



AGRONOMY | ORIGINAL ARTICLE

## Evaluation of local, high yielding and hybrid transplanted *aman* rice varieties for phenology, grain morphology and yield

Mohammad Joyel Sarkar<sup>1</sup>, Ahmed Khairul Hasan<sup>2\*</sup>, Najrul Islam<sup>2</sup>, Fahmina Yasmine<sup>1</sup>, Shams Shaila Islam<sup>3</sup>, Md Harun Rashid <sup>2</sup>

<sup>1</sup>Bangladesh Institute of Nuclear Agriculture, Mymensingh 2202, Bangladesh

<sup>2</sup>Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

<sup>3</sup>Hajee Mohammad Danesh Science & Technology University, Dinajpur 5200, Bangladesh

### ARTICLE INFORMATION

#### Article History

Submitted: 02 Dec 2021

Accepted: 28 Dec 2021

First online: 30 Dec 2021

#### Academic Editor

Sabina Yeasmin

[sabinayeammin@bau.edu.bd](mailto:sabinayeammin@bau.edu.bd)

#### \*Corresponding Author

Ahmed Khairul Hasan

[akhasan@bau.edu.bd](mailto:akhasan@bau.edu.bd)



### ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University during the period from June to December 2016 to evaluate local, high yielding and hybrid transplanted *aman* rice varieties for grain morphology and grain yield. The experiment was comprised of 15 transplanted *aman* (*T. aman*) rice varieties *viz.*, high yielding varieties (HYV): BR11, BRRI dhan34, BRRI dhan38, BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan62, Binadhan-7, Binadhan-12, Binadhan-13; local varieties: Balam, Kalizira, Nizersail, Bashiraj; and hybrid variety: Agro dhan-12. Duration of the phenological events such as date of emergence of seedlings, booting, heading, anthesis, physiological maturity and total growth duration was higher in local varieties compared to high yielding and hybrid. The lowest duration of these events were recorded in BRRI dhan62 and BRRI dhan56. The tallest plant was obtained from local variety Kalizira (167.27 cm) and the shortest one was obtained from HYV BRRI dhan56 (105.20 cm). Hybrid variety Agro dhan-12 possessed the highest number of effective tillers  $\text{hill}^{-1}$  (17.0) which was similar to HYV BRRI dhan49 (17.0) and the lowest number was recorded in HYV BRRI dhan38. Number of grains panicle<sup>-1</sup> was the highest in hybrid variety Agro dhan-12 (235) and the lowest was present in local variety Balam. Thousand grain weight was highest at hybrid variety Agro dhan-12 (35 g) and the lowest one was observed in BRRI dhan34 (12.07 g). Grain yield was highest in hybrid variety Agro dhan-12 (6.50 t  $\text{ha}^{-1}$ ) which was similar to high yielding varieties BRRI dhan49 (6.0 t  $\text{ha}^{-1}$ ). In lower part of panicle, primary and secondary grain length (L), breadth (B), volume, L/B ratio was maximum in Binadhan-7 and Agro dhan-12. In middle part of the panicle, primary and secondary grain length, volume was found the maximum in Binadhan-7 and breadth was maximum in BR11, Agro dhan-12. Height was maximum in BRRI dhan56. In upper part of the panicle, primary and secondary grain length and volume was maximum in Binadhan-7 and breadth was maximum in Agro dhan-12 and height was maximum in BRRI dhan52.

**Keywords:** Phenology, hybrid variety, local variety, HYV, rice



**Cite this article:** Sarkar MJ, Hasan AKH, Islam N, Yasmine F, Islam SS, Rashid MH. 2021. Evaluation of local, high yielding and hybrid transplanted *aman* rice varieties for phenology, grain morphology and yield. *Fundamental and Applied Agriculture* 6(4): 415–426. doi: 10.5455/faa.82922

## 1 Introduction

Rice (*Oryza sativa* L.) is the staple food for nearly half of the world's population as well as for 157.90 million people of Bangladesh (AIS, 2017). To feed the fast-increasing global population, the world's annual rice production must be increased to 760 million tons by the year 2020 (Kundu and Ladha, 1995). Rice production has to be increased annually by 1% to deliver sufficient rice for the ever-growing population of rice-consuming countries. Rice plays absolutely dominant role in Bangladesh agriculture as it covers 65% of total cropped area. Annual per capita consumption of rice in Bangladesh is the highest in the world (Nasiruddin, 1993). However, Bangladesh needs to increase the rice yield further in order to meet the growing demand. The National Commission of Agriculture projected that in order to remain self-sufficient, Bangladesh would need to produce 47 million tons of paddy (31.6 million tons of clean rice) by the year 2020, implying a required growth rate of production of 1.7% per year.

There are three rice growing seasons in Bangladesh namely *aus*, *aman* and *boro*. *Aman* is one of the main crops in Bangladesh. It is the second largest rice crop in the country in respect to the volume of grain yield and production. It is notable that the area coverage of *aman* is the largest as a single crop. The production of *aman* depends on the weather condition of the country. Average yield rate of *aman* for the year 2018-19 has been estimated to be 2.50 tons ha<sup>-1</sup> which is 1.46% higher than that of the last year (BBS, 2020). This is quite lower compared to that of many other rice growing countries like China, Japan, Korea and USA where yields are 6.23, 6.79, 6.59 and 7.04 t ha<sup>-1</sup>, respectively (FAO, 2004). There are different types of transplanted *aman* rice varieties such as local, inbred or high yielding and hybrid. To ensure the food security for the increasing population, the cropping area under rice cultivation could hardly be increased but 15–30% yield advantage could be obtained with the modern inbred rice varieties over conventional pure line varieties (Julfiquar et al., 2002; Yuan et al., 2005). The latter do not frequently exhibit higher yield (Yang et al., 2002; Horie et al., 2003; Nayak et al., 2003; Hejun et al., 2008; Abou Khalifa, 2009). Higher grain yield of hybrid rice is an intricate outcome of the genotype and environment interaction.

