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ASSESSMENT OF COLCHICINE AND GAMMA RAYS-INDUCED MUTAGENESIS FOR IMPROVED YIELD AND QUALITY TRAITS IN FONIO (*DIGITARIA EXILIS* [KIPPIST.] STAPF.)

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Abstract

Experiment was carried out to investigate the effect of colchicine and gamma rays for the improvement of fonio yield and seeds quality. Some seeds of five fonio accessions (Dinat, Jakah, Jiw 1, Jiw 2 and Nkpowas) were irradiated with five doses of gamma rays (100 Gy, 200 Gy, 400 Gy 500 Gy and 0 Gy as control) and some seeds were treated with five concentrations of colchicine (0.1 Mm, 0.5 mM, 1.0 mM, 2.0 mM and 0.0 mM as control) with the aim of improving fonio yield and seeds quality. The seeds were sown in a plot in a Completely Randomized Block Design with three replications to rise the first mutant generation (M_1 Generation). The M_1 generation was advanced to M_2 generation. The data obtained analyzed from the M_2 generation revealed highly significant difference ($P \leq 0.01$) in the effects of the doses and concentrations on the selected traits of fonio. The effects are dose or concentration dependent decrease with increase in dose or concentration. However,

the result implies that colchicine improves the sizes of the traits of interest such as height, leaf area, diameter and weights of the seeds while gamma rays improve the number of the selected traits such as leaf number, number of tillers and spikes and number of seeds/spike. We therefore recommended the use of lower colchicine concentration (0.1 mM) and low dose of gamma rays (100 Gy) for genetic improvement of fonio.

Key Words: *Colchicine, Concentration, Dose, Fonio, Gamma Rays*

INTRODUCTION

Fonio (*Digitaria exilis* [Kippist.] Stapf.) popularly known as Acha, hungry rice, petit mil, fundi or findi (Jideani, 1999) is one of the most ancient cereal of African origin cultivated for thousands of years; since about 5000 B.C (Chukwu and Abdulqadir, 2008). It is traditionally grown in the savannah zone of West-Africa and it is essential to the diets of millions of tribal people and deserve high value in their cultural traditions. This native African grain crop fits perfectly into the low-input farming systems of resource-poor African farmers because of its unique ability to withstand drought and tolerate poor and marginal soils (Vietmeyer *et al*., 1996; Aslafy, 2003). It has potential to improve nutrition, boost food security, foster rural development and support sustainable use of the land (Anonymous, 2011). Fonio grains are among the best tasting and nutritious of all grains known to man (Vietmeyer *et al*., 1996).

Ironically, despite all the tremendous importance of fonio nutraceutically, pharmaceutically and culturally, it is still unimproved and its cultivation is not beyond subsistence level in Nigeria due to low yields and neglect by the scientific community. Its cultivation relies only on traditional landraces that are poor yielding. More so, the miniature size of its grains and floral organs made hybridization impracticable (Kuta *et al*., 2003). Alternative techniques are therefore needed to create variability in fonio accessions that could be utilized for genetic improvement of fonio yield and seeds quality. Mutations (changes in the genetic materials of an organism) are known to enhance the genetic variability of crop plants. Induced mutations facilitate the development of improved varieties (Maluszynski, 1990). Induced mutations have been used to generate genetic variability and have been successfully utilized to improve yield components of various crops (Naik and Murthy, 2009). It provides raw materials for the genetic improvement of economic crops (Adamu *et al.,* 2004) by facilitating the isolation, identification and cloning of genes which would ultimately help in designing crops with improved yield, increased stress tolerance and longer life span with reduced agronomic in-puts (Ahloowalia and Maluszynski, 2001). Several mutagenic agents have been known to induce mutations in plants. However, this study employed the use of gamma rays; which are widely employed for mutation studies (Khin, 2006; Zhu *et al*., 2006) and colchicine, a poisonous alkaloid derived from autumn crocus (*Colchicum autumnale*) with the aim of creating additional variability that could be exploited in fonio yield and seed quality traits improvement.

MATERIALS AND METHODS

Study Site

The research was conducted at the Botanical Garden of the Department of Biological Sciences, Ahmadu Bello University, Zaria, located within the tropical guinea savanna zone of Nigeria (Lat 11^0 11^1 N; Long 7^0N 38^1E and on alt 660m above sea level) during the 2015 wet season.

