

ASSESSMENT OF ⁶⁰CO GAMMA RADIATION ON EARLY PHENOLOGICAL STAGES OF TWO GENERATIONS OF *OFADA* RICE

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ABSTRACT

Traditional Ofada rice varieties from South-West, Nigeria is preferred for its unique taste, aroma and massive potential for export but has low yield. Based on this background, two Ofada rice varieties, FUNAABOR 1 and FUNAABOR 2 were irradiated to create genetic variability as it affects vegetative traits. Seeds from the varieties were exposed to nine levels of ⁶⁰Co gamma irradiation (0, 50, 100, 150, 200, 250, 300, 350 and 400 Gy). The seeds were nursed for 30 days before M₁ seedlings were transplanted into a well tilled soil in a two factorial RCBD with three replicates. Selections from M₁ plants were used to establish M₂ plants generation. The results revealed diverse effects of ⁶⁰Co gamma irradiation treatments on different plant vegetative traits. The establishment rates of M₁ Ofada rice population were unaffected ($p > 0.01$) by increasing gamma irradiation from 0 to 300 Gy but decreased at 350 Gy. Above 300 Gy, tiller numbers, plant height, lodging incidence, leaf number, leaf length and leaf angle decreased significantly when compared with control ($p < 0.01$) in both generations (M₁ and M₂). Moderately tillered (10 tillers), tall plant (116.9 cm) obtained from 350 dosage rate recorded highest grain weight of 7.8 g per panicle. High phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) promoted by the irradiation dosages in M₁ selection indicate the extent of environmental influence. High broad sense heritability observed from leaf number, leaf angle, leaf length, leaf blade colour, basal leaf sheath colour and grain weight per panicle shows possibility of rapid genetic improvement of these characters through selection.

Key words: Ofada, mutation, selection, variability, irradiation

INTRODUCTION

Rice is an important staple food in Africa, consumed by more than 60% of Nigeria population and occupies a higher percentage in household food budget (Samarendu, 2013). Despite high investment in local rice production, high tariff and ban on importation of rice in Nigeria, rice importation for 2017 was over 2.9 million metric tons (FAO, 2017). In Nigeria, rice is grown in all agro-ecological zones (Ojo *et al.*, 2020) with significant proportion of traditional varieties cultivated in various parts of Nigeria. *Ofada* rice is one of the indigenous varieties grown in South-West, Nigeria and it gained more prominence in the last decade possibly due to its positive taste, natural flavour and higher nutritive value compared to polished rice to Akinbode *et al.* (2011) but has low yield potential. The local rice cultivars were long-lived and generally poor in crop harvest (Wahdah *et al.*, 2009). The mean yield of *Ofada* rice grown with or without fertilizer according to Saka *et al.* (2005) was observed to be between 1.40 and 1.09 t ha⁻¹,

respectively while improved variety grown without fertilizer recorded 2.6 t ha⁻¹. Improving the traditional varieties for a balance between vegetativeness and yield, in addition to other traits like days to maturity, genetic uniformity, diseases and pest tolerance is dire. Low yield of rice in the tropics has been linked to the tallness and expansive leafiness of typical rice plant in the region (Chandler, 1969). Rice yield is determined by combined effect of different traits (Kumbhar *et al.*, 2013). Tiller trait in rice is a major determinant for panicle production (Smith and Dilday, 2003). Fewer tillers result in fewer panicle panicles; excess tillers cause high tiller abortions, small panicles, poor grain filling and reduction in low yield (Pandey *et al.*, 2009). The high yielding genotypes were also observed to be short. This, according to Oladosu *et al.* (2014) could be as a result of short internode and also as a result of very effective assimilate partitioning at the expense of vegetative growth. Therefore, tall varieties normally have lower yield than the short ones. Low genetic variability for these major traits

within available '*Ofada*' populations is however a limiting factor for its improvement. (Shehata *et al.*, 2009) had affirmed the use of induced mutations for genetic enhancement of different crops; induced mutations can provide additional source of variability for both quantitative and qualitative inherited traits in number of crops.