Now-a-days, different hybrid and high yielding rice varieties are available which have more yield potential than conventional local varieties. Rice grain dimensions, traditionally including length, breadth, and thickness, are the major breeding targets, as they affect yield and grain quality, and marketability (Huang et al., 2013). Grain size, shape (length-to-breadth ratio) have a direct implication on the commercial success of rice cultivars. Long and slender grains are generally preferred by the majority of consumers. Additionally, grain dimension is positively

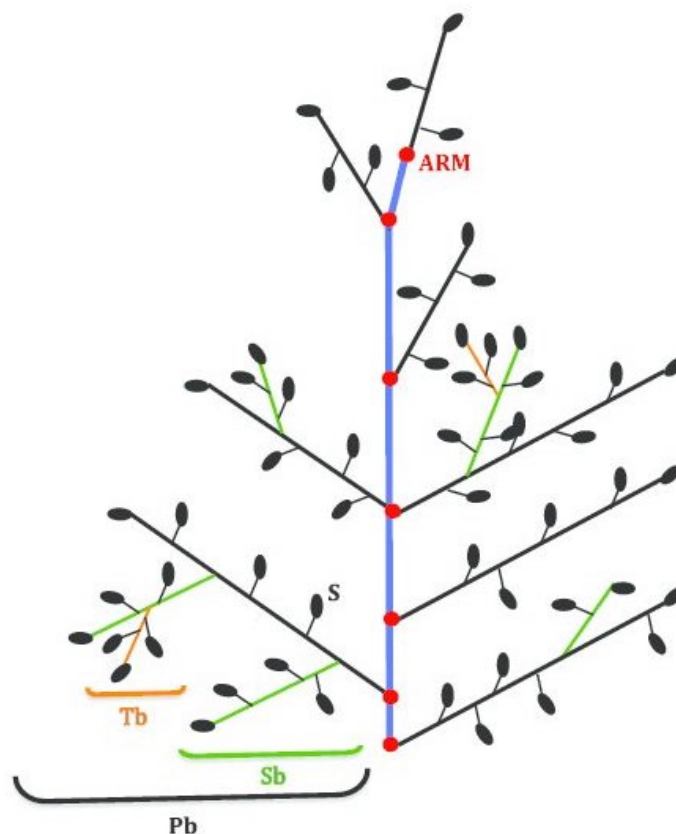
associated with grain weight and it is one of the most important factors determining yield potential of a rice cultivar (Xin et al., 1999; Yang et al., 2002; Zhang and Tang, 2004; Yongmei et al., 2007; Guo-qing, 2010). Therefore, proper knowledge on grain morphology of these hybrid varieties are required in order to gain insight in to their adaptability in the prevailing socio-economic condition of Bangladesh.

The information is limited on varietal response more particularly in respect of grain morphology of the panicles. There is limited knowledge on grain architecture specially, the length, breadth, height, volume and length breadth ratio of local, high yielding and hybrid rice varieties. Grain characters of rice are considered as one of most important characters for varietal acceptance and rejection of rice by the farmers. These characters like length, shape, 1000-grain weight etc. are main important characters for classification of rice genotypes. Kato et al. (2007) have studied various grain characters like grain size, grain length, breadth, height, volume, length breadth ratio and shape of rice varieties (local, high yielding and hybrid) and reported that the these characters have direct effect on grain yield. Literature typically suggests that grain length, breadth, and height are the only determining factors of grain weight and grain quality (Sakamoto and Matsuoka, 2008). Under the above circumstances the present experiment was undertaken to examine the plant characters, grain morphology and yield of local, high yielding and hybrid T. *aman* rice varieties.

## 2 Materials and Methods

### 2.1 Study location

This experiment was implemented at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during the transplanted *aman* season (June to December 2016). The experimental field is located at 24°43'10.3"N, 90°25'40.7"E at an elevation of 18 m above the sea level. It belongs to the Non-calcareous Dark Grey Floodplain Soil (Old Brahmaputra Alluvial Soil Tract) under the Old Brahmaputra Floodplain of Agro Ecological Zone-9. The experimental field was medium high land with loamy soil having pH value of 5.7. The area is under the sub-tropical climate. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total numbers of unit plots were 45. The size of each unit plot was 10 m<sup>2</sup> (4 m × 2.5 m). The spaces between blocks and plots were 1 m and 0.75 m, respectively. The experimental plots were fertilized as per the recommendations for respective varieties. Intercultural operations were done properly. When 80-90% of the grains became golden yellow, the crops were considered to be matured. An area of 1 m<sup>2</sup> was selected in the middle portion of each plot to record the grain morphology and yield of grain.



**Figure 1.** Structure of a rice panicle. Schematic representation of a rice panicle comprising a main central axis (blue line) named rachis, to which primary branches (Pb) are attached (black lines); the primary branches bear secondary branches (Sb, green lines), which in turn bear tertiary branches (Tb, orange lines). Spikelets (Sp) are attached to the branches by a peduncle. Nodes are represented by red dots (ARM, Aborted Rachis Meristem). In the P-TRAP output results, the following terms are used instead of botanical terminology: Primary Axis (PA) for the blue line, the secondary axes (SA) for the black lines; the tertiary axes (TA) for the green lines and the quaternary axes (QA) for the orange lines. Source: Al-Tam et al. (2013)

Grains were then sun dried at 14% moisture level and cleaned. Finally, grain yield  $\text{plot}^{-1}$  were recorded and converted to  $\text{t ha}^{-1}$ . Phenological events (booting, heading, anthesis, physiological maturity) recorded using the scale proposed by Zadoks et al. (1974). Grain morphology (length, breadth, height), volume and L/B ratio was recorded as a panicle was divided into three parts such as lower, middle and upper and grains belong to central axis in the lower part are called lower primary grains (LPGN) and grains produced from the primary rachis are called lower secondary grains (LSGN), are similarly middle primary grains (MPGN), middle secondary grains (MSGN) and upper primary grains (UPGN), upper secondary grains (USGN). An architectural view of rice panicle is shown in Fig. 1. Following this diagram, six grain categorized (LPGN, LSGN, MPGN, MSGN, UPGN and USGN) were counted and weighted for each variety. The individual grain weight of the varieties from a panicle of the lower primary secondary, middle primary, secondary grain and upper primary and sec-

ondary grain length (cm) was taken with the help of the digital caliper in the Laboratory of Department of Agronomy, Bangladesh Agricultural University, Mymensingh. The collected data were analyzed using computer package program STATIX-10 and the mean differences were read judged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

## 3 Results and Discussion

### 3.1 Phenological parameters

Rice plants undergo some phenological events like emergence to booting (Em-Bo), booting to heading (Bo-Hd), Heading to anthesis (Hd-At) and Anthesis to physiological maturity (At-PM). *T. aman* rice varieties can be categorized into two groups on the basis of phenological events like short duration varieties which mature in 105-125 d and long duration varieties which mature in 150 d or more. In present study, the high yielding varieties like BRRI dhan62 took less

time 70 d at Em-Bo. BRRI dhan56, Agro dhan-12, and Binadhan-7 took similar time and Binadhan-13 required maximum 101 d at booting stage and the local varieties Balam, Kalizira, Nizersail, Bashiraj spent 97 d to complete its booting stage. Binadhan-7 among the varieties took more time (12 d) and BRRI dhan49 needed less (3 d) at heading stage (Fig. 2). Among local varieties Bashiraj took more (10 d). BRRI dhan62 took more days (9 d) at anthesis, on the other hand high yielding variety BRRI dhan52 required minimal day (2 d). Among the local varieties Balam need more duration at anthesis. Ripening followed fertilization can be subdivided into milky, dough, yellow, ripe, and maturity stages. These terms were primarily based on the texture and color of the growing grains. PM is usually affected by temperature, with a range from about 30 d in the tropics to 65 d in cool temperate regions. Binadhan-12 required maximum 54 d to reach PM. The local varieties *viz.*, Balam, Bashiraj, Kalizira, and Nizersail required more time to reach PM (Fig. 2). However, it is well known that most of the *T. aman* rice varieties are photosensitive and there is distinct difference of phenological event for local, high yielding and hybrid varieties (Biswas et al., 2019).

