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Performance Evaluation of Five Boro Rice Cultivars Based on Some Morpho-chemical Characters

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To study the performance of five Boro rice cultivars based on some morpho-chemical characters.
Design: The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.
Place and Duration of Study: The experiment was carried out at the research filed of the department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during the period of February to May, 2014.
Methodology: The morpho-chemical performance of five selected Boro rice cultivars viz. BINA dhan 7, Hybrid SL-8H, Poshusail, Jirasail and Swarna were evaluated.
Results: The experimental results elucidate that leaf Proline content as well as mineral content was varied amongst the studied cultivar at pre-flowering stage. Results of the study revealed the morpho-chemical, yield and yield attributes were significantly differ of the studied cultivars. The hybrid cultivars showed short plant height, high tillering ability, much leaf number and higher number

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of grains panicle^{-1} which support superior growth characters and yield (8.42 t ha^{-1}). Among the cultivars, hybrid rice cv. SL-8H produced the highest yield and higher chlorophyll-a, phosphorus content.

Conclusion: From the present study it may be concluded that Hybrid SL-8H showed the highest yield potential than those of Boro rice cultivars. Therefore, it can be suggested that Hybrid SL-8H might be selected for cultivation in Northwest Bangladesh using modern agronomic practices due to its high yield potential but further study is suggested.

Keywords: Boro rice; morphological; biochemical; performance.

1. INTRODUCTION

Rice is the major source of nutrition for about two-thirds of world's population and grown extensively as a cereal crop throughout the tropical and subtropical regions of the world [1]. More than half of the people including three billion Asian consume rice as staple food [2]. In Bangladesh rice is the staple food for the people and in national economy play a vital role [3,4]. Bangladesh is the fourth largest rice producer and consumer country in the world and provides 75% of the calories and 55% of the protein in the average daily diet [5]. One half of the agricultural GDP and one sixth of the national income were contributed by rice sector in Bangladesh [6]. Depending upon water availability and temperature conditions rice can be grown in different environments. The optimum temperature for rice cultivation is between 25^{0}C and 35^{0}C, but it may vary with genotypes, duration of critical temperature, diurnal changes and physiological status of the plant. In rice cultivation cold stress is a common problem that affects global production as a crucial factor. Serious yield and yield components losses occur when low temperature prevails during the reproductive stages of rice. Due to low temperature at high latitude and altitude areas yield loss were well documented in Northeast and southern China, Bangladesh, India, Nepal and other countries [7,8]. Cold stress can reduce germination [9,10], cause delay and poor establishment [11-15], slow phenological development as well as increase spikelet sterility [7,16-18] resulting in low yield. In Bangladesh under low temperature the effects of genotypes and physiological age of rice seeds on seed germination were reported by [9]. Again during vegetative stage if low temperature occur results delay growth and reduce seedling vigor [5], lower seedling number, reduce tillering [19] increase plant mortality [3,20,21] increase the growth period and in reproductive stage, increases panicle sterility and decreases grain production and yield [19]. The low temperature prevails from October to early March in Bangladesh. During this time the temperature often reaches below 20℃. Boro (winter rice), one of the most important rice crops in Bangladesh, might suffer from critical low temperature at the different growth stages. The Boro season is longer, extending from November to June. However, the sterility frequency is increasing in Boro rice; the problem is getting importance now a days.

As the cold environment has numerous adverse effects on raising rice seedling as well as on rice production, we should screen out cold stress tolerant rice cultivar or varieties suitable for cultivation in Bangladesh. That is why the present study was conducted to study the physiological and morphological characteristics of selected rice cultivars at seedling stage and to manage the upcoming extreme cold environment in order to ensure food security.

2. MATERIALS AND METHODS

2.1 Plant Material

In this investigation five rice genotypes were used where the seeds were collected from Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh (Table 1).

2.2 Experimental Design and Growing Conditions

The experiment was layout in Randomized Complete Block Design (RCBD) with three replications during Boro season of February to May, 2016 at the research field of the Department of Agricultural Chemistry of Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. The site is located 34.5 m above the mean sea level belongs to AEZ-1 (Agro Ecological Zone-1) categorized as Himalayan Piedmont Plain as classified by [22] having soil with soil pH 6.0. The size of unit plot was 2 m x 2 m. The replications were separated from one another by one meter border. The border between the individual plots was 0.5 m. Recommended rice production procedure of Bangladesh Agricultural Research Council [23] was followed. The chemical fertilizers like Urea, TSP, MOP and Gypsum were applied at the rate of 215 kg, 180 kg, 100 kg, and 20 kg ha^{-1}, respectively. One half of urea, full dose of TSP and MOP and gypsum were applied at the final land preparation. The remaining half of urea was applied in two splits, one at tillering and other at booting stages. The 40 days aged healthy seedlings were transplanted in the experimental plots following the distance of 20 cm × 20 cm on February 12, 2016. After one week gap filling was done. Intercultural operations such as weeding, applications of pesticides were done as per need. When 90% of the grains became golden yellow in color then harvesting was done. After recording necessary data the harvested crops per hill were dried in the sun and then in an oven at 65^{o}c for 72 hour for calculating dry matter and straw weight.

