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Evaluation of M_6 *Ofada* Rice Mutant Selections and Parents for Grain Physico-Chemical and Nutritional Characters

***[1]Adewusi, K.M., [2]Showemimo, F.A., [1]Nassir, A.L. and [1]Oguntade, O.A.**

[1]Crop Production Department, College of Agricultural Sciences,
Olabisi Onabanjo University, P.M.B 2002, Ago-Iwoye, Ogun State, Nigeria
[2]Department of Plant Breeding and Seed Technology, College of Plant Science and Crop Production,
Federal University of Agriculture (FUNAAB), P.M.B 2240, Abeokuta, Ogun State, Nigeria
Corresponding Author's email: kayode.adewusi@oouagoiwoye.edu.ng

Abstract
Rice consumers are becoming more conscious of the varieties they consume in terms of nutritional quality. Selection for quality improvement would benefit from induced variability as innate sources are becoming exhausted. This study was carried out to assess the extent of improvement of rice grain quality yield for the benefit of the farmers and the consumers. Two *Ofada* rice varieties (*FUNAABOR* 1 and *FUNAABOR* 2) were irradiated with ^{60}Co gamma rays to elicit variation towards selection for grain improvement in 2013. Individual seed selections from different treatment levels in M_1 and subsequent generations were harvested and replanted for advancement to M_6 generation. Harvested seeds from selected promising M_6 mutants and parents were subjected to physical, chemical and nutritional analysis. Analysis of Variance (ANOVA) was applied to data to generate character overall mean and variance estimates from which heritability estimates were computed. Means of the different mutants were compared with parents using Duncan Multiple Range Test (DMRT). *Ofada* rice mutants and parents varied significantly for all the studied grain traits. The mutants and parents had long grains (6.6mm - 7.1mm). Mutant, OG13602 _100 had high values for amylose content (20.01%), followed by OG13608_300 (19.47%). The two mutants (OG13602_100 and OG13608_300) respectively also recorded the highest values for crude protein (6.41% and 6.28%), fat (3.94% and 3.81%), fibre (2.14% and 2.05%), and ash content (3.92% and 3.71%). Overall, the entries clustered into two groups along the parental lines and present opportunities for hybridization. High heritability with concomitant high genetic advance was recorded for amylose, ash and moisture content. All selected promising *Ofada* rice mutants and parents had long grains. Specifically, mutants OG13602_100 and OG13608_300 which expressed superior amylose, protein, fat, fibre and ash contents present opportunities for further improvement for grain quality. The significant variability of the studied traits revealed additional gains from further selection.

