

Effects of gamma Irradiation on the Growth and Survival of M₁ Population of Bambara Groundnut (*Vigna subterranea* L. Verdc.)

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ABSTRACT

Understanding the influence of mutagens on growth response and survival of self-pollinating legumes such as Bambara groundnut (*Vigna subterranea* L. Verdc.) is essential for identifying tolerant genotypes to facilitate its genetic improvement. This study assessed mutagenic stress tolerance and survivability in Bambara groundnut exposed to gamma radiation. Seeds from three landraces (Alk-C, Alk-M and Alk-B) were irradiated with varying doses of Gamma rays (0, 50, 100, 150, and 200 Gy) from a Cobalt – 60 (⁶⁰Co) source to generate twelve (12) factorial treatments, which were planted in a Randomized Block Design (RBD) and replicated three times. A progressive reduction in plant height, number of branches, number of leaves, terminal leaf length, terminal leaf width and survival rate was observed in the mutagenic treatments across all growth stages. These deleterious effects were more pronounced in higher gamma radiation doses (150 and 200 Gy), likely due to genetic and physiological damage to meristematic cells or tissues, resulting in abnormal cell division and reduced plant growth. However, the low gamma radiation dose (50 Gy) enhanced growth in these parameters, indicating a stimulatory effect at this level. The significant interaction between gamma-ray dose and landrace revealed that Alk-C exhibited a higher degree of tolerance to mutagenic treatment across the evaluated parameters, suggesting its potential as a promising candidate for breeding and genetic improvement programmes.

Keywords: *Bambara groundnut, gamma radiation, induced mutagenesis, vegetative growth and survival rate.*

INTRODUCTION

The narrowing base of global food security is increasingly limiting livelihood options for the rural poor, particularly in Sub-Saharan Africa (IPGRI, 2000). Exploiting underutilized crops that possess abundant genetic resources and potentially beneficial traits has been widely recognized as a viable strategy in developing a more diversified agricultural system and additional food sources needed to address food and nutritional security challenges (Williams & Haq, 2002; Jaenicke & Höschle-Zeledon, 2006; Mayes et al., 2011). Underutilized legumes such as Bambara groundnut are often regarded as minor crops in terms of cultivation and general utilization. However, these crops play a significant role in the livelihoods of small holder farmers, provide numerous socio-economic benefits to rural communities, and have considerable potential to improve incomes, food security and nutrition,

particularly in combating hidden hunger caused by micronutrient deficiencies (IPGRI, 2000).

Bambara groundnut (*Vigna subterranea* L. Verdc), is one of the most promising underutilized legumes, with substantial potential and prospect to address food and nutritional security challenges in Sub-Saharan Africa (Temegne *et al.* 2018). It is a neglected African legume belonging to the family Fabaceae and is highly valued for its nutritional quality, drought resistance, tolerance to poor soils, salt stress and its ability to produce under conditions where other legumes fail (Taffouo *et al.*, 2010). Bambara groundnut is a major source of plant protein in sub-Saharan Africa and constitutes an important component of local diets, culture and rural economy (Adu-Dapaah and Sangwan 2004; Boateng *et al.* 2013). Its high nutritional value and rich content of essential amino acids further underscores its importance for food and nutritional security (Yao *et al.*, 2015). Despite these advantages, the crop remains unfortunately less cultivated and poorly utilized in tropical Africa, largely due to the lack of improved varieties (Temegne *et al.*, 2018).

Induced mutagenesis is a process in which sudden heritable changes occur in the genetic information of an organism, not through genetic segregation or genetic recombination, but as a result of exposure to chemical, physical or biological agents (Bhat *et al.*, 2006; Bhat *et al.*, 2007; Roychowdhury and Tah, 2013). It has emerged as an effective approach for inducing genetic variability in staple crops, particularly in grain legumes, which often possess a narrow genetic base due to their predominantly self-pollinating nature. Genetic diversity can be expanded through the use of physical and chemical mutagens, which are widely adopted because of their simplicity, applicability and economic viability. The primary goal of any breeding programme is to improve existing germplasm and develop superior varieties, a process that can be efficiently achieved through mutation breeding (Bhat *et al.*, 2006). This technique offers advantages over conventional breeding methods in enhancing both qualitative and quantitative traits in crops.

