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RESEARCH ARTICLE

Evaluation of Yield and Yield Related Attributes of Selected Black Rice Accessions Under Low Country Wet Zone Conditions in Sri Lanka

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ABSTRACT

Rice plays a major role globally and nationally as a staple food due to its high nutritional value. It has thousands of varieties grown worldwide, showing wide genetic diversity. Black rice is considered a superior food because of its numerous health benefits. However, in Sri Lanka, limited information is available on the agronomic performance and yield potential of black rice. This study evaluated the agronomic and yield-related traits of fourteen black rice accessions grown at the Regional Rice Research and Development Centre, Bombuwela, during the 2022/2023 Maha season. The experiment was conducted as a Randomized Complete Block Design (RCBD) with three replicates. Data were collected at vegetative and reproductive stages, including plant height, culm length, panicle length, productive tiller count, effective panicles per plant, and grain yield. Analysis of Variance (ANOVA) was used, and mean separation was performed using Duncan's Multiple Range Test (DMRT) for data analyses. Results revealed that the tested black rice accession BR 16 v recorded the longest panicle (24.83 cm) and highest culm length (92.53 cm), while BR 58 iii had the lowest plant height (78.6 cm). BR 26 iii produced the highest number of effective panicles per plant. The highest grain yield (2.33 t ha $^{-1}$) was observed in BR 16 v followed closely by BR 11 ii (2.30 t ha $^{-1}$). Correlation analysis revealed non-significant negative relationships between yield and both productive tiller count and effective panicles per plant. Overall, the study identified promising black rice accessions with desirable agronomic traits and yield potential, providing useful insights for future breeding programs in Sri Lanka.

***Keywords**: Agronomic traits, Black rice, Correlation analysis, Genetic variability, Grain yield*

INTRODUCTION

Rice (*Oryza sativa* L.) is the primary food source for more than half of the world's population and plays a crucial role in global food security. In Asia, over 90% of the world's rice is consumed emphasizing its socio-economic and nutritional importance (IRRI, 2013). Developing rice varieties with higher grain yield is one of the major objectives of the rice breeding programmes, particularly under diverse environmental conditions.

Rice exhibits wide genetic diversity with considerable variation in agronomic and yield-related traits among genotypes in Sri Lanka and other rice-growing countries (Arachchi and Wijerathne, 2008; Islam *et al*., 2021; Kumar *et al*., 2022). Among the diverse genetic background of rice types, pigmented rice varieties, especially black rice, have gained increasing attention due to their genetic variability and nutritional importance (Bhuyan *et al*., 2007; Ahmed *et al*., 2023).

Black rice contains high levels of anthocyanin and antioxidant compounds together with essential vitamins, minerals, and dietary fiber, contributing to its functional food value (Zhang *et al*., 2021; Chen *et al*., 2022; Ahmed *et al*., 2023). Due to its nutritional and health-promoting properties, consumer demand for black rice has increased in both local and international markets (Ahmed *et al*., 2023; Zhao *et al*., 2025). Black rice creates opportunities for the development of improved varieties with high yield and quality. Black rice is widely cultivated in several Asian countries and has gained increasing attention due to its nutritional and medicinal value, as well as its unique genetic background among indigenous rice landraces (Chakraborty and Ray, 2019; Ahmed *et al*., 2023).

Despite its importance, the cultivation and improvement of black rice in Sri Lanka are still limited. In particular, under low country wet zone conditions, there is insufficient information on the agronomic performance, yield potential, and adaptability of available black rice accessions. Environmental conditions including rainfall, humidity, temperature, and soil fertility significantly influence rice growth and grain yield performance (Prasanth *et al*., 2020).

However, systematic evaluation of black rice germplasm under these specific conditions has not been adequately addressed. Therefore, there is a clear need to evaluate black rice accessions to identify superior genotypes with better yield performance and adaptability to the low country wet zone of Sri Lanka. Such evaluations are essential for supporting breeding programs aimed at developing high yielding and nutritionally rich black rice varieties suitable for local cultivation. Therefore, the study was conducted to evaluate the agronomic and yield related traits of selected black rice accessions under low country wet zone conditions in Sri Lanka and to identify superior genotypes with high yield potential and desirable agronomic characteristics for future breeding and varietal development programs.