Keywords: Mutant, FUNAABOR 1, FUNAABOR 2, heritability, variety

Introduction

In Nigeria, rice as a major crop is no longer an occasional food eaten during festive periods but has become an everyday food consumed by most of the people in the country (Moses and Adebayo, 2007). It is commonly eaten in many localities and can be processed into different forms such as (jollof) rice, fried rice, white rice and even milled into flour turned into *Tuwo* etc. Rice is the only cereal crop cooked and consumed mainly as whole grains and quality considerations are much more important than for any other food crop (Hossain *et al*., 2009). According to Kemashalini (2018) rice-flour is a good substitute for wheat flour. Rice has a high proportion of lysine and high protein digestibility (Chaudhari *et al*., 2018). It produces 20% of energy, 15% of protein and up to 50% of the dietary calories for millions living in poverty and hence, underscoring its importance for food security (Sumithra *et al*., 2014). Rice quality is evaluated on the basis of its suitability for a specific end use with respect to consumers (Tokpah, 2010; Danbaba *et al*., 2011; Sultana *et al*., 2022). The quality of rice also determines its market price and acceptance by the consumers. Visual characteristics of rice grains, inclusive of grain size and shape are both visual characters based on length and width ratio and are important search attributes that affect consumers' purchasing decisions (Graham, 2002). In addition, apparent amylose content (AAC), gel consistency (GC) and gelatinization temperature (GT) have been identified as three parameters deem most important in gauging the cooking and eating quality of rice variety. As apparent amylose content increases, cooked rice grains tend to be increasingly harder (Juliano *et al*., 1981). Several studies have revealed that variations in composition and cooking quality of rice is mainly dependent on the genetic as well as surrounding environmental factors where they are grown (Roychowdhury, 2008; Oko *et al*., 2012). NERICA rice varieties with gene inheritance from *Oryza glabberima* for instance, had high amylose content while the varieties with gene inheritance from *Oryza sativa* had been reported with lower amylose content (Kishine *et al*., 2008). Nigerians prefer imported rice to locally produced types which has a number of challenges like poor quality, broken grain, low swelling capacity, breakages, and lack of competition advantages, while the only constraints to imported rice consumption are high cost and affordability of the products (Onu, 2018). These constraints are also typical of the *Ofada* rice variety which though is sought after but may also have quality issues. Like grain yield, quality is not easily amenable to selection due to its complex nature (VenkataSubbaiah *et al*., 2011). The technique that could be used to obtain superior varieties is by cross breeding and mutation (Mugiono and Dewi, 2009). Mutation breeding has the potential to create genetic variability through mutagens, identification of superior lines, multiplication and management of mutant varieties (Karthikeya *et al*., 2018). Mutants can be released as a new variety or used as one of the parents in future breeding programmes. Therefore, a shift in the rice breeding strategies from quantity centered approach to quality oriented effort is inevitable. High yield alone without good grain qualities is inadequate as both (high yield and good grain quality) play vital roles in adoption of a particular rice grain variety. A number of mutant selections were made from M_6 selections for higher yield from initial population of local *Ofada* rice. This study was therefore conceived to provide information on physical grain characters, chemical and nutritional grain composition of promising *Ofada* rice selections and the base parents.

Materials and Methods

Origin of sample materials

Two varieties of *Ofada* rice (*FUNAABOR* 1 & *FUNAABOR* 2) released in 2011 (Showemimo *et al.*, 2011) were irradiated at Ghana Atomic Energy Commission (GAEC), Accra, Ghana in 2013 and taken through six cycles of cultivation/selection (M_1 – M_6) along with the parents between late planting season of year 2013 and early planting season of the year 2016. The field experiments were carried out at Olabisi Onabanjo University, College of Agricultural Sciences, Ayetoro campus, Ogun State, Nigeria. Ayetoro is located at the latitude 7°12'N and longitude 3°3'E in derived Savannah area of Ogun State, Nigeria. Seeds of all treatments (levels of irradiation) were directly sown after irradiation to raise M_1 plants. Seedlings were transplanted on a well prepared land at spacing of 25cm × 25cm in Randomized Complete Block Design with three replications for each treatment with 3m long for 12 rows. Selection based on desirable traits, genetic confirmation, multiplication and stabilization of field performance of mutant were carried out continuously from M_1 to M_6. Harvested grains from selected promising M_6 mutants and the parents were subjected to physico-chemical and nutritional analysis at the Biochemistry Laboratory of the Institute of Agricultural Research and Training (IAR&T), Moor plantation, Ibadan, Nigeria.

Laboratory Analysis

Determination of physicochemical parameters

One hundred seeds of whole grains of rice free from any physical damage or insect damages were selected randomly and used for the analysis. Grain length and width of the selected seeds were measured with the use of Vernier caliper. Thereafter, the samples were weighed with the sensitive weighing balance. Thereafter, the rice grain samples were ground with pestle on mortar, packed in air tight plastic bags and stored at 40°C for chemical analysis according to Thomas *et al*. (2013).

(a) Analysis of Amylose and Amylopectin content

Amylose content was evaluated by the method described by Perez *et al*. (1987) and the amylopectin content was estimated by the difference method.

(b) Gel consistency

Gel consistency was determined based on the consistency of milled rice paste that has been gelatinized by boiling in dilute alkali and then cooled to room temperature. Tubes were laid horizontally on a table lined with millimeter graph paper and total length of the gel measured in millimeters.

Proximate composition

Proximate composition of the rice grain was analyzed and determined using methods of Association of Analytical chemistry (AOAC, 2005).

