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RESEARCH ARTICLE

Morphological Diversity and Genetic Variability of Selected Rice Accessions (*Oryza Sativa L.)* Cultivated Across Different Seasons in the Low Country Wet Zone of Sri Lanka

D.M.Withanawasam[1*], T.G. Chamalie[2], R.F. Hafeel[3], T.G.I. Sandamalie[4], W.D.P.Weerasinghe[1], H.K.C.H. Kumara[5]

[1]*Regional Rice Research and Development Centre, Bombuwala, Sri Lanka*
[2]*Rice Research Station, Labuduwa, Sri Lanka*
[3]*Horticulture Crop Research and Development Institute, Gannoruwa, Sri Lanka*
[4]*Rice Research Station, Benthota, Sri Lanka*
[5]*Rice Research Station, Ambalanthota, Sri Lanka*

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*Correspondence: witha1974@gmail.com

ABSTRACT

Rice (Oryza sativa L.) is cultivated throughout Sri Lanka under diverse environmental conditions, including the wet zone. Enhancing rice production in this region requires identifying suitable genetic materials with adaptable characteristics. The present study was conducted at the Rice Research Station, Bentota, to evaluate the extent and patterns of morphological diversity among 20 selected rice varieties. The experiment was carried out across two cropping seasons using a Randomized Complete Block Design (RCBD) with five replicates. Morphological variation was assessed using six quantitative traits and fifteen qualitative traits. Results revealed significant seasonal variation in quantitative traits, with leaf length ranging from 25.32 cm -57.20 cm in Maha and 24.14 cm -56.94 cm in Yala, and culm length ranging from 57.74 cm -116.90 cm and 60.44 cm -117.50 cm, respectively, indicating strong genotype × environment interaction. Notably, panicle length, a key determinant of grain number was found to be positively and significantly correlated with leaf length and width, culm length, and culm number, indicating the potential of these traits for indirect selection in breeding programs. Principal Component Analysis identified culm length, leaf length, and panicle length as key traits contributing to variation among genotypes. Therefore, these traits are closely related and contribute similarly to PC1, implying a strong correlation among them. In addition, two diverse major clusters were identified. Overall, considerable morphological variation was observed among the tested rice varieties. The identified diverse genotypes can be utilized in hybridization programme. These, findings are valuable for developing rice varieties adapted to low country wet zone conditions.

Keywords*: Genetic variability, Morphological diversity, Principal Component Analysis, Rice breeding, Seasonal variation*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops and serves as the staple food for more than half of the world's population, playing a critical role in global food security (Jabeen *et al., 2023).* To meet the increasing food demand of a growing population, the development of high-yielding rice varieties is essential. Consequently, numerous improved rice varieties have been developed through breeding programmes worldwide. The success of any plant breeding programme largely depends on the availability and utilization of genetic diversity among cultivated and wild rice germplasm, which provides the foundation for the development of superior cultivars with enhanced yield and stress tolerance (Yang *et al.*, 2024).

Morphological evaluation is a critical initial step in assessing variability and understanding the relationships among rice cultivars (Kumar *et al.*, 2019; Sinha *et al.*, 2021). Studying morphological traits is particularly important for developing high-yielding genotypes tailored to different cultivation practices and seasonal conditions (Li *et al.*, 2019). Rice germplasm represents a valuable reservoir of beneficial genes that breeders can utilize in crop improvement programs (Mackill *et al.*, 2012). Morphological traits are fundamental indicators of genetic variation and play a vital role in germplasm evaluation. These traits aid in germplasm screening and can be used to predict potential genetic gains (Kumar *et al.*, 2019; Wang *et al.*, 2019).

Understanding the genetic diversity among rice varieties is a key tool for breeders in selecting suitable parents for crossing. Parent selection based on genetic diversity tends to yield more promising results in breeding programs (Nivedha *et al.*, 2024). Therefore, the classification of rice genotypes using multiple morphological characteristics is crucial for identifying varietal adaptation and enhancing the evaluation of varieties for potential. Adaptability under different environmental conditions has been widely reported in rice, and genotype × environment interactions play a crucial role in determining the stability and performance of rice genotypes across diverse environments (Lee *et al.*, 2023). Rice is cultivated across both the dry and wet zones of Sri Lanka. However, high-yielding rice varieties introduced to the wet zone often underperform due to a range of unforeseen challenges, primarily abiotic stresses (Flowers and Yeo, 1981; Munns and Tester, 2008; Dasanayake *et al.*, 2023).

Abiotic stresses such as salinity and submergence are major constraints to rice production globally (Munns and Tester, 2008; Ismail *et al.*, 2017). These stresses include flash floods, prolonged waterlogging and adverse soil conditions such as acidity and salinity, which are common in the wet zone. Most of the existing rice varieties were originally bred under different climatic conditions and were not specifically screened for tolerance to these environmental stresses (Dissanayake *et al.*, 2022). Although several studies on iron toxicity tolerance, salinity tolerance, and soil acidity in rice have been conducted in Sri Lanka, comprehensive screening of genotypes under stress prone wet zone conditions remains limited (Ismail *et al.*, 2017). In line with the objectives of initiating a targeted rice breeding programme, existing rice germplasm was evaluated at a model site that represents typical wet zone abiotic stresses. Therefore, the primary aim of this study was to assess the morphological diversity among a selection of local, exotic and traditional rice varieties across different cropping seasons, at both vegetative and maturity growth stages in the wet zone of Sri Lanka. Specifically, the study sought to evaluate quantitative and qualitative morphological traits, determine the extent and pattern of variation and examine the consistency of these traits across seasons.

