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Research Article

Phenology and Yield Performances of HYV and Local Rice Cultivars during Boro and Aman Seasons in Haor Ecology of Sylhet

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ABSTRACT

Rice is the principal staple crop, securing nutritional demand for more than half of the world's population. Due to unpredictable rainfall patterns, frequent flash floods, and higher acidity, rice production challenges are increasing day by day in Sylhet region of Bangladesh. A study was conducted in the haor area of Sylhet with 51 local and high yielding rice varieties (HYVs) in the Boro and Aman seasons. The experiment was arranged in randomized complete block design (RCBD) with three replications to observe phenology, yield characteristics, and yield of rice varieties. BRRI dhan85 (145.82 days), BRRI dhan84 (148.32 days), BRRI dhan81 (148.38 days), and local cultivars Tepi (128 days) and Rata (129 days) were short-duration Boro rice varieties. In contrast, BRRI dhan75 (117 days), BRRI dhan33 (122 days), BRRI dhan39 (126 days), and local cultivars Lalbinni (119.66 days) and Nazirshail (121 days) were short-duration Aman rice varieties. BRRI dhan29 (6.11 t ha^{-1}), BRRI dhan28 (5.50 t ha^{-1}), and BRRI dhan92 (5.50 t ha^{-1}) showed maximum yield in Boro season, while BRRI dhan49 (4.59 t ha^{-1}), BR22 (4.47 t ha^{-1}), and BR11 (4.41 t ha^{-1}) showed maximum yield in Aman season. BRRI Dhan85, Tepi, BRRI dhan39, and Nazirshail are short-duration and high-yielding rice varieties/cultivars among Boro HYVs, Boro local, Aman HYVs, and Aman local rice cultivars respectively. PCA revealed significant genetic variation where first three PCs accounted for 60% of total cumulative variability. PC1 and PC2 exhibited most of the variation (33% and 47% of the total cumulative variability). Cultivating these high yielding and short-duration rice could help to escape the impact of flash floods and increase the ultimate rice production in this region.

Introduction

Rice (*Oryza sativa* L.) is the most crucial cereal crop in the Poaceae family, used as a staple food for over 50% of the global population. Though rice consumption was moderate (437.18 million metric tons) in 2008–2009, global consumption increased to 18% (520.4 million metric tons) in 2022–23 (Statista, 2024). Despite 75% of the total land area of Bangladesh being covered by rice cultivation, the average yield is lower than most rice-growing countries worldwide (Shelley et al., 2016). The average rice yield of Bangladesh was 3.20 t ha^{-1}, whereas in Japan and China it was 5 t ha^{-1} and 4.74 t ha^{-1} respectively (FAO, 2022).

Rice production faces severe challenges in the Sylhet region due to unpredictable rainfall patterns, frequent flash floods, higher acidity, and poor fertility. Flash floods are a major concern for rice production as water level impacts growth stages and yields in this region (Hossain et al., 2017). Even the intensity of flash floods has increased recently because of the adverse effects of climate change (Haque et al., 2016). Rice production is closely related to climate change, while the meteorological condition of Haor basin areas has been deteriorating in recent years (Nowreen et al., 2013). Occurrence of early flash floods before Boro harvesting impacts rice cultivation in some areas of the northeastern regions of Bangladesh (Mondal et al., 2019).

Flash floods in the Aman season destroy rice seedbeds, impact young seedlings, and delay harvest (Hasan et al., 2016). Frequent flash floods reduce crop growth, resulting in lower grain yield that affects overall rice production (Matsumoto and Asada, 2015). Increased pre-monsoon rainfall and its shifting from May to April increased the frequency of flash floods and resulted damage of the rice crop, as April-May is the harvesting

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time of Boro rice (Akter et al., 2023). Short-duration rice varieties can reach maturity faster and cover a shorter growing season than traditional genotypes, reducing crop damage risk caused by flash floods (Panda and Barik., 2021). Besides, short-duration rice varieties increase cropping intensity by incorporating other crops in the existing cropping pattern of this region (Bir et al. 2018). Hence, adopting short-duration rice varieties could bring several advantages during Boro and Aman rice production to avoid the adverse impacts of flash floods.

High-yielding rice varieties increase grain production, becoming a reliable option for rice-dependent regions (Rahman and Connor 2022). Even HYVs offer a more efficient use of water and nutrients than local landraces, potentially resulting in higher economic benefits for farmers (Shew et al. 2019). Various HYVs withstand adverse climatic conditions such as flash floods, adapting to the impacts of climate change (Jamal et al. 2023). However, the growth and yield parameters of rice rely on various genotypes and environmental factors (Alam et al. 2008). Short duration varieties or cultivars can escape flash floods, while high yielding varieties can increase total rice production in the region. Considering the above circumstances an experiment was conducted to screen short-duration and high yielding Aman and Boro rice varieties suitable for the flood-prone areas of the Sylhet region.

Materials and Methods

Experimental site

The experiment was conducted at the seed production and research field of M. Ahmed Group at Chiknagul, Jaintapur Upazilla, Sylhet (25°0' N- 25°12'30" N and 92°0' E- 92°27'30" E) during Boro and Aman rice seasons from 2021 and 2022. The experimental field was situated in the Eastern Surma-Kushiyara Floodplain Agro-ecological Zone (AEZ 20) of Bangladesh, consisting of acidic (pH 5.8) and silty clay loam soil. The soil contained a lower amount of organic matter (1.67%), nitrogen (0.11%), phosphorus (12.0 ppm), and sulphur (21 ppm), where potassium (0.18 me/100 g), zinc (95 ppm), and boron (0.42 ppm) contents of the soil were medium. The experimental site consisted of a subtropical climate with moderately high temperatures and heavy rainfall during the kharif season (March to October) and low rainfall along with low temperatures during the rabi season (November to February). The experiment was conducted maintaining a 10 m^2 (4 m × 2.5 m) plot size with spacing of 20 cm × 15 cm between rows and hills respectively.

Plant material

Sixteen HYVs and ten local cultivars of Bangladesh were evaluated during the Boro season. HYVs include BR14, BRRI dhan28, BRRI dhan29, BRRI dhan48, BRRI dhan58, BRRI dhan67, BRRI dhan81, BRRI dhan82, BRRI dhan84, BRRI dhan85, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96, BRRI dhan101, Binadhan-10. Local Boro rice cultivars were Begoni, Lalteer, Black Rice, Jholok, Kaula, Kolabinni, Tepi, Khoiyaboro, Rata, and Begunbichi. In Aman season, thirteen HYVs were evaluated, which were BR11, BR22, BRRI dhan32, BRRI dhan33, BRRI dhan39, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan75, BRRI dhan79, BRRI dhan87, Binadhan-11, and Swarna. Twelve local Aman rice cultivars of Bangladesh were used in this experiment, which were Bajaldhan, Balam, Biroin, Champasuri, Gaindha, Joria, Kajallota, Lalbinni, Lalbalam, Nonabokhra, Nunia, and Nazirshail. The seeds were collected from local farmers and Bangladesh Agricultural Development Corporation (BADC).

