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RESEARCH ARTICLE

MORPHO-PHYSIOLOGICAL AND GENETIC CHARACTERIZATION OF TRANSPLANTED *AMAN* RICE VARIETIES UNDER OLD BRAHMAPUTRA FLOOD PLAIN (AEZ-9) IN BANGLADESH

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Abstract

Rice is a staple food in terms of acreage and production in Bangladesh. The assessment of genetic variability in rice genotypes is essential to identify suitable characters for its further improvement. An experiment was carried out to study the morpho-physiological and genetic characteristics of transplanted *Aman (*one of the important rice growing seasons in Bangladesh) rice cultivars. Ten *Aman* rice varieties were tested as treatments and the experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The analysis of morpho-physiological traits in tested rice varieties demonstrated that the higher number of effective tillers per hill, panicle length, grains per panicle and 1000 grain weight was the most yield contributing traits those were influenced to produce higher grain yield. In terms of genetic traits analyses, all the studied traits exhibited high heritability (>60%) except panicle length. And in correlation studies, grain yield showed the significant positive correlation with 1000 seed weight, panicle length, effective tiller number per hill along with biological yield, straw yield and harvest index. Moreover, path coefficient analysis revealed that biological yield and harvest index showed a high and positive direct effect on grain yield. Thus, after studying different traits among ten varieties of Aman rice there after considering the three categories, hybrid varieties performed better followed by HYV compared to traditional rice varieties. And the Dhanigold variety might be recommended as a higher yield producing cultivar along with the economic return.

Keywords: genetic characterization, morpho-physiology, *Aman* rice, agro ecological zone (AEZ)

INTRODUCTION

Rice (*Oryza sativa* L.), one of the leading predominant food crops, is capable of feeding over half of the global population (USDA, 2020). Asian people are dominated regarding rice production as well as its consumption, amounting almost 90% of the global rice production (Bandumula, 2017). And Asia is the key source of rice genetic diversity to achieve global food security, especially for the developing countries which are solely depends on it. Globally, rice contributes an average 20% of apparent caloric intake in which Asian people grab almost 30% (Shelley *et al*. 2016). In Bangladesh, rice contributes 95% of food production. And about 74.85% of cropped area of Bangladesh is used for rice production, with annual production of 3.6 million metric tons from 21784038 acres of land (BBS, 2018). Population growth rate in Bangladesh also shows an increasing trend, however, the

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cultivable land area is restricted due to urbanization and industrialization, imposing a great threat to the food security within the country. The rice production in Bangladesh has to be increased by at least 60% to meet the rice requirement of the increasing population by the year 2030 (Masum, 2019). Since, expansion of lands under rice cultivation is a challenge with the current trends in urbanization, the best possible strategy to meet this ever-increasing demand for the food would be enhancing the yield of rice per unit land area.

Rice is extensively grown in Bangladesh in the three seasons namely, *Aus, Aman* (broadcasted and transplanted) and *Boro* which covers total 80% of the total cultivable area of the country (AIS, 2011). Among these cropping seasons transplanted *Aman* is the most important and occupied about 46% of the rice cultivation land in 2019-2020. Area covered by *Aman* rice is 55.3 lac hectares and production is about 131.9 lac metric ton (BBS, 2018). To increase the cultivation area as well as production, research should be emphasized regarding morpho-physiological and genetic characteristics of *Aman* rice in which a little information have been reported earlier (Hossain *et al*. 2010; Shelley *et al*. 2016). Thus, it is a crucial need to conduct more research work to develop sustainable technologies regarding higher yield production suitable for cultivation in the *Aman* season of Bangladesh. The existing low yielding traditional varieties of *Aman* rice have many undesirable characteristics such as long and droopy leaves, weak culms, and taller plant height which make them highly susceptible for lodging (Kabir *et al*. 2019). But, the improved varieties possess short and stout culms with dark green, thick and erect leaves which are tolerant for lodging (Sarkar, *et al*. 2016). Therefore, farmers tend to replace the traditional low yielding rice varieties with high yielding improved rice varieties developed by the Bangladesh Rice Research Institute (BRRI) which guarantee 20 to 30% more yield per unit land area (Al Mamun *et al*. 2021; Kabir *et al*. 2020).

Variety itself plays an important role for the improvement of a particular crop. And the availability of genetic diversity present in the rice and their effective utilization can helps its further improvement (Tabassum *et al*. 2020a; Tabassum *et al*. 2020b). Till to date many researchers have been noted that High Yielding Varieties (HYV) and hybrid rice varieties yielded almost 15-30% more yield over the traditional varieties (Rahman *et al*. 2019; Hossain *et al*. 2017). Breeding and adoption of rice varieties with high yield potential and short duration, is a common objective of a rice breeders (Hasan *et al*. 2008; Sarkar *et al*. 2021). Therefore, genetic analysis of rice genotypes along with desirable morphological traits would provide important information for further development of rice yield potential.