MATERIALS AND METHODS

The experiment was carried out at the Regional Rice Research and Development Centre, Bombuwela, Kalutara, Sri Lanka, during the 2022/23 Maha season. The research centre was located in 6°.57"N latitude and 80°.01"E longitudes and belonging to the agro-ecological zone WL_{1a}. For this study, fourteen well-performing advanced black rice breeding lines such as *BR 11 ii, BR 13 ii, BR 58 iii, BR 61 ii, BR 61 viii, BR 54 ii, BR 47 xii, BR 27 ii, BR 26 iii, BR 13 iii, BR 47 vii, BR 16 iv, BR 61 vi* and *BR 16* v were used. The experiment was conducted using a randomized complete block design (RCBD) with three replicates, where blocks were arranged along a soil fertility gradient to reduce variability among experimental units. Each plot measured 10 m^2, and the seed rate per plot was 115 g. Pre-germinated seeds of each black rice accession were broadcast in the experimental plots and standard agronomic practices were followed as per the recommendations of the Department of Agriculture (DOA, 2013).

Table 1: Evaluated agronomic and yield related characters and their measurement criteria

Character	**Measurement description**
Panicle Length (cm)	Measured from the base to the tip of the panicle at near maturity
Culm Length (cm)	Measured from ground level to the base of the panicle. Average of five culms after heading
Plant Height (cm)	Measured from the base of the plant to the tip of the tallest panicle (excluding awn)
Productive tiller count per plant	Number of tillers bearing panicles
Effective panicles per plant	Number of panicles per plant
Crop yield (t ha^{-1})	Weight of harvested grain per unit area, adjusted to 14% moisture content

(Source : SES, 2014, IRRI) Note : All measurements in the present study were recorded as the average of five randomly selected plants.

Due to logistical and time constraints, the study focused on key agronomic and yield related traits such as plant height, culm length, panicle length, number of productive tillers per plant and grain yield (t/ha) were collected, according to the Standard Evaluation System for rice developed by the International Rice Research Institute (IRRI, 2014). All collected data were analyzed using analysis of variance (ANOVA), and treatment means were compared using Duncan's Multiple Range Test (DMRT). In addition, correlation analysis was performed to determine the relationships among measured variables using SAS version 9.4. Data on agronomic and yield-related characters were recorded from plants within each plot measured 10 m^2, and a central net area was used for data collection after excluding border rows to avoid edge effects. Five plants were randomly selected from the net plot area for recording agronomic traits. Yield was determined from the net plot area and converted to yield per hectare. The measurement procedures for agronomic and yield-related characters are presented in Table 1.

RESULTS AND DISCUSSION

The mean performance of evaluated agronomic and yield related traits of fourteen black rice accessions are presented in Table 2. Significant differences were observed ($p<0.05$) for plant height and culm length, while other traits had non-significant variation.

Table 2: Average mean values of recorded characters of fourteen tested black rice accessions

Entry No	Black rice accessions	Panicle length (cm)	Plant height (cm)	Culm length (cm)	Productive tiller count per plant	Effective panicles per plant	Crop yield (t ha^{-1})
1	*BR 11 ii*	22.53	82.36	75.23^{bc}	2.40	2.00^{b}	2.30
2	*BR 61 viii*	22.36	87.36	79.86^{bc}	1.53	2.13^{b}	1.83
3	*BR 54 ii*	22.53	85.46	76.73^{bc}	2.00	2.13^{b}	1.86
4	*BR 13 iii*	23.16	86.50	78.13^{bc}	2.00	2.20^{b}	1.30
5	*BR 58 iii*	22.26	78.60	70.46^{c}	2.40	2.20^{b}	1.50
6	*BR 26 iii*	22.40	83.70	76.33^{bc}	1.86	3.06^{a}	1.16
7	*BR 47 xii*	23.06	86.00	78.40^{bc}	1.86	2.20^{b}	1.26
8	*BR 13 ii*	22.96	88.83	80.06^{b}	2.00	2.86^{a}	1.93
9	*BR 47 vii*	22.20	82.46	73.20^{bc}	2.00	2.20^{b}	1.36
10	*BR 61 ii*	22.10	82.23	73.53^{bc}	1.80	2.26^{b}	1.46
11	*BR 27 ii*	22.40	81.16	72.90^{bc}	3.00	2.20^{b}	1.20
12	*BR 16 iv*	24.03	86.53	76.93^{bc}	2.06	2.06^{b}	1.16
13	*BR 16 v*	24.83	99.86	92.53^{a}	2.00	2.06^{b}	2.33
14	*BR 61 vi*	23.16	83.86	74.66^{bc}	2.20	2.20^{b}	1.90
CV (%)		5.00	7.46	7.31	29.49	8.03	40.60

