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Physio-morphological Appraisal of Aromatic Fine Rice (*Oryza sativa* L.) in Relation to Yield Potential

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Abstract: A field experiment was conducted to determine the physio-morphological attributes in relation to yield potential of modern and aromatic rice varieties. The experiment was laid out in a randomized complete block design (RCBD) with five replications. The results indicated that physio-morphological attributes, yield and yield contributing characters were varied among the varieties. The modern rice varieties BRRIdhan32 and Binasail showed larger grains, rice yield, biomass production and harvest index as compared to aromatic fine rice varieties. On the other hand, aromatic rice varieties showed tallest plant stature, profuse tillers hill^{-1}, panicle hill^{-1} and larger panicle but smaller grain, higher grain yield, lowest straw yield and harvest index. Modern rice varieties generally had higher Total Dry Matter (TDM), Leaf Area Index (LAI), Leaf Area Ratio (LAR), Crop Growth Rate (CGR), Relative Growth Rate (RGR) whereas aromatic varieties resulted in higher Net Assimilation Rate (NAR). The results concluded that the modern rice varieties were more efficient in transfer of photosynthate to economic sink. The highest grain yield of modern rice varieties was due to the higher harvest index. Poor yield in aromatic rice varieties was due to lower translocation of assimilates. However, they have some characters viz., weak culms, drooping leaves, lodging which influence low yield. The results suggested that breeding programme may be undertaken to eliminate those defective characters for developing improved aromatic rice varieties.

Key words: Aromatic, modern rice, physio-morphology, yield, rice

INTRODUCTION

Rice cultivation is one of the major income generating practices of many rice-growing developing countries like Bangladesh. And, farmer's net income increased by 23% with the adoption of modern varieties (Shrestha *et al.*, 2002). Unlike modern coarse rice, aromatic rice's have also created an excellent demand both in internal and external trade markets. The price of aromatic rice is much higher compared to modern coarse varieties. It is also preferred by some consumer despite of their high price and lower yield. However, their yield potentials are low as compared to modern rice varieties. Lodging is one of the prime factors of yield in local aromatic rice especially tall varieties with long and droopy leaves, weak culms which cause a great reduction in rice yield. Most aromatic rice cultivars are highly photosensitive and a slight change in day length causes adverse effect on their growth and development. Sharma and Haloi (2001) characterized some local aromatic rice on the basis of their physiological and assimilate partitioning behavior and suggested that the improvement of partitioning efficiency is one of the best criteria for improvement of aromatic rice. On the other hand, modern varieties possess short and stout culms with dark green, thick leaves and do not lodge. Dutta *et al.* (1997) pointed out some physiological limitations of modern *indica-japonica* type of rice and suggested improvement over IRRI scientists' proposed new model for rice improvement. This information package might be valuable information for the breeders for fixing breeding strategy.

Physio-morphological characters play a vital role in breeding of rice which is essential to know the physiological behavior and genetic expression of aromatic and modern rice cultivar for definite breeding objectives for the improvement. Therefore, the experiment was undertaken with a view to assess the morpho-physiological characteristics of aromatic and modern rice cultivars and to find out the limitations and suggesting for further improvement.

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MATERIALS AND METHODS

An experiment was conducted in the farm of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. Texturally the soil was silty loam having pH 6.5, organic matter, total N, 1.8, 0.11%, available P, S, Zn, B, Mn, Fe 12.5, 11.8, 0.78, 0.25, 10.03, 52.2 μg g^{-1}, exchangeable K, Ca, Mg, Na 0.18, 4.37, 2.60, 9.87 me %. Four rice varieties namely Binashail, BRRIdhan32, Ukunmadhu and Kataribhough were used in the experiment. The experiment was laid out in a randomized complete block design. The whole amount of muriate of potash (MOP) (K-40 kg ha^{-1}), triple super phosphate (TSP) (P-18 kg ha^{-1}) and gypsum (S-60 kg ha^{-1}) were applied at the final land preparation. Nitrogen (N-70 kg ha^{-1}) was applied in the form of urea in three equal splits at 15 Days After Transplanting (DAP), active tillering and panicle initiation stages. The seedlings were uprooted carefully without causing any injury to the roots and transplanted in the main field. All the intercultural operations were done as and when necessary. Harvesting was done when 80 to 90% of the grains became golden in color. Ten hills (excluding boarder hills) were randomly selected outside a one-square meter area kept for yield data from each unit plot. Data on morphological characters like plant height, tillering pattern, maturity date, number of panicle, panicle length, number of primary branches, number of secondary branches, 1000-grain weight (g), total dry matter (TDM) $hill^{-1}$ (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), harvest index (HI) and physiological characters like leaf area index (LAI), leaf area ratio (LAR), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) were estimated.

