# COMPARATIVE SEED POLYMORPHISM OF SOME GENOTYPES OF SOME RICE SPECIES

Aliyu R.E
Department of Botany, Faculty of Life Science, Ahmadu Bello University, Zaria, Nigeria
email: s.ramatu@gmail.com, enehezeyi@abu.edu.ng

**ABSTRACT**
*The seed samples of ninety one (91) rice genotypes from two rice species (Oryza sativa -25), Oryza glaberrima - 48) and an interspecific hybrid (NERICA-18) were evaluated for physical seed characteristics (hull colour, presence or absence of awn, awn length, brown rice length, brown rice width, grain length, grain width, seed colour, seed shape and chalkiness). Ten random seeds were selected from each bulk genotype and evaluated. Correlation studies were also done to analyze the relationship between the seed physical characters. The result showed significant ($p<0.05$) variability between and within rice species and genotypes. Their variability can be linked to their geographical origin of collection and domestication. Four hull (light brown, brown, tawny and black) and seed colours (brown, speckled brown, white and red) were observed across species. Black hull colour was observed in TOG 6203-A only while TOG14357 was the only O. glaberrima genotype with white seed colour. NERICA genotypes were dominated by slender grained seeds (94.44%) while bold seeds (20.83%) were largest amongst Oryza glaberrima genotypes. Seed chalkiness was highest amongst NERICA genotypes (33.33%) followed sequentially by Oryza sativa (28%) and O. glaberrima (0%). The significant positive correlation between hull colour and brown rice length ($r^2$=0.74) and grain length ($r^2$=0.65) suggested that hull colour in NERICA is indicative of the seed lengths of the genotypes. The physical attributes of the light brown hull colour of NERICA makes it preferable for future yield improvement programme of NERICA.*

**Keywords:** Rice, Seed polymorphism, *Oryza sativa, Oryza glaberrima,* NERICA

## INTRODUCTION

The morphologies of most *Oryza glaberrima* and *Oryza sativa* genotypes are hardly distinguishable (Semon, 2005). Seed produced within a somatic polymorphism may vary in size, colour and/or external structure. These variations in morphology are frequently accompanied by difference in germination requirement with the consequences that the germination of polymorphic seeds maybe staggered in time (Silvertown, 1984). Visual quality is one of the most important determinants of seed polymorphism and is considered as important breeding objective (Anuradha *et al.,* 2009). Due to wide variation in different agro-climatic conditions and diversified selection for a wide range of uses of rice grain; a great diversity exists for its size and shape (Satoh *et al*., 1990). Researchers like Malavasi (1996), Murali (1997), Mandal *et al*. (1997) and Girish *et al.* (2001) had expressed that physical grading could improve the physiological quality characters of the seeds due to the biochemical variations, which become the causes for the variation observed with physiological characters. Seed polymorphism has been noticed in crops within and between populations with respect to seed coat colour and seed size (Latha *et al.,* 2013). Variation in any one character or character combination could result in the changed quality of rice grain (Siddiqui *et al*., 2007). This variation plays an important role in crop improvement programme since the variability in seed quantitative characters exhibits a direct relationship with the seed yield of the crop (Latha *et al.,* 2013). Seed viability may relate to seed polymorphism where seed of a species exhibits two or more distinctly different morphology in size, colour and shape (Baskin and Baskin, 1994). That different form of seeds may show marked difference in plant abiotic stress and identifying useful traits is an important activity in rice improvement (IRRI, 2002). Grain yield of rice is basically determined by genotype, climate and edaphic environment, and management (Slafer, 1994; Richards, 2000).

The seed fetches much value only on possession of seed quality characters and only these characters can improve the nursery and planting value of the seedlings (Swaminathan *et al.,* 1991) Seeds require specific quality characters for optimum performance with uniformity on seedling production (Venudevan and Srimathi, 2013). However, the relative importance and influence of quality related traits on grain quality have changed over time as a result of rice improvement. Moreover, quality potential of a variety is a hypothetical concept determined by a complex series of interaction with the components of the environment it is exposed to (Samita *et al.,* 2005). Therefore, classification using multiple morphological characteristics is important for identifying adaptation of a variety and to improve the evaluation of varieties for potential adaptation (Lin and Binns, 1985) and crop improvement (Latha *et al*., 2013)

## MATERIALS AND METHODS

### SOURCE OF MATERIALS

Ninety one (91) seeds of *Oryza* species comprising of 25 *Oryza sativa*, 48 *Oryza glaberrima* and 18 interspecific hybrid (NERICA) were evaluated for physical seed characteristics (hull colour, presence or absence of awn, awn length, brown rice length, brown rice width, grain length, grain width, seed colour, seed shape and chalkiness). Ten random seeds were selected from each bulk genotype and evaluated for the study. The seeds were obtained from the cold store of Africa Rice, International Institute for Tropical Agriculture (IITA), Ibadan station. Nigeria.