## 3.2 Yield parameters

### 3.2.1 Plant height

Kalizira produced the tallest plant height (167.27 cm) and the shortest plant height was obtained from BRRI dhan56 (105.20 cm) (Fig. 3a). These differences are mostly due to the genetic variation among the varieties. These results are in consistent to those of Khisha (2002), Mia (2003), and Anjuman (2012) who recorded variable plant height among varieties.

### 3.2.2 Number of total tillers hill<sup>-1</sup>

The tiller number of the varieties increased with the advancement of growth stages. But it was not consistent as reduced number of tillers hill<sup>-1</sup> was observed at harvest in some of the varieties. Death of some tillers was the reason behind the reduction of effective tillers. Hybrid Agro dhan-12 showed the highest number of total tillers hill<sup>-1</sup> (18.67) which was similar to high yielding variety BRRI dhan49 (18.67). On the other hand, minimum tillers hill<sup>-1</sup> was found in case of inbred BRRI dhan38 (8.60). Bhowmick and Nayak (2000) reported similar trend of tillering habits with different varieties of rice.

### 3.2.3 Number of effective tillers hill<sup>-1</sup>

The highest number of effective tillers hill<sup>-1</sup> was produced by hybrid variety Agro dhan-12 (17.0) which was similar to high yielding variety BRRI dhan49 (17.0). Among the local varieties Kalizira produced

highest number of effective tillers hill<sup>-1</sup> (11.13) and the lowest number was produced by hybrid variety BRRI dhan38 (7.73) (Fig. 3b). Among the local varieties Bashiraj produced the lowest tillers (9.33). These findings collaborated with those reported by BRRI (2000) who stated that effective tillers hill<sup>-1</sup> varied with variety.

### 3.2.4 Number of non-effective tiller hill<sup>-1</sup>

The results showed that the highest number of non-effective tillers hill<sup>-1</sup> was produced by Binadhan-7 (3.0), BRRI dhan52 produced the second highest number of non-effective tillers hill<sup>-1</sup> (2.23) which was greater than hybrid Agro dhan-12 (2.20) (Table 1). The lowest number of non-effective tillers hill<sup>-1</sup> was produced by local Kalizira (0.53). Variable effect of the variety on number of non-effective tillers hill<sup>-1</sup> was also reported by Islam (1995) who noticed that number of total tillers hill<sup>-1</sup> differed among varieties.

### 3.2.5 Number of grains panicle<sup>-1</sup>

Hybrid variety Agro dhan-12 produced the highest number of grains panicle<sup>-1</sup> (235) which was statistically similar to the inbred variety BRRI dhan49 (234.67) (Fig. 3c). Among the local varieties Kalizira showed the best performance (182.09) for grains panicle<sup>-1</sup>. The results obtained by Bhowmick and Nayak (2000) and Patel (2000) were in agreement with the findings of present study.

### 3.2.6 Panicle length

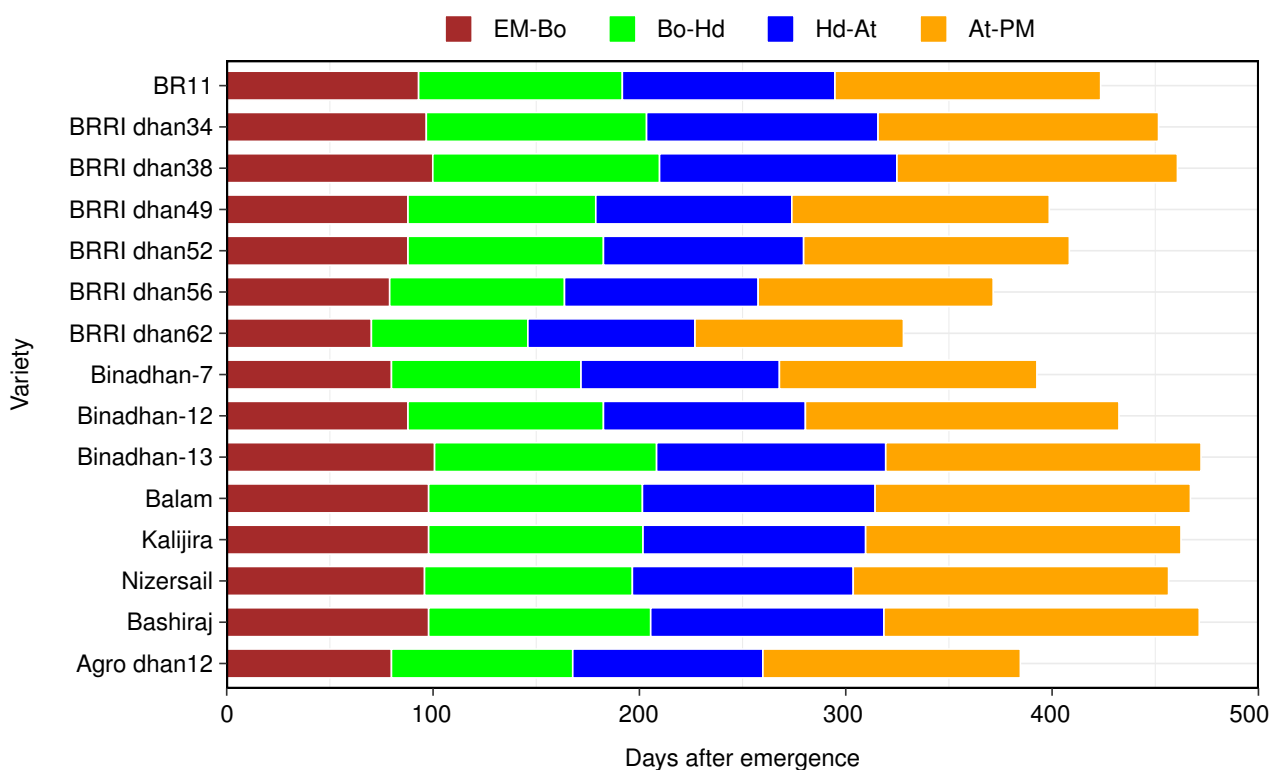
The results showed that the longest panicle was produced by hybrid variety Agro dhan-12 (32.0 cm) which was identical with high yielding BRRI dhan49 (31.0 cm) (Fig. 3d). Among the local varieties Kalizira produced highest panicle length (26.04 cm) and lowest was observed in Nizersail (24.85 cm). These results were similar to Anjuman (2012) and Haque (2011) who reported that panicle length has significant relationship with variety.

