Agronomy Research **20**(S1), 1014–1025, 2022
https://doi.org/10.15159/AR.22.072

Location specific field performance of aman rice cultivars in tidal flood prone ecosystem of Bangladesh

M.A.A. Mamun*, M.A. Mannan* and M.A. Karim

Bangabandhu Sheikh Mujibur Rahman Agricultural University, Faculty of Agriculture, Department of Agronomy, BD1706 Gazipur, Bangladesh
*Correspondence: aamamun@bsmrau.edu.bd; mannanagr@bsmrau.edu.bd

Received: September 3rd, 2022; Accepted: October 17th, 2022; Published: October 28th, 2022

Abstract. Cultivation of modern high yielding rice varieties are ecologically limited in a tidal flood (TF) prone area of Bangladesh. Therefore, rice growers are cultivating local rice cultivars that resist tidal water pressure and survive under waterlogged condition in a tidal ecosystem. A farmers' participatory field experiment was conducted at Wazirpur, Bakergonj and Babugonj upazila of Barisal and Nalchity upazila under Jhalokati districts of Bangladesh to identify location specifies some aman rice cultivars that resist TF and give higher grain yield. There were fifty-sixty local rice cultivars along with five modern rice varieties were included in this trial. The experimental sites were extensively TF prone and 10 to 80 cm of flood water entered into the crop field during active tillering to flowering stage of rice. Data on plant height, yield and yield components were recorded. The results revealed that local rice cultivars performed better than modern one in the experimental sites. Taller plant, production of more panicles per unit area, higher number of grains panicle^{-1} and heavier grains were the most important traits associated with plant adaptation of aman rice cultivars in tidal areas. Collectively, this study suggested that Dudmona1 and Khoiyamota1 at Wazirpur (2.98 to 3.10 t ha^{-1}); Dishari1 and Sadamota2 at Bakergonj (2.92 to 2.98 t ha^{-1}); Shorna at Babugonj (3.56 t ha^{-1}); Moulata2, Achin and Sadamota2 at Nalchity (2.96 to 2.98 t ha^{-1}) were most promising rice cultivar in terms of adaptation and grain yield.

Key words: local rice cultivars, lodging, low yield, tidal flood, water pressure.

INTRODUCTION

Rice (*Oryza sativa* L.) is grown in a wide range of ecosystem and is considered one of the most important cereals for global food security, especially in Asia (GRiSP, 2013). Rice is staple food for about half of the world population (Worldmeters, 2020; UN, 2020).

Rice is cultivated throughout the year in Bangladesh and 80% of the total crop land of the country is occupied by rice. It is grown in three seasons namely aus (March to June), aman (July to November) and boro season (November to April). The total production of rice was 36.40 million tons grown in 2019 (BBS, 2019). However, the average yield of rice is 4.5 t ha^{-1}in Bangladesh, whereas it is 6.0 to 6.5 t ha^{-1} in China, Korea and Japan (BRRI, 2020). Drought, salinity, inset and pest, cold and submergence cause an enormous loss each year worldwide due to reduction in crop productivity and crop failure.

The seedlings of boro rice face cold injury during their early growing period during the month of December (BRRI, 2020). Therefore, growth of seedling reduces and becomes yellowing in color (Talukder et al., 2022). Aus season is the hottest time of the country and plants experiences high temperature during the growing period. Aman season is the rainy season and submergence causes' severe damage of the aman rice. The submergence may occur for a day to as long as few weeks (Mamun et al., 2021). The submergence problem is very common in aman season in norther region of Bangladesh. Bangladeshi scientists have developed some submergence tolerant rice varieties like BRRI dhan51 and BRRI dhan52 (BRRI, 2020). Islam et al. (2019) and Abedin et al. (2019) also reported that BRRI dhan33, BRRI dhan56 and BRRI dhan57 gave satisfactory yield after submergence.

The aman rice of southern region of Bangladesh experiences tidal flood (TF) submergence every year. About 2.0 m ha of land in Barishal, Patuakhali and Jhalokati districts of Bangladesh is TF prone where 10–80 cm of surge water enters twice a day in cropland from April to November every year (Roy et al., 2003; Brammer, 2014). Ecologically these areas are unfavorable and low productive because farmers can little scope of using modern improved rice varieties and management practices. Thus, the hydrology of these areas influences the cropping system, agricultural production, and farmer's socio-economic condition. Aman rice is the main crop in these areas and farmers cultivate local cultivars such as Sadamota, Lalmota, Rajashail, Kutiagni, Lalpayka, Mutha, Lothor, Lalchikon, Sadachikon, Moulata and Sadapajam, etc (Abedin et al., 2015). These cultivars are locally popular because they are tall, long duration, photoperiod sensitive and resistant to TF. Though the yield of these cultivars is low, but they perform better than modern rice varieties (Hamid et al., 2015). Usually, farmers transplant taller (60 to 70 cm) and older rice seedlings (50 to 60 days) maintaining wider spacing (40×40 cm) in TF-prone areas. These are not recommended practices for rice cultivation. On the other hand, nitrogen (N) fertilization is often impossible because of surface N losses to floodwater (Mamun et al., 2018). But the local cultivars were found responsive to the added N and have potentiality to give better yield under upland condition (Mamun et al., 2020).

The native N content of the soils of tidal floodplain soils are low (Mamun et al., 2016) and earlier studies concluded that the yield of local rice increases with urea deep placement due to absorption of higher amount of N by grains (Mamun et al., 2017a; Mamun et al., 2017b). Therefore, developing suitable high-yielding rice varieties for the TF ecosystem is essential but it requires much time through breeding process. Therefore, identification of location-specific suitable high-yielding rice cultivars might be an immediate solution for rice growers in TF-prone areas. The selection and adoption of the cultivars will improve farm productivity, farmer's income and ensure food security of tidal areas in Bangladesh.