Sources of the Seeds

Seeds of five different accessions of fonio (Dinat, Jakah, Jiw 1, Jiw 2 and Nkpowas) used were obtained from the National Cereal Research Institute, Badeggi, Niger state.

Treatment and Experimental Design

The seeds (100 g) of five fonio accessions were exposed to ^{60}Co gamma rays at five different doses (100 Gy, 200 Gy, 400 Gy, 500 Gy and 0 Gy as the control) at the Plant Breeding and Molecular Biology Laboratory, International Atomic Energy Agency (IAEA), Vienna, Austria. Another 100 g of the seeds were treated with colchicine at five different concentrations (0.1 mM, 0.5 mM, 1.0 mM, 2.0 mM and 0.0 mM as the control) via pre-soaking for four hours after which they are washed thoroughly in running water for four hours and allowed to dry overnight on Whatman No.1 filter paper. The treated seeds were sown in the field plots along with untreated control (soaked in distilled water) in a plot in a Completely Randomized Block Design (CRBD) in a factorial arrangement with three replications to rise the first mutant generation (M_1 generation). The M_2 generation was raised from the M_1 generation. All the recommended agronomic and cultural practices such as planting, fertilizer application, weeding and thinning as well as harvesting methodologies were done according to the procedures described by NAERLS (2012) to raise a good crop.

Statistical Analysis

Based on the observations recorded on quantitative traits of both the five accessions of fonio in the M_2 generation, the data obtained were subjected to Multivariate Analysis of variance (MANOVA) using SAS (2002) Version 9.1. Duncan's multiple range tests (DMRT) was used to separate the means.

RESULTS

The result obtained (Table 1) revealed highly significant difference ($P \leq 0.01$) in the effects of different gamma doses and colchicine concentrations on all the selected traits of the five fonio accessions. Similar result was found among the treatments. However, highly significant difference ($P \leq 0.01$) was found among the accessions in terms of number of leaves, leaf area and tiller number.

Table 1: M_2 Generation Mean Squares for the Effects of Gamma Rays and Colchicine on the Agronomic Traits of Fonio

Sources of Variation	df	%Germ (2 WAP)	% Survival	Height at Maturity (cm)	No of Leaves	Leaf Area (cm^2)	No of Tillers	No of Spikes	No of Seeds/Spike	1000 Seeds Weight (g)	Seeds Diameter (mm)	No of Days to Maturity
Dose/Conc	4	2326.91**	3457.09**	4759.04**	21.76**	141.62**	100.36**	11.56**	4729.76***	0.009**	0.13**	1956.68**
Accession	4	103.79ns	56.53ns	46.48*	7.52**	18.40**	180.32**	1.74ns	138.15ns	0.0003ns	0.003ns	44.19*
Treatment	1	2555.89**	7934.48**	13895.37**	40.19**	491.75**	434.08**	23.52**	2548.49***	0.005**	0.05**	703.82**
Dose/Conc x Accession	16	26.05ns	36.65ns	9.95ns	0.64ns	4.27**	3.04ns	0.37ns	50.62ns	0.0001ns	0.00	21.04 ns
Dose/Conc x Treatment	4	0.00ns	0.00ns	0.00ns	12.28**	0.00ns	0.00ns	7.87**	175.42*	0.00ns	0.00 ns	440.29**
Accession x Treatment	4	73.49ns	87.53ns	59.21*	4.69*	14.68**	42.57**	1.54ns	127.46ns	0.00ns	0.01 ns	83.58**
Conc x Access x Treatment	16	21.74ns	0.00ns	15.72ns	0.37ns	0.00ns	4.62ns	0.45ns	0.00ns	0.00ns	0.00 ns	0.00
Error		29.01	31.84	9.22	0.65	0.49	2.02	0.42	32.52	0.0001	0.002	7.64

Keys: `ns= No significant difference *= Significant difference (P≤0.05) ** = Highly significant difference (P≤0.01)

However, the result for the mean effects of different doses of gamma rays and colchicine on the traits of fonio was presented in Table 2. The result showed that gamma rays produced mutants that displayed 31.37-60.87% germination after two weeks of planting with a survival rate of 43.27-80.23% survival. The mutants attained a range of height between 42.54-55.73 cm producing 3-7 leaves and 11-18 tillers. The gamma rays induced mutants of fonio produced 3-6 spikes that bear 63-113 seeds/spike. More so, 1000 mutants' seeds weigh 0.55-0.61 g and had seeds diameter of 0.78-0.98 mm. The gamma rays induced mutants were also found to mature 95-105 days after planting. The effect is dose dependent, increases with decrease in dose of gamma rays.