The land use pattern of Bangladesh is altered by soil physiographic, agro-ecology and climatic factors. Considering these variations, the total land area of Bangladesh has been categorized into thirty agro ecological zones (AEZ). The present study focused on the area under AEZ-9 (Old Brahmaputra flood plain) which comprises the areas of Sherpur, Jamalpur, Tangail, Mymensingh, Netrokona and Kishoreganj districts. To date, the morpho-physiological characteristics of traditional *Aman* rice cultivars along with their genetic analysis were not studied in detail in these region (Ullah *et al*. 2016). Therefore, the present study was aimed to characterize the important morpho-physiological characteristics of traditional, HYV and hybrid transplanted *Aman* rice and to determine the phenotypic and genotypic variance, heritability and genetic advance for yield and yield associated traits of the tested rice varieties.

MATERIALS AND METHODS

Experimental materials

The field experiment was conducted at the Agronomy Field of Bangladesh Agricultural University, Mymensingh which is under Old Brahmaputra Floodplain AEZ-9 during Aman season from June to December 2019 to study the morpho-physiological and genetic characterization of ten transplant Aman rice varieties. The ten varieties were comprised of three traditional (Bashiraj, Nizershail, Kalizira), five HYV (Binadhan-7, BR11, BRRI dhan32, BRRI dhan34 and BRRI dhan49) and two hybrid varieties (Dhanigold and Agrodhan-12). The seeds of hybrid varieties were sourced from Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh.

Soil and climate of the experimental site

Geographically, the experimental site is located at 24°25"N latitude and 90°50"E longitude. The experimental field was medium high land with loamy soil having pH value of 6.10. The land was flat, well drained and above the flood level. Soil of the experimental field was more or less neutral in reaction, low in organic matter content and its general fertility level was also low. Soil contained 2.02% organic matter, 0.14% total nitrogen, 3.19 ppm available phosphorus, 4.56 ppm available sulphur and 0.10 ppm exchangeable potassium. And the experimental area is under the sub-tropical climate which is characterized by its heavy rainfall during Kharif season (April to September) and scanty rainfall occurred during Rabi season (October to March). The information in respect of rainfall pattern, sun-shine hours, temperature fluctuations, relative humidity during the study period is presented in Table 1.

Experimental design

Single factor experiment was conducted using ten transplanted *Aman* rice varieties which were considered as the treatment in the present study. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of each unit plot was 10 m2 (4.0 m x 2.5 m). The space between individual unit plots was 1 m and 0.5 m, respectively. Recommended fertilization (Urea, TSP, MP, Gypsum, Zinc sulphate and Borax @150, 100, 100, 60, 10 and 10Kg/ha, respectively), irrigation, weeding, pest control, mulching and other management operations were carried out as per the requirement.

Collection of experimental data

Five hills were selected randomly from each experimental plot to record necessary data. An area of 1 meter square was selected in the middle portion of each plot to record the yield of grain and straw. The data on plant height (cm) was measured during the plant growth stages such as 30DAT (days after transplanting), 45DAT, 60DAT, 75DAT and at the time of harvest. And the data on dry weight per plant (g) was also measured at 30DAT, 45DAT and 60DAT. The number of total tillers, effective tillers and non-effective tillers were counted based on per meter square area of experimental plot. Other yield parameters viz. panicle length (cm), number of grains per panicle and number of sterile spikelets per panicle were collected just before the harvesting time of rice plant. The 1000-grain weight (g), grain yield (initially grain yield was measured kg per plot which was then converted in ton per hectare), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) were measured after the

Table 1: Recorded weather and climatic condition of the experimental site

Months	Monthly average air temperature (°C)			Monthly total rainfall (mm)	Monthly avg. Rel. humidity (%)	Monthly total sunshine (hrs)
	Maximum	Minimum	Average			
June 2019	32.2	26.1	29.2	421.3	84.4	109.9
July 2019	32.5	26.7	29.6	582.9	84.5	120.5
August 2019	33.3	27.3	30.2	116.5	81.6	199.7
September 2019	32.4	26.3	29.3	203.0	84.6	147.9
October 2019	31.2	23.3	27.3	200.9	87.3	164.6
November 2019	30.2	19.5	24.7	2.0	83.4	214.9
December 2019	24.5	13.4	19.2	1.6	82.7	160.8

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University harvesting of rice plant along with proper sun drying of grain and straw. The phenological information such as date of booting, heading, anthesis and physiological maturity of the studied rice cultivars were recorded (Table 2).

Biological yield (t ha^{-1}) was measured using grain yield and straw yield which was calculated using the following formula:

Biological yield = Grain yield (tha^{-1}) + Straw yield (tha^{-1})

Harvest index (%) was calculated using the following formula:

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

Statistical Analysis

The data were analyzed in using R-Studio statistical software (Developed by JJ Allaire which was published by Chapman and Hall/ CRC; 2nd edition) and the differences among the treatment means were compared by Duncan's New Multiple Range Test (Gomez and Gomez, 1984) at the 5% significance level.

Estimation of Genetic Parameters

Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variance was estimated according to the formula given by Johnson *et al*. (1995).

$$\text{Genotypic variance}, \sigma_g^2 = \frac{\text{GMS} - \text{EMS}}{\text{r}}$$

Where,
GMS= Genotypic mean square
EMS= Error mean square
r= Number of replication

Phenotypic variance, $\sigma^2p = \sigma^2g + EMS$
Where,
σ^2g = Genotypic variance
EMS= Error mean square

Estimation of heritability

Heritability in broad sense (h^2b) was estimated according to the formula suggested by Johnson *et al*. (1995).

$$\text{Heritability}, h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,
σ^2 g = Genotypic variance
σ^2 p =Phenotypic variance

Estimation of genetic advance

Estimation of genetic advance was done following formula given by Johnson *et al.* (1995).