MATERIAL AND METHODS

Experimental Site

The experimental site was located in the south coastal region of Bangladesh under Ganges Tidal Floodplain (Agro-Ecological Zone-13). The experiment was farmers' participatory and the sites included Wazirpur, Bakergonj and Babugonj of Barisal and Nalchity, Jhalokati districts. This region occupies an extensive area of tidal floodplain land in the south-west of the country. There is a general pattern of grey, slightly calcareous, heavy soils on river banks and grey to dark grey, noncalcareous, heavy silty clays in the extensive basins. Noncalcareous Grey Floodplain soil is the major component of General Soil Types.

In general, most of the top soils are acidic and subsoils are neutral to mildly alkaline. The experiment was conducted on July to December, 2021 called aman season in Bangladesh.

Planting Materials

Sixty-one (61) rice cultivars were included in this experiment (28 at Wazirpur, 11 from Nalchity, 11 Bakergonj and 11 from Babugonj). Among the cultivars 56 were local and 5 were modern. The cultivars at Wazirpur, Barisal were Dudmona1, Kutiagni1, Motadhan1, Lalpayka1, Jalkucha, Rajashail, Sadamota1, Lalmota1, Lalchikon, Lothor, Sada pajam, Sadachikon, Kalagura, Joina, BR25, Kajla, Balam1, Chikondhan, Haludmota1, Mothamota1, Moyna, Sonashail, Boleshormota, Kalizira, Kalomota, Moulata3, Khoiyamota1 and Kachamota. Similarly, the cultivars at Nalchity, Jhalokati were Khoiya, Moulata2, Aochin, Nakochimota2, Lalmota3, Dishari2, Dudkolom2, Sadamota2, BRRI dhan44, Haudmota2, Balam2. However, the cultivars at Bakergonj, Barisal were Dudkolom1, Motadhan2, Moulata1, Dishari1, Sadamota4, Nakochimota1, Lalmota4, Lalpayka2, Kutiagni2, Mothamota2 and Khoiyamota2. Furthermore, the cultivars at Babugonj, Barisal were Bhushiara, Chinigura, BRRI dhan76, Lalmota2, Dudmona2, BRRI dhan87, Shorna, Sadamota3, Shakhorkora, BRRI dhan41 and Moulata4.

Crop culture and management

The selected farmers were sown their own seeds in the seed bed. About 30-day-old seedlings were transplanted from first week of August to last week of September in 2021. About 3–4 seedlings hill^{-1} were transplanted maintaining 40 cm × 40 cm plant spacing. A randomized complete block design was followed for the experimentation. The size of each plot was 400 m^2. The number of farmers grown each cultivar is considered as replication and the number replications were 4. No fertilizer was applied to plots. One hand weeding was done at 20 days after transplanting to remove some aquatic weeds. The height of tidal water that entered into the crop field measured every day.

Data Collection

Water depth in the rice field, days to flowering (DF), days to maturity (DM), plant height (cm) (Ph), number of panicles m^{-2} (PPM), number of filled grains panicle^{-1} (GPP), 1,000-grain weight (g) (TGW) and grain yield (t ha^{-1}) (GY) were recorded. Yield of rice grain was determined by harvesting 5.0 m^2 areas of the middle of each plot. The grains were sun dried and winnowed before weighing and converted into t ha^{-1}. The grain yield was adjusted to 14% moisture content using the following formula:

$$\text{Adjusted weight} = \frac{W\cdot(100-M_1)}{(100-M_2)}\cdot 100$$

where, W, M_1 and M_2 were fresh weight, fresh and adjusted moisture percent of the grain, respectively.

Data Analysis

The data were analyzed using computer software CropStat 7.2 and the graphs were prepared using excel program. Descriptive statistics and multiple linear regression were performed for the collected data. Categorization of rice cultivars based on DM, Ph, TGW and GY. Correlation analysis, dendrogram, principal component analysis was done. Correlation, dendrogram, and principal component analysis were performed.

RESULTS AND DISCUSSION

Water depth in the crop field during crop growing period

Flood water entered into the crop field during the crop growing period. So that the crop faced challenges of tidal surge during their life cycle. At Wazirpur, the height of tidal water ranged from 0 to 68 cm. The highest water depth was measured during the month of September at Wazirpur. Similarly, the water depth in the rice field varied from 0 to 85 cm at Babugonj, 0 to 65 cm at Nalchity and 0 to 70 cm at Bakergonj upazila (Fig. 1). In all sites, the highest water depth was recorded during the month of 07 to 15 September. After September, the pressure of tidal water decreased gradually (Mamun et al., 2020). The experimental sites were near to sea and influenced by tides. These areas cover 32% of land area of Bangladesh with an average elevation between 3 and 6 m (MoWR, 2005). Lands were subjected to seasonal flooding and remain inundated July to October. High tide followed by low tide twice a day is the characteristics feature of the experimental sites (Roy et al., 2003; Brammer, 2004; Hamid et al., 2015).