Table 2: M_2 Generation Mean Effect of Gamma Irradiation and Colchicine Treatments on Agronomic Traits of Fonio Accessions

Treatment	Dose (Gy)	%Germination (2 WAP)	% Survival	Height at Maturity (cm)	No of Leaves	No of Tillers	No of Spikes	No of Seeds/Spike	1000 Seeds Weight (g)	Seeds Diameter (mm)	No of Days to Maturity
Gamma Rays	0	52.71^{b*1}	70.73^{b}	71.27^{a}	3.33^{d}	11.87^{d}	3.40^{c}	77.60^{d}	0.57^{d}	0.85^{c}	123.27^{a}
	100	60.87^{a}	80.23^{a}	55.73^{b}	7.27^{a}	17.80^{a}	5.86^{a}	112.80^{a}	0.61^{a}	0.98^{a}	94.53^{d}
	200	53.42^{b}	66.03^{c}	52.25^{c}	5.60^{b}	15.73^{b}	4.80^{b}	104.13^{b}	0.60^{b}	0.96^{a}	97.20^{c}
	400	42.05^{c}	52.93^{d}	47.80^{d}	5.00^{c}	13.53^{c}	3.53^{c}	89.93^{c}	0.59^{c}	0.88^{b}	98.40^{c}
	500	31.37^{d}	43.27^{e}	42.54^{e}	3.33^{d}	10.66^{d}	2.53^{d}	63.40^{e}	0.55^{e}	0.78^{d}	105.80^{b}
	Means	48.08	62.64	53.91	4.91	13.92	4.02	89.57	0.59	0.89	103.84
Colchicine	0.0	50.78^{c}	73.93^{cb}	72.67^{d}	3.07^{c}	10.93^{d}	2.80^{b}	73.26^{e}	0.57^{d}	0.81^{d}	124.53^{a}
	0.1	65.73^{a}	85.80^{a}	84.26^{a}	5.40^{a}	15.53^{a}	3.87^{a}	103.13^{a}	0.62^{a}	1.01^{a}	96.27^{d}
	0.5	59.36^{b}	76.53^{b}	81.87^{b}	4.67^{b}	14.13^{b}	3.87^{a}	97.67^{b}	0.61^{b}	0.98^{ba}	101.27^{c}
	1.0	53.93^{c}	71.00^{c}	80.00^{c}	4.33^{b}	13.13^{c}	3.73^{a}	90.47^{c}	0.60^{b}	0.95^{b}	103.80^{b}
	2.0	51.24^{c}	66.07^{d}	78.80^{c}	4.20^{b}	12.27^{c}	3.13^{b}	81.86^{d}	0.59^{c}	0.91^{c}	105.80^{b}
	Means	56.21	74.67	79.52	4.33	13.19	3.48	89.28	0.59	0.93	106.33

N.B: *1 Means within the columns with the same superscript letter(s) are not significantly different (P≤0.05)

Similarly, the result for the effect of various colchicine concentrations was presented in Table 2. The result indicated 51.24-65.73% germination among colchicine treated mutants with a survival rate of 66.07-85.80%. More so, the colchicine induced mutants were found to attained plant height of 78.80-84.26 cm producing 4-5 leaves and 12-15 tillers. The mutants also produced 3-4 spikes bearing 82-103 seeds/spike. The mutant seeds weigh 0.59-0.62 g with a seed diameter of 0.91-1.01 mm and attained maturity 96-105 days after planting. The effect is also concentration dependent increases with decrease in colchicine concentration.

