

Assessment of the effects of gamma irradiation on the growth and yield of *Digitaria exilis* [Haller]

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ABSTRACT

Objective: Mutagenesis has been used in several crop improvement programmes but only on a very limited scale for *Digitaria* improvement and in order to further strengthen the existing conventional improvement methods, we report enrichment of *Digitaria exilis* variability by exploiting the effects of gamma radiation of different doses on yield and growth of the crop.

Methodology and Results: *Digitaria exilis* seeds were exposed to gamma irradiation (20Gy, 40Gy, 80Gy, and 100Gy) from ⁶⁰Co source and irradiated seeds were sown for evaluation. The effects of the irradiation doses were studied on germination, seedling characters, growth, and yield parameters at maturity. Days to emergence and percentage germination were enhanced at low irradiation doses with 80Gy producing optimally. Plant height, tillering and number of leaves were significantly affected by gamma irradiation and analysis of obtained data showed irradiation significantly affects percentage seed-set, number of spikes/tiller and number of spikelets/spike. Also, early maturity was achieved among irradiated plants and 100-grain weight was highest at 80Gy.

Conclusion: Plant from 80Gy irradiation dose performed optimally for all the characters evaluated in this study. Hence, 80Gy or slightly low dosage form of gamma irradiation using cobalt (60) could be utilised to increase variability and yield in *Digitaria exilis*. The new or modified traits so created could be screened for the possibility of isolating and selection of mutants that are promising for further improvement breeding programmes.

Keywords: Characters, Irradiation, Improved, Agronomical, Yield

INTRODUCTION

In the wakes of climatic change with its impending danger of food scarcity and insecurity, nearly a billion poor people of dry land environments of Africa and Asia lives depend on cereals that can be grown on drought and water stressed environments such as millet, sorghum and other dryland crops (CGIAR, 2012). The poor rural people whose main occupation is still farming

awaits their salvaging crops whose genetics are well understood and require low input to develop hybrids of improved yield and stable crops for such conditions. *Digitaria exilis* is an important orphan crop component of food security in West Africa and is assuming a greater importance in the context of changing climate and increasing demand for highly nutritious food with low cost input. *Digitaria exilis* is

one of the promising cereals in fighting hunger in Sub-Saharan Africa (Vietmeyer *et al.*, 1996). Although a large number of *Digitaria* species are recognised as weeds, cultivated species have been identified for their use as forage and human food (Aliero and Morakinyo, 2001). *D. Exilis*, fondly called "Acha", "hungry rice", "fonio", "fundu" is grown in the savannah zone of the West Africa from Senegal to Cameroon and Nigeria as staple crop. It is a traditional cereal well adapted to local conditions, and has good nutritional and culinary properties (Jean-Francois, 2004). In Nigeria, Acha is majorly cultivated in Plateau, Bauchi, Kebbi, Kaduna, Niger, Kastina and Borno States and recently among the local farmers in the Federal Capital Territory area (Maji *et al.*, 2005). Utilization of *Digitaria* species for food or other uses is restricted to areas of production; its relative importance has not been generally recognized over the years except in the areas of its cultivation.

The small grain of Acha is used to make porridge and dishes of Acha, which showed higher preference than those of rice and millet among the growers (Jean-Francois, 2004). The flour is used along with baobab milk to produce mixture of high nutritional value (Obizola and Anyinka, 1994). *D. exilis* grain is used for brewing beer and the straw provides useful fodder, stuffing of mattresses or livestock bedding and raw materials for local soap and paper industry (Phillips, 1977). Awolola (1984) reported an increase in the consumption of *acha* in Nigeria and that the percentage in food demand increases with increase in yield over the years. Acha is one of the worlds' fastest growing cereal and its potential to provide food early in season when other crops are yet to mature for harvesting could be effective in fighting hunger in a continent that is ravaged by poverty, drought and flood (Kuta *et al.*, 2003; Uwakungwu *et al.*, 2003; Dachi and Gana, 2008). *D. exilis* have great genetic developmental potentials and its long storage life