### 3.2.7 Number of sterile grains panicle<sup>-1</sup>

The results showed that the highest number of sterile grains panicle<sup>-1</sup> was observed in BRRI dhan34 (30.0) and the lowest number (7.34) was obtained from high yielding variety BR11 (Table 1). In general, all the local varieties in this study possess average (26.94) maximum sterile grains panicle<sup>-1</sup>.

### 3.2.8 1000-grain weight

The highest 1000-grain weight (WTS) (35 g) was obtained from hybrid variety Agro dhan-12 (Fig. 3e). Among the local varieties Nizersail produced highest WTS (23.59 g). The result is in contradiction with



**Figure 2.** Growth duration (days) of *T. aman* rice varieties

Kundu and Ladha (1995) who found that variety does not show any significant effect on WTS.

### 3.2.9 Grain yield

The results indicated that hybrid variety Agro dhan-12 produced ( $6.50 \text{ t ha}^{-1}$ ) which was identical to high yielding variety BRR1 dhan49 ( $6.0 \text{ t ha}^{-1}$ ) and the second highest grain yield was produced by another high yielding variety BRR1 dhan52 ( $5.83 \text{ t ha}^{-1}$ ), Binadhan-7 ( $5.42 \text{ t ha}^{-1}$ ) which was on an average 30-40% more than local varieties performance and hybrid Agro dhan-12 gave 15-20% more yield than high yielding varieties (Fig. 3f). The lowest grain yield was produced by Binadhan-13 ( $2.67 \text{ t ha}^{-1}$ ). Among the local varieties, Nizersail produced the highest grain yield ( $3.76 \text{ t ha}^{-1}$ ). The probable reason of the different grain yields due to the different yield parameters (number of tiller, number of grain panicle<sup>-1</sup>, number of filled grains panicle<sup>-1</sup>, 1000-grain weight etc.) influenced by the genetic make-up of the variety. Grain yield differences due to varieties were also reported by Saha (2013), Anjuman (2012) and Khisha (2002) who observed variable grain yield among varieties.

### 3.2.10 Straw yield

The result showed that Bashiraj produced the highest straw yield ( $7.63 \text{ t ha}^{-1}$ ), which was statistically similar with another local variety Nizersail ( $7.62 \text{ t ha}^{-1}$ )

(Table 1). The lowest straw yield was obtained from high yielding BRR1 dhan56 ( $5.42 \text{ t ha}^{-1}$ ), which was statistically identical with BRR1 dhan49 ( $5.46 \text{ t ha}^{-1}$ ). The probable reason of the different straw yield due to the different yield parameters which was mainly influenced by the genetic make-up of the variety. The results were similar with Kirttania (2013) and Chowdhury et al. (1993) who found different straw yield among the varieties.

### 3.2.11 Biological yield

The result showed that local Nizersail produced the highest biological yield ( $11.58 \text{ t ha}^{-1}$ ), which was statistically similar with another Bashiraj ( $10.78 \text{ t ha}^{-1}$ ), high yielding Binadhan-7 ( $10.72 \text{ t ha}^{-1}$ ) (Table 1). The lowest values was obtained from BRR1 dhan49 ( $8.71 \text{ t ha}^{-1}$ ), which was statistically identical with Binadhan-13 ( $8.94 \text{ t ha}^{-1}$ ).

### 3.2.12 Harvest index

The highest harvest index (HI) (41.06%) was observed in BRR1 dhan34 which was statistically at par with Binadhan-7 (39.89%), BRR1 dhan56 (39.39%), and hybrid Agro dhan-12 (34.41%) (Table 1). The lowest HI (28.73%) was observed in Bashiraj which was statistically at par with inbred Binadhan-13 (30.13%). Almost all the high yielding varieties exhibited better HI than the local varieties under the present study.