Experimental design and crop husbandry

The experiment was conducted using RCBD design with three replications. Pre-germinated seeds were broadcasted in the wet seedbed during the Boro season on 10 November 2021 and seedlings were transplanted in the main field on 9 December 2021. The experimental plot was uniformly fertilized with urea, TSP, MoP, gypsum, and zinc sulphate at 296.74, 98.85, 165.58, 111.21, and 11.12 kg ha^{-1}, respectively (BRRI 2020). During Aman season, pre-germinated seeds were broadcasted in the wet seedbed on 13 July 2022, and seedlings were transplanted on August 8, 2021. The experimental plot was uniformly fertilized with urea, TSP, MoP, gypsum, and zinc sulphate at 165.58, 59.31, 105.03, 66.72, and 7.41 kg ha-1, respectively (BRRI 2020).

In both Boro and Aman season, the full amount of TSP, MoP and the half dose of Urea were applied as basal doses. The rest of the urea was top-dressed at two equal splits at 30 days after transplanting (DAT) (tillering stage) and at 50 DAT (booting stage). Water management, intercultural operations, and pest control measures were taken as per the BRRI 2020 recommendation guide.

Collection of data

Phenology, growth, and yield related data were collected on parameters such as days to panicle initiation (DPI), days to 50% flowering (DF), days to 80% maturity (DM), plant height, effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, panicle length, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, 1000-grain weight (TGW), grain yield and straw yield.

Statistical analysis

Data were analyzed by using R software version 4.2.2 and the mean was separated using the least significant difference (LSD) at 5% level of significance. Principal component analysis (PCA) was performed using the standardized data of 12 selected growth and yield parameters (i.e., traits having numerical variation) of 51 rice landraces using

Results

Days to panicle initiation

Among the HYVs in Boro season (Fig. 1a), the minimum DPI was recorded in BRRI dhan82 (77) followed by BRRI dhan28 (79.7), whereas the maximum DPI was recorded in BRRI dhan89 (89.87). In contrast, the lowest DPI was observed in Tepi (64), followed by Rata (67) among the boro local cultivars (Fig. 1b), while the highest DPI was observed in Black Rice (107.66) followed by Lalteer (85.33). In terms of HYVs in Aman season (Fig.1c), BRRI dhan75 (66) showed the minimum DPI which was statistically similar to BRRI dhan39 (66), whereas BRRI dhan51 (81.66) showed the maximum DPI which was similar to BR22 (81.33) and BRRI dhan52 (81). For Aman local cultivars (Fig. 1d), the minimum DPI was observed in Lalbinni (57.66) followed by Nazirshail (62.66), while the maximum DPI was observed in Nunia (79.66) which was statistically similar to Joria (79.66).

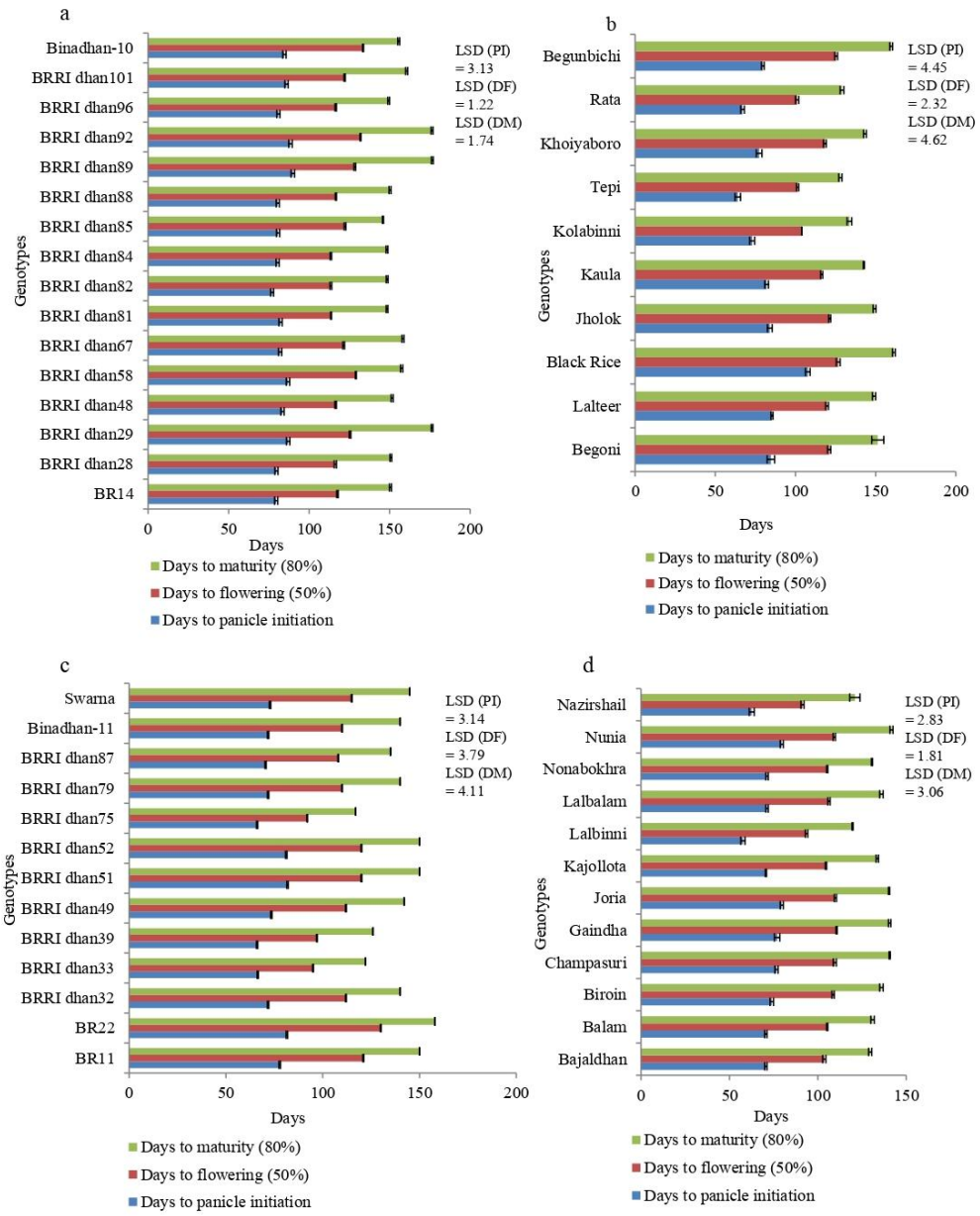

Fig. 1. Phenology of a) HYVs in Boro, b) Boro local, c) HYVs in Aman, and d) Aman local rice genotypes

Days to flowering

In terms of HYVs in Boro season (Fig. 1a), the minimum DF was obtained from BRRI dhan85 (103.33), followed by BRRI dhan82 (113.46), whereas the maximum DF was obtained from Binadhan-10 (133.48) followed by BRRI dhan92 (131.89). Regarding Boro local cultivars (Fig. 1b), Rata (101.00) showed the lowest DF which was similar to Tepi (101.33), while Begunbichi (125.33) showed the highest DF followed by Black Rice (121.66). For the Aman HYVs (Fig. 1c), the minimum DF was recorded in BRRI dhan75 (92), followed by BRRI dhan33 (95), where the maximum DF was recorded in BR22 (130), followed by BR11 (121). In terms of Aman local cultivars (Fig. 1d), Nazirshail (91.33) showed the minimum DF followed by Lalbinni (93.66), while Gaindha (110.66) showed the maximum DF which was similar to Joria (110).