Statistical Analysis

All measurements and data were subjected to Analysis of Variance (ANOVA) using SAS software version 9.1 (SAS institute, 1998). The means were separated by the least significant difference (LSD) at 5% probability level. Variance components were estimated to determine genetic variation among the selected mutant lines, parents and also to access genetic and environmental effects on characters studied. The variance component include; genotypic variance, phenotypic variance, error variance, phenotypic and genotypic co-efficient of variation (PCV and GCV). These were calculated according to Singh and Choudhary (1985). Broad sense heritability (H^2b.s) as well as genetic advance (G.A) was also estimated according to Falconer (1989).

Genetic Analyses

Genotypic Variance ($\delta^2 g$)

Genotypic variance was estimated by the formula:

$\delta^2 g = (MSG – MSE)/r$; where MSG is the mean square of genotypes, MSE is mean square of error and r is the number of replications.

Phenotypic Variance ($\delta^2 p$)

Phenotypic variance was estimated as the sum of theestimated genotypic variance ($\delta^2 g$) and the environmental variance (MSe or $\delta^2 e$).

Genotypic Coefficient of Variation (GCV)

$$\text{GCV}(\%) = \frac{\sqrt{\delta^2 g}}{x} \text{x} 100$$

Phenotypic Coefficient of Variation (PCV)

$$\text{PCV}(\%) = \frac{\sqrt{\delta^2 p}}{x} \text{x} 100$$

Heritability Broad Sense [h^2(b.s)]

The broad-sense heritability h^2(b.s) was estimated as described by Johnson *et al*. (1955) thus;

$$h^2(\text{b.s})(\%) = \delta^2 g \text{ x} 100$$

Results and Discussion

Results

Variation among selected promising Ofada rice mutant lines and parents

Physical grain characters

The mean values and genetic parameters for 100-grain weight, grain length, and grain width are presented in Tables 1 and 2. The 100-grain weight for all entries (mutants and parents) varied from 2.83g - 3.40g. Mutants derived from *FUNAABOR* 1 recorded high values for hundred grain weight and grain width compared to mutants from *FUNAABOR* 2. The highest mean grain weight (3.40g) was recorded by mutants OG13608_300 and OG13609_300 both from *FUNAABOR* 1 variety while least mean value of 2.83 g was recorded by mutant OW13618_250 from *FUNAABOR* 2 (Table 1). The mean grain width ranged between 1.7 mm – 2.7 mm with highest mean value of 2.7 mm recorded from OG13608_300. The mean grain length was between 6.6 mm – 7.1 mm with OW13620_250 and OW13624_300 from *FUNAABOR* 2 parent recording highest mean value of 7.1 mm. The genetic parameters for physical grain characters among promising selections of *Ofada* rice mutants and parents (Table 2) were generally low. The highest phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was for grain width (8.01, 8.01, respectively) while those of grain length (3.72, 3.72, respectively) were the least. The estimates of heritability (broad sense) for the grain characters were quite high at 96.3%, 100%, 100% for 100-grain weight, grain length and grain width, respectively. Genetic advance (GA) estimate was lowest for grain length (7.66) but a bit higher at 14.64 and 16.66 for hundred grain weight and grain width respectively.

Chemical properties and nutritional values among selected promising Ofada rice mutants and parents in M_6 plant–generation