2.3 Data Collection

Data were collected on plant height (cm),effective tiller $hill^{-1}$, non-effective tiller $hill^{-1}$, total number of tiller $hill^{-1}$, filled grain $panicle^{-1}$, 1000 grain wt. (g), panicle length (cm), leaf number $hill^{-1}$, dry root weight, root depth (cm), total dry matter (t ha^{-1}) straw wt. (t ha^{-1}), grain yield (t ha^{-1}), harvest index (%), Chl-a, Chl-b, total Chlorophyll, Ca, Mg, P and K content.

2.4 Determination of Proline Content of Flag Leaf

Fresh leaf samples from rice seedlings at different times were used for the determination of Proline. Free Proline content was estimated using the acid Ninhydrin method [24]. About 40 to 50 mg of fresh leaf sample by weight was collected in an eppendorf tube containing 0.5 ml 3% sulfosalicylic acid and homogenized well using eppendorf pastel. It was then placed on a vortex mixer for about 10 minutes. Then 0.5 mL of 3% sulfosalicylic acid was added in it again. The eppendorf tube was then centrifuged for 20 minutes at 25℃ temperature with 15000 rpm. Then the supernatant was collected in a test tube carefully with the help of micropipette. Then 1.0 mL of 3% sulfosalicylic acid was added again to the eppendorf tube and centrifuged for 20 minutes at 25℃ temperature with 15000 rpm followed by mixing well using vortex mixer for 10 minutes. The supernatant was collected and added to the previously collected supernatant. Acid ninhydrin solution was made by adding 1.25 g ninhydrin with 30 mL glacial acetic acid and 20 mL of 6 M phosphoric acid and warmed it until it dissolved. Standard Proline solution was also prepared by adding 0, 1, 5, 20, 50, 100, 150, 200 and 300 µg per 2 mL of 3% sulfosalicylic acid in test tubes for preparing standard curve. Then 2 mL each of glacial acetic acid and acid ninhydrin solution were added to the test tubes containing sample and standard Proline solution. The test tubes were then heated for 15 minutes in dry block heater maintaining 96-100℃ temperature and the reaction was terminated in an ice bath.

The optical densities of the solutions (sample and standard solution) were measured at 520 nm wave length using UV-visible spectrophotometer. The amount of Proline was determined from a standard curve.

2.5 Determination of Chlorophyll Content of Flag Leaf

The chlorophyll content of rice seedling was determined by the method described by [25]. On the other hand, total chlorophyll was determined using the formulae given by [26].

The concentration of chlorophyll-a (Chl-a), chlorophyll-b (Chl-b), total chlorophyll and total carotenoid was measured by using following formula.

Chl-a= $12.21\ A_{663}-2.81A_{646}$ (µg ml^{-1} of plant extract or mgg^{-1} fresh weight)

Chl-b=$20.13\ A_{646} – 5.03\ A_{663}$

Total chlorophyll = $17.76\ (A_{646}) + 7.34\ (A_{663})$

2.6 Determination of Leaf Nutrient Content

The concentration of P, K, Ca and Mg was analyzed by digesting a 0.5 g leaf sample with 10 ml 2:1 HNO_3: $HClO_4$ [27].

2.7 Data Analysis

The collected data were analyzed statistically for the analysis of variance (ANOVA) and means were compared by Duncan's Multiple Range Test (DMRT) as described by [28] using the statistical computer package program, MSTAT-C [29].

Table 1. Name and source of the selected rice cultivars

Cultivar	Name of rice cultivars	Source of the cultivars
V_1	BINA dhan 7	Bangladesh Agricultural Development Corporation
V_2	Hybrid SL-8H	Bangladesh Agricultural Development Corporation
V_3	Poshushail (Hobiganj 6)	Bangladesh Agricultural Development Corporation
V_4	Jirasail	Bangladesh Agricultural Development Corporation
V_5	Swarna	Bangladesh Agricultural Development Corporation

3. RESULTS AND DISCUSSION

Among the five cultivars, Poshusail produced the tallest plant (130 cm) which was statistically different with other cultivars (Fig. 1). The shortest plant was recorded in BINA dhan 7 (86 cm) at the time of harvesting. Variation in genetic makeup of the varieties may be the reason behind of different plant height. Variable plant height among the rice cultivars were observed by [30-32].