Furthermore, the result for the mean effects of different doses of gamma rays on individual accessions of fonio was shown in Table 3. The result revealed that in accession Dinat, gamma rays produced mutants with 33.00-61.67% germination after two weeks of planting. More so, the mutants attained a height range of 37.00-53.00 cm at matured stage with survival rate of 44.33-80.33%. The mutants also produced 2-6 leaves and 10-19 tillers. The number of spikes produced by the mutants was found to be 2-5 spikes. The mutants' spikes produced 63-112

seeds/spike which weigh 0.56-0.62 g and have seed diameter of 0.77-1.00 mm. The mutants reached maturity 92-107 days after planting.

Similarly, the gamma irradiated mutants of accession Jakah (Table 3) displayed germination percent of 34.63-61.70% after two weeks of planting. The mutants also displayed survival rate of 46.33-79.83% and attained heights of 49.33-57.66 cm at maturity. More so, the mutants produced 5-10 leaves and 16-21 tillers. Similarly, the mutants produced 2-5 spikes bearing 64-108 seeds/spike. Furthermore, 1000 mutants' seeds weigh 0.55-0.60 g with diameter between 0.81-0.97 mm. The mutants attained maturity between 92-104 days after sowing.
More so, the effects of different doses of gamma rays on the traits of accession Jiw 1 was shown in Table 3. The result indicated that 30.70-58.67% of the mutants germinated after two weeks of planting. The mutants were also found to be 41.00-54.33 cm in height with survival percentage of 39.33-78.00%. Similarly, the mutants produced 3-7 leaves. More so, the number of tillers and spikes were found to be 9-18 tillers and 2-6 spikes respectively. Furthermore, the mutants produced 68-116 seeds that are 0.81-0.98 mm in diameter and which 1000 seeds weigh 0.55-0.61 g. Also, the mutants reached maturity 98-107 days after planting.

However, the mean effects of different doses of gamma rays on the traits of accession Jiw 2 (Table 3) showed germination percents of 31.37-61.73% after two weeks of planting. The mutants were 44.37-56.00 cm in height with 42.00-80.00% survival. The mutants produced 3-6 leaves and produced 8-12 tillers with 3-6 spikes bearing 62-116 seeds/spike. The mutants' seeds were found to be 0.78-0.96 mm in diameter and 1000 seeds weigh 0.56-0.62 g and reached maturity 90-103 days after planting.

Similarly, the mean effects of different doses of gamma rays on the traits of Nkpowas (Table 3) showed 27.13-60.60% germination after two weeks of planting. The mutants were 41.00-57.66 cm in height with 44.33-83.00% survival. They produced 4-7 leaves and 11-19 tillers with 3-7 spikes bearing 61-112 seeds/spike. The mutants' seeds weigh 0.55-0.61 g with seeds diameter between 0.72-0.99 mm. Also the mutants reached maturity 100-107 days after sowing.

Table 3: M_2 Generation Mean Effect of Gamma Irradiation on Agronomic Traits of Individual Fonio Accessions