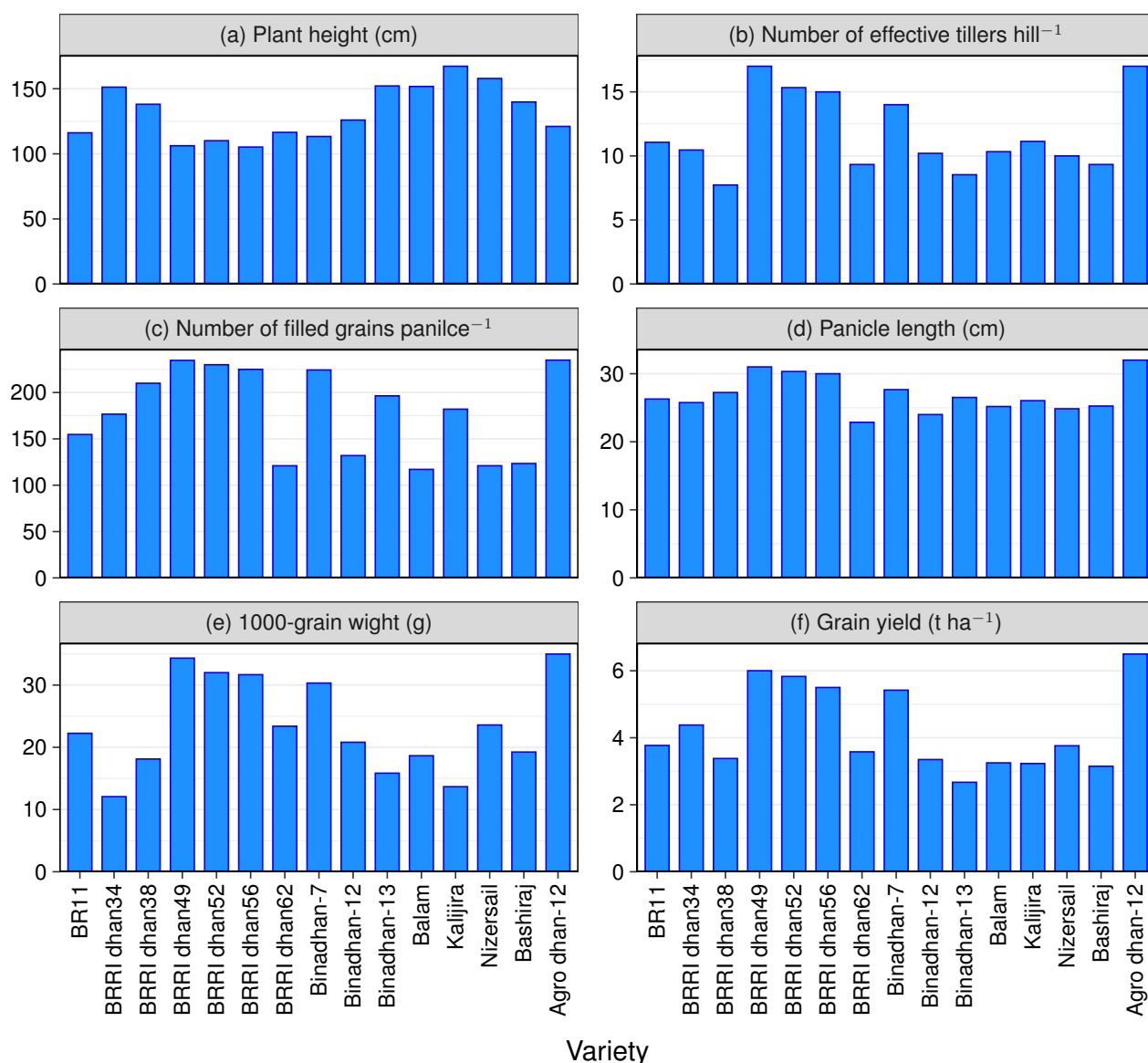


Figure 3. Growth and yield characters of different *T. aman* rice varieties at harvest

### 3.3 Panicle and grain morphology

#### 3.3.1 Panicle structure

The major structures of the panicle are the base, axis, primary and secondary branches, pedicel, rudimentary glumes, and the spikelets. The panicle axis extends from the panicle base to the apex; it has 8-10 nodes at 2- to 4-cm intervals from which primary branches develop. Secondary branches develop from the primary branches. Pedicels develop from the nodes of the primary and secondary branches.

#### 3.3.2 Grain number

The highest lower primary grain was observed in local variety Kalizira (24.1) and the lowest primary grain was found high yielding variety Binadhan13 (11.75) and the highest lower secondary grain was

observed in high yielding variety BRR1 dhan62 variety (27.50) and the lowest secondary was counted in Binadhan-13 (12.50) (Table 2).

#### 3.3.3 Middle part of the panicle

In middle part of the panicle, the highest primary grain number was counted in local variety Kalizira (20.83) and lowest primary grain was counted in local variety Bashiraj (10.50). In middle part of the panicle, the highest secondary grain number was counted in high yielding variety BRR1 dhan49 (44.66) and lowest secondary grain was present in Binadhan-13 (17.0).

#### 3.3.4 Upper part of the panicle

The highest upper primary grain was counted in high yielding variety BRR1 dhan49 (15.83) and the lowest upper primary grain was present in high yielding

**Table 1.** Growth, yield contributing characters and yield of *T. aman* rice

Variety	No. of non-effective tillers hill <sup>-1</sup>	No. of unfilled grains panicle <sup>-1</sup>	Straw yield (t ha <sup>-1</sup> )	Biological yield (t ha <sup>-1</sup> )	Harvest index (%)
BR11	1.60c	7.34e	6.44d	10.19b	36.85a-d
BRR1 dhan34	1.13de	30.00a	6.29d	10.68ab	41.064a
BRR1 dhan38	0.90ef	29.75a	6.75b-d	10.13b	33.37b-f
BRR1 dhan49	2.23b	18.13c	5.46e	8.71d	37.32a-c
BRR1 dhan52	2.23b	15.56cd	7.39ab	10.70ab	30.95d-f
BRR1 dhan56	1.70c	16.05cd	5.42e	8.94cd	39.39ab
BRR1 dhan62	1.36cd	15.85cd	6.51cd	10.09b	35.19ab-e
Binadhan-7	3.00a	13.00d	6.44d	10.72ab	39.89a
Binadhan-12	2.30b	14.02cd	7.15a-c	10.50ab	31.87c-f
Binadhan-13	0.93e	24.17b	6.27d	8.94cd	30.13ef
Balam	0.83ef	27.68ab	7.25ab	10.50ab	30.87d-f
Kalizira	0.53f	28.36ab	6.75b-d	9.97bc	32.15c-f
Nizersail	0.80ef	28.06ab	7.62a	11.38a	32.96c-f
Bashiraj	0.93e	23.67b	7.63a	10.78ab	28.73f
Agro dhan-12	2.20b	16.43cd	6.59cd	10.37ab	36.41a-d
LSD (0.05)	0.3938	4.9385	0.6583	1.0534	6.0531
Sig. level	**	**	**	**	**

\*\* designates significant at 1% level of significance,

variety BRR1 dhan38 (9.08) and the lowest upper secondary grain was counted in high yielding variety BRR1 dhan56 (11.16).

### 3.4 Individual grain weight

#### 3.4.1 Lower part of the panicle

The highest individual primary mean grain weight was recorded in Binadhan-12 (22.17 mg) and lowest individual mean grain weight was observed in high yielding variety BRR1 dhan38 (16.48 mg) (Table 3). The highest individual lower secondary grain weight was recorded in high yielding variety BRR1 dhan56 and hybrid variety Agro dhan-12 (19.93 mg). The lowest grain weight was found in local variety Kalizira (12.24 mg).

#### 3.4.2 Middle part of the panicle

The highest individual middle primary grain weight was recorded in local variety Bashiraj (20.67 mg) and was identical to hybrid variety Agro dhan-12 (19.98 mg). The lowest grain weight was found in inbred variety BR11 (15.15 mg). The highest individual middle secondary grain weight was calculated in local variety Balam (20.84 mg) and the lowest grain weight was calculated in inbred variety Binadhan-12 (14.59 mg).

#### 3.4.3 Upper part of the panicle

The highest individual upper primary grain weight was recorded in high yielding variety BRR1 dhan34 (21.29 mg) and the lowest primary individual grain

weight was calculated in local variety Kalizira (17.27 mg). The highest individual upper secondary grain weight was recorded in high yielding variety Binadhan-7 (20.83 mg).

