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Gamma-ray-induced radiosensitivity of two selected rice (*Oryza sativa* L.) varieties in Liberia as a pre-requisite for mutation breeding

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Abstract
Rice is the primary staple food and cultural mainstay of Liberia, accounting for nearly half of the daily caloric intake of its population, yet local production does not meet demand. Improving local varieties through induced mutation is a sure way of transforming the foundational local cultivars to address the prevailing challenge. However, no radiosensitivity data exist for Liberian rice varieties, so breeders must rely on doses established elsewhere, which risks either an ineffective treatment or excessive seedling mortality. This study was undertaken to determine the radiosensitivity of two locally adapted lowland rice varieties, Suakoko-8 Red and Suakoko-8 White, to gamma radiation to identify suitable doses for mutation induction. Seeds with a moisture content of 11.6% were irradiated at 0, 100, 200, 300, 400 and 600 grays in a completely randomized design with two replications and germinated on moist blotting paper. Germination percentage, seedling emergence, seedling survival and seedling height were recorded at seven and fourteen days after sowing. Data were analyzed using analysis of variance with Tukey's Honestly significant test at the 5% probability level for means separation, and regression models were fitted to estimate the lethal dose and the doses that reduce seedling height by 30% and 50%. Germination differed between the varieties (75% for Suakoko-8 Red and 90% for Suakoko-8 White) but not among doses. Seedling height was the most sensitive indicator, being significantly reduced from 300 grays in both varieties and reaching only about 0.4 cm at 600 grays. The doses that reduced height by 50% and 30% were 377.35 and 266.03 grays for Suakoko-8 Red and 316.90 and 294.45 grays for Suakoko-8 White. Suakoko-8 White showed a sharper response threshold, so accurate dose delivery is more critical for this variety. Doses of about 266 to 377 grays for Suakoko-8 Red and 294 to 317 grays for Suakoko-8 White are proposed for mutation induction, subject to validation in the first mutant generation.

Keywords: Gamma irradiation, Radiosensitivity, *Oryza sativa*, Mutation breeding, Suakoko-8

Introduction

Rice underpins food security in Liberia and is both the main staple and a cultural mainstay for most of the population. However, domestic production has not kept pace with rising consumption demand, leaving the country heavily dependent on imported rice thereby underscoring the need to raise local rice production (Africa Rice Center *et al.*, 2025) [1]. Varietal improvement is one route to closing this gap, and it can proceed through conventional hybridization, marker-assisted selection, or the induction of mutations with physical or chemical mutagens. Gamma radiation is among the most widely used physical mutagens in crop mutation breeding, since it produces heritable variation at both the nucleotide and chromosomal levels (Bharath *et al.*, 2024; Herdiyanti *et al.*, 2025) [2, 3]. Many crop varieties released officially around the world originated from induced mutation (Rasmussen *et al.*, 2024) [4], and gamma-ray programs continue to be useful for creating variability in crops with a narrow gene pool, such as many elite rice cultivars (Elsherbiny *et al.*, 2024) [5].
Liberia's rice sub-sector depends on a limited set of local landraces and internationally bred improved lines, and research on locally adapted, high-yielding varieties remains limited (Africa Rice Center *et al.*, 2025) [1]. Local genotypes are valuable sources of adaptive genes (Lazaridi *et al.*, 2024) [6] and suit farmers' agro-ecologies and taste preferences, but they tend to be tall, lodging-prone and comparatively low yielding, a pattern also reported for local cultivars in other tropical regions (Herdiyanti *et al.*, 2025) [3]. Hybridization is a slow way to correct these deficiencies and is further limited by modest research capacity and infrastructure (Africa Rice Center *et al.*, 2025) [1]. Induced mutagenesis is faster because defects can be fixed within adapted, farmer-preferred backgrounds while the identity of the variety is preserved (Elsherbiny *et al.*, 2024; Herdiyanti *et al.*, 2025) [5, 3]. This approach, however, cannot be pursued responsibly without first under

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standing how the target genotypes respond to the mutagen. Without genotype-specific data, researchers must rely on doses established for genotypes from other countries and ecologies, which risks either an ineffective treatment or excessive mortality in the treated population.