Induced mutagenesis has gained increasing recognition in recent decades and is regarded as one of the driving forces for crop evolution and improvement (Toker, 2009). The usefulness of mutagens in mutation breeding depends not only on their mutagenic effectiveness but also on their mutagenic efficiency in minimizing undesirable effects such as sterility, lethality and biological injuries (Bhat *et al.*, 2007; Girija and Dhanavel, 2009). The success of any plant improvement through induced mutagenesis largely depends on the successful growth and survival of the first mutant generation (M_1), from which desirable mutants are identified and selected for subsequent generations. However, understanding of the effects of radiation on growth and development in Bambara groundnut remains limited, and the available data are insufficient. Therefore, this study was carried out to evaluate the growth responses of Bambara groundnut to different gamma radiation doses at various stages, as well as the survival rate of mutant plants at maturity.

MATERIALS AND METHOD

Seeds from three Bambara groundnut landraces were obtained from local farmers in Alkaleri Local Government Area (LGA) of Bauchi State, Nigeria. The landraces were characterized based on their seed testa colour and designated as Alkaleri Cream (Alk-C), Alkaleri Mottled (Alk-M), and Alkaleri Black (Alk-B). Dry, healthy seeds were selected and irradiated with four (4) doses of gamma rays (50, 100, 150 and 200 Gy), while the un-irradiated seeds served as the control. Gamma Irradiation of the seed

samples was conducted using a Gamma Beam X-200 machine with Cobalt – 60 (^{60}Co) as the radiation source at a dose rate of 0.01032 Gy/s, at the Institute for Radiation Protection and Research (NIRPR), University of Ibadan, Nigeria. The three (3) Bambara groundnut landraces and five (5) gamma radiation doses were combined to form twelve (12) factorial treatments, which were arranged in a Randomized Block Design (RBD) and replicated three times.

Data were collected on plant height, number of branches, number of leaves, terminal leaf length and terminal leaf width at different stages of plant development, while data on survival rate (%) was recorded at maturity. The data were subjected to Analysis of variance (ANOVA) using Minitab statistical software (version 16.0). Values are expressed as mean \pm standard deviation (SD). The means were separated using the Least Significant Difference (LSD) at 5% level of significance to test for treatment effects.

Survival rate was calculated as the ratio of the number of plants at maturity to the number of seedlings that emerged, multiplied by 100 as expressed below:

$$\text{Survival rate (\%)} = \frac{\text{number of plants at maturity}}{\text{number of seedlings that emerged}} \times 100$$

RESULTS AND DISCUSSION

Results from this study revealed that different doses of gamma radiation significantly influenced the growth and survival of Bambara groundnut landraces. Table 1 shows significant differences ($p < 0.05$) in plant height among gamma radiation doses at all sampling stages. A significant increase in plant height was observed at 50 Gy, whereas a marked reduction occurred at the higher doses (150 and 200 Gy). The landraces did not differ significantly in plant height across most growth stages, except at 27 days after sowing (DAS), where Alk-B grew tallest. The number of branches per plant varied significantly ($p < 0.05$) among radiation doses at 27, 34 and 55 DAS (Table 2). Plants treated with 50 Gy produced more branches compared with other doses, while higher gamma radiation doses adversely affected branch proliferation across all sampling stages as shown in the table. Differences among landraces were significant only at 48 DAS, where Alk-B recorded a higher number of branches than the other landraces. A similar trend was observed for the number of leaves (Table 3). Significant differences ($p < 0.05$) were recorded at 27, 34 and 55 DAS, with progressive reduction in leaf number as radiation dose increased across all growth stages, particularly at the higher gamma radiation doses. However, plants treated with 50 Gy dose produced more leaves than the control. The number of leaves did not differ significantly among landraces across most sampling periods, except at 48 DAS, where Alk-B recorded the highest number of leaves.