Ionizing radiation has been used successfully in inducing genetic variability in rice. Gamma irradiation doses of 200 Gy has been reported by Masruroh *et al.* (2016) to shorten plant harvest age on the local red rice, likewise irradiation doses above 300 Gy could cause short and dwarf plants (Daeli *et al.*, 2013). Although studies have revealed variation in radiosensitivity not only between different species but also between different commercial varieties within the same species (Issa *et al.*, 2011); gamma irradiation has significantly affected the number of tiller and number of grain in upland rice studied due to radiation hormesis that are stimulating to the growth and development of the plants (Aziliana *et al.*, 2015). A significant number of rice mutant varieties have been released over the years, e.g., Mayang released in 2004, Yuwono released in 2004, Meraoke in 2001, Cilosari in 1996, Atomita 1 in 1982, Atomita 2 in 1983 (Ismachin and Sobrizal, 2006). Two *Ofada* rice varieties, FUNAABOR 1 and FUNAABOR 2 with yield range of 2.2-2.7 t ha⁻¹ and 2.0-2.5 t ha⁻¹, respectively were developed and released by Federal University of Agriculture, Abeokuta, Ogun State, Nigeria in 2011 (Showemimo *et al.*, 2011). This research work therefore aims at evaluating the response of rice traits in early generations M₁ and M₂ from two ⁶⁰Co irradiated FUNAABOR 1 AND FUNAABOR 2 '*Ofada*' rice varieties with a special focus on yield increase through a balance of vegetative and yield components.

MATERIALS AND METHODS

Plant Establishment

Two field experiments involving two mutant generations namely M₁ (Mutant generation 1) and M₂ (Mutant generation 2) from ⁶⁰Co irradiated *Ofada* rice were conducted over two cropping seasons of late rainy season of 2013 and early rainy season of 2014 at research field of Olabisi Onabanjo University, Ayetoro, Ogun State, South West, Nigeria (Lat 7°12'N, Long 3°3'E). The site is in the derived savannah ecological zone. The climatic data and key properties of the soil (sandy loam) are shown in

Tables 1 and 2. Dried seeds of the two varieties (12% MC) FUNAABOR 1 and FUNAABOR 2 were exposed to nine doses of gamma irradiation 0, 50, 100, 150, 200, 250, 300, 350 and 400 Gy from ⁶⁰Co source at the Radiation Technology Center (RTC), Ghana Atomic Energy Commission (GAEC) Kwambenya, Accra, Ghana. The irradiated and untreated (control) seeds were raised in the nursery between 5th Sep. 2013 and 5th Oct. 2013 to generate M₁ seedling. At 30 days after sowing (DAS), seedlings were transplanted to research field on a well tilled soil at spacing of 25 cm × 25 cm in a two factorial Randomized Complete Block Design (RCBD) with three replications to raise the M₁ generation. Each treatment plot consisted of 3 rows of rice each 3 m long with 12 plants spaced 25 cm apart, giving 36 plants altogether. An inter-plot spacing of 50 cm was maintained. Blocks containing replicates of treatments were separated by 1 m.

Manual weeding was done at 2 and 6 weeks after planting (WAP). Fertilizer in the form of NPK 20-10-10 was applied at 2 WAP at the rate of 120 kg N ha⁻¹. Urea at 60 kg N was applied 6 weeks later at which time most plants had reached the boot stage. Insect control was done at 2 week-intervals from 4 WAP with foliar sprayer of Cypermethrin at 2 ml liter⁻¹ of water. Birds were controlled with the use of net. Rodents were also checked with the use of net fence constructed round the paddy. Supplementary surface irrigation was done to keep the soil wet (Oladosu *et al.*, 2014). Based on visual phenol typing, three best M₁ plants based on vegetative and panicle traits were selected per treatment and used to obtain plant data. The first two panicles per hill for each of the resultant 27 selected M₁ plants were harvested and used to establish the M₂ plant populations.