Study location and Methodology

The determination of seed morphology was carried out at the Department of Biological Sciences, Ahmadu Bello University, Samaru, Zaria.

Seeds were graded according to genotypes and evaluated for polymorphism traits. Ten seeds per genotype were randomly evaluated and replicated thrice. Seed characters were evaluated following the methods described by the International Rice Research Institute (IRRI), 1997.

Data collection

Data on grain length (mm), grain width (mm), brown rice length (mm), brown rice width (mm) were measured with a venire veneer caliper using the formula: (MSR + VSR x LC). Where MSR: Main scale reading, VSR: Venire scale reading and LC: Least count. (IRRI 1997). Seed shape was estimated by Length-width ratio. (IRRI 1997)

Data on seed colour, seed shape, and chalkiness of endosperm, hull color and presence or absence of awn were taken by adopting the standard evaluation system for Rice (IRRI, 1997).

Statistical analyses

Data obtained were subjected to Analysis of Variance (ANOVA) and the means separated by Duncan's Multiple Range Test (DMRT). The inter relationship between seed parameters were correlated using Pearson correlation coefficient.

RESULTS

The seeds of the rice species were polymorphic ($P<0.05$) across species and genotypes (Table 1, 3 and 6). The hull colour of the rice genotypes observed were light brown, brown, tawny and black. The predominant hull colour observed across specie were light brown (68% in *Oryza sativa*, 72.92% in *Oryza glaberrima* and 72.22% in NERICA) followed sequentially by tawny,

**Table 1: Standard** scale used for evaluation of seed polymorphism of Oryza species

| Score | Hull Colour | Awn | Awn length | Seed Colour | Seed Shape | Chalkiness |
|---|---|---|---|---|---|---|
| 0 | | Absent | Absent | | | Non |
| 1 | Light brown | Present | | Light brown | Slender | |
| 2 | Brown | | | Brown | | |
| 3 | Tawny | | Short | Speckled/brown | Medium | |
| 4 | Green | | | Whitish | | |
| 5 | Black | | Long | Black | Bold | Small |
| 6 | | | | Red | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | Large |

Source: IRRI 1997

brown and black (Figure 1). NERICA had the highest genotype (66.67%) with awns followed by *Oryza glaberrima* genotypes (16.67%) and lastly, *Oryza sativa* (0%) genotypes. Awn length ranged from 0.00-2.33mm within *Oryza sativa* genotypes. While awn length of up to 7mm was recorded in NERICA and *Oryza glabberima* genotypes.

The seed colour observed amongst the rice genotypes were dark brown, white, speckled brown and red. Majority of the *Oryza sativa* genotypes (80%) were white while 16% and 4% were dark brown and speckled brown respectively (Figure 1). This seed colour trend was similar to that observed in NERICA genotypes where 88.89% of the seeds were white and 11.11% were dark brown. Red seed colouration amongst *Oryza glaberrima* genotypes were predominant (97.92%) with only one dark brown coloured genotype (TOG 14357).

Seed shape varied and were significantly different ($p<0.05$) across genotypes and species. Within *Oryza sativa* genotypes, the percentages of slender shaped seeds, medium and bold shaped seeds observed were 68%, 28% and 4% respectively. Similarly, the seed shapes of *Oryza glaberrima* genotypes were slender (43.75%), medium (37.56%), and bold (20.83%). Only slender (94.44%) and medium (5.56%) shaped genotypes of NERICA were observed. Endosperm chalkiness was absent in *Oryza glaberrima* genotypes and highest amongt NERICA genotypes (33.33%).

Brown rice lengths varied but were majorly medium in shape within genotypes and species. NERICA genotypes, with a mean brown length of

1.52mm exhibited the longest brown rice lengths and ranged between 1.18 and 1.81mm (Table 5). Amongst the *Oryza sativa* genotypes, brown rice length ranged between 0.95-1.72mm with a mean length of 1.34mm (Table 1). The grain lengths observed in NERICA genotypes were longest (1.40-2.08mm) and shortest amongst *Oryza glaberrima* genotypes. The mean brown rice length of 1.18mm recorded from *Oryza glaberrima* genotypes was least and ranged from 0.79-1.48mm (Table 3). Mean brown rice width was longest (0.46mm) in *Oryza glaberrima* genotypes (Table 1) and narrowed sequentially from *Oryza sativa* (0.38mm) to NERICA (0.33mm). The grain width was also narrowest (0.43mm) in NERICA and expanded sequentially from *Oryza sativa* (0.46mm) to *Oryza glaberrima* (0.56mm). Generally, a significant reduction of grain length to brown rice length of 0.1 to 0.3 mm of after dehulling was observed.