Table 1: Effects of varying Gamma radiation doses and landraces on Plant height of Bambara groundnut at 27, 34, 41, 48, and 55 days after sowing

	27 DAS	34 DAS	41 DAS	48 DAS	55 DAS
<u>DOSE</u>					
Control	16.2 ± 3.31 ^{ab}	19.5 ± 2.42 ^{ab}	20.9 ± 2.79 ^a	20.6 ± 1.31 ^{ab}	20.2 ± 1.44 ^{abc}
50 Gy	17.8 ± 2.62 ^a	21.0 ± 2.21 ^a	23.0 ± 1.73 ^a	21.5 ± 1.30 ^a	21.7 ± 1.86 ^a
100 Gy	16.8 ± 3.14 ^{ab}	20.7 ± 2.88 ^{ab}	22.2 ± 1.18 ^a	20.9 ± 2.41 ^{ab}	21.4 ± 1.93 ^{ab}
150 Gy	12.9 ± 3.78 ^b	17.3 ± 2.78 ^{bc}	17.3 ± 3.77 ^b	17.8 ± 3.56 ^b	18.9 ± 3.59 ^{bc}
200 Gy	8.5 ± 2.49 ^c	14.0 ± 3.55 ^c	15.8 ± 2.76 ^b	18.3 ± 2.77 ^{ab}	17.8 ± 0.81 ^c
LSD _{0.05}	3.8	3.5	3.3	3.2	2.7
<u>LANDRACE</u>					
Alk – C	13.1 ± 4.97 ^b	17.1 ± 4.31	19.3 ± 3.79	19.9 ± 2.59	20.7 ± 2.01
Alk – M	14.4 ± 4.70 ^{ab}	19.0 ± 3.74	20.2 ± 3.65	20.1 ± 2.40	20.3 ± 1.93
Alk – B	15.8 ± 3.75 ^a	19.3 ± 2.91	20.0 ± 4.12	19.4 ± 3.35	19.1 ± 3.28
LSD _{0.05}	4.9	NS	NS	NS	NS
<u>INTERACTION</u>					
D × L	NS	NS	NS	NS	**

Values are presented as mean ± SD. Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using LSD

** Significant at 1% level of probability

DAS = Days after sowing

NS = Not significant

Table 2: Effects of varying Gamma radiation doses and landraces on Number of branches of Bambara groundnut at 27, 34, 41, 48, and 55 days after sowing

	27 DAS	34 DAS	41 DAS	48 DAS	55 DAS
<u>DOSE</u>					
Control	6.1 ± 0.78 ^a	8.8 ± 1.48 ^{ab}	11.4 ± 1.13	14.6 ± 1.53	17.3 ± 1.23 ^{ab}
50 Gy	6.7 ± 0.50 ^a	10.0 ± 1.00 ^a	11.9 ± 1.69	13.9 ± 3.25	19.1 ± 3.06 ^a
100 Gy	6.3 ± 0.87 ^a	9.8 ± 1.64 ^a	10.8 ± 1.09	13.2 ± 6.86	17.0 ± 3.57 ^{ab}
150 Gy	4.7 ± 1.00 ^b	9.2 ± 1.72 ^{ab}	10.4 ± 2.01	12.8 ± 1.75	15.3 ± 1.00 ^b
200 Gy	5.4 ± 1.59 ^{ab}	7.4 ± 1.01 ^b	9.8 ± 2.86	12.3 ± 1.65	14.3 ± 2.65 ^b
LSD _{0.05}	1.3	1.8	NS	NS	3.3
<u>LANDRACE</u>					
Alk – C	5.4 ± 1.50	8.7 ± 1.95	10.6 ± 2.56	12.0 ± 2.56	17.0 ± 3.46
Alk – M	5.9 ± 0.99	9.2 ± 1.27	10.5 ± 1.55	12.7 ± 1.84	16.1 ± 2.87
Alk – B	6.3 ± 0.96	9.3 ± 1.62	11.5 ± 1.51	13.6 ± 2.32	16.8 ± 2.46
LSD _{0.05}	NS	NS	NS	NS	NS
<u>INTERACTION</u>					
D × L	NS	NS	NS	**	**

Values are presented as mean \pm SD. Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using LSD

** Significant at 1% level of probability

DAS = Days after sowing

NS = Not significant

Table 3: Effects of varying Gamma radiation doses and landraces on Number of leaves of Bambara groundnut at 27, 34, 41, 48, and 55 days after sowing