### 3.5 Grain dimension

#### 3.5.1 Lower part of the panicle

The highest primary length of grain was measured in high yielding variety Binadhan-7 (9.37 mm) and was identical to hybrid variety Agro dhan-12 (9.07 mm). The lowest primary length was measured in Binadhan-13 (5.13 mm) (Table 4). The highest primary breadth of grain was measured in hybrid variety Agro dhan-12 (1.89 mm) and the lowest primary breadth was measured in Balam (1.69 mm). The highest primary height of grain was measured in high yielding variety BRR1 dhan56 (2.56 mm), lowest primary height was measured in BRR1 dhan34 (1.67 mm). The highest lower primary volume of the grain was measured in high yielding variety Binadhan-7 (21.95 mm<sup>3</sup>) and was identical to hybrid Agro dhan-12 (20.19 mm<sup>3</sup>) and the lowest primary volume was measured in BRR1 dhan34 (5.76 mm<sup>3</sup>). The highest lower primary L/B ratio of the grain was measured in high yielding variety Binadhan-7 and lowest primary L/B ratio was measured in Binadhan-13 (3.19). The highest secondary length of grain was measured in high yielding variety Binadhan-7 (9.25 mm). The second highest secondary grain length was measured in hybrid variety Agro dhan-12 and the lowest secondary length was measured in high yielding variety BRR1 dhan38 (5.57 mm) and identical to local variety Kalizira (5.91 mm). The highest primary breadth of

**Table 2.** Grain number in lower, middle and upper part of a panicle bearing primary and secondary grain in *T. aman* rice varieties

Variety	LP grain number	LS grain number	MP grain number	MS grain number	UP grain number	US grain number
BR11	20.75bc	20.42cd	18.00b	22.50ef	13.00b-d	13.50c-e
BRR1 dhan34	14.33e-g	19.00d-f	15.67cd	21.33ef	11.17ef-h	16.17b
BRR1 dhan38	14.58ef	15.08hi	13.67de	23.75de	9.08i	15.17bc
BRR1 dhan49	13.00f-h	13.50ij	17.67bc	44.66a	10.67f-i	15.17bc
BRR1 dhan52	14.50ef	17.67e-g	15.67cd	22.50ef	15.833a	18.67a
BRR1 dhan56	21.00b	16.16gh	19.50ab	27.83bc	13.33b-d	11.16f
BRR1 dhan62	19.16bc	27.50a	18.50b	26.00cd	10.47g-i	13.42c-e
Binadhan-7	12.16gh	19.83de	14.92de	17.83gh	10.17hi	15.00bc
Binadhan-12	20.83bc	22.50bc	18.25b	27.50bc	12.25d-f	18.75a
Binadhan-13	11.75h	12.50j	11.34fg	17.00h	10.00hi	12.83d-f
Balam	18.67cd	19.33def	18.50b	29.33b	11.92d-g	15.83b
Kalizira	24.16a	16.83f-h	20.83a	25.33cd	14.00bc	12.34ef
Nizersail	13.67f-h	19.00d-f	12.84ef	21.00f	12.50c-e	12.83d-f
Bashiraj	13.42gh	17.67e-g	10.50g	19.83fg	9.75hi	14.83b-d
Agro dhan-12	16.50de	23.83b	13.67de	22.50ef	14.50ab	20.33a
LSD (0.05)	2.2193	2.5614	2.1053	2.69	1.746	2.1667
Sig. level	**	**	**	**	**	**

LP = lower primary, LS = lower secondary, MP = middle primary, MS = middle secondary, UP = upper primary, and US = upper secondary; \*\* designates significant at 1% level of significance,

**Table 3.** Individual grain weight of the panicles in lower, middle, upper parts bearing primary and secondary seed in *T. aman* rice varieties

Variety	LP grain weight (mg)	LS grain weight (mg)	MP grain weight (mg)	MS grain weight (mg)	UP grain weight (mg)	US grain weight (mg)
BR11	19.44	17.59c-e	15.15e	16.26c-e	19.95a-c	16.68
BRR1 dhan34	20.53	18.97a-c	18.20b-d	17.80b-d	21.29a	18.56
BRR1 dhan38	16.48	16.86c-e	18.83a-d	19.24b	19.07a-c	17.43
BRR1 dhan49	20.13	21.51ab	18.64a-d	19.15a-c	17.82bc	20.47
BRR1 dhan52	17.36	20.16a-c	16.57de	18.01a-d	20.44ab	19.07
BRR1 dhan56	19.27	22.38a	19.02a-c	19.32ab	18.83a-c	20.82
BRR1 dhan62	20.15	19.78a-c	18.82a-d	17.12b-e	18.75a-c	19.82
Binadhan-7	18.21	18.40b-d	16.96c-e	18.66a-d	19.167a-c	20.83
Binadhan-12	22.17	14.49ef	18.68a-d	14.59e	19.84a-c	18.52
Binadhan-13	21.47	17.89b-e	18.64a-d	16.28c-e	18.90a-c	19.01
Balam	19.53	17.48cde	17.25c-e	20.84a	19.01a-c	18.39
Kalizira	20.22	12.24f	18.83a-d	18.73a-d	17.27c	18.85
Nizersail	18.32	18.70a-d	19.32a-c	17.17 b-e	18.04bc	16.87
Bashiraj	20.82	15.17d-f	20.67a	16.03de	19.22a-c	19.67
Agro dhan12	18.85	19.93a-c	19.98ab	18.23a-d	19.22a-c	18.41
LSD (0.05)	4.0758	3.7195	2.3941	2.927	2.982	3.4249
Sig. level	NS	**	*	**	*	NS

LP = lower primary, LS = lower secondary, MP = middle primary, MS = middle secondary, UP = upper primary, and US = upper secondary; \* and \*\* designate significant at 5% and 1% levels of significance, respectively. NS = non-significant at 5% level of significance



**Table 4.** Grain dimensions in the lower part of the panicle in *T. aman* rice varieties

Variety	LPL (mm)	LPB (mm)	LPH (mm)	LPV (mm <sup>3</sup> )	LPR	LSL (mm)	LSB (mm)	LSH (mm)	LSV (mm <sup>3</sup> )	LSR
BR11	7.93cd	1.88a	2.48b	19.38c	4.22e	7.90cd	1.84ab	2.50b	19.05bc	4.28c-e
BRR1 dhan34	5.70gh	1.15e	1.67f	5.76h	4.95ab	5.62g	1.17f	1.62f	5.61i	4.80ab
BRR1 dhan38	5.70gh	1.75bc	2.15de	11.29g	3.24ij	5.57g	1.73de	2.18e	11.00h	3.23g
BRR1 dhan49	8.19bc	1.73b-d	2.18d	16.25de	4.73bc	7.78c-e	1.75c-e	2.20e	15.64ef	4.46cd
BRR1 dhan52	7.33ef	1.87a	2.34c	16.85d	3.91fg	7.50d-f	1.87a	2.37cd	17.48cd	4.014ef
BRR1 dhan56	7.71c-e	1.84a	2.56a	19.06c	4.20ef	7.80c-e	1.84ab	2.61a	19.63b	4.24de
BRR1 dhan62	8.510b	1.84a	2.42b	19.89bc	4.62cd	8.57b	1.87a	2.45bc	20.55ab	4.59bc
Binadhan-7	9.37a	1.84a	2.43b	21.95a	5.08a	9.25a	1.82abc	2.42bc	21.32a	5.09a
Binadhan-12	7.07f	1.87a	2.46b	17.10d	3.77gh	7.03f	1.87a	2.44bc	16.78de	3.76f
Binadhan-13	5.41h	1.70b-d	2.12e	10.31g	3.19j	5.59g	1.71e	2.16e	10.82h	3.27g
Balam	7.69c-e	1.69d	2.20d	14.95ef	4.56cd	7.31ef	1.70e	2.18e	14.18fg	4.31c-e
Kalijira	6.04g	1.71b-d	2.14de	11.52g	3.55hi	5.91g	1.75c-e	2.15e	11.60h	3.38g
Nizersail	7.43d-f	1.69cd	2.09e	13.81f	4.38de	7.46d-f	1.68e	2.14e	14.034g	4.45cd
Bashiraj	8.04bc	1.76b	2.33c	17.33d	4.56cd	8.04c	1.78b-d	2.30d	17.25d	4.50b-d
Agro dhan12	9.07a	1.89a	2.32c	20.91ab	4.78bc	8.68b	1.8867a	2.30d	19.71b	4.60bc
LSD (0.05)	0.56	0.0601	0.07	1.52	0.30	0.05	0.07	0.08	1.60	0.33
Sig. level	**	**	**	**	**	**	**	**	**	**