Days to maturity

Among the HYVs in Boro season (Fig. 1a), the lowest DM was observed in BRRI dhan85 (145.82) followed by BRRI dhan84 (148.32), whereas the highest DM was observed in BRRI dhan89 (176.52) which was similar to BRRI dhan92 (176.28). On the other hand, Tepi (128) exhibited the minimum DM followed by Rata (129) whereas Black Rice (161.33) exhibited the maximum DM followed by Begunbichi (159.66) for local Boro rice cultivars (Fig. 1b). Again, the minimum DM was obtained from BRRI dhan75 (117) followed by BRRI dhan33 (122) in terms of the HYVs in Aman season (Fig. 1c), where the maximum DM was obtained from BR22 (158). For Aman local cultivars (Fig. 1d), Lalbinni (119.66) showed the lowest DM followed by Nazirshail (121), while Joria (140.33) showed the highest DM which was similar to Gaindha (140.66).

Plant height

In terms of HYVs in Boro season (Table 1), the highest plant height was recorded in BRRI dhan 92 (110.18 cm) followed by BRRI dhan 89 (101.61 cm), whereas the lowest plant height was recorded in BRRI dhan88 (78.85 cm) followed by BRRI dhan81 (80.35 cm). In contrast, Rata (163.11 cm) exhibited the maximum plant height followed by Begunbichi (143.59 cm), whereas Black Rice (82.76 cm) exhibited the minimum plant height followed by Begoni (84.59 cm) for local Boro rice genotypes (Table 2). Among the HYVs in Aman season (Table 3), the highest plant height was obtained from BRRI dhan32 (112.58 cm) that was statistically similar to BR22 (111.75 cm) and BRRI dhan52 (108.34 cm). On the contrary, the minimum plant height was found in BRRI dhan 51 (84.45 cm) followed by Binadhan-11 (93.43). Among Aman local cultivars (Table 4), Nazirshail (152.12 cm) showed the maximum height followed by Lalbinni (138.47 cm), while Lalbalam (60.36 cm) showed the minimum plant height followed by Bajaldhan (66.20 cm).

Effective tillers hill^{-1}

Among the HYVs in Boro season (Table 1), the highest number of effective tillers hill^{-1} was found in BRRI dhan82 (14.07) followed by BRRI dhan85 (13.2), while the lowest number of effective tillers hill^{-1} was found in BRRI dhan101 (8.87) which was similar to Binadhan-10 (8.93). In contrast, Kolabinni (14.99) showed the highest number of effective tillers hill^{-1} which was similar to Begunbichi (14.90) and Khoiyaboro (14.76), whereas Begoni (10.20) showed the lowest number of effective tillers hill^{-1} among local Boro rice cultivars (Table 2). In case of HYVs in Aman season (Table 3), the maximum number of effective tillers hill^{-1} was recorded in Swarna (17.5), followed by BRRI dhan39 (15.48), while the minimum number of effective tillers hill^{-1} was recorded in BRRI dhan87 (9.34) followed by Binadhan-11 (9.79). Again, Kajollota (17.07) followed by Bajaldhan (14.85) exhibited the highest number of effective tillers hill^{-1} among the Aman local cultivars (Table 4), whereas Lalbinni (6.00) exhibited the lowest number of effective tillers hill^{-1} which was statistically similar to Nazirshail (6.72).

Table 1. Growth and yield parameters of Boro HYVs

Variety	Plant height (cm)	Effective tillers/hill	Non-effective tillers/hill	Panicle length (cm)	Filled grains/panicle	Un-filled grains/ panicle	1000-grain weight (g)	Straw yield (t/ha)
BR14	99.72 bc	10.61 c-e	0.67 cd-f	21.89 e-g	101.83 c	33.71 a-c	30.07 b	5.18 e
BRRI dhan28	95.68 de	10.4 de	0.47 d-g	24.87 b	138.03 a	15.53 d-f	25.31 e	6.19 bc
BRRI dhan29	99.74 bc	11.27 cd	0 g	25.15 b	145.07 a	26.87 b-d	28.01 c	6.50 b
BRRI dhan48	89.95 fg	10.73 c-e	0.27 fg	20.28 h	141.55 a	16.11 d-f	27.22 cd	6.54 b
BRRI dhan58	90.03 fg	10.93 cd	1.33 ab	21.27 f-h	131.40 ab	39.27 a	21.13 hi	4.57 f
BRRI dhan67	101.45 b	12.02 b-d	0.22 fg	23.61 cd	104.15 c	18.97 d-f	23.19 f	4.64 f
BRRI dhan81	80.35 h	12.47 a-c	0.97 b-d	21.2 f-h	106.23 c	21.2 d-f	25.09 e	3.82 gh
BRRI dhan82	87.36 g	14.07 a	0.87 b-e	21.23 f-h	113.33 bc	11.68 f	23.07 fg	2.68 i
BRRI dhan84	92.45 ef	11.35 b-d	0.27 fg	24.73 b	102.47 c	41.8 a	22.1 gh	4.43 f
BRRI dhan85	87.93 g	13.2 ab	1.27 ab	21.87 e-g	96.21 c	12.01 f	26.8 d	4.38 f
BRRI dhan88	78.85 h	11.23 cd	1.14 a-c	21.01 gh	107.61 c	13.13 ef	21.01 i	5.21 de
BRRI dhan89	101.61 b	11.47 b-d	0.33 e-g	24.2 bc	133.91 a	24.01 c-e	25.01 e	6.62 b
BRRI dhan92	110.18 a	12.22 a-d	0.41 d-g	27.27 a	146.51 a	34.84 a-c	32.56 a	9.42 a
BRRI dhan96	96.89 cd	10.93 cd	0.23 fg	22.2 ef	134.33 a	17.88 d-f	19.8 j	3.49 h
BRRI dhan101	99.53 bc	8.87 e	0.41 d-g	22.80 de	101.31 c	36.73 ab	24.56 e	4.30 fg
Binadhan -10	93.67 de	8.93 e	1.62 a	24.67 b	95.12 c	14.87 ef	27.48 cd	5.69 cd
LSD	3.55	1.92	0.58	1.03	20.08	11.67	0.99	0.51

