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GROWTH, YIELD AND NUTRIENT CONTENT BEHAVIOR OF DIVERSE BANGLADESHI RICE CULTIVARS

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Abstract

Rice is the backbone of Bangladesh's agriculture and food security, yet its productivity remains lower than that of other leading rice-producing countries. High-yielding varieties (HYVs) have significantly enhanced grain output which otherwise concerns over declining genetic diversity and nutrient uptake efficiency that necessitates a comparative evaluation of modern and indigenous cultivars. Therefore, a study was done at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh, during Boro season of 2022-2023 to compare the agronomic traits and nutrient content of 30 Bangladeshi rice varieties. The experiment followed a randomized complete block design with three replications. The findings revealed that modern varieties outperformed local cultivars in most of the traits. Notably, the maximum plant height, panicle length, tillers hill^{-1}, grains panicle^{-1}, and 1000-grain weight were recorded in Begunbichi, BR9, Deshi Boro, BR17, and Binadhan-10, respectively. Additionally, BAU dhan3 yielded 68% more grain yield than the low-yielding Begunbichi, while Kalizira produced 49% more straw yield than BR2. The highest content of nitrogen, phosphorus, potassium, and sulfur was observed in BRRI dhan68, BR16, BRRI dhan69, and BAU dhan3, respectively. Findings suggest that while HYVs with superior nutrient content potential serve as valuable genetic resources for yield improvement and local varieties with resilience to environmental stresses could also contribute to breeding programs aimed at enhancing both productivity and sustainability in rice cultivation.

Keywords: Genetic diversity, HYV rice, Nutrient content, Rice yield

1. Introduction

Rice is the second leading cereal crop and a staple food for half of the world's population, contributing to over one-fifth of global calorie intake. Around 90% of the global production, totaling 645 million tons, is cultivated by Asian farmers across 114 countries (FPMU, 2023). In Bangladesh, rice occupies approximately 75% of the total cropped area and more than 80% of the total irrigated land (BRRI, 2024). The global average rice yield is 3.18 t ha^{-1}, with Bangladesh slightly surpassing this at 3.25 t ha^{-1}. However, Bangladesh's yield still lags behind countries like Japan (5.00 t ha^{-1}) and China (4.74 t ha^{-1}) (BRRI, 2023). During Boro season of 2022-23, rice was cultivated on 4.85 million ha in this country, with an estimated yield of 4.28 metric t ha^{-1}, an increase of 2.07% compared to 4.19 metric t ha^{-1} in the previous year (BBS, 23). With the country's population projected to grow from 169 million to 220 million by 2050 (UNFPA, 2022), the importance of enhancing rice production becomes even more critical. Rising population pressures continuously challenge farmers to increase rice yields to meet escalating food demands (Banoc and Garcia, 2020).

The potential for increasing rice production in Bangladesh largely depends on integrating improved crop management practices for different varieties into existing cultivation systems (Chowhan *et al.,* 2017). Variety selection is a key genetic factor that directly influences the growth and yield attributes of rice (Zhang *et al.,* 2022), with each variety possessing unique characteristics and nutritional composition (Shozib *et al.,* 2018). Indigenous rice varieties traditionally yield less (Rahman *et al.,* 2021; Nayak *et al.,* 2022), whereas HYVs, with larger panicles and heavier seeds, achieve higher yields (Wahyuni *et al.,* 2024; Akhter *et al.,* 2023). These varieties also offer additional advantages, including shorter growth cycles, improved tolerance to heat and salinity, and greater resistance to pests (Nayak *et al.,* 2022). As a result, farmers have progressively replaced traditional, low-yielding indigenous varieties with HYVs which provide 20-30% higher yield per unit of land (Chowhan *et al.,* 2017). However, the shift towards HYVs monoculture has led to a notable reduction in rice biodiversity, with a significant number of indigenous varieties disappearing (Dwiningsih, 2023).