Means within each column followed by the same letter are not significantly different at the 5% probability level

CV – Coefficient of Variance

Panicle length (cm)

There was no significant difference between black rice accessions for the panicle length (Table 2). However, the mean panicle length ranged from 22.1 to 24.83 cm during the tested season, with the longest panicle length (24.83 cm) was recorded in *BR 16 v*. Panicle length is an important yield component trait, as it is positively associated with the number of grains per panicle, thereby influencing overall grain yield. A relatively narrow variation in panicle length was observed among the tested accessions. Similar variations in panicle length among rice genotypes were reported by Islam *et al*. (2021) and Kumar *et al*. (2022). Therefore, although *BR 16 v* had the highest panicle length, its contribution to yield should be considered along with other yield components.

Plant height (cm)

Significant differences (p<0.05) were observed for the plant height of the tested entries (Table 2). The highest plant height (99.86 cm) was recorded in *BR 16 v,* while the lowest (78.6 cm) was observed in *BR 58 iii*. The variation in plant height is primarily attributed to genetic differences among accessions, as plant height is a heritable trait influenced by varietal characteristics. Taller plants may have higher biomass production, however, excessive plant height may increase the risk of lodging, which negatively affects grain yield under high rainfall and wind conditions typical of the low country wet zone. Similar variation in plant height among rice genotypes has been reported in recent rice evaluation studies (Kumar *et al*., 2022). Therefore, moderate plant height is considered desirable for achieving a balance between biomass production and lodging resistance.

Culm length (cm)

Culm length had a significant variation (p<0.05) among the tested black rice accessions (Table 2). The highest culm length (92.53 cm) was recorded in *BR 16 v*, while the lowest (70.46 cm) was observed in *BR 58 iii*. Culm length is closely associated with plant height and plays an important role in structural stability. The culm length varied significantly among treatments, with taller plants exhibiting longer culms. Increased culm length contributes to greater plant height but may also increase susceptibility to lodging, particularly under high rainfall conditions. In contrast, shorter culms are generally associated with improved lodging resistance and yield stability in rice (Kumar *et al*., 2022). This observation is consistent with findings reported by Akinwale *et al.* (2011) who noted that culm length plays a key role in determining plant architecture and yield stability in rice. Therefore, selection of accessions with optimal culm length is important for improving adaptability.

Productive tiller count per plant

There were no significant differences (p<0.05) observed among the tested black rice accessions for productive tiller count. However, variation was observed among accessions, indicating genetic diversity. Productive tillers are considered important yield components because they influence panicle production and grain yield in rice (Prasanth *et al*., 2020; Kumar *et al*., 2022).
Despite this, the present study indicated a non-significant relationship between productive tiller count and grain yield, suggesting that higher tiller numbers do not always result in increased yield. This may be due to competition among tillers

for nutrients and assimilates, resulting in reduced grain filling and lower productivity (Prasanth *et al.*, 2020).