	27 DAS	34 DAS	41 DAS	48 DAS	55 DAS
<u>DOSE</u>					
Control	19.3 \pm 2.50 ^{ab}	27.3 \pm 4.24 ^{ab}	34.7 \pm 2.65	43.7 \pm 3.71	52.2 \pm 3.46 ^{ab}
50 Gy	20.2 \pm 1.79 ^a	30.0 \pm 4.74 ^a	31.9 \pm 5.40	40.0 \pm 5.41	57.3 \pm 9.18 ^a
100 Gy	18.9 \pm 2.26 ^{ab}	29.0 \pm 3.00 ^a	32.4 \pm 3.09	39.1 \pm 6.99	43.4 \pm 7.92 ^b
150 Gy	14.3 \pm 2.83 ^c	27.8 \pm 4.92 ^{ab}	35.7 \pm 5.07	37.0 \pm 3.97	46.0 \pm 3.00 ^b
200 Gy	16.3 \pm 4.47 ^{bc}	22.4 \pm 2.74 ^b	29.7 \pm 8.00	37.2 \pm 3.94	51.2 \pm 10.38 ^{ab}
LSD _{0.05}	3.7	5.2	NS	NS	9.7
<u>LANDRACE</u>					
Alk – C	16.7 \pm 4.70	26.5 \pm 5.53	32.1 \pm 7.19	36.1 \pm 7.37	51.3 \pm 10.31
Alk – M	17.7 \pm 2.92	27.7 \pm 3.92	32.1 \pm 4.00	38.3 \pm 4.85	48.3 \pm 8.30
Alk – B	19.0 \pm 2.48	28.4 \pm 4.61	34.4 \pm 4.52	41.8 \pm 6.97	50.5 \pm 7.34
LSD _{0.05}	NS	NS	NS	NS	NS
<u>INTERACTION</u>					
D \times L	NS	NS	NS	**	**

Values are presented as mean \pm SD. Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using LSD

** Significant at 1% level of probability

DAS = Days after sowing

NS = Not significant

Data on the effects of varying doses of gamma radiation on terminal leaf length (Table 4) showed a consistent decrease in leaf length at higher radiation doses (100, 150 and 200 Gy) across all growth stages. In contrast, plants treated with 50 Gy produced considerably longer terminal leaves. Gamma radiation doses showed no significant differences in terminal leaf width at most sampling stages, except at 27 and 55 DAS (Table 5). At these stages, the low-dose treatment (50 Gy) recorded significantly broader terminal leaves than the other treatments. No significant differences were observed among the genotypes in either terminal leaf length or terminal leaf width across all growth stages, as indicated in Tables 4 and 5.

Table 4: Effects of varying Gamma radiation doses and landraces on Terminal leaf length of Bambara groundnut at 27, 34, 41, 48, and 55 days after sowing

	27 DAS	34 DAS	41 DAS	48 DAS	55 DAS
<u>DOSE</u>					
Control	6.6 ± 0.60 ^{ab}	7.2 ± 0.89 ^{ab}	7.6 ± 0.66 ^{ab}	7.6 ± 0.89 ^{ab}	7.4 ± 0.79 ^a
50 Gy	7.3 ± 0.96 ^a	8.6 ± 1.02 ^a	8.9 ± 0.53 ^a	8.7 ± 0.91 ^a	8.3 ± 1.14 ^a
100 Gy	5.5 ± 0.97 ^b	7.7 ± 1.25 ^{ab}	8.3 ± 1.39 ^a	7.7 ± 1.16 ^{ab}	7.9 ± 1.08 ^a
150 Gy	4.5 ± 1.09 ^{ab}	7.3 ± 0.63 ^{ab}	6.9 ± 1.41 ^b	6.8 ± 1.27 ^b	6.2 ± 1.58 ^b
200 Gy	3.5 ± 2.83 ^c	6.4 ± 1.65 ^b	5.3 ± 0.55 ^c	6.5 ± 0.79 ^b	5.9 ± 0.21 ^b
LSD _{0.05}	1.2	1.8	1.2	1.5	1.1
<u>LANDRACE</u>					
Alk – C	5.4 ± 1.72	7.2 ± 1.49	7.1 ± 1.23	7.3 ± 0.85	7.7 ± 1.36
Alk – M	5.6 ± 1.65	7.9 ± 1.20	7.8 ± 1.77	7.8 ± 1.22	7.2 ± 1.28
Alk – B	6.0 ± 1.35	7.4 ± 1.75	7.1 ± 1.46	7.1 ± 1.43	6.8 ± 1.36
LSD _{0.05}	NS	NS	NS	NS	NS
<u>INTERACTION</u>					
D × L	NS	NS	NS	NS	**

Values are presented as mean ± SD. Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using LSD

** Significant at 1% level of probability

DAS = Days after sowing

NS = Not significant

Table 5: Effects of varying Gamma radiation doses and landraces on Terminal leaf width of Bambara groundnut at 27, 34, 41, 48, and 55 days after sowing