MATERIALS AND METHODS

The study was conducted at Rice Research Station, Benthota during 2022/2023 *Maha* and 2023 *Yala* season. Based on the experience of cultivation and research in the area, twenty rice accessions representing both improved (07 accessions), traditional (04 accessions) and exotic varieties (03 accessions) and 06 accessions previously evaluated for abiotic stress tolerance were used for the study. Rice accessions used in this study are listed in Table 1. The experiment was conducted in a Randomized Complete Block Design (RCBD) with five replications. Each tested entry was arranged in the research field as three rows of 1.5 m length with spacing of 20 cm between rows and 15 cm between plants, respectively. At twenty-one day old single seedlings were transplanted per hill in well puddled field. Fertigation was applied according to the fertilizer recommendation for rice in Department of Agriculture, Sri Lanka (DOA, 2013). All other cultural and agronomic practices were done according to the recommendations of the DOA, Sri Lanka.

Twenty rice accessions were characterized using agro morphological traits 06 quantitative; leaf length (cm), leaf width (cm), panicle length (cm), ligule length (cm), culm length (cm), culm number and 15 qualitative traits (leaf blade pubescence, blade colour, basal leaf sheath colour, leaf angle, flag leaf angle, ligule colour, ligule shape, collar colour, culm angle, internode colour, culm strength, panicle type, panicle exertion, panicle axis, grain awning) based on Standard Evaluation System for rice developed by the International Rice Research Institute, (2014). For each tested entry, five randomly selected plants were used to collect data on their respective characteristic. The data were analyzed using ANOVA and mean separation was done by Duncan's multiple range test (DMRT) using SPSS, 22 version. Principal Component Analysis and hierarchical cluster analysis were performed by SPSS (22 version).

Table 1: Important characteristics of tested entries

Serial Number	Tested rice accessions	Varietal special characteristics	Reference
1	*Bg 300*	Adaptable to the wet zone, high yielding, white pericarp intermediate bold grains	DOA, 2024
2	*Bg 366*	High yielding, suitable for general cultivation, white pericarp intermediate bold grains	DOA, 2024
3	*Bg 455*	Suitable for water logging conditions, red pericarp intermediate bold grains	DOA, 2024
4	*Bw 163*	Suitable for anerobic germination	RRRDC, 2023
5	*Bw 267-3*	Suitable for low country wet zone, iron toxicity tolerant, white pericarp intermediate bold grains, good grain quality	DOA, 2024
6	*Bw 312*	90 days age, suitable for general cultivation, adaptable to wet zone, red pericarp intermediate medium grains, stay greenness, good architecture	Weerasinghe *et al.*, 2020
7	*Bw 372*	Tolerant to iron toxicity, red pericarp intermediate medium grains, adaptable to wet zone	DOA, 2024
8	*Bw 400*	120 days age, suitable for saline and acidic soil, red pericarp intermediate bold grains, submergence tolerence	Shyamalee and Ranawake, 2023; DOA, 2024
9	*Devaraddari*	Moderately tolerant to submergence, red pericarp	RRRDC, 2024
10	*Goda heenati*	Moderately tolerant to submergence, good health properties	Shyamalee and Ranawake, 2023
11	*Kahata wee*	Iron toxicity tolerent	Siriwardana *et al.*, 2019
12	*Karamana*	Traditionally known for submergence tolerance	RRRDC, 2024

13	*IR 07F 291*	Contains the sub 1 gene	Xu *et al.*, 2006
14	*IR 64*	Developed root system	Mackill *et al.*, 2018
15	*IRRI 119*	Submergence tolerant	Mackill *et al.*, 2012
16	*Ld N2B4*	Tolerant to salinity	Millawithanach-chi *et al.*, 2022; RRRDC, 2024
17	*Ld S1F3-2*	Tolerant to salinity	Millawithanach-chi *et al.*, 2022; RRRDC, 2024
18	*Ld S2B7*	Tolerant to salinity and submergence	Millawithanach-chi *et al.*, 2022; RRRDC, 2024
19	*Ld SS-3-26-2*	Tolerant to salinity	Millawithanach-chi *et al.*, 2022; RRRDC, 2024
20	*Ld SS 4-4*	Tolerant to salinity	Millawithanach-chi *et al.*, 2022; RRRDC, 2024

RESULTS AND DISCUSSION

Character variability among the tested rice accessions

Agro-morphological characterization of rice varieties is fundamental for assessing genetic diversity, identifying desirable traits, and providing essential information for plant breeding programmes and germplasm conservation (Yadav *et al.*, 2024). The results of quantitative characters are shown in Table 2.

Leaf size

In this study, significant seasonal and varietal differences in leaf size were observed. In the 2022/2023 *Maha* season, the leaf length ranged from 25.32 cm to 57.2 cm and *Devaraddari* (traditional variety) had the longest leaves (57.2 cm). The leaf length of improved local varieties ranged between 37.2 cm and 47.86 cm while exotic varieties had shorter leaves and thus lower photosynthetic area. In the 2023 *Yala* season it ranged from 24.14 cm to 56.94 cm. *Bw 400* (local improved variety) had the highest leaf length (56.94 cm). Leaf size, particularly the length and width of the upper three leaves, plays a vital role in determining the photosynthetic capacity and grain yield of rice (Wang *et al.,* 2019; Sinha *et al.,* 2021). Larger leaves contribute to greater leaf area and biomass accumulation, enhancing plant growth and yield potential.

