest in RM-16 (N)-8 (19.77). In contrast, the lowest tiller production was recorded in BRRI dhan58 (15.95 hill^{-1}). The highest leaf area was recorded in RM-16 (N)-10 (1182.4 cm^2 hill^{-1}) and the lowest was recorded in RM-16 (N)-8 (1088.9 cm^2 hill^{-1}). Genotypic variation in plant height, leaf area and tiller production was also reported by many workers (Rebetzke *et al*., 2004; Das and Taliaferro, 2009; Sripathi *et al.* 2013; Kumar and Roy, 2015) that supported the present experimental results. Internode length was greater in the variety BRRI dhan58 than the two mutants that causes lodging of the variety, BRRI dhan58 which is not desirable character. The variety BRRI dhan58 matured earlier than the two mutants, RM--16 (N)-8 and RM--16 (N)-8. RM-16 (N)-10 took longest days to maturity (156 days) and this mutant also performed the highest grain yield. This result is agrees with Khare *et al*. (2015) and Atsedemariyam, (2018) who reported that days to maturity was positively correlated with grain yield in rice.

Table 1. Variation in morphological and phenological parameters of three *Boro* rice mutants/variety (mean over 5 locations)

Genotypes	Plant height (cm)	Leaf area (cm^2 $hill^{-1}$)†	Total tillers $hill^{-1}$ (no.)	Internode length† (cm)	Lodging tendency (%)	Growth duration (days)	Days to maturity
RM-16 (N)-8	92.5 b	1088.9 b	19.77 a	14.84 c	0.00	123.3 b	153 b
RM-16 (N)-10	94.2 b	1182.4 a	17.31 ab	15.23 b	0.00	126.1 a	156 a
BRRI dhan58	109.1 a	1110.4 b	15.95 b	17.88 a	60.0	118.2 c	148 c
F-test	**	*	*	**		**	**
CV (%)	6.66	6.48	11.23	2.51		2.12	2.72

In a column, figure (s) with same letter do not differ significantly at $p \leq 0.05$; **, * significant at 1% and 5% level of probability, respectively; †: data collected at Mymensingh only.

Growth parameters

The effect of rice genotypes on growth characters like total dry mass (TDM) at three growth stages (booting, panicle initiation and mature), absolute growth rate (AGR) and relative growth rate (RGR) was significant (Table 2). Results indicated that TDM production increased with age until maturity whereas reverse trend was observed in AGR and RGR. At later growth stages (panicle initiation and mature stages), the highest TDM $plant^{-1}$ was recorded in BRRI dhan58. The mutant RM-16(N)-8 produced the lowest TDM at all growth stages. The mutant RM-16 (N)-10 produced the highest TDM $plant^{-1}$ at early growth stages (booting stage) followed by second highest TDM at later growth stages (panicle initiation and mature stages). Generally, high yielding genotypes produced higher TDM and LAI (Mondal *et al*., 2013). In the present experiment, the variety BRRI dhan58 and the mutant RM-16(N)-10 were the yielder with highest/higher TDM and LAI producer variety/mutant. The value of AGR and RGR was greater early growth stages than later growth stages (Table 2). At later growth stages, AGR and RGR were higher in mutants than the variety, BRRI dhan58 but at early growth stages, reverse trend was in case of AGR and RGR. Results indicated that rice grain yield had no relation with AGR and RGR. It means selection of mutants based on superior growth parameters may be misleading. Plant growth and yield are represented by the crop's early ability to intercept solar radiation and its subsequent utilization for biomass production (Hanlan *et al.,* 2006). Increase interception of solar radiation at early seedling stages enable plant to make rapid early growth, resulting in high yield (Gautam *et al.,* 2018). In the present experiment, the mutant RM-16 (N)-10 showed early higher growth rate and also showed high yield potential. Similar result was also reported by Akther *et al.,* 2019 who observed that the genotypes which had capacity to early higher growth rate also showed higher seed yield in rice.