Accession	Dose (Gy)	%Germination (2 WAP)	% Survival	Height at Maturity (cm)	No of Leaves	No of Tillers	No of Spikes	No of Seeds/Spike	1000 Seeds Weight (g)	Seeds Diameter (mm)	No of Days to Maturity
Dinat	0	52.83*1^{c}	73.67^{b}	70.66^{a}	2.67^{c}	12.00^{d}	3.00^{d}	73.33^{d}	0.57^{d}	0.85^{d}	122.67^{a}
	100	61.67^{a}	80.33^{a}	53.00^{b}	6.33^{a}	19.00^{a}	5.33^{a}	112.00^{a}	0.62^{a}	1.00^{a}	92.33^{e}
	200	56.60^{b}	64.66^{c}	46.00^{c}	5.33^{b}	14.67^{b}	4.67^{b}	105.67^{b}	0.61^{b}	0.99^{b}	94.33^{d}
	400	40.04^{d}	50.67^{d}	41.00^{d}	3.67^{b}	13.00^{c}	4.00^{c}	95.00^{c}	0.59^{c}	0.92^{c}	93.33^{c}
	500	33.00^{e}	44.33^{e}	37.00^{e}	2.33^{c}	9.66^{e}	2.33^{e}	62.67^{e}	0.56^{e}	0.77^{e}	107.33^{b}
Jakah	0	49.00^{b}	69.66^{b}	68.67^{a}	4.33^{c}	17.67^{d}	3.33^{c}	80.00^{d}	0.58^{c}	0.88^{c}	124.33^{a}
	100	61.70^{a}	79.83^{a}	57.66^{b}	9.67^{a}	21.00^{b}	5.00^{a}	108.00^{a}	0.60^{a}	0.97^{a}	92.33^{e}
	200	49.20^{b}	64.87^{c}	53.00^{c}	7.33^{b}	23.00^{a}	3.67^{b}	101.33^{b}	0.60^{a}	0.94^{b}	92.66^{d}
	400	35.80^{c}	51.67^{d}	51.00^{d}	7.00^{b}	18.33^{c}	3.00^{c}	92.67^{c}	0.59^{b}	0.87^{d}	94.67^{c}
	500	34.63^{d}	46.33^{e}	49.33^{e}	4.67^{c}	16.00^{e}.	2.33^{d}	63.66^{e}	0.55^{d}	0.81^{e}	103.67^{b}
Jiw 1	0	51.07^{c}	70.33^{b}	69.33^{a}	2.33^{d}	12.00^{c}	3.00^{c}	81.00^{d}	0.56^{d}	0.84^{d}	122.30^{a}
	100	58.67^{a}	78.00^{a}	54.33^{b}	7.00^{a}	18.00^{a}	5.67^{a}	116.33^{a}	0.61^{a}	0.98^{a}	98.00^{e}
	200	54.20^{b}	71.33^{b}	51.67^{c}	5.00^{b}	13.00^{b}	4.66^{b}	105.00^{b}	0.59^{b}	0.97^{b}	101.33^{d}
	400	36.23^{d}	52.67^{c}	47.00^{d}	4.67^{c}	12.00^{c}	3.33^{c}	86.67^{c}	0.57^{c}	0.89^{c}	103.00^{c}
	500	30.70^{e}	39.33^{d}	41.00^{e}	2.67^{d}	9.33^{d}	2.33^{d}	67.66^{e}	0.55^{e}	0.81^{e}	107.33^{b}
Jiw 2	0	54.67^{b}	68.67^{b}	73.67^{a}	4.00^{c}	5.33^{e}	3.66^{c}	79.00^{d}	0.57^{d}	0.84^{b}	121.66^{a}
	100	61.73^{a}	80.00^{a}	56.00^{b}	6.33^{a}	12.00^{a}	6.00^{a}	116.00^{a}	0.62^{a}	0.96^{a}	89.67^{e}
	200	51.43^{b}	67.96^{b}	56.57^{b}	5.00^{b}	10.33^{b}	4.67^{b}	105.67^{b}	0.61^{b}	0.97^{a}	95.33^{d}
	400	47.07^{c}	58.67^{c}	51.00^{c}	5.33^{b}	9.30^{c}	3.33^{c}	88.66^{c}	0.59^{c}	0.86^{b}	97.00^{c}
	500	31.37^{d}	42.00^{d}	44.37^{d}	3.33^{d}	7.66^{d}	2.67^{d}	62.33^{e}	0.56^{e}	0.78^{c}	103.33^{b}
Nkpowas	0	55.97^{b}	71.33^{b}	74.00^{a}	3.33^{d}	12.33^{d}	4.00^{c}	74.67^{d}	0.57^{d}	0.83^{d}	125.33^{a}
	100	60.60^{a}	83.00^{a}	57.66^{b}	7.00^{a}	19.00^{a}	7.33^{a}	111.67^{a}	0.61^{a}	0.99^{a}	100.33^{e}
	200	55.67^{b}	61.33^{c}	54.00^{c}	5.33^{b}	17.67^{b}	6.33^{b}	103.00^{b}	0.60^{b}	0.94^{b}	102.33^{d}
	400	51.10^{c}	51.00^{d}	49.00^{d}	4.33^{c}	15.00^{c}	4.00^{c}	86.67^{c}	0.59^{c}	0.86^{c}	104.00^{c}
	500	27.13^{d}	44.33^{e}	41.00^{e}	3.67^{d}	10.67^{e}	3.00^{d}	60.66^{e}	0.55^{e}	0.72^{e}	107.33^{b}