Leaf width of entries in 2022/2023 *Maha* ranged from 0.76 cm –1.72 cm while in 2023 *Yala* ranged from 0.66 cm –1.58 cm. *Ld SS 4-4* recorded the widest leaves (1.72 cm), significantly higher than the others. According to Wei Huan-he *et al.* (2020), increased leaf length and width improved photosynthetic efficiency and biomass accumulation. Erect leaf orientation was also associated with higher grain yield, particularly under favorable growing conditions.

Ligule length

In the 2022/2023 *Maha* season, significant differences in ligule length were observed among the tested rice entries. The shortest ligule length was recorded in the accession *Ld S1F3-2*, with a value of 0.40 cm. A similar trend was observed in the 2023 *Yala* season, where the same accession recorded an even lower ligule length of 0.28 cm (Table 2). It supports the variety of escaping from foreign materials. The ligule plays an important role in protecting the leaf sheath and stems from environmental elements such as water, dust, and pathogens. By keeping the sheath closed, the ligule acts as a physical barrier, reducing the risk of disease and mechanical damage. Additionally, ligule length can influence the angle of leaf orientation, which affects light interception and, consequently, photosynthetic efficiency. Plants with longer ligules may be better positioned to capture sunlight, enhance photosynthesis and overall plant vigor (Tanaka *et al.*, 2022).

In contrast, the traditional rice variety *Kahata Wee* exhibited the highest ligule length in both seasons as 2.08 cm in the 2022/2023 *Maha* season and 1.70 cm in the 2023 *Yala* season. The longer ligule of *Kahata Wee* may contribute to its improved leaf orientation and enhanced disease resistance. This trait could partly explain its reputed tolerance to diseases such as blast, making it a valuable genetic resource for breeding disease-resistant rice varieties.

Culm length

A significant interaction was observed between variety and season for culm length. In the 2022/2023 *Maha* season, culm length ranged from 52.74 cm (*Bw 312*) to 116.90 cm (*Devaraddari*). In the 2023 *Yala* season, it ranged from 60.44 cm (*IR 64*) to 117.50 cm (*Devaraddari*). Notably traditional varieties such as *Devaraddari*, *Kahata Wee*, and *Goda Heenati* consistently showed greater culm length across both seasons. A strong and stable culm is essential for rice plants to resist lodging caused by environmental stresses like wind, which can severely reduce grain yield. Lodging (stem collapse) can cause yield losses up to 80% (Wang *et al.*, 2019; Sinha *et al.*, 2021). Most of the traditional rice varieties are lodging susceptible. It might be higher in length and lower in diameter and probably lower cellulose level in the culm.

Culm number

In the 2022/2023 *Maha* Season significant varietal differences were observed in culm number. Improved varieties, i.e., *Bw 312 and Bw 400* recorded the highest culm numbers (6.2). Traditional varieties (*Devaraddari*: 3.8, *Karamana (Red)*: 3.4) had the lowest tiller counts. In the 2023 *Yala* Season, Overall culm numbers increased compared to *Maha*. *Bw 312* again had the highest tillering with 8.6 culms, highlighting its strong vegetative vigor. An increase in culm number (tillers) can enhance rice yield by increasing the number of panicles per plant and improving the plant's ability to utilize sunlight and nutrients effectively (Silva *et al.*, 2022). Rice is a facultative short-day plant, and its photoperiod sensitivity affects key developmental traits like tillering and flowering. Environmental cues (e.g., day length, temperature) interact with genetic factors to influence culm number, explaining seasonal variations (Yano, 2001).

Panicle length

A significant difference in panicle length was observed between the 2022/2023 Maha and 2023 Yala cropping seasons. The traditional variety *Kahata Wee* consistently had the longest panicles; 34.2 cm in 2022/2023 *Maha* and 33.56 cm in 2023 *Yala*. The lowest panicle lengths were recorded by exotic varieties such as *IR 07F291* (22.02 cm) in 2022/2023 *Maha* and *IRRI 119* (22.68 cm) in 2023 *Yala*. Wang *et al*. (2019) and Sinha *et al*. (2021) reported that longer panicles and extended grain filling duration contribute to higher yield through greater dry matter accumulation, especially in favorable environments. The observed variation in panicle length is attributed to genotype × environment interaction (G×E), which complicates selection in breeding programs (Kumar *et al*., 2019). Panicle length is a key trait in rice breeding due to its direct impact on grain number and overall yield (Wang *et al.,* 2019; Sinha *et al.,* 2021). Varieties with longer panicles generally produce more grains, making this trait a major focus in varietal improvement programs.