Harvest index, the ratio of economic yield to biological yield (Gardner *et al.*, 1985) was calculated by using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where:
Economic yield = grain yield
Biological yield = grain yield+straw yield

Leaf area index, the ratio of leaf area and its ground area was measured with the leaf area meter (LI-3000) and calculated as follows:

$$\text{LAI} = \frac{\text{LA}}{\text{p}}$$

Where:
LA = Leaf area
P = Ground area

Leaf area ratio, the ratio of assimilator material per unit of plant material was calculated according to the following formula:

$$\text{LAR} = \frac{\text{LA}}{\text{W}} \text{cm}^2 \text{g}^{-1}$$

CGR, increase of plant material per unit of time per unit of ground area was calculated according to the following formula:

$$\text{CGR} = \frac{1}{A} . \frac{W_2 - W_1}{T_2 - T_1} \text{gm}^{-2} \text{day}^{-1}$$

RGR, increase of plant material per unit of material present per unit of time was calculated according to the following formula:

$$\text{RGR} = \frac{\text{LnW}_2 - \text{LnW}_1}{T_2 - T_1} \text{gg}^{-1} \text{day}^{-1}$$

NAR, increase of plant material per unit of leaf area per unit of time was calculated according to the following formula:

$$\text{NAR} = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\text{LnLA}_2 - \text{LnLA}_1}{\text{LA}_2 - \text{LA}_1} \text{gm}^{-2} \text{day}^{-1}$$

Where:
LA = Total leaf area
W_1 = Total plant dry weight at time T_1
W_2 = Total plant dry weight at time T_2
W = Total plant dry matter weight
Ln = Natural logarithm.
LA_1 = Leaf area at time T_1
LA_2 = Leaf area at time T_2

Data analysis: Recorded data were analyzed statistically with the help of computer package programme MSTATC (Russel, 1986). The mean values of the morpho-physiological and yield parameters among the treatments were evaluated by Least Significance Difference (LSD) (Gomez and Gomez, 1984).

RESULTS

Plant height: Plant height increased with the progression of growth stage and declined thereafter flowering where; the tallest plant was recorded in Ukunmadhu followed by Binasail (Fig. 1).

Tillering pattern: There was significant difference in the number of tillers among the cultivars throughout growth stages (Fig. 2). Binasail and BRRIdhan32 produced the highest number of tillers at tillering stage thereafter declined gradually till maturity. And other varieties Ukunmadhu and Kataribhough produced the greatest number of tiller at panicle initiation stage and declined gradually up to maturity.

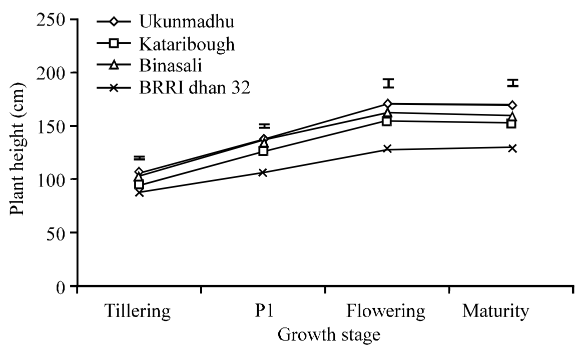

Fig. 1: Plant height development pattern of aromatic fine and coarse rice varieties vertical bar represents the LSD at 5% level of significance