Table 2. Variation in total dry mass production and absolute growth rate at different growth stages of three *Boro* rice mutants/variety†

Genotypes	Total dry mass production at			Absolute growth rate at (g $hill^{-1}$ day^{-1})		Relative growth rate at (mg g^{-1} day^{-1})	
	Booting stage	Panicle initiation stage	Mature stage	BS-PI stage	PI- MS stage	TS-PI stage	PI- MS stage
RM-16 (N)-8	40.4 b	90.90 c	138.3 b	1.68 c	1.58 a	27.0 ab	13.99 a
RM-16 (N)-10	48.6 a	104.2 b	148.0 a	1.85 b	1.46 a	24.4 b	11.76 ab
BRRI dhan58	43.2 b	112.6 a	150.4 a	2.31 a	1.26 b	31.9 a	9.65 b
F-test	**	**	*	**	*	**	**
CV (%)	9.16	6.88	12.20	9.02	10.54	8.66	9.95

In a column, figure (s) with same letter do not differ significantly at $p \leq 0.05$; *, ** significant at 5% and 1% level of probability, respectively; BS, booting stage; PI, panicle initiation; MS, mature stage; †: data collected at Mymensingh only.

The effect of rice genotypes on leaf area index (LAI) at four growth stages like tillering, booting, panicle initiation and physiological maturity stages was significant (Table 3). Results indicated that LAI increased with age until heading stage followed by a decline due to leaf shading. The mutant RM-16(N)-10 showed the highest LAI at all growth stages and the lowest LAI at most growth stages was recorded in the mutant, RM-16(N)-8. Leaf area index (LAI) is a key variable used in field crops involving the relation between crop growth and yield. LAI is commonly used as an important structural and biophysical indicator of vegetation for crop photosynthesis (Brown *et al*., 2020), productivity (Kanniah *et al*., 2021), and water utilization (Gan *et al*., 2018). This variable can be a very useful tool when looking to evaluate the performance of a crop. The LAI is correlated with yield (Rahman *et.al*., 2020). In this experiment, the high yielding mutant, RM-16(N)-10 showed superior LAI at all growth stages and also showed higher grain yield.

Biochemical parameters

Genotypes had no high variation on photosynthesis (Pn) in leaves at all growth stages of rice genotypes (Table 3). However, Pn increased with age until heading stage followed by a decline. The highest/higher Pn was recorded in RM-16(N)-10 and this mutant also showed higher seed yield which indicated seed yield is positively correlated with Pn. On the other hand, the mutant, RM-16(N)-8 showed inferiority in Pn and also showed lower yield performance. These results indicate that Pn rate is very much important for getting higher grain yield. These results are consistent with many workers (Long *et al*., 2006; Islam, 2010; Makino, 2011;) who reported Pn was positively correlated with yield in rice. On the other hand, a lack of correlation between photosynthesis and plant yield has been frequently observed when different genotypes of a crop are compared (for wheat, Evans and Dunstone, 1970; for rice, Takano Y, Tsunoda S. 1971). This is also true because modern cultivars have been bred for various traits besides photosynthesis.

Table 3. Changes in leaf area index and leaf photosynthesis rate of three *Boro* rice mutants/variety†

Genotypes	Leaf area index at				Photosynthesis rate in leaves (μmol$CO^2m^{-2}S^{-1}$) at			
	Tillering stage (30 DAT)	Booting stage (60 DAT)	Heading stage (90 DAT)	Three weeks after heading	Tillering stage	Booting stage	Heading stage	Three weeks after heading
RM-16 (N)-8	3.84 b	4.82 c	6.91 c	6.39 a	18.66 b	24.34	23.8 b	14.43
RM-16 (N)-10	4.16 a	5.90 a	7.90 a	6.54 a	21.30 a	24.15	26.40 a	15.22
BRRI dhan58	4.09 ab	5.58 b	7.36 b	5.41 b	19.58 ab	23.24	24.11 ab	14.01
F-test	*	**	**	**	**	NS	*	NS
CV (%)	8.45	6.40	9.12	6.92	6.66	9.80	9.14	11.34

In a column, figure (s) with same letter do not differ significantly at $p \leq 0.05$; *, ** significant at 5% and 1% level of probability, respectively; NS, not significant; †: data collected at Mymensingh only.