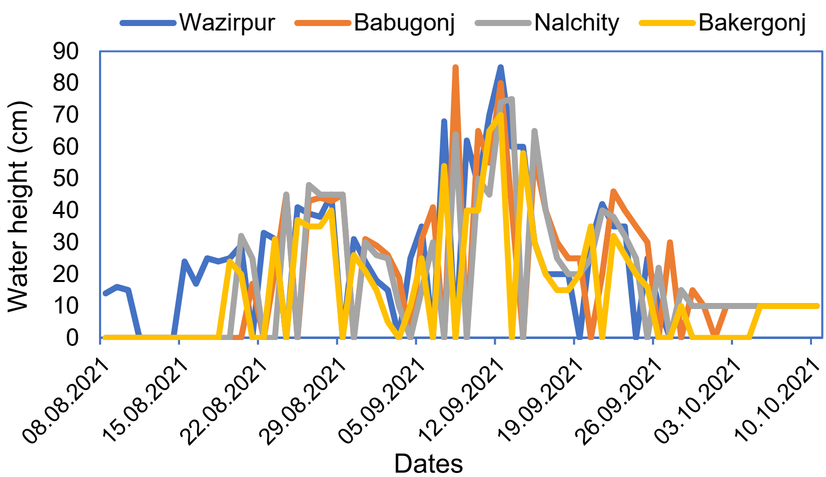

Figure 1. Water depth in the rice field during growing period.

Difference in morphology, phenology and yield

The rice plants needed 92 to 122 days for flowering, while 120 to 155 days for maturity (Table 1 and Fig. 2). The time for flowering and maturity were 108 and 141 days, respectively. The plant height of the rice cultivars varied from 120 to 178 cm with an average 143 cm. There was huge variation in panicle production in the testing rice material. The maximum number of panicles produced by the cultivars was 165 m^{-2}, while minimum was 75 m^{-2}. The number of grains ranged from 54 to 134 $panicle^{-1}$, while average was 90 (Table 1 and Fig. 2). The grain size (1,000-grain weight) of the testing cultivars ranged from 13.06 to 34.53 g (Table 1 and Fig. 2). The maximum grain yield was 3.56 t ha^{-1}, while minimum was 1.28 t ha^{-1}. The average grain yield was 2.51 t ha^{-1} (Table 1 and Fig. 2). Tiller production is an important trait for yield formation in rice. Large variation in tillering capacity among varieties has been reported (Mamun et al., 2020; Nuruzzaman et al., 2000). Indigenous variety Sadamota produced large number of tillers $hill^{-1}$ as reported by Hamid et al. (2015). Altering tiller production due to variation in agronomic practices has been reported earlier (Mamun et al., 2017a; Huang et al., 2011). Under field condition, the yield of local rice cultivar is relatively low (Senthilkumar et al., 2020). The genetic potentiality of cultivars may also have been deteriorated in the farmers' field for multiple reasons including out-crossing, admixtures of different cultivars and genetic erosion or mutation (Parlevliet, 2007). In addition, lack of proper management practices results in low yield of any cultivars (Liliane & Charles, 2020). The yield in local rice was mostly contributed by tiller $hill^{-1}$, filled grains and test weight. In many studies, similar plant characters including tillers production capacity, grains in a panicle and their weight were reported to be the major factors contributing to the yield (Sabri et al., 2020; Huang et al., 2020; Oladosu et al., 2018).

Table 1. Variations in the yield and yield contributing characters of locally popular landrace T. Aman rice cultivars in tidal flood prone region

Traits	Mean	Maximum	Minimum	*CV* (%)
Days to flowering	108.80	122.00	92.00	8.09
Days to maturity	141.72	155.00	120.00	8.28
Plant height (cm)	142.59	178.00	120.00	10.71
Panicle (no. m^{-2})	120.82	165.00	75.00	19.87
Grains (no. $panicle^{-1}$)	89.53	134.00	54.00	17.95
1,000-grain weight (g)	26.82	34.53	13.06	5.22
Grain yield (t ha^{-1})	2.51	3.56	1.28	0.44

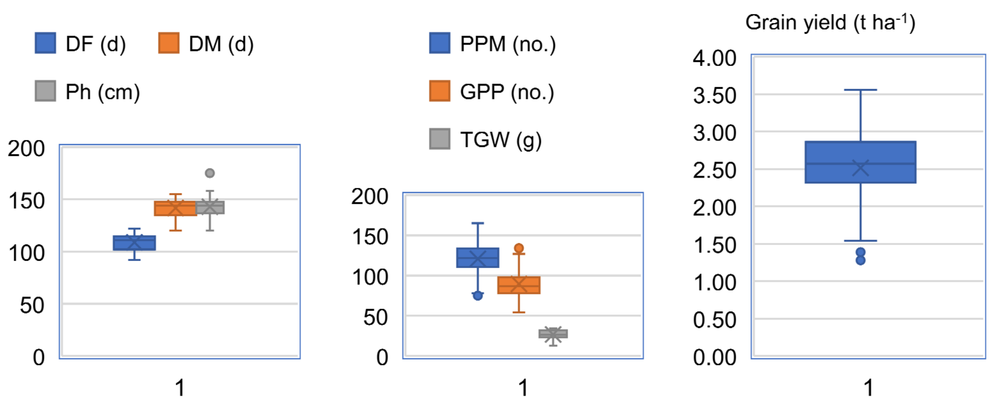

Figure 2. Phenology, plant height, panicle and grain production of T. aman rice cultivars.