and keeping qualities are particularly of importance in replacing the super cereals in industrial and food production of tomorrow. It has ambient ability to survive continuous and intermittent drought conditions that occur because of rainfall fluctuation. Acha production in Nigeria is faced with a number of problems, one of which is low yield (Dachi and Barko, 2003; Maji *et al.*, 2003; Ukwungwu *et al.*, 2003). Due to the low grain yield and the small grain size that shatters and matures unevenly, the crop has not been fully exploited and has generally remained unimproved. The very small grain size of Acha largely constitutes a problem in harvesting and makes mechanical harvesting almost impracticable due to its logging, which is a wild character (Morakinyo and Adelakun, 1997). Currently, the genetic improvement of Acha centres on germplasm collection and morpho-agronomic characterization with the objective of broadening the crop gene pool. However, morphological characterization alone might not provide the much needed diversity for breeding programme. Also, the traditional hybridization for new cultivar appears unfeasible due to the miniature size of the floral organs and inadequate floral biology. Very little information is available on *D. exilis* improvement by mutagenesis and therefore, this work aimed at assessing the effects of application of gamma irradiation from ^{60}Co source on the growth characteristics of the crop. Mutagenesis has been used to introduce novel genetic variability in a number of crops. More recently, it has become a powerful tool in gene discovery (Pathirana *et al.*, 2002; Amanda *et al.*, 2008). Improvement is hoped to be achieved in vegetative characteristics, yield components and maturity. To this end, the present study will evaluate gamma radiation effects on *Digitaria exilis* with a view determine the optimum dose that will create useful variability in the vegetative structure and improve the yield components of the crop.

MATERIALS AND METHODS

Seeds of *D. exilis* (Ex-Sum-I) with accession number vde 004 were collected from the National Cereal Research Institute, Badeggi, Niger-State of Nigeria. Seed colour, shape and seed coat texture were

observed and recorded before and after the treatments were applied. 150 g of dry seeds were exposed to Gamma-radiation of ^{60}Co at Sheda Science and Technology Complex (NTC SHESTCO), Abuja, Nigeria.

Four doses of irradiation were assayed in increasing concentrations of 20, 40, 80, and 100 Gy, ranging from 0.020-0.10 kGy (1 Gy is equivalent to 100 rads of radiation). Alanine Dosimeter was used to verify the dosage conformation. After the dosage confirmation, the treated seeds for each radiation dosage were kept in a paper envelop, well sealed till sowing time. The control seed were soaked in distilled water for 3 hrs before planting. The seeds were sown (broadcasted) on nursery beds rich in loamy soil (0.5 m X 0.5 m) for each of the treatments and control. The experiment was designed in a Complete Randomized Design (CRD), nursery management such as watering and shading was provided and weeding was done as required. Seedlings were transplanted three weeks after sowing, three (3) plants were transplanted into planting bag filled with loamy soil and labelled corresponding to the treatment of the seedlings in five

replicates arranged in random order inside the screen house. Parameters on which treatments were evaluated include; number of days to emergence, percentage germination, number of leaves/tiller, plant height, number of nodes per plant, inters node length, leaf width, leaf length, number of tiller/plant, leaf sheath length, number of days to maturity, peduncle length, spike length, number of spike/plant, number of days to 50% flowering, number of spikelets/spike, percentage seed set and 100-grain weight. Quantitative data obtained on the vegetative growth and yield of the treated *D. exilis* were analyzed using SPSS 16.0 Microsoft Software for Window. The data was subjected to analysis of variance (ANOVA) to determine significant of variations due to effect of irradiation doses on the plants and the means were separated using Duncan Multiple Range Test (DMRT).

RESULTS

Seed colour, shape and texture were the same before and after treatment. This suggests that the treatments have no observable effect on the seed morphology of *D. exilis*. Germination was fastest in 80 Gy seed with mean germination of 5.1 days, and 92% percentage germination. The average germination day for the untreated seeds was 6.2 days, but with the highest percentage germination of 93%. Nonetheless, other

different doses of radiation produced relatively good germination effect on the seeds. Figures 1 and 2 show the mean number of days to germination, percentage germination and the percentage survival of the seedling after transplant. Survival rate was highest for the control with 96.41% and closely followed by the 80 Gy seedlings (95.39%), while 20 Gy, 40 Gy and 100 Gy recorded 92.1%, 93.35 and 86.81% respectively.