Variation in starch, vitamins and proximate composition among the selected promising *Ofada* mutants and parents are shown in Tables 3, 4 and 5. The entries were significantly ($p<0.01$) different for all the studied chemical properties and nutritional contents (Table 3). The amylose content of the selected mutants and parents ranged between 6.81% - 20.01%. Mutant OG13602_100 had the highest amylose content, (20.01%) followed by OG13608_300, (19.47%), OG13609_300 (19.32%) and OG13606_250 (17.84%) while *FUNAABOR* 2 recorded the least amylose of 6.81% (Table 4). The values of amylopectin ranged between 80.12% - 93.19%. The values were higher in *FUNAABOR* 2 parent and mutants (90.04 - 93.19%) than in *FUNAABOR* 1 and selected mutants (80.12 – 83.20%). High gel consistency was recorded in OG13602_100 (46.40%) followed by OG13608_300 (44.53%), OG13609_300 (42.75%), OG13606_250 (42.23%) and the parent, *FUNAABOR* 1 (40.13%). *FUNAABOR* 2 recorded least gel consistency value of 23.70% (Table 4). The mean values for vitamins presented in Table 4 revealed that the vitamin contents in selected *Ofada* rice mutants and parents ranged between 9.91 – 13.25µg/kg, 2.05 – 2.70mg/kg and 3.32 – 3.78mg/kg in studied vitamins A, C and E respectively. Mutant OG13602_100 from *FUNAABOR* 1 had the highest contents for the three vitamins, followed by selected mutant OG13608_300 and OG13609_300. On the contrary, *FUNAABOR* 2 parent recorded least content for all the vitamins. The crude protein content of brown rice from the eight selected mutants and parents ranged from 3.61% to 6.41%. *FUNAABOR* 1 and the mutants recorded higher (5.48 – 6.41%) crude protein than *FUNAABOR* 2 and its mutants. Mutant OG13602_100 from *FUNAABOR* 1 variety recorded highest level of protein content (6.41%) while parent, *FUNAABOR* 2 recorded lowest (3.61%) crude protein (Table 4). Fat content in this study varied between 2.28% - 3.94% which was higher in *FUNAABOR* 1 and its mutants (Table 4). Mutant, OG13602_100 recorded highest fat content (3.94%) followed by OG13608_300 (3.81%) and OG13609_300 (3.72%). The lowest mean fat content of 2.28% was obtained from *FUNAABOR* 2.

Fibre content in this study ranged between 1.55% - 2.14%. Selected mutants recorded higher percentage of fibre content than either of the two parents. *FUNAABOR* 2 parent recorded the least (1.55%) followed by *FUNAABOR* 1 (1.63%). Highest fibre content was obtained from mutant OG13602_100 with a value 2.14%. Ash content among the 8 selected mutants and 2 parents ranged from 1.72 % - 3.92 %. Ash content was higher in *FUNAABOR* 1 and its mutant lines compared with *FUNAABOR* 2 and its selected lines. The two parents recorded low ash contents compared to their respective mutant lines. Mutant OG13602_100 recorded highest value of 3.92% for ash while the lowest ash content (1.72%) was obtained from *FUNAABOR* 2. Moisture levels of the 8 selected *Ofada* mutants and the two parents varied between 3.49% - 6.72%. *FUNAABOR* 1 and its mutant lines recorded lower moisture levels which varied between 3.49% for OG13602_100 and 3.92% for *FUNAABOR* 1 parent. Moisture content among *FUNAABOR* 2 and selected lines varied from 6.19% for OW13618_250 to 6.72% obtained from OW13620_250. The highest magnitude of genotypic and phenotypic variance was recorded for amylose content, amylopectin and gel consistency while least estimate were recorded for vitamin A, C and E (Table 5). The phenotypic coefficients of variation (PCV) were however similar to the genotypic coefficients of variation (GCV) for all the traits. High heritability values were recorded for all the grain quality characters. High estimate of genetic advance were recorded for amylose content (81.90%), ash content (66.17%), moisture content (60.63%) and gel consistency (45.66%). The least estimate of genetic advance of 8.81% was recorded by Vitamin E (Table 5). Moderate genetic advance was observed in crude fat (39.18%), crude protein (37.93%) and crude fibre (20.55%).

The dendrogram from proximate composition of the M_6 mutant selections and their parents are presented in Figure 1. The selections from *FUNAABOR* 1 and *FUNAABOR* 2 along with the parents separated into two major clusters I and II respectively. Cluster I membership was defined by higher values for all the proximate composition with the exception of amylopectin and percent moisture content which were relatively higher in membership of Cluster II.

Discussion

The highly significant differences in grain weight, length and width among selected promising *Ofada* rice mutants and parents in this study indicate inherent variability in genetic makeup. Hundred grain weight (2.83-3.40g) from the current study is within the range of the values obtained by Tamu *et al*. (2017). The grain length of promising *Ofada* mutants and parents of 6.6mm – 7.1mm in this study classifies them as long grains. The length however still lies within 5.9mm – 9.0mm recorded by Danbaba *et al*. (2012) for local *Ofada* rice cultivars. Rice grains whose length are greater than 6mm are classified as long grains according to Dipti *et al.* (2002) while those that ranged between 5mm – 6mm are medium and those with length less than 5mm are regarded as short grain rice. Long grain rice according to Hossain *et al*. (2009) is widely considered acceptable. This places the selections in this study at an advantage even as the possibility of further improvement is not foreclosed. The significant variation in grain quality traits expresses appreciable variation that could still be exploited for hybridization and selection. The higher seed quality traits observed for the mutants (selections) compared to the parent line attests to the importance of mutagenic rays in creating generational variation in plants and its advantageous use for directional selection in the development of varieties. However, the variation in the selections from different levels of radiation for different traits indicate the necessity to have further understanding of radiation level that is best for a particular trait. Noteworthy, however is the observation of OG13602_100 which recorded the highest value for all the traits except amylopectin and moisture content.