Significant ($p<0.05$) positive and negative correlations in seed polymorphism were observed within species amongst genotypes (Tables 3, 5 and 7). Across species, the Brown rice length showed positive correlation with grain length. In addition, presence of awn also positively correlated with awn length. However, it was observed that the brown rice length in *Oryza glaberrima* showed negative correlation (-0.43) with brown rice width (Table 4). Furthermore, the grain length showed negative correlation (-0.34) with the seed shape. In NERICA genotypes (Table 7), the hull colour showed a strong positive correlation with the brown rice length (0.74) and the grain length (0.65).

## DISCUSSION

Seed polymorphism is a common phenomenon associated with discrete or continuous morphology or physiological variation among individual seeds produced by an individual or population (Latha *et al*., 2013). All physical qualities can be affected by the growth conditions of the plant (Linares, 2002). Grain length, width and thickness vary widely among rice varieties (Maclean *et al.,* 2002). Seed produced within a somatic polymorphism may vary in size, colour and/or external structure. In plants showing seed polymorphism, two or more sharply defined distribution patterns are seen (Xie, 2013). Attributes such as seed size, shape or internal structures are some of the forms in which polymorphism maybe manifested (Siddiqui *et al*., 2007). Seed polymorphism has been noticed in the crop within and between populations with respect to seed coat colour and seed size. Variation in any one character or character combination could result in changed quality of rice grain (Siddiqui *et al*., 2007).

Predominance of light brown hull colour observed across species could be attributed to the ripened brown pigmentation of ripe dried seeds across genus. In addition, differences in seed colour in rice have been attributed to specie domestication and genotype (Latha *et al*., 2013). The red seed colour, awns and bold seed shape observed amongst *Oryza glaberrima* could be attributable to the specie genome and domestication. According to Carney (1998), *Oryza glaberrima* is characterized by its red seed, bold shape and presence or absent of apical Awn. The wide variations in genotype seed lengths across specie could be attributed to individual differences that must have arisen as a result of environmental influences during the growth of the genotype. The ratio of the length and the width is used internationally to describe the shape and class of the variety (Xie *et al.,* 2013). Similar variations in seed lengths within and between species have been reported by Sidddiqui *et al*. (2007). Slender seed shape of *Oryza sativa* and NERICA genotypes have been reported by several researchers (West Africa Rice Development Agency (WARDA) 2008; Sinha *et al*., 2015). Furthermore, Siddiqui *et al*. (2007) reported that seed colour of *Oryza sativa* and NERICA genotypes were either white or brown. The highly undesirable chalkiness in the seeds of a good percentage of NERICA and *Oryza sativa* genotypes might have arisen from malformed starch granules with air spaces between them. Similar observations have been reported by Ward (2009) and Vanaja and Babu (2006). A positive correlation in seed traits in NERICA genotypes suggests that the hull colour influences the brown rice length and the grain length.

In conclusion, the results in general showed that there existed tremendous variability between and within rice species and genotypes which can be directly utilized in rice breeding programme. Their variability can be linked to their geographical origin of collection and domestication. The significant correlation between hull colour and brown rice length and grain length suggested that hull colour in NERICA was detrimental in discerning the seed lengths of the genotypes. Hence, light brown hull colour could be the preferred colour for future yield improvement programme of NERICA.