Radiosensitivity, the way a genotype responds to increasing mutagen doses, must therefore be determined first in any induced-mutation program (Almendral Vera Cruz *et al.*, 2025; Herdiyanti *et al.*, 2025) [7, 3]. Tolerance varies between genotypes and is influenced by seed moisture content, seed vigor and genotype-specific DNA repair efficiency (Herdiyanti *et al.*, 2025) [3]. Radiosensitivity is usually measured with dose response bioassays that record germination percentage, seedling height, root length, survival and fertility over a range of doses; the results are then used to derive reference points such as the lethal dose 50 (LD_{50}) and the reduction dose 50 (RD_{50}) (Almendral Vera Cruz *et al.*, 2025; Herdiyanti *et al.*, 2025) [3]. In rice, low-to-moderate doses usually maintain or stimulate growth, while doses of 400 gray (Gy) and above generally impair it (Elsherbiny *et al.*, 2024) [5], and radiosensitivity has been established for rice varieties in Kenya (Wagatua *et al.*, 2022) [8]. Comparable data are not yet available for the rice genotypes cultivated in Liberia, which have been characterized mainly for agronomic performance rather than for mutagen response.

This study therefore aimed to generate genotype-specific radiosensitivity data as a foundation for a later mutation-breeding program targeting improved yield potential, lodging resistance and tolerance to prevalent local stresses. Specifically, it determined the radiosensitivity of two locally adapted lowland rice varieties, Suakoko-8 Red and Suakoko-8 White, to gamma radiation to establish suitable doses for mutation induction.

Materials and Methods

Experimental site and design

The experiment was conducted at the Malaysian Nuclear Agency, Malaysia. Seeds were irradiated at the irradiation facility of the Agrotechnology and Biosciences Division (Acute Biobeam Gamma Cell Facility), and seedlings were grown at the Plant Physiology Laboratory. A completely randomized design with two replications was used to ensure unbiased allocation of treatments, with six gamma doses applied to each of the two varieties.

Plant materials

Two locally adapted lowland rice varieties, Suakoko-8 Red and Suakoko-8 White, were obtained from the Central Agricultural Research Institute (CARI), Liberia. The average moisture content of the seeds before irradiation was 11.6%.

Gamma irradiation treatment

The study followed the FAO/IAEA radiosensitivity protocol (FAO/IAEA, 2024) [9] with some modifications. Six gamma-ray doses (0, 100, 200, 300, 400 and 600 Gy), adapted from Lee *et al.* (2019) [10] were applied; the 0 Gy treatment served as the control. For each variety, approximately 60 seeds were randomly drawn from the seed lot and placed in a labeled brown paper envelope for each dose, and the envelopes were placed in a Petri dish on the irradiator. Irradiation was carried out using a Gamma Cell BioBeam GM 8000 cesium-137 irradiator at a dose rate of 8.6 Gy/min.

Sowing of M1 seeds

Immediately after irradiation, the seeds were soaked for 24 hours in a solution of 3 g of active Ancom Thiram 80 fungicide in 5 ml of water (0.6 g/ml), transferred to Petri dishes and incubated in a growth chamber. The seeds were then placed on moist paper using the growing-rack (sandwich blotter) technique in a germination chamber at the Plant Physiology Laboratory, with the temperature maintained between 21 and 32 °C, relative humidity (RH) at 80–95%, and a controlled photoperiod provided by LED fluorescent lighting.

Data collection

Data were collected on germination percentage, seedling emergence, seedling survival and seedling height, following Gupta *et al.* (2021) [11]. Germination was recorded when the primary root (radicle) had emerged, and the percentage was taken at 7 days after sowing (DAS). Seedling emergence, scored as the presence of a shoot, was recorded as a rate (proportion of seedlings per replicate) at 7 and 14 DAS, and seedling survival was recorded at 14 DAS. Seedling height (cm) was measured at 7 and 14 DAS. The LD_{50} was calculated from emergence and survival rates, whereas the median reduction dose (RD_{50}) and the reduction dose 30 (RD_{30}; Lee *et al.*, 2019) [10] were calculated from seedling height at 14 DAS, following Gupta *et al.* (2021) [11].