Table 2. Growth and yield parameters of Boro local

Variety	Plant height (cm)	Effective tillers/ hill	Non-effective tillers/hill	Panicle length (cm)	Filled grains/ panicle	Un-filled grains/ panicle	1000-grain weight (g)	Straw yield (t/ha)
Begoni	84.59 f	10.20 b	1.86 a	21.73 cd	45.26 f	77.46 a	30.27 a	7.93 de
Lalteer	100.40 e	13.06 ab	0.86 bc	20.33 d	70.26 de	7.80 e	22.99 c	11.01 a
Black rice	82.76 f	12.93 ab	0.86 bc	21.94 bc	59.40 e	27.86 b	24.40 b	10.59 ab
Jholok	108.96 e	12.93 ab	1.13 b	21.66 cd	101.66 c	21.26 bc	21.50 d	8.36 d
Kaula	136.95 bc	12.31 ab	0.33 c	22.66 bc	106.29 c	15.30 cd	20.50 e	6.75 f
Kolabinni	124.93 d	14.99 a	0.85 bc	25.98 a	78.57 d	14.90 c-e	25.00 b	8.06 de
Tepi	139.69 b	12.63 ab	0.50 bc	23.19 b	106.20 c	9.30 de	18.50 g	8.98 cd
Khoiyaboro	130.11 cd	14.76 a	0.72 bc	22.09 bc	75.55 d	22.44 b	22.00 d	9.51 bc
Rata	163.11 a	14.34 a	0.35 c	21.97 bc	120.34 b	11.88 de	19.43 f	7.07 ef
Begunbichi	143.59 b	14.90 a	0.97 bc	22.91 bc	132.70 a	24.38 b	12.66 h	5.32 g
LSD	8.88	3.36	0.69	1.4	11.66	7.13	0.88	1.14

Table 3. Growth and yield parameters of Aman HYVs

Variety	Plant height (cm)	Effective tillers hill-1	Non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains/ panicle	Un-filled grains/ panicle	1000-grain weight (g)	Straw yield (t/ha)
BR11	98.21 b	10.84 d-g	2.10 d	25.24 a-c	145.86 ef	14.10 f	24.37 b	6.35 a
BR22	111.75 a	11.52 de	2.35 c	24.35 a-d	166.72 cd	19.37 b-d	19.25 fg	5.38 b-d
BRRI dhan32	112.58 a	9.96 e-g	1.49 f	25.13 a-c	183.55 a	19.19 b-d	23.28 c	5.33 b-e
BRRI dhan33	98.28 b	10.99 d-f	1.98 de	25.99 a	152.25 e	17.23 de	25.83 a	5.77 a-c
BRRI dhan39	96.57 b	15.48 b	1.52 f	25.49 ab	116.96 gh	14.42 f	24.00 b	5.64 a-c
BRRI dhan49	94.46 b	13.76 c	3.28 a	22.89 c-e	181.44 ab	20.31 bc	19.78 ef	5.88 ab
BRRI dhan51	84.45 c	10.54 d-g	2.39 c	22.53 de	123.95 g	18.20 c-e	19.83 ef	5.53 a-c
BRRI dhan52	108.34 a	10.89 d-g	1.50 f	25.74 ab	165.34 cd	21.61 b	26.04 a	4.98 c-e
BRRI dhan75	94.63 b	12.08 d	1.86 e	20.51 e	108.45 h	15.73 ef	20.57 d	4.63 d-f
BRRI dhan79	95.35 b	10.40 e-g	1.91 de	23.43 b-d	173.57 bc	28.06 a	24.01 b	4.50 ef
BRRI dhan87	97.13 b	9.34 g	2.07 de	24.13 a-d	163.96 d	17.42 de	20.33 de	4.01 f
Binadhan-11	93.43 b	9.79 fg	2.65 b	22.99 cd	138.72 f	16.27 ef	25.67 a	4.98 c-e
Swarna	97.50 b	17.5 a	2.59 bc	11.91 f	176.10 ab	19.69 b-d	19.03 g	5.08 b-e
LSD	6.12	1.58	0.24	2.43	9.23	2.68	0.59	0.84

Table 4. Growth and yield parameters of Aman local

Variety	Plant height (cm)	Effective tillers/ hill	Non-effective tillers/hill	Panicle length (cm)	Filled grains/ panicle	Un-filled grains/ panicle	1000-grain weight (g)	Straw yield (t/ha)
Bajaldhan	66.20 i	14.85 ab	2.33 cd	25.24 bc	150.36 a	19.53 c	16.41 g	6.10 bc
Balam	71.60h	11.64 cd	1.46 de	25.73 b	108.56 d	8.43 f	21.46 cd	5.35 de
Biroin	115.23c	14.80 ab	1.33 de	24.43 b-d	134.46 b	8.53 f	20.53 d	6.40 bc
Champasuri	100.33e	11.55 c-e	1.60 de	25.56 b	73.23 g	8.96 ef	31.48 a	4.76 e-g
Gaindha	111.23d	12.56 b-d	1.66 c-e	23.86 b-d	126.43 c	19.16 c	19.24 e	5.86 cd
Joria	81.33g	11.31 de	0.85 e	22.00 d	67.80 g	17.76 c	20.99 cd	3.68 h
Kajollota	71.50h	17.07 a	1.86 c-e	26.60 b	121.16 c	12.00 de	17.24 fg	6.75 b
Lalbinni	138.47b	6.00 f	3.66 ab	24.26 b-d	111.23 d	8.67 f	21.66 c	4.31 f-h
Lalbalam	60.36j	13.83 bc	1.26 e	26.33 b-d	135.76 b	6.40 f	24.55 b	6.33 bc
Nonabokhra	92.66f	12.23 cd	2.33 cd	22.50 cd	83.80 f	13.43 d	16.30 g	4.25 gh
Nunia	83.46g	9.23 e	2.66 bc	24.93 b-d	96.70 e	53.43 a	17.15 fg	5.03 ef
Nazirshail	152.12 a	6.72 f	4.40 a	30.95 a	124.39 c	38.62 b	18.23 ef	8.58 a
LSD	2.67	2.36	1.005	2.96	6.75	3.16	1.11	0.72

Non-effective tillers hill^{-1}

The highest non-effective tillers hill^{-1} was recorded in Binadhan-10 (1.62), while the lowest non-effective tillers hill^{-1} was recorded in BRRI dhan29 (0) for HYVs in Boro season (Table 1). In contrast, the maximum number of non-effective tillers hill^{-1} among local genotypes in Boro (Table 2) was found in Begoni (1.86), followed by Jholok (1.13), where the minimum number of non-effective tillers hill^{-1} was found in Kaula (0.33) and Rata (0.35). For HYVs in Aman season (Table 3), BRRI dhan49 (3.28) exhibited the highest number of non-effective tillers hill^{-1} while BRRI dhan32 (1.49) exhibited the lowest number of non-effective tillers hill^{-1} that was identical to BRRI dhan52 (1.50) and BRRI dhan39 (1.52).On the other hand, the maximum number of non-effective tillers was recorded in Nazirshail (4.40), while the minimum number of non-effective tillers was recorded in Joria (0.85) and Lalbalam (1.26) in Aman local landraces (Table 4).

