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Physiological Behaviour and Yield Contribution of *Oryza sativa* Under Different Cultivation System in Boro Season

Md. Shoriful Islam^{1*}, Md. Moinul Hoque¹, Kamal Uddin Ahamed¹,
Parvin Akter Bithy¹ and Sarmin Akter Ranu¹

¹Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

Authors' contributions

This work was carried out in collaboration among all authors. Author MSI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MMH, KUA, SAR and PAB managed the analyses of the study. Authors MSI, SAR and PAB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objectives of the research work were to evaluate the physiological behaviour and yield contributing attributes of rice under different system of cultivation in *boro* season.

Study Design: The experiment was laid out in a randomized complete block design (RCBD) with three replications.

Place and Duration of Study: Central research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during November 2015 to May 2016.

Methodology: In this research we used three System of cultivation [T_1 : Low land transplant (anaerobic) condition; T_2 : Raised upland (aerobic) condition, and T_3 : Raised transplant (aerobic) condition] and five rice Varieties [V_1 : BRRI hybrid dhan3; V_2 : Bolaka; V_3 : Moina; V_4 : Gold and V_5 : BRRI dhan 45], where different morpho-physiological data was taken for evaluation their performance. The significance of the difference among the treatment means were estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability [1].

Results: Among the different system of cultivation significant variation was observed on growth,

*Corresponding author: E-mail: shorif@sau.edu.bd;

yield and yield contributing parameters. All the studied hybrid varieties showed superiority in respect of physiological characters, yield and yield attributes in anaerobic condition over aerobic condition. BRR1 hybrid dhan3 provided the highest grain yield (8.05 t ha^{-1}) at low land transplant condition. BRR1 hybrid dhan3 performed well due to yield attributes [amount of chlorophyll (2.47 mg g^{-1}) in its flag leaves, leaf area index (4.25), shoot reserve translocation (34.97%), grain dry matter accumulated from current photosynthesis (85.87%), higher filled grains per panicle and 1000 grain weight] than others varieties and the lowest (4.28 t ha^{-1}) was obtained from BRR1dhan45 at raised transplant condition.

Conclusions: The results showed that Low land transplant condition with BRR1 hybrid 3 showed the best performance regarding growth, yield and yield contributing characters of *Boro* rice varieties than others.

Keywords: Rice; system of cultivation; hybrid; yield.

1. INTRODUCTION

Rice is the second most widely grown cereal and primary source of food for more than half of the world population, and about 90% of the world rice is grown in Asia which is carrying about 60% of the world population [2]. Rice is not only the foremost staple food but it also provides nearly 48% of the rural employment, about two-third of the total calories supply and about one-half of the protein intake of an average person in the country [3]. The population of Bangladesh is increasing at an alarming rate and the cultivable land is decreasing due to urbanization and industrialization resulting in the shortage of food. The nation is still adding about 2.3 million every year to its total of 150 million people [4]. Population growth required a continuous increase in rice production in Bangladesh. So, the highest priority has been given to produce more rice. Rice yields are either stagnating/declining in post-green revolution era mainly due to system of cultivation, late or early planting, imbalance use of fertilizer, irrigation and weeding schedule, type of cropping system practiced, lack of suitable rice genotypes for low moisture adaptability and disease resistance [5].

About 90% of the world's rice production is harvested from irrigated or rainfed lowland rice fields.

One third of the World's developed freshwater is used to irrigate rice [6] with this figure being half of all freshwater supplies for Asia. But scarcity of water is getting a problem everywhere in the irrigated ecosystem. Rice requires soil moisture content of 70% throughout the season [7]. Continuous flooding is no more needed to have a good yield of rice. Aerobic system of rice cultivation has been developed very recently where rice can be grown successfully with saving

of 40-70% irrigation water [8,9,7] i.e. it requires less water than lowland rice. In aerobic system, water is made available (through rainfed or irrigation practice) to a level when the plant really deserves it to maintain its sound physiological system. Currently, aerobic system of rice cultivation has been advocated towards saving irrigation water for *Boro* rice (Satter, 2009).

The conventional (submerged) irrigated system requires 3500-5000 L of water for 1 kg of rice grain production [6,7]. The dwindling of fresh water resources in coming years forced the farmers to grow rice in aerobic condition under water limiting situation. As fresh water for irrigation is getting increasing scarce, system of aerobic rice cultivation is being expanded as an appropriate technology into regions with more intensive cropping in the year to come. Rice growing countries like India, China and Vietnam has already given their attention on system of aerobic rice cultivation including hybrid rice in it. The System of Rice Intensification (SRI) has been promoted for more than a decade as a set of agronomic management practices for rice cultivation that enhances yield [10].