Table 2: Physico-chemical properties of the soil at the experimental site

Sample parameters	Value
pH	6.87
% Sand	92.10
% Silt	3.33
% Clay	4.57
Ca (cmol/kg)	3.27
Mg (cmol/kg)	1.26
Na (cmol/kg)	0.57
K (cmol/kg)	1.83
Exch. acidity (cmol/kg)	0.77
ECEC (cmol/kg)	7.69
% Total Nitrogen	0.68
% Organic Carbon	1.30

Table 1: Mean monthly temperature, relative humidity and rainfall for the study months in M₁ and M₂ planting season

M ₁ Generation				M ₂ Generation			
Months	Temperature (°C)	Rel. humidity (%)	Rainfall (mm)	Months	Temperature (°C)	Rel. humidity (%)	Rainfall (mm)
Sep., 2013	29.4	87.7	123	Mar., 2014	35.4	87.7	47
Oct., 2013	29.9	82.3	85	April, 2014	28.3	75.4	31.9
Nov., 2013	31.9	76.8	76	May, 2014	33.1	83.8	125.3
Dec., 2013	31.1	82.7	-	June, 2014	28.8	89.9	18.1
Jan., 2014	32.4	59.4	-	July, 2014	29.3	63.5	28.1
Feb., 2014	42.5	65.3	-	Aug., 2014	25.9	87.0	9.9

Table 3: Vegetative characters used in the analysis and methods of measurement/scoring

S/No.	Character	Description of measurement/Scoring
1.	Culm strength (Cs)	Scores; 1 - strong (no bending); 3 - Moderately strong (most plant bending); 5 - intermediate; 7 - weak; 9 - very weak
2.	Lodging incidence (Lg)	Scores; 0 - no lodging; 1 - < 20%; 3 - 20-40%; 5 - 41-60%; 7 - 61-80%; 9 - > 80%
3.	Tillering ability (Ti)	Counted
4.	Plant height (Ht)	Measured in cm
5.	Leaf number (LN)	Counted
6.	Leaf length (LL)	Measured in cm
7.	Leaf angle (LA)	Scores; 1 - erect; 5 - horizontal; 9 - droopy
8.	Leaf blade colour (LBC)	Scores; 1 - pale green; 2 - green; 3 - dark green; 4 - purple tips; 5 - purple margins; 6 - purple mixed with green (purple blotch); 7 - purple
9.	Basal leaf sheath colour	Scores; 1 - green 2 - purple line; 3 - light purple; 4 = purple
11.	Grain weight per panicle	weighed in grams

In the early planting season of 2014, M₂ seedlings from the seeds of each of the 27 M₁ plants were raised and were transplanted at 30 DAS, into research field using single seed descent method. Data were taken on only three M₂ plants visually adjudged to have high vegetativeness, erect stature, and distinct tallness.

Data Collection

For both M₁ and M₂ experiments, data were taken at maturity from selected plants on germination rate (percentage) culm strength (scored), lodging (scored), tillering ability (counted), plant height (measured in cm), leaf number (counted), leaf length (measured in cm), leaf angle (scored), leaf blade colour (scored), basal leaf sheath colour (scored) and grain weight per panicle (weighed in grams) (Table 3) as described by IRRI (2013).

Data Analysis

All the vegetative data were subjected to analysis of variance (ANOVA). The SAS 9.1 software was used and the means of the different mutants were compared with their respective control using Duncan Multiple Range Test (DMRT). Variance components such as phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variability (PCV), genotypic coefficient of variation (GCV), heritability in the broad sense (Hb) and expected Genetic advance (GA) were computed as described by Singh *et al.* (1991), Falconer (1989) and Singh and Chaudhary (1985).

Genetic Analyses

Genotypic Variance (δ^2g)

Genotypic variance was estimated by the formula:

$$\delta^2g = (MSG - MSE)/r;$$

where MSG is mean square of genotypes, MSE is mean square of error, and r is number of replications.

Phenotypic Variance (δ^2p)

Phenotypic variance was estimated as the sum of the estimated genotypic variance (δ^2g) and the environmental variance (MS_e or δ^2e).

Genotypic Coefficient of Variation (GCV)

$$GCV (\%) = \frac{\sqrt{\delta^2g} \times 100}{\bar{X}}$$

Phenotypic Coefficient of Variation (PCV)

$$PCV (\%) = \frac{\sqrt{\delta^2p} \times 100}{\bar{X}}$$

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

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

$$h^2(b.s) (\%) = \frac{\delta^2g}{\delta^2t} \times 100;$$

where δ^2g is induced genotypic variance, and δ^2t is the total phenotypic variance ($\delta^2t = \delta^2g + \delta^2e$) calculated from the treated populations.