Two kinds of starches: amylose and amylopectin in the rice grains are known to be of great importance in the cooking and eating characteristics of rice (Asghar *et al*., 2012). Cruz and Khush (2000) grouped rice into waxy (0 – 2%), very low (3 – 9%), low (10 – 19%), intermediate (20 – 25%) and high (>25%) based on the level of their amylose content. *Ofada* mutant, OG13602_100 and OG13608_300 with highest percentage of amylose content (20.01% and 19.47%) in the current study ranged intermediate may absorb more water and have a fluffy texture after cooking according to Frei and Becker (2003) than mutants derived from *FUNAABOR* 2 with low amylose values. Amylopectin is composed of glucose molecules that are less resistant to digestion (Danbaba *et al*., 2011). Rice varieties with a greater proportion of starch in the form of amylopectin are possible to have a higher glycaemic Index (GI), pronounced increase in blood sugar level and possibly to absorb less water upon cooking; hence have a sticky texture (Frei and Becker, 2003). With regards to gel consistency classification, all mutants derived from *FUNAABOR* 1"can be classified as medium. Meanwhile, based on ranking, mutants OG13602_100 and OG13608_300 are considered softer than others. Rice with soft gel consistency cook more tender and remain soft cook even upon cooking. Hence, according to Tang *et al*. (1991), mutants OG13602_100 and OG13608_300 would be preferred by consumer for their tender texture. Also, the amylopectin and gel consistency values are quite variable among the entries. This is unlike the values obtained for the other grain quality traits which are more similar. The implication is that opportunities abound for varietal selection for these traits. There is also the chance of further hybridization of amylopectin and gel consistency with other traits.

Increase in health awareness and greater concern for health issues has led to growing and breeding for special rice varieties that are rich in bioactive compound such as vitamins (Shammugasamy *et al*., 2015). One of the features to determine the quality of rice according to Bergman and Xu (2003) is the content of vitamin E which is observed to vary depending on the rice genetic composition and environmental conditions. Juliano *et al*. (1993) revealed that rice was a good source of B vitamins, thiamine, riboflavin and niacin but low in vitamin C, D or β carotene which is the precursor of vitamin A. There are several reports on vitamin E contents of whole rice of different varieties (Kim *et al*., 2012; Gunaratne *et al*., 2012). The range of vitamin C (ascorbic acid) and vitamin E among the selected mutants and parents in this study lies within the range values of raw ascorbic reported by Otemuyiwa *et al*. (2018) and vitamin E presented by Shammugasamy *et al*. (2015) respectively. High values of vitamin A from *FUNAABOR* 1 mutants appeared to be at variance with the reports from Juliano *et al*. (1993) that rice grain has little or no vitamin A, C or D. Protein content of the grains were considered to be low but of high nutritional value according to Chaudhary and Tran (2001). Rice nutrient composition differs significantly between varieties (Juliano and Villareal, 1993). Banerjee *et al*. (2010) revealed the varying levels of protein contents from 4.91 – 12.08% in rice accessions. Selected mutants from *FUNAABOR* 1 *Ofada* rice recorded high range values of protein content (5.68 - 6.41%) than what Das *et al*. (2018) reported from some indigenous rice varieties at Assam, India.