In general, hybrids are known to have more tolerance to abiotic stresses because of their genetic plasticity [11]. As far as it is known, no hybrid rice variety has been released in Bangladesh considering the case of aerobic condition. So, suitability of hybrid rice varieties is to be found out for aerobic situation. Since hybrid rice is a new introduction to our country and for the same reason, not much research works have been done on it. Research on aerobic cultivation of hybrid rice is absent or meager in Bangladesh. So, it is imperative/ needed to generate information on agronomic and physiological performance of hybrid rice varieties in aerobic condition for extending/ intensify its cultivation at

irrigation limited area in *Boroseason*. Considering the above-mentioned facts and based on the prior observation, an investigation was undertaken to evaluate the physiological behaviour and yield contributing attributes of rice varieties under different system of cultivation.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207 from November 2015 to May 2016. The soil of the experimental field belongs to the general soil type, shallow red brown terrace soil with silty clay in surface and silty clay loam in sub-surface region. Soil pH was 6.7 and has organic carbon 0.45%.

2.2 Varieties and Treatment of the Experiment

The experiment was comprised of two factors- a) System of cultivation(3): T₁: Low land transplant (anaerobic) condition; T₂: Raised upland (aerobic) condition, and T₃: Raised transplant (aerobic) condition, and factors- b) Variety(5): V₁: BRRi hybrid dhan3; V₂: Bolaka; V₃: Moina; V₄: Gold and V₅: BRRi dhan 45.

2.3 Layout and Land Preparation of the Experiment

The experiment was laid out in a randomized complete block design (RCBD) with three replications. There were 45 plots of size 2.5 m × 4 m in each of 3 replications. The treatments of the experiment were assigned at random into each replication following the experimental design.

2.4 Seedlings Emergence

The seedlings were raised in seedbed and 21 days old seedlings were transplanted in the experimental plot. Various system of cultivation maintaining the standard spacing of 25 cm x 15cm with two seedlings hill-1. The fertilizers were applied as per recommendation and other intercultural operations were done whenever necessary.

2.5 Data Collection

Data were recorded as the average of same 10 hills selected at random from the outer side rows (started after 2 rows from outside) of each plot

from which different data were collected. Data on the following parameters were recorded during the course of the experiment such as –Plant height, Leaves per hill, Leaf area index, Chlorophyll content, Tillers per hill. Dry matter per hill, Shoot dry matter accumulation and its remobilization to grain, Grain dry matter from current photosynthate, Grains per panicle, 1000 grain weight, Grain yield, Biological yield and Harvest index (%).

2.6 Statistical Analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C software to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means were estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability [1].

3. RESULTS AND DISCUSSION

The findings have been presented and discussed by using tables, graphs and possible interpretations given under following headings:

3.1 Plant Height

Cultivation system affected the plant height of rice significantly at 75DAT and at harvest (Table 1). The tallest plant (69.28 and 102.70 cm at 75DAT and at harvest, respectively) was recorded with T₁ (Low land transplant condition) treatment. In contrast, the shortest plant (63.22 cm) was recorded from T₃ (Raised transplant condition), which was statistically similar with T₂ treatment (Raised upland condition) at 75DAT and at harvest. The height of rice plant is directly related to the depth of water and generally increases with increasing water depth [12]. Khaliq and Cheema, [13] also observed tallest plant in the water logged condition and shortest plant height in alternate wet and dry condition. With advancing plant age, water requirement increased and reducing water to field capacity condition significantly reduced plant height especially at maturity as well as tiller production during later growth stages. Beyrouy et al. [14] also observed reduction in plant height but not tiller production when flood was delayed.

3.2 Leaves Per Hill

Significant variation was observed in case of leaves per hill as influenced by cultivation system of *Boro* rice at different growth stages (Table 1). Results showed that at all growth stage the highest leaves per hill was recorded by T_1 (71.27 and 75.05 at 75 DAT and at harvest, respectively). The results obtained from T_3 showed the lowest leaves per hill (48.67 and 45.07 at 75 DAT and at harvest, respectively) which was statistically similar with T_2 at 75 DAT and at harvest.