Genetic Advance (GA)

The estimate of genetic advance at 1% selection intensity was computed by the following formula:

$$GA = k. \sigma_p. h^2(b.s)$$

$$GA (\% \text{ of } \bar{X}) = \frac{GA}{\bar{X}} \times 100;$$

where σ_p is phenotypic standard deviation of the mean performance of treated populations, h^2 is heritability (broad-sense), and K is constant for 1% selection intensity with a value of 2.64.

RESULTS

M₁ Generation

Table 4 presents the mean squares for vegetative traits and grain weight per panicle of M₁ irradiated *Ofada* rice plants. Significant ($p < 0.01$) differences between varieties were detected for most of the studied characters with the exception of culm strength, leaf blade colour and basal leaf sheath colour. All the vegetative characters vary significantly ($p < 0.01$) across the irradiation dosage levels. Except for culm strength, plant height, leaf length and leaf blade colour, all the vegetative characters recorded significant differences for variety \times dosage (VAR \times DOS) interaction.

Table 4: Mean squares for vegetative traits of M₁ selections of irradiated *Ofada* rice varieties

Source	Germination (%)	Culm strength (s)	Lodging (s)	Tiller number (counted)	Plant height (cm)	Leaf number (counted)	Leaf length (cm)	Leaf angle (s)	Leaf blade colour (s)	Basal leaf sheath colour (s)	Grain wt per panicle (g)
Variety (VAR)	0.05**	4.35	4.94**	152.23**	12030.30**	3596.06**	4260.74**	188.27**	0.07	2.11	13.93**
Dosage (DOS)	0.07**	21.62**	1.25**	782.85**	23963.79**	9802.06**	9458.02**	129.20**	2.47**	6.30**	112.91**
Replicate (REP)	0.00	1.03	0.16	0.13	245.16	14.22	121.49	0.58	0.06	0.26	1.00
VAR×DOS	0.07**	1.45	1.25**	43.14**	390.21	506.62**	178.62	38.88**	0.04	5.69**	8.02**

* and ** indicate significant mean square at 5% and 1% probability levels, respectively; wt - weight; s - score; g - gram

The means of vegetative characters and grain weight per panicle for M₁ plants are shown in Table 5. Different irradiation dosages recorded the highest mean value for each vegetative character. However, 150 and 200 Gy accounted for the highest mean for most of the characters with the former recording the highest mean plant height (125.35 cm), leaf length (78.28 cm), leaf angle score (4.63) and basal leaf sheath colour (2.22) while the latter had the highest mean for culm strength (2.7), tiller number (16.04), leaf number (57.20). Meanwhile, grain weight per panicle had the highest mean value of 7.58 g at 300 Gy which increased from 50 Gy but decreased as dosage rate increased above 300 Gy. Mean values of vegetative traits declined with increase in dosage levels above 250 Gy. The seed germination percentage remained unaffected for dosage levels from 0 to 300 Gy but decreased thereafter. Dosage rate 400 Gy recorded least value of 62.89 cm for plant height against 118.59 cm recorded from 0 Gy representing a 47% depression. Highest mean plant height of 125.35 cm was recorded from 150 Gy though similar to 125.22 cm and 124.65 cm from 100 Gy and 200 Gy,

respectively but amounted to 5.7% above the 0 Gy. Least culm strength score of 1.89 was recorded for 100 Gy while the highest lodging score was recorded for 100 Gy. The highest mean value for tiller number was recorded by 200 Gy (16) and least by 400 Gy (4). The least plant height of 62.89 cm, least leaf length (38.52 cm) and least leaf angle score (0.69) were recorded by 400 Gy dosage level altogether, moderately tall plant (106.76 cm) with tiller number of 10 from 300 Gy recorded highest mean values of 7.58 g for grain weight per panicle.

The estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for almost all the studied vegetative traits in M₁ generation (Table 6). The highest magnitude of genotypic and phenotypic variance was recorded for plant height. The PCV estimates were higher than GCV for all the studied traits except leaf blade colour. The difference between the PCV and GCV estimates were relatively low for all the traits except culm strength, lodging and basal leaf sheath colour. High heritability values were recorded for all the traits except leaf blade colour and basal leaf sheath colour.