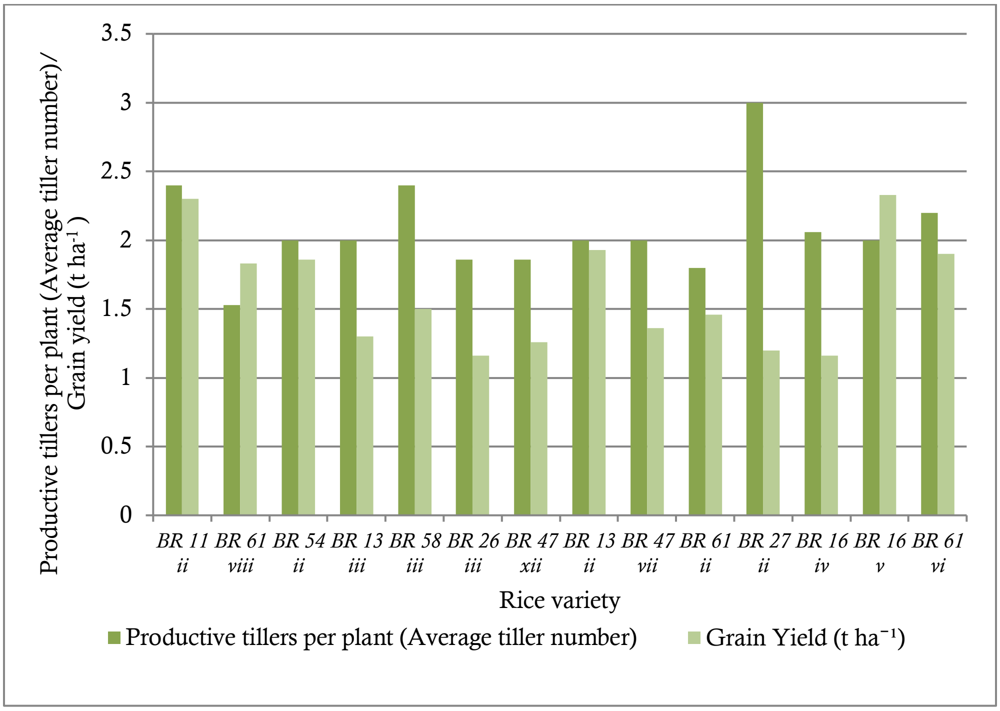

Figure 1: Relationship between productive tiller count per plant and grain yield of the tested black rice accessions evaluated under low country wet zone conditions in Sri Lanka

The relationship between productive tiller count per plant and grain yield is presented in Figure 1. The bar graph indicates a weak association between productive tiller number and grain yield, which is consistent with the non significant correlatin coefficient obtained in the study.

Effective panicles per plant

The number of effective panicles per plant did not show significant variation (p<0.05) among the tested black rice accessions, although *BR 26 iii* recorded the highest value (Table 02). Effective panicles represent the number of panicles contributing directly to grain yield and are considered an important yield determining trait. However, the lack of significant differences and the observed negative correlation with yield suggest that an increase in panicle number alone does not guarantee higher productivity. This may be due to limitations in assimilate partitioning or environmental stress conditions affecting grain filling. Similar findings were reported by Kumar *et al.* (2022), who observed that panicle number alone is not a reliable predictor of grain yield.

Crop yield (t ha^{-1})

Crop yield did not have a significant variation (p<0.05) among the tested black rice accessions (Table 02).