3.3 Leaf Area Index

Significantly varied result was observed in case of leaf area index as influenced by cultivation system of *Boro* rice at different growth stages (Fig. 1). Result showed that the highest leaf area index was recorded by T_1 (4.13), which was statistically similar with T_2 . The results obtained from T_3 showed the lowest leaf area index (3.73). Saikia U et al [15] also reported that Water stress also caused drastic reduction in LAI, which ranged from 11.1 to 22.5% (vegetative stage) and 12.2 to 18.8% (reproductive stage) over the controls.

3.4 Chlorophyll Content

In the present investigation there was a significant decrease in the total chlorophyll content in the plants of raised upland condition while under normal rained condition (Fig. 2). Results showed that the highest chlorophyll content was recorded by T_1 (2.36 mg g⁻¹). The results obtained from T_3 showed the lowest chlorophyll content (2.26 mg g⁻¹). Jahan, et al.

[16] and Chutia, et al. [17] also reported that the total chlorophyll content in the plants reduced under water stress condition.

3.5 Tillers Per Hill

Significantly varied result was observed in case of tillers per hill as influenced by cultivation systems *Boro* rice at different growth stages (Table 2). Results showed that at all growth stage the highest tillers per hill was recorded by T_1 (18.67 and 32.20 at 75 DAT and at harvest respectively). The results obtained from T_3 showed the lowest tillers per hill (11.07 and 11.53 75 DAT and at harvest, respectively) which was statistically similar with T_2 at 75 DAT. Rice growth low land transplant condition give higher tillers per hill than raised upland condition, comparable with raised transplant condition. This finding is in agreement with Anwar et al. 2010 [18]. Toung and Bouman [19] also found the highest tillers per hill in the saturated condition.

3.6 Dry Matter Per Hill

Significantly varied results were observed in terms of dry weight per hill as influenced by different cultivation system *Boro* rice at different growth stages (Table 2). Results showed that at all growth stage the highest dry weight per hill was recorded by T_1 (27.99, 46.27 and 68.87 g at vegetative, flowering and harvest, respectively). The results obtained from T_3 showed the lowest dry weight per hill (15.50, 33.87 and 45.73 g at vegetative, flowering and harvest, respectively). The results obtained from all other treatments showed significantly different results compared to the highest and the lowest result of dry weight per hill.

Table 1. Effect of cultivation systems of rice on the plant height and leaves per hill

Treatment	Plant height (cm)				Leaves per hill			
	75 DAT		at harvest		75 DAT		at harvest	
T_1	69.28	a	102.7	a	71.27	a	75.05	a
T_2	64.38	b	98.97	b	55.13	b	46.8	b
T_3	63.22	b	98.77	b	48.67	b	45.07	b
LSD _(0.05)	4.738		2.813		10.16		6.029	
CV (%)	7.29		6.59		7.63		10.35	

Values with common letter (s) within a column do not differ significantly at 5% level of probability; T_1 = Low land transplant condition, T_2 = Raised upland condition, T_3 = Raised transplant condition

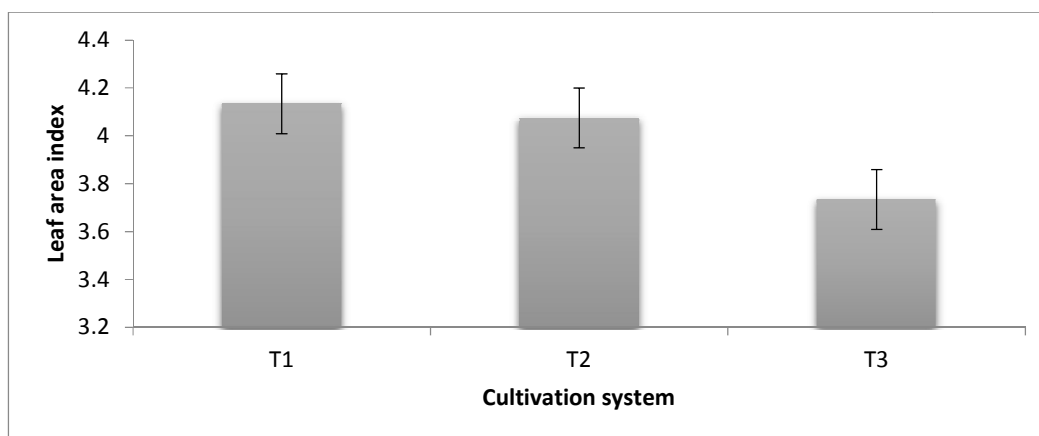


Fig. 1. Effect of cultivation systems on leaf area index of rice

*T*₁= Low land transplant condition, *T*₂= Raised upland condition, *T*₃= Raised transplant condition; Vertical bar represents LSD value