N.B: *1 Means within the columns with the same superscript letter(s) are not significantly different (P≤0.05)

More so, the result for the mean effects of various colchicine concentrations on the traits of individual fonio accessions was presented in Table 4. The result showed that, in accession

Dinat, colchicine produced mutants that displayed 47.63-68.43% germination after two weeks of planting. These mutants attained height of 76.00-81.67 cm with 68.67-89.00% survival. The number of leaves among the mutants was found to be 4-5 leaves. Also, the mutants produced 12-16 tillers with 3-4 spikes bearing 81-99 seeds/spike. The 1000 mutants' seeds weigh 0.59-0.63 g with diameter of 0.91-1.02 mm. And also, the mutants reached maturity 101-107 days after planting.

However, in accession Jakah (Table 4) colchicine produced mutants with 51.40-63.93% germination after two weeks of planting. The mutants attained height of 79.67-85.00 cm with surval rate of 61.66-84.67%. The mutants produced 4-6 leaves and 15-19 tillers that have 3-4 spikes bearing 85-108 seeds/spike. The 1000 seeds weight of the mutants was found to be between 0.60-0.62 g. More so, the seed diameter of the mutants was found to be between 0.89-0.99 mm and reached maturity 100-105 days after sowing.

Furthermore, in accession Jiw 1 (Table 4), colchicine treatments induced mutants with 56.40-64.87% after two weeks of planting. The mutants were 79.66-85.33 cm in height with percentage survival of 67.33-86.67%. The mutants produced 4-6 leaves and 13-14 tillers with 3-4 spikes bearing 83-102 seeds/spike. The mutant seeds are found to weigh 0.58-0.64 g with seeds diameter between 0.91-1.02 mm. More so, the mutants reached maturity 94-107 days after planting.

Similarly, in accession Jiw 2 (Table 4), the mutants induced by colchicine displayed 51.17-67.33% germination after two weeks of planting. The mutants are 80.00-84.33 cm in height with 67.00-86.00% survival. Also, the mutants produced 4-5 leaves and produced 11-12 tillers with 3 spikes bearing 83-106 seeds/spike. The mutants also produced seeds that weigh 0.59-0.62 g with seed diameter of 0.91-1.00 mm. The utants matured 93-105 days after planting.

More so, the mean effects of colchicine on accession Nkpowas was shown in Table 4. The result revealed the presence of mutants with 49.60-64.07% germination after two weeks of planting. The mutants are 78.66-85.00 cm in height with 65.66-82.66% survival. The mutants produced 4-5 leaves and 11-17 tillers with 3-4 spikes bearing 78-101 seeds/spike. The mutant seeds weigh 0.59-0.62 g with seed diameter 0.93-1.01 mm. And also the mutants reached maturity 93-105 days after sowing.

Table 4: M_2 Generation Mean Effect of Colchicine on Agronomic Traits of Individual Fonio Accessions