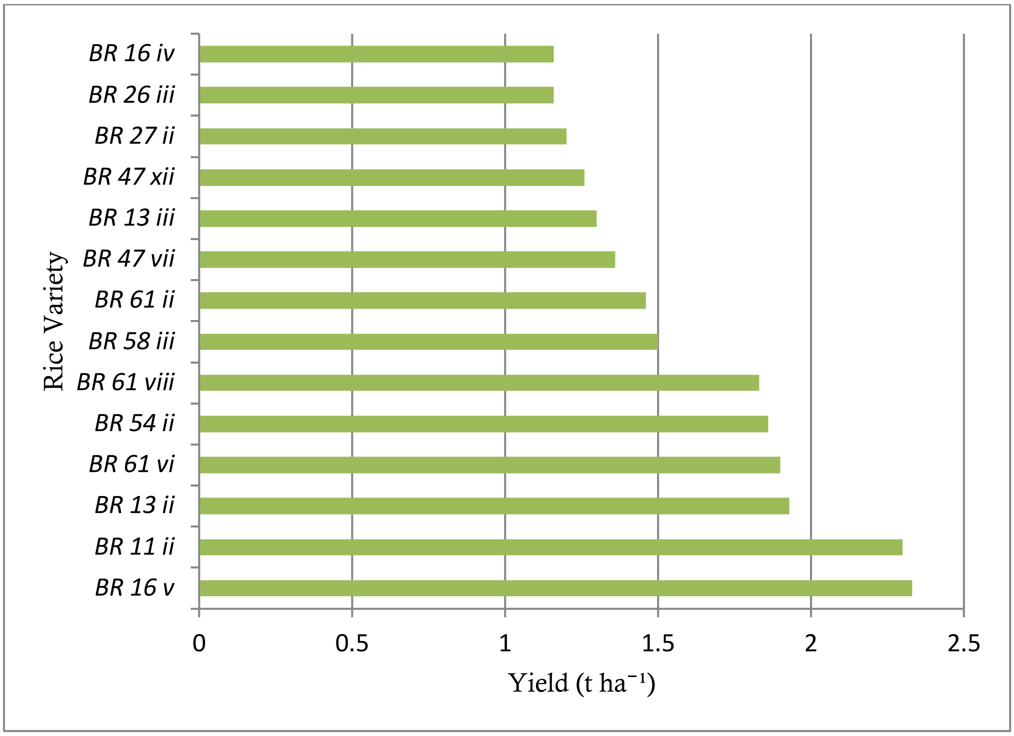

Figure 2: Grain yield (t ha^{-1}) of fourteen black rice accessions evaluated under low country wet zone conditions in Sri Lanka

The highest grain yield (2.33 t ha^{-1}) was recorded in *BR 16 v*, followed closely by *BR 11 ii* (2.30 t ha^{-1}). The lack of significant differences in yield may be due to environmental influences and the complex interaction of multiple yield components. In the present study, the non-significant and negative correlations observed between yield and certain traits indicate that yield performance was not determined by a single component but rather by the combined effect of multiple traits. Grain yield in rice is a complex quantitative trait influenced by multiple yield components and genotype × environment interactions (Kumar *et al.*, 2022). Therefore, accessions such as *BR 16 v*, which had favorable performance in multiple traits, can be considered promising for further breeding programs.

