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EFFECT OF GAMMA RAYS ON THE VARIABILITY OF YIELD ATTRIBUTING TRAITS AND GENETIC PARAMETERS IN FONIO (*DIGITARIA EXILIS* STAPF.)

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ABSTRACT

A research was conducted to investigate the extent of genetic variability induced by different doses of gamma rays with the aim of identifying the suitable dose to be employed in fonio (*Digitaria exilis*) improvement program. Seeds of five different accessions of fonio were irradiated with five different doses of gamma rays (100 Gy, 200 Gy, 400 Gy, 500 Gy and 0 Gy as control). The experiment was conducted during 2014 and 2015 wet seasons and was laid out in Randomized Completely Block Design with three replications. The result obtained from the M_2 generation revealed highly significant difference ($P \leq 0.01$) in the effects of different doses of gamma rays for all the selected agronomic traits of fonio indicating the presence of induced variability among the accessions. The LD_{50} values of gamma rays in the five fonio accessions were found to be genoype dependents. The results for the estimation of genetic parameters revealed higher PCV and GCV values and that PCV values were slightly greater than GCV values for all the traits studied. However, moderate to high heritability among the mutants' traits indicates that the traits are primarily under genetic control. While, the predominance of moderate heritability estimates and high GAM in most of the traits revealed additive gene effects induced by the mutagen in controlling such traits indicating that selection for improvement might be effective. Thus, 100 Gy is found to be suitable for fonio improvement.

Keywords: Doses, Fonio, Gamma Rays, Genetic Estimates.

INTRODUCTION

Fonio (*Digitaria exilis* Stapf.) is known as Acha or hungry rice (Purseglove, 1972). It is traditionally grown in the savannah zone of West-Africa. Due to its hardy nature, this traditional millet is regarded as priority crop in West-Africa, where it is essential to the diets of millions of people in Africa and has 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 diseases, drought and tolerate poor soils (Aslafy, 2003). Fonio improvement requires understanding of the genetic mechanism governing yield and yield components. The grain yield is basically a complex trait being the consequence of several genes and their interaction as stressed by Rashid *et al*. (2012).

Despite all the tremendous benefits of fonio to human livelihood, it is generally unimproved and its cultivation is not beyond subsistence level in Nigeria. There is neglect from the authorities concerned as there is no single fonio variety registered in the country. Farmers grow traditional landraces with poor yields and there is paucity of information on the inheritance of agronomic traits in fonio which makes its germplasm analysis to depend on phenotypic traits that can easily be influenced by the environment. More so, the miniature size of its grains and floral organs make hybridization very difficult to practice. Researches (Irving and Jideani, 1997; Kwon-Ndung and Misari, 1999) have previously reported fonio facing the problems of low yield and narrow genetic variability; yet its genetic improvement is not well explored. Mutations (changes in the genetic materials of an organism) are known to enhance the genetic variability of crop plants. 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). Gamma irradiations have been known to produce changes in plants by improving growth and yield components. This research therefore aimed at creating variability in fonio using different doses of gamma rays that could be utilized in the genetic improvement of the crop.

MATERIALS AND METHODS

Experimental site

The research was conducted at the Botanical Garden of the Department of Botany, Ahmadu Bello University, Zaria, located within the northern guinea savanna zone of Nigeria (Lat 11º 11´ N; Long 7ºN 38´E and on alt 660m above sea level).

Sources of the Seeds

Seeds of five different accessions of fonio used for this research were obtained from the National Cereal Research Institute, Badeggi, Niger state.

Treatment and Experimental Design

The seeds of five fonio accessions (Dinat, Jakah, Jiw 1, Jiw 2 and Nkpowas) were exposed to ^{60}Co gamma rays at five different doses (100 Gy, 200 Gy, 400 Gy, and 500 Gy) at the Plant Breeding and Molecular Biology Laboratory, International Atomic Energy Agency (IAEA), Vienna, Austria. The treated seeds of the accessions were sown along with respective controls to raise the M_1 generation. The seeds were planted in a Randomized Completely Block Design (RCBD) with three replications. 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. Ten competitive plants were selected from each accession in each replication of the M_2 generation.