	27 DAS	34 DAS	41 DAS	48 DAS	55 DAS
<u>DOSE</u>					
Control	1.7 ± 0.21 ^a	1.9 ± 0.19	2.1 ± 0.27	2.0 ± 0.21	2.4 ± 0.17 ^a
50 Gy	1.8 ± 0.19 ^a	2.0 ± 0.26	2.1 ± 0.12	2.0 ± 0.19	2.0 ± 0.06 ^{bc}
100 Gy	1.5 ± 0.42 ^a	1.9 ± 0.60	2.0 ± 0.17	2.2 ± 0.32	2.0 ± 0.09 ^{bc}
150 Gy	1.0 ± 0.31 ^b	1.6 ± 0.26	2.1 ± 0.29	1.9 ± 0.19	2.1 ± 0.03 ^{ab}
200 Gy	1.4 ± 0.35 ^{ab}	1.6 ± 0.53	1.9 ± 0.27	1.9 ± 0.35	1.7 ± 0.01 ^c
LSD _{0.05}	0.4	NS	NS	NS	0.4
<u>LANDRACE</u>					
Alk – C	1.4 ± 0.51	1.8 ± 0.42	1.9 ± 0.25	2.0 ± 0.31	2.0 ± 0.31
Alk – M	1.4 ± 0.39	1.9 ± 0.51	2.1 ± 0.20	2.0 ± 0.25	2.1 ± 0.45
Alk – B	1.6 ± 0.22	1.8 ± 0.32	2.0 ± 0.24	2.1 ± 0.28	2.0 ± 0.23
LSD _{0.05}	NS	NS	NS	NS	NS
<u>INTERACTION</u>					
D × L	NS	NS	NS	NS	NS

Values are presented as mean ± SD. Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using LSD

** Significant at 1% level of probability

DAS = Days after sowing

NS = Not significant

The survival rate of the Bambara groundnut landraces decreased appreciably with increasing gamma radiation doses (Fig. 1). Survival was adversely affected by the varying gamma radiation doses and was most severely reduced in Alk-M landrace at the higher doses of 150 and 200 Gy, with survival rates ranging from 28.2% - 40% as shown in Figure 2. In contrast, the Alk-C landrace demonstrated greater tolerance to gamma irradiation than the other landraces, recording survival rates ranging from 52.5% to 62.7% at the higher gamma radiation doses (150 and 200 Gy).

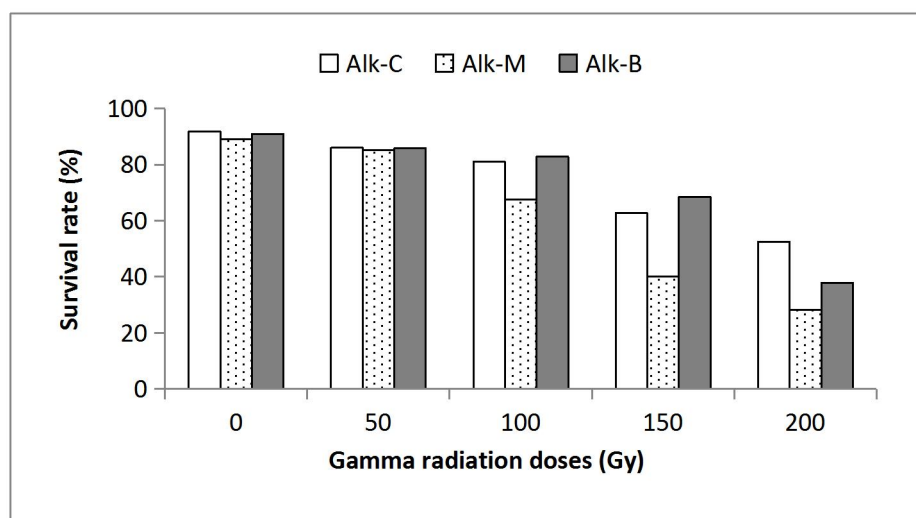


Fig. 1: Effects of different gamma radiation doses (Gy) on the survival rate of three landraces of Bambara groundnut