Leaf number of different cultivars varied markedly among themselves. Among the studied cultivars, Hybrid SL-8H recorded the highest leaf number hill^{-1} (47.77) and Poshusail showed lower leaf number hill^{-1} (28.07) which is statistically similar with Swarna (Fig. 2). Considering dry root weight of rice significant variation was found amongst the studied cultivars. The highest dry root weight was observed in Hybrid SL-8H (4.71 g) which was statistically similar with Jirasail (4.48), while the lowest root dry weight was in Poshusail (3.46 g) that was statistically similar with Swarna (3.57 g) (Fig. 3). The differential response of root dry weight in the cultivars could be attributed to its genetic potentiality. The result was conformed to [32].

The cultivars effect on root depth production at harvesting stage was significantly different. The highest root depth was observed in Poshusail (15 cm) followed by BINA dhan 7 (13 cm) while the lowest root depth was found in Swarna (11 cm) at harvesting stage (Fig. 4). The highest effective tillers hill^{-1} was observed in BINA dhan 7 (10.88) and the lowest effective tillers hill^{-1} was found in Swarna (5.77) (Table 2). The above results of variability in effective tillers hill^{-1} were in full agreement with many workers such as [33-36].

Again, Swarna (3.66) followed by Poshusail (2.22) produced the highest number of non-effective tillers hill^{-1}. On the contrary, the lowest non-effective tillers hill was observed in BINA dhan 7 (0.66) followed by Hybrid SL-8H (0.99). This result was in agreement with [37-38]. On the other hand, tiller number increased till 77 DAT followed by a decline at harvest due to death of some undeveloped tillers. Hybrid SL-8H (11.74) produced maximum number of total tillers hill^{-1} which is statistically similar with BINA dhan 7 (11.54). In contrast Swarna produced the lowest number of tillers hill^{-1} (9.43) at all growth stages. The number of tillers hill^{-1} differed due to varietal variation stated by [39]. The number of filled grains panicle^{-1} is the most important attribute which was markedly different among the cultivars. The highest filled grain number panicle^{-1} was recorded in Poshusail (118.3) and the lowest filled grain number panicle^{-1} was in Swarna (105.0) and they are statistically different. At reproductive growth stage the cultivars effect on panicle length was variable (Fig. 5). The result elucidate panicle length was highest in Jirasail followed by Poshusail. Again, Swarna showed the lowest panicle length at reproductive stage. Similar results were also observed by [40,41] who recorded that panicle length influenced by different cultivars. Grain yield is the ultimate result of all the character combination. The highest grain weight was produced in Hybrid SL-8H (8.42 t ha^{-1}) the lowest grain weight was recorded in Swarna (5.67 t ha^{-1}). Hybrid SL-8H produced maximum grain yield which might be due to the production of higher number of effective tillers hill^{-1} and higher number of filled grain panicle^{-1}. The genotypes; those produced higher number of effective tillers hill^{-1} and higher number of grains panicle^{-1} inflammation higher grain yield [42]. Similar results were also reported by [32,43]. In relation to 1000-grain weight there was a significant difference among the Boro rice cultivars (Table 2). The highest 1000-grain weight was recorded in Hybrid SL-8H (27.03 g) which is statistically different from the other varieties whereas Swarna (18.83 g) produced the lowest grain weight. [38] Studied three local and one modern cultivar of transplant Boro rice and stated that 1000-grain weight differed significantly among the cultivars.

Table 2. Yield contributing characters of five Boro rice cultivars

Cultivars	Effective tiller hill^{-1}	Non-effective tiller hill^{-1}	Total number of tiller hill^{-1}	Filled grain panicle^{-1}	1000 grain wt. (g)
BINA dhan 7	10.88a	0.66e	11.54a	109.0c	22.63c
Hybrid SL-8H	10.71a	0.99d	11.74a	114.3b	27.03a
Poshusail	7.88d	2.22b	10.1c	118.3a	25.33b
Jirasail	9.11b	1.44c	10.55b	108.0d	20.70d
Swarna	5.77e	3.66a	9.43d	105.0e	18.83e
CV (%)	5.43	6.76	7.21	5.54	8.78