	Concentration (mM)	%Germination (2 WAP)	% Survival	Height at Maturity (cm)	No of Leaves	No of Tillers	No of Spikes	No of Seeds/Spike	1000 Seeds Weight (g)	Seeds Diameter (mm)	No of Days to Maturity
Dinat	0.0	52.70^{d*1}	77.33^{c}	72.00^{d}	3.00^{c}	10.67^{e}	2.33^{d}	70.33^{e}	0.58^{d}	0.73^{d}	124.33^{a}
	0.1	68.43^{a}	89.00^{a}	81.67^{a}	5.33^{a}	15.66^{a}	4.33^{a}	99.33^{a}	0.63^{a}	1.02^{a}	101.33^{d}
	0.5	65.36^{b}	80.67^{b}	79.33^{b}	5.00^{a}	13.33^{b}	3.67^{b}	91.66^{b}	0.60^{b}	0.98^{b}	105.00^{c}
	1.0	55.60^{c}	77.00^{c}	79.00^{b}	4.00^{b}	12.67^{c}	3.67^{b}	84.00^{c}	0.61^{ba}	0.93^{c}	105.00^{c}
	2.0	47.63^{e}	68.67^{d}	76.00^{c}	4.00^{b}	11.66^{d}	3.00^{c}	80.67^{d}	0.59^{c}	0.91^{c}	107.66^{b}
Jakah	0.0	52.10^{d}	72.66^{b}	72.66^{d}	3.33^{e}	12.67^{e}	3.00^{c}	74.33^{d}	0.57^{c}	0.83^{e}	124.66^{a}
	0.1	63.93^{a}	84.67^{a}	85.00^{a}	6.00^{a}	19.00^{a}	4.00^{a}	107.66^{a}	0.62^{a}	0.99^{a}	99.66^{d}
	0.5	58.40^{b}	72.00^{b}	81.67^{b}	5.33^{b}	16.33^{c}	3.67^{b}	107.00^{a}	0.60^{b}	0.94^{b}	102.33^{c}
	1.0	53.63^{c}	67.00^{c}	80.33^{b}	4.67^{c}	17.33^{b}	3.66^{b}	95.67^{b}	0.60^{b}	0.92^{c}	103.67^{c}
	2.0	51.40^{d}	61.66^{d}	79.67^{c}	4.33^{d}	15.00^{d}	3.00^{c}	84.66^{c}	0.60^{b}	0.89^{d}	105.33^{b}
Jiw 1	0.0	49.73^{d}	74.33^{c}	70.66^{d}	3.33^{d}	11.00^{d}	2.33^{c}	73.33^{e}	0.58^{e}	0.85^{d}	125.33^{a}
	0.1	64.87^{a}	86.67^{a}	85.33^{a}	5.66^{a}	13.66^{b}	4.00^{a}	102.33^{a}	0.64^{a}	1.02^{a}	93.66^{d}
	0.5	56.83^{b}	75.00^{b}	82.33^{b}	4.00^{c}	15.00^{a}	4.33^{a}	96.67^{b}	0.62^{b}	1.00^{a}	104.67^{c}
	1.0	54.63^{c}	72.66^{d}	80.67^{c}	5.00^{b}	12.33^{c}	4.00^{a}	93.66^{c}	0.59^{c}	0.96^{b}	104.67^{c}
	2.0	56.40^{b}	67.33^{e}	79.66^{c}	4.33^{c}	13.00^{b}	3.33^{b}	83.00^{d}	0.58^{d}	0.91^{c}	106.67^{b}
Jiw 2	0.0	51.37^{d}	68.66^{c}	73.66^{c}	2.67^{d}	9.67^{d}	3.33^{c}	73.33^{e}	0.58^{e}	0.86^{e}	124.33^{a}
	0.1	67.33^{a}	86.00^{a}	84.33^{a}	5.00^{a}	12.00^{a}	3.33^{c}	105.66^{a}	0.62^{a}	1.00^{a}	93.33^{e}
	0.5	62.17^{b}	78.00^{b}	84.33^{a}	4.00^{b}	11.00^{b}	4.00^{a}	99.33^{b}	0.61^{b}	0.95^{b}	97.00^{d}
	1.0	55.60^{c}	68.67^{c}	80.33^{b}	4.33^{c}	10.66^{c}	3.67^{b}	94.33^{c}	0.60^{c}	0.94^{c}	102.66^{c}
	2.0	51.17^{d}	67.00^{c}	80.00^{b}	4.33^{c}	10.67^{c}	3.00^{c}	83.33^{d}	0.59^{d}	0.91^{d}	104.66^{b}
Nkpowas	0.0	48.00^{e}	76.66^{c}	74.33^{e}	3.00^{d}	10.66^{e}	3.00^{c}	75.00^{e}	0.57^{d}	0.80^{d}	124.00^{a}
	0.1	64.07^{a}	82.66^{a}	85.00^{a}	5.00^{a}	17.33^{a}	3.66^{a}	100.66^{a}	0.62^{a}	1.01^{a}	93.33^{e}
	0.5	54.03^{b}	77.00^{b}	81.67^{b}	5.00^{a}	15.00^{b}	3.66^{a}	93.67^{b}	0.60^{b}	1.01^{a}	97.33^{d}
	1.0	50.16^{c}	69.66^{d}	79.67^{c}	3.67^{c}	12.66^{c}	3.67^{a}	84.66^{c}	0.60^{b}	0.97^{b}	103.00^{c}
	2.0	49.60^{d}	65.66^{e}	78.66^{d}	4.00^{b}	11.00^{d}	3.33^{b}	77.67^{d}	0.59^{c}	0.93^{c}	104.66^{b}