The interactions between Gamma-ray doses and landraces had a highly significant effect ($p < 0.01$) on the growth parameters evaluated in Bambara groundnut at the later stages of growth (48 and 55 DAS) as shown in Figures 2 – 7. Increasing gamma-ray doses generally reduced plant height, number of branches, number of leaves and terminal leaf length across all landraces; however, the degree and magnitude of these reductions varied among genotypes. At the 200 Gy gamma radiation dose, Alk-B recorded a higher number of branches (Fig. 2) and number of leaves (Fig. 3) compared with the control (0 Gy), whereas the Alk-M landrace recorded the lowest number of branches and leaves at the same dose (200 Gy). At the final growth stage evaluated (55 DAS), Alk-C attained the greatest plant height at 100 Gy (Fig. 4) and recorded higher numbers of branches (Fig. 5) and leaves (Fig. 6) compared with the control at 150 Gy. In contrast, Alk-M recorded the lowest number of branches and leaves at the 50 Gy dose. The longest terminal leaf was observed in Alk-C at 50 Gy, while Alk-B recorded the shortest terminal leaf at 150 Gy as shown in Fig. 7.

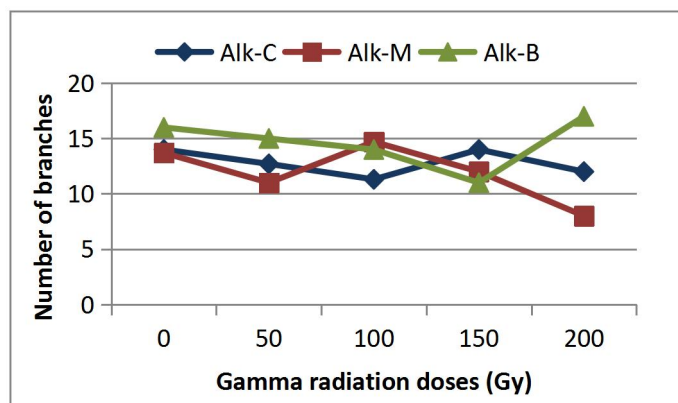


Fig. 2: Effects of Interactions between varying Gamma radiation doses and Landraces on the Number of branches of Bambara groundnut at 48 DAS

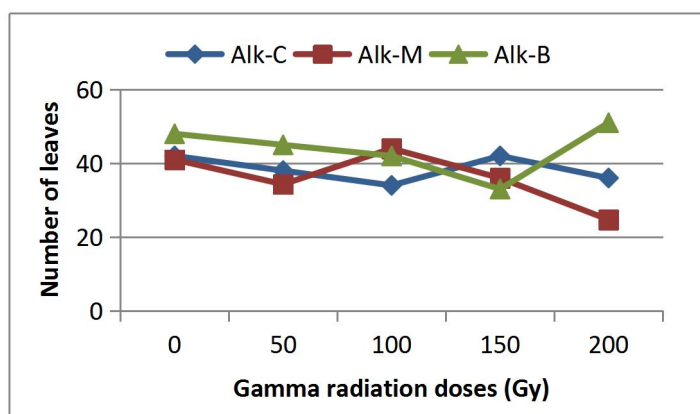


Fig. 3: Effects of Interactions between varying Gamma radiation doses and Landraces on the Number of leaves of Bambara groundnut at 48 DAS

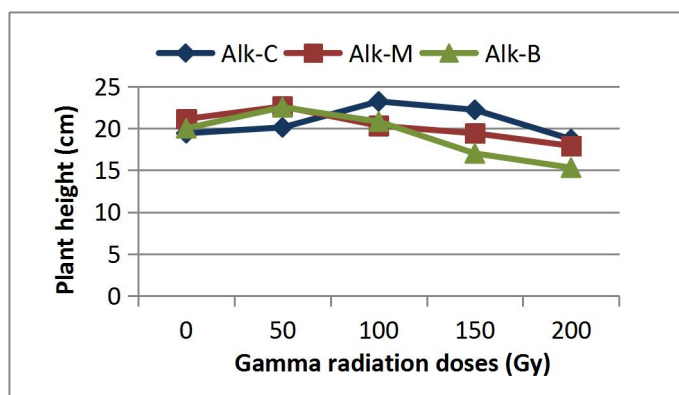


Fig. 4: Effects of Interactions between varying Gamma radiation doses and Landraces on Plant height of Bambara groundnut at 55 DAS