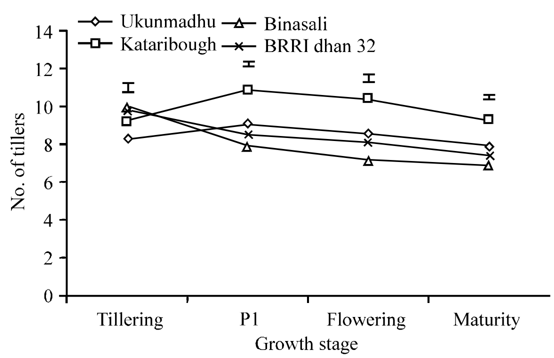

Fig. 2: Tillering pattern of aromatic fine and coarse rice varieties vertical bar represents the LSD at 5% level of significance

Panicle hill^{-1}: There was significant difference in the number of panicles hill^{-1} among the cultivars where Kataribhough showed the highest number of panicles followed by Ukunmadhu. The variety Binasail recorded the lowest number of panicle hill^{-1} (Table 1).

Panicle length: The variety Binasail recorded the longest panicle and BRRIdhan 32 showed the lowest. The result also showed that there was no significant difference in Binasail, Ukunmadhu and Kataribhough but BRRIdhan 32 showed significantly the shorter panicle compared to others (Table 1).

Primary branches panicle^{-1}: Number of primary branches revealed significant difference among the varieties (Table 1). The highest number of primary branches showed in Ukunmadhu followed by BRRIdhan32 and Kataribhough.

Number of secondary branches: There was significant difference in the number of secondary branches among the cultivars (Table 1). The highest secondary branches were recorded in Binasail followed by Ukunmadhu.

1000-grain weight: There was spectacular and significant difference of 1000-grain weight among the cultivars (Table 1). The highest 1000-grain weight was recorded in BRRIdhan32 followed by Binasail.

Total Dry Matter (TDM): There were significant differences in TDM among the varieties at different growth stages (Fig. 3). Total dry matter increasing pattern was almost the same for all varieties. The highest TDM at flowering stage was recorded in Binasail followed by Ukunmadhu.

Grain yield: Varieties exhibited the significant difference in grain yield. The results showed that BRRIdhan32 produced the maximum grain yield and Ukunmadhu (Table 1).

Straw yield: There were significant differences of straw yield among the varieties. The highest straw yield was recorded in BRRIdhan 32 and the lowest was obtained in Ukunmadhu (Table 1).

Table 1: Yield and yield attributes of aromatic fine and modern coarse rice varieties

Variety	Panicle No. per hill	Panicle length (cm)	Primary branch Panicle^{-1}	Secondary branch panicle^{-1}	1000 grain weight	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Days to maturity (seed to seed)
Ukonmadhu	7.90	26.40	31.20	95.00	11.50	2.80	5.50	33.40	140
Katarobough	9.50	26.30	27.20	51.00	16.90	2.90	5.20	35.70	134
Binasail	7.00	26.90	26.50	99.20	17.10	3.90	5.60	40.90	137
BRRI dhan 32	7.50	24.90	28.60	84.80	21.50	5.20	6.70	43.50	130
LSD 0.05	0.64	1.29	3.36	3.77	0.97	0.39	0.51	2.43	2.79

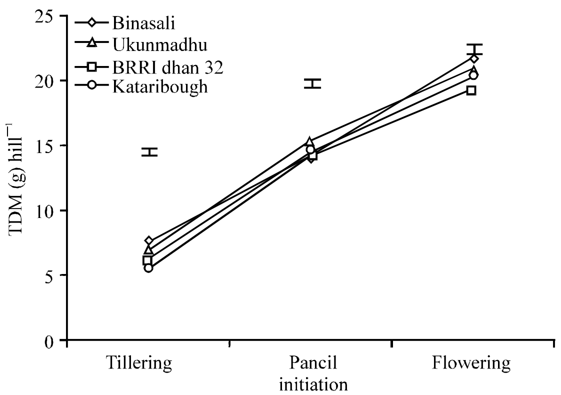

Fig. 3: Dry matter production of aromatic fine and coarse rice varieties vertical bar represents the LSD at 5% level of significance