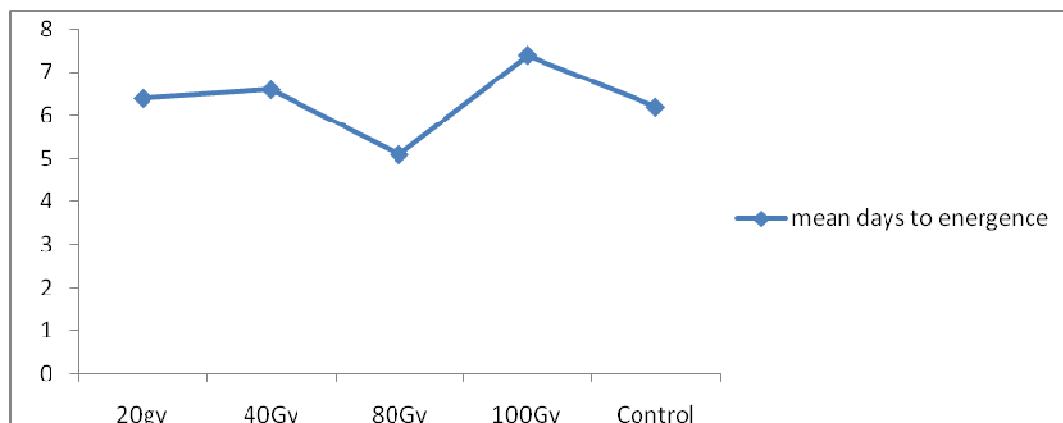


Fig 1a: Chart showing mean number of days to germination of *Digitaria exilis* in response to gamma radiation treatments

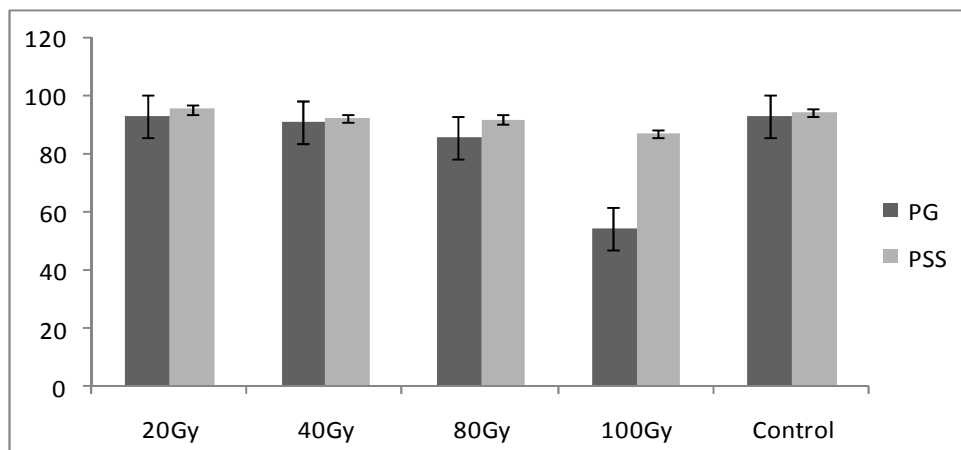


Fig 1b: Chart showing mean percentage germination (PG) and Percentage seedling survival (PSS) of *Digitaria exilis* in response to gamma radiation treatments

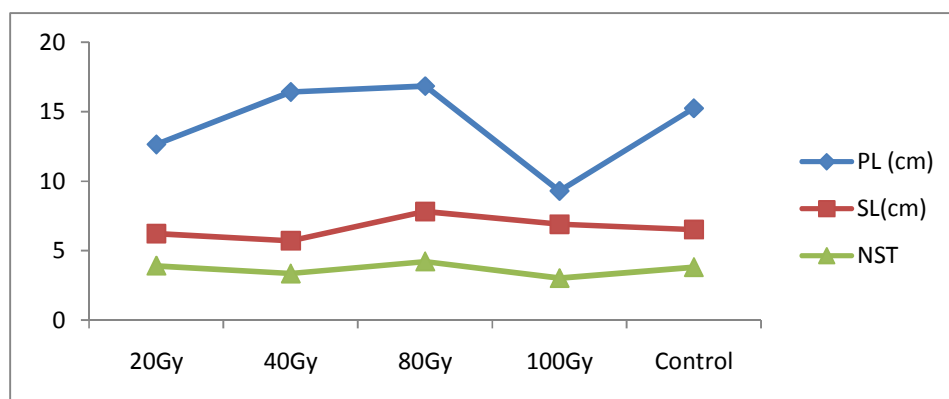


Fig 2: Showing mean Peduncle length (PL), Spike length (SL) and Number of spike/tiller of *Digitaria exilis* treated with different doses of gamma radiation

On emergence, seedlings of 20 Gy radiation and control are similar with green leaves, green leaf sheaths and green stem bases. Other irradiated seedlings, had reddish-green leaves, sheaths and reddish stem bases. The quantitative characters studied 3weeks after sowing; number of leaves was highest in 80 Gy group with a mean value of 4.2,

followed by the 40 Gy which had mean value of 3.6 and control 3.4 while 100 Gy had the lowest value of 2.8. Leave length and plant height at 3weeks after sowing trends were similar to the number of leaves for all the treatments, while the highest mean plant height was obtained in 80 Gy seedlings (Table 1).

