



RESEARCH ARTICLE

# Assessment of phenotypic diversity in rice (*Oryza sativa* L.) based on qualitative traits

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## Abstract

The experiment was conducted on 21 rice genotypes at the appropriate crop growth stages, following the distinctiveness, uniformity and stability (DUS) guidelines prescribed by the Protection of Plant Varieties and Farmers' Rights Act (PPV & FRA, 2007), during the kharif seasons of 2022 and 2023 at the Department of Seed Science and Technology, College of Agriculture, Professor Jayashankar Telangana Agricultural University (PJTUAU), Rajendranagar, Hyderabad. Among the 19 morphological traits evaluated, the traits viz., colour of awns as late-stage observation and presence of secondary branching in the panicle showed no variation among the genotypes. Seven traits exhibited 2 states, 5 traits fell into 3 phenotypic classes, 3 traits resulted in 4 different categories and 2 traits exhibited 5 states. Maximum phenotypic variation among the genotypes was recorded for traits such as leaf pubescence on the blade surface, curvature of the main axis of the panicle, colouration at the tip of the lemma, attitude of panicle branches and shape of the decorticated grain (lateral view). This characterisation of rice genotypes provides valuable information for breeders, farmers and researchers, facilitating their use in crop improvement programs and ensuring legal protection under the PPV & FRA framework.

**Keywords:** distinctiveness uniformity and stability testing; morphological descriptors; phenotypic variation; protection of plant varieties and farmers' rights act; rice

## Introduction

Paddy, commonly known as rice (*Oryza sativa* L.), is a staple food crop relied upon by more than half of the world's population for daily caloric intake. It is the second most extensively produced cereal crop globally, with cultivation spanning diverse agro-ecological regions across Asia, Africa and other parts of the world (1). It is cultivated across 47.83 Mha, with a total production of 137.83 Mt and an average productivity of 2765 kg/ha (2). India ranks first in rice cultivation area and second in production, after China (3). Price fluctuations of quality seed often result in the sale of spurious seed in place of the preferred variety. Since morphological descriptors have limited ability to distinguish closely related cultivars with a narrow genetic base, varietal identification becomes challenging. It is essential to ensure the protection of varieties through the registration and certification of newly released and notified varieties. The Protection of Plant Varieties and Farmers' Rights Act

(PPV and FR act) was passed by the Indian government in 2001 to safeguard the intellectual property of varieties, including farmers' rights to traditional varieties.

Morphological classification based on Distinctness, Uniformity and Stability (DUS) is necessary for variants to be recorded under the PPV and FRA (4, 5). The main aim is to establish the distinctiveness of genotypes based on their unique morphological profiles, ensure uniformity throughout the crop duration and confirm stability across different locations. In this context, an attempt was made to evaluate the phenotypic diversity of 21 rice genotypes based on qualitative traits.

## Materials and Methods

The experiment was carried out during the kharif seasons of 2022 and 2023, at the Seed Production Farm, Agricultural Research Institution and the Department of Seed Science and

Technology of the Seed Research and Technology Centre, College of Agriculture, Professor Jayashankar Telangana Agricultural University (PJTU), Hyderabad. The experiment was laid out in a randomised block design, with 4 rows of 4 m length, with 2 replications and spacing of 20 × 15 cm<sup>2</sup>. The standard agronomic practices were followed uniformly for all the experimental units by adopting the recommended package of practices. Data were recorded from 10 plants selected at the appropriate crop growth stages, as per the guidelines for the conduct of the DUS test on rice prescribed by the PPV and FRA (2007), namely at the booting, beginning of anthesis to dough development, ripening and caryopsis hard stages. The details of rice genotypes used for testing are mentioned in Table 1. The 19 traits studied under the investigation were evaluated based on the frequency distribution tables of 2 consecutive years and the list of traits is presented in Table 2.

## Results

Nineteen traits were recorded in this study. The details of all the traits are presented in Table 2. Table 3 and 4 show the variation observed in 10 traits, viz., panicle- presence of secondary branching (Fig. 1), panicle- colour of awns (late observation), flag leaf- attitude of blade (early observation), flag leaf- attitude of blade (late observation), spikelet- density of pubescence of lemma, lemma and palea colour, panicle- awns, panicle- distribution of awns, grain- phenol reaction of lemma and decorticated grain- aroma.

### Awns

The traits awns in the panicle were recorded as present (score 9) in 4 genotypes (JGL 24423, RNR 15435, WGL 20471 and WGL 915) while the remaining 17 genotypes were recorded as absent (score 1). At late-stage observation, awn colour was scored as 1

with yellowish white in 4 genotypes. In the present study, the distribution of awns in the panicle was observed as tip only (score 1) in JGL 24423 and as upper half only (score 3) in 3 genotypes (WGL 20471, WGL 915 and RNR 15435).

### Lemma and palea colour

For the trait lemma and palea colour, genotype RNR 15459 scored as 8, described as purple spots/furrows on straw, while the remaining 20 genotypes were recorded as straw-coloured with a score of 1.