Despite lower yields, local rice varieties excel in resilience, resisting biotic and abiotic stresses while maintaining quality traits. Their unique physiology enables adaptation to adverse conditions, ensuring stable yields (Zainol *et al.,* 2023; Islam *et al.,* 2023). Local varieties also retain higher nutrient levels compared to polished HYVs, which lose essential vitamins and minerals during processing (Akhter *et al.,* 2023). Additionally, their distinctive taste and texture are often preferred by consumers, increasing their market demand (Matsue *et al.,* 2024). Furthermore, local rice farming practices promote biodiversity and reduce dependence on chemical inputs (Tonapha *et al.,* 2024). Several studies have shown that indigenous rice cultivars exhibit significant genetic diversity in ecological, morpho-physiological characteristics, nutritional attributes, and disease resistance (Fatamatuzzohora *et al.,* 2023; Krishnan *et al.,* 2023). Though not specifically targeted for stress adaptation, local rice varieties often possess valuable genes against adverse conditions such as cold tolerance and blast resistance (Shanmugam *et al.,* 2024). These traits could be pivotal in varietal improvement programs aimed at increasing resilience and productivity. Indigenous cultivars provide diverse parental selections for enhancing yield components and overall crop characteristics (Velprabakaran *et al.,* 2020). Incorporating the advantageous traits of local varieties into HYVs could significantly boost the productivity of modern varieties. Therefore, a comparative study on the various traits of local and HYV rice is essential. While HYVs have significantly boosted rice yields, the alarming decline in genetic diversity and nutrient uptake efficiency poses a major challenge to long-term sustainability. To address this, the present study comprehensively evaluates the agronomic performance and nutrient uptake of diverse rice cultivars, aiming to enhance productivity while preserving genetic resources for sustainable rice production in Bangladesh.

2. Materials and Methods

2.1 Experimental site and soil properties

The field experiment was conducted at the Field Laboratory of Soil Science Department of Bangladesh Agricultural University (BAU), Mymensingh from December 2022 to April 2023. Geographically, the site is located at 24°43'21"N latitude and 90°25'24"E longitude, with an elevation of 18 meters above sea level. The soil at the experimental site belongs to the Sonatala series within the Old Brahmaputra Floodplain (AEZ-9) (UNDP, 1988). To comprehensively understand the study conditions, the detailed physicochemical characteristics of the soil at the experimental field are outlined in Tables 1.

Table 1. Different properties of initial soil with methods of analyses

Soil properties	Results	Methods
Soil textural class	Silt loam	Hydrometer (Bouyoucos, 1936)
Bulk density (g/cc)	1.35	Cresswell and Hamilton (2002)
pH	6.69	Glass Electrode pH meter (Michael, 1965)
Organic carbon (%)	1.19	Wet oxidation (Walkley & Black, 1934)
Total Nitrogen (%)	0.134	Semi-micro Kjeldahl (Bremner & Mulvaney, 1982)
Available Phosphorus (P) (ppm)	6.57	Olsen (Olsen *et al.* 1954)
Exchangeable Potassium (K) (me%) %	0.077	Amm. acetate extraction (Knudsen *et al*., 1982)
Available Sulfur (S) (ppm)	12.5	$CaCl_2$ Extraction (Williams and Steinbergs, 1959)
Available Zinc (Zn) (ppm)	0.92	Kalambe (2021)

2.2 Experimental design and treatments

Thirty rice varieties (23 BRRI, 3 indigenous, 3 BINA, and 1 BAU) were evaluated as treatments (Table 2) using a randomized complete block design with three replications. Each variety was randomly assigned within blocks, with a single line of 20 hills.

2.3 Crop management

The recommended doses of fertilizers for BAU farm soil was 180 kg N, 24 kg P, 76 kg K, 12 kg S, and 1.5 kg Zn ha^{-1} which were supplied as Urea, TSP, MoP, Gypsum, and Zinc sulfate, respectively (Ahmmed *et al.,* 2018). According to Fertilizer Recommendation Guide-2018, all the fertilizers except urea were applied before transplanting. Urea was applied in three equal splits at 10, 30, and 53 DAT. For better growth and development of rice seedlings, various intercultural operations viz. gap filling, irrigation, weeding, and pest control using Brifer 5G insecticide @ 2 kg ha^{-1}, were accomplished. Depending upon the maturity of each cultivar, 18 hills of each variety were harvested manually, with the produce individually bundled to facilitate precise yield assessment. Grain yield was recorded as t ha^{-1}, adjusted to a 14% moisture basis, and straw yield was determined as t ha^{-1} on a sun-dry basis. Five hills for each variety from each block were taken to measure the yield components.

2.4 Analysis of grain samples

Grain samples, digested with 1.1 g of catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se powder = 100: 10: 1), 3 ml of 30% H_2O_2 and 5 ml of conc. H_2SO_4 was used for the analysis of grain N content and nitric-perchloric acid digested grain samples were used for the determination of P, K, and S contents following standard methods.