Table 2: The mean values of quantitative traits of tested varieties

Varieties	Quantitative Characteristics											
	Leaf length (cm)		**Leaf width (cm)**		**Ligule length (cm)**		**Culm length (cm)**		**Culm Number**		**Panicle length (cm)**	
	2022/23 Maha	***2023Yala***	***2022/23 Maha***	***2023 Yala***	***2022/23 Maha***	***2023 Yala***	***2022/23 Maha***	***2023 Yala***	***2022/23 Maha***	***2023 Yala***	***2022/23 Maha***	***2023 Yala***
Bg 300	37.20^{efgh}	40.84^{efgh}	1.14^{cde}	1.40^{bc}	0.64^{efg}	0.98^{ef}	67.60^{hij}	75.60^{gh}	4.00^{ef}	5.60^{bcd}	23.32^{def}	28.12^{bc}
Bg 366	47.86^{b}	49.40^{bcd}	1.06^{def}	1.08^{fgh}	0.72^{ef}	1.02^{ef}	75.50^{efg}	71.20^{hi}	4.60^{bcdef}	5.40^{bcde}	26.76^{c}	24.26^{efg}
Bg 455	37.60^{efgh}	36.82^{ghi}	0.84^{ghi}	0.82^{jk}	1.14^{c}	1.14^{de}	73.40^{fgh}	64.40^{jk}	5.00^{abcde}	4.80^{cde}	25.90^{cde}	25.90^{cde}
Bw 163	35.00^{gh}	40.26^{fghi}	1.30^{bc}	1.10^{efg}	0.58^{fgh}	1.02^{ef}	65.92^{ijk}	71.90^{hi}	4.00^{ef}	4.40^{cde}	25.18^{cdef}	25.20^{defg}
Bw 267-3	47.20^{bc}	48.60^{bcd}	0.78^{hi}	0.80^{jk}	0.96^{cd}	1.32^{cd}	83.40^{d}	89.40^{d}	4.60^{bcdef}	5.00^{cde}	26.54^{cd}	24.60^{defg}
Bw 312	45.80^{bcd}	37.60^{ghi}	0.96^{efghi}	1.30^{bcd}	1.12^{c}	0.68^{g}	52.74^{l}	68.50^{ij}	6.20^{a}	8.60^{a}	23.84^{cdef}	24.50^{defg}
Bw 372	40.40^{defg}	40.26^{fghi}	1.12^{cdef}	0.66^{k}	0.80^{de}	1.28^{cd}	78.60^{def}	89.24^{d}	4.20^{def}	6.80^{b}	24.54^{cdef}	25.90^{cde}
Bw 400	43.44^{bcd}	56.94^{a}	1.02^{efg}	1.12^{defg}	1.06^{c}	1.48^{bc}	71.40^{ghij}	85.52^{de}	6.20^{a}	5.00^{cde}	25.42^{cde}	25.62^{cdef}
Devaraddari	57.20^{a}	53.10^{ab}	1.02^{efg}	1.06^{fghi}	0.96^{cd}	0.96^{ef}	116.90^{a}	117.50^{a}	3.80^{ef}	4.60^{cde}	24.76^{cdef}	23.72^{efg}
Goda heenati	34.44^{h}	33.84^{i}	0.92^{fghi}	0.86^{j}	0.58^{fgh}	1.20^{de}	104.00^{b}	105.80^{b}	4.20^{def}	4.60^{cde}	25.36^{cde}	25.20^{defg}
IR 07F291	37.60^{efgh}	44.20^{def}	0.98^{efgh}	1.34^{bc}	0.56^{fgh}	0.72^{g}	71.80^{ghi}	79.62^{fg}	4.40^{cdef}	5.60^{bcd}	22.02^{f}	27.00^{cd}
IR 64	25.32^{i}	24.14^{j}	0.76^{i}	0.88^{ij}	1.54^{b}	1.50^{bc}	60.04^{k}	60.44^{k}	5.20^{abcde}	5.00^{cde}	22.62^{ef}	23.12^{fg}
IRRI 119	27.76^{i}	35.04^{hi}	1.04^{defg}	0.90^{hij}	0.98^{cd}	0.86^{fg}	78.80^{def}	75.64^{gh}	5.60^{abcd}	6.00^{bc}	25.20^{cdef}	22.68^{g}
Kahata wee	56.64^{a}	50.96^{bc}	1.40^{b}	1.22^{cdef}	2.08^{a}	1.70^{ab}	106.80^{b}	104.20^{b}	5.80^{abc}	5.60^{bcd}	34.20^{a}	33.56^{a}

Karamana	36.20^{fgh}	36.84^{ghi}	1.00^{efg}	1.28^{bcde}	0.80^{de}	0.42^{h}	74.60^{fg}	88.74^{d}	3.40^{f}	5.40^{bcde}	23.42^{cdef}	24.26^{efg}
Ld N2B4	36.88^{efgh}	37.06^{ghi}	1.24^{bcd}	1.42^{ab}	1.80^{de}	1.46^{c}	65.04^{jk}	75.42^{gh}	4.20^{def}	5.20^{bcde}	23.54^{cdef}	24.64^{defg}
Ld S1F3-2	34.50^{h}	46.78^{cde}	1.10^{cdef}	1.32^{bc}	0.40^{h}	0.28^{h}	83.78^{d}	85.72^{de}	4.80^{bcdef}	5.60^{bcd}	26.28^{cd}	29.54^{b}
Ld S2B7	42.00^{cde}	35.44^{ghi}	1.36b	1.30^{bcd}	0.48^{gh}	1.90^{a}	92.10^{c}	80.60^{efg}	6.00^{ab}	4.20^{de}	30.18^{b}	27.02^{cd}
Ld SS 3-26-2	41.10^{def}	41.92^{efg}	1.06^{def}	0.96^{ghij}	0.96^{cd}	0.96^{ef}	81.56^{de}	82.44^{ef}	4.80^{bcdef}	4.60^{cde}	23.80^{cdef}	23.96^{efg}
Ld SS 4-4	35.36^{gh}	36.18^{ghi}	1.72^{a}	1.58^{a}	0.94^{cd}	1.12^{de}	82.26^{d}	94.72^{c}	4.80^{bcdef}	3.80^{e}	26.16^{cd}	25.04^{defg}
CV (%)	9.83	10.90	13.30	11.86	15.65	15.24	5.97	4.86	19.92	21.47	8.61	6.87

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

CV – Coefficient of Variance

Table 3: Correlation coefficients between each quantitative values of the tested varieties in different cropping seasons