Mean followed by the same letter(s) did not differ significantly at 5 % level

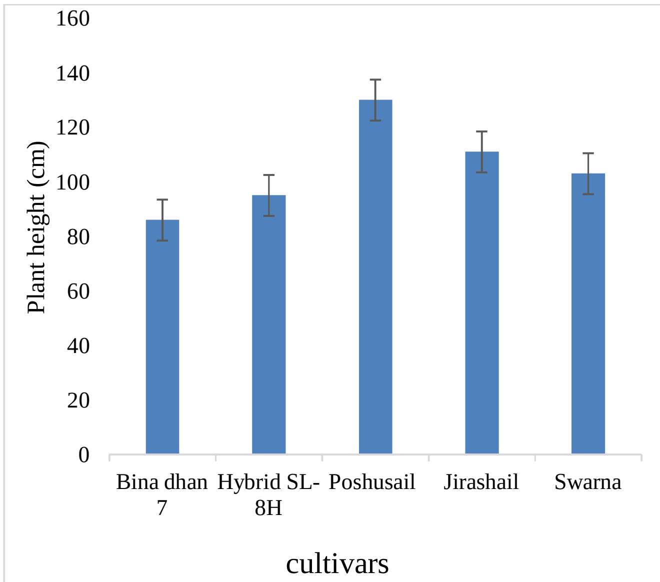

Fig. 1. Plant height (cm) of selected rice cultivars

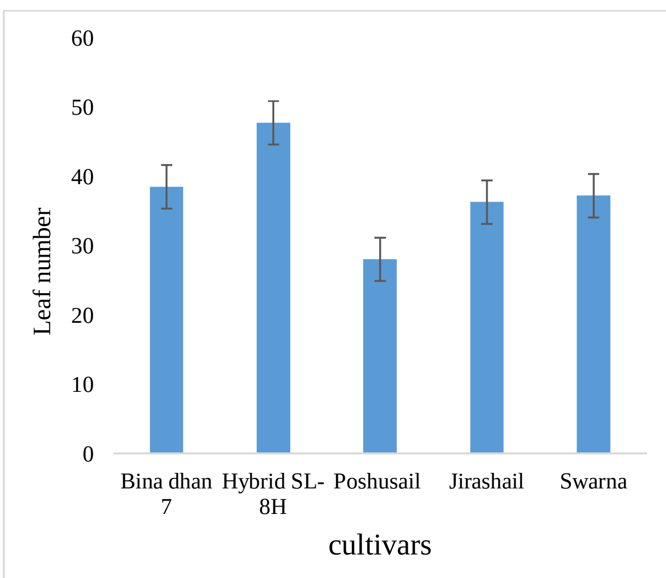

Fig. 2. Leaf number hill^{-1} of selected rice cultivars

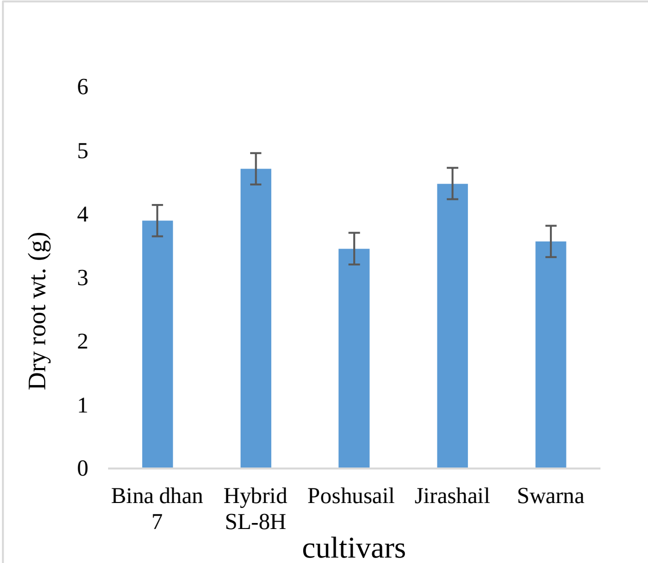

Fig. 3. Dry root weight of selected rice cultivars

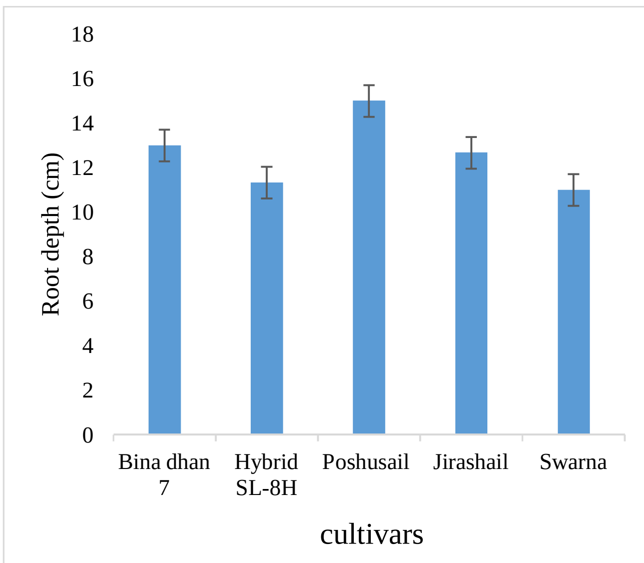

Fig. 4. Root depth (cm) of selected rice cultivars

Poshusail resulted the highest straw yield (21.88 t ha^{-1}) followed by Hybrid SL-8H. Where BINA dhan 7 produced the lowest straw yield (12.58 t ha^{-1}). [44] Reported that grain yield was positively correlated with biological yield in rice. Similar result was also reported by [36]. However, there was significant difference in total dry matter among the Boro rice cultivars (Table 3). Similarly the highest total dry matter was recorded in Hybrid SL-8H (31.75 t ha^{-1}) and the lowest in Swarna (22.40 t ha^{-1}. [32,38] were also found the similar result. Likewise, harvest index differed significantly among the cultivars. The highest harvest index was recorded for Hybrid SL-8H (34.74%) and the lowest harvest index was recorded in Poshusail (21.25%) (Table 3). The result revealed that HYV showed higher harvest index compare to local cultivars. It means dry matter partitioning to economic yield is inferior in Poshusail, Swarna, and Jirasail than Hybrid SL-8H or BINA dhan 7. Harvest index is the measure of the efficiency of conversion of photosynthate into economic yield of a crop plant [32,45].