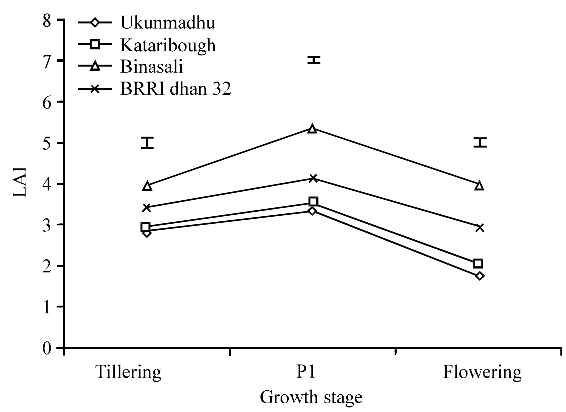

Fig. 4: Leaf area index of different aromatic and modern rice varieties at different growth stages. Vertical bar represents the LSD at 5% level of significance

Harvest Index (HI): Harvest index differed significantly and the highest value was recorded in BRRIdahn 32 followed by Binasail (Table 1).

Leaf Area Index (LAI): The significant difference of LAI was observed among the varieties which increased progressively from tillering to panicle initiation stage and thereafter declined after flowering (Fig. 4). The highest LAI was recorded in Binasail at panicle initiation followed by BRRIdhan32 and the lowest was found in Kataribhough.

Leaf Area Ratio (LAR): Leaf area ratio of different varieties differed significantly throughout the growth stages and declined from tillering to flowering stage (Fig. 5). At tillering, BRRIdhan 32 possessed the highest LAR and Ukunmadhu showed lowest value. At panicle initiation stage Binasail showed higher value and Kataribhough showed the lowest LAR.

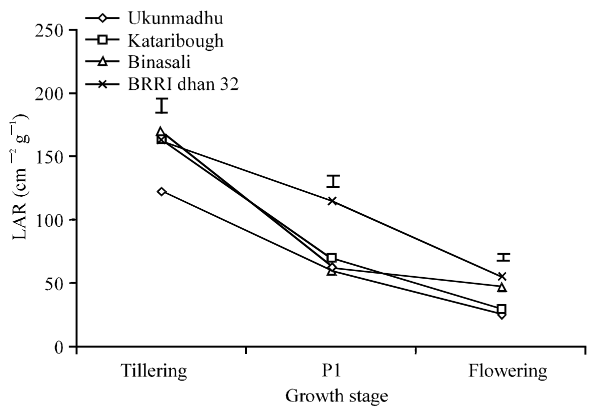

Fig. 5: Leaf area ratio of different aromatic and modern rice varieties at different growth stages, vertical bar represents the LSD at 5% level of significance

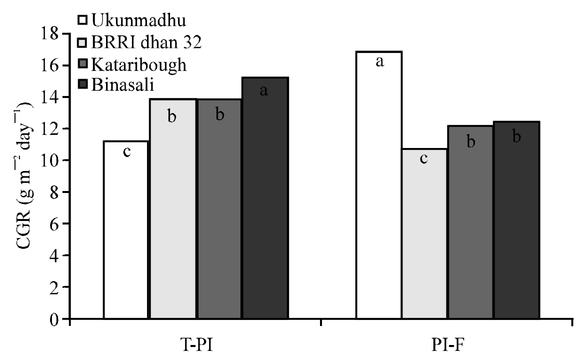

Fig. 6: Crop growth rate of aromatic fine and coarse rice varieties, different level indicate significant effects using the LSD at 5% level of significance

Crop Growth Rate (CGR): The pattern of crop growth rate revealed that the modern variety Binasail had the highest CGR during the panicle initiation to flowering stage and the lowest in panicle initiation stage (Fig. 6). And other varieties namely BRRIdhan 32, Ukunmadhu and Kataribhough showed a declining trend of CGR from panicle initiation to flowering stage.

Relative Growth Rate (RGR): Relative growth rate differed significantly among the varieties at all the stages and a declining pattern was observed from panicle initiation to flowering stage. The highest RGR from tillering to panicle initiation stage was recorded in Kataribhough followed by BRRIdhan 32 (Fig. 7).