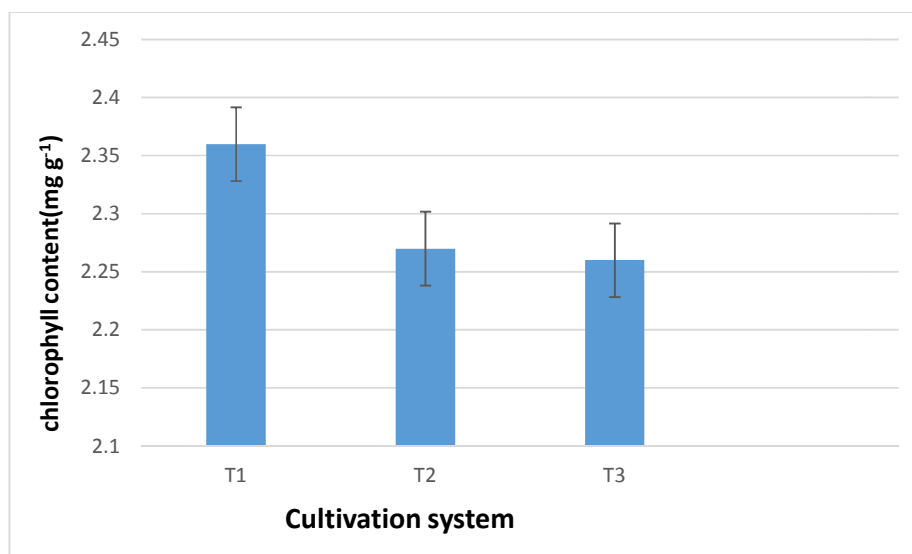


Fig. 2. Effect of cultivation system on chlorophyll content of rice varieties

*T*₁= Low land transplant condition, *T*₂= Raised upland condition, *T*₃= Raised transplant condition; Vertical bar represents LSD value

Table 2. Effect of cultivation systems on the tillers per hill and dry matter per hill of rice varieties

Treatment	Tillers per hill		Dry matter per hill			
	75 DAT	At harvest	Vegetative stage (g)		Flowering stage (g)	
<i>T</i> ₁	18.67 a	32.20 a	27.99 a	46.27 a	68.87 a	
<i>T</i> ₂	12.47 b	16.60 b	17.79 ab	49.00 a	60.40 b	
<i>T</i> ₃	11.07 b	11.53 c	15.50 b	33.87 b	45.73 c	
LSD _(0.05)	1.50	4.32	11.79	8.58	7.57	
CV (%)	9.33	8.72	6.43	9.93	10.33	

Values with common letter (s) within a column do not differ significantly at 5% level of probability; *T*₁= Low land transplant condition, *T*₂= Raised upland condition, *T*₃= Raised transplant condition

Table 3. Effect of cultivation systems on shoot dry matter accumulation, its translocation to the grain and grain dry matter accumulation from current photosynthesis in rice

Treatment	Shoot dry mater at flowering stage (g)		Shoot dry mater at maturity stage (g)		Changes in shoot dry mater (g)		Shoot reserve translocation (%)		Grain dry matter from current photosynthesis (%)	
T ₁	39.93	a	29.79	b	10.13	ab	25.39	a	82.19	A
T ₂	27.47	b	24.23	c	3.23	b	11.77	b	79.32	ab
T ₃	42.33	a	33.47	a	8.87	a	20.97	a	78.08	B
LSD (0.05)	11.76		3.88		8.28		6.11		3.63	
CV (%)	5.89		5.56		7.89		28.56		7.33	

Values with common letter (s) within a column do not differ significantly at 5% level of probability; T₁= Low land transplant condition, T₂= Raised upland condition, T₃= Raised transplant condition

Table 4. Effect of cultivation systems on yield contributing characters of rice

Treatment	Filled grain per panicle		Unfilled grain per panicle		Thousand grain weight (g)
T ₁	159.80	a	17.67	c	29.29
T ₂	154.90	b	25.60	b	28.88
T ₃	152.90	c	38.07	a	27.62
LSD (0.05)	3.73		6.47		ns
CV (%)	8.87		7.04		4.97

Values with common letter (s) within a column do not differ significantly at 5% level of probability, ns=non-significant; T₁= Low land transplant condition, T₂= Raised upland condition, T₃= Raised transplant condition