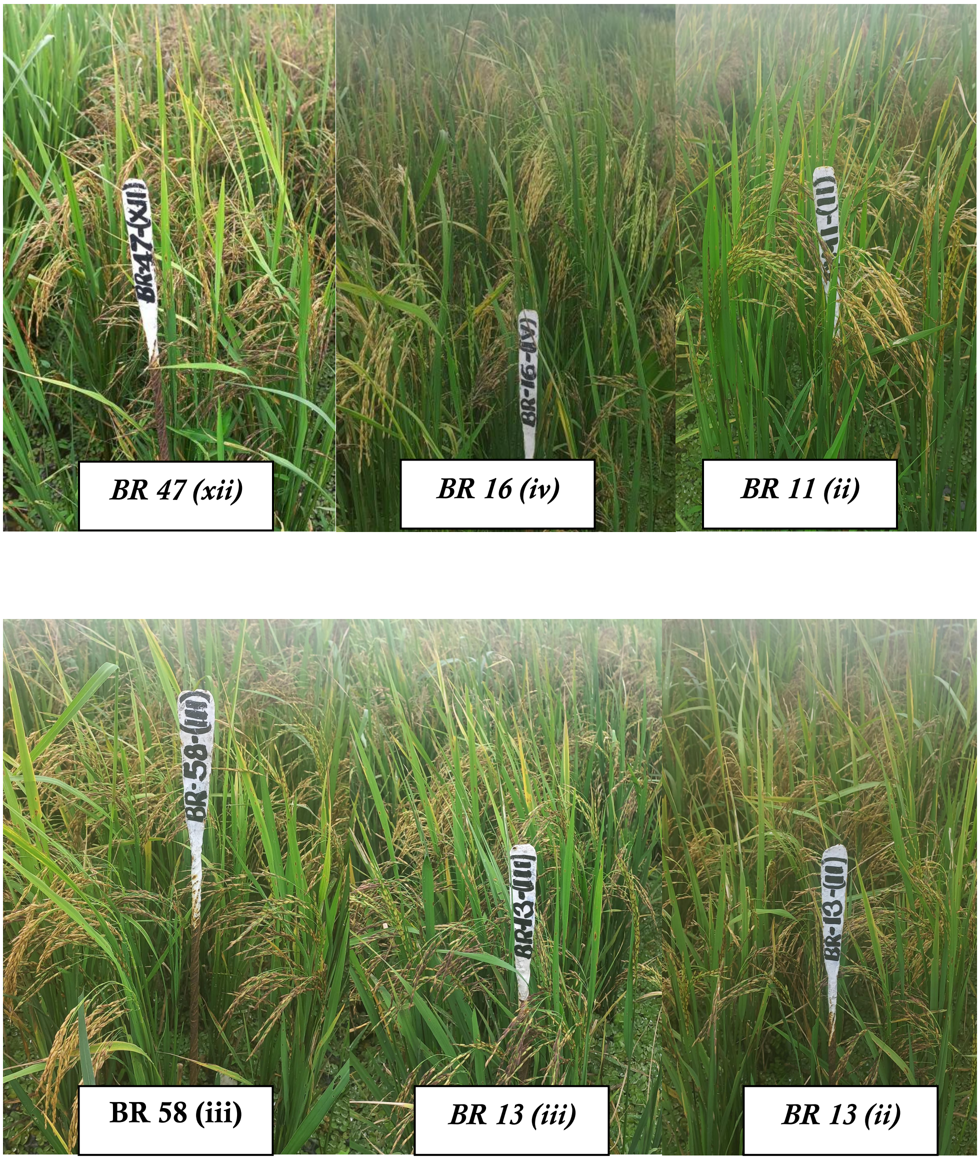

Figure 3: Field performance of tested black rice accessions under low country wet zone conditions in Sri Lanka

Correlation analysis among agronomic traits and grain yield of tested black rice accessions

The correlation analysis revealed non-significant and negative relationship between crop yield and both productive tiller count per plant (-0.018) and effective panicles per plant (-0.004) (Table 3). This indicates that an increase in these traits did not contribute positively to yield under the tested conditions. Such negative or weak associations may result from competition among tillers and limitations in assimilate distribution, leading to reduce grain filling and lower yield performance (Prasanth *et al.*, 2020). In contrast, panicle length (0.245), culm length (0.003), plant height (0.044) had non-significant and positive correlations with yield, suggesting a minor contribution of these traits to yield improvement. Furthermore, panicle length (0.505) and culm length (0.946) had strong positive correlations with plant height, indicating their close association in determining plant architecture. These findings are consistent with recent studies reporting that relationships among yield components vary depending on genotype and environmental conditions (Islam *et al.*, 2021; Kumar *et al.*, 2022). Therefore, grain yield in rice should be considered as a complex trait influenced by multiple interacting factors rather than a single component.

Table 3: Estimation of reproductive characters correlation between yield characteristics and crop yield of tested black rice accessions

Productive tiller count per plant	Panicle length (cm)	Culm length (cm)	Plant height (cm)	Effective panicles per plant	Crop yield (t ha^{-1})
1	0.141	-0.341*	-0.218	-0.153	-0.018
0.141	1	0.34*	0.505***	-0.204	0.245
-0.341*	0.34*	1	0.946***	-0.067	0.003
-0.218	0.505***	0.946***	1	-0.074	0.044
-0.153	-0.204	-0.067	-0.074	1	-0.004
-0.018	0.245	0.003	0.044	-0.004	1

**** Correlation is significant at 0.001 level (two tailed)*
*** Correlation is significant at 0.01 level (two tailed)*
** Correlation is significant at 0.05 level (two tailed)*

CONCLUSION

Among the fourteen tested black rice accessions, the longest panicle length (24.83 cm) was recorded in *BR 16 v*, while the lowest plant height (78.6 cm) and culm length (70.46 cm) were observed in BR 58 iii. Considering effective panicles per plant, *BR 26 iii* recorded the highest value. The maximum crop yield of (2.33 t ha^{-1}) was recorded in *BR 16 v*, followed closely by *BR 11 ii* (2.30 t ha^{-1}), indicating their superior yield potential under the tested conditions.Correlation analysis revealed a non-significant and negative relationship between crop yield and both productive tiller count per plant and effective panicles per plant. This suggests that productive tiller count per plant did not positively contribute to yield improvement in the tested black rice accessions. However, it is important to note that the relationship between yield and its components may vary depending on genotype, environmental conditions, and crop management practices. The evaluated accessions demonstrated favorable agronomic and yield-related characteristics and can be considered as potential genotypes for future varietal development programs. Therefore, the superior accessions identified in this study should be further evaluated and utilized in breeding programs aimed at improving both grain yield and quality.

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