N.B: *1 Means within the columns with the same superscript letter(s) are not significantly different (P≤0.05)

DISCUSSION

Artificial induction of mutation using physical and chemical mutagens was confirmed as an important aspect creating variability for the improvement of yield and quality of economic crops. The mutagens at lower concentration/dose were found to stimulate germination process probably by stimulating water absorption capacity of the mutant seeds, stimulate enzymatic activities or both. This finding is in consistent with the work of Aney (2013) who reported increased in germination percentage among low doses of gamma rays induced mutants of pea. Similar results were also reported by Aynehband and Afsharinafar (2012) in amaranth and Hemavathy (2015) in mungbean. However, high doses/concentrations of the mutagens reduced the survival rates of the plants may be due to the injury they infer upon the plant cells thereby inhibiting plants morphogenesis. This finding is contrary to the work of Anu-Vainola (2000) who reported decrease in survival rates in Rhododendron mutant cultivars with increase in the mutagenic concentrations as more seedlings were killed by high colchicines concentration (2.0mM). Improvements in the survival rates of fonio observed was probably achieved due to increase in the assimilation rates, bio-synthesis of growth materials and other adaptive strategies. Therefore colchicine and gamma rays may improve the quality and quantity of fonio growth and yield components by increasing its survival rates. The increased in the plant height induced by colchicine on fonio can be attributed to the ability of the mutagen to alter the plant genome integrated by environmental signals as reported by Uno *et al*. (2001); probably by increasing the rates of cellular division and expansion at their meristematic regions. This was in agreement with the findings of Chiangmai *et al*. (2014) in physic nut; but was in contrast to the findings of .Ramesh and Yoganda Murthy (2014) in mulberry who reported decreased in plant height with decrease in doses of the mutagen. The mutagen might have probably influenced the activities of auxin as reported by Murali *et al*. (2013) or cytokinin which are of paramount importance in the fundamental processes of plant growth and development including cell division as suggested by Deikman and Ulrich (1995). Gamma rays on the other hand produce dwarf mutants in contrast to colchicine. More so, leaves attributes such as size and number were also affected by gamma rays and colchicine. Increased leaf number and area in the fonio mutants was in agreement with the findings of Maluszynski *et al*. (2001) and Pasztor *et al*. (1985) who independently reported an increase in leaf area among *Zea mays* mutants. The increase in leaf area provides an increase in the surface area for gaseous ex-change which has considerable effect on the process of photosynthesis. Similar findings were found in the work of Duranceau *et al*. (2001) who reported a greater leaf mass per leaf area and enriched organic matter in the leaves of *Nicotiana sylvestris* mutants. The mutagen stimulated growth of the cells of the lamina causing its remarkable expansion. Besides the leaf area, the number of leaves produced per plant due to the effect of the mutagens was in agreement with that of Hoballah (1999) who reported increase in the number of leaves among sesame mutants due to gamma irradiation.

Therefore, the ability of gamma rays and colchicine to improve the yield of fonio was in line with the previously established facts that artificial induction of mutation improve plant yield. This is in conformity with the findings of Karim *et al*. (2008) who reported increase in the yield

of chickpea due to induced mutagenesis. More so, mutation induction for improved earliness in fonio is in agreement with the findings of Rutger (1982) who reported early maturing mutants in medium grain Japonica cultivar; but was in contrast to that of Archana *et al*. (2004) who reported increase in the number of days required for maturity due to increased doses of mutagen treatments in *Glycine max*. More so, the results obtained by this research are in line with the findings of Dhakshanamoorthy *et al*. (2010) in Jatropha, Gandhi *et al*. (2014) in chilli, Aruldoss and Mullainathan (2015) and Sood *et al*. (2016) in *Capsicum annum* who individually reported increase in yield with decrease in mutagen dose/concentration.

CONCLUSION

Gamma rays and colchicine were found to play a significant role in the improvement of fonio yield and grain size. Colchicine was found to increase the sizes of the traits of agronomic interest such as height, leaf area, diameter and weights of the seeds while gamma rays played significant role in improving number of the selected traits such as leaf number, number of tillers and spikes and number of seeds/spike.

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