Table 5: Mean values of selected M₁ vegetative characters over dosage rate

Dosage	Germination (%)	Culm strength (s)	Lodging (s)	Tiller number (counted)	Plant height (cm)	Leaf number (counted)	Leaf length (cm)	Leaf angle (s)	Leaf blade colour (s)	Basal leaf sheath colour (s)	Grain wt per panicle (g)
0	100.00 ^a	1.85 ^c	0.00 ^b	12.72 ^d	118.59 ^{ab}	44.37 ^d	72.65 ^{bc}	2.85 ^c	2.00 ^a	1.17 ^{de}	5.78 ^d
50	100.00 ^a	1.59 ^c	0.00 ^b	13.72 ^c	121.02 ^{ab}	48.65 ^c	75.43 ^{abc}	3.22 ^c	2.00 ^a	1.28 ^{cde}	6.25 ^c
100	100.00 ^a	1.89 ^c	0.33 ^a	13.67 ^c	125.22 ^a	48.07 ^c	77.43 ^a	4.48 ^a	2.00 ^a	1.44 ^{bcd}	6.62 ^{bc}
150	100.00 ^a	2.19 ^b	0.28 ^a	14.70 ^b	125.35 ^a	52.44 ^b	78.28 ^a	4.63 ^a	2.00 ^a	2.22 ^a	6.91 ^b
200	100.00 ^a	2.70 ^a	0.30 ^a	16.04 ^a	124.65 ^a	57.20 ^a	76.85 ^{ab}	3.82 ^b	2.00 ^a	1.50 ^{bc}	6.95 ^b
250	100.00 ^a	1.26 ^d	0.00 ^b	12.52 ^d	114.56 ^b	45.20 ^d	71.07 ^c	1.89 ^d	2.00 ^a	1.72 ^b	7.54 ^a
300	100.00 ^a	1.28 ^d	0.00 ^b	10.76 ^c	106.76 ^c	38.37 ^e	65.54 ^d	1.00 ^e	2.00 ^a	1.48 ^{bcd}	7.58 ^a
350	98.00 ^a	0.89 ^c	0.00 ^b	7.26 ^f	89.44 ^d	26.20 ^f	55.07 ^e	0.89 ^c	1.78 ^b	1.43 ^{bcd}	4.75 ^c
400	85.00 ^b	0.72 ^c	0.00 ^b	4.09 ^e	62.89 ^e	14.56 ^e	38.52 ^f	0.69 ^c	1.37 ^c	1.06 ^e	3.02 ^f

Mean with similar letters are not significantly different at $p \leq 0.05$ using Duncans Multiple Range Test (DMRT); wt - weight; s - score; g - gram

Table 6: Overall variances, means and genetic parameters of vegetative characters at M₁ generation

Characters	Variety	Dosage	Replicate	Error	Mean	δ^2_g	δ^2_p	GCV	PCV	$h^2(b.s)$
Culm strength	4.75	16.39	1.12	0.61	1.67	1.38	1.99	70.33	84.35	69.52
Lodging	5.21	1.22	0.17	0.06	0.11	1.72	1.78	1238.27	1260.79	96.46
Tiller number	176.97	465.23	0.70	2.55	12.29	58.14	60.69	62.04	63.38	95.81
Plant height	9701.87	6623.63	15.64	36.03	115.28	3221.95	3257.98	49.24	49.51	98.89
Leaf number	4181.76	5694.6	21.77	32.90	43.75	1382.95	1415.85	85.01	86.02	97.68
Leaf length	3399.52	2736.97	18.40	11.72	71.24	1129.27	1140.99	47.17	47.41	98.97
Leaf angle	194.70	111.72	0.35	2.34	2.74	64.12	66.46	292.62	297.91	96.48
Leaf blade colour	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
Basal leaf sheath colour	1.44	4.87	0.15	0.59	1.55	0.28	0.88	34.38	60.33	32.48
Grain weight per panicle	21.58	48.48	0.20	0.39	6.45	7.06	7.45	41.18	42.38	94.77

δ^2_g - genotypic variance, δ^2_p - phenotypic variance, GCV - genotypic coefficient of variation, PCV - phenotypic coefficient of variation, $h^2(b.s)$ - heritability (broad-sense)

M₂ Generation

Vegetative characters and grain weight per panicle were significantly affected by gamma irradiation treatments except leaf blade colour. The mean squares for the M₂ selections are shown in Table 7. Variety was significant ($p \leq 0.01$) only for leaf length, leaf angle, leaf blade colour and grain weight per panicle. Dosage and VAR \times DOS were significant ($p \leq 0.01$) for all the traits except leaf blade colour.