**Table 1: Seed polymorphism evaluated amongst 25 *Oryza sativa* genotypes**

| S/N | Genotypes | Hull Colour | Awn P/A | Awn length (cm) | SC | SS | C/K | BrL (mm) | BrW (mm) | GL (mm) | GW (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BG 90-2 | 3.00 b | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 0.00 c | 1.72 a | 0.32g-J | 2.00 a | 0.41def |
| 2 | BOKUCHI | 1.00d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 9.00 a | 1.64ab | 0.33 f-1 | 1.97ab | 0.56 a |
| 3 | CISADANE | 1.00d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 0.00 c | 1.40 def | 0.34 f-1 | 1.59fgh | 0.43 c-f |
| 4 | EBAGICHI | 1.00d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 9.00 a | 1.14hij | 0.38 f-1 | 1.63 d-h | 0.44 c-f |
| 5 | FARO 14 | 1.00d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 9.00 a | 1.45cde | 0.34 f-1 | 1.82 c | 0.44 b-f |
| 6 | FARO 35 | 1.00d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 0.00 c | 1.33 d-g | 0.33 f-1 | 1.72 c-f | 0.53abc |
| 7 | FARO 36 | 1.00d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 0.00 c | 1.22ghi | 0.31hij | 1.49 g-j | 0.42 c-f |
| 8 | FARO 37 | 1.00d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 3.00bc | 1.28fgh | 0.39 c-f | 1.55 g-j | 0.49 a-d |
| 9 | FARO 44 | 3.33 a | 0.33 a | 2.33 a | 4.00 a | 1.00 d | 9.00 a | 1.34 def | 0.42bcd | 1.61 e-f | 0.48 a-e |
| 10 | FARO 50 | 1.00 d | 0.33 a | 0.00 b | 4.00 a | 1.00 d | 9.00 a | 1.35 d-g | 0.33 g-h | 1.73 c-f | 0.43 c-f |
| 11 | FKR 19 | 3.00 b | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 9.00 a | 1.46cde | 0.36 e-h | 1.64 d-g | 0.54abc |
| 12 | GAMBIAKA (L) | 1.00 d | 0.00 b | 0.00 b | 2.67 b | 3.00 b | 6.00ab | 0.99jk | 0.38 e-h | 1.18 k | 0.40 def |
| 13 | IR 42 | 1.00 d | 0.00 b | 0.00 b | 4.00 a | 3.00 b | 0.00 c | 1.10 ij | 0.46 b | 1.48hij | 0.44 b-f |
| 14 | IR 64 | 3.00 b | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 0.00 c | 1.46cd | 0.30ij | 1.79cd | 0.36ef |
| 15 | IRRI 119 | 1.00 d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 0.00 c | 1.64ab | 0.27 j | 1.85bc | 0.34 f |
| 16 | LADANCHI | 1.00 d | 0.00b | 0.00 b | 4.00 a | 3.00 b | 3.00bc | 1.13hij | 0.34 f-i | 1.41 j | 0.39 def |
| 17 | MALEGBELI | 1.00 d | 0.00 b | 0.00 b | 2.00 c | 3.00 b | 0.00 c | 1.28fgh | 0.45bc | 1.43 ij | 0.51 a-d |
| 18 | MOROBEREKAN | 3.00 d | 0.00 b | 0.00 b | 4.00 a | 3.00 b | 9.00 a | 1.42 c-f | 0.44bcd | 1.64 d-g | 0.50 a-d |
| 19 | PIE BELEO | 2.00 d | 0.00 b | 0.00 b | 2.00 c | 1.00 d | 0.00 c | 1.42 c-f | 0.38 e-h | 1.65 d-g | 0.47 a-e |
| 20 | SUAKOKO | 3.00 b | 0.00 b | 0.00 b | 4.00 a | 3.00 b | 0.00 c | 1.22ghi | 0.45bc | 1.53 g-J | 0.56ab |
| 21 | SWARNA | 1.00 d | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 0.00 c | 1.30d f-g | 0.31ij | 1.59fgh | 0.50 a-d |
| 22 | SWARNA SUB 1 | 1.00 d | 0.00 b | 0.00 b | 4.00 a | 3.00 b | 0.00 c | 0.95 k | 0.38 d-g | 1.22 k | 0.41 def |
| 23 | TORMA | 1.00 d | 0.00 b | 0.00 b | 2.00 c | 1.00 d | 0.00 c | 1.56bc | 0.32 g-J | 1.75cde | 0.43 c-f |
| 24 | WITA | 3.00 b | 0.00 b | 0.00 b | 4.00 a | 1.00 d | 0.00 c | 1.35d-g | 0.35 f-I | 1.74 c-f | 0.39 def |
| 25 | YIRIKIRU | 1.00 d | 0.00 b | 0.00 b | 2.00 c | 5.00 a | 0.00 c | 1.30efg | 0.91 a | 1.21 k | 0.54abc |
| | MEAN | 1.61 | 0.01 | 0.09 | 3.63 | 1.67 | 3.00 | 1.34 | 0.38 | 1.61 | 0.46 |
| | CV | 7.16 | 866.03 | 866.03 | 6.37 | 13.86 | 60.82 | 6.15 | 8.78 | 5.17 | 13.15 |
| | S.D | 0.93 | 0.12 | 0.81 | 0.78 | 1.11 | 4.27 | 0.20 | 0.12 | 0.22 | 0.08 |
| | $R^2$ | 0.99 | 0.35 | 0.35 | 0.94 | 0.97 | 0.88 | 0.89 | 0.95 | 0.91 | 0.61 |
| | P VALUE | 0.0001 | 0.4843 | 0.4843 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0003 |

Means with the same subscript along columns are not significantly different ($p<0.05$) using the Duncan Multiple Range Test.