Inter-trait associations among studied traits and contribution of yield attribute to yield of rice

Correlation analysis of studied parameters showed that grain yield had a strong positive association with days to flowering and maturity, plant height, panicle and grain production (Table 2 and Fig. 3). There was a positive but weak relation between grain yield and 1,000-grain weight. However, 1,000-grain weight also showed a weak but positive relationship with days to flowering and maturity, plant height, panicle and grain production. On the other hand, 1,000-grain weight had a negative but very weak relationship with grains panicl^{-1}. Similarly, number of grains panicle^{-1} had a strong association with days to flowering and maturity and panicle production. There was a weak but positive relationship between grain production and plant height. Plant height and panicle production had a strong association with days to flowering and maturity. The functional relationship between predicted yield and actual yield showed that $r = 83$ ($P < 0.01$) (Fig. 3). The number of panicle m^{-2}, grain production and 1,000-grain weight had great contribution in grain yield. Yield = - 1.360 – 0.0081 DF + 0.0213 DM – 0.0024 Ph + 0.0116^{**} PPM + 0.0039^{*} GPP + 0.0121^{*} TGW. Higher yield in rice is associated with greater number of panicles per unit area, number of grains panicle^{-1} (spikelets), higher filled grains (Zhao et al., 2006; Hamid et al., 2015). Higher yield is often associated with high dry matter accumulation (Hu et al., 2015), but high translocation rate after heading directly contributes to grain formation that eventually results in higher yield in cereal crops.

Table 2. Inter-trait associations among studied traits of T. aman rice cultivars

	DF	DM	Ph	PPM	GPP	TGW	GY
DF	1.000						
DM	0.997**	1.000					
Ph	0.354**	0.363**	1.000				
PPM	0.586**	0.574**	0.261	1.000			
GPP	0.490**	0.485**	0.143^{ns}	0.582**	1.000		
TGW	0.275	0.270	0.199	0.317	-0.028^{ns}	1.000	
GY	0.651**	0.644**	0.644*	0.785**	0.571*	0.357	1.000

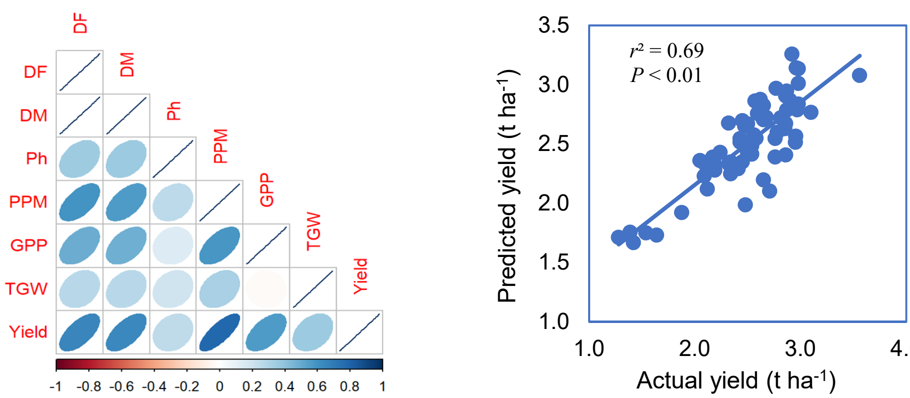

Figure 3. Inter-trait associations among studied traits and functional relationship between actual and predicted yield of rice cultivars of aman rice cultivars.
DF = days to flowering; DM = days to maturity; Ph = plant height; PPM = panicle m^{-2}; GPP = grains panicle^{-1}; TGW = 1,000-grain weight; GY = Grain yield.

Categorization of rice cultivars:

Based on growth duration, the rice cultivars were categorized into three classes (Fig. 4). The growth duration categories were short (< 120 days), medium (120–140 days) and long (> 140 days). The average yield of short duration cultivar was 2.1 t ha^{-1}, medium duration 2.34 t ha^{-1} and long duration 2.65 t ha^{-1}. It indicated that the grain yield increases with the increases of growth duration of the cultivars. However, only 2 rice cultivars were belonged to short duration, 21 from medium duration and rest 39 from long duration cultivars. The majority of rice cultivars in the TF prone areas were medium to long duration cultivars. Mamun et al. (2017b) reported that Rajashail and Kutiagni flowered mid and last week of October, respectively and they were short duration cultivars. However, rest of the cultivars flowered mid-November and they are long duration cultivar (Mamun et al., 2017b).

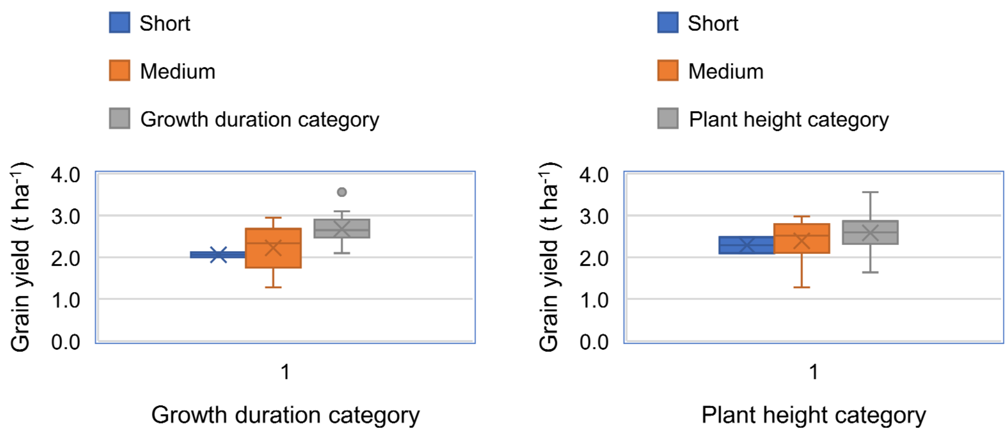

Figure 4. Categorization of rice cultivars based on growth duration and plant height.