The variation in chlorophyll, total sugar and soluble protein content in leaves among the mutants/cultivar was assessed at four growth stages and presented in Tables 4 and 5. There was no significant variation in chlorophyll content of leaves at early growth stages (tillering and booting stages) and significant variation was also observed at later growth stages (Heading and mature stages). It was observed that chlorophyll content in leaves increased with age until heading stage followed by a rapid decline. On the other hand, total sugar and soluble protein content in leaves increased with age till booting stage followed by a decline (Table 5). It indicates that from heading to grain filling stages assimilates produce in leaves remobilized more from leaves to grains. The mutant RM-16 (N)-10 showed the highest chlorophyll, total sugar and soluble protein content in leaves at most growth stages and also showed the highest grain yield. In contrast, the lowest chlorophyll, total sugar and soluble protein content in leaves at most of the growth stages was observed in RM 16(N)-8 and also showed the lowest grain yield. Grain yield is positively correlated with chlorophyll content in leaves of rice as reported by many researchers (Xu *et al*., 1997; Thomas *et al.*, 2005; Poshtmasari *et al*., 2007; Nahakpam, 2017). Further, Caddell *et al*., 2023 reported that quantum yield photosynthesis is closely related with chlorophyll density in leaves.

Table 4. Variation in chlorophyll content (mg g^{-1} fw) in rice leaves at four growth stages of three *Boro* rice mutants/variety (data collected at Mymensingh only)

Genotypes	Growth stages			
	Tillering stage	Booting stage	Heading stage	Two weeks after heading
RM-16 (N)-8	2.22	2.61	3.16 a	1.82 b
RM-16 (N)-10	2.25	2.75	3.06 a	2.15 a
BRRI dhan58	2.28	2.64	2.86 b	1.84 b
F-test	NS	NS	*	*
CV (%)	6.59	8.20	4.87	5.62

In a column, figure (s) with same letter does not differ significantly at $p \leq 0.05$; *, significant at 5% level of probability; NS, not significant.

Table 5. Changes in total sugar and soluble protein content in leaves of three *Boro* rice mutants/variety†

Genotypes	Total sugar (mg g^{-1}fw) at				Soluble protein (mg g^{-1}fw) at			
	Tillering stage	Booting stage	Heading stage	Two weeks after heading	Tillering stage	Booting stage	Heading stage	Two weeks after heading
RM-16 (N)-8	60.3	124.5 b	102.6 b	75.3	47.5	51.3 b	42.5 b	37.5
RM-16 (N)-10	58.2	138.4 a	117.3 a	73.0	44.3	56.1 a	47.0 a	39.6
BRRI dhan58	64.0	116.8 b	103.5 b	79.0	44.6	52.0 b	44.3 ab	41.5
F-test	NS	**	**	NS	NS	*	*	NS
CV (%)	14.30	16.00	13.42	11.22	10.64	7.70	9.90	14.34

In a column, figure (s) with same letter do not differ significantly at $p \leq 0.05$; *, ** significant at 5% and 1% level of probability, respectively; NS, not significant; †: data collected at Mymensingh only.

Grain yield and yield attributes

Significant genotypic variation is also observed in case of grain yield and yield attributes (Tables 6 and 7). The highest grain yield both per hill and per hectare was observed in RM-16(N)-10 while the mutant RM-16(N)-8 produced lowest grain yield. The check variety BRRI dhan58 showed its moderate yield performance. The yield was higher in RM-16(N)-10 due to production of higher number of effective tillers hill^{-1} and grains panicle^{-1}. The variety BRRI dhan58 produced the highest number of grains panicle^{-1} with performing second highest grain yield might be due to production of fewer number of effective tillers hill^{-1}. Mondal *et al.* (2005) reported that the genotypes, which produced higher number of effective tillers hill^{-1} and higher number of grains panicle^{-1} also showed higher grain yield. Similar results were also reported by many previous report (Oladosu *et al.* 2014; Mondal, 2018; Paudel *et al.*,2021).