### Panicle: Secondary branching

Secondary branching was observed in the panicles of all 21 genotypes. The secondary branching was weak in RNR 15435, strong in 19 genotypes and clustered in RNR 15459 (Fig. 1, Table 5).

### Panicle: Attitude of branches

The attitude of branches in the panicle was presented in Fig. 2 and Table 6. The attitude of the flag leaf blade ranged from erect in WGL 44; erect to semi-erect in RNR 15048, RNR 29325, RNR 15459, RNR 21278, RNR 28361, WGL 14, WGL 1119 and WGL 1246; semi-erect in RNR 11718, RNR 15435, KNM 1638, KNM 733, KPS 2874 and KPS 6251; semi-erect to spreading in JGL 24423, JGL 27356, WGL 20471, WGL 915 and WGL 962; and spreading in KNM 118.

### Grain: Phenol reaction of lemma

In the grains, the phenol reaction was absent in 5 genotypes (RNR 15048, RNR 21278, KNM 733, WGL 44 and WGL 1246) and present in 16 genotypes.

### Decorticated grain: Aroma

For the trait decorticated grain, aroma was present in 3 (RNR 15435, RNR 15459 and WGL 14) and absent in eighteen genotypes.

### Leaf: Intensity of green colour

Intensity of green colouration of leaf showed light green in

**Table 1.** List of rice genotypes and the source of seed

Sl. No.	Name of the genotype	Parentage	Source
1	JGL 24423 (Jagtial Rice-1)	MTU 1010/NLR 34449	Regional Agricultural Research Station (RARS), Polasa, Jagtial
2	JGL 27356 (Jagtial Rice-3)	JGL 11470/Jai Sriram	Regional Agricultural Research Station (RARS), Polasa, Jagtial
3	RNR 15048 (Telangana Sona)	MTU 1010/JGL 3855	Rice Research Unit, ARI, Rajendranagar, Hyderabad
4	RNR 11718 (Rajendranagar Vari -1)	MTU 1010/NLR 34449	Rice Research Unit, ARI, Rajendranagar, Hyderabad
5	RNR 15435 (Rajendranagar Vari-2)	RNR 17818/Vasumathi	Rice Research Unit, ARI, Rajendranagar, Hyderabad
6	RNR 29325 (Rajendranagar Vari-5)	TME 80518/BPT 5204	Rice Research Unit, ARI, Rajendranagar, Hyderabad
7	RNR 15459 (Rajendranagar Vari-3)	RNR 17818/Chitti Mutyalu	Rice Research Unit, ARI, Rajendranagar, Hyderabad
8	RNR 21278 (Rajendranagar Vari-4)	RNR 2465/NLR 34449	Rice Research Unit, ARI, Rajendranagar, Hyderabad
9	RNR 28361 (Rajendranagar Vari- 28361)	Bhadrakali × HKR 05-22	Rice Research Unit, ARI, Rajendranagar, Hyderabad
10	KNM 118 (Kunaram sannalu)	MTU 1010/JGL 13595	Agricultural Research Station, Kunaram
11	KNM 1638 (Kunaram Vari-2)	JGL 3844/BPT 5204	Agricultural Research Station, Kunaram
12	KNM 733 (Kunaram Rice-1)	MTU 1010/JGL 11470	Agricultural Research Station, Kunaram
13	KPS 2874	MTU 1010/JGL 11470	Agricultural Research Station, Kampasgar
14	KPS 6251	MTU 1010/Chitti Muthyalu	Agricultural Research Station, Kampasgar
15	WGL 44 (Siddhi)	BPT 5204/ ARC 5984// Kavya//Kavya/ BPT 5204	Regional Agricultural Research Station, Warangal
16	WGL 14 (Warangal Samba)	BPT 5204/ ARC 5984// BPT 3291	Regional Agricultural Research Station, Warangal
17	WGL 20471 (Erramallelu)	BC 5-55/WR-708	Regional Agricultural Research Station, Warangal
18	WGL 915 (Warangal Rice-1)	SN 22 R/IRBBN 39	Regional Agricultural Research Station, Warangal
19	WGL 962 (Warangal Rice-2)	BPT 5204/ GEB 24//BPT 5204/ Shatabdi	Regional Agricultural Research Station, Warangal
20	WGL 1119	WGL 32100//B95-1 × Abhaya	Regional Agricultural Research Station, Warangal
21	WGL 1246	Kavya /JGL 13595	Regional Agricultural Research Station, Warangal

**Table 2.** List of traits under the study

Trait	Trait
Leaf: Intensity of green colour	Panicle: Distribution of awns
Leaf: Pubescence of the blade surface	Panicle: Presence of secondary branching
Flag leaf: Attitude of blade (early observation)	Panicle: Secondary branching
Flag leaf: Attitude of blade (late observation)	Panicle: Attitude of branches
Spikelet: Density of pubescence of lemma	Panicle: Exertion
Panicle: Curvature of main axis	Grain: Phenol reaction of lemma
Spikelet: Colour of the tip of the lemma	Decorticated grain: Shape (in lateral view)
Lemma and palea: Colour	Decorticated grain: Colour
Panicle: Awns	Decorticated grain: Aroma
Panicle: Colour of awns (late observation)	