**KEY**: Brl-Brown rice length, BrW-Brown rice width, GL-Grain length, GW-Grain width, SC- Seed colour, SS- Seed shape, Clk-Chalkiness of Endosperm

**Table 2: Correlation coefficients of evaluated seed characters for *Oryza sativa* genotypes**

| Parameters | HC | Awn P/A | Awn length (cm) | BrL (mm) | BrW (mm) | GL (mm) | GW (mm) | SC | SS | CLK |
|---|---|---|---|---|---|---|---|---|---|---|
| HC | 1 | | | | | | | | | |
| Awn P/A | 0.18 | 1 | | | | | | | | |
| Awn length | 0.17 | 1.00* | 1 | | | | | | | |
| BrL (mm) | 0.31 | 0.08 | 0.08 | 1 | | | | | | |
| BrW (mm) | -0.03 | 0.05 | 0.05 | -0.19 | 1 | | | | | |
| GL (mm) | 0.29 | -0.05 | -0.05 | 0.82* | -0.49 | 1 | | | | |
| GW (mm) | 0.02 | 0.22 | 0.22 | -0.00 | 0.35 | -0.11 | 1 | | | |
| SC | 0.21 | 0.06 | 0.66 | 0.02 | -0.45 | 0.30 | -0.11 | 1 | | |
| SS | -0.09 | -0.07 | -0.07 | -0.43 | 0.79 | -0.66 | 0.26 | -0.39 | 1 | |
| CLK | 0.11 | 0.16 | 0.16 | -0.08 | -0.08 | 0.15 | 0.14 | 0.27 | -0.17 | 1 |

*Significant, $P<0.05$

KEY: Brl-Brown rice length, BrW-Brown rice width, GL-Grain length, GW-Grain width, SC- Seed colour, SS- Seed shape
Clk-Chalkiness of Endosperms

**Table 3: Seed polymorphism evaluated amongst 48 *Oryza glaberrima* genotypes**

| S/NO | Genotypes | Hull color | Awn P/A | Awn length(cm) | SC | SS | CLK | BrL (mm) | BrW (mm) | GL (mm) | GW (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | TOG 6427 | 1.00e | 1.00a | 5.00abc | 6.00a | 5.00a | 0.00a | 1.25b-j | 0.32hi | 1.46a-h | 0.49efg |
| 2 | TOG12255 | 2.00c | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.28b-h | 0.40f-i | 1.45a-h | 0.51efg |
| 3 | TOG13714 | 2.00c | 0.33bc | 1.67de | 6.00a | 1.00e | 0.00a | 1.19c-m | 0.34hi | 1.59a-h | 0.46fg |
| 4 | TOG14357 | 2.00c | 0.33bc | 1.67de | 2.00b | 3.00b | 0.00a | 1.21b-l | 0.47e-i | 1.35b-g | 0.56c-g |
| 5 | TOG16780 | 1.00e | 0.00c | 0.00e | 6.00a | 5.00a | 0.00a | 1.03l-q | 0.46e-i | 1.30e-j | 0.56c-g |
| 6 | TOG 16803 | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.11f-p | 0.42f-i | 1.61ab | 0.77a-d |
| 7 | TOG 5317-B | 1.00e | 0.00c | 0.00e | 6.00a | 5.00a | 0.00a | 1.03L-q | 0.51c-g | 1.67ij | 0.56c-g |
| 8 | TOG 5429-A | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.29b-f | 0.35hi | 1.45a-i | 0.49efg |
| 9 | TOG 5499-A | 2.00c | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.13e-n | 0.45e-i | 1.37a-j | 0.55c-g |
| 10 | TOG 5552 | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.22b-k | 0.33hi | 1.56a-e | 0.41g |
| 11 | TOG5556-A | 1.67cd | 1.00a | 5.00abc | 6.00a | 1.00e | 0.00a | 1.31a-e | 0.35hi | 1.44a-i | 0.48fg |
| 12 | TOG 5696-A | 1.00e | 0.00c | 0.00e | 6.00a | 5.00a | 0.00a | 1.01m-q | 0.69bcd | 1.13j | 0.71a-f |
| 13 | TOG 5923 | 2.00c | 0.67ab | 3.33bcd | 6.00a | 1.00e | 0.00a | 1.27b-i | 0.26i | 1.55a-f | 0.51efg |
| 14 | TOG5968 | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.36abc | 0.47e-i | 1.55a-e | 0.55c-g |
| 15 | TOG 5980-A | 1.00e | 0.00c | 0.00e | 6.00a | 5.00a | 0.00a | 0.95o-r | 0.67b-e | 1.32c-j | 0.82ab |
| 16 | TOG5987-A | 2.00c | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.09h-p | 0.44f-i | 1.29e-j | 0.56c-g |
| 17 | TOG 6203-A | 5.00a | 0.33bc | 1.67de | 6.00a | 5.00a | 0.00a | 0.93pqr | 0.71bc | 1.32c-j | 0.77a-d |
| 18 | TOG 6223-B | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.27b-i | 0.50c-h | 1.35b-j | 0.57c-g |
| 19 | TOG 6256 | 1.00e | 0.33bc | 2.33cde | 6.00a | 1.67d | 0.00a | 1.29b-g | 0.39ghi | 1.49a-h | 0.49efg |
| 20 | TOG 6417 | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.48a | 0.41f-i | 1.65a | 0.60b-g |