Statistical analysis

Data were entered in Microsoft Excel 2024. Analysis of variance was performed in R software version 4.6.2, followed by mean separation using Tukey's honestly significant difference (HSD) test at $P < 0.05$ where the effect was significant. Germination percentage, emergence rate, survival rate and seedling height were fitted to regression models in CurveExpert Professional version 2.7.3, with gamma dose as the independent variable. Emergence and survival were expressed as a percentage of the 0 Gy rate, and seedling height at 14 DAS as a percentage of the 0 Gy control, before model fitting. Graphs were prepared in GraphPad Prism 9.3.1.

Results and Discussion

Germination percentage

Analysis of variance showed that gamma dose had no significant effect on germination percentage, whereas the two varieties differed significantly (Table 1). Suakoko-8 White had the higher germination (90%, group a) and Suakoko-8 Red the lower (75%, group b; Figure 1). The absence of a dose effect agrees with Wagatua *et al.* (2022) [8], who found no significant effect of gamma irradiation on germination in four Kenyan rice varieties.

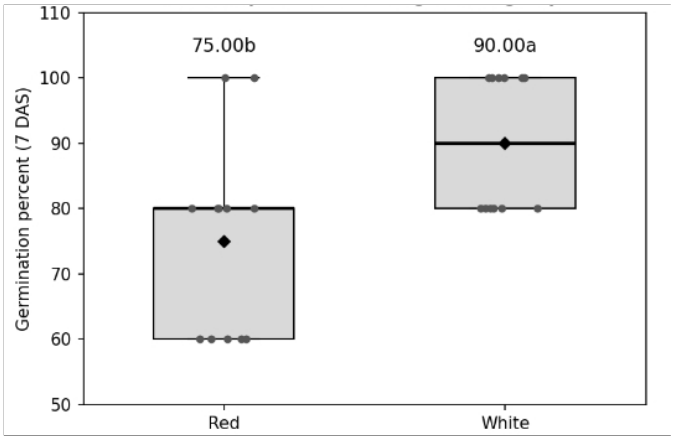


Figure 1. Mean germination percentage of Suakoko-8 Red and Suakoko-8 White (diamonds, means; dots, replicate values). Means with different letters differ significantly (Tukey HSD, $P < 0.05$). Source: Authors, 2026.

Effect of gamma dose on seedling emergence

Gamma dose had no significant effect on the rate of seedling emergence in either variety at 7 or 14 DAS (Table 2), and no dose differed from the control (all means share the letter a; Table 3; Figure 2). The lowest rates were recorded for Suakoko-8 White at 400 Gy at 14 DAS (0.50) and for Suakoko-8 Red at 400 Gy at 7 DAS and 600 Gy at 14 DAS (0.60). These values did not follow a dose trend, and Suakoko-8 Red at 600 Gy at 7 DAS (1.00) equaled the control, which illustrates the scatter in the data.

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Table 1. Analysis of variance for germination percentage.

Source of variation	Df	Mean square	Significance
Dose	5	150.00	ns
Variety	1	1350.00	*
Residual	17	173.53	

* significant at $P < 0.05$; ns, not significant. Source: Authors, 2026.

DAS, days after sowing; ns, not significant. Source: Authors, 2026. Red, Suakoko-8 Red; White, Suakoko-8 White. Means within a column followed by the same letter are not significantly different (Tukey HSD, $P < 0.05$). Source: Authors, 2026.

Table 2. Analysis of variance (mean squares) for the rate of seedling emergence at 7 and 14 DAS in both varieties.

Source of variation	Df	Suakoko-8 Red	Suakoko-8 White
Dose	5	0.0390 ns	0.0350 ns
Replicate	1	0.0817 ns	0.0017 ns
DAS	1	0.0150 ns	0.0150 ns
Residual	16	0.0483	0.0271