**Table 3.** Characterisation of 21 paddy genotypes through DUS testing (Pooled)

Genotypes	Panicle: Presence of secondary branching	Colour of awns (late observation)	Flag leaf: Attitude of blade (early observation)	Flag leaf: Attitude of blade (late observation)	Spikelet: Density of pubescence of lemma
JGL 24423	Present	Yellowish white	Erect	Semi-erect	Medium
JGL 27356	Present	-	Erect	Erect	Weak
RNR 15048	Present	-	Erect	Semi-erect	Weak
RNR 11718	Present	-	Erect	Erect	Weak
RNR 15435	Present	Yellowish white	Erect	Semi-erect	Weak
RNR 29325	Present	-	Erect	Erect	Weak
RNR 15459	Present	-	Erect	Semi-erect	Weak
RNR 21278	Present	-	Erect	Erect	Weak
RNR 28361	Present	-	Erect	Erect	Medium
KNM 118	Present	-	Erect	Semi-erect	Medium
KNM 1638	Present	-	Erect	Semi-erect	Weak
KNM 733	Present	-	Erect	Semi-erect	Medium
KPS 2874	Present	-	Erect	Semi-erect	Medium
KPS 6251	Present	-	Erect	Semi-erect	Medium
WGL 44	Present	-	Erect	Erect	Weak
WGL 14	Present	-	Erect	Erect	Medium
WGL 20471	Present	Yellowish white	Erect	Semi-erect	Medium
WGL 915	Present	Yellowish white	Erect	Erect	Medium
WGL 962	Present	-	Erect	Erect	Absent
WGL 1119	Present	-	Semi-erect	Semi-erect	Weak
WGL 1246	Present	-	Erect	Erect	Medium

**Table 4.** Characterisation of 21 paddy genotypes through DUS testing (Pooled)

Genotypes	Lemma and palea colour	Panicle: Awns	Panicle: Distribution of awns	Grain: Phenol reaction of lemma	Decorticated grain: Aroma
JGL 24423	Straw	Present	Tip only	Present	Absent
JGL 27356	Straw	Absent	-	Present	Absent
RNR 15048	Straw	Absent	-	Absent	Absent
RNR 11718	Straw	Absent	-	Present	Absent
RNR 15435	Straw	Present	Upper half only	Present	Present
RNR 29325	Straw	Absent	-	Present	Absent
RNR 15459	Purple spots/ furrows on straw	Absent	-	Present	Present
RNR 21278	Straw	Absent	-	Absent	Absent
RNR 28361	Straw	Absent	-	Present	Absent
KNM 118	Straw	Absent	-	Present	Absent
KNM 1638	Straw	Absent	-	Present	Absent
KNM 733	Straw	Absent	-	Absent	Absent
KPS 2874	Straw	Absent	-	Present	Absent
KPS 6251	Straw	Absent	-	Present	Absent
WGL 44	Straw	Absent	-	Absent	Absent
WGL 14	Straw	Absent	-	Present	Present
WGL 20471	Straw	Present	Upper half only	Present	Absent
WGL 915	Straw	Present	Upper half only	Present	Absent
WGL 962	Straw	Absent	-	Present	Absent
WGL 1119	Straw	Absent	-	Present	Absent
WGL 1246	Straw	Absent	-	Absent	Absent

**Table 5.** Grouping of rice genotypes based on panicle: Secondary branching (Pooled)

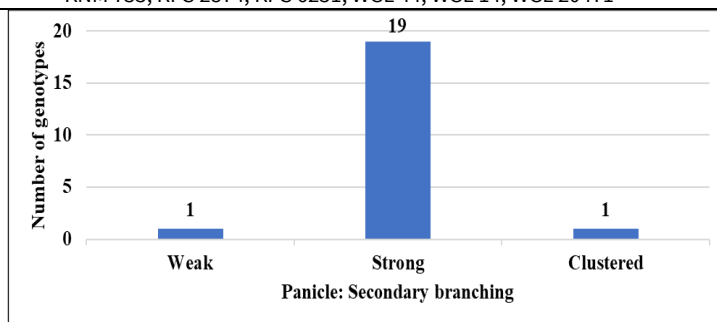
Panicle: Secondary branching		
Weak (1)	Strong (19)	Clustered (1)
RNR 15435	KPS 6251; WGL 44; WGL 14; WGL 20471; WGL 915; WGL 962; WGL 1119; WGL 1246	RNR 15459