| S/NO | Genotypes | Hull color | Awn P/A | Awn length(cm) | SC | SS | CLK | BrL (mm) | BrW (mm) | GL (mm) | GW (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | TOG 6461 | 3.00b | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.24b-j | 0.39ghi | 1.44a-j | 0.49efg |
| 22 | TOG 6509 | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.05k-q | 0.44e-i | 1.57a-e | 0.58b-g |
| 23 | TOG 6547 | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.18c-m | 0.50c-h | 1.41a-j | 0.53d-g |
| 24 | TOG 6603-B | 1.00e | 0.00c | 0.00e | 6.00a | 5.00a | 0.00a | 1.01m-q | 0.78ab | 1.41a-i | 0.74a-e |
| 25 | TOG 6649 | 2.00c | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.15d-m | 0.44e-i | 1.36b-j | 0.51efg |
| 26 | TOG 6732 | 1.00e | 1.00a | 5.ooabc | 6.00a | 1.00e | 0.00a | 1.29b-g | 0.30hi | 1.48a-h | 0.48efg |
| 27 | TOG 6790-A | 2.00c | 1.00a | 7.00a | 6.00a | 3.00b | 0.00a | 1.22b-k | 0.47e-i | 1.54a-f | 0.66a-g |
| 28 | TOG 7138 | 1.00e | 0.33bc | 1.67de | 6.00a | 1.67d | 0.00a | 1.32a-d | 0.44e-i | 1.53a-g | 0.55c-g |
| 29 | TOG  7208 | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.35abc | 0.32hi | 1.61abc | 0.50efg |
| 30 | TOG7213 | 1.00e | 1.00a | 5.00abc | 6.00a | 3.00b | 0.00a | 0.96o-r | 0.39ghi | 1.41a-j | 0.52d-g |
| 31 | TOG7238 | 1.33de | 0.67ab | 3.33bcd | 6.00a | 3.00b | 0.00a | 1.01j-e | 0.44e-i | 1.22hij | 0.53d-g |
| 32 | TOG7249 | 1.00e | 0.00c | 0.00e | 6.00a | 5.00a | 0.00a | 0.90qr | 0.61b-f | 1.43a-i | 0.64a-g |
| 33 | TOG7253 | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.03l-q | 0.72b | 1.35b-j | 0.87a |
| 34 | TOG 7260-A | 3.00b | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.19c-m | 0.39ghi | 1.43a-i | 0.53d-g |
| 35 | TOG7279 | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.21b-l | 0.38hi | 1.56a-e | 0.55c-g |
| 36 | TOG 7323-A | 1.00e | 1.00a | 5.67ab | 6.00a | 3.00b | 0.00a | 1.08i-q | 0.50c-h | 1.37a-j | 0.80abc |
| 37 | TOG 7386 | 1.00e | 0.33bc | 2.33cde | 6.00a | 5.00a | 0.00a | 1.22b-k | 0.79ab | 1.31d-j | 0.57b-g |
| 38 | TOG 7400 | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.17c-m | 0.42f-i | 1.55a-f | 0.56c-g |
| 39 | TOG 7412 | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.34abc | 0.63b-c | 1.56a-e | 0.81abc |
| 40 | TOG 7453-A | 2.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.40ab | 0.30hi | 1.43a-i | 0.43g |
| 41 | TOG 7986-A | 1.00e | 0.00c | 0.00e | 6.00a | 2.33c | 0.00a | 1.34abc | 0.46e-i | 1.60a-d | 0.53dg |
| 42 | TOG 7993-A | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.23b-j | 0.38hi | 1.44a-i | 0.50efg |
| 43 | TOG 7994 | 2.67b | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 0.97n-q | 0.30hi | 1.24f-j | 0.41g |
| 44 | TOG 7995 | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.22b-k | 0.34hi | 1.52a-g | 0.44g |
| 45 | TOG8347 | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.31a-e | 0.48d-i | 1.59a-d | 0.58b-g |
| 46 | TOG 9266 | 1.00e | 0.00c | 0.00e | 6.00a | 1.00e | 0.00a | 1.34a-d | 0.33hi | 1.62ab | 0.45fg |
| 47 | TOG9276 | 1.00e | 0.00c | 0.00e | 6.00a | 5.00a | 0.00a | 0.79r | 0.93a | 1.53a-g | 0.46fg |
| 48 | TOG 9331 | 1.00e | 0.00c | 0.00e | 6.00a | 3.00b | 0.00a | 1.32a-d | 0.50c-h | 1.53a-g | 0.46fg |
| | MEAN | 1.42 | 0.19 | 1.03 | 2.08 | 2.61 | 0.00 | 1.18 | 0.46 | 1.44 | 0.56 |
| | CV | 20.18 | 132.66 | 135.30 | 0.00 | 11.04 | 0.00 | 7.91 | 24.18 | 9.60 | 22.09 |
| | S.D | 0.80 | 0.39 | 2.17 | 0.57 | 1.51 | 0.00 | 0.17 | 0.17 | 0.17 | 0.15 |
| | R2 | 0.92 | 0.73 | 0.73 | 1.00 | 0.98 | 0.00 | 0.79 | 0.72 | 0.55 | 0.57 |
| | P VALUE | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | 0.0002 | 0.0001 |

Means with the same subscript along columns are not significantly different ($p<0.05$) using the Duncan's  Multiple Range Test.