Based on plant height, the rice cultivars were categorized into three classes (Fig. 4). The plant height categories were short (< 120 cm), medium (120–140 cm) and long (> 140 cm). The average yield of short stature cultivar was 2.3 t ha^{-1}, medium stature 2.52 t ha^{-1} and long stature 2.60 t ha^{-1}. It indicated that the grain yield increases with the increases of plant height of the cultivars. However, only 2 rice cultivars were belonged to short stature, 22 from medium stature and rest 38 from long stature cultivars. The majority of rice cultivars in the TF prone areas were medium to long stature cultivars. Hamid et al. (2015) reported the local rice cultivars are tall statured in nature.

Based on 1,000-grain weight, the rice cultivars were categorized into four classes (Fig. 5). The grain size categories were small (< 20.0 g), medium (20.0–25.0 g), large (20.0–25.0 g) and very large (> 30.0 g). The average yield of small grain sized cultivar was 1.6 t ha^{-1}, medium grain 2.68 t ha^{-1}, large grain 2.43 t ha^{-1} and very large grain 2.76 t ha^{-1}. It indicated that the grain yield increases with the increases of grain size of the cultivars. However, only 5 rice cultivars were belonged to small grain, 17 from medium grain, 19 from large grain and rest 20 from very large grain cultivars. The majority of rice cultivars in the TF prone areas were medium to very large grain sized cultivars. Previous study also confirmed that the local cultivars are having bold grained with grain size or 1,000-grain weight of 30.03 to 31.5 g (Hamid et al., 2015).

Based on grain yield, the rice cultivars were categorized into three classes. The grain yield categories were low (< 2.0 t ha^{-1}), medium (2.0–3.0 t ha^{-1}) and high (> 3.0 t ha^{-1}) (Fig. 5). The average yield of low yielded cultivar was 1.5 t ha^{-1}, medium 2.59 t ha^{-1} and high 3.33 t ha^{-1}. However, only 6 rice cultivars were belonged to low yielding, 53 from medium and rest 2 from high yielding cultivars. The majority of rice cultivars in the TF prone areas were medium yielding rice cultivars. Relatively lower yield in indigenous cultivars indicate the potential constraint of translocation of biomass to grains during grain filling stage (Hamid et al., 2015; Mamun et al., 2017a, Mamun et al., 2020). Grain yield of local aman rice cultivars were comparatively low (Mia et al., 2022; Senthilkumar et al., 2020). The low yield was due to low yield potential of local cultivars.

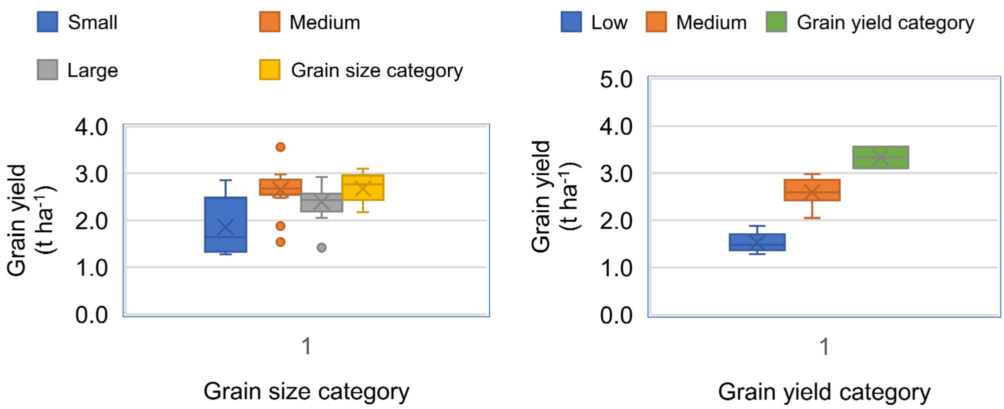

Figure 5. Categorization of rice cultivars based on grain size and grain yield.

When we categorize the landraces according to plant height, we observed that yield is significantly higher in the cultivars with longer plant height. This result contradicts with many previous findings where longer plant height is shown to be a negative character (Oladosu et al., 2018). In the context of coastal agro-ecosystems, it is, however, often a common phenomenon since dwarf plant cannot withstand tidal inundation/flooding. Therefore, longer plant of rice is a desired trait for cultivars to be grown in this ecosystem. Moreover, heavier grain is associated with higher grain yield, a phenomenon reported in the previous literature (Wenhui et al., 2019; Li et al., 2019). Considering all these factors, it can be suggested that longer plant with heavier grain are two important characters for local rice grown in coastal ecosystem.

Principal component and cluster analysis

Principal component analysis showed that different rice cultivars had association with different paraments (Fig. 6). Grain production show close association with BRRI dhan76, 1,000-grain weight with Sadamota 4, yield with Moulata. Dudmona1 and Khoiyamota1 at Wazirpur yielded 2.98 to 3.10 t ha^{-1}; Dishari1 and Sadamota2 at Bakergonj yielded 2.92 to 2.98 t ha^{-1}; Shorna at Babugonj gave 3.56 t ha^{-1}; Moulata2, Achin and Sadamota2 at Nalchity yielded 2.96 to 2.98 t ha^{-1}. These were most promising rice cultivar in terms of adaptation and grain yield in the study areas. In breeding program, these cultivars might be included.