2.6 Statistical analysis

The experimental data were analyzed using R programming software (version 4.2.2). Analysis of variance (ANOVA) was performed to determine the significance of treatment effects, and Tukey's Honest Significant Difference (HSD) test was used for pairwise comparisons at the 5% significance level, following the methodology outlined by Gomez and Gomez (1984). Graphical representations of the results were created using the ggplot2 package in R. Moreover, Principal Component Analysis (PCA) was done by the factoextra package.

3. Results

3.1 Growth and yield contributing characters of rice varieties

Statistical analysis showed significant varietal effects on growth parameters (Table 2). Specifically, BRRI dhan50, statistically similar to BRRI dhan59, was the tallest, growing 46% taller than Begunbichi, the shortest variety. Likewise, panicle length varied, ranging from 17.99 cm in BRRI dhan67 to 23.68 cm in BR9. Furthermore, Deshi Boro produced the highest number of tillers, which was 73% more than Kalizira, the lowest producer. However, despite its lower tiller count, Kalizira had the heaviest grains, weighing 48% more than those of Binadhan-10, the lightest.

Table 2. Yield contributing characters of different rice varieties

Varieties	Plant height (cm)	Panicle length (cm)	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	1000- grain weight (g)
BR1	77.1 m	20.0 cdefg	25.0 b	117 abcd	20.6 n
BR2	112.4 c	20.2 cdef	18.3 bcde	116 abcd	20.6 mn
BR3	85.2 ijk	19.9 cdefg	20.0 bcd	116 abcd	25.3 ghi
BR9	118.4 b	23.7 a	17.3 bcde	118 abc	27.0 ef
BR14	103.0 e	20.6 bcdef	19.3 bcd	112 abcde	29.1 c
BR16	84.4 jk	20.4 cdef	19.3 bcd	120 ab	29.0 c
BR17	118.3 b	20.7 bcde	16.0 cde	123 a	29.6 bc
BR18	108.5 cd	20.6 bcdef	17.7 bcde	118 abcd	24.6 hi
BRRI dhan28	83.4 kl	20.4 cdef	18.0 bcde	106 cdefgh	24.7 ghi
BRRI dhan29	83.5 kl	19.7 defg	23.7 bc	110 bcdefg	21.5 lmn
BRRI dhan35	97.0 fg	20.3 cdef	17.0 bcde	108 cdefgh	22.9 jkl
BRRI dhan47	94.8 gh	20.2 cdef	17.7 bcde	108 bcdefg	28.5 cd
BRRI dhan50	73.9 m	21.3 bc	23.7 bc	98 ghij	21.0 mn
BRRI dhan55	88.2 ijk	19.0 fgh	14.7 de	80 klm	27.2 de
BRRI dhan58	95.5 gh	20.1 cdefg	17.3 bcde	107 cdefgh	22.4 kl
BRRI dhan59	75.3 m	18.5 gh	19.0 bcde	88 jkl	21.5 lmn
BRRI dhan60	89.0 ij	21.0 bcd	17.7 bcde	107 cdefgh	25.1 ghi
BRRI dhan67	78.7 lm	18.0 h	15.3 cde	100 efghi	23.2 jk
BRRI dhan68	85.6 ijk	19.6 defg	25.3 b	74 m	24.0 ij
BRRI dhan69	88.5 ijk	19.9cdefg	15.7 cde	100 fghij	24.6 ghi
BRRI dhan74	84.1 jk	19.5 defgh	18.0 bcde	78 lm	30.9 b
BRRI dhan84	87.5 ijk	19.6 defg	14.7 de	110 bcdefg	22.0 klm
BRRI dhan88	84.7 jk	19.5 defgh	14.0 de	96 hij	21.9 klmn
Bindhan-5	102.4 e	22.1 b	15.7 cde	108 cdefgh	31.0 b
Binadhan-6	99.6 efg	20.8 bcd	17.3 bcde	107 cdefgh	26.0 efg
Binadhan-10	90.4 hi	20.5 cdef	19.0 bcde	109 bcdefg	32.4 a
Begunbichi	135.6 a	21.0 bcd	19.7 bcd	91 ijk	22.5 kl
Kalizira	132.4 a	22.1 ab	10.3 e	106 defgh	17.1 o
Deshi boro	104.4 de	19.2 efgh	37.7 a	74 m	25.3 ghi
BAU dhan3	100.8 ef	19.8 cdefg	19.0 bcde	112 abcdef	25.7 fgh
SE (±)	0.93	0.28	1.61	2.19	0.25
CV (%)	1.69	2.42	14.85	3.66	1.73