**Table 6.** Grouping of rice genotypes based on panicle: Attitude of branches (Pooled)

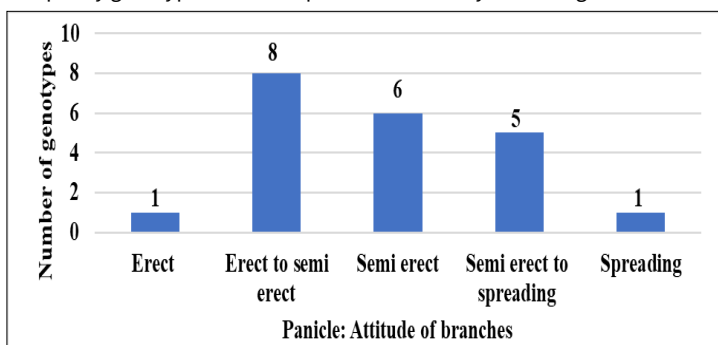
Panicle: Attitude of branches				
Erect (1)	Erect to semi-erect (8)	Semi erect (6)	Semi-erect to spreading (5)	Spreading (1)
		RNR 11718		
	RNR 15048; RNR 29325;	RNR 15435	JGL 24423	
	RNR 15459; RNR 21278;	KNM 1638	JGL 27356	
WGL 44	RNR 28361; WGL 14;	KNM 733	WGL 20471	KNM 118
	WGL 1119; WGL 1246	KPS 2874	WGL 915	
		KPS 6251	WGL 962	

**Table 7.** Grouping of rice genotypes based on leaf: Intensity of green colour (Pooled)

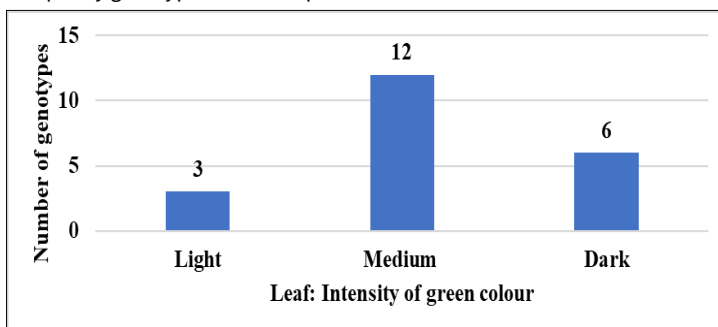
Leaf: Intensity of green colour		
Light (3)	Medium (12)	Dark (6)
RNR 15459; RNR 21278; WGL 1119	JGL 27356; RNR 15048; RNR 11718; RNR 15435; RNR 29325; KNM 118; KNM 733; KPS 2874; KPS 6251; WGL 44; WGL 14; WGL 20471	JGL 24423; RNR 28361; KNM 1638; WGL 915; WGL 962; WGL 1246



**Fig. 1.** Graph showing the number of paddy genotypes based on panicle: Secondary branching.



**Fig. 2.** Graph showing the number of paddy genotypes based on panicle: Attitude of branches.



**Fig. 3.** Graph showing the number of paddy genotypes based on leaf: Intensity of green colour.

3 genotypes with a score of 3 (RNR 15459, RNR 21278 and WGL 1119), medium green in 12 with a score of 5 and dark green in 6 genotypes with a score of 7 (Fig. 3 and Table 7).

**Leaf: Pubescence of the blade surface**

Pubescence of leaf blade surface was absent in 2 (RNR 28361 and WGL 1119), weak in 8, medium in 10 and very strong in 1 (JGL 24423) with 1, 3, 5 and 9 scores, respectively (Fig. 4 and Table 8).

**Flag leaf: Attitude of the blade**

The attitude of the flag leaf blade at the early stage was characterised as erect in 20 genotypes (score 1) and semi-erect in

1 genotype, WGL 1119 (score 3). At the late stage of observation, it was recorded as erect in 10 genotypes (score 1) and semi-erect in 11 genotypes (score 3).

**Panicle: Curvature of main axis**

Curvature of the main axis of the panicle was noted as straight (3 genotypes), semi-straight (7 genotypes), deflexed (6 genotypes) and drooping (5 genotypes) with 1, 3, 5, 7 respective scores (Fig. 5 and Table 9).