The fat content for the *Ofada* rice mutants and parents from this study had higher values compared to six aromatics and two non-aromatics rice investigated by Verma and Srivastav (2017). The fat content of rice in this study was however, similar to what Oko *et al*. (2012) obtained from indigenous rice varieties. Fat is a good source of linoleic and other essential fatty acid and known to contain no cholesterol (Eggum *et al*., 1982). Rice with high fat content has been identified to be tastier than those with less fat content (Hirokadzu *et al*., 1979). Mutant OG13602_100 with highest fat content would therefore be expected to be tastier than the two parents and other selected mutant lines. Fibre contents detected` from the selected *Ofada* mutants and parents are higher than values reported by Misra *et al*. (2018) and Verma and Srivastav (2017). The range values are somewhat similar to selected indigenous and newly introduced hybrid rice investigated by Oko *et al*. (2012). Fibre in the diet has a good laxative effect in the gut according to Mbatchou and Dawda, 2013. This is as a result of increase in the bulk of faeces. The level of the ash content of a food sample gives an idea of the mineral element in the food sample (Thomas *et al*., 2013). The ash content of brown rice of selected "*Ofada*" mutants and parents were found to be higher (1.72% - 3.92%) than those reported earlier (Ibukun, 2008; Nadiger and Kasturiba, 2015). Mutant, OG13602_100 is most likely to have high level of essential minerals with high level of ash content.

The low moisture content recorded from the selected mutants and parents in this study, though similar in range with those reported by Oko *et al*. (2012), indicated that the selected *Ofada* rice mutants has the potential of long term storage. The values were indeed lower than the moisture contents obtained by Verma and Srivastav (2017). According to Das *et al*. (2018), the differences in moisture content among the rice accessions might be due to the variety of rice, yield, proportionate amount of chemical constituents of the grains, processing and even environmental factor. Moisture content has been identified as a nutritional component that affects the quality and palatability of rice grains. It also plays a vital role in determining the shelf life of the grains (Oko and Onyekwere, 2010). 14% moisture content has been identified for the safe storage of processed rice and 12% recommended for long term storage according to Cogburn (1985). The separation of the entries into clusters is consistent with the observed differences in the variables involved in the assessment. It points out the possibility of inter-cluster hybridization in order to widen the genetic base for subsequent selection for further improvement.

Knowledge on the nature and magnitude of genetic variation governing the inheritance of these quantitative traits is essential for effecting genetic improvement. In this study, the highest magnitude of genotypic and phenotypic variance noted for gel consistency was similar to what was reported by VenkataSubbaiah *et al*. (2011). The high estimate of PCV and GCV for amylose content, amylopectin and gel consistency indicated that simple selection can be practiced for further improvement of these characters whereas lower PCV and GCV value for vitamin C and E in the study indicated that the scope for improvement of these traits by selection was limited. High heritability coupled with high genetic advance recorded for traits, particularly amylose and gel consistency indicates additive gene effects in the genetic control of these traits. These traits can be improved upon by simple selection. Similar observations of high heritability couple with high genetic advance for amylose were reported by VenkataSabbaiah *et al*. (2011). Crude protein, fat and fibre content with high heritability coupled with moderate genetic advance suggest that gain on selection for the improvement of these characters may be rewarding following the position of Paikhomba *et al*. (2014) and Kumar *et al*. (2006) but may require more cycles compared to other traits with high genetic advance.

Conclusion

The findings from this study revealed high genetic variability among the selected mutants and parents for physical grain characters as well as the chemical and proximate composition and such variability can be exploited for further improvement in breeding programme. It also affirms the merit of practical use of mutagenesis for creation of useful variation in traits. The study also showed that the mutants and the two parents are long grain rice with considerable amount of nutrients. *FUNAABOR* 1 and selected mutants revealed high values for amylose, protein, fat, fibre, ash and even vitamin A. Mutant, OG130602_100 was superior to other selected mutants and parents in amylose, protein, fat, fibre, ash, and also in vitamin A. Low moisture content among selected *Ofada* mutants and parents is particularly advantageous for safe storage. The entries were clustered into two groups with possibility of inter-cluster hybridization and selection. High GCV and PCV recorded for selected mutants for amylose, amylopectin and other traits alludes to the use of simple selection which can be practiced for further improvement of these characters. High heritability (broad sense) coupled with high genetic advance for amylose, ash and moisture content points to additive gene control of these traits and can also be improved by simple selection.