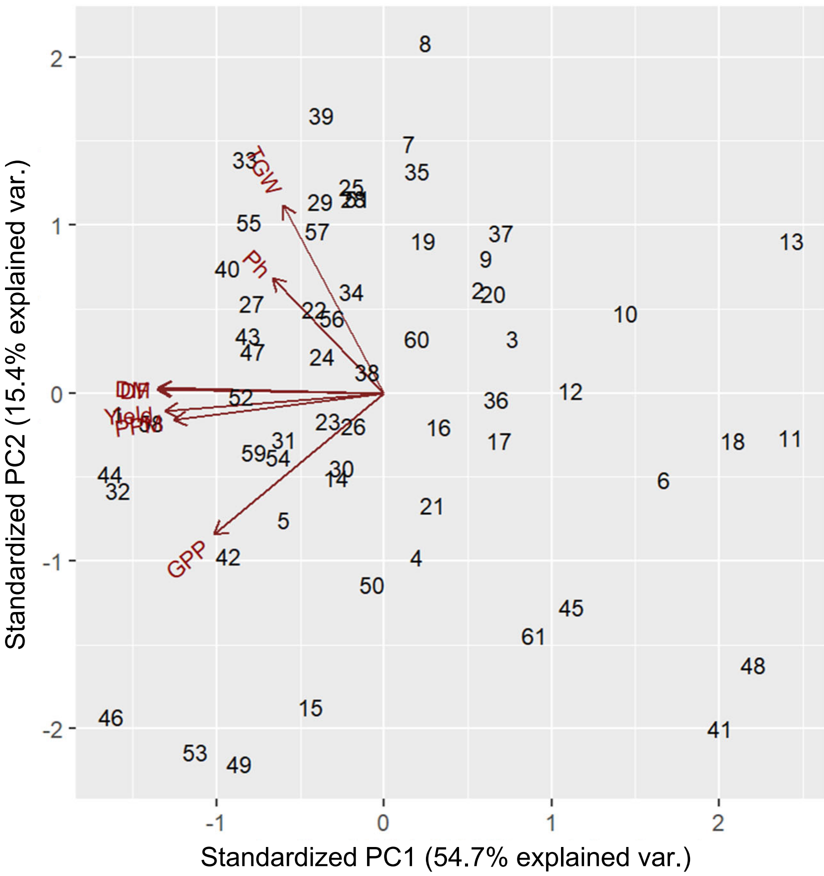

Figure 6. Inter relationship between studied parameters of aman rice obtained by principal component analysis.
DF = days to flowering; DM = days to maturity; Ph = plant height; PPM = panicles m^{-2}; GPP = grains panicle^{-1}; TGW = 1,000-grain weight; GY = Grain yield; 1 = Dudmona1; 27 = Khoiyamota1; 32 = Dishari1; 33 = Sadamota4 (TGW); 46 = Shorna; 52 = Moulata2; 53 = Achin; 58 = Sadamota2.

Based on the studied parameters, the cultivars were grouped into seven cluster (Fig. 7). Cluster 1 included 2 cultivars like Dudmona 1 and Dudmona 2; cluster 2 included 38 cultivars like Kutiagni, Mota dhan 1, Lalpayka, Jalkucha, Lalmota, Sadamota, Rajashail, Lalchikon, Sadachikon, Joina, Balam 1, BR25, Kajla, Haludmota 1, Mothamota 1, Moyna, Sonashail, Boleshormota, Kalizira, Kalomota, Moulata3, Khoiyamota1, Kachamota, Dudkalam, Moulata1, Sadamota 4, Nakochimota1, Lalmota 4, Lalpayka2, Kutiagni 2, Mothamota2, Khoiyamota3, Kiyamoat1, Lalmota3, Dishari2, Dudkolam2, BRRI dhan44 and Haludmota 2; cluster 3 included 3 cultivars like Lother, Sadapajam and Kalagura; cluster 4 included 5 cultivars like Motadhan2, Dishari1, Moulata2, Aochin and Nakochimota2; cluster 5 included 5 cultivars like Bhushiara, BRRI dhan76, Lalmota2, Sadamota3 and Moulata4; cluster 6 included 4 cultivars like Chinigura, BRRI dhan87, Shakhorkora and Balam2; and cluster 7 included 2 cultivars like Shorna and Sadamota2.