**Table 8.** Grouping of rice genotypes based on leaf: Pubescence of blade surface (Pooled)

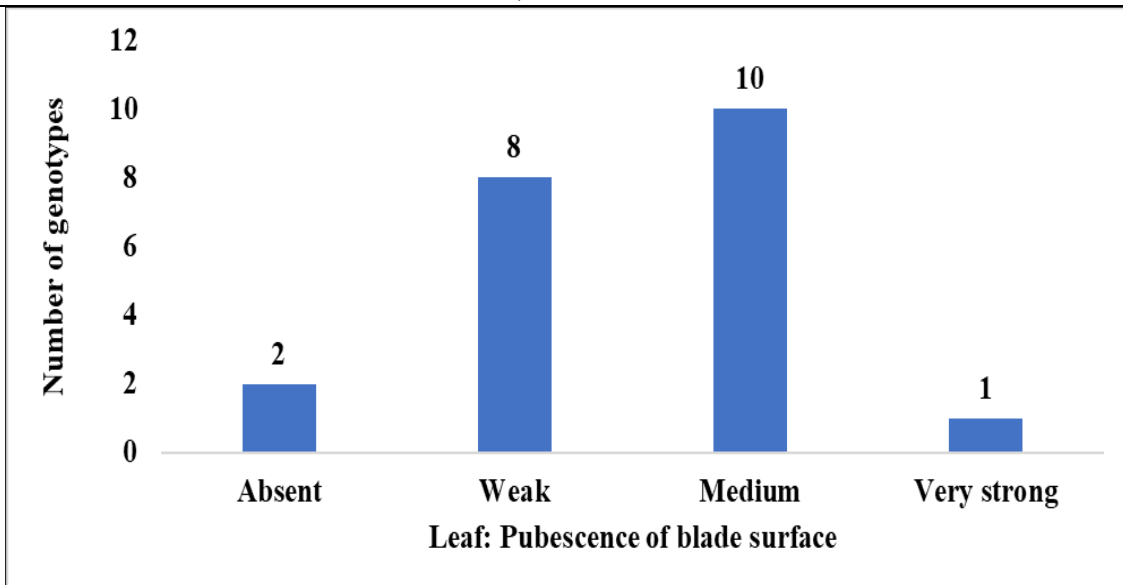
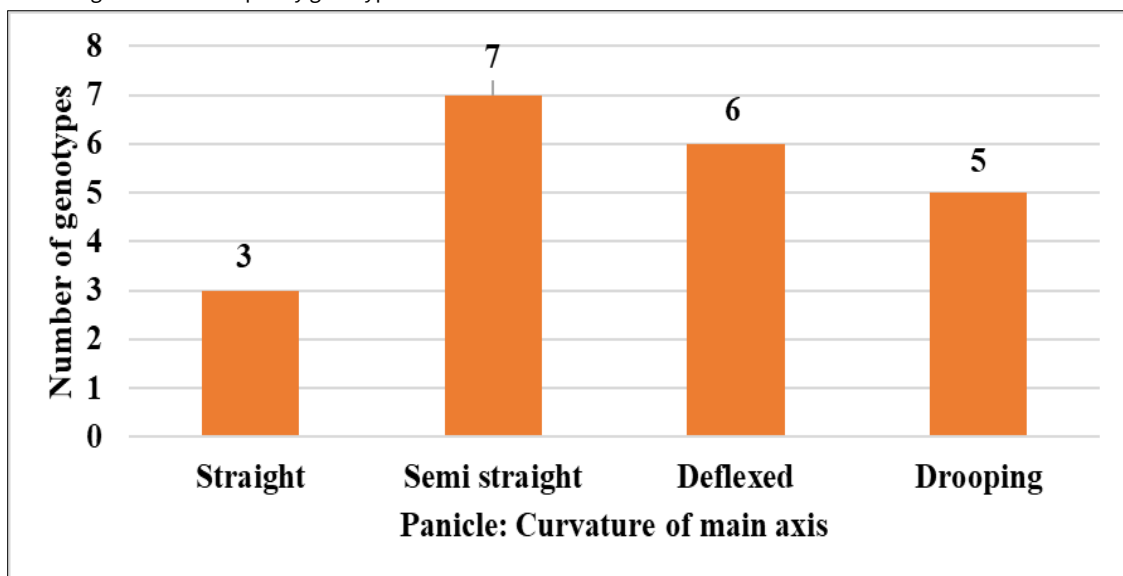
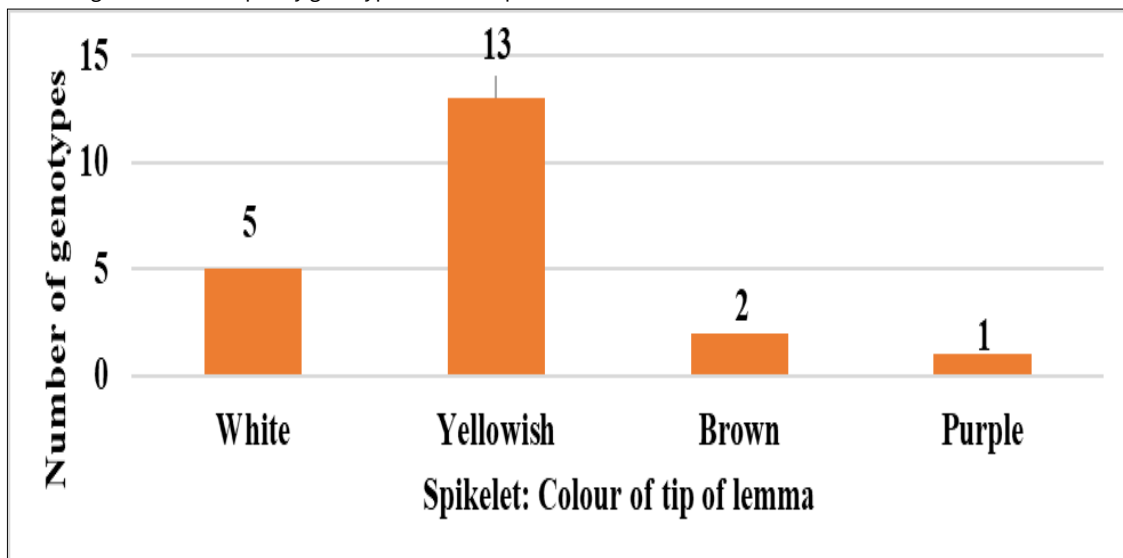
Leaf: Pubescence of the blade surface			
Absent (2)	Weak (8)	Medium (10)	Very strong (1)
RNR 28361; WGL 1119	JGL 27356; RNR 15048; RNR 11718; RNR 15435; RNR 29325; RNR 21278; KPS 6251; WGL 1246	RNR 15459; KNM 118; KNM 1638; KNM 733; KPS 2874; WGL 44; WGL 14; WGL 20471; WGL 915; WGL 962	JGL 24423