Table 5. Effect of cultivation systems on yield and harvest index of hybrid and inbred rice varieties

Treatment	Grain yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
T ₁	7.01	15.14	42.02
T ₂	5.77	12.37	42.34
T ₃	5.45	12.25	40.59
LSD (0.05)	0.51	1.14	0.79
CV (%)	5.83	7.08	8.30

Values with common letter (s) within a column do not differ significantly at 5% level of probability; T₁= Low land transplant condition, T₂= Raised upland condition, T₃= Raised transplant condition

3.7 Shoot Dry Matter Accumulation and Its Remobilization to Grain

Significantly varied results were observed in terms of shoot dry matter accumulation as influenced by different cultivation system in *Boro* rice at flowering and maturity stages (Table 3). Results showed that the highest shoot dry matter accumulation was recorded by T₃ (42.43 at flowering). At maturity stage, the highest shoot dry matter accumulation was recorded by T₃ (33.47g). The reserve translocation was the highest (25.39%) from T₁ treatment. The results obtained from T₂ showed the lowest shoot dry matter accumulation (27.47 and 24.23 g at flowering and maturity stage, respectively). The reserve translocation was the lowest (11.77%) in T₂ treatment.

3.8 Grain Dry Matter from Current Photosynthesis

Grain dry matter accumulation from current photosynthesis significantly varied on system of Cultivation (Table 3). Results showed that the highest grain dry matter from current photosynthesis recorded by T₁ (82.19%) where the lowest (78.08%) was obtained from T₃.

3.9 Filled Grains Per Panicle

Different system of cultivation had significant effect on filled grains per panicle (Table 4). Results showed that the highest filled grains per panicle was recorded by T₁ (159.8) where the lowest compared to the highest and the lowest grains per panicle.

The result under the present study (152.9) was obtained from T₃. The results obtained from T₂ showed medium result was similar with the findings of Bouman et al. [8].

3.10 Unfilled Grains Per Panicle

Significant influence was observed on unfilled grains panicle⁻¹ (Table 4) based on different

water treatment. Results showed that the highest unfilled grains per panicle was recorded by T₃ (38.07) where the lowest (17.67) was obtained from T₁. The results obtained from T₂ showed medium result compared to the highest and the lowest grains per panicle.

3.11 1000 Grain Weight

Level of water in the field had minor effect on 1000 grain weight rice (Table 4). Results showed that the highest 1000 grain weight was recorded by T₁ (29.29 g) where the lowest (27.62 g) was obtained from T₃. The results obtained from T₂ showed medium result compared to the highest and the lowest 1000 grain weight.

3.12 Grain Yield

Grain yield of rice was varied remarkably due to different systems of cultivation (Table 5). The highest grain yield was recorded by T₁ (7.01 t ha⁻¹) where the lowest (5.45 t ha⁻¹) was obtained from T₃ treatment, which was statistically similar with T₂ treatment. Bouman and Tuong (2010) suggested that there is a reduction in the grain yield in alternate wetting and drying when compared with rice grown with standing water. Grain yield, however decreased significantly when water was reduced to field capacity condition and this was in agreement with previous findings [14,20].

3.13 Biological Yield

Biological yield of rice varied significantly due to different system of cultivation (Table 5). Results showed that the highest Biological yield was recorded by T₁ (15.14 t ha⁻¹) where the lowest (12.25 t ha⁻¹) was obtained from T₃, which was statistically similar with T₂ treatment.

3.14 Harvest Index

Cultivation system had significant effect on harvest index (Table 5). The highest harvest index was recorded by T₂ (42.34), which were

statistically similar with T₂ treatment. The lowest harvest index (40.59) was obtained from T₃ treatment.

4. CONCLUSION

From the above summary of the study, it can be concluded that in aerobic condition rice demonstrated lower performance due to low leaf area index, chlorophyll content, tillering, shoot dry matter accumulation and grain dry matter from current photosynthesis. Again, among the different cultivation system, low land transplant condition showed the best performance where the raised transplant condition gave the lowest efficiency considering growth, yield and yield contributing characters. As combined effect of the present study low land transplant condition with BRRI hybrid 3 showed the best performance regarding growth, yield and yield contributing characters of *Boro* rice varieties. However, further study may be needed regarding the other rice varieties with different management practices in different Agro-Ecological Zones (AEZ) of Bangladesh for testing the regional compliance and other quality attributes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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