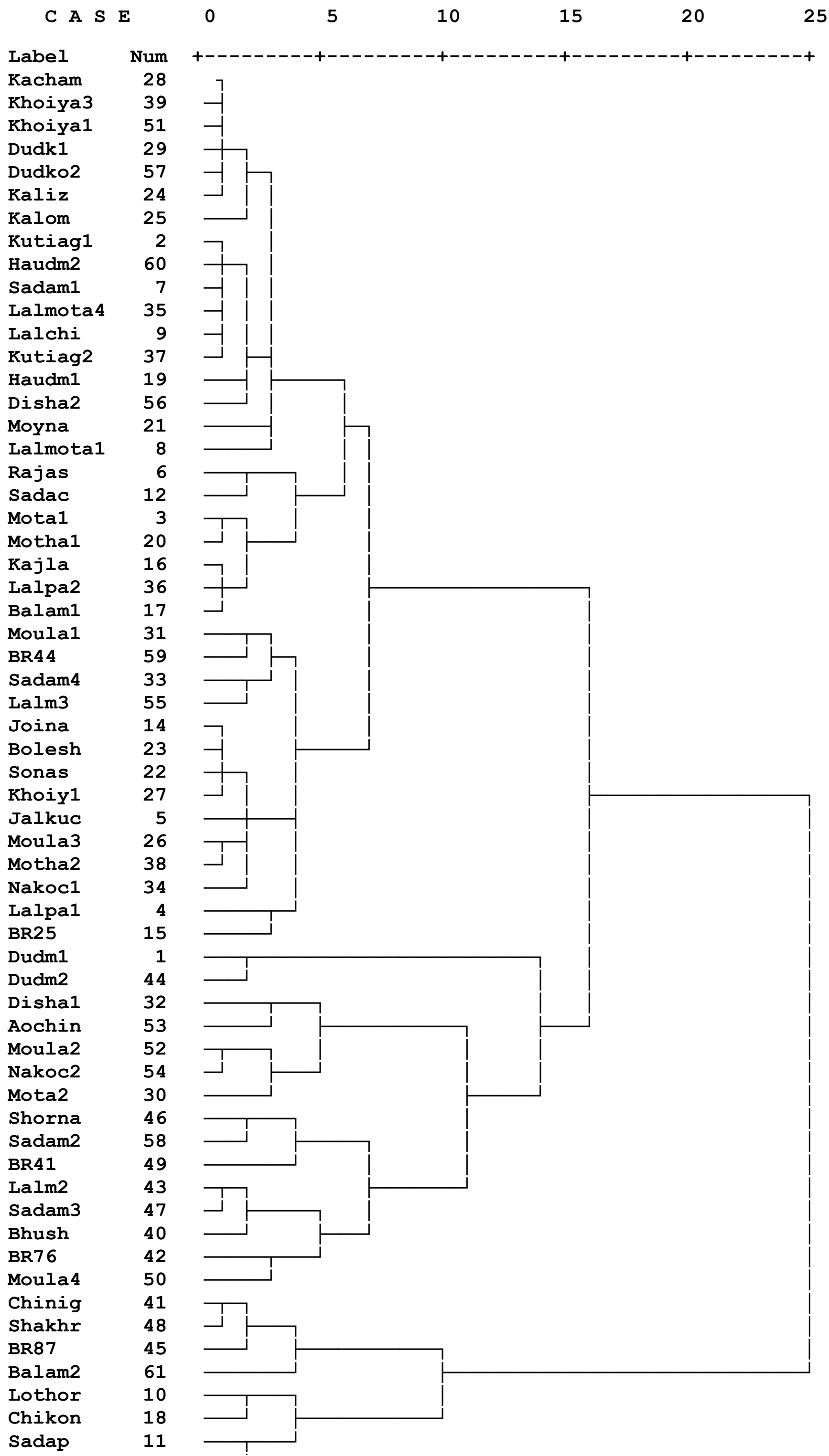

Figure 7. Dendrogram of studied T. Aman rice cultivars.

CONCLUSIONS

Local cultivars performed better than modern rice. Taller plant, production of more panicles per unit area, higher number of grains panicle^{-1} and heavier grains are the most important traits associated with plant adaptation of aman rice cultivars in tidal areas. Collectively, this study suggested that Dudmona1 and Khoiyamota1 at Wazirpur; Dishari1 and Sadamota2 at Bakergonj; Shorna at Babugonj; Moulata2, Achin and Sadamota2 at Nalchity were most promising rice cultivar in terms of adaptation and grain yield. In breeding program, these cultivars might be included. However, improved management practices should be developed from the research findings.

ACKNOWLEDGEMENTS. The study was funded by the Improving Farm Productivity in Unfavorable Tidal Flooded Coastal Region of Bangladesh (Project ID LS20201411), of the Bangladesh Bureau of Educational Information & Statistics (BANBEIS), Ministry of Education, Government of the People's Republic of Bangladesh.

REFERENCES

Abedin, S.M.S., Mannan, M.A., Mamun, M.A.A., Rahman, G.K.M.M. & Mridha, A.J. 2015. Growth and yield performance of tidal local aman rice as influenced by USG application at nontidal condition. *Bangladesh Agron. J.* **18**(1), 71–80.

Abedin, M.H., Mamun, M.A.A., Mia, M.A.B.& Karim, M.A. 2019. Evaluation of submergence tolerance in landrace rice cultivars by various growth and yield parameters. *J. Crop Sci. Biotechnol.* **22**(4), 335–344.

BBS (Bangladesh Bureau of Statics). 2019. Statistics & informatics division. Ministry of planning, Government of the People's Republic of Bangladesh. 144p.

Brammer, H. 2014. Bangladesh's Dynamic Coastal Regions and Sea-Level Rise. *Climate Risk Manag.* 1, 51–62.

BRRI (Bangladesh Rice Research Institute). Modern Rice Cultivation. 23rd Edition. 5p.

GRiSP (Global Rice Science Partnership). 2013. Rice Almanac: Source Book for One of the Most Important Economic Activities on Earth, 4th Edition. http://ageconsearch.umn. edu/handle/164484

Hamid, A., Ullah, M.J., Haque, M.M., Mollah, M.F.H.& Rahman, M.M. 2015. Improving grain yield of indigenous rice in tidal floodplain of southern Bangladesh: effect of seedling age and transplanting method. *Agril. Sci.***6**, 1538–1546.

Hu, Z., Liu, Y., Huang, L., Peng, S., Nie, L., Cui, K., Huang, J. & Wang, F. 2015. Premature heading and yield losses caused by prolonged seedling age in double cropping rice. *Field Crops Res.* **183**, 147–155.

Huang, M., Zou, Y., Jiang, P., Xia, B., Feng, Y., Cheng, Z. & Mo, Y. 2011. Yield component differences between direct-seeded and transplanted super hybrid rice. *Plant Prod. Sci.* 14, 331–338.

Huang, M., Shan, S., Cao, J., Fang, S., Tian, A., Liu, Y., Cao, F., Yin, X. & Zou, Y. 2020. Primary-tiller panicle number is critical to achieving high grain yields in machine-transplanted hybrid rice. *Sci. Rep.* **10**, 2811.

Islam, M.Z., Islam, M.R., Mamun, M.A.A., Haque, M.M., Ahmed, J.U., Akter, N.& Karim, M.A. 2019. Genetic variability of submergence tolerance in rice related to yield and yield contributing traits. *J. Plant Stress Physiol.* **5**, 22–27.