Genetic advance, GA= $h^2{}_b .K. \sigma_p$

Where,
$h^2{}_b$= Heritability
K= Selection differential, the value of which is 2.06 at 5% selection intensity
σ_p = Phenotypic standard deviation

Table 2: Phenology of transplant *Aman* rice varieties used in the experiment

Treatments/ Variety	Booting DAT	Heading DAT	Anthesis DAT	Physiological maturity DAT
Naizershail	72	74	79	127
Bashiraj	83	86	91	132
Kalizira	74	76	80	128
Binadhan-7	52	56	62	92
BR11	82	84	90	130
BRRI dhan32	58	61	66	115
BRRI dhan34	55	57	62	112
BRRI dhan49	69	71	77	106
Agrodhan-12	61	63	69	102
Dhanigold	60	62	67	101

RESULTS AND DISCUSSION

Morpho-physiological characters

Plant height

Plant height exhibited a remarkable variation among the tested rice varieties (Figure 1). The plant height was measured at five times of the plant growth stages (30DAT, 45DAT, 60DAT, 75DAT and at harvest) in which all the cultivars grown rapidly upto 60DAT. Because rice plants grow quickly at the early stage of their vegetative phase, before reaching to their booting and heading stages. The results of plant height demonstrated that the traditional *Aman* rice varieties produced the tallest plants compared to the other high yielding varieties (HYV) and hybrid rice varieties due to the presence of long internode. A longer plant height were reported in the conventional rice cultivars than the HYV because of having longer internodes (Islam *et al*. 2019), which also can contribute to enhance the straw yield (Howlader *et al*., 2017).

Number of effective, non-effective and total tillers per hill

To some extent, yield potential of rice cultivars depend on the tillering capacity. In this study, there was a significant difference noticed among effective tillers per hill among the studied varieties (Table 3). Results showed that the highest number of effective tillers was observed in the hybrid varieties while the lowest number of effective tillers was observed in the traditional varieties of rice. Generally rice plants having more tillers can exhibit a higher inconsistency in mobilizing assimilates and nutrients among tillers (Dubey *et al*. 2018), resulting in variations in grain development and yield (Wang *et al*. 2016). Moreover, number of non -effective tillers was significantly influenced by different varieties of transplant *Aman* rice varieties (Table 3). Results showed that the highest number of non-effective tillers was observed in the traditional *Aman* rice varieties rather than HYV and hybrids varieties. It has also been demonstrated that either excessive or insufficient tillering is unfavourable for high yield (Dubey *et al*. 2018).

Total tiller production was affected markedly by the variety and showed significant variation on number of total tillers per hill (Table 3). Results showed that the highest number of total tillers was found in the hybrid varieties, closely similar to that of traditional one. The present results of this study showed that there was noticeable variation of the tiller productivity and survival characteristics, which was influenced the grain yield among the studied rice varieties. Tillering ability is

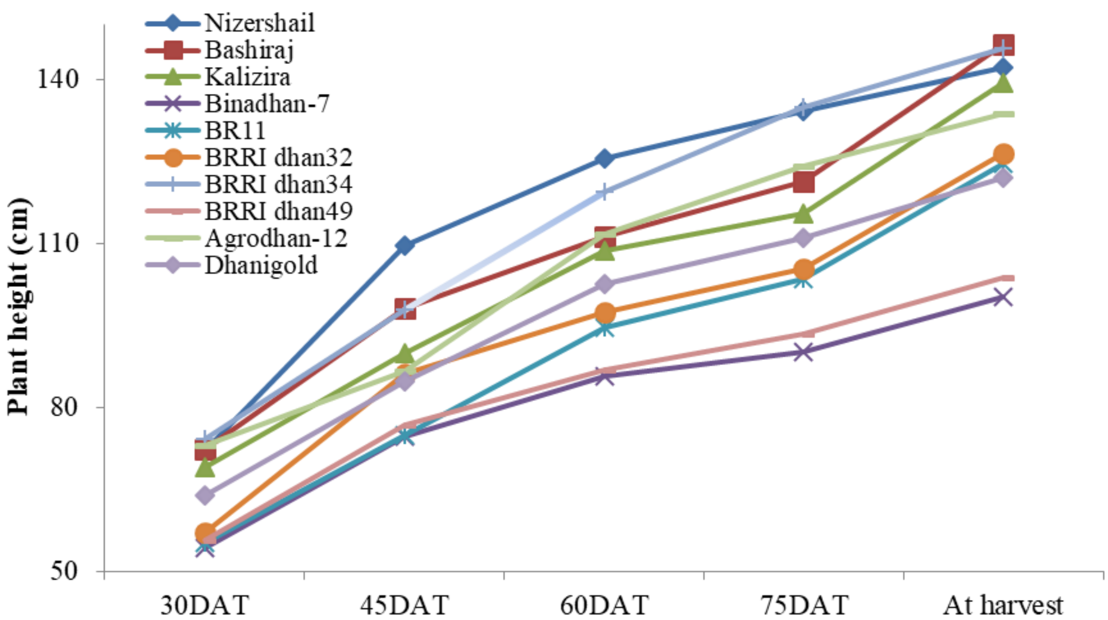

Figure 1: Varietal differences of plant height among the transplanted *Aman* rice

one of the most important traits of rice plant, since it can have a significant influence on production of panicles (Murthy *et al*. 2014), which in turn is highly correlated with grain yield (Jisan *et al*. 2014).