Table 1: Quantitative characteristics of *D. exilis* 3weeks after sowing

Treatments	No of leaves	Leaf length (cm)	Plant height (cm)
20 Gy	3.2 ±1.30	2.2 ±0.61	3.26 ±0.48
40 Gy	3.6 ±1.14	1.6 ±0.91	3.88 ±0.38
80 Gy	4.2 ±1.30	3.4 ±1.06	4.06 ±0.21
100 Gy	2.8 ±0.84	1.6 ±0.30	3.24 ±0.55
Control	3.4 ±1.14	2.8 ±0.91	3.82 ±0.63

At maturity, *D. exilis* showed different responses to the mutagenic treatments of different level of dosages. Plant height was highest in 80 Gy plant (99.8 cm) among all the irradiated plants; the mean plant height values were high with no value less than 90.0 cm. In addition, the response of plant leaf length to treatment varied for all the treatment applied. The leaf length for 80 Gy was the highest (19.84 cm). The 20 Gy and 40 Gy plants responses to treatment in term of leaf length were very close and not significantly different (20 Gy-17.56 cm and 40 Gy-17.6 cm), but significantly difference from leaf length of the control plants (16.28 cm) and 100 Gy plant with least mean leaf length (15.62 cm). The highest number of tillers per plant was observed in 40 Gy plants (11.6) while the control plants produced an average of 8.4 tillers per plant. Other quantitative observations on the vegetative characters

of the treatments were summarized in the Table 2. The levels of significant differences in all the examined characters were indicated. The DMRT analysis showed that treated plants were significantly different in the number of nodes/plant, inter-nodal length and number of days to maturity. Treatment effects were highest in the irradiated plants of 80 Gy. The number of spikelets per spike varied with 80Gy plants having the highest spikelet per spike, followed by 20 Gy plants and control plants with 95.8, 92.6 and 90.2 mean values respectively. Also, plants responses to gamma radiation treatment differ with regards to fruiting characteristics such as peduncle length, spike length and number of spike per tiller (Fig. 2). Weight of 100 grains for 80 Gy plants had the highest value and was closely trailed by 40 Gy plants and control seeds (Fig. 3).

Table 2: Quantitative characters of *Digitaria exilis* in response to treatments by doses of gamma radiation

Treatments	No of tiller/plant	Leaf length(cm)	No of nodes/tiller	Inter nodal length (cm)	Plant height (cm)	Leaf sheath length(cm)	Leaf width (cm)	No of days to maturity	No of spikelet/spike
20Gy	10.21±1.03b	17.56±1.09b	7.80±0.580a	6.68±0.48b	93.34±3.21a	5.32±0.32abc	0.76±0.04a	79.20±2.47a	92.60±2.78a
40Gy	11.60±1.15a	17.60±1.20b	7.20±1.019b	6.66±0.57b	98.52±3.31a	5.82±0.54abc	0.66±0.09ab	82.40±2.66b	90.31±2.89a
80Gy	11.30±1.09a	19.84±1.73a	7.60±1.872a	8.05±0.54a	99.82±2.96a	6.82±0.48a	0.23±0.07c	87.60±4.63b	95.80±2.96a
100Gy	8.51±1.03c	15.62±1.30c	5.80±0.347c	6.42±0.76b	90.46±2.54b	5.90±0.48b	0.70±0.08b	89.80±3.44abc	87.12±2.76b
(control)	8.42±0.99c	16.28±1.26ab	7.20 ±0.53b	6.10±0.44 b	95.60±2.52a	0.424±0.21c	0.76±0.23a	92.60±2.12c	90.25±2.61a

Probability level P < 0.05

Values with same alphabet are not significantly difference along the column while values followed by different alphabets are significantly different.