In a column, values with the same letter (s) or without a letter do not differ significantly ($p<0.05$); SE = Standard error of means; CV = Co-efficient of variation

3.2 Yield comparison among different rice varieties

Statistical analysis showed significant cultivar effects on yield parameters (Fig. 1). BAU dhan3 had the highest grain yield, followed by Bindhan10, both yielding almost 68% more than Begunbichi, which was statistically similar to Deshi Boro. In contrast, Kalizira produced the most straw, yielding nearly 49% more than BR2.

3.3 Nutrient concentration of grains of different rice varieties

The grain samples of various rice cultivars were analyzed for N, P, K, and S concentrations, revealing significant variation between the varieties (Table 3). BRRI dhan68 had the highest N content, 68% more than local varieties. Similarly, BR16 contained the most P, around 71% higher than indigenous cultivars. For K, BRRI dhan69 and BRRI dhan55 had the highest levels, nearly 73% more than local varieties. Finally, BAU dhan3 and Binadhan-10 had the highest S content, approximately 75% greater than indigenous varieties.

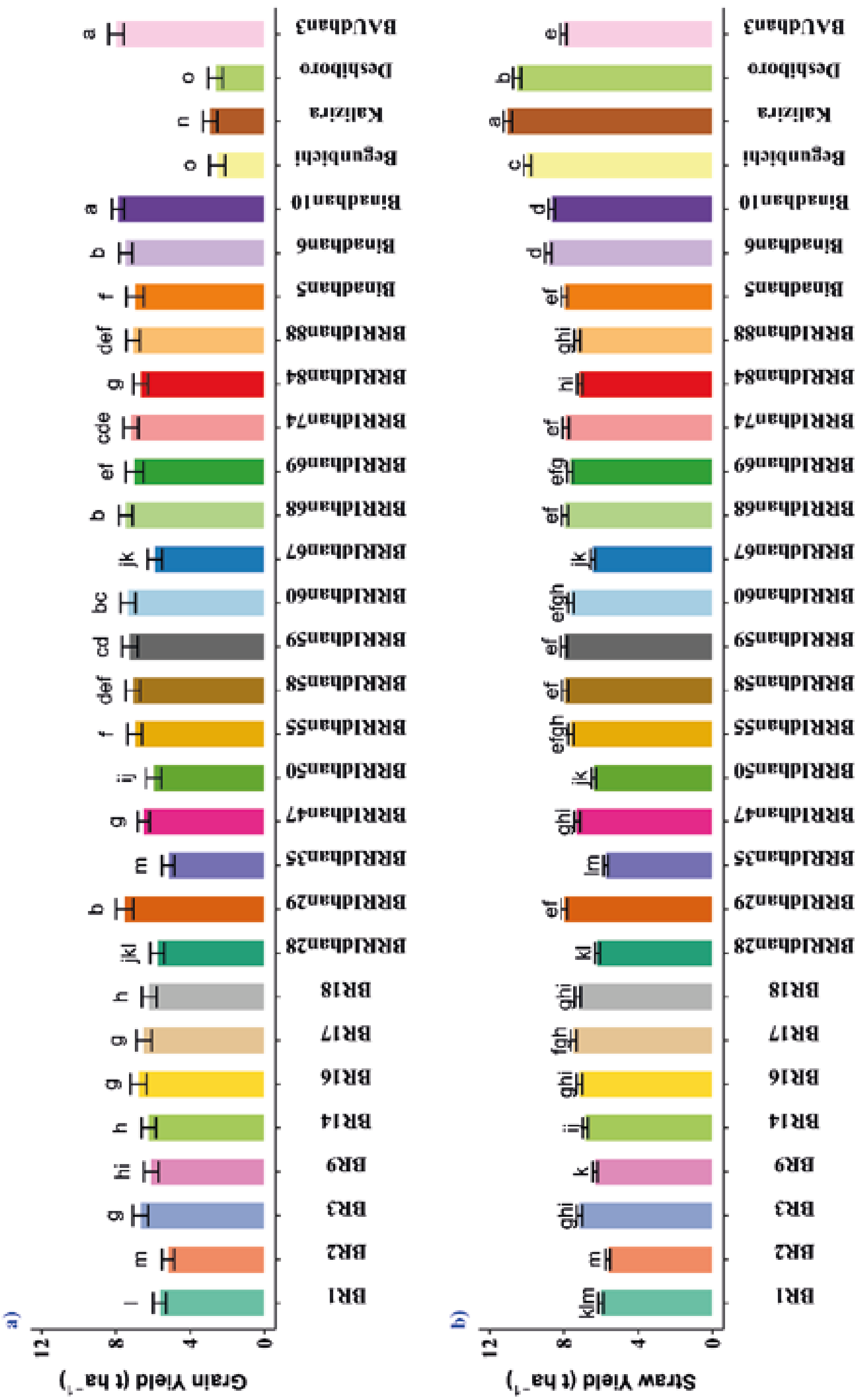

Fig. 1 Yield comparison of different rice cultivars: (a) Grain yield and (b) Straw yield. Data are presented as mean ± SE (n = 3; p<0.05).

Table 3. Nutrient concentration of grains of different rice varieties

Rice varieties	Nutrient content (%)			
	N	P	K	S
BR1	1.46 l	0.25 b	0.23 cdefg	0.33 abc
BR2	1.46 l	0.26 b	0.25 abc	0.33 abc
BR3	1.33 m	0.22 b	0.26 ab	0.33 abc
BR9	1.07 p	0.25 b	0.23 cdefg	0.32 bcde
BR14	1.46 l	0.25 b	0.22 efg	0.31 cdef
BR16	1.56 j	0.32 a	0.25 abc	0.33 ab
BR17	1.30 n	0.16 b	0.21 fgh	0.31 efgh
BR18	1.57 j	0.23 b	0.23 bcdef	0.31 defg
BRRI dhan28	1.68 f	0.25 b	0.26 ab	0.33 ab
BRRI dhan29	1.45 l	0.25 b	0.23 bcdef	0.31 efg