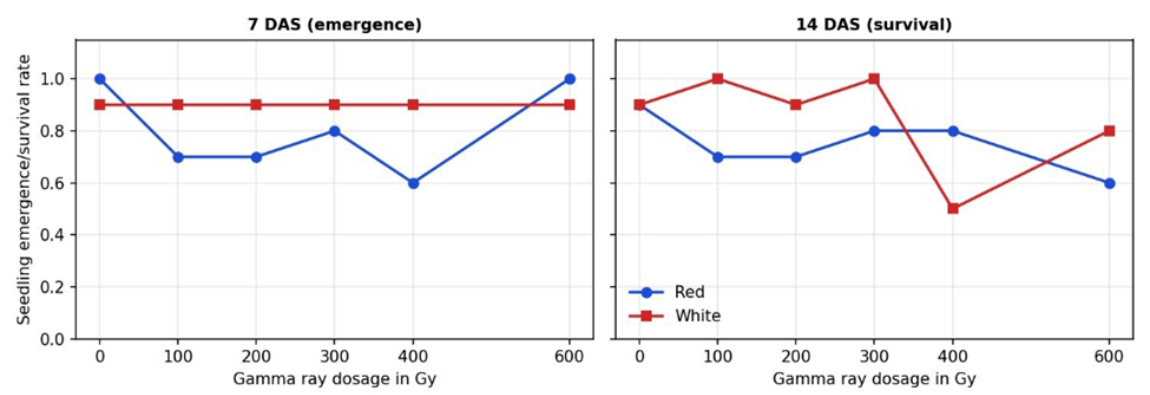


Figure 2. Seedling emergence (7 DAS) and survival (14 DAS) rates of Suakoko-8 Red and Suakoko-8 White at different gamma doses. Source: Authors, 2026.

Wagatua *et al.* (2022) [8] reported significant reductions in emergence from 400 Gy, whereas none was detected here up to 600 Gy. Two explanations are likely. First, each cell of the design contained only ten seedlings (two replicates of five), which limits the power to detect moderate effects. Second, emergence was scored as the presence of a shoot, so a seedling that emerged but then stopped growing was still counted. The height data support this: seedlings at 600 Gy were present but only about 0.4 cm tall (Table 5). Emergence alone therefore underestimates damage at high doses, and shoot growth is the more sensitive indicator. Dose-dependent declines in germination and survival, with no seedlings surviving beyond 600 Gy, were recently reported for the Philippine variety NSIC Rc 218 (Almendral Vera Cruz *et al.*, 2025) [7].

Table 3. Effect of gamma radiation on the rate of seedling emergence per variety at 7 and 14 DAS.

Gamma dose (Gy)	Red, 7 DAS	Red, 14 DAS	White, 7 DAS	White, 14 DAS
0	1.0000a	0.9000a	0.9000a	0.9000a
100	0.7000a	0.7000a	0.9000a	1.0000a
200	0.7000a	0.7000a	0.9000a	0.9000a
300	0.8000a	0.8000a	0.9000a	1.0000a
400	0.6000a	0.8000a	0.9000a	0.5000a
600	1.0000a	0.6000a	0.9000a	0.8000a

Effect of gamma radiation on seedling survival

When emergence (7 DAS) and survival (14 DAS) were analyzed together, dose, replicate and DAS were all non-significant in both varieties (Table 2). Emergence and survival therefore did not differ significantly, and gamma irradiation up to 600 Gy did not significantly reduce survival to 14 DAS (Table 3). Survival at 14 DAS ranged from 0.60 to 0.90 in Suakoko-8 Red and from 0.50 to 1.00 in Suakoko-8 White, with the lowest values for Suakoko-8 Red at 600 Gy (0.60) and Suakoko-8 White at 400 Gy (0.50). In contrast, Wagatua *et al.* (2022) [8] found that survival fell significantly from 300 to 400 Gy in their most sensitive varieties. The absence of a survival effect here is most likely explained by the short 14-day scoring window, the small number of seedlings per replicate and the proxy definition used for survival. Survival measured over a longer period, or defined by seedling vigor, would be more informative.