**Table 9.** Grouping of rice genotypes based on panicle curvature of main axis (Pooled)

Panicle: Curvature of the main axis			
Straight (3)	Semi straight (7)	Deflexed (6)	Drooping (5)
WGL 44; WGL 14; WGL 20471	RNR 15048; KNM 118; KNM 1638; KNM 733; KPS 2874; KPS 6251; WGL 1119	JGL 27356; RNR 11718; RNR 15435; RNR 29325; RNR 21278; WGL 1246	JGL 24423; RNR 15459; RNR 28361; WGL 915; WGL 962

**Table 10.** Grouping of rice genotypes based on spikelet: Colour of tip of lemma (Pooled)

<b>Spikelet: Colour of the tip of the lemma</b>			
<b>White (5)</b>	<b>Yellowish (13)</b>	<b>Brown (2)</b>	<b>Purple (1)</b>
RNR 15048; KPS 6251; WGL 44; WGL 1119; WGL 1246	JGL 24423; RNR 11718; RNR 15435; RNR 29325; RNR 21278; RNR 28361; KNM 118; KNM 1638; KNM 733; KPS 2874; WGL 14; WGL 20471; WGL 915	JGL 27356; WGL 962	RNR 15459

**Fig. 4.** Graph showing the number of paddy genotypes based on leaf: Pubescence of blade surface.**Fig. 5.** Graph showing the number of paddy genotypes based on panicle: Curvature of the main axis.**Fig. 5.** Graph showing the number of paddy genotypes based on panicle: Curvature of the main axis.

**Spikelet: Colour of tip of lemma**

Colouration on the tip of the lemma was observed to be white in 5 genotypes (RNR 15048, KPS 6251, WGL 44, WGL 1119 and WGL 1246), yellowish (13 genotypes), brown (JGL 27356 and WGL 962) and purple (RNR 15459) with respective scores of 1, 2, 3 and 5 (Fig. 6; Table 10).

**Panicle: Exertion**

Panicle exertion was recorded as partly exerted with a score of 3 in RNR 29325, mostly exerted with a score of 5 in 3 (KPS 6251, WGL 44 and WGL 1246) and the rest of the 17 genotypes were recorded as well exerted and scored as 7 (Fig. 7; Table 11).

**Decorticated grain: Shape (in lateral view)**

Decorticated grain shape (lateral view) was recorded as short slender with score 1 in 4 genotypes (JGL 27356, RNR 15048, RNR 21278 and KNM 733); short bold with score 2 in 1 (RNR 15459); medium slender with score 3 in 9 genotypes (RNR 11718, KNM 1638, KPS 2874, KPS 6251, WGL 44, WGL 14, WGL 962, WGL 1119 and WGL 1246); long bold with score 4 in 2 genotypes (JGL 24423 and WGL 915); long slender in 4 genotypes (RNR 29325, RNR 28361, KNM 118 and WGL 20471) and long slender (for basmati type- RNR 15435) with 1 and all the long slender (including basmati type) were scored as 5 (Fig. 8 and Table 12).

**Spikelet: Density of pubescence of lemma**

Density of pubescence of lemma in spikelet was absent in 1 genotype, weak in 10 genotypes and medium in 10 genotypes.

**Decorticated grain: Colour**

Decorticated grain colour was white with score 1 in JGL 24423 and RNR 28361; variegated brown with score 3 in RNR 15459; the rest of the 18 genotypes were recorded as light brown with a score of 2 (Fig. 9; Table 13).