Dry weight per plant

Dry matter production increased with age of rice plants and remarkable variations were observed in terms of dry weight per plant at different growth stages influenced by different rice varieties (Figure 2). Results illustrated that the highest dry weight per plant was obtained in the hybrid varieties which was closely followed by traditional *Aman* rice varieties. Hybrid varieties exhibited a wide range of variation in number of tillers and plant height which may have contributed towards higher biomass accumulation. Paul *et al*. (2021) reported the total dry matter per hill may increase progressively with the advancement of time due to application of nitrogen and potassium fertilization from tillering to physiological maturity stage. Hannan *et al*. (2020a) also demonstrated that the dry matter production per plant depends on tillering capacity of the rice cultivar.

Panicle length

Panicle length exhibited remarkable variation in the different tested rice varieties (Table 3). It was recorded that Dhanigold gave the highest (23.58 cm) panicle length which was statistically similar to BRRI dhan32 and the lowest (20.44 cm) panicle length was found in the variety Bashiraj which was significantly differed from the rest of the varieties. In general, the longest panicle was observed both in hybrid and HYV varieties compare to their traditional rice varieties. Panicle length showed the greatest variation over the number of tillers among all yield components (Roy *et al*. 2015) indicating that more tillers bring obvious negative impact on grain number per panicle, leading to reduced panicle weight as the increased competition for growth requirements among tillers. This result is consistent with the result of Hossain *et al*. (2016) who reported that panicle length was significantly varied among rice varieties.

Number of grain per panicle

The performance of variety was statistically significant in respect of number of grains per panicle (Table 3). It was recorded that Kalizira gave the highest number of grain per panicle (130.87) which was significantly differed from the rest of the varieties and the lowest number of grain (91.07) was found in the variety BR11. Among the three categories of *Aman* rice, hybrid varieties comparatively produced the higher number of grains per panicle. Hossain *et al*. (2017) agreed with the present results in which they found moderate

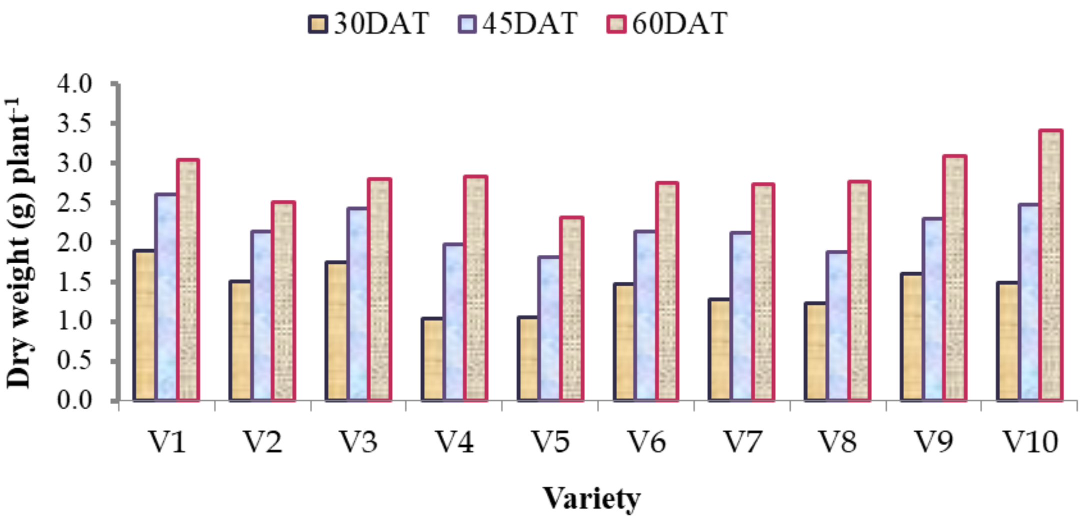

Figure 2: Effect of variety on the dry weight (g) plant^{-1} of transplant *Aman* rice

Here, V_1 = Nizershail, V_2 = Bashiraj, V_3 = Kalizira, V_4 = Binadhan-7, V_5= BR11, V_6 = BRRI dhan32, V_7 = BRRI dhan34, V_8 = BRRI dhan49, V_9 = Agrodhan-12, V_{10} = Dhanigold

Table 3. Morpho-physiological characteristics of transplant *Aman* rice varieties