DATA ANALYSES

Multivariate analysis of variance was carried out using SAS (2008) version 9.0 with DMRT to separate the means. Probit analysis was used to determine the LD_{50} of different mutagenic treatment in each accession of fonio. The variability present in the population was estimated from combined analysis of variance by their mean performance. Phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were estimated based on the formula described by Syukur *et al*. (2012) as follow:

$$\sigma^2_G = [(MSG) – (MSE)] /r$$

$$\sigma^2_P = [\sigma^2_G + (\sigma^2E/r)].$$

Where: σ^2_G = Genotypic variance; σ^2_P = Phenotypic variance; σ^2E = environmental variance (error mean square from the analysis of variance); MSG = mean square of genotypes; MSE = error mean square; r = number of replications.

$$GCV (\%) = \frac{\sqrt{(\sigma^2_G)}}{x} \times 100$$

$$PCV (\%) = \frac{\sqrt{(\sigma^2_P)}}{x} \times 100$$

Where: σ^2_G = Genotypic variance; σ^2_P = Phenotypic variance; x is grand mean of a character. The Broad Sense Heritability (H^2), Genetic Advance (GA) and Genetic Advance as percent of the Mean (GAM) were estimated according to the formula described by Singh and Choudhury (1985).

$$H^2 (\%) = \frac{\sigma^2_G}{\sigma^2_P} \times 100$$

$$GA = k\sigma_P H^2$$

Where k is the selection differential in standard units in the present study and it was 2.06 at 5% level of selection, σ_P is standard deviation of the phenotypic variance and H^2 is Broad sense heritability. Genetic advance expressed as percentage of mean (GAM) was measured by the following formula:

$$GAM (\%) = \frac{GA}{x} \times 100$$

PCV, GCV, heritability, G,A and GAM were classified as follows:

PCV and GCV: 0 – 10 % = Low, 10 – 20 % = Moderate and >20 % = High

H^2: 0 – 30 % = Low, 30 – 60 % = Moderate and >60 % = High.

GA: 0 – 10 % = Low, 10 – 20 % = Moderate and >20 % = High.

RESULTS

The result for the effect of gamma rays on growth and yield attributing traits of fonio is shown in Table 1. The result revealed highly significant difference ($P\leq0.01$) in the effect of the mutagen on all the selected traits of fonio. It revealed that, gamma irradiations produced mutants that displayed germination percents of 46.74-71.50% after one week of planting. The result showed that the mutants attained heights of 3.32-3.60 cm at seedlings stage and 42.54-55.73 cm at matured stage. The mutants produced 3-7 leaves that were 4.19-7.53 cm^2 in cross sectional area and which produced 11-18 tillers. More so, the mutants were found to produce 3-6 spikes that were 8.27-10.86 cm long and which bear 63-113 seeds/spike. Furthermore, 1000 seeds weights of the mutants were measured to be 0.55-0.61 g and produce 6.51-10.15 g of dry matter contents.

Table 1: Means for the Effect of Gamma Rays on Agronomic Traits of Fonio

Dose (Gy)	%Germination (1 WAP)	Seedlings Height (cm)	Height at Maturity (cm)	No. of Leaves	Leaf Area (cm^2)	No. of Tillers	No. of Spikes	Spikes Length (cm)	No. of Seeds/spike	1000 Seeds Weight (g)	Dry Weight (g)
0	73.43^{a*1}	4.16^a	71.27^a	3.33^d	5.21^c	11.87^d	3.40^c	9.10^b	77.60^d	0.57^d	7.11^{dc}
100	71.50^a	3.60^b	55.73^b	7.27^a	7.53^a	17.80^a	5.86^a	10.86^a	112.80^a	0.61^a	10.15^a
200	62.90^b	3.57^b	52.25^c	5.60^b	6.35^b	15.73^b	4.80^b	11.18^a	104.13^b	0.60^b	8.98^b
400	56.37^c	3.41^c	47.80^d	5.00^c	5.03^c	13.53^c	3.53^c	10.64^a	89.93^c	0.59^c	7.42^c
500	46.74^d	3.32^d	42.54^e	3.33^d	4.19^d	10.66^d	2.53^d	8.27^c	63.40^e	0.55^e	6.51^d
Means	62.19	3.61	53.91	4.91	5.66	13.92	4.02	10.01	89.57	0.59	8.03
S.E (±)	5.84	0.12	1.86	0.70	0.75	1.78	0.76	0.88	6.45	0.01	0.83

N.B: *¹ Means within the columns with the same superscript letter(s) are not significantly different ($P\leq0.05$)

However, significant variation was found in the LD_{50} among the accessions (Table 2). The LD_{50} values of gamma rays in the five fonio accessions were found to range from 180 Gy (in accession Jiw 1) to 228 Gy (in accession Dinat and Jiw 2). This result showed that the LD_{50} values are genotype dependents.