BRRI dhan35	1.50 k	0.22 b	0.22 efg	0.29 hij
BRRI dhan47	1.71 de	0.25 b	0.25 bcd	0.32 bcde
BRRI dhan50	1.72 bcd	0.26 b	0.28 a	0.34 a
BRRI dhan55	1.69 ef	0.25 b	0.25 abc	0.30 fghi
BRRI dhan58	1.51 k	0.22 b	0.17 ij	0.30 ghi
BRRI dhan59	1.64 gh	0.25 b	0.21 efg	0.31 defg
BRRI dhan60	1.23 o	0.23 b	0.20 gh	0.32 bcde
BRRI dhan67	1.73 bc	0.25 b	0.17 ij	0.32 abcd
BRRI dhan68	1.79 a	0.22 b	0.20 gh	0.29 hij
BRRI dhan69	1.60 i	0.25 b	0.25 abc	0.33 abc
BRRI dhan74	1.72 bcd	0.23 b	0.22 defg	0.31 defg
BRRI dhan84	1.72 bcd	0.22 b	0.15 j	0.28 j
BRRI dhan88	1.66 g	0.24 b	0.16 ij	0.29 ij
Binadhan-5	1.57 j	0.23 b	0.18 hi	0.30 fghi
Binadhan-6	1.62 hi	0.25 b	0.17 ij	0.30 fghi
Binadhan-10	1.60 i	0.23 b	0.18 hi	0.31 cdef
Begunbichi	1.74 b	0.24 b	0.18 hi	0.24 kl
Kalizira	1.55 j	0.25 b	0.18 hij	0.23 l
Deshi Boro	1.65 g	0.26 b	0.20 gh	0.25 k
BAU dhan3	1.69 ef	0.25 b	0.21 efg	0.31 defg
SE (±)	0.004	0.003	0.004	0.003
CV (%)	0.41	2.47	3.06	1.57

In a column, the values with the same letter (s) or without a letter do not differ significantly ($p<0.05$); SE = Standard error of means; CV = Co-efficient of variation

4. Discussion

The initial soil analysis indicated that the soil had almost neutral pH, showing a favorable environment for optimal nutrient availability, as supported by Bedada & Abebaw (2020) and Sarah *et al.* (2024). The different rice cultivars exhibited significant variations in growth and yield-contributing traits, aligning with the findings of Chakrabarty *et al.* (2019) and Masud *et al.* (2023). These variations were likely influenced by genetic factors, fertilizer application, and environmental conditions during grain development, which collectively shaped the physicochemical and nutritional properties of the plants, as suggested by Aiswarya & Thomas (2016) and Vanlalrinngama *et al.* (2023).