The highest mean values were obtained from the lower dosages (50-150 Gy) for vegetative traits and these were generally above those of 0 Gy (control) (Table 8). Selections from higher dosage levels (250-400 Gy) had vegetative trait means that were generally lower than those of control. Mean plant height increased from 116.93 cm (0 Gy) to 127.28 cm (100 Gy) while the least mean plant height (113.56 cm) was recorded from 250 Gy. In a similar trend, the shortest and longest leaves of

65.91 and 77.83 cm were recorded from 250 and 100 Gy, respectively. The highest mean tiller number of 12 per hill was recorded from 50 Gy. Moreover, grain weight per panicle recorded the highest mean value of 7.80 g from a plant with moderate tiller numbers (10) and high plant height (116.91 cm) from 350 Gy.

The variances, means and genetic parameters for vegetative characters and grain weight per panicle in the M₂ generation are presented in Table 9. As observed for M₁ plants, the PCVs were generally higher than the GCVs. However, the PCVs and GCVs were lower for tiller number, plant height, leaf number and leaf blade colour. High heritability (broad sense) was observed for all the leaf traits and grain weight per panicle except for leaf number which was moderate. Heritability estimates for other traits ranged from low (8.9) for culm strength to moderate (49.3) for tiller number (Table 9).

Table 7: Mean squares for vegetative traits of M₂ selections from irradiated *Ofada* rice

Source	Culm strength (s)	Lodging (s)	Tiller number (counted)	Plant height (cm)	Leaf number (counted)	Leaf length (cm)	Leaf angle (s)	Leaf blade colour (s)	Basal leaf sheath colour (s)	Grain wt per panicle (g)
Variety (VAR)	1.85	0.1	21.83	3.81	344.2	3788.99**	420.38**	0.25**	1.73	20.49**
Dosage (DOS)	2.91**	1.60**	29.57**	1306.95**	346.04**	1143.06**	100.13**	0.03	3.37**	23.59**
Replicate (REP)	0.55	0.05	0.69	29.00	11.68	29.73	4.18	0.01	0.34	2.07
VAR \times DOS	10.67**	1.05**	104.29**	1020.32**	1437.79**	407.42**	30.90**	0.03	8.15**	4.65**
Error	0.74	0.11	4.11	47.88	60.36	22.12	2.77	0.02	0.78	0.74

*. ** mean square value significant at 5% and 1% probability level, respectively; wt - weight; s - score; g - gram

Table 8: Means of vegetative traits of M₂ selections from *Ofada* rice over dosage levels

Dosage	Culm strength (s)	Lodging (s)	Tiller number (counted)	Plant height (cm)	Leaf number (counted)	Leaf length (cm)	Leaf angle (s)	Leaf blade colour (s)	Basal leaf sheath colour (s)	Grain wt per panicle (g)
0	1.85 ^a	0.00 ^d	11.28 ^{bc}	116.93 ^{cd}	44.35 ^b	73.41 ^b	3.52 ^b	2.00 ^a	1.57 ^{bc}	5.91 ^c
50	2.19 ^a	0.17 ^c	12.54 ^a	122.85 ^b	45.49 ^a	77.04 ^a	4.70 ^a	1.94 ^a	2.09 ^a	6.15 ^c
100	1.59 ^b	0.48 ^a	10.65 ^{cd}	127.28 ^a	40.15 ^{cd}	77.83 ^a	4.63 ^a	1.94 ^a	1.33 ^{bc}	7.43 ^b
150	1.70 ^b	0.30 ^b	10.56 ^{cd}	125.72 ^a	39.22 ^{cd}	75.13 ^b	3.74 ^b	2.00 ^a	1.59 ^{bc}	7.06 ^{cd}
200	2.07 ^a	0.07 ^{cd}	11.85 ^{ab}	118.39 ^c	44.35 ^{ab}	69.17 ^c	1.59 ^d	1.96 ^a	1.63 ^b	6.97 ^d
250	1.56 ^b	0.00 ^d	10.24 ^d	113.56 ^c	37.96 ^d	65.91 ^c	1.00 ^d	1.96 ^a	1.35 ^{bc}	7.36 ^{bc}
300	1.52 ^b	0.00 ^d	10.63 ^{cd}	114.35 ^{de}	39.52 ^{cd}	66.52 ^{de}	1.52 ^d	2.00 ^a	1.61 ^{bc}	7.69 ^{ab}
350	1.70 ^b	0.00 ^d	10.93 ^{cd}	116.91 ^{cd}	40.67 ^{cd}	68.63 ^c	2.70 ^c	2.00 ^a	1.44 ^{bc}	7.80 ^a
400	1.67 ^b	0.00 ^d	10.57 ^{cd}	116.74 ^{cd}	38.92 ^{cd}	67.98 ^{cd}	2.41 ^c	1.96 ^a	1.24 ^c	7.49 ^{ab}