Net Assimilation Rate (NAR): Binasail and Ukunmadhu showed an increasing trend of NAR at panicle initiation to flowering stage and the Kataribhough and BRRIdhan 32 had a declining pattern at panicle initiation to flowering stage (Fig. 8). The highest NAR at

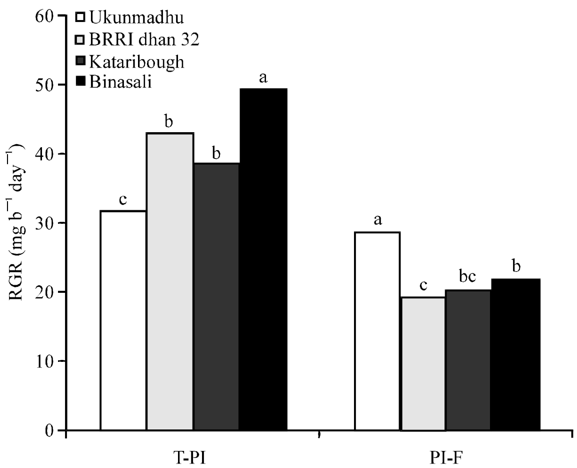

Fig. 7: Relative growth rate of aromatic fine and coarse rice varieties

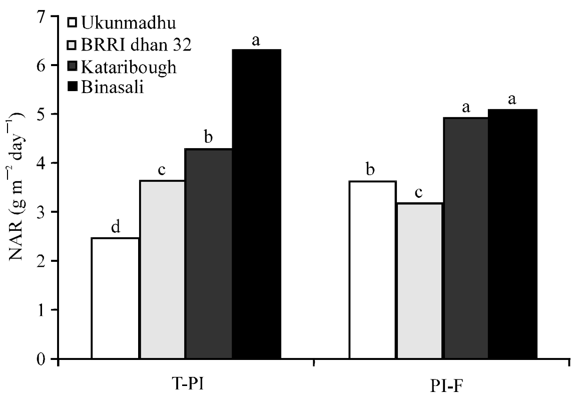

Fig. 8: Net assimilation rate of aromatic fine and coarse rice varieties different letters show LSDT at 5% level of significant

tillering to panicle initiation stage was recorded in Kataribhough followed by Ukunmadhu.

Total Growth Duration (TGD): The fine grain Ukunmadhu required the longest growth duration (140 days) followed by Binasail and the shortest duration was observed in BRRIdhan 32.

DISCUSSION

The higher dry matter production was attributed due to higher LAI where the variety Binasail resulted in higher leaf area consequently produced the greatest total dry matter content. The increase of TDM was dependent on the leaf area production as reported by Weng *et al.* (1982) and Tanaka (1983). The results showed that modern varieties produced higher TDM than the aromatic varieties. These were because of the better photosynthetic capacity due to higher leaf area index and net assimilation rate. In modern varieties, the leaves are oriented vertically thereby harvesting more photos for synthesis of plant biomass. This variety also showed higher crop growth rate because of higher values of LAI.

The significant variation in dry matter production among the cultivars was also reported by Arjuna *et al.* (1990). Generally, dry matter production was positively correlated with grain yield (Chen *et al.*, 1991). Grain yield differences due to varieties were reported by Wu *et al.* (1998).

The results showed wide differences of plant height amongst cultivars. Generally, the plant height of modern cultivars was lower than aromatic fine grain. The differences of plant height are due to genetic make of these Ukunmadhu and longer plant height is not physiologically encouraging as there may be a possibility of lodging in different situation. This observation was supported by Awasthi and Sharma (1996). Hossain and Alam (1991) also observed variation in plant height due to varietals differences. It was generally noticed in aromatic fine cultivars that the number of tillers hill^{-1} ranged between 7 to 11 which are quite high as compared to high yielding modern cultivars. The numbers of tillers were higher but yield was lower. On the other hand, modern varieties had low number of tillers but yield was higher. So, in this condition number of tillers did not play an important role in yield contributing characters of rice. Number of panicle was the result of the number of tillers produced and the proportion of effective tillers which survived produce a panicle (Hossain and Alam, 1991).