Table 2: Lethal Doses Values of Different Gamma Rays in Different Fonio Accessions

Accession	%Germination (2 WAP)	% of Control	% Reduction over Control	Observed % Mortality	LD_{50}
Dinat	49.66	59.29	20.71	43	228Gy
Jakah	43.17	61.40	18.56	47	204Gy
Jiw 1	43.98	55.83	24.17	48	180Gy
Jiw 2	40.91	59.80	20.20	49	228Gy
Nkpowas	48.77	63.90	16.09	43	204Gy

More so, the estimates of phenotypic and genotypic coefficient of variation among fonio mutants induced by different doses of gamma rays are presented in Table 3. The PCV values were found to be slightly higher than the GCV values in all the different gamma rays induced mutants of fonio (except in seedlings heights). The PCV and GCV values expressed in terms of percentages were higher at 500 Gy doses of gamma rays for all the quantitative traits of gamma-induced fonio mutants. The GCV and PCV values were high at some of the growth and yield parameters of 500 Gy induced mutants of fonio such as number of leaves (47.19%; 65.59%), leaf area (34.67%; 47.97%), number of tillers (54.97%; 77.15%), number of spikes (34.46%; 45.58%) and spikes length (24.33%; 33.86%).

Furthermore, high heritability estimates (Table 3) were induced by different doses of gamma rays in most of the fonio traits except in germination percents (1 WAP) and dry weights where moderate values were found and survival percents where low values were found (Table 20). The genetic advance (GA) and genetic advance as percent of the means (GAM) values were high in almost all doses of gamma rays treatment. However, 100 Gy of gamma rays revealed highest values of heritability in terms of number of leaves/plant (71.97%), number of seeds/spike (75.61%) and number of days to maturity (73.04%). Similarly, high Genetic Advance (GA) and Genetic Advance as percent of the Means (GAM) estimates were recorded to be induced by all the gamma ray doses in fonio. However, the highest values of GA and GAM were found among 500 Gy induced mutants of fonio. The GA and GAM values were found to increase with increased in gamma rays doses.

Table 3: Estimates Genetic Parameters Induced by Different Doses of Gamma Rays on Agronomic Traits of Fonio

Dose	Parameter	%Germ (1WAP)	SH (cm)	HM (cm)	NL	LA (cm^2)	NT	NS	SL (cm)	NS/S	1000 SW (g)	DW (g)
Control	GCV	1.66	6.79	6.28	47.19	27.88	49.37	25.64	22.11	2.13	1.47	1.99
	PCV	3.02	4.81	8.76	65.10	38.57	69.28	33.92	30.76	3.04	1.75	4.87
	H^2	54.97	99.70	71.69	72.49	72.28	71.26	175.59	71.88	70.07	84.00	40.86
	GA	196.77	535.99	437.09	1204.83	924.77	1221.87	906.69	821.23	122.16	228.91	185.76
	GAM	267.97	12884.38	613.29	36181.08	17749.90	10293.77	26667.35	9024.51	157.42	40159.65	2612.66
100 Gy	GCV	1.71	7.86	8.04	21.62	19.29	32.92	14.88	18.53	1.46	1.37	1.39
	PCV	3.11	5.56	11.20	30.04	26.69	46.20	19.68	25.78	2.09	1.64	3.41
	H^2	54.98	141.36	71.78	71.97	72.27	71.26	75.61	71.87	69.86	83.54	40.76
	GA	199.75	565.43	494.89	817.45	769.19	997.71	690.96	751.79	208.04	220.38	155.06
	GAM	279.37	15706.39	888.01	11244.15	10215.01	5605.11	11791.13	6922.56	184.43	36127.87	1527.68
200 Gy	GCV	1.94	7.92	8.57	20.07	22.88	37.25	18.16	18.00	1.59	1.39	1.58
	PCV	3.53	5.60	11.87	39.00	31.65	52.28	24.03	25.04	2.27	1.67	3.86
	H^2	54.96	141.42	72.19	51.46	72.29	71.25	75.57	71.88	70.04	83.23	40.95
	GA	212.71	689.44	248.75	662.13	837.79	1061.26	763.14	746.32	217.39	221.57	165.66
	GAM	338.17	19312.05	476.08	11823.75	13193.54	6746.73	15898.75	6675.49	208.77	36928.33	1844.77
400 Gy	GCV	2.17	8.29	9.37	31.43	28.88	43.31	24.69	18.91	1.84	1.42	1.91
	PCV	3.94	5.87	13.06	43.68	39.96	60.78	32.67	26.32	2.62	1.69	4.67
	H^2	55.08	141.23	71.75	71.96	72.27	71.26	75.57	71.85	70.23	84.02	40.89
	GA	225.21	704.86	534.12	979.65	941.13	1144.39	889.84	759.30	234.17	225.02	182.03
	GAM	399.52	20670.38	1117.41	19593	18710.34	8458.17	25207.93	7136.28	260.39	4240.68	2453.23
500 Gy	GCV	2.61	8.52	10.53	47.19	34.67	54.97	34.46	24.33	2.61	1.52	2.17
	PCV	4.76	6.02	14.67	65.59	47.97	77.15	45.58	33.86	3.72	1.82	5.32
	H^2	54.83	141.53	71.78	71.95	72.27	71.25	75.60	71.85	70.16	83.52	40.79
	GA	246.44	715.33	566.34	1200.32	1031.18	1289.21	1051.47	861.32	278.76	232.09	193.81
	GAM	527.26	21546.08	1331.31	36045.65	24610.50	12093.90	41560.08	10414.99	439.68	42198.18	2977.11