Variety	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of sterile spikelets panicle^{-1}	1000 grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
Nizershail	9.70^{cd}	7.47^{d}	2.23^{ab}	20.77^{bc}	96.56^{e}	22.28^{a}	16.27cd	7.08c	33.51d
Bashiraj	10.14^{ed}	8.59^{b}	1.55^{c}	20.44^{c}	114.61^{c}	19.06^{ab}	19.05bc	8.90bc	37.18c
Kalizira	10.04^{bc}	7.56^{d}	2.47^{a}	21.36^{a-c}	130.87^{a}	17.53^{bc}	21.57ab	9.13bc	38.59c
Binadhan-7	9.43^{cd}	7.81^{cd}	1.61^{bc}	23.32^{ab}	102.90^{d}	14.91^{cd}	23.01a	10.34a-c	45.66ab
BR11	9.92^{cd}	8.50^{b}	1.42^{c}	21.24^{a-c}	91.07^{f}	17.23^{bc}	23.33a	11.92ab	47.23ab
BRRI dhan32	9.69^{cd}	8.25^{bc}	1.44^{c}	23.52^{a}	126.32^{b}	17.58^{bc}	23.60a	9.89bc	45.63ab
BRRI dhan34	9.21^{d}	7.65^{d}	1.56^{c}	22.12^{a-c}	124.99^{b}	17.31^{bc}	14.81d	7.79c	45.39b
BRRI dhan49	10.32^{bc}	7.67^{d}	2.65^{a}	21.90^{a-c}	125.35^{b}	15.38^{cd}	17.96cd	10.04bc	47.58ab
Agrodhan-12	10.91^{ab}	9.49^{a}	1.42^{c}	21.86^{a-c}	123.31^{b}	14.21^{cd}	22.14ab	12.19ab	47.60ab
Dhanigold	11.63^{a}	10.01^{a}	1.61b^{c}	23.58^{a}	124.00^{b}	13.36^{d}	23.98a	13.72a	47.92a
S$\bar{x}$	0.17	0.22	0.16	0.35	4.88	0.81	1.09	0.57	1.76
Level of sig.	**	**	**	**	**	**	**	**	**
CV (%)	8.73	12.78	10.36	8.59	1.63	11.20	9.19	8.73	4.33

Means with the same letters within the same column do not differ significantly. **= Significant at 1% level of probability

number of grains per panicle with high genetic advance in percent of mean during working with developed hybrid rice genotypes. Rahman *et al.* (2019) also completely supported the findings of the present experiment while working with hybrid rice variety for seed production.

Number of sterile spikelets per panicle

Among the undesirable traits unfilled grain per panicle was important and different varieties of *Aman* rice showed significant variation on number of sterile spikelet (Table 3). It was recorded that Nizershail showed the highest number of sterile spikelet (22.28) per panicle which was statistically similar to Bashiraj. Similarly, the lowest number of sterile spikelet (13.36) per panicle was observed in the variety Dhanigold which was significantly differed from the rest of the tested varieties. Among the three types of studied *Aman* rice, traditional varieties produced the highest number of sterile spikelet per panicle. The growth of the spikelets on their panicle depends on the numbers of vascular bundles in rice tillers. And poor vascularization reduces the supply of assimilates and hormones from the source leaves to the panicle, and thereby, significantly restricting spikelet development (Murthy *et al.* 2014).

1000 grain weight

1000 grain weight was significantly differed among the rice varieties (Table 3). It was noted that BR11 showed the highest 1000 grain weight (23.98 g) which was statistically similar to Dhanigold, BRRI dhan32 and Binadhan-7. And the lowest 1000 grain weight (14.81 g) was observed in the variety BRRI dhan34 which was significantly differed from the rest of the tested varieties. This difference might be due to weight or size of the grain. Taking into account 1000 grain weight among the studied three categories of *Aman* rice, hybrid varieties produced the higher weight which may be due to the larger grain size when compared with other varieties. Similar results were also observed by Murshida *et al.* (2017) and Hossain *et al.* (2017) in which they stated that larger grain size increased the weight of rice grain.

Grain yield

Grain yield was markedly differed among the studied rice varieties (Figure 3). The hybrid variety Dhanigold showed the highest grain yield (6.57 t ha^{-1}) followed by Agrodhan-12 (5.8 t ha^{-1}) while the lowest grain yield (2.36 t ha^{-1}) was found in the traditional variety Nizershail. Among three categories, hybrid varieties produced the highest grain yield whereas traditional varieties yielded comparatively the lowest yield. These differences happened maybe due to the number of effective tiller per hill, panicle length, grains per panicle and 1000 grain weight. Huang and Yan (2016) reported that generally the yield of hybrid rice varieties is 10%-15% more than the improved inbred varieties. The present results on grain yield were also corroborated with the findings of Murshida *et al*. (2017) and Hossain *et al.* (2017) in which they stated that the genotype which ceased tiller emergence at an early stage, increased the partition of newly gained assimilates to the existing tillers, contributing towards higher yields.

Straw yield

Significant variation was observed in the different varieties of *Aman* rice on straw yield (Figure 3). Among three categories, hybrid varieties produced better straw yield compared to both traditional and hybrid rice varieties. It was recorded that Dhanigold showed the highest straw yield (7.14 t ha^{-1}) which was significantly differed from the rest of the varieties. The obtained differences were obtained due to plant height, number of effective tillers of respective variety. The vegetative growth period was longer in some transplanted rice varieties, leading to a higher accumulation of biomass, causing greater straw yield (Sarkar *et al*. 2021).