Besides this, among the biochemical traits the leaf chlorophyll content is most important that closely related to the photosynthetic ability of rice [46]. The highest chlorophyll-a content was found in Hybrid SL-8H (22.83 mg g^{-1}) and while the lowest was estimated in Poshusail and Jirasail, which were statistically similar at 50 DAT. Hybrid cultivar found to have the highest chlorophyll-a content among the cultivars. At the same time Jirashail and Poshusail contained lowest chlorophyll-a at reproductive stage. Positive correlation between chlorophyll content and photosynthetic rate was stated by [47]. Moreover, Swarna produced the highest amount of chlorophyll-b content (5.36 mg g^{-1}) and is significantly higher than other cultivars at 5% level of significance, but the lowest was observed in Poshusail plants (4.21 mg g^{-1}). In contrast to chlorophyll-a, the Swarna rice plants showed the superior due to higher chlorophyll-b synthesis in flag leaf in the present study which seems to be attributed by genetically.

In this study, the total chlorophyll content of selected rice cultivars was varied significantly during the experimental period which is shown in (Table 3). The highest total chlorophyll content was found in Hybrid SL-8H (2.32 mg g^{-1}) while the lowest total chlorophyll synthesis was observed in Poshusail (2.26 mg g^{-1}) and they are statistically similar with other cultivars. More importantly rice is not considered as a rich source of mineral nutrient. Four nutrient element measured and they showed significant differences among the studied cultivars. Among the leaf nutrients the Ca, Mg and K content was highest in BINA dhan 7 (5.34, 5.83 and 6.99 mg %) and Hybrid SL-8H (Figs. 6-8) whereas the lowest value was found in Swarna in most of the cases. But the maximum P content was observed in Hybrid SL-8H (0.32 mg %) followed by BINA dhan 7 (0.31 mg %). On the other hand, the minimum P content was recorded in Poshusail (0.26 mg %) followed by Swarna (0.28 mg %). Hybrid SL-8H can be considered as sustainable cultivar on the basis of phosphorus content (Fig. 9).

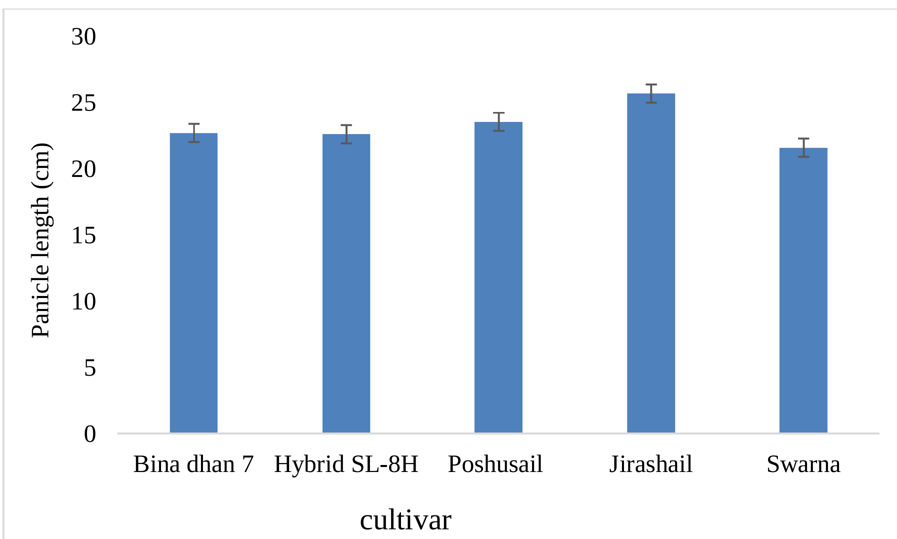

Fig. 5. Panicle length (cm) of different rice cultivars

Table 3. Yield contributing characters of five Boro rice cultivars (contd.)