**Discussion**

In this study, the colour of awns as late-stage observation in awned genotypes (JGL 24423, RNR 15435, WGL 20471 and WGL 915) was found to be uniform, which is in accordance with previous studies (6–8). The presence of secondary branching in the panicle showed no variation among the genotypes. These two traits exhibited their consistent expression across all genotypes, indicated a high level of genetic stability. Previous studies on variation in panicle secondary branching reported that, among 187 landraces, 32.09 % exhibited weak branching, 66.84 % showed strong branching and 1.07 % displayed clustered branching (8). Similar results of secondary branching were reported including weak in 37 lines, strong in 34 lines and clustered in 12 lines (9). Seven traits exhibited 2 states, namely: flag leaf- attitude of blade (early observation), flag leaf- attitude of blade (late observation), lemma and palea colour, panicle- awns, panicle- distribution of awns, grain- phenol reaction of lemma and decorticated grain- aroma. Previous studies on panicle awns and their distribution reported that, among 20 genotypes, 16

**Table 11.** Grouping of rice genotypes based on panicle: Exertion (Pooled)

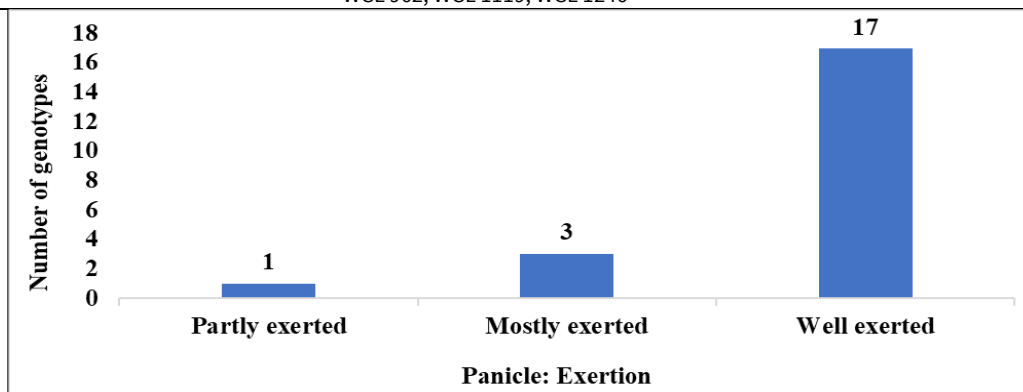
Panicle: Exertion		
Partly exerted (1)	Mostly exerted (3)	Well exerted (17)
RNR 29325	KPS 6251; WGL 44; WGL 1246	JGL 24423; JGL 27356; RNR 15048; RNR 11718; RNR 15435; RNR 15459; RNR 21278; RNR 28361; KNM 118; KNM 1638; KNM 733; KPS 2874; WGL 14; WGL 20471; WGL 915; WGL 962; WGL 1119

**Table 12.** Grouping of rice genotypes based on decorticated grain: Shape (in lateral view) (Pooled)

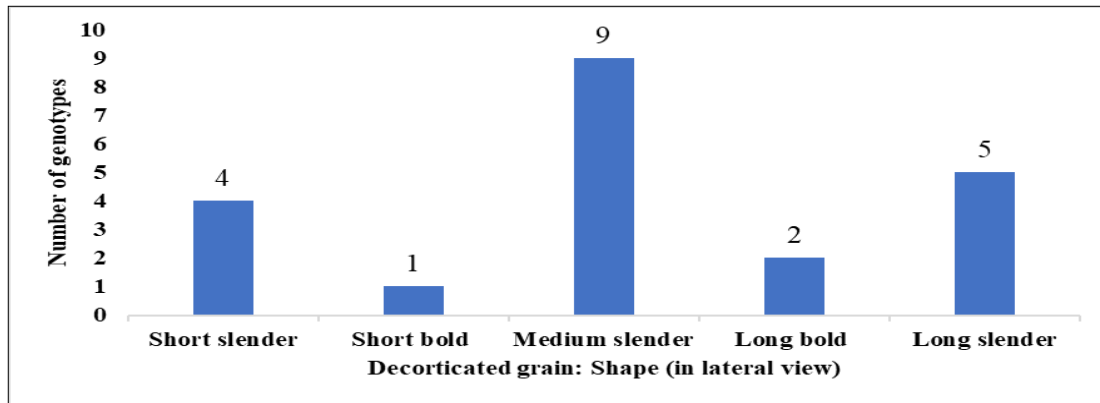
Decorticated grain: Shape (in lateral view)				
Short slender (4)	Short bold (1)	Medium slender (9)	Long bold (2)	Long slender (5)
		RNR 11718		
		KNM 1638		
JGL 27356		KPS 2874		RNR 15435
RNR 15048		KPS 6251		RNR 29325
RNR 21278	RNR 15459	WGL 44	JGL 24423	RNR 28361
KNM 733		WGL 14	WGL 915	KNM 118
		WGL 962		WGL 20471
		WGL 1119		
		WGL 1246		