Mean with similar letters are not significantly different at $p \leq 0.05$ using Duncan's Multiple Range Test (DMRT); wt - weight; s - score; g - gram

Table 9: Variance estimates, means and genetic parameters of vegetative characters from M₂ generation

Characters	Variety	Dosage	Replicate	Error	Mean	δ^2_g	δ^2_p	GCV	PCV	$h^2(b.s)$
Culm strength	1.85	2.88	0.55	0.91	1.76	0.31	1.23	31.80	62.84	25.60
Lodging	0.10	1.60	0.05	0.13	0.11	-0.10	0.12	89.96	302.27	8.90
Tiller number	22.57	29.01	0.83	5.77	11.02	5.60	11.37	21.47	30.59	49.30
Plant height	9.28	1303.25	19.61	63.96	119.24	-18.23	45.74	3.58	5.67	39.90
Leaf number	359.14	335.23	12.95	83.15	40.91	20.00	175.15	23.45	32.35	52.50
Leaf length	3843.05	1135.76	23.96	28.58	71.32	1271.49	1300.07	50.00	50.56	97.80
Leaf angle	423.88	98.85	3.70	3.25	2.87	140.21	143.46	412.00	416.75	97.70
Leaf blade colour	0.25	0.03	0.01	0.02	1.98	0.08	0.10	14.04	15.92	77.80
Basal leaf sheath colour	1.52	3.34	0.37	0.89	1.54	0.21	1.10	29.77	68.28	90.00
Grain weight per panicle	20.80	23.62	2.16	0.80	7.09	6.67	7.47	36.40	38.54	89.20

δ^2_g - genotypic variance, δ^2_p - phenotypic variance, GCV - genotypic coefficient of variation, PCV - phenotypic coefficient of variation, $h^2(b.s)$ - heritability (broad-sense), GA - genetic advance

DISCUSSION

The results from M_1 and M_2 plant populations from irradiated *Ofada* rice indicated that both the parent and early mutant generations varied for most of the vegetative traits. The germination percentages observed in M_1 plant population were unaffected by increasing gamma radiation doses from 0-300 Gy but decreased from 350 Gy. This was similar to the reports of Gowthami *et al.* (2016) and Cheema and Atta (2003) that at higher dosage of mutagen, the seed germination got delayed and reduced. Also, Kadhimi *et al.* (2016) reported that germination rate of irradiated two elite rice varieties MRQ74 and MR269 showed an increase with low doses of 0-100 Gy but reduction in germination with doses above 200 Gy. This, as well as the observation in this study, is contrary to Harding *et al.* (2012) who reported that increasing doses of gamma irradiation had no effect on germination rate of 13 varieties of rice in Sierra Leone. This points to the possibility of influence of the genotypes used in different studies.