KEY:Brl-Brown rice length, BrW-Brown rice width, GL-Grain length, GW-Grain width, SC- Seed colour, SS- Seed shape, Clk-Chalkiness of Endosperm

**Table 4: Correlation coefficients of evaluated seed characters for *Oryza glaberrima* genotypes.**

| Parameters | H C | Awn P/A | Awn length | BrL (mm) | BrW (mm) | GL (mm) | GW (mm) | SC | SS |
|---|---|---|---|---|---|---|---|---|---|
| H C | 1 | | | | | | | | |
| Awn P/A | 0.07 | 1 | | | | | | | |
| Awn length | 0.07 | 0.99* | 1 | | | | | | |
| BrL (mm) | -0.12 | 0.04 | 0.05 | 1 | | | | | |
| Brw(mm) | -0.06 | - 0.13 | -0.010 | -0.43* | 1 | | | | |
| GL (mm) | -0.18 | -0.03 | -0.02 | 0.52* | -0.22 | 1 | | | |
| GW (mm) | -0.03 | 0.04 | 0.06 | -0.20 | 0.37 * | -0.09 | 1 | | |
| SC | 0.11 | 0.05 | 0.04 | 0.03 | 0.01 | -0.008 | -0.01 | 1 | |
| SS | -0.04 | -0.03 | -0.01 | -0.56 | 0.54 | -0.34* | 0.26 | 0.04 | 1 |

*Significant, P<0.05

KEY:Brl-Brown rice length, BrW-Brown rice width, GL-Grain length, GW-Grain width, SC- Seed colour, SS- Seed shape