N.B: PCV and GCV: 0 – 10 % = Low, 10 – 20 % = Moderate and >20 % = High.
H^2: 0 – 30 % = Low, 30 – 60 % = Moderate and >60 % = High.
GA: 0 – 10 % = Low, 10 – 20 % = Moderate and >20 % = High.

%Germ = % germination SH= Seedlings height HM= Height at Maturity NL= Number of Leaves LA= Leaf Area NT= Number of Tillers NS= Number of Spikes SL= Spikes Length NS/S= Number of Seeds/Spike SD= Seed Diameter 1000SW=1000 Seeds Weight DW= Dry Weight NDM= Number of Days to Maturity

DISCUSSION

Seed germination is an important parameter to estimate the effect of mutagen on plants. Inhibition in seed germination, after the treatment of seed with different mutagen is a convenient technique for studying their effects of mutagens on plants as reported by Wani *et al*. (2013). The decreased in seed germination with increasing dose of gamma rays doses in fonio indicates that the mutagens have exerted an inhibitory effect on seed germination at higher doses. Such a dose dependant inhibition of germination was reported earlier by Kumar and Mishra (2004) in Okra. Reduction in germination in mutagenic treatments has been explained due to delay or inhibition of physiological and biological processes necessary for seed germination, which include enzyme activity, hormonal imbalances and inhibition of mitotic process as reported by Ananthaswamy *et al*. (1971). Similar results of decrease in the level of germination via induced mutagenesis were reported by Talebi *et al*. (2012).

Reduction in plant heights in fonio due to gamma irradiation was similar to the previous findings by Toker *et al*. (2005) who reported decrease in shoot length at high dose. However, disparity in the effects of gamma radiation on plant growth was reported by Melki and Marouani (2009). The induced reduction in plant height caused by gamma rays could be attributed to the ability of gamma rays to cause DNA damage and interrupt the metabolic pathway as stressed by Esnault *et al*. (2010) thereby slowing growth process. However, Marcu *et al*. (2013) reported a contrary finding reporting growth stimulation by the effect of a low dose of gamma rays.

The significant improvement in fonio yield due to low gamma rays exposure reported by the present study is in conformity with the work of Tshilenge-Lukanda *et al.* (2013) who reported similar observation among gamma rays induced mutants of groundnut. It therefore implies that it is possible to improve yield components of economic plants using a gamma dose of 100 Gy. This finding is in conformity with the work of Kara *et al*. (2016) in *Glycine max* and Suresh *et al*. (2017) in *Phaseolus lunatus.* More so, Mudibu *et al.* (2010) reported a result that was slight different from the finding of this research as they recorded highest grain yield increase in soy- bean among 200 Gy gamma irradiated mutants. However, the findings of this study were almost similar to that of Animasaun *et al*. (2014) who reported 80 Gy gamma ray dose as low dosage form of gamma irradiation using cobalt (60) that could be utilized to increase variability and yield in *Digitaria exilis* but is contrary to the findings of Khan *et al*. (2005) who reported a significant increase of chick-pea grain yield using gamma irradiation at 600 Gy. The 100 Gy dose of gamma rays radiation is important for inducing genetic variation that can lead to genetic improvement among fonio mutants.