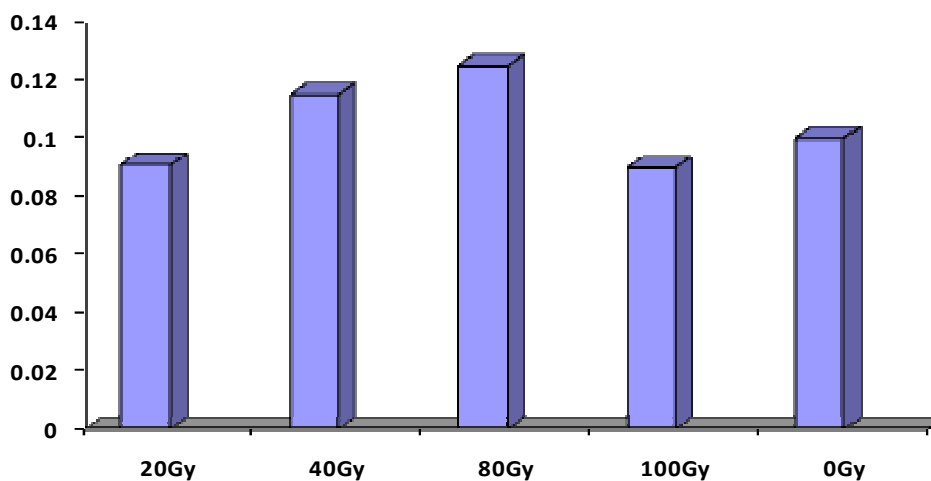


Fig 3: 100-seed weight (g) of M₁ progeny of *Digitaria exilis* exposed to different gamma radiation doses

DISCUSSION

Both quantitative and qualitative characters evaluated showed distinct differences in most of the characteristics, though there were few characteristics with no significant differences in responses to the applied treatments. The ability of the irradiated seeds to germinate between 4-8 days in respect to the control showed that the irradiation induced increase enzymatic activities, which could be responsible for the early germination. This is in agreement with earlier report by Kaplan, (1963) partially in agreement with Mensah *et al.*, (2007) who reported that germination decreases with increase in dose of chemical mutagens while working on sesame seeds. In the present study, 80 Gy seeds responded vigorously to germination just as 20 Gy and 40 Gy treated seeds germinated earlier than the control, although 100 Gy had negative effect on germination. It therefore suggested that at optimal dose, irradiation can be used to induce germination in Acha. However, percentage germination and seedling survival reduced with increase in irradiation dosage. Many workers have reported adverse effects of physical and chemical mutagens on percentage germination and seedling survival of crops (Mensah *et al.*, 2007; Khan and Goyal, 2009; Chowdhury and Tah, 2011; Shagufta *et al.*, 2013). The reduced percentage germination and seedling survival at high dosage of irradiation possibly indicate the greater sensitivity of the crop due to occurrence of more genic chromosomal and physiological disturbances at these concentrations. Plant height, tillering, leaf formation, and other vegetative traits studied responded to 80Gy irradiation.

This implies that 80 Gy or slightly less doses would be appropriate in producing optimal effects in respect to the vegetative characters, although higher dosage exposure of the crop to gamma irradiation resulted in negative response. This correlates with the findings of Mensah *et al.* (2005) and Warghat *et al.*, (2011) who reported that appropriate application of dosage or concentration of mutagens improves vegetative yields of cowpea (*Vigna unguiculata*) and Musk okra (*Abelmoschus moschatus*). The growth effects observed could be attributed to mitotic activities which are sustained from seedling till maturity, resulting in the proliferation of axillary bud in response to irradiation as studied by Prat (1967). The marked differences observed in the studied characters even at the level of different dosages could have arisen from mutagenic effects of the gamma irradiations on the DNA and genetic structure of the plants. This position is corroborated by the work of Reddy and Smith (1994), who opined that chemical mutagen (EMS), induced notable vegetative characters in treated *Sorghum bicolor*. Considering seed characters, variations were observed in the number of spikelets produced per spike and percentage seed set was highest among 80Gy plants. The average weight of 100-grains for 80Gy was also the highest. This result concurred with the reports of Shamsi and Sofajay, (1980) and Shamsulzaman *et al.*, (2005) who had earlier reported increased in yield of crops treated with mutagens. The effects of gamma irradiation of 80 Gy on *D. exilis* as observed in this study could have arisen from changes in genetic

material which promotes growth and yield of the plants. While irradiation doses of 20 Gy, and 40 Gy were not possibly enough to effect significant developmental and growth effects on the plants of the treated seeds. 100 Gy irradiation dose among all the levels of irradiations

tested produced the least desirable effects in almost all the evaluated characters of the Acha plants studied. Therefore, the dosage of 100 Gy had likely overshoot the required gamma irradiation dosage for optimal growth and yield of *D. exilis*.

CONCLUSION

This study has established that ionizing radiation mutagenesis could be routinely used to generate genetic variability for breeding improved crop and for the purpose of genetic studies in *D. exilis*. In order to increase the likelihood of inducing distinct type of genetic variation in the crop, gamma rays of 80Gy radiation, which consistently produced the optimal

effects on the crop should be adopted and for effective mutation breeding, character to be bred for should be singly screened and appropriate dosage for the treatment of such crop should be applied. It is also worthy of mentioning that in using irradiation for *D. exilis* to enhance variability, the probable optimal dose range lies between 65-85Gy.

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