Panicle Length

Among the HYVs in Boro season (Table 1), the highest panicle length was obtained from BRRI dhan92 (27.27 cm), followed by BRRI dhan28 (24.87 cm), whereas the

lowest panicle length was obtained from BRRI dhan 48 (20.28 cm) that was similar to BRRI dhan 88 (21.01 cm). In terms of local Boro rice varieties (Table 2), Kolabinni (25.98 cm) exhibited the maximum panicle length followed by Tepi (23.19 cm), while Lalteer (20.33 cm) exhibited the minimum panicle length which was similar with Jholok (21.66 cm). Regarding the HYVs in Aman season (Table 3), the highest panicle length was recorded in BRRI dhan33 (25.99 cm) that was identical to BRRI dhan52 (25.74 cm), whereas the lowest panicle length was recorded in Swarna (11.91 cm), followed by BRRI dhan75 (20.51 cm). In contrast, Nazirshail (30.95 cm), followed by Kajollota (26.60) showed the highest panicle length, whereas Joria (22 cm) showed the lowest panicle length among the local cultivars in Aman season (Table 4).

Filled grains panicle^{-1}

On the basis of observed data, among the HYVs in Boro season (Table 1), BRRI dhan92 (146.51) exhibited the maximum number of filled grains panicle^{-1} that was identical with BRRI dhan29 (145.07), whereas Binadhan-10 (95.12) exhibited the minimum. On the other hand, the highest number of filled grains panicle^{-1} was observed in Begunbichi (132.70), followed by Rata (120.34), whereas the lowest number of filled grains panicle^{-1} was observed in Begoni (45.26), followed by Black Rice (59.40) in Boro local cultivars (Table 2). Again, in terms of HYVs in Aman season (Table 3), BRRI dhan 32 (183.55) showed the maximum number of filled grains panicle^{-1} followed by BRRI dhan 49 (181.44), while BRRI dhan75 (108.45) showed the minimum number of grains panicle^{-1} that was identical to BRRI dhan39 (116.96). On the contrary, the highest number of filled grains panicle^{-1} was observed in Bajaldhan (150.36) followed by Lalbalam (135.76), while the lowest number of filled grains panicle^{-1} was observed in Joria (67.80) and Champasuri (73.23) for Aman local cultivars. (Table 4).

Number of unfilled grains panicle^{-1}

In terms of HYVs in Boro season (Table 1), the lowest number of unfilled grains panicle^{-1} was recorded in BRRI dhan82 (11.68) which was similar with BRRI dhan85 (12.01), whereas the highest number of unfilled grains^{-1} per panicle was recorded in BRRI dhan84 (41.80). In contrast, Lalteer (7.80) showed the minimum number of unfilled grains panicle^{-1} which was similar to Tepi (9.30) while Begoni (77.46) showed the maximum number of unfilled grains panicle^{-1} followed by Black Rice (27.86) in local Boro rice cultivars (Table 2). Among the HYVs in Aman season (Table 3), the minimum number of unfilled grains panicle^{-1} was obtained from BR11 (14.10) that was similar with BRRI dhan 39 (14.42), whereas the maximum number of unfilled grains panicle^{-1} was obtained from BRRI dhan79 (28.06) followed by BRRI dhan52 (21.61). On the other hand, the lowest number of unfilled grains panicle^{-1} was recorded in Lalbalam (6.40) and Balam (8.43), while the highest number was recorded in Nunia (53.43) followed by Nazirshail (38.62) for local cultivars in Aman season (Table 4).

Thousand grain weight

Among HYVs in Boro season (Table 1), TGW was highest in BRRI dhan92 (32.56 g) followed by BR14 (30.07 g), whereas TGW was lowest in BRRI dhan96 (19.8 g) followed by BRRI dhan88 (21.01 g). In contrast, Begoni (30.27 g) showed the maximum TGW followed by Kolabinni (25.00 g), whereas Begunbichi (12.66 g) showed the minimum TGW followed by Tepi (18.50 g) in Boro local cultivars (Table 2). Among the HYVs in Aman season (Table 3), the highest TGW was obtained from BRRI dhan52 (26.04 g) which was identical to BRRI dhan33 (25.83 g) and Binadhan-11 (25.67 g), whereas the lowest TGW was obtained from Swarna (19.03 g) that was similar with BR22 (19.25 g). On the contrary, the maximum TGW was observed in Champasuri (31.48 g), followed by Lalbalam (24.55 g), where the minimum TGW was observed in Nonabokhra (16.30 g) for the local cultivars in Aman season (Table 4).

Grain yield

In terms of HYVs in Boro season (Fig. 2a), the highest grain yield was observed in BRRI dhan29 (6.11 t ha^{-1}) followed by BRRI dhan28 (5.50 t ha^{-1}) which was similar with BRRI dhan92 (5.50 t ha^{-1}), whereas the lowest grain yield was observed in BRRI dhan82 (3.25 t ha^{-1}) that was identical to BRRI dhan81 (3.32 t ha^{-1}). On the other hand, among the Boro local cultivars (Fig. 2b), Black Rice (4.50 t ha^{-1}) exhibited the maximum grain yield which was similar with Lalteer (4.31 t ha^{-1}), while Begunbichi (2.00 t ha^{-1}) exhibited the minimum grain yield. In terms of HYVs in Aman season (Fig. 2c), the highest grain yield was obtained from BRRI dhan49 (4.59 t ha^{-1}) which was similar with BR22 (4.47 t ha^{-1}) and BR11 (4.41 t ha^{-1}), while the lowest grain yield was obtained from BRRI dhan87 (2.95 t ha^{-1}) that was identical to BRRI dhan75 (3.21 t ha^{-1}). In contrast, Nazirshail (3.17 t ha^{-1}) followed by Kajollota (2.36 t ha^{-1}) showed the maximum grain yield and Joria (1.30 t ha^{-1}) showed the minimum grain yield which was similar with Nonabokhra (1.43 t ha^{-1}) for the local cultivars in Aman season (Fig. 2d).