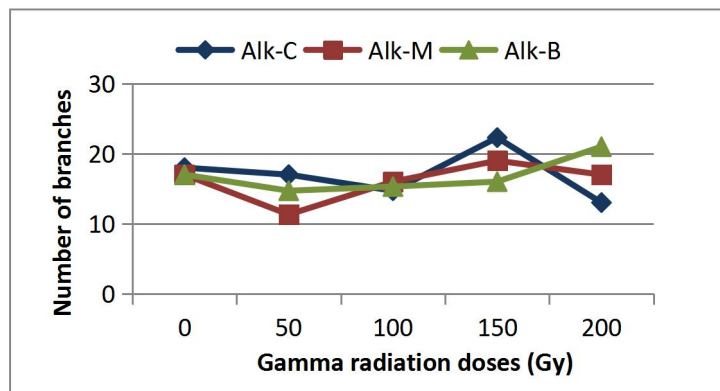


Fig. 5: Effects of Interactions between varying Gamma radiation doses and Landraces on the Number of branches of Bambara groundnut at 55 DAS

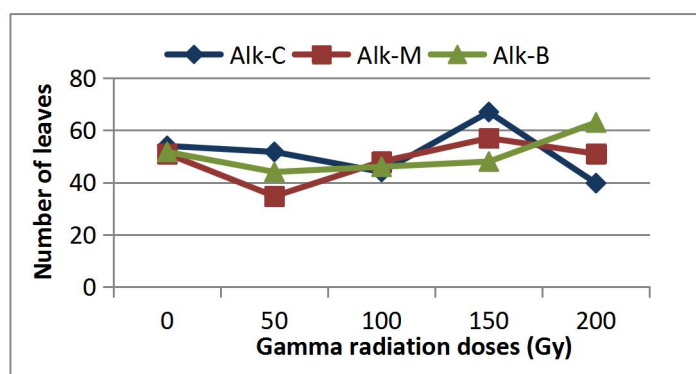


Fig 6: Effects of Interactions between varying Gamma radiation doses and Landraces on the Number of leaves of Bambara groundnut at 55 DAS

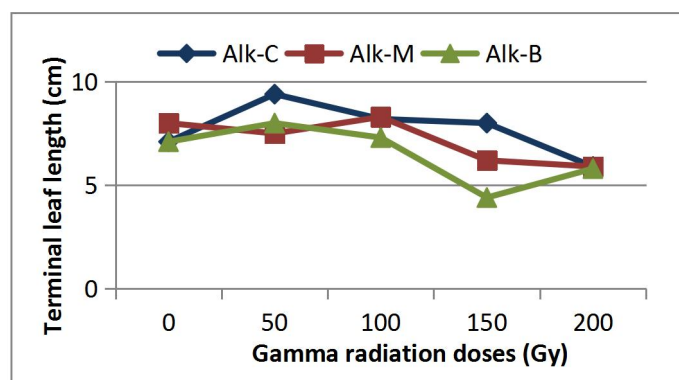


Fig. 7: Effects of Interactions between varying Gamma radiation doses and Landraces on Terminal leaf length of Bambara groundnut at 55 DAS

The biological consequences of radiation may manifest at different stages of plant development and these include; abnormal cell division, cell death, mutation, tissue and organ failure and overall reduction in plant growth (Olasupo et al., 2016). Previous studies have also demonstrated that radiation-induced anomalies in plants are strongly dependent on the developmental stage, with differentiating tissues being the most sensitive and susceptible to damage (Zaka et al 2003). In the present study, increasing doses of gamma radiation progressively inhibited the plant height, number of branches and number of leaves across all Bambara groundnut landraces. The reduction in plant height at higher radiation doses has been attributed to a decrease in the bioactive content of gibberellic acid (GA) or inhibition of GA signalling pathways, which modifies the expression of the GA 2-oxidase gene that regulates plant height (Hedden, 2003; Ford et al., 2018). In addition, inhibition of cell division and cell elongation in irradiated populations may have contributed to growth retardation, resulting in reduced plant height, branching and leaf production at higher mutagenic doses. This observation is consistent with the findings of Kawakami et al. (2009), who reported reduced vegetative growth in rice varieties exposed to thermal neutron irradiation. Conversely, at low radiation dose (50 Gy) a significant increase in the mean values of these growth parameters was observed. This is corroborated by the report of Kumara (2011), who documented stimulatory effects of mutagens on certain vegetative traits of winged bean, leading to the development of desirable mutants with potential agronomic value. A plausible explanation is that low-dose irradiation may stimulate growth by modifying hormonal signalling networks in plant cells or enhancing the anti-oxidative capacity of the cells, enabling them to better cope with daily environmental stresses such as fluctuations in light intensity and temperature. This physiological enhancement may ultimately promote growth and yield, as reported by Wi *et al.* (2007).