Characters		**Leaf length (cm)**		**Leaf width (mm)**		**Ligule length (mm)**		**Culm length (cm)**		**Culm Number**		**Panicle length (cm)**	
	Season	***2022/23 Maha***	***2023 Yala***	***2022/23 Maha***	***2023 Yala***	***2022/23 Maha***	***2023 Yala***	***2022/23 Maha***	***2023 Yala***	***2022/23 Maha***	***2023 Yala***	***2022/23Maha***	***2023 Yala***
Leaf length (cm)	*2022/23 Maha*			0.168		0.232*		0.564***		-0.031		0.387***	
	2023 Yala				0.129		0.063		0.429***		-0.013		0.357***
Leaf width (mm)	*2022/23 Maha*					-0.012		0.167		0.008		0.292**	
	2023 Yala						-0.139		0.029		0.008		0.270**
Ligule length (mm)	*2022/23 Maha*							0.081		0.251*		0.283**	
	2023 Yala								0.044		-0.204*		0.110
Culm length (cm)	*2022/23 Maha*									-0.067		0.469***	
	2023 Yala										-0.156		0.210*
Culm Number	*2022/23 Maha*											0.284**	
	2023 Yala												0.018

Relationship of morphological traits with grain yield related traits

The correlations of important traits that contribute to grain yield are shown in Table 3. Generally, panicle length is strongly associated with grain yield due to its direct effect on the number of spikelets. In the present study, culm number (2022/2023 *Maha*: 0.284; 2023 *Yala*: 0.018), leaf length (*Maha*: 0.387; *Yala*: 0.357) and leaf width, ligule length, and culm length in both seasons were positively correlated with panicle length. The results indicate that longer panicles and taller plants often carry more grains. Higher culm number results in more panicles per plant, boosting grain yield. Improved varieties like *Bw 312* had higher tillering, particularly in the *Yala* season. Leaf length positively correlated with panicle length, culm length, and leaf width but negatively correlated with culm number, indicating a potential trade-off. Leaf width is moderately correlated with other yield traits and photosynthetic capacity. Ligule length indirectly affects photosynthesis by influencing leaf orientation exhibited low to moderate positive correlations with leaf length, culm length, and panicle length, which may contribute to light interception efficiency and stress tolerance. Grain yield in rice is a complex trait influenced by multiple morphological and physiological characteristics, including panicle length, culm number, leaf traits, and ligule length. These traits are controlled by quantitative genes and are also shaped by environmental conditions (Wang, 2012).

Morphological characterization of rice genotypes using qualitative traits

This study evaluated 20 rice accessions, including improved, traditional, exotic, and abiotic stress-tested lines, using 15 qualitative morphological descriptors. The evaluation was carried out following the Standard Evaluation System for rice developed by the International Rice Research Institute (IRRI, 2014), which provides standardized guidelines for morphological characterization and trait scoring. Among qualitative leaf blade traits, leaf blade pubescence (85% intermediate, 15% glabrous), basal leaf sheath color (100% green), leaf angle (75% intermediate, 25% erect) and flag leaf angle (90% erect, 10% intermediate) are very important traits for plant breeding (Table 4). Leaf pubescence plays an important role in reducing thrips infestation and contributes to improved drought tolerance in rice (O'Toole and Cruz., 1980; Heinrichs *et al.*, 1985). All entries exhibited white ligules with variation in ligule shape, where 65% were of the split type and 35% were acute to acuminate. Ligule shape is an inherent character for varietal identification. Culm traits like culm angle had 35% erect, 55% intermediate, 10% open among entries. Variation in internode color was observed among the tested rice accessions. This may be associated with genetic differences and can serve as a useful morphological marker for varietal identification (Subba Rao, 2013). According to Subba Rao, (2013), these qualitative traits serve as morphological markers, valued for their stability across environments. Qualitative characters are important with respect to the characterization of rice cultivars, because they are less influenced by environmental changes (Subba Rao, 2013; Kalyan *et al.*, 2017).

Culm strength representing lodging resistance can be categorized as 50% strong, 30% moderately strong, 20% intermediate among varieties. The best panicle type is the intermediate type which showed in 15% of varieties. Panicle exertion is most important for protection from diseases. Out of entries, 75% had well exerted panicles. Grain awn was considered an undesirable trait in traditional foot threshing practices due to its inconvenience during handling. In the present study, 75% of the varieties were found to be awnless.

Table 4: Frequency distribution of tested accessions of rice for qualitative characteristics developed by IRRI, SES 2014

No	Descriptor	Code	Guide	No of tested accessions	Name of the accessions	Frequency %
1.	Leafblade pubes-cence	1	Glabrous	03	*IR 07F 291 , Bg 455, Bg 300*	15
		2	Intermediate	17	*Bw 372, Bw 267-3, IR 64, IRRI 119, Bw 312, Bw 400, Bw 163, Bg 366, Karamana (Red), Goda heenati, Kahata wee, De-varaddari, Ld SS-4-4, Ld N2B4, Ld S2B7, Ld SS-3-26-2, Ld S1F3-2*	85
		3	Pubescent			
2.	Blade color	1	Pale Green	02	*Bg 455, Ld S1F3-2*	10
		2	Green	13	*Bw 267-3, IR 64, IRRI 119, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Devaraddari, Ld N2B4, Ld S2B7, Ld SS-3-26-2*	65
		3	Dark Green	05	*Bw 372, Karamana (Red), Goda Heenati, Kahata wee, Ld SS 4-4,*	25
		4	Purple Tips			
		5	Purple Margins			
		6	Purple Blotch			
		7	Purple			
3.	Basal leaf sheath color	1	Green	20	*Bw 267-3, IR 64, IRRI 119, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Devaraddari, Ld N2B4, Ld S2B7, Ld SS-3-26-2, Bg 455, Ld S1F3-2, Bw 372, Karamana (Red), Goda Heenati, Kahata wee, Ld SS 4-4*	100
		2	Purple Lines			