Effect of gamma radiation on seedling height at 7 and 14 DAS

Dose, DAS and replicate effects on seedling height were assessed for each variety (Table 4). Dose and DAS were highly significant in both varieties ($P < 0.001$), and replicate was significant for Suakoko-8 Red only ($P < 0.05$). Seedlings were taller at 14 DAS than at 7 DAS, as expected for growth over time. Residual degrees of freedom differ between varieties because seedlings without a shoot measurement were excluded. Mean separation showed that height was significantly reduced from 300 Gy in both varieties and at both ages (Table 5). At 14 DAS, seedlings radiated with 300 Gy reached about two-thirds of the control height (Suakoko-8 Red, 12.93 cm against 19.37 cm; Suakoko-

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8 White, 13.14 cm against 20.07 cm). Reduction was severe at 400 Gy and almost complete at 600 Gy (about 0.4 cm in both varieties). The two varieties differed at 400 Gy: Suakoko-8 Red kept 9.04 cm (about 47% of the control) at 14 DAS, whereas Suakoko-8 White fell to 1.20 cm (about 6%), placing it in the same statistical group as 600 Gy.

Table 4. Analysis of variance (mean squares) for seedling height at 7 and 14 DAS, per variety.

Variety	Source of variation	Df	Mean square
Suakoko-8 Red	Dose	5	477.84 ***
	Replicate	1	49.54 *
	DAS	1	1461.56 ***
	Residual	85	9.70
Suakoko-8 White	Dose	5	864.15 ***
	Replicate	1	8.73 ns
	DAS	1	845.35 ***
	Residual	97	12.68

*** significant at $P < 0.001$; * significant at $P < 0.05$; ns, not significant. Source: Authors, 2026.

Red, Suakoko-8 Red; White, Suakoko-8 White. Means within a column followed by the same letter are not significantly different (Tukey HSD, $P < 0.05$). Source: Authors, 2026.

Table 5. Mean separation of seedling height (cm) at different gamma doses, per variety and DAS.

Gamma dose (Gy)	Red, 7 DAS	Red, 14 DAS	White, 7 DAS	White, 14 DAS
0	7.79a	19.37a	11.83a	20.07a
100	9.49a	21.11a	11.64a	20.88a
200	8.20a	18.31a	10.11a	19.33a
300	4.62b	12.93b	7.04b	13.14b
400	2.87bc	9.04b	2.21c	1.20c
600	0.47c	0.45c	0.41c	0.40c

No gamma dose produced a significant gain in height. Nevertheless, the 100 Gy mean was the highest of all doses (Suakoko-8 Red at 7 and 14 DAS, and Suakoko-8 White at 14 DAS), for example 21.11 cm against 19.37 cm for Suakoko-8 Red at 14 DAS. This non-significant tendency is consistent with the low-dose stimulation reported in rice, where doses of 50 to 150 Gy increased seedling survival and height (Wagatua *et al.*, 2022) [8], and where 50 Gy gave the highest germination and increased tillering in the cultivar Mayas (Herdiyanti *et al.*, 2025) [3]. Shoot growth was also slightly stimulated at 100 and 200 Gy in NSIC Rc 218 (Almendral Vera Cruz *et al.*, 2025) [7]. The reduction from 300 Gy matches the threshold above which growth was significantly reduced in earlier rice studies (Harding, 2012; Wagatua *et al.*, 2022) [12, 8]. The growth inhibition seen at high doses is usually explained by oxidative damage from reactive oxygen species, arrest of the cell cycle at the G2/M phase, and disturbed hormone and enzyme function (Kang *et al.*, 2020; Kant *et al.*, 2020; Solim *et al.*, 2021) [13, 14, 15].

Estimated LD_{50} values and regression models

Emergence and survival rates were expressed as a percentage of the 0 Gy rate (7 and 14 DAS pooled) and fitted with regression models. Neither variety reached 50% lethality within 0 to 600 Gy, so the LD_{50} could not be estimated (Table 6); meaning the lethal doses for both varieties may likely be higher than the doses used during the experiment. The pooled rate never fell below about 74% of the control in Suakoko-8 Red or about 78% in Suakoko-8 White. The exponential decay models explained little of the variation (r^2 = 0.102 for Suakoko-8 Red and 0.246 for Suakoko-8 White), and extrapolating beyond 600 Gy would not be reliable. On these data, the LD_{50} of both varieties exceeds 600 Gy, which is higher than the 354 to 556 Gy range reported for four Kenyan rice varieties (Wagatua *et al.*, 2022) [8] and the approximately 295 Gy reported for the Indonesian cultivar Mayas (Herdiyanti *et al.*, 2025) [3]. Direct counts of emerged and surviving seedlings are needed before a reliable LD_{50} can be given for either variety.