Results indicated that harvest index was higher in mutants than the check variety BRRI dhan58 (Table 6). The highest harvest index was recorded in RM-16(N)-8 followed by RM-16 (N)-10 with same statistical rank. The lower harvest index was recorded in BRRI dhan58 (40.84). Generally, high yielding genotypes produced higher TDM and LAI (Mondal *et al*., 2013). In the present experiment, the mutant RM-16(N)-10 was the highest yielder with highest TDM and LAI producer variety. Further, the TDM's negative response to HI in BRRI dhan58 could be explained in way that high TDM producing capacity might have used assimilate for other vegetative sinks (taller plant) and that it deprived translocation of assimilates to economic sink. In other word, dry matter partitioning to economic yield was lower in BRRI dhan58 which is not desirable character. But dry matter partitioning to economic yield is more important than TDM production. However, the mutant RM-16(N)-10 produced intermediate TDM with highest dry matter partitioning to economic yield (49.26%) and resulting higher grain yield that is the desirable character.

Table 6. Variation in yield attributes and harvest index of three *Boro* rice mutants/variety (mean over 5 locations)

Genotypes	Effective tillers hill^{-1}	Grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight (g)	Grain weight 4m^{-2} (kg)	Biological yield 4m^{-2} (kg)	Harvest index (%)
RM-16 (N)-8	12.57 a	138.4 b	34.1 b	23.21 b	2.87 b	5.85 b	49.06 a
RM-16 (N)-10	12.95 a	151.7 a	31.2 b	24.06 a	3.32 a	6.74 a	49.26 a
BRRI dhan58	10.67 b	157.7 a	43.1 a	24.23 a	2.95 b	6.95 a	42.45 b
F-test	**	**	**	*	**	**	**
CV (%)	8.16	8.88	16.20	1.98	10.11	9.22	4.72

In a column, figure (s) with same letter do not differ significantly at $p \leq 0.05$; *, ** significant at 5% and 1% level of probability, respectively; †: data collected at Mymensingh only.

Considering grain yield over locations (Table 7), the mutant RM-16(N)-10 showed the highest grain yield (7.68 t ha^{-1}) at all 5 locations and showed 10.8% higher grain yield than check variety, BRRI dhan58 (6.93 t ha^{-1}). On the other hand, the mutant RM-16(N)-8 showed higher grain yield than the check variety, BRRI dhan58 at 3 locations with non-significant different to check variety. However, BRRI dhan58 showed lodging tendency in 3 locations out of five (Table 1).

Table 7. Variation in grain yield of two Boro rice mutants and one Boro rice variety at five locations during 2021-22

Mutants/ variety	Grain yield (t ha^{-1})					Mean (t ha^{-1})	Yield Changed over control (%)
	Mymensingh	Sherpur	Jamalpur	Natore	Naogaon		
RM-16(N)-8	6.73 b	6.10 b	6.23 b	7.14 b	8.00 c	6.84 b	- 1.3
RM-16(N)-10	7.23 a	7.06 a	6.79 a	7.54 a	9.79 a	7.68 a	10.8
BRRI dhan58	6.58 b	5.82 b	6.33 b	7.33 a	8.70 b	6.93 b	--
F-test	**	**	**	*	**	**	
CV (%)	8.88	13.20	8.56	5.67	10.13	9.29	

Same letter (s) in a column indicates do not differ significantly at P≤ 0.05.

Conclusion

From the study, it is evident that out of three mutants/variety, RM 16(N)-10 showed superiority in respect of growth, biochemical parameters and grain yield that may be selected effectively to be a physiological superior mutant. This mutant may be released as improve variety after few more trails under farmers' field conditions at different agro-ecological zones of the country.

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