		3	Light Purple			
		4	Purple			
4.	Leaf angle	1	Erect	05	*Bg 455, Bg 366, Devaraddari, Ld S2B7, Ld SS-3-26-2*	25
		3	Intermediate	15	*Bw 267-3, IR 64, IRRI 119, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 300, Ld N2B4, Ld S1F3-2, Bw 372, Karamana (Red), Goda Heenati, Kahata wee, Ld SS 4-4*	75
		5	Horizontal			
		9	Drooping			
5.	Flag leaf angle	1	Erect	18	*Bw 267-3, IR 64, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Devaraddari, Ld N2B4, Ld S2B7, Ld SS-3-26-2, Bg 455, Ld S1F3-2, Bw 372, Karamana (Red), Kahata wee, Ld SS 4-4*	90
		3	Intermediate	02	*IRRI 119, Goda Heenati*	10
		5	Horizontal			
		7	Descending			
6.	Ligule color	1	White	20	*Bw 267-3, IR 64, IRRI 119, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Devaraddari, Ld N2B4, Ld S2B7, Ld SS-3-26-2, Bg 455, Ld S1F3-2, Bw 372, Karamana (Red), Goda Heenati, Kahata wee, Ld SS 4-4*	100
		2	Purple Lines			
		3	Purple			
7.	Ligule shape	1	Acute To Acuminate	07	*IRRI 119, Bw 312, Bw 163, IR 07F 291, Bg 300,Ld N2B4, Ld S1F3-2*	35

		2	2-Cleft	13	*Bw 267-3, IR 64, Bw 400, Bg 366, Devaraddari, Ld S2B7, Ld SS-3-26-2, Bg 455, Bw 372, Karamana (Red), Goda Heenati, Kahata wee, Ld SS 4-4*	65
		3	Truncate			
8.	Collar color	1	Pale Green	19	*Bw 267-3, IR 64, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Devaraddari, Ld N2B4, Ld S2B7, Ld SS-3-26-2, Bg 455, Ld S1F3-2, Bw 372, Karamana (Red), Goda Heenati, Kahata wee, Ld SS 4-4*	95
		2	Green	01	*IRRI 119*	5
		3	Purple			
9.	Culm angle	1	Erect	07	*IR 64, Bw 312, Bg 455, Bg 300, Ld SS-4-4, Ld SS-3-26-2, Ld S1F3-2*	35
		3	Intermediate	11	*Bw 267-3, IRRI 119, Bw 400, Bw 163, IR 07F 291, Bg 366, Devaraddari, Ld N2B4, Bw 372, Karamana (Red), Kahata wee*	55
		5	Open	02	*Ld S2B7, Goda Heenati*	10
		7	Spreading			
		9	Procumbent			
10.	Internode color	1	Green	20	*Bw 267-3, IR 64, IRRI 119, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Devaraddari, Ld N2B4, Ld S2B7, Ld SS-3-26-2, Bg 455, Ld S1F3-2, Bw 372, Karamana (Red), Goda Heenati, Kahata wee, Ld SS 4-4*	100
		2	Light Gold			
		3	Purple Lines			

		4	Purple			
11.	Culm strength (Lodging resistance)	1	Strong	10	*Bw 267-3, IR 64, Bw 163, IR 07F 291, Bg 366, Bg 300, Ld N2B4, Ld S2B7, Ld S1F3-2, Bw 372*	50
		3	Moderately Strong	06	*IRRI 119, Bw 312, Bw 400, Bg 455, Ld SS 4-4, Ld SS-3-26-2*	30
		5	Intermediate	04	*Karamana (Red), Goda Heenati, Kahata wee, Devaraddari*	20
		7	Weak			
		9	Very Weak			
12.	Panicle type	1	Compact	03	*Ld SS-3-26-2, Goda Heenati, IRRI 119*	15
		5	Intermediate	15	*Bw 267-3, IR 64, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Devaraddari, Ld N2B4, Ld S2B7, Bg 455, Bw 372, Karamana (Red), Ld SS 4-4*	75
		9	Open	02	*Kahata wee, Ld S1F3-2*	10
13.	Panicle exertion	1	Well Exserted	15	*Bw 267-3, IR 64, IRRI 119, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Ld N2B4, Ld SS-3-26-2, Bg 455, Bw 372, Karamana (Red), Ld SS 4-4*	75
		3	Moderately Well Exserted	04	*Kahata wee, Devaraddari, Ld S2B7, Ld S1F3-2*	20
		5	Just Exserted			
		7	Partly Exserted	01	*Goda Heenati*	5
		9	Enclosed			
14.	Panicle axis	1	Straight	10	*IR 64, Bw 312, Bw 400, Bw 163, Bg 455, Bg 366, Ld SS-4-4, Ld N2B4, Ld S2B7, Ld S1F3-2*	50

		2	Droopy	10	*Bw 267-3, IRRI 119, IR 07F 291, Bg 300, Devaraddari, Ld SS-3-26-2, Bw 372, Karamana (Red), Goda Heenati, Kahata wee*	50
15.	Grain awning	0	Absent	15	*Bw 267-3, IR 64, Bw 312, Bw 400, Bw 163, IR 07F 291, Bg 366, Bg 300, Ld SS-3-26-2, Bg 455, Bw 372, Karamana (Red), Goda Heenati, Kahata wee, Ld SS 4-4*	75
		1	Short and Partly Awned	05	*IRRI 119, Devaraddari, Ld N2B4, Ld S2B7, Ld S1F3-2*	25
		5	Short and Fully Awned			
		7	Long and Partly Awned			
		9	Long and Fully Awned			

Principal component analysis (PCA)

Principal component analysis revealed which traits (variables) contributed most to the observed variation (Figure 1). For example, if culm length and leaf length heavily load on PC1, they are key Scatter plot of rice genotypes/accessions based on the first two principal components is shown in Figure 1. Each black dot represents a rice accession plotted along with the First Component (PC1) and Second Component (PC2). The spread of points indicates genetic diversity among the accessions. Most accessions are clustered near the origin, indicating similar morphological traits, while a few outliers exhibit distinct traits. These outliers could represent accessions with extreme values for one or more key traits such as very long culms or panicles. This helps in selecting diverse parents for breeding.