Biological yield

Different varieties of *Aman* rice showed significant variation on biological yield (Table 3). The result demonstrated that Dhanigold produced the highest biological yield (13.72 t ha^{-1}) which was statistically similar to Agrodhan-12 (12.19 t ha^{-1}) and BR11 (11.92 t ha^{-1}). Considering three categories of rice, hybrid varieties produced the highest biological yield compared to traditional and HYV rice varieties. This result showed conformity with the findings of Hossain *et al*. (2017) and Sarkar *et al*. (2021) who reported that hybrid rice varieties produced more biological yield than local cultivars.

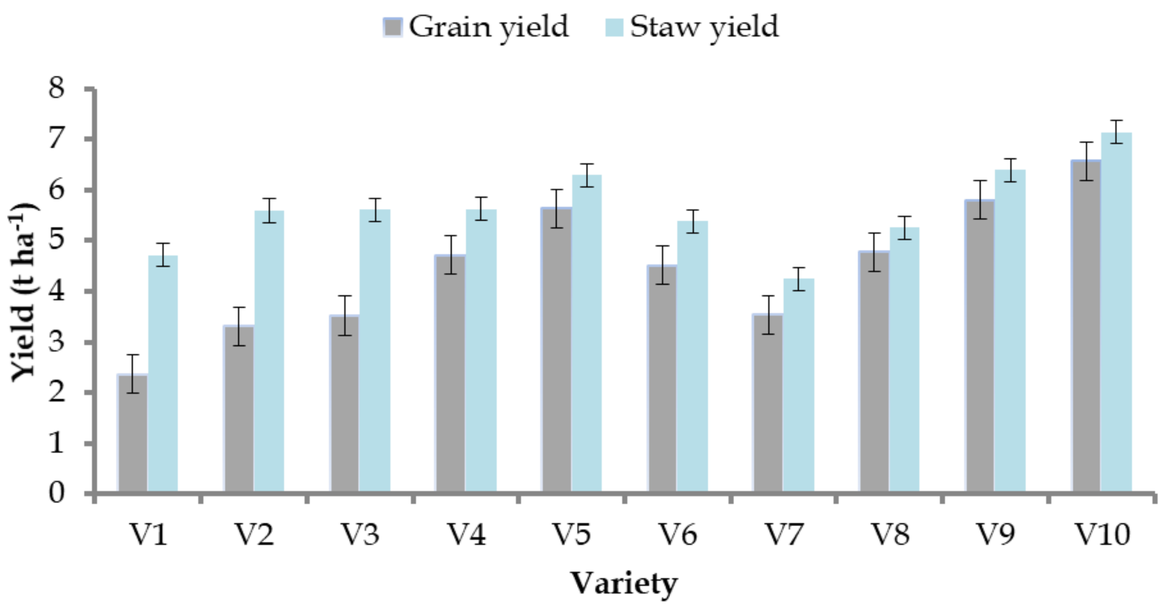

Figure 3. Effect of variety on the yield of transplant *Aman* rice

Here, V_1= Nizershail, V_2= Bashiraj, V_3= Kalizira, V_4= Binadhan-7, V_5= BR 11, V_6= BRRI dhan32, V_7= BRRI dhan34, V_8= BRRI dhan49, V_9= Agrodhan-12, V_{10}= Dhanigold

Harvest index (%)
Harvest index (HI) differed considerably among the traditional, HYV and hybrid rice varieties (Table 3). Result demonstrated that the Danigold produced the highest harvest index (47.92%) which was closely followed by Agrodhan-12 (47.60%), BRRI dhan49 (47.58%), and BR11 (47.23%). According to the three categories of studied *Aman* rice, traditional rice varieties yielded the lowest harvest index rather than HYV and hybrid varieties. Harvest index varied may be due to the similarity in morphological aspects of vegetative growth among the studied *Aman* rice cultivars such as time to initiate heading and duration of the grain heading, for example, biomass accumulation in the form of stem biomass increase at heading and decline during grain filling which may have finally affected the final yield (Roy *et al*. 2015; Shew *et al*. 2019). The differences of harvest index also reported by Sarkar *et al*. (2021) in which they illustrated that the highest grain yield of rice have contributed to the higher harvest index.

Estimation of genetic characters
The estimation of different genetic characters of *Aman* rice genotypes are shown in the Table 4. In this study, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) showed higher values (20%) for plant height, moderate values (10-20%) for number of effective tiller per hill, number of non-effective tiller per hill and harvest index and low values (<5%) for the other studied traits (Table 4). This result suggested that the possibility of yield improvement through selection of these traits is highly desirable (Abebe *et al*. 2017). The magnitude of PCV ranged from 1.00 % (panicle length) to 28.99% (plant height), while the magnitude of GCV ranged from 0.75% in panicle length to 28.81% in plant height. The result is corroborated the findings of Hannan *et al*. (2020b).