The LD_{50} values of gamma rays obtained by this research were fixed between 180 Gy (in accession Jiw 1) to 228 Gy (Dinat and Jiw 2). These values were almost similar to that of Rajarajann *et al*. (2016) who reported LD_{50} values of gamma rays in rice to be 229Gy *in vitro* and 235Gy *in vivo*. Similarly, the LC_{50} values of colchicine concentrations in the present study were fixed between 0.35 mM (Nkpowas) to 0.90 (Jakah). These values were within the range obtained by Jency *et al*. (2017) who reported the LC_{50} concentration for EMS to be fixed at 0.42% *in vitro* and 0.49% *in vivo* in Kodomillet and is in line with the findings of Ramchander *et al*. (2015) in some rice varieties.

The slight differences between PCV values above GCV values indicate the presence of high contribution of genotypic effect for phenotypic expression of the selected traits and that there is high genetic variability for the traits. This finding is in conformity with that of Yohannes *et al*. (2015) who reported similar finding in sorghum. More so, the low differences between PCV and GCV implies that the characters studied were influenced by environment to lesser extent, thus the selection based on phenotypic performance will be reliable as reported by Islam *et al*. (2009). The presence of moderate to high heritability in most of the traits was similar to the work of Chee and Campbell (2009) and Liu *et al*. (2010) who reported similar findings. Heritability values are helpful in predicting the expected progress to be achieved through selection process. Moderate to high heritability, G.A and GCV estimates coupled with high GAM explained the influence of additive gene effect as reported by Ibrahim and Hussein (2006) and that heritability is a property of a character in the population, environment and the conditions of the genotypes as stressed by Yadav *et al*. (2011). This also conforms to the earlier findings of Vashistha *et al*. (2013) in maize, Wolie *et al*. (2013) in finger millet, Ogunbayo *et al*. (2014) in rice, Mishra *et al*. (2014) in gladiolus and Shrimali *et al*. (2017) in barley that these parameters were important for selection. Induction of mutations for factors which govern the heredity of quantitative characters are therefore promising tools for creating new genotypes as reported by El-Degwy (2013) thereby causing changes in major genes at loci governing quantitative characters. Thus, mutants with such characters need to be selected for improvement. Broad sense heritability (H^2) therefore represents the relative strength of the traits and indicates the efficiency of selection systems as reported by Hugar *et al*. (2015).

CONCLUSION

It was concluded that lower doses of gamma rays (100 Gy) induced high genetic variability in fonio and the LD_{50} fixed between 180 Gy (in accession Jiw 1) to 228 Gy (Dinat and Jiw 2). It was found that moderate to high heritability, GA and GAM estimates were found in most of the traits studied indicating that selection for improvement might be effective.

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REFERENCES

Adamu, A.K., Chung, S.S. and Abubakar, S. (2004). The effect of ionizing radiation (Gamma rays) on tomato (s.n.). *Nigerian Journal of Experimental Biology*, **5**(2):185-193.

Ahloowalia, B.S. and Maluszynski, M. (2001). Induced mutation: A new paradigm in plant breeding. *Euphytica*, **118:**167-173**.**

Ananthaswamy, H.M., Vakil, V. and Srinivasan, A. (1971). Biochemical and physiological changes in gamma irradiated wheat during germination. *Radiation Botany*, **11**: 1-2.

Animasaun, D.A., Morakinyo, J.A. and Mustapha, O.T. (2014). Assessment of the effects of gamma irradiation on the growth and yield of *Digitaria exilis* [Haller]. *Journal of Applied BioScience,* **75**: 6164-6172.

Aslafy, J.H. (2003). Organic fonio to woo Europe. *Spore,* 106.

Chee, P.W. and Campbell, B.T. (2009). Bridging classical and molecular genetics of cotton fiber quality and development. *In:* Paterson AH (ed) *Genetics and genomics of cotton*. Springer, New York, 283–311 pp.

El-Degwy, S.I. (2013). Mutation induced genetic variability in rice (*Oryza sativa* L.). *International Journal of Agriculture and Crop Sciences*. **5** (23): 2789-2794

Esnault, M.A., Legue, F. and Chenal, C. (2010). Ionizing radiation: advances in plant response. *Environmental and Experimental Botany,* **68**(3): 231–237.