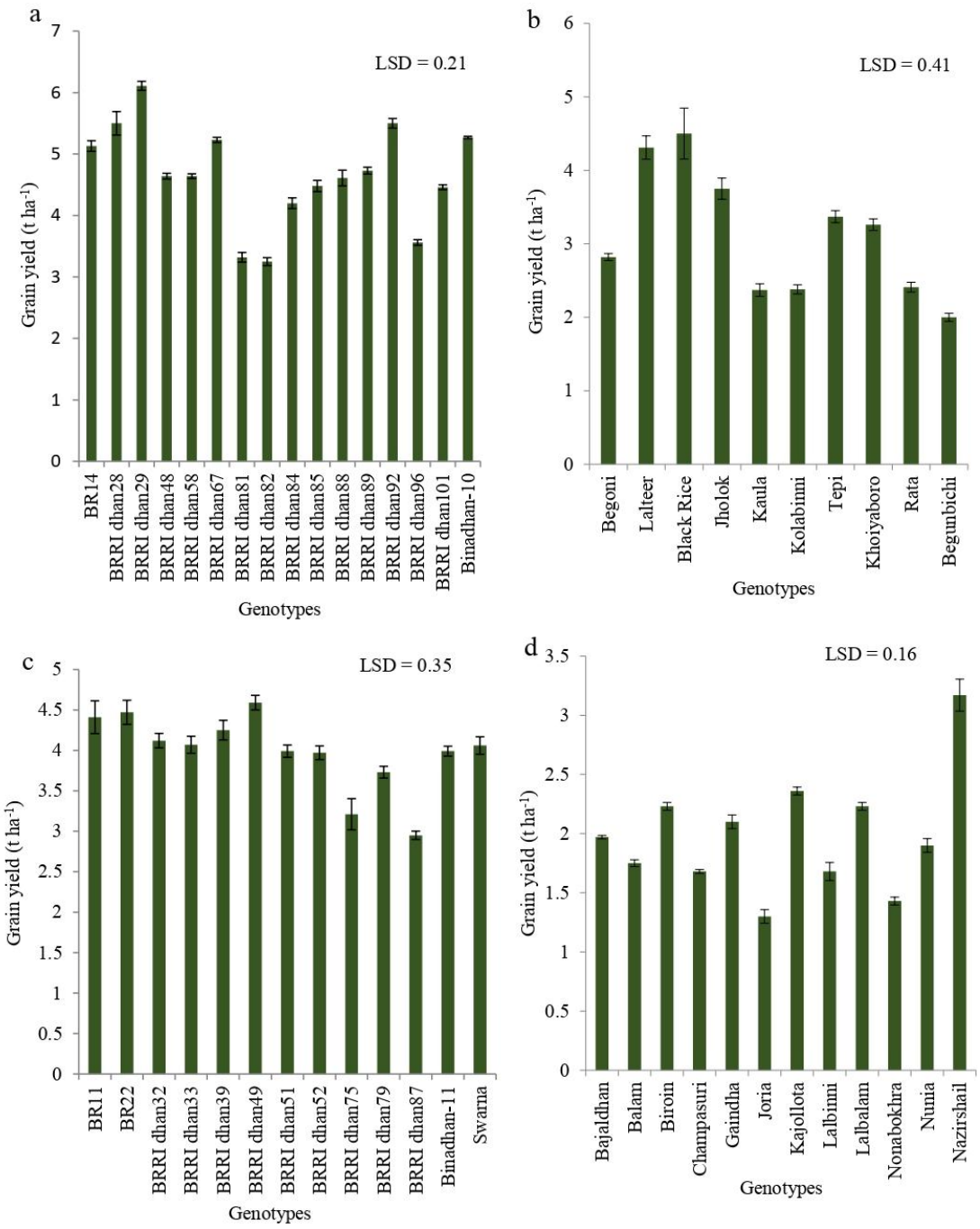

Fig. 2. Grain yield of a) HYVs in Boro, b) Boro local, c) HYVs in Aman, and d) Aman local rice genotypes

Straw yield

Among the HYVs in Boro season (Table 1), the maximum straw yield was recorded in BRRI dhan92 (9.42 t ha^{-1}), whereas the minimum straw yield was recorded in BRRI dhan82 (2.68 t ha^{-1}) followed by BRRI dhan96 (3.49 t ha^{-1}). On the other hand, Lalteer (11.01 t ha^{-1}) exhibited the highest straw yield which was similar with Black Rice (10.59 t ha^{-1}), while Begunbichi (5.32 t ha^{-1}) exhibited the lowest straw yield followed by Kaula (6.75 t ha^{-1}) for local cultivars in Boro season (Table 2). Among HYVs in Aman season (Table 3), the highest straw yield was obtained from BR11 (6.35 t ha^{-1}) while the lowest straw yield was obtained from BRRI dhan87 (4.01 t ha^{-1}). In contrast, Nazirshail (8.58 t ha^{-1}) showed the maximum straw yield, whereas Joria (3.68 t ha^{-1}) showed the minimum straw yield for the local cultivars in Aman season (Table 4).

Principle Component Analysis (PCA)

PCA of 51 rice landraces showed significant variations in 12 selected growth and yield parameters. 60% of the total cumulative variation was obtained from the first

three principal components (Table 5). PC1 and PC2 grouped the landraces based on the overall plant growth and yield parameters. PC1 accounted for 33% of the total cumulative variation where positive associations were found with the days to panicle initiation, days to flowering, days to maturity, plant height, effective tillers hill^{-1} (as indicated by larger positive coefficients) and negative associations were obtained from non-effective tillers hill^{-1}, panicle length, filled grain panicle^{-1} unfilled grains panicle^{-1}, TGW, grain yield, straw yield (Fig. 3). On the other hand, PC2 contributed 47% of the total cumulative variation. Larger positive coefficients were manifested by PC2 for days to panicle initiation, days to maturity, plant height, effective tillers hill^{-1}, non-effective tillers hill^{-1}, panicle length, filled grain panicle^{-1}, straw yield; and negative coefficients were manifested by days to flowering, unfilled grain panicle^{-1}, TGW, grain yield.

Table 5. Component loadings of selected growth and grain parameters of 51 rice landraces as determined by the PCA

Attributes	PC1	PC2	PC3	PC4
Days to panicle initiation	0.12	0.01	-0.40	0.50
Days to flowering	0.02	-0.65	0.04	0.12
Days to maturity	0.30	0.33	0.11	-0.10
Plant height (cm)	0.11	0.44	-0.28	0.21
Effective tillers/hill	0.07	0.18	0.53	0.55
Non-effective tillers/hill	-0.18	0.34	-0.19	-0.35
Panicle length (cm)	-0.28	0.26	-0.09	-0.01
Filled grains/panicle	-0.35	0.18	0.19	0.37
Un-filled grains/panicle	-0.10	-0.12	-0.61	0.30
1000-grain weight (g)	-0.46	-0.08	-0.06	-0.15
Grain yield (t/ha)	-0.45	-0.03	0.10	0.05
Straw yield (t/ha)	-0.47	0.02	0.09	0.09
Individual (%)	**0.33**	**0.14**	**0.12**	**0.10**
Cumulative (%)	**0.33**	**0.47**	**0.60**	**0.70**