Reduced vegetative growth in mutagen-treated plants may also be attributed to the deleterious effects of mutagens, which typically cause genetic and physiological damage to embryonic cells or tissues. These damages result in abnormal cell division, mutation, tissue or organ failure and consequently, reduced plant growth. This agrees with the findings of Kumara (2011), who observed decreased vegetative growth in Bambara groundnut with increasing gamma-ray doses. Shu *et al.*, (2011) further reported that the destruction of enzymes and growth hormones, such as auxins, at higher mutagenic doses contributes to the reduced cell division, cell multiplication and overall plant growth. Similarly, Moyima et al. (1999) observed that growth inhibition induced by ionizing radiation is generally associated with exposure to high mutagenic doses. Such doses suppress mitotic activity in proliferating tissues, leading to the development of weak root systems, which consequently, reduce the plant's capacity for water and nutrient uptake. This disruption impairs normal physiological and metabolic processes essential for the growth and development of young plants.

Furthermore, the reduced terminal leaf length and terminal leaf width observed at higher gamma radiation doses can be attributed to radiation-induced growth retardation. Zaka et al. (2003) reported that decreased mitotic activity following irradiation leads to reduced plant growth and development and that radiation-induced destruction of enzymes further contributes to the slowdown of cell division and generally plant development.

Survival Rate

Survival of M₁ generation plants to maturity is generally regarded as an important criterion for estimating the effective dose of a given mutagen. In the present study, the survival rate decreased progressively with increasing doses of gamma radiation, indicating a clear inverse relationship between mutagen dose and plant survival. These findings are in agreement with the reports of Girija and Dhanavel, (2009) in cowpea, which attributed reductions in survival percentage of mutant populations to disturbed physiological processes and chromosomal damage leading to mitotic arrest. Similarly, Kawakami *et al.*, (2009) reported that severe and irreparable damage caused by mutagenic treatment can result in cell death, thereby reducing plant survival. The reduction in survival was particularly pronounced at the highest gamma radiation dose (200 Gy). This effect may be attributed to the lethal impact of mutagens on the meristematic tissues of growing plants, as reported by Ramya *et al.*, (2014). Kiong *et al.* (2008) further noted that plant survival to maturity depends on the nature and extent of chromosomal damage induced by irradiation; at higher doses, both the frequency and severity of such damage increase, thereby contributing to reduced survival percentages.

Interaction effects between Gamma-ray dose and Landrace

The significant interactions observed between gamma-ray dose and landrace at some sampling stages in this study indicate the presence genotypic variation in sensitivity to gamma irradiation among Bambara groundnut landraces. Such differential responses are attributable to underlying genetic variability, which results in varied genotypic reactions to mutagenic treatments. This observation is in conformity with the findings of Khan and Wani (2006), who reported variable responses to mutagens among green gram varieties, with some genotypes exhibiting greater sensitivity than others due to differences in their genetic composition.

In the present study, Alk-C appeared more tolerant to mutagenic stress, maintaining relatively higher vegetative growth under increased radiation exposure, whereas Alk-M was more susceptible to damage. These contrasting responses may reflect inherent genetic differences related to DNA repair capacity and oxidative stress tolerance. The enhanced efficiency in these protective mechanisms may promote growth and development under stress conditions, as reported by Wi *et al.* (2007).

CONCLUSION

The application of gamma radiation significantly affected the vegetative growth and survival of the Bambara groundnut landraces evaluated in this study. Exposure to higher radiation doses resulted in marked reduction in growth parameters, including plant height, number of branches, number of leaves and survival rate, with effects being particularly pronounced in Alk-M landrace. In contrast, treatment with the low dose (50 Gy) led to a considerable improvement in these traits. The significant interactions observed between gamma-ray doses and landraces further indicate that Alk-C exhibited greater tolerance to mutagenic stress across most evaluated parameters, highlighting its potential suitability for consideration in breeding and mutation improvement programmes.

CONFLICTS OF INTEREST

The authors declares no conflicts of interest

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