Hugar, A. and Savithramma, D.L. (2015). Genetic variability studies for yield and surrogate traits related to water use efficiency in the recombinant inbred line (RIL) population derived from NRCG 12568 X NRCG 12326 of groundnut (*Arachis hypogaea* L.). *International Journal of Agricultural Science Research,* **5**:321–328.

Ibrahim, M.M. and Hussein, R.M. (2006). Variability, heritability and genetic advance in some genotypes of Roselle (*Hibiscus sabdariffa* L.). *World Journal of Agricultural Science*, **2**(3): 340-345.

Irving, D.W. and Jideani, I.A. (1997). Microstructure and composition of *Digitaria exilis* Stapf (acha): a potential crop. *Cereal Chemistry,* **74**:224-228.

Islam, M.R., Amin, M.R., Kabir, A.K.M.A. and Ahmed, M.U. (2009). Comparative study between semi-intensive and scavenging production system on the performances of Black Bengal goat. *Journal of Bangladesh Agricultural University,* **7**(1): 79–86.

Jency, J.P., Ravikesavan, R., Sumathi, P. and Raveendran, M. (2017). Effect of chemical mutagen on germination percentage and seedling parameters in Kodomillet variety Co3. *International Journal of Chemical Studies*, **5**(2): 166-169

Kara, Y., Vaizoğullar, H. and Kuru, A. (2016). Gamma radiation effects on crude oil yield of some soybean seeds: Functional properties and chemical composition of *Glycine max*-ataem-7 seeds. *Tropical Journal of Pharmaceutical Resesearch,* **15** (12): 2579-2585.

Khan, S., Wani, M.R., Bhat, M. and Parveen, K. (2005): Induced chlorophyll mutations in chickpea (*Cicer arietinum* L.). *International Journal of Agriculture and Biology*, **7**: 764-767.

Kumar, A. and Mishra, M.N. (2004): Effect of gamma-rays, EMS and NMU on germination, seedling vigour, pollen viability and plant survival in M1and M2 generation of Okra (*Abelmoschus esculentus* (L.) Moench). *Advances in Plant Science*, **17**(1): 295-297.

Kwon-Ndung, E.H. and Misari, S.M. (1999). Overview of research and development of fonio (*Digitaria exilis* Kippis Stapf) and prospects for genetic improvement in Nigeria. *In: Genetics and Food Security in Nigeria.* Genetic Society of Nigeria Publication, Nigeria, 71-76 pp.

Liu, S., Llewellyn, D.J., Stiller, W.N., Jacobs, J., Lacape, J. and Constable, G.A. (2010).

Heritability and predicted selection response of yield components and fibre properties in an interspecific derived RIL population of cotton. *Euphytica*, **178**: 309–320.

Marcu, D., Cristea, V. and Darban, L. (2013). Dose-dependent effects of gamma radiation on lettuce (*Lactuca sativa* var. capitata) seedlings. *International Journal of Radiation Biology,* **89**: 219–223.

Melki, M. and Marouni, A. (2009). Effects of gamma rays irradiation on seeds germination and growth of hard wheat. *Environmental Chemistry Letters*, **10**.1007/s 10311-0090222-1.

Mishra, P., Singh, A.K. and Singh, O.P. (2014): Genetic variability, heritability, Genetic advance, correlation coefficient and path analysis in gladiolus. *Journal of Agriculture and Veterinary Science*, **7**(7): 23-26.

Mudibu, J., Nkongolo, K.K., Kalonji-Mbuyi, A. and Kizungu, R. (2010). Effect of Gamma Irradiation on Morpho-Agronomic Characteristics of Soybeans (*Glycine max* L.). *American Journal of Plant Science.* **3**(3): 331-337.

NAERLS/ National Agricultural Extension Research and Liason Services (2012). Crop Production Manual.

Naik, P.M. and Murthy, H.N. (2009): The effects of gamma and ethyl methane sulphonate treatments on agronomical traits of niger (*G. abyssinica* Cass.). *African Journal of Biotechnology*, **8**(18): 4459-4464.

Ogunbayo, S.A., Sie, M., Ojo, D.K., Sanni, K.A., Akinwale, M.G., Toulou, B., Shittu, A., Idehen, E.O., Papoola, A.R., Daniel, I.O. and Gregorio, G.B. (2014). Genetic variation and heritability of yield and related traits in promising rice genotypes (*Oryza sativa* L.). *Journal of Plant Breeding and Crop Science*, **6**(11): 153-159.