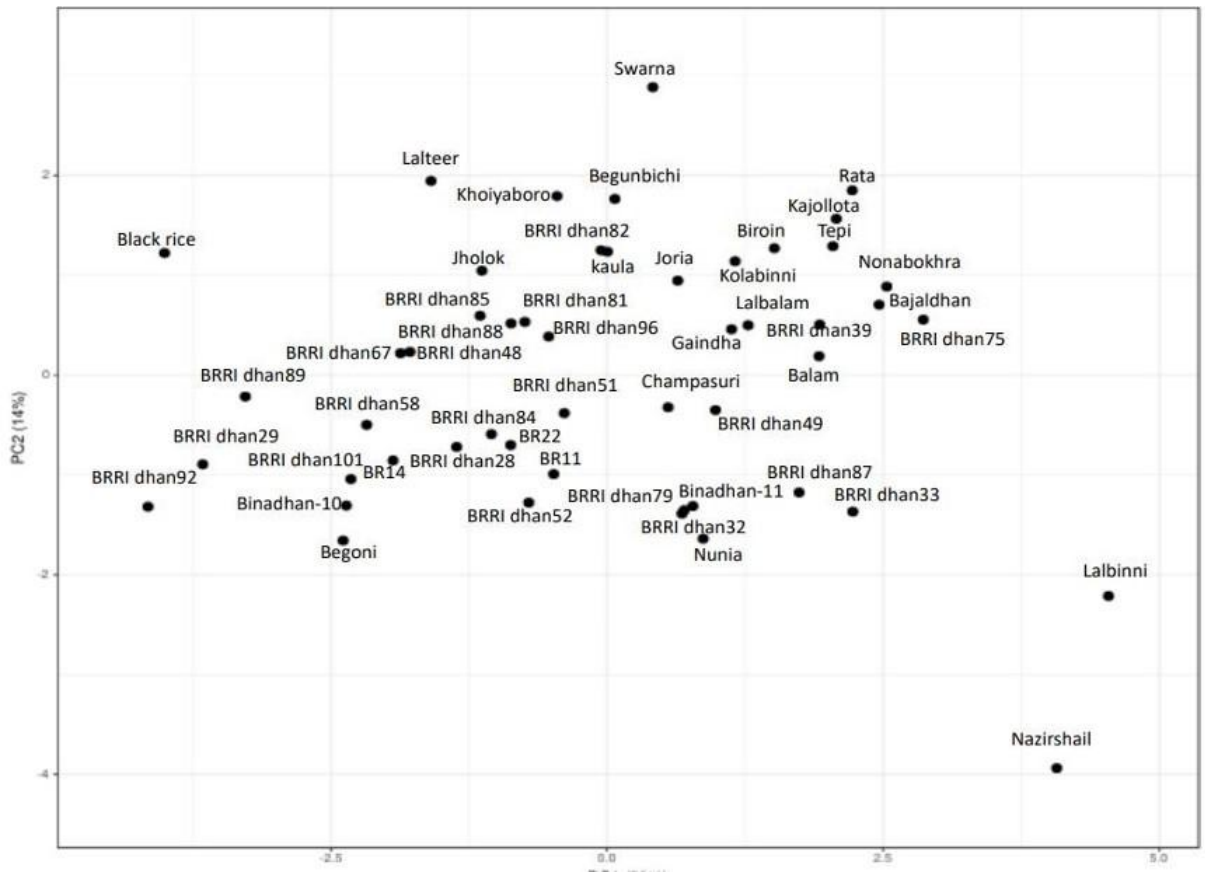

Fig. 3. Score plot of selected growth and grain traits of 51 rice landraces as determined by the PCA. Traits having numerical variation were selected for PCA analysis

Analysis of Variance (ANOVA)

ANOVA was calculated and the mean sum of squares regarding different traits was presented. F test represented significant variation among the genotypes of Boro HYVs (Table 6a), Boro local (Table 6b), Aman HYVs (Table 6c), and Aman local (Table 6d). ANOVA represented whether the variation for different traits was significant or not.

Table 6a. ANOVA for phenology, growth, and yield components of Boro HYVs

Sl. No.	Characters	Mean sum of squares (MSS)		
		Genotype	Replication	Error
1	df	15	2	30
2	Days to panicle initiation	40.27***	49.63***	0.01
3	Days to flowering	370.5	203.2	258
4	Days to maturity	340.1***	0	1.1
5	Plant height (cm)	202.83***	5.71	4.54
6	Effective tillers/hill	5.487***	0.252	1.325
7	Non-effective tillers/hill	0.7018***	0.2061	0.1205
8	Panicle length (cm)	11.571***	0.094	0.384
9	Filled grains/panicle	1086.6***	93.7	145
10	Un-filled grains/panicle	326.4***	11.2	48.9
11	1000-grain weight (g)	35.90***	1.83*	0.35
12	Grain yield (t/ha)	1.9467***	0.0191	0.0167
13	Straw yield (t/ha)	7.7***	0.041	0.092

*Significant at 5% level, **Significant at 1% level, ***Significant at 0.1% level

Table 6b. ANOVA for phenology, growth, and yield components of Boro local

Sl. No.	Characters	Mean sum of squares (MSS)		
		Genotype	Replication	Error
1	df	9	2	18
2	Days to panicle initiation	438.2***	4.1	6.8
3	Days to flowering	255.26***	1.2	2.24
4	Days to maturity	412.6***	3	7.3
5	Plant height (cm)	2113.9***	18.8	26.8
6	Effective tillers/hill	6.674	0.585	3.84
7	Non-effective tillers/hill	0.5921*	0.2172	0.165
8	Panicle length (cm)	6.524***	1.831	0.667
9	Filled grains/panicle	2357.7***	61.7	46.3
10	Un-filled grains/panicle	1220.5***	119.9**	17.3
11	1000-grain weight (g)	63.96***	0.94*	0.26
12	Grain yield (t/ha)	2.2547***	0.0657	0.0593
13	Straw yield (t/ha)	9.161***	0.359	0.446

*Significant at 5% level, **Significant at 1% level, ***Significant at 0.1% level

Table 6c. ANOVA for phenology, growth, and yield components of Aman HYVs

Sl. No.	Characters	Mean sum of squares (MSS)		
		Genotype	Replication	Error
1	df	12	2	24
2	Days to panicle initiation	96.23***	31.29***	0.01
3	Days to flowering	366.2***	0	0
4	Days to maturity	431.3***	0	0
5	Plant height (cm)	185.41***	19.22	13.19
6	Effective tillers/hill	17.353***	0.666	0.876
7	Non-effective tillers/hill	0.8152***	0.1949***	0.0203
8	Panicle length (cm)	41.21***	1.23	2.08
9	Filled grains/panicle	1884.4***	8.3	30
10	Un-filled grains/panicle	39.61***	0.42	2.52
11	1000-grain weight (g)	21.953***	0.059	0.122
12	Grain yield (t/ha)	0.6538***	0.0275	0.0422
13	Straw yield (t/ha)	1.1969***	1.7945***	0.0019