LPL = lower primary length, LPB = lower primary breadth, LPH = lower primary height, LPV = lower primary volume, LPR = lower primary ratio, LSL = lower secondary length, LSB = lower secondary breadth, LSH = lower secondary height, LSV = lower secondary volume, and LSR = lower secondary ratio

**Table 5.** Grain dimensions in the middle part of the panicle in *T. aman* rice varieties

Variety	MPL (mm)	MPB (mm)	MPH (mm)	MPV (mm <sup>3</sup> )	MPR	MSL (mm)	MSB (mm)	MSH (mm)	MSV (mm <sup>3</sup> )	MSR
BR11	7.86de	1.86a	2.49b	19.14b	4.22fg	7.72de	1.85ab	2.52ab	18.88bc	4.16ef
BRR1 dhan34	5.78ij	1.22f	1.67h	6.16h	4.74b	5.47h	1.21e	1.65i	5.75g	4.53bc
BRR1 dhan38	5.51j	1.71e	2.21f	10.88g	3.22i	5.57h	1.78c	2.17gh	11.22f	3.13h
BRR1 dhan49	7.92d	1.75cd	2.17fg	15.77de	4.52b-e	7.84cd	1.82bc	2.21fg	16.47d	4.32c-e
BRR1 dhan52	7.44fgh	1.86a	2.38cd	17.27c	4.00gh	7.38e-g	1.88a	2.46bc	17.87c	3.924f
BRR1 dhan56	8.53bc	1.85ab	2.61a	21.50a	4.62cd	7.94cd	1.87ab	2.56a	19.99ab	4.23de
BRR1 dhan62	8.27c	1.85a	2.39cd	19.15b	4.47c-e	8.15bc	1.86ab	2.40cd	19.02bc	4.38c-e
Binadhan-7	9.36a	1.85a	2.38cd	21.60a	5.06a	9.12a	1.83a-c	2.41cd	21.08a	4.975a
Binadhan-12	7.22h	1.89a	2.42c	17.18c	3.84h	7.17g	1.83a-c	2.41cd	16.51d	3.934f
Binadhan-13	5.67ij	1.67e	2.12g	10.56g	3.38i	5.54h	1.68d	2.14h	10.46f	3.30gh
Balam	7.57e-g	1.72de	2.19f	14.92ef	4.4df	7.59d-f	1.71d	2.25f	15.32d	4.44b-d
Kalijira	5.90i	1.74cd	2.12g	11.37g	3.39i	5.83h	1.72d	2.13h	11.16f	3.40g
Nizersail	7.36gh	1.73de	2.12g	14.07f	4.27ef	7.29fg	1.72d	2.12h	13.91e	4.24de
Bashiraj	7.74d-f	1.79bc	2.29e	16.58cd	4.33ef	7.53d-g	1.78c	2.32e	16.36d	4.25de
Agro dhan12	8.64b	1.84ab	2.33de	19.27b	4.72bc	8.53b	1.84a-c	2.32e	19.03bc	4.65b
LSD (0.05)	0.33	0.06	0.0703		0.25	0.41	0.06	0.06	1.22	0.26
Sig. level	**	**	**	**	**	**	**	**	**	**

MPL = middle primary length, MPB = middle primary breadth, MPH = middle primary height, MPV = middle primary volume, MPR = middle primary ratio, MSL = middle secondary length, MSB = middle secondary breadth, MSH = middle secondary height, MSV = middle secondary volume, and MSR = middle secondary ratio

**Table 6.** Grain dimensions in the upper part of the panicle in *T. aman* rice varieties

Variety	UPL (mm)	UPB (mm)	UPH (mm)	UPV (mm <sup>3</sup> )	UPR	USL (mm)	USB (mm)	USH (mm)	USV (mm <sup>3</sup> )	USR
BR11	7.98cde	1.87a	2.47b	19.32bc	4.27cd	7.74cd	1.89a	2.49ab	19.18cd	4.08f
BRRRI dhan34	5.62h	1.17f	1.65h	5.71h	4.81ab	5.64fg	1.19g	1.68g	5.94i	4.72b
BRRRI dhan38	5.72h	1.75cd	2.18fg	11.43g	3.25f	5.52g	1.75de	2.17d-f	10.97h	3.15h
BRRRI dhan49	7.96c-e	1.77cd	2.20def	16.24de	4.50bc	7.88cd	1.83b	2.20de	16.58f	4.32d-f
BRRRI dhan52	8.16cd	1.85ab	2.56a	20.32ab	4.39cd	8.08c	1.82bc	2.52a	19.34b-d	4.44cd
BRRRI dhan56	7.70d-f	1.89a	2.47b	18.80c	4.08de	7.716cd	1.87ab	2.49ab	18.52de	4.13ef
BRRRI dhan62	8.82ab	1.84ab	2.41bc	20.48ab	4.79ab	8.68b	1.86ab	2.43b	20.58ab	4.67bc
Binadhan-7	9.19a	1.81bc	2.39c	20.78a	5.09a	9.38a	1.84ab	2.42bc	21.92a	5.07a
Binadhan-12	7.03g	1.86ab	2.43bc	16.64d	3.78e	7.14e	1.89a	2.46ab	17.36ef	3.78g
Binadhan-13	5.57h	1.68e	2.16fg	10.60g	3.312f	5.42g	1.70ef	2.13ef	10.23h	3.21 h
Balam	7.56efg	1.73de	2.19d-f	14.95ef	4.39cd	7.53de	1.67f	2.17def	14.26g	4.53b-d
Kalijira	5.834h	1.73de	2.19ef	11.60g	3.36f	5.97f	1.70ef	2.17d-f	11.53h	3.52g
Nizersail	7.37fg	1.68e	2.12g	13.72f	4.38cd	7.52de	1.72d-f	2.11f	14.33g	4.36de
Bashiraj	7.74def	1.76cd	2.26d	16.19de	4.39cd	7.79cd	1.76cd	2.23d	16.07f	4.42cd
Agro dhan12	8.45bc	1.86ab	2.26de	18.66c	4.54bc	8.78b	1.88ab	2.35c	20.35bc	4.66bc
LSD (0.05)	0.54	0.06	0.0723	1.37	0.03	0.41	0.06	0.08	1.34	0.27
Sig. level	**	**	**	**	**	**	**	**	**	**