Li, R., Li, M., Ashraf, U., Liu, S. & Zhang, J. 2019. Exploring the relationships between yield and yield-related traits for rice varieties released in China from 1978 to 2017. *Front. Plant Sci.* **10**, 543.

Liliane, T.N. & Charles, M.S. 2020. Factors affecting yield of crops. *Agron-Clim Change Food Secur.* 9.

Mamun, M.A.A., Haque, M.A., Khaliq, Q.A., Karim, M.A., Karim, A.J.M.S., Mridha, A.J. & M.M., Saleque. 2016. Assessment of soil chemical properties and rice yield in tidal submergence ecosystem. *Bangladesh Agron. J.* **18**(2), 79–87.

Mamun, M.A.A., Haque, M.A., Khaliq, Q.A., Karim, M.A., Karim, A.J.M.S., Mridha, A.J. & M.M., Saleque. 2017a. Yield and nitrogen use efficiency of locally improved rice varieties in rice based tidal flooded ecosystem of Bangladesh. *Bangladesh Agron. J.* **19**(2), 39–49.

Mamun, M.A.A., Haque, M.M., Saleque, M.A., Khaliq, Q.A., Karim, M.A. & Karim, A.J.M.S. 2017b. Nitrogen fertilizer management for tidal submergence tolerant landrace rice (*Oryza sativa* L) cultivars. *Ann. Agricl. Sci.* **62**(2), 193–203.

Mamun, M.A.A., Haque, M.M., Khaliq, Q.A., Karim, M.A. & Karim, A.J.M.S. 2018. Response of some land-race rice (*Oryza sativa* L.) cultivars to applied nitrogen in lowland ecosystem. *The Agriculturis* **16**(1), 1–12.

Mamun, M.A.A., Haque, M.M., Saleque, M.A., Khaliq, Q.A., Karim, A.J.M.S., Khan, M.A.R., Katun, A. & Karim, M.A. 2020. Management strategy, uptake and translocation of nitrogen in tidal flooded rice ecosystem. *J. Plant Nutrit.* **43**(14), 2186–2199.

Mamun, M.A.A., Bishas, K., Sultan, M.S. & Karim, M.A., 2021. Plant traits associated with stagnant flooding tolerance in rice (*Oryza sativa* L.). *J. Agron. Technol. Eng. Manag*. **4**(3),598–612.

Mia, S., Ahmed, N.U., Islam, M.Z., Rashad, M.M.I., Islam, M.M. & Zaman, A.K.M.M. 2022. Genetic diversity and yield performance among T. *Aman* rice (*Oryza sativa* L.) landraces in Barishal region of Bangladesh. *J. Crop Sci. Biotechnol.* **25**, 123–132.

MoWR. (Ministry of Water Resources) 2005. Coastal Zone Policy, The People's Republic of Bangladesh.

Nuruzzaman, M., Yamamoto, Y., Nitta, Y., Yoshida, T. & Miyazaki, A. 2000. Varietal Differences in tillering ability of fourteen japonica and indica rice varieties. Soil Sci. *Plant Nutrit*. **46**, 381–391.

Oladosu, Y., Rafii, M.Y., Magaji, U., Abdullah, N., Miah, G., Chukwu, S.C., Hussin, G., Ramli, A. & Kareem, I. 2018. Genotypic and phenotypic relationship among yield components in rice under tropical conditions. *Biomed. Res. Int.* https://doi.org/10.1155/2018/8936767

Parlevliet, J.E. 2007. How to maintain improved cultivars. *Euphytica.***153**, 353–362. https://doi.org/10.1007/s10681-006-9169-5

Roy, B.C., Hossain, M.A. & Khan, M.A.I. 2003. Suitable Transplanting Time for the Modern T. Aman Rice Varieties in Tidal Non-Saline Wetland Situation of Bangladesh. *Pakistan J. Biolog. Sci*. **6**, 661–665.

Sabri, R.S., Rafii, M.Y., Ismail, M.R., Yusuff, O., Chukwu, S.C. & Hasan, N.A. 2020. Assessment of agro-morphologic performance, genetic parameters and clustering pattern of newly developed blast resistant rice lines tested in four environments. *Agron* **10**(8), 1098.

Senthilkumar, K., Rodenburg, J., Dieng, I., Vandamme, E., Sillo, F.S., Johnson, J.M., Rajaona, A., Ramarolahy, J.A., Gasore, R., Abera, B.B., Kajiru, G.J., Mghase, J., Lamo, J., Rabeson, R. & Saito, K. 2020. Quantifying rice yield gaps and their causes in Eastern and Southern Africa. *J. Agron. Crop. Sci.* **206**(4), 478–490.

Talukder, S., Mamun, M.A.A., Hossain, M.S., Khan, M.A.R., Rahman, M.M., Talukder, M.R., Haque, M.M. & Biswas, J.C. 2022. Duration of low temperature changes physiological and biochemical attributes of rice seedling. *Agron. Res*. **20**.

UN. 2020. World population day 11 July 2020, United Nations. Accessed 11 July 2020.

Wenhui, W., Linlin, W., Yujun, Z., Yeyang, F. & Jieyun, Z. 2019. Fine-mapping of qTGW1.2a, a quantitative trait locus for 1,000-grain weight in rice. *Rice Sci.* **26**(4), 220–228

Worldmeters. 2020. Current world population, July 2020. https://www.worldometers.info/world-population/. Accessed 11 July 2020.

Zhao, B.H., Wang, P., Zhang, H.X., Zhu, Q.S. & Yang, J.C. 2006. Source-sink and grain filling characteristics of two-line hybrid rice Yangliangyou 6. *Rice Sci*. **13**, 34–42.