Cultivars	Total dry matter (t ha^{-1})	Straw wt. (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)	Chl-a mg g^{-1} FW	Chl-b mg g^{-1} FW	Total Chlorophyll mg g^{-1} FW
BINA dhan 7	26.53c	12.58d	5.833cd	31.63b	19.41c	4.840b	2.31a
Hybrid SL-8H	31.75a	15.00b	8.417a	34.74a	22.83a	4.433cd	2.32a
Poshusail	28.79b	18.88a	6.292b	21.25e	18.68d	4.207d	2.26a
Jirasail	25.18d	14.58c	6.000c	29.23c	18.60d	4.643bc	2.29a
Swarna	22.40e	14.83bc	5.667d	23.13d	21.25b	5.357a	2.28a
CV (%)	6.16	7.43	5.54	4.78	6.65	4.34	3.32

Mean followed by the same letter(s) did not differ significantly at 5 % level

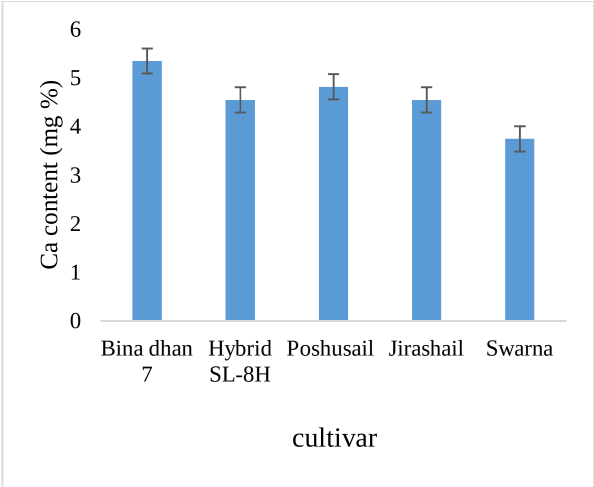

Fig. 6. Ca content in the leaves of selected rice cultivars

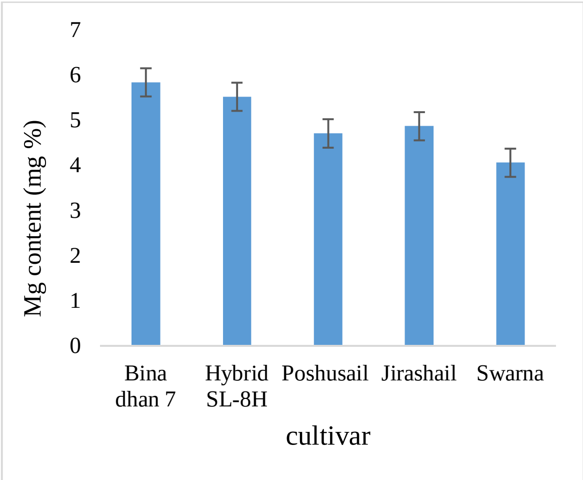

Fig. 7. Mg content in the leaves of selected rice cultivars

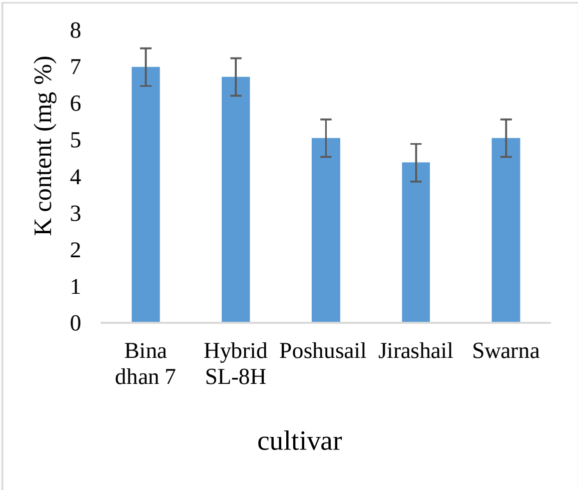

Fig. 8. K content in the leaves of selected rice cultivars

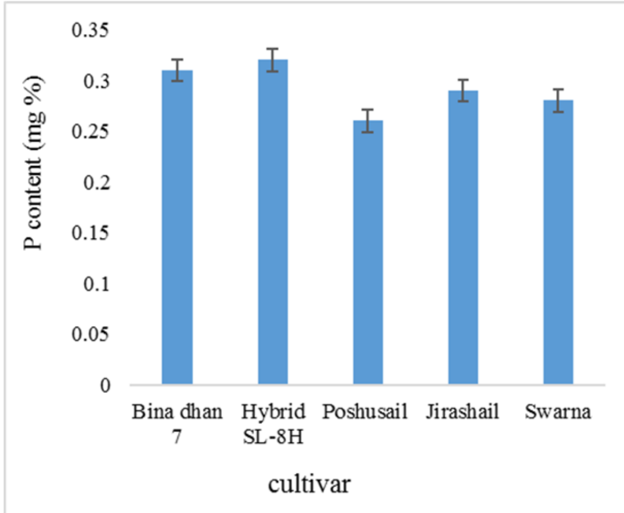

Fig. 9. P content in the leaves of different rice cultivars

4. CONCLUSION

From the present study it may be concluded that Hybrid SL-8H showed the highest yield potential than those other Boro rice cultivars. Therefore, it can be suggested that Hybrid SL-8H might be selected for cultivation using modern agronomic practices due to its high yield potential among the other cultivars but further study is suggested.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Vaughan DA, Morishima H, Kadowak K. Diversity in the *Oryza* genus: Current opinion. Journal of Plant Biology. 2003; 6:139-146.
2. Waghmare CR, Guhey A, Saxena R, Kulkarni AA, Agrawal K. Genetic divergence of morpho-physiological traits in rainfed early rice genotypes. Agricultural Science Digest. 2008; 28(3):198–200.
3. Faruq G, Zulaani KN. Jennifer AH, Subha B, Zulqarnain, Nazia AMM, Mohammad O. Evaluation of kernel elongation ratio and aroma association in global popular aromatic rice cultivars in tropical environment. African Journal of Agricultural Research. 2010;5(12):1515–1522.
4. Trans DV. Closing the rice yield gap for food security. In: Peng S, Hardy B, (eds.). Rice research for food security and poverty alleviation. Progressing of the Intl. Rice Res. Conf. 31 March-3 April, 2000. Los Banos, IRRI, Philippines. 2001;692-693:27-41.
5. Bhuiyan NI, Paul DNR, Jabber MA. Feeding the extra millions by 2025-challenges for rice research and extension in Bangladesh. Proceedings of the National Workshop on Rice Research and Extension, January 29-31, 2002, Gazipur, Bangladesh. 2002;9:1-24.
6. BRRI (Bangladesh Rice Research Institute), Annual report for 1996, Bangladesh rice res. Inst. Joydebpur, Gazipur, Bangladesh. 2011;8-15.
7. Lee MH. Low temperature tolerance in rice: The Korean experience. International Rice Research Institute (IRRI), PBGB, MCPO Box 3127, 1271, Canberra, ACT 2601. 2001;138–146.
8. Kaneda C, Beachell HM. Response of indica-japonica rice to low temperature. SABRO J. 1974;6:17–32.
9. Ali MG, Naylor R, Matthews S. Distinguishing the effects of genotype and seed physiological age on low temperature tolerance of rice (*Oryza sativa* L.). Exp. Agric. 2006;42:337–349.
10. Basnayake J, Sihathep V, Sonekham PS, Senthonghae M, Sibounheuang V, Phamixay V, Sengkeo CM, Fukai S. Effects of time of planting on agronomic and yield performance of several rice cultivars under various temperature conditions in Lao PDR. In: Proceedings

of the 11th Agronomy Conference. Melbourne.
Available:www.regional.org.au/au/asa/2003/last
(Accessed 6.02.2010)
11. Shimono H, Hasegawa T, Iwama K. Response of growth and grain yield in paddy rice to cool water at different growth stages. Field Crops Res. 2002;73:67–79.