In this study, broad-sense heritability ranged from 57.06% (panicle length) to 100% (grain yield), while corresponding values of genetic advance ranged from 1.17% (panicle length) to 58.99% (plant height) (Table 4). All the studied traits exhibited high heritability (>60%) except panicle length. Most of the traits showed high heritability which illustrated that these were less influenced by the environment and thus help in effective selection of these traits and suggested the opportunity for genetic improvement. Majority of the traits including panicle length, sterile spikelets per panicle, 1000 seed weight, grain yield, straw yield and biological yield displayed low genetic advance (0-10%). This result indicated that non-additive gene action, thus selection should be practiced with care (Iqbal *et al*. 2018). High heritability (>60%) with high genetic advance (>20%) was assessed for plant height, number of effective tiller per hill, and harvest index (Table 4). Traits with high heritability and genetic advance were mostly governed by additive gene effects, so direct selection of these traits depending on phenotypic expression would be effective because of gathering higher additive genes results in further improvement (Akter *et al*. 2019; Edukondalu *et al*. 2017).

Correlation analysis
A correlation analysis was executed to reveal the association among the morphological traits. Grain yield showed significant positive correlation with biological yield (r= 0.97), straw yield (r = 0.88), harvest index (r= 0.84), 1000 seed weight (r= 0.66), panicle length (r= 0.46) and number of effective tiller per hill (r= 0.46) but displayed significant negative correlation with sterile spikelets per panicle (r= -0.78), plant height (r= -0.62) and number of non-effective tiller per hill (r= -0.37) (Table 5). Correlation coefficients give apparent relationship between two or more parameters. Association analysis measures the interrelationship between various characters and also finds the component traits which can be selected to improve yield. The results of this experiment showed some similarities with the previous findings of Edukondalu *et al*. (2017) and Kalyan *et al*. (2017) stated that grain yield is positively correlated with total tiller number, panicle length and grain weight.

Path coefficient analysis
Path coefficient analysis partitions the correlation coefficient into direct and indirect

Table 4: Estimation of different genetic characters for various morpho-physiological traits of studied transplant *Aman* rice

Traits	PCV	GCV	σ^2g	h^2b	GA	GA (%)	
PH	28.99	28.81	292.12	295.70	98.79	34.99	58.99
TT/hill	6.51	5.90	0.48	0.58	82.21	1.29	11.02
ET/hill	10.51	10.28	0.74	0.77	95.69	1.73	20.72
NET/hill	11.34	10.19	0.20	0.25	80.78	0.83	18.87
PL	1.00	0.75	1.02	1.79	57.06	1.57	1.17
G/P	8.91	8.84	197.52	200.48	98.52	28.74	18.07
SS/P	3.25	3.03	6.43	7.41	86.80	4.87	5.82
1000 SW	5.88	5.31	10.20	12.48	81.69	5.95	9.89
GY	3.05	3.05	1.70	1.70	100.00	2.68	6.28
SY	1.95	1.86	0.67	0.73	91.23	1.61	3.66
BY	3.91	3.88	4.16	4.24	98.26	4.17	7.92
HI	11.08	10.65	26.32	28.47	92.44	10.16	21.09

GCV= Genotypic coefficient of variance, PCV= Ghenotypic coefficient of variance, σ^2g= Genetic variance, σ^2p= Phenotypic variance, h^2b= Broad sense heritability, GA = Genetic advance, GA (%)= Genetic advance as percent of mean, PH= Plant height (cm), TT/hill= Total tiller per hill, ET/hill= Number of effective tiller hill^{-1}, NET /hill=Number of non-effective tiller hill^{-1}, PL=Panicle length (cm), G/P= Grain per panicle, SS/P= Sterile spikelets panicle^{-1}, 1000 SW= 1000 seed weight (g), GY= Grain yield (t/ha), SY= Straw yield (tha^{-1}), BY=Biological yield, HI= Harvest index (%).

effect and hence provide the clear picture about whether the association of a character with grain yield is because of direct effect or because of indirect effect through other component traits and hence useful in indirect selection. Path analysis revealed that biological yield, harvest index, straw yield, total tiller per hill, plant height, panicle length and number of non-effective tiller per hill exhibited positive direct effect on grain yield (Table 6). Among them, biological yield (0.565) and harvest index (0.507) had the highest positive direct effect in grain yield. This indicated that, an increase of number of effective tillers, panicle length and 1000 grain weight, the grain yield has been increased even if the other parameters remain unchanged. Similar result was found for biological yield and harvest index in rice genotypes (Iqbal *et al*. 2018, Kalyan *et al*. 2017). Therefore, these traits of biological yield and harvest index could be used as selection criteria for improving rice grain yield. Maximum and positive indirect effect was exhibited by straw yield through biological yield (0.520) followed by 1000 seed weight through biological yield (0.401) (Table 6). The residual effect of the present study was 0.001, indicating that about 99% variability in grain yield might be contributed by these eleven yield contributing traits studied in the path analysis. This result gave an impression that some other minor characters than those involved in the present study also contributed to the variability of grain yield.