Table 6. Estimated LD_{50} values and regression models from seedling emergence and survival rates (percentage of the 0 Gy rate; 7 and 14 DAS pooled).

Variety	LD_{50}	Regression model
Suakoko-8 Red	Not reached (> 600 Gy)	Exponential decay, $y = 85.907e^{-0.000193x}$; $r = 0.319$, $r^2 = 0.102$, SE = 10.80
Suakoko-8 White	Not reached (> 600 Gy)	Exponential decay, $y = 103.755e^{-0.000248x}$; $r = 0.496$, $r^2 = 0.246$, SE = 10.09

Source: Authors, 2026.

Observed values stayed between about 74 and 84% of the control in Suakoko-8 Red and between about 78 and 106% in Suakoko-8 White (Figure 3). The only noticeable drop in Suakoko-8 White was at 400 Gy (77.8%). The fitted curves decline gently, reaching 76.5% in Suakoko-8 Red and 89.4% in Suakoko-8 White at 600 Gy, well above the 50% level that defines the LD_{50}, so the LD_{50} lies beyond the tested range. The low coefficients of determination (0.102 and 0.246) confirm that dose explained little of the variation, which agrees with the non-significant dose effects in Tables 2 and 3. The curves differ from the sigmoidal survival curves of Wagatua *et al.* (2022) [8], in which survival fell steeply from 300 to 400 Gy in the most sensitive varieties and the LD_{50} ranged from 354 to 556 Gy. The shallow slopes here probably reflect how survival was scored: a seedling was counted as long as a shoot was recorded, although seedlings at 600 Gy were only about 0.4 cm tall (Table 5) and were unlikely to be viable. In NSIC Rc 218, no seedlings survived beyond 600 Gy and ger

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mination and survival fell sharply from 500 Gy (Almendral Vera Cruz *et al.*, 2025) [7]. The LD_{50} of both Suakoko-8 varieties may therefore be close to 600 Gy, and a viability criterion would be needed to estimate it.

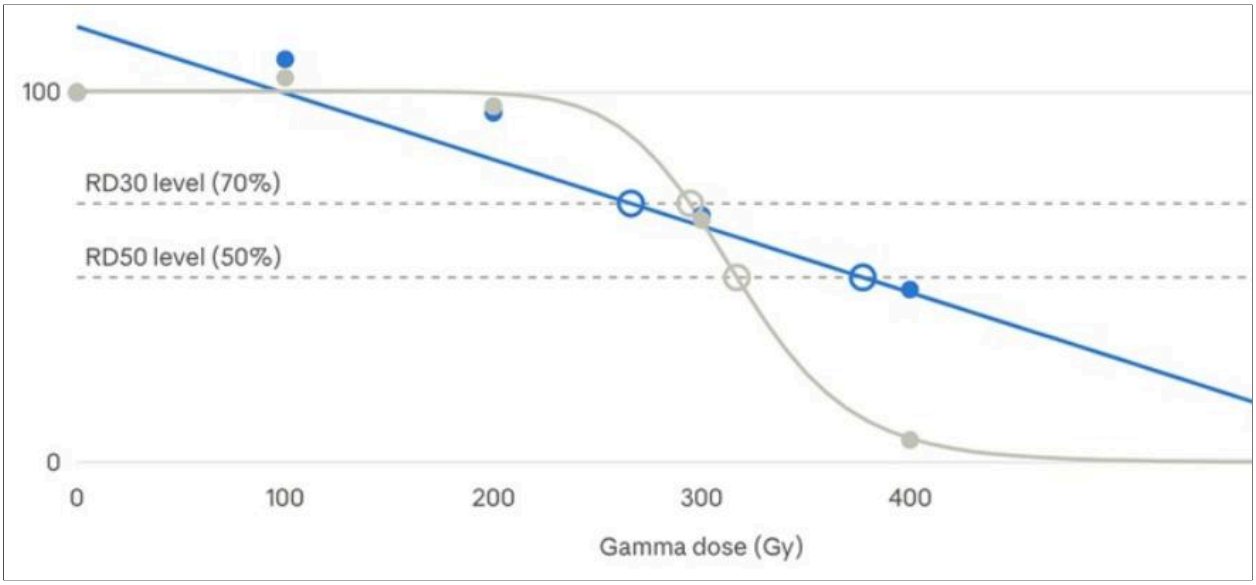


Figure 3. Observed emergence and survival (% of the 0 Gy rate) with the fitted exponential decay models. Source: Authors, 2026.