12. Shimono H, Hasegawa T, Fujimura S, Iwama K. Responses of leaf photosynthesis and plant water status in rice to low water temperature at different growth stages. Field Crops Res. 2004;89: 71–83.
13. Shimono H, Okada H, Kanda E, Arakawa EI. Low temperature induced sterility in rice: Evidence for the effects of temperature before panicle initiation. Field Crops Res. 2007;101:221–231.
14. Lewin L, Maccaffery D. Rice seedling growth is influenced by water depth and temperature. Farmer's Newsl. Large Area 127; 1985.
15. Sasaki T. The relationship between germination rate of rice seeds low temperature and the subsequent early growth of seedlings: VI. Effect on the germinability at low temperature and initial growth of seedling by high temperature treatment of rice seeds Japan. J. Crop Sci. 1981;50(1):19–24.
Available:http://www.affrc.go.jp/en/
(Released: February 14, 2008)
16. Gunawardena TA, Fukai S, Blamey P. Low temperature induced spikelet sterility in rice. I. Nitrogen fertilisation and sensitive reproductive period. Aust. J. Agric. Res. 2003a;54:937–946.
17. Gunawardena T, Fukai SA, Blamey P. Low temperature induced spikelet sterility in rice. II. Effects of panicle and root temperature. Aust. J. Agric. Res. 2003b; 54:947–956.
18. Farrell TC, Fox KM, Williams RL, Fukai S, Reinke RF, Lewin LG. Temperature constraints to rice production in Australia and Lao PDR: A shared problem. In: Fukai S, Basnayake J. (Eds.), ACIAR Proceedings 101; Increased Lowland Rice Production in the Mekong Region. Australian Centre for International Agricultural Research, GPO Box 1571, Canberra, ACT 2601. 2001;129–137.
19. Das SK, Singh J, Tripathy M, Mishra D. Association of quantitative traits and path analysis in medium land rice. Environmental Ecology. 1996;14(1):99-102.
20. Dipti SS, Hossain ST, Bari MN, Kabir KA. Physico-chemical and cooking properties of some fine rice varieties. Pakistan Journal of Nutrition. 2002;1(4):188-190.
21. Dela CN, Khush GS. Rice grain quality evaluation procedures. In: Aromatic rices. Singh RK, Singh US, Khush GS, (Eds). Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India. 2000;16-28.
22. UNDP (United Nations Development Programme), FAO (Food and Agriculture Organization), Land report appraisal of Bangladesh for Agricultural Development report on 2 Agro-ecological regions of Bangladesh. United Nations Development Program and Food and Agriculture Organization. 1988;212-221.
23. BARC, Bangladesh Agricultural Research Council. Fertilizer Recommendation Guide. 2005;65.
24. Bates LS, Waldren RP, Teare ID. Rapid determination of free proline for water stress studies. Plant Soil. 1973;39:205-207.
25. Arnon DI. Copper enzymes in isolated chloroplasts, polyphenol oxidase in *Beta vulgaris* L. Plant Physiology. 1949;24:1-15.
26. Porra RJ. The chequered history of the development and use of simultaneous equations for the accurate determination of chlorophylls a and b. Photosynthesis Research. 2002;73:149-156.
27. Yoshida S. Fundamentals of rice crop science. International Rice Research Institute. Los Banos, Philippines; 1981.
28. Gomez KA, Gomez AA. Statistical procedures for agricultural research, 2nd Ed., John Wiley and Sons Inc., New York; 1984.
29. Russell DF. MSTAT-C package programme. Crop and Soil Science Department, Michigan State University, USA; 1986.
30. Das B, Mannan MA, Das PK. Performance study of three high yielding varieties of Bangladesh and one exotic rice cultivar. B.Sc. Ag. Thesis. Agrotechnology Discipline, Khulna University. 2012;78.
31. Khatun R. Effect of cultivar and nitrogen on the performance of fine rice. M.Sc. Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh. 2001;93.
32. Sarker BC, Roy B, Islam MA, Ara J, Rahman MS. Comparative studies of root