**Table 13.** Grouping of rice genotypes based on decorticated grain: Colour (Pooled)

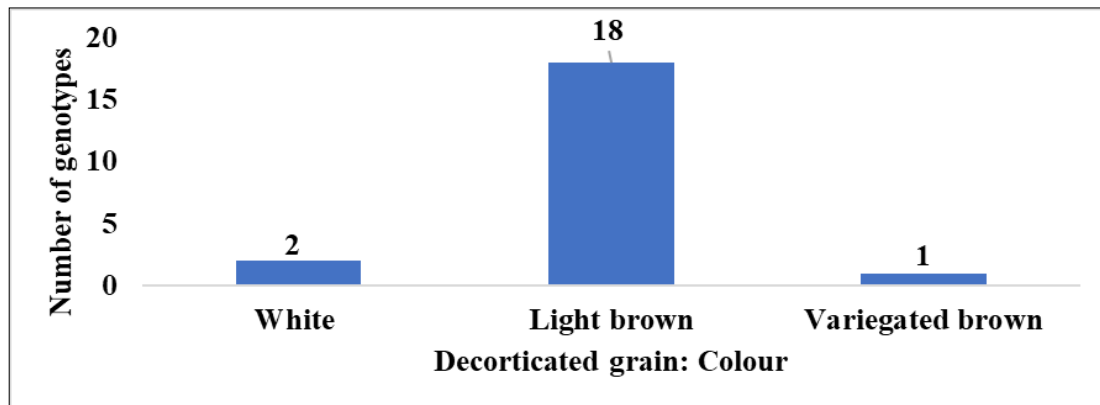
Decorticated grain: Colour		
White (2)	Light brown (18)	Variegated brown (1)
JGL 24423; RNR 28361	JGL 27356; RNR 15048; RNR 11718; RNR 15435; RNR 29325; RNR 21278; KNM 118; KNM 1638; KNM 733; KPS 2874; KPS 6251; WGL 44; WGL 14; WGL 20471; WGL 915; WGL 962; WGL 1119; WGL 1246	RNR 15459



**Fig. 7.** Graph showing the number of paddy genotypes based on panicle: Exertion.



**Fig. 8.** Graph showing the number of paddy genotypes based on decorticated grain: Shape (in lateral view).



**Fig. 9.** Graph showing the number of paddy genotypes based on decorticated grain: Colour.

possessed awns; among 44 genotypes, only 7 showed the presence of awns; and among 62 genotypes, only 8 exhibited awns in the panicle (10-12). Awn distribution is restricted to the upper half in 5 genotypes and to the tip in 1 genotype out of 45 genotypes, while another report documented tip-only awns in a single genotype (12, 13). For the trait, lemma and palea colour, earlier results of straw- coloured lemma and palea, straw coloured sterile lemma 78 lines and purple coloured found in 4 lines (9, 13). In grains, the phenol reaction was reported as absent and present; similar observations have been documented in rice (7, 14, 15). For the trait decorticated grain, aroma was absent in 81 % of the landraces (7). Intensity of green colouration of leaf showed light green, medium green and dark green were observed in paddy (7, 9). Leaf blade pubescence was observed as weak, medium, strong and very strong, which is in accordance with earlier studies (7, 9, 13). For flag leaf attitude of the blade, both variations have been previously reported (7, 11). Consistent results were also observed for panicle curvature of the main axis, colouration of the lemma tip and panicle exertion in rice (7, 9, 11, 16). Comparatively, earlier studies reported multiple variations in decorticated grain shape and genes influencing seed length also partially govern seed shape (13, 17, 18). Density of pubescence of lemma in spikelet was weak and medium; the decorticated grain colour with all white, light brown and variegated brown was reported in paddy (7, 12, 13). Maximum variation in the genotypes was observed for five traits, viz., leaf: pubescence of blade surface, panicle: curvature of main axis, spikelet: colour of tip of lemma, panicle: attitude of branches and decorticated grain: shape (in lateral view). Strong pubescence on the leaf blade surface and panicle: attitude of branches indicated the best agronomic performance and pubescence can be an effective trait for breeding rice varieties resistant to leaf-damaging insects and diseases (9).

## Conclusion

The morphological descriptors employed were effective in discriminating the rice genotypes. Among the 19 traits studied, maximum phenotypic variation was observed for leaf blade pubescence, curvature of the panicle main axis, colouration at the lemma tip, attitude of panicle branches and the shape of the decorticated grain (lateral view). Qualitative trait-based fingerprints can be standardised to facilitate variety registration, genetic purity testing and protection of intellectual property rights. Advanced imaging and AI-driven phenomics tools can automate the measurement of qualitative traits like grain shape, colour and awn, enabling high-throughput and unbiased phenotypic assessment.

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## Authors' contributions

AK contributed to the writing the original draft, formal analysis and editing of the manuscript. SP contributed to the conceptualisation of the study, provided supervision and guidelines and assisted in writing the original draft, formal analysis and editing of the manuscript. PJMR contributed to writing the original draft, performed formal analysis and assisted in editing the manuscript. KP, SNCVLP and KR contributed to the

verification and finalisation of the manuscript. All authors read and approved the final version of the manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

## Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT and Quiltbot in order to rephrase, form sentences and perform spelling and grammar checking. After using these tools/services, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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