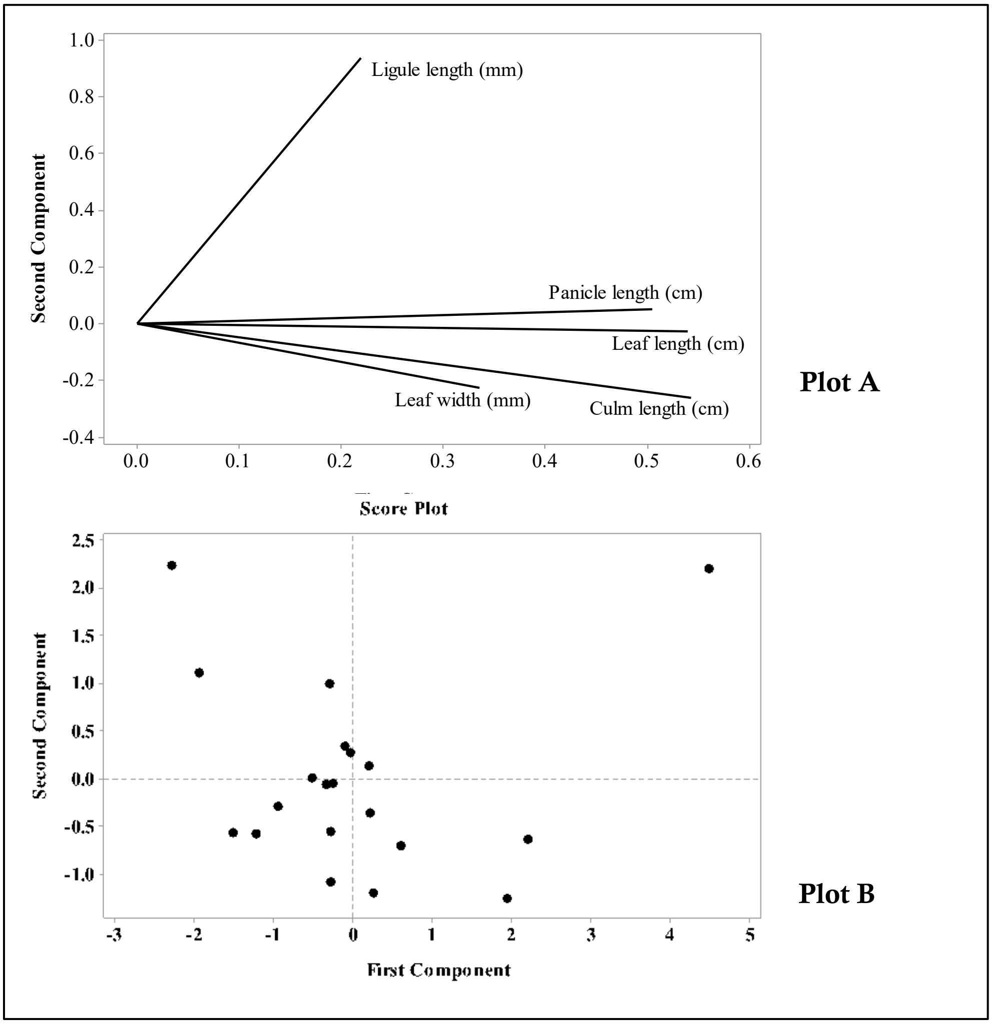

Figure 1: Score plot (A) and Loading Plot (Variable Contributions) (B)

The loading plot shows how traits are related to each other and to the principal components. PC1 helped group 20 rice accessions and showed that traits like culm length, leaf length, and panicle length are important in distinguishing genotypes. Therefore, these traits are closely related and contribute similarly to PC1, implying a strong correlation among them. Ligule length (mm) contributes mostly to PC2 (vertical axis), suggesting it varies independently from the other traits. Ligule length behaves differently, affecting PC2 more strongly, and may help distinguish genotypes not well separated by the other traits. PCA aids in choosing parents for developing new rice varieties adapted to wet zone or abiotic stress conditions.

Cluster Analysis

The dendrogram in Figure 2 represents the hierarchical clustering of 20 rice accessions based on their morphological traits using Euclidean distance as the measure of dissimilarity. The clustering grouped the accessions into distinct clusters, indicating substantial morphological variation among the rice accessions.