Panicle length was not significantly diverged among the varieties however number of primary and secondary branches of panicle was varied as well which was affected on grain yield. Yamagishi *et al.* (2003) reported that high yielding variety possess relatively large number of primary rachis branches as compared with the secondary rachis branches. The most distinction of all cultivars is observed in respect of 1000-grain weight where Ukunmadhu and Kataribhough showed lower values, whereas BRRIdhan 32 showed very high values.

The highest grain yield in BRRIdhan 32 may be due to higher harvest index. All other cultivars *vis-a-vis* Ukunmadhu recorded lower yields which might be assigned to lower harvest index. However, high yielding cultivars, the harvest index is around 43.48% that means the translocation of reserved assimilates from source to sink is poor and there is a possibility of improving this character by increasing the partitioning of assimilates towards grain. Cui-Jing *et al.* (2000) and Reddy *et al.* (1994) also observed higher grain yield with the significant increase of harvest index. The shortest stature of the high yielding variety had the highest harvest index.

There were direct relations between plant height and harvest index which is supported by Lim *et al*. (1993).

The cultivar showed that the leaf area ratio of BRRIdhan32 was much higher than that of Ukunmadhu and Kataribhough and leaf area index was much higher than that of Binasail. The LAI of Ukunmadhu was lower and that of Kataribhough was still lower indicating enough mutual shading.

The modern varieties possessed higher values throughout the whole growth period which led to the higher biomass production and yield than those of the traditional varieties (Reddy *et al*., 1994). Leaf area index was also significantly and positively associated with grain yield (Chandra and Das, 2000). In this respect BRRIdahn 32 and Binasail were better than Ukunmadhu and Kataribhough. If this character may be improved there might be possibility of improvement of these cultivars by altering their translocation pattern and manufacture of recent photosynthate. Higher CGR of the modern varieties than the aromatic varieties as shown in the results may be due to the higher LAI. Decreases of CGR from panicle initiation to flowering stage were due to decreasing LAI following leaf senescence of older leaves (Miah *et al*., 1996). The CGR is the product of LAI and NAR values. The higher CGR resulted in probably due to the higher LAI. The result of RGR at tillering to panicle initiation stage was higher due to rapid increase in growth rate, quick increase of LAI and their enhanced activities which was supported by the higher plant height of the plants. The RGR value at panicle initiation to flowering stages was less than that at tillering to panicle initiation stage, because of the gradual development of the plant and the plant vigor was directed towards the reproductive events for generation of new sinks, ultimately the relative growth was reduced.

Higher NAR at early growth stage manifested the higher photosynthetic efficiency. In the present results NAR tended to increase at panicle initiation to flowering stage which might assigned to increase sink demand for grain formation.

The relationship and variation in the different morpho-physiological characters such as plant height, tillering pattern and number of panicle, panicle character and grain character, TDM, HI, CGR, LAR, RGR and NAR among the modern and aromatic varieties might be explained due to their parental variation in genetic make up.

CONCLUSIONS

The tillering pattern in both types of rice varieties did not appear a definite distinction. Binasail and BRRIdhan 32 possessed the highest number of tillers at vegetative stage. Ukunmadhu and Kataribough showed the highest number of tiller at panicle initiation stage. Number of panicle, panicle length and number of primary and secondary rachis in modern rice varieties were different compared to aromatic varieties. Grain size, grain and straw yield varied significantly among aromatic and modern rice varieties. The modern rice varieties showed higher values of TDM, LAI, LAR and CGR whereas aromatic rice varieties showed only higher value of RGR and NAR and crop duration was higher as well. The overall results of the experiment concluded that BRRIdhan32 had the best agronomic performance of grain yield and Binasail showed the better physiological attributes. Ukunmadhu and Kataribough showed the lowest record in grain yield although they possessed good grain quality. It may be recommended that the height of these cultivars should be shortened up to the level of BRRIdhan32 to have a positive improvement in these cultivars.

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