growth and yield potential of five Boro rice varieties. Journal of Science and Technology. 2015;13. (in press).
33. Yong F, Wang XL, Ma JY, Ling FL. A comparative analysis of yield component factors of the two rice varieties of JNI and JND 13. J. Jilin Agril. Univ. 2001;23(4):21-24.
34. Dutta RK, Mia MAB, Khanum S. Plant architecture and growth characteristics of fine grain and aromatic rice and their relations with yield. Int. Rice Comm. Newsl. 2002;51:51-55.
35. Shrirame MD, Muley DM. Variability and correlation studies in rice. J Soil Crops. 2003;13:165-167.
36. Munshi RU. A comparative morpho-physiological study between two and two modern rice cultivars. M. S. Thesis, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh. 2005;78-88.
37. Aktar MB. Morpho-physiological evaluation and characterization in four t-aman rice genotypes. M. S. Thesis, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh. 2005;79-89.
38. Hoque MN. Morpho-physiological studies in aromatic and modern cultivars. M. S. Thesis, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh. 2004;75-86.
39. Ramasany S, Chandrasekaran B, Sankaran S. Effect of spacing and seedlings hill-1on rice yield. International Rice Research Newsletter, IRRI, Philippines. 1987;12(4):49.
40. Idris M, Matin MA. Response of four exotic strains of aman rice to urea. Bangladesh Journal of Agricultural Science. 1990; 17(2): 271-275.
41. Anonymous, Annual Report. Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. 1993;143.
42. Pruneddu G, Spanu TA. Varietal comparison of rice in Sardinia. Dipartimentodi Science Agronomiche Genetica vegetable Agaria, Universita degli, Italy Informatore-Agrario. 2001; 57(5):47-49.
43. Mondal MMA, Islam AFMS, Siddique MA. Performance of 11 modern transplant aman cultivar in the northern region of Bangladesh. Bangladesh J. Crop Sci. 2005;16:23-29.
44. Chowdhury SA, Majid MA, Hoque KS, Islam M, Rahman MM. Effect of cultivar on yield and nutritive value of rice straw. Asian J. Animal Sci. 1995;8(4):329-335.
45. Dutta RK, Mondal MMA. Evaluation of lentil genotypes in relation to growth characteristics, assimilate distribution and yield Potential. LENS Newsl. 1998;25:51-55.
46. Teng T. QTL analysis of leaf photosynthetic rate and related physiologicaltraits in rice (*Oryza sativa* L.). International Journal of the Faculty of Agriculture and Biology, Communications in Biometry and Crop Science. 2004;2(1): 1-7.
47. Araus JL, Amaro T, Voltas J, Nakkoul H, Nachit MM. Chlorophyll fluorescence as a selection criterion for grain yield in durum wheat under Mediterranean conditions. Field Crops Research. 1998;55:209-223.

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