CONCLUSION

The analysis of morpho-physiological traits in tested rice varieties illustrated that grain yield increased with the number of effective tillers per hill, panicle length, grains per panicle and 1000 grain weight. Genetic analysis results through correlation studies indicated that grain yield had significant positive correlation with biological yield, harvest index, 1000 grain weight, panicle length and number of effective tiller per hill. Moreover, path analysis revealed that biological yield, harvest index, straw yield, total tiller per hill, plant height, panicle length and number of non-effective tiller per hill exhibited positive direct effect on grain yield. Therefore, to get an economic yield, among the studied ten

Table 5: Simple correlation coefficient among different variables for studied transplant *Aman* rice genotypes

Traits	PH	TT/hill	ET/hill	NET/hill	PL	G/P	SS/P	1000 SW	GY	SY	BY	HI
PH	1											
TT/hill	-0.05	1										
ET/hill	-0.01	0.95**	1									
NET/hill	-0.13	-0.01	-0.33	1								
PL	-0.43*	0.23	0.30	-0.25	1							
G/P	0.02	0.19	0.12	0.17	0.25	1						
SS/P	0.60**	-0.01	-0.07	0.19	-0.55**	-0.35	1					
1000 SW	-0.55**	0.18	0.26	-0.29	0.42*	-0.04	-0.46*	1				
GY	-0.62**	0.36	0.46*	-0.37*	0.46*	0.11	-0.78**	0.66**	1			
SY	-0.40*	0.49**	0.56**	-0.31	0.27	0.02	-0.54**	0.70**	0.80**	1		
BY	-0.56**	0.43*	0.52**	-0.36*	0.40*	0.08	-0.72**	0.71**	0.97**	0.93**	1	
HI	-0.64**	0.13	0.23	-0.32	0.50**	0.22	-0.76**	0.42*	0.84**	0.36*	0.69**	1

*, ** = Significant at ≤ 5%, ≤ 1% level of probability respectively, PH= Plant height (cm), TT/hill= Total tiller per hill, ET/hill= Number of effective tiller per hill, NET/hill= Number of non-effective tiller per hill, PL= Panicle length (cm), G/P= Grain per panicle, SS/P= Sterile spikelets per panicle, 1000 SW= 1000 seed weight (g), GY= Grain yield (t/ha), SY= Straw yield (tha^{-1}), BY= Biological yield, HI= Harvest index (%).

varieties of transplant *Aman* rice, Dhanigold variety can be recommended. Further, extensive research with more parameters of rice plant is suggested to have more information. More experiments are required with the varieties of the present study at different locations of Bangladesh for final recommendation.

AUTHOR CONTRIBUTION

MAY, MS, FIM and AKH conducted the experiment and prepared the draft manuscript. MAY, MS, FIM and AKH conceptualized and designed the study and reviewed the manuscript. All authors assisted the design of experiment and the preparation of the manuscript.

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Table 6: Path coefficient showing direct and indirect effects of yield components on grain yield

Character	PH	TT/hill	ET/hill	NET/hill	PL	G/P	SS/P	1000 SW	GY	SY	BY	HI
PH	**0.068**	-0.005	0.002	-0.002	-0.021	-0.001	0.056	0.015	-0.224	-0.092	-0.316	-0.325
TT/hill	-0.003	**0.105**	-0.162	0.000	0.011	-0.007	-0.001	-0.005	-0.224	0.113	0.243	0.066
ET/hill	-0.001	0.100	**-0.171**	-0.004	0.014	-0.004	-0.007	-0.007	0.165	0.129	0.294	0.117
NET/hill	-0.009	-0.001	0.056	**0.013**	-0.012	-0.006	0.018	0.008	-0.132	-0.071	-0.203	-0.162
PL	-0.029	0.024	-0.050	-0.003	**0.048**	-0.009	-0.052	-0.011	0.162	0.062	0.226	0.254
G/P	0.001	0.020	-0.020	0.002	0.012	**-0.035**	-0.033	0.001	0.04	0.005	0.045	0.112
SS/P	0.041	-0.001	0.012	0.002	-0.026	0.012	**0.094**	0.012	-0.283	-0.124	-0.407	-0.385
1000 SW	-0.038	0.019	-0.044	-0.004	0.020	0.001	-0.043	**-0.027**	0.240	0.161	0.401	0.213
SY	-0.027	0.052	-0.096	-0.004	0.013	-0.001	-0.051	-0.019	**0.290**	0.230	0.520	0.183
BY	-0.038	0.045	-0.089	-0.005	0.019	-0.003	-0.068	-0.019	0.353	**0.212**	0.565	0.350
HI	-0.044	0.014	-0.039	-0.004	0.024	-0.008	-0.072	-0.011	0.307	0.083	**0.390**	0.507
Correlation	-0.62**	0.36	0.46*	-0.37*	0.46*	0.11	-0.78**	0.66**	0.17	0.80**	0.97**	**0.84****

*, ** = Significant at ≤ 5%, ≤ 1% level of probability respectively

Bold figures indicate the direct effect, Residual effect= 0.001, PH-Plant height (cm), TT/hill= Total tiller per hill, ET/hill= Number of effective tiller per hill, NET/hill= Number of non-effective tiller per hill, PL=Panicle length (cm), G/P= Grain per panicle, SS/P= Sterile spikelets per panicle, 1000 SW= 1000 seed weight (g), SY= Straw yield (t/ha), BY= Biological yield, HI= Harvest index (%).

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