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Table 1: Mean values for physical grain characters among eight selected *Ofada* rice mutants and two parents

Selected Mutants and Parents	Hundred Grain Weight (g)	Grain Length (mm)	Grain Width (mm)
FUNAABOR 1	2.93[kl]	6.7[ab]	2.4[ab]
OG13602_100	3.30[cd]	6.7[ab]	2.5[ab]
OG13606_250	3.17[f ghi]	6.6[ef]	2.4[ab]
OG13608_300	3.40[bcd]	6.6[ef]	2.7[a]
OG13609_300	3.40[bcd]	6.9[cde]	2.6[a]
FUNAABOR 2	2.93[kl]	7.0[bc]	2.0[d]
OW13618_250	2.83[lm]	7.0[bcd]	1.7[e]
OW13620_250	2.97[jkl]	7.1[bc]	2.2[bcd]
OW13621_300	2.87[lm]	7.0[bcd]	2.0[e]
OW13624_300	2.90[lm]	7.1[bc]	2.2[bcd]

Means with similar alphabets are not significantly different at P≤0.05 following the Duncan Multiple Range Test (DMRT

Table 2: Genetic parameters for physical grain characters among eight selected "*Ofada*" rice mutants and parents

Characters	PCV	GCV	H^2 (b.s)	G.A
Hundred Grain weight	7.38	7.24	96.34	14.04
Grain Length	3.72	3.72	100	7.66
Grain Width	8.01	8.01	100	16.50

PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, H^2(b.s) = Heritability broad sense, G.A = Genetic advance

Table 3: Mean squares for proximate composition of eight selected promising "*Ofada*" rice mutants and two parents at M_6 generation

Source of variation	Df	Starch Content			Vitamins			Proximate Composition				
		Amylose	Amylopectin	Gel-consistency	Vitamin A (µg/100g)	Vitamin C (µg/100g)	Vitamin E (µg/100g)	Crude protein (%)	Fat content (%)	Fibre content (%)	Ash content (%)	Moisture (%)
Mutant lines	9	88.29**	88.57**	92.28**	4.70**	0.15**	0.07**	2.70**	1.11**	0.10**	2.37**	6.75**
Error MS	20	0.00	0.00	0.06	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
Mean	-	13.65	86.35	36.11	11.54	2.27	3.55	5.18	3.20	1.84	2.77	5.10
Coefficient of variation (CV)	-	0.31	0.03	0.68	0.20	0.90	0.76	1.70	0.84	1.55	1.29	0.66
Adjusted R^2	-	1.00	1.00	1.00	1.00	0.99	0.98	0.99	0.10	0.98	0.10	1.00

***** Mean square value significant at 1% probability level***

Table 4: Mean values for proximate composition of selected promising eight "*Ofada*" rice mutants and two parents at M_6 Plant- generation

Source of Variation	Starch Content			Vitamins			Proximate Composition				
	Amylose	Amylopectin	Gel-consistency	Vitamin A (µg/100g)	Vitamin C (µg/100g)	Vitamin E (µg/100g)	Crude protein (%)	Fat content (%)	Fibre content (%)	Ash content (%)	Moisture (%)
FUNAABOR 1	16.80^{e}	83.20^{f}	40.13^{e}	11.92^{e}	2.14^{f}	3.42^{f}	5.48^{d}	3.55^{e}	1.63^{g}	3.33^{e}	3.92^{e}
OG13602_100	20.01^{a}	80.12^{j}	46.40^{a}	13.25^{a}	2.70^{a}	3.78^{a}	6.41^{a}	3.94^{a}	2.14^{a}	3.92^{a}	3.49^{i}
OG13606_250	17.84^{d}	82.16^{g}	42.23^{d}	12.25^{d}	2.26^{d}	3.52^{d}	5.68^{c}	3.64^{d}	1.78^{e}	3.41^{d}	3.84^{f}
OG13608_300	19.47^{b}	80.46^{i}	44.53^{b}	13.14^{b}	2.59^{b}	3.71^{b}	6.28^{a}	3.81^{b}	2.05^{b}	3.71^{b}	3.55^{h}
OG13606_300	19.32^{c}	80.69^{h}	42.75^{c}	12.70^{c}	2.40^{c}	3.61^{c}	5.98^{b}	3.72^{c}	1.94^{c}	3.59^{c}	3.61^{g}
FUNAABOR 2	6.81^{j}	93.19^{a}	23.70^{j}	9.91^{j}	2.05^{h}	3.32^{h}	3.61^{g}	2.28^{j}	1.55^{h}	1.72^{i}	6.54^{c}
OW13618_250	7.90^{i}	92.10^{b}	27.67^{i}	10.81^{f}	2.20^{e}	3.70^{b}	4.58^{e}	2.41^{i}	1.70^{f}	1.92^{h}	6.19^{d}
OW13620_250	8.97^{h}	91.03^{c}	29.47^{h}	10.25^{i}	2.10^{g}	3.38^{g}	4.38^{f}	2.73^{h}	1.81^{de}	2.01^{fg}	6.72^{a}
OW13621_300	9.96^{f}	90.04^{e}	31.53^{g}	10.70^{g}	2.16^{f}	3.54^{d}	4.53^{ef}	2.86^{g}	1.85^{d}	2.07^{f}	6.61^{b}
OW13624_300	9.50^{g}	90.50^{d}	32.67^{f}	10.49^{h}	2.13^{fg}	3.47^{e}	4.45^{ef}	3.04^{f}	1.94^{c}	1.98^{gh}	6.49^{c}