UPL = upper primary length, UPB = upper primary breadth, UPH = upper primary height, UPV = upper primary volume, UPR = upper primary ratio, USL = upper secondary length, USB = upper secondary breadth, USH = upper secondary height, USV = upper secondary volume, and USR = upper secondary ratio

grain was measured in hybrid variety Agro dhan-12 (1.88 mm). The lowest secondary breadth was measured in inbred variety BRRRI dhan34 (1.17 mm). The highest secondary height of the grain was measured in high yielding variety BRRRI dhan56 (2.61 mm) and the lowest primary height was measured in BRRRI dhan34 (1.62 mm). The highest lower secondary volume of the grain was measured in high yielding variety Binadhan-7 (21.32 mm<sup>3</sup>) and the second highest volume of lower secondary grain was measured in hybrid Agro dhan-12 (19.71 mm<sup>3</sup>). The lowest volume of lower secondary grain was measured in inbred variety BRRRI dhan34 (5.61 mm<sup>3</sup>). The highest lower secondary L/B ratio of the grain was measured in high yielding variety Binadhan-7 (5.09) and the L/B ratio of lower secondary grain in hybrid Agro dhan-12 (4.60).

### 3.5.2 Middle part of the panicle

The highest middle primary length of grain was measured in high yielding variety Binadhan-7 (9.36 mm) and hybrid variety Agro dhan-12 (8.64 mm) and the lowest primary length was measured in BRRRI dhan38 (5.51 mm) (Table 5). The highest primary breadth of grain was measured in high yielding varieties Binadhan-12 (1.89 mm) and the lowest primary breadth was measured BRRRI dhan34 (1.22 mm). The highest primary height of grain was measured in high yielding variety BRRRI dhan56 (2.61 mm) and the lowest primary height was measured in BRRRI dhan34 (1.67 mm). The highest middle primary volume of the grain was measured in high yielding vari-

ety Binadhan-7 (21.60 mm<sup>3</sup>) and the second highest middle primary volume of the grain was measured in hybrid variety Agro dhan-12 (19.27 mm<sup>3</sup>) and the lowest primary volume was measured in BRRRI dhan34 (6.16 mm<sup>3</sup>). The highest secondary length of grain was measured in high yielding variety Binadhan-7 (9.12 mm) and hybrid variety Agro dhan-12 (8.53 mm) and the lowest secondary length was measured in high yielding variety BRRRI dhan38 (5.57 mm). The highest secondary breadth of grain was measured in inbred BRRRI dhan52 (1.88 mm). The lowest secondary breadth was measured in high yielding variety BRRRI dhan34 (1.21 mm). The highest primary height of grain was measured in high yielding variety BRRRI dhan56 (2.56 mm). The highest middle secondary volume of the grain was measured in high yielding variety Binadhan-7 (21.08 mm<sup>3</sup>) and the lowest secondary volume was measured in BRRRI dhan34 (5.75 mm<sup>3</sup>). The highest lower primary L/B ratio of the grain was measured in high yielding variety Binadhan-7 (4.97) and hybrid Agro dhan-12 (4.65) and the lowest secondary L/B ratio was measured in high yielding BRRRI dhan38 (3.13). There is a great relations of grain dimensions (length, breadth, height, volume) with yield exacerbate. If the breeder can amplify lower, middle, upper part of grain it will be a revolution for yield increasement.

### 3.5.3 Upper part of the panicle

The highest upper primary length of grain was measured in high yielding variety Binadhan-7 (9.19 mm) and lowest primary length was measured in

Binadhan-13 (5.57 mm) (Table 6). The highest primary breadth of grain was measured in high yielding variety BRRi dhan52 (1.89 mm) and the lowest primary breadth was measured BRRi dhan34 (1.17 mm). The highest primary height of grain was measured in high yielding variety BRRi dhan56 (2.56 mm) and the lowest primary height was measured in BRRi dhan34 (1.65 mm). The highest upper primary volume of the grain was measured in high yielding variety Binadhan-7 (20.78 mm<sup>3</sup>) and the lowest upper volume was measured in BRRi dhan34 (5.71 mm<sup>3</sup>). The highest upper primary L/B ratio of the grain was measured in high yielding variety Binadhan-7 (5.09) and the lowest primary L/B ratio was measured in high yielding BRRi dhan38 (3.25). The highest upper secondary length of grain was measured in high yielding variety Binadhan-7 (9.38 mm) and hybrid variety Agro dhan-12 (8.78) and the lowest secondary length was measured in Binadhan-13 (5.42 mm). The highest upper secondary breadth of grain was measured in high yielding variety Binadhan-12 (1.89 mm) and hybrid variety Agro dhan-12 (1.88 mm) and the lowest upper secondary breadth was measured in BRRi dhan34 (1.19 mm). The highest secondary height of grain was measured in high yielding variety BRRi dhan56 (2.52 mm) and the lowest primary height was measured in BRRi dhan34 (1.68 mm). The highest upper secondary volume of the grain was measured in high yielding variety Binadhan-7 (21.92 mm<sup>3</sup>) and the lowest upper secondary volume was measured in BRRi dhan34 (5.94 mm<sup>3</sup>). The highest upper secondary L/B ratio of the grain was measured in high yielding variety Binadhan-7 (5.07) and hybrid Agro dhan12 (4.66) and the lowest secondary L/B ratio was measured in high yielding BRRi dhan38 (3.15).

## 4 Conclusion

The present study suggests that the Agro dhan-12, Binadhan-7, BRRi dhan49, BRRi dhan52, BRRi dhan56 varieties under this study may preferable to obtain better grain quality and yield under AEZ-9 in *Aman* season. But studies at different agro-ecological zones are needed to arrive at a definite conclusion.

## Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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The Official Journal of the  
**Farm to Fork Foundation**  
 ISSN: 2518–2021 (print)  
 ISSN: 2415–4474 (electronic)  
<http://www.f2ffoundation.org/faa>