*Significant at 5% level, **Significant at 1% level, ***Significant at 0.1% level

Table 6d. ANOVA for phenology, growth, and yield components of Aman local

Sl. No.	Characters	Mean sum of squares (MSS)		
		Genotype	Replication	Error
1	df	11	2	22
2	Days to panicle initiation	127.30***	2.58	2.8
3	Days to flowering	117.29***	2.03	1.15
4	Days to maturity	165.04***	6.58	3.28
5	Plant height (cm)	2538.4***	0.069	2.5
6	Effective tillers/hill	32.00 ***	1.41	1.95
7	Non-effective tillers/hill	3.243***	0.737	0.352
8	Panicle length (cm)	15.707***	12.513	3.069
9	Filled grains/panicle	2039.3***	10.8	15.9
10	Un-filled grains/panicle	607.0***	0.782	3.5
11	1000-grain weight (g)	55.20***	0.4	0.43
12	Grain yield (t/ha)	0.7419***	0.0146	0.0096
13	Straw yield (t/ha)	5.432***	0.358	0.185

*Significant at 5% level, **Significant at 1% level, ***Significant at 0.1% level

Discussion

Identification and development of short duration high yielding rice varieties could be a significant strategy to achieve proper growth and ultimate production in rice. Phenology refers to the development through different growth stages of a plant (Juskiw et al. 2001). The stages of plant growth from panicle initiation to flowering and from flowering to physiological maturity are crucial for determining yield (Fageria et al., 1997). In the present study, significant variations were observed regarding the phenological traits viz. DPI, DF and DM, which were aligned with Hussain et al. 2014 and Gupta et al. 2022 who also stated that phenological stages differed significantly among rice genotypes. Even those difference affected the ultimate growth, yield and yield components of rice (Ranawake et al. 2014).

Short-duration varieties possess more advantages with a potential crop growth rate and biomass production than longer duration varieties (Xu et al. 2018; Vergara et al. 1966). BRRI dhan84, BRRI dhan85, Tepi, and Rata were short-duration Boro, while BRRI dhan75, BRRI dhan33, and Lalbinni were short-duration Aman rice varieties. Cultivation of these short duration varieties in Sylhet region will result early land vacancy, that will enhance cropping intensity, which is as per with Lima et al. (2021), where they stated that early harvesting of rice resulted early land vacancy with intensive crop cultivation. Samant et al., 2015 reported that longer duration rice genotype could be replaced by shorter duration one due to its better performance regarding with yield contributing characters. In our study, local genotype Nazirshail displayed lower days to maturity (121 days) with better yield (3.17 t ha^{-1}), which could be grown in haor areas of Sylhet.

Plant height is an important crop growth factor which can influence crop architecture, yield-contributing characters and yield (Niu et al. 2021). The term 'green revolution' was mainly associated with development of short stature rice genotype (90–110 cm) that were less susceptible to lodging (Yoshida, 1981). Besides, short stature plant can enhance yield in rice (Sarker et al., 2013). We observed lowest plant height in local genotype Black Rice (82.76 cm) and Lalteer (100.40 cm) with promising grain yield 4.50 t ha^{-1} and 4.31 t ha^{-1} respectively; HYV Boro BRRI dhan29 (99.74 cm) having 6.11 t ha^{-1} yield and HYV Aman BRRI dhan49 (94.46 cm) with 4.59 t ha^{-1} yield.

Rice panicle length is one of the most important yield-related traits (Xiao et al., 1998) that contributes to higher grain yield (Sajid et al. 2015). In our study, BRRI dhan29 and BRRI dhan92 exhibited higher panicle length with higher grain yield (6.11 t $ha^{-1}$and 5.50 t ha^{-1} respectively). Roy et al. (2022) observed similar findings and they found the maximum grain yield in BRRI dhan74 with the highest panicle length. In both cases, positive correlations between panicle length and grain yield were observed. In the present study, BRRI dhan49 and Khoiyaboro showed positive relationship between effective tiller $hill^{-1}$ (13.76 and 14.76 respectively) and higher grain yield (4.59 t ha^{-1} and 3.26 t ha^{-1} respectively). Pachauri et al. (2017) also observed higher effective tiller $hill^{-1}$ determined higher grain yield.

Filled grains $panicle^{-1}$ positively influenced grain yield in rice varieties (Dutta et al. 2002; Kiani and Nematzadeh, 2012). In our experiment, BRRI dhan29, BRRI dhan28, and BRRI dhan32 exhibited a higher filled grains $panicle^{-1}$ and grain yield, which means a positive correlation was present between those traits. BRRI dhan92 showed the highest TGW with grain yield 5.5 (t ha^{-1}). Haque and Biswash (2014) stated that BRRI dhan 29 showed higher TGW (20.9 g) and with maximum biological yield per plant (49.61g) which was similar to our findings. During Boro and Aman season, grain yield was differed

significantly among the rice varieties. BRRI dhan29, BRRI dhan92, and BRRI dhan28 are high-yielding Boro, where BRRI dhan49 is high-yielding Aman rice variety. Sarker et al. (2013) supported our findings and they observed that BRRI dhan28 showed the highest grain yield. These above mentioned high yielding varieties displayed higher grain yield along with better performance regarding most of the growth and yield contributing traits such as effective tiller hill^{-1}, panicle length, filled grains panicle^{-1}, and TGW in this experiment. These results rein accordance with Khatun et al. (2020), who reported that Binadhan-17 exhibited higher growth rate, tiller number, filled grain, 1000 grain weight with promising yield.

PCA is a useful tool for gathering data from strongly correlated parameters (Yano et al., 2019) to assess the relative contribution among the traits for determining the genetic variability (Nachimuthu et al., 2014). In the present study, the first three components contributed 60% variability. Ravikumar et al., 2015 also found 83% variability from the first three components in their experiment. Most of the variability were consolidated in PC1 and PC2 (33% and 47% of total cumulative variability respectively). These findings were supported by Nachimuthu et al. (2014) where they also observed higher cumulative variation from PC1 (28.46%) and PC2 (45.26%).

In conclusion, BRRI Dhan85 (4.48 t ha^{-1}), Tepi (3.37 t ha^{-1}), BRRI dhan39 (4.29 t ha^{-1}) and Nazirshail (3.17t ha^{-1}) are short-duration and high yielding rice varieties/cultivars among Boro HYVs, Boro local, Aman HYVs, and Aman local respectively. Cultivating these high yielding and short-duration rice could help farmers to escape the adverse impact of flash floods in Boro and Aman season and increase the total rice production in the Sylhet region.

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Conflict of Interest

The authors declare that there is no conflict of interest among the authors.

Ethical Standard

The study was conducted with the ethical standard.

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