Purseglove, J.W. (1972). *Tropical crops. Monocotyledons.* Vol. I. Longmans publication, 142-143 pp.

Rajarajan, D., Saraswathi, R. and Sassikumar, D. (2016). Determination of lethal dose and effect of gamma ray on germination percentage and seedling parameters in ADT (R) 47 rice. *International Journal of Advanced Biological Research*, **6**(2): 328-332

Ramchander, S., Ushakumari, R. and Arumugam, P. (2015). Lethal dose fixation and sensitivity of rice varieties to gamma radiation. *Indian Journal of Agricultural Research*, **49** (1): 24-31.

Rashid, M.A.K., Khan, A.S. and Iftikar, R. (2012). Genetic studies for yield and yield related parameters in bread wheat. *American-Eurasian Journal of Agriculture and Environmental Sciences*, **12**(12): 1579-1583.

SAS.(2008). Statistical analysis system, version 9.2. SAS Institute Inc. Cary, NC, USA.

Shrimali, J., Shekhawat, A.S. and Kumari, S.(2017). Genetic variation and heritability studies for yield and yield components in barley genotypes under normal and limited moisture conditions. *Journal of Pharmacognosy and Phytochemistry*, **6**(4): 233-235

Singh, R.K. and Chaudhary, B.D. (1985). *Biometrical methods in quantitative genetic analysis*. Kalyani Publishers, New Delhi, Ludhiana, India. 1985: 39-78.

Suresh, D., Poonguzhali, S., Sridharan, S. and Rajangam, J. (2017). Determination of Lethal Dose for Gamma Rays Induced Mutagenesis in Butter Bean (*Phaseolus lunatus L*) Variety KKL-1. *International Journal of Current Microbiology and Applied Sciences*, **6**(3): 712-717.

Syukur, M., Sujiprihati, S. and Yunianti, R. (2012). Teknik Pemuliaan Tanaman. Penebar Swadaya. Jakarta.

Talebi, A.B., Talebi, A.B. and Jafarpour, M. (2012). Identify the Lethal Dose of EMS and Gamma Radiation Mutagenesis in Rice MR219. 2nd International Conference on Environmental Science and Biotechnology IPCBEE vol.48 (5) IACSIT Press, Singapore 22-26 pp.

Toker, C., Uzen, B., Canci, H. and Ceylan, F.O (2005): Effects of gamma irradiation on the shoot length of *Cicer* seeds. *Radiation Physics and Chemistry*, **73**: 365-367.

Tshilenge-Lukanda, L., Kalonji-Mbuyi, A., Nkongolo, K.K.C. and Kizungu, R.V. (2013). Effect of Gamma Irradiation on Morpho-Agronomic Characteristics of Groundnut (*Arachis hypogaea* L.). *American Journal of Plant Science*, **4**: 2186-2192.

Yadav, A. K., Maan, R. K., Kumar, S. and Kumar, P. (2011). Variability, heritability and genetic advance for quantitative characters in hexaploid wheat (*Triticum aestivum* L.). *Electronic Journal of Plant Breeding*, **2**(3): 405-408

Vashistha, A., Dixit, N.N., Dipika, S., Sharma, K. and Marker, S. (2013). Studies on heritability and genetic advance estimates in Maize genotypes. *Bioscience Discovery*, **4**(2):165-168.

Wani, M.R., Kozgar, M.I., Khan, S. and Dar, N.A. (2013). Induction of Genetic Variability Through Artificial Mutagenesis in Chickpea (*Cicer arietinum* L.). *Thai Journal of Agricultural Science*, **46**(3): 141-147.

Wolie, A., Dessalegn, T. and Belete, K. (2013). Heritability, variance components and genetic advance of some yield and yield related traits in Ethiopian collections of finger millet (*Eleusine coracana* (L.) Gaertn.) genotypes. *African Journal of Biotechnology*, **12** (36): 5529-5534.

Yohannes, T., Weldetsion, M., Abraha, N., Manyasa, E. and Abraha, T. (2015): Combine selection for earliness and yield in pedigree developed sorghum (*Sorghum bicolor* L. Moench) progenies in Eritrea. *Journal of Plant Breeding and Genetics*, **3** (01):1-8.