Among the tested cultivars, BAU dhan3 produced the highest grain yield, with BRRI (2020) reporting over 6 t ha^{-1} during the Boro 2019-20 season. Similarly, it is noted that BAU dhan3 achieved an average yield of 7-8 t ha^{-1}, exceeding BRRI dhan28 by 1-2 t ha^{-1} (Daily Asian Age, 2019). In contrast, local varieties recorded significantly lower yields than HYVs. The yield disparity can be attributed to the superior tillering ability and enhanced nutrient uptake of HYVs, as evidenced by the PCA plot (Fig. 2). The yield disparity can be attributed to the superior tillering ability and enhanced nutrient uptake of HYVs, as evidenced by the PCA plot. These factors contributed to a higher leaf area index (LAI) and improved photosynthetic efficiency, ultimately leading to greater biomass accumulation (Guo *et al.,* 2023). These factors contributed to a higher leaf area index (LAI) and improved photosynthetic efficiency, ultimately leading to greater biomass accumulation (Guo *et al.,* 2023). Additionally, HYVs demonstrated more efficient utilization of water, nutrients, and radiation, resulting in yield improvements of over 30% compared to traditional cultivars (Lu *et al.,* 2022). Moreover, unlike local cultivars, which thrived under specific conditions, HYVs were bred for broader environmental adaptability, enabling them to perform well across diverse ecological zones (Islam *et al.,* 2023).

Similarly, nutrient content and uptake varied significantly among the rice cultivars, primarily due to genetic differences influencing nutrient use efficiency and uptake patterns (Nayaka *et al.,* 2022; Vu *et al.,* 2020). HYVs generally exhibited higher nutrient content, which was attributed to their advanced genetics, efficient nutrient utilization, and breeding strategies aimed at improving grain quality (Sampath *et al.,* 2017; Vu *et al.,* 2020; Akhter *et al.,* 2023).

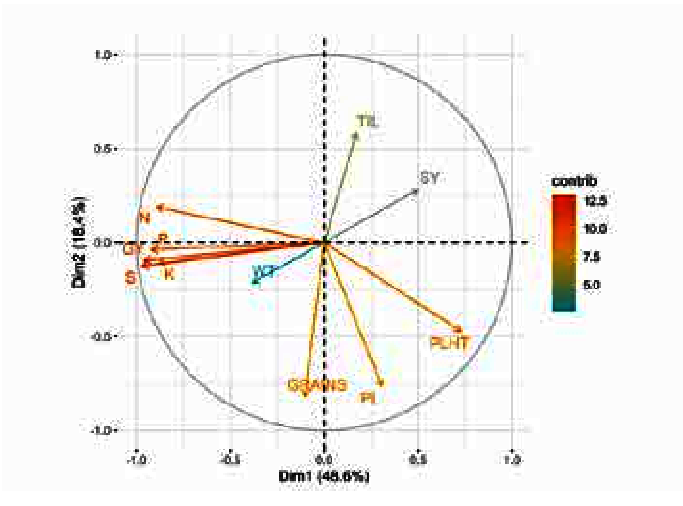

Fig. 2 PCA of growth and yield-contributing traits in different rice varieties (PLHT= Plant height; PL= Panicle length; TIL= No. of effective tillers; GRAINS= Grains panicle^{-1}; WT= 1000-grain weight; GY= Grain Yield; SY= Straw Yield).

5. Conclusions

The growth, yield-contributing traits, and yield of different rice varieties showed significant variation across the varieties. Among the HYVs, BAU dhan3 demonstrated superior performance in terms of yield, nutrient content, and nutrient uptake compared to other varieties, while BRRI dhan29 and BRRI dhan68 outperformed other BRRI cultivars. For local varieties, Kalizira exhibited better yield and yield-related traits, and comparing BINA cultivars, Biandhan-10 showed superior performance. These varieties hold great potential as valuable genetic resources for future varietal development. However, further extensive research with a broader range of cultivars and more parameters across different regions of Bangladesh is recommended to provide stronger data for concrete recommendations.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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