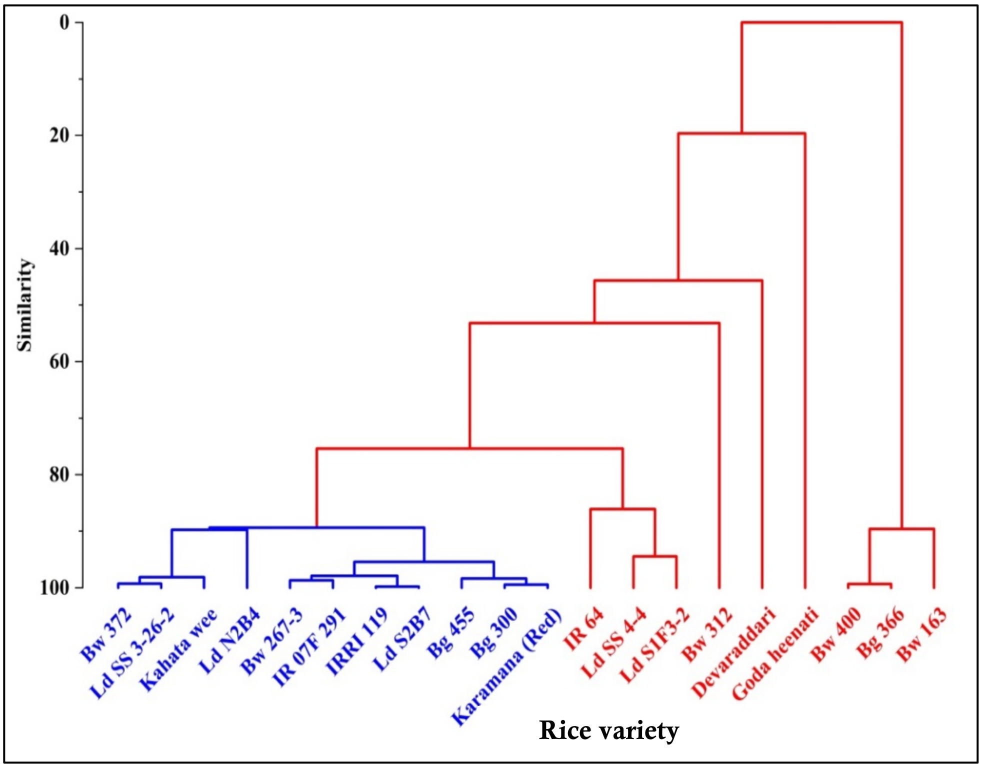

Figure 2: Dendrogram of hierarchical clustering

The accessions are grouped into two major clusters as cluster A and B. Cluster A (blue colour) included mostly exotic and improved local varieties with higher similarity (>91%), such as *Bw 372*, *Ld SS 3-26-2*, *Kahata wee* and *Bw 267-3, IR 07F 291, IRRI 119, LdS2B7, Bg 455, Bg 300* and *Karamana (Red).* These pairs are very closely related morphologically (nearly 100% similarity). The inclusion of the traditional variety *Karamana* (Red) within cluster A may be attributed to its morphological similarity with improved and exotic varieties, particularly in traits such as moderate culm length (74.60 cm-88.74 cm), relatively shorter panicle length (23.42 cm-24.26 cm), and comparable tillering ability. In addition a traditional variety *Kahata wee* is also included into cluster A. The traditional variety of *Kahata wee* in cluster A may be due to its similarity in culm length, panicle length and tillering ability with other accessions in this cluster.

Cluster B (red colour) included traditional and widely used exotic and local improved varieties, showing greater morphological divergence, such as *IR 64, LdSS 4-4, LdS1F3-2, Bw 312, Devaraddari*, *Goda heenati*, *Bw 400, Bg 366*, and *Bw 163*. Highly similar accessions are *IR 64, LdSS 4-4, LdS1F3-2* and *Bw 400, Bg 366, Bw 163* due to their similar improved characteristics.

Most Divergent Accessions are *Devaraddari* and *Goda heenati* are the most genetically and morphologically distinct, with the lowest similarity (~43 and 20 respectively). For example, crossing a highly improved variety like *Bw 372* with a traditional, divergent variety like *Devaraddari* may enhance yield stability or stress resilience. These likely represent traditional varieties with unique traits, useful for breeding programs targeting genetic diversity or stress tolerance.

CONCLUSION

A considerable range of morphological variation was observed among the tested rice accessions in the present study. Seasonal differences had a notable impact on plant growth, particularly influencing traits such as leaf characteristics, culm length, culm number, and panicle structure. Leaf length and culm length are varied in *Maha* season and Yala season indicating strong genotype × environment (G×E) interactions. Genotype × environment (G×E) effects influence the expression of quantitative traits across environments, emphasizing the need for careful analysis of G×E interactions when selecting stable or environment-specific rice genotypes for breeding. The performance of varieties also varied significantly. Traditional varieties had the highest leaf length and culm length, but both the type had the highest leaf width. Leaf width is the most critical parameter for enhancing leaf area while breeding. Improved recommended and exotic varieties generally showing higher tillering ability while some traditional varieties exhibited superior panicle length. Based on the correlation study, traits such as panicle length, and culm length ($r=0.469$ in Maha) were positively associated, indicating their combined influence on grain number and yield potential. The correlations observed varied slightly between the 2022/2023 Maha and 2023 Yala seasons, reflecting the role of G×E interactions. Principal component analysis revealed that culm length, leaf length, and panicle length contributed most to the total variation, while cluster analysis grouped the 20 accessions in to two major clusters with distinct genetic backgrounds. Highly divergent genotypes such as *Devaraddari* and *Goda heenati* were identified, highlighting their potential use as parents in hybridization programs specially for improving submergence tolerance. The study revealed wide variability in both qualitative and quantitative traits, attributed to the diverse genetic backgrounds of the tested accessions. Such variability is crucial for breeding programs targeting the low country wet zone conditions, enabling breeders to identify and select diverse parental materials for hybridization based on stable, heritable morphological markers.

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