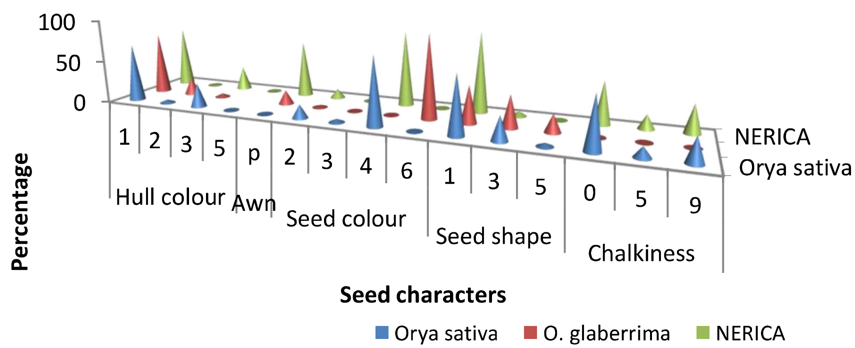


Figure 1: comparative seed polymorphism of three rice (*Oryza* spp) species

**Table 5: Seed polymorphism evaluated amongst 18 NERICA genotypes.**

| S/NO | Genotypes | Hull color | Awn P/A | Awn length | SC | SS | CLK | BrL (mm) | BrW(mm) | GL (mm) | GW (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NERICA-L-41 | 1.00b | 0.00b | 0.00c | 3.67b | 1.00b | 0.00c | 1.40c | 0.36abc | 1.73cde | 0.43abc |
| 2 | NERICA-L-11 | 1.00b | 1.00b | 0.00c | 2.00c | 1.00b | 0.00c | 1.51b | 0.31b-g | 1.80cd | 0.50a |
| 3 | NERICA-L-12 | 1.00b | 1.00b | 0.00c | 2.00c | 1.00b | 0.00c | 1.51b | 0.33b-g | 1.75cde | 0.46ab |
| 4 | NERICA-L-15 | 1.00b | 1.00b | 0.00c | 4.00a | 1.00b | 5.00b | 1.60b | 0.41a | 2.06a | 0.44abc |
| 5 | NERICA-L-17 | 3.00b | 1.00b | 0.00c | 4.00a | 1.00b | 0.00c | 1.72a | 0.32b-g | 2.08a | 0.43abc |
| 6 | NERICA-L-2 | 1.00b | 1.00b | 0.00c | 4.00a | 1.00b | 9.00a | 1.54b | 0.30c-g | 1.83cd | 0.40bc |
| 7 | NERICA-L-20 | 3.00b | 1.00b | 0.00c | 4.00a | 1.00b | 9.00a | 1.76a | 0.32b-g | 1.99ab | 0.41abc |
| 8 | NERICA-L-3 | 1.00b | 0.33b | 1.67c | 4.00a | 1.00b | 9.00a | 1.57a | 0.27g | 1.87bc | 0.42abc |
| 9 | NERICA-L-34 | 3.00b | 1.00b | 0.00c | 4.00a | 1.00b | 0.00c | 1.75a | 0.33b-f | 2.02a | 0.44abc |
| 10 | NERICA-L-5 | 3.00b | 0.33b | 1.67c | 4.00a | 1.00b | 5.00b | 1.73a | 0.34b-e | 1.98ab | 0.44abc |
| 11 | NERICA-L-58 | 3.00b | 0.33b | 1.67c | 4.00a | 1.00b | 9.00a | 1.81a | 0.30d-g | 2.00ab | 0.36c |
| 12 | NERICA-L-59 | 1.00b | 1.00b | 0.00c | 4.00a | 1.00b | 9.00a | 1.56b | 0.40a | 1.69de | 0.46ab |
| 13 | NERICA-U-1 | 1.00b | 0.33b | 1.67c | 4.00a | 1.00b | 5.00b | 1.39c | 0.30d-g | 1.62ef | 0.38bc |
| 14 | NERICA-U-2 | 1.00b | 1.00a | 5.67c | 4.00a | 1.00b | 0.00c | 1.24d | 0.29fg | 1.51fg | 0.37bc |
| 15 | NERICA-U-3 | 1.00b | 0.33b | 1.67c | 4.00a | 3.00b | 0.00c | 1.18d | 0.36a-d | 1.50g | 0.47ab |
| 16 | NERICA-U-4 | 1.00b | 1.00b | 0.00c | 4.00a | 1.00b | 0.00c | 1.23d | 0.28g | 1.51fg | 0.41abc |
| 17 | NERICA-U-5 | 1.00b | 1.00a | 7.00a | 4.00a | 1.00b | 0.00c | 1.61b | 0.36ab | 1.83cd | 0.41abc |
| 18 | NERICA-U-7 | 1.00b | 0.67ab | 3.33b | 4.00a | 1.00b | 9.00a | 1.34c | 0.33b-f | 1.40g | 0.43abc |
| | MEAN | 1.56 | 0.24 | 1.35 | 3.76 | 1.11 | 3.83 | 1.52 | 0.33 | 1.79 | 0.43 |
| | CV | 0 | 141.8 | 127.40 | 3.62 | 0 | 0 | 3.47 | 8.98 | 4.50 | 11.55 |
| | S.D | 0.91 | 0.43 | 2.47 | 0.64 | 0.46 | 4.10 | 0.19 | 0.05 | 0.22 | 0.05 |
| | $R^2$ | 1.00 | 0.60 | 0.69 | 0.97 | 1.00 | 1.00 | 0.95 | 0.73 | 0.91 | 0.46 |
| | P VALUE | 0.0001 | 0.0034 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.14 |

Means with the same subscript along columns are not significantly different ($p<0.05$) using the Duncan Multiple Range Test.
KEY:Brl-Brown rice length, BrW-Brown rice width, GL-Grain length, GW-Grain width, SC- Seed colour, SS- Seed shape, Clk-Chalkiness of Endosperm

**Table 6: Correlation coefficients of evaluated seed characters for NERICA genotypes.**

| Parameters | H C | Awn P/A | Awn length (cm) | BrL (mm) | BrW (mm) | GL (mm) | GW (mm) | SC | SS | CLK |
|---|---|---|---|---|---|---|---|---|---|---|
| H C | 1 | | | | | | | | | |
| Awn P/A | -0.16 | 1 | | | | | | | | |
| Awn length | -0.17 | 0.98* | 1 | | | | | | | |
| BrL (mm) | 0.74* | -0.18 | -0.16 | 1 | | | | | | |
| BrW(mm) | -0.08 | -0.10 | -0.06 | 0.10 | 1 | | | | | |
| GL (mm) | 0.65* | -0.27 | -0.25 | 0.85* | 0.13 | 1 | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| GW (mm) | -O.11 | -0.20 | -0.19 | -0.04 | 0.43 | 0.02 | 1 | | | |
| SC | 0.24 | 0.21 | 0.21 | 0.04 | 0.04 | 0.03 | -0.34 | 1 | | |
| SS | -O.15 | 0.05 | 0.03 | - 0.43 | 0.15 | -0.32 | 0.19 | 0.09 | 1 | |
| CLK | -0.04 | 0.07 | 0.06 | 0.28 | 0.01 | 0.08 | -0.24 | 0.36 | -0.23 | 1 |

*Significant, $P<0.05$

KEY:Brl-Brown rice length, BrW-Brown rice width, GL-Grain length, GW-Grain width, SC- Seed colour, SS- Seed shape, Clk-Chalkiness of Endosperms.

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