The varieties and gamma irradiation doses also elicited significant variation for most of the vegetative characters and grain weight per panicle. Higher phenotypic variation above genotypic variation is indicative of environmental influence on the expression of the traits. These variations however showed the presence of different magnitudes of genetic causes and the possibility of improvement through further selection. The non-significant variety \times dosage rate interaction for plant height, culm strength, leaf length and leaf blade colour indicated a consistency in performance of the *Ofada* rice variety used across different irradiation treatments. Similar results were obtained by Tabasum *et al.* (2011) for plant height of Basmati rice genotypes. The significant variety \times dosage rate in M_1 population for germination rate, lodging, tillering ability, leaf number, leaf blade colour basal leaf sheath colour and grain weight per panicle also indicated that influence of mutagenesis on characters varied between the two varieties of rice. This is instructive on the general applicability of the dosage rates across rice varieties. This view was supported by the conclusion of Fujii and Matsumura (1958) that radio-sensitivity widely varies not only between different species but also between different commercial varieties within the same species. Also, Harding *et al.* (2012) realized variation in the optimum dose determined for improving efficiency of the rice varieties (ROK18 and ROK22) on percentage field survival. Hence, there is need to study the efficiency of gamma irradiation in the process of mutation in different rice cultivars as to induce genetic variability for selecting mutants with desirable characters. However, the non-significance of the variety component of the mean squares at M_2 , particularly for the commercial traits (culm strength, tiller number, leaf number), indicated similarity in rice response in this generation.

The significant difference among the irradiation dosage rate for the vegetative traits and grain weight per panicle implies marked effect of the increasing level of irradiation on the genetic make-up of rice and the emanating variability that can be exploited for selection, hybridization and further selection for improvement of the studied vegetative characters.

The reduction in tiller number, plant height, lodging incidence, leaf number, leaf length, leaf angle and grain weight per panicle as gamma dosage increased above 300 Gy agrees with the position of Shadakshari *et al.* (2001) as a way of improving for high yielding in rice. Also, Daeli *et al.* (2013) reported that radiation doses above 300 Gy could cause short and dwarf plants. Plant height indicates the relative growth and vigour of crop plants, and is mostly used as an index to determine M_1 mutagenic effects on biological characters on crops (Konzak *et al.*, 1972). Tall plants are preferred in upland paddies for their better ability to compete with weeds. The negative effect on lodging however necessitates development of moderate height cultivars where effective weed management is practiced. In this study, moderately tall plants in M_1 (106.76 cm) and M_2 (116.91 cm) with tiller number, 10.76 and 10.93 recorded highest mean values of 7.58g and 7.80g respectively for grain weight per panicle from irradiation rate of 300 and 350 Gy respectively. These results were supported by the findings of Domingo *et al.* (2007) that semi-dwarf cultivars of rice are high yielding. In such cases, mutants with reduced heights (semi-dwarf), leaf number, leaf length and even those with erected leaves from higher dosage rate above 300 Gy in M_1 and M_2 plant population compared to their parents can be selected and used to develop promising varieties for higher yield.

The appreciable GCV and PCV promoted by the irradiation dosages in M_1 and transmitted into the M_2 selections indicate the extent of environmental influence on the traits. Differences in these parameters have been reported by Idris and Mohamed (2013) and Rao *et al.* (2014) where high PCV and low GCV were recorded for plant height in particular. Idris and Mohamed (2013) had affirmed that large differences reflect high environmental influence while small differences reveal high genetic influence. The low PCV and GCV recorded for plant height in M_2 plant population, just one selection into the mutant generations, indicates that it may be governed by additive few genes which may be fixed over few generations. However, the complexity likely to be introduced by the effect segregation of succeeding mutant generation suggests the need to minimize environmental influence on assessment of other mutant generations. The high broad-sense heritability recorded for some of the vegetative characters indicates the possibility of rapid genetic improvement of these characters through selection. Similar results have been reported by Sarawgi *et al.* (2000).

CONCLUSION

The study revealed high genetic variability among the mutants and parents in M₁ and M₂ plant populations and such variability can be exploited for selection, hybridization and further improvement of the characters. High dosage rate affected the expression of lodging, tillering ability, leaf number, leaf angle and basal leaf sheath colour in M₁ plant population. This indicates that the influence of mutagenesis on the characters varied between the two varieties. At higher dosage of mutagen above 350 Gy, germination percentage were reduced but unaffected between dosage rates of 0-300 Gy. The higher dosage rate of 350 Gy from M₂ generation had an average tiller number of 10. They are semi dwarf with moderate leaf angle and also recorded the highest mean grain weight per panicle of 7.8 g.

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