Mean with similar alphabets are not significantly different at $p \leq 0.05$ using Duncan Multiple Range Test (DMRT)

Table 5: Genetic parameters for quality characters of the selected promising M_6 "*Ofada*" rice mutants and parents

Characters	PCV	GCV	H^2(b.s)	G.A
Amylose	74.02	74.02	100.00	81.90
Amylopectin	469.18	469.18	100.00	12.96
Gel consistency	289.08	289.03	99.97	45.66
Vitamin A (µg/100g)	14.45	14.45	99.98	22.34
Vitamin C (µg/100g)	0.50	0.50	100.00	19.94
Vitamin E (µg/100g)	0.55	0.54	98.59	8.81
Crude protein (%)	4.87	4.87	99.70	37.93
Fat content (%)	1.95	1.95	99.91	39.18
Fibre content (%)	0.34	0.34	99.03	20.55
Ash content (%)	2.46	2.46	99.96	66.17
Percentage Moisture (%)	7.65	7.65	99.99	60.63

PCV= Phenotypic coefficient of variation, GCV=Genotypic coefficient of variation, H^2(b.s)=Heritability broad sense

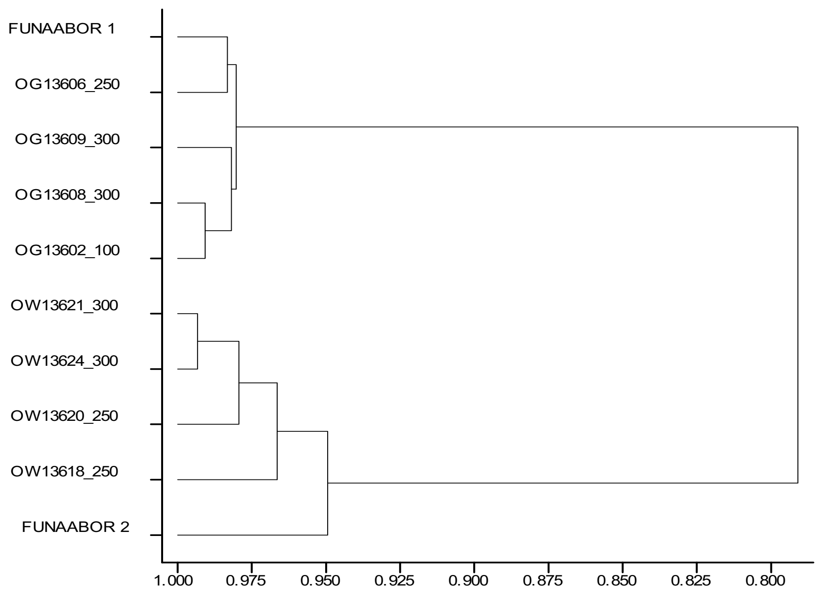

Figure 1: Dendrogram from proximate composition of the M_6 Mutant selections and their parents