Regression models and estimated RD_{30} and RD50

Seedling height at 14 DAS, expressed as a percentage of the 0 Gy control, was fitted with regression models to estimate the doses causing 30% and 50% growth reduction (RD_{30} and RD_{50}; Table 7). The fits were good for both varieties (r^2 = 0.923 for Suakoko-8 Red and 0.997 for Suakoko-8 White). The RD_{50} was 377.35 Gy for Suakoko-8 Red and 316.90 Gy for Suakoko-8 White, and the RD_{30} was 266.03 Gy and 294.45 Gy, respectively. The RD_{50} of Suakoko-8 Red falls within the 335 to 531 Gy range reported for four Kenyan rice varieties (Wagatua *et al.*, 2022) [8] and the 350 to 500 Gy range cited by FAO/IAEA (Spencer-Lopes *et al.*, 2018) [16], whereas that of Suakoko-8 White is slightly lower.

RD_{50} and RD_{30}, doses causing 50% and 30% reduction in seedling height. Source: Authors, 2026.

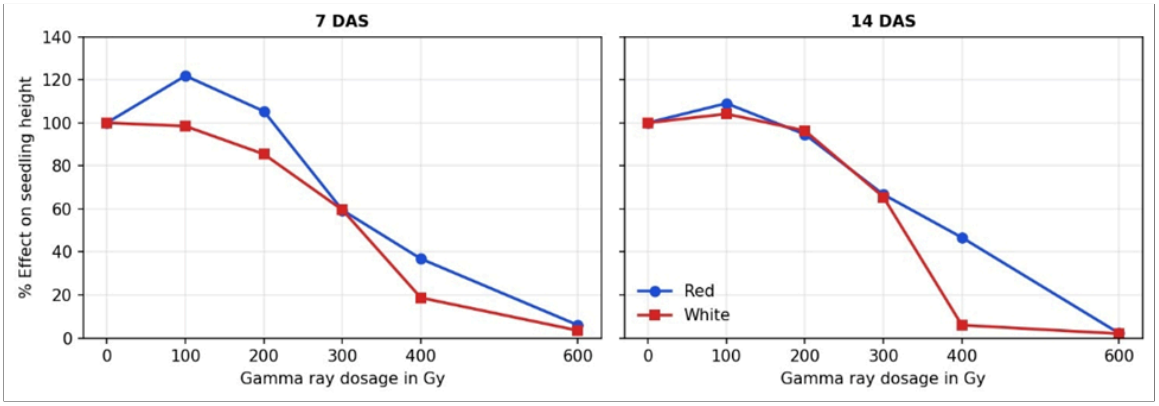


Figure 4. Effect of gamma radiation on seedling height (percentage of the 0 Gy control) in Suakoko-8 Red and Suakoko-8 White at 7 and 14 DAS. Source: Authors, 2026.

The varieties differ in the shape of their response. Suakoko-8 White maintained its height up to about 300 Gy and then collapsed (6% of the control at 400 Gy), so its RD_{30} and RD_{50} are only about 22 Gy apart. Suakoko-8 Red declined more gradually, giving a wider interval of about 111 Gy. Both varieties retained 94 to 109% of their control height up to 200 Gy and fell to about two-thirds of it at 300 Gy (66.8% in Suakoko-8 Red, 65.5% in Suakoko-8 White; Figure 4). Beyond 300 Gy the varieties diverged: Suakoko-8 Red declined steadily to 46.7% at 400 Gy, whereas Suakoko-8 White dropped to 6.0%, and both were almost fully inhibited at 600 Gy (2.3 and 2.0%). The sharp transition in Suakoko-8 White means that a small error in delivered dose could change the outcome considerably.

Table 7. Regression models and estimated RD_{30} and RD_{50} from seedling height data at 14 DAS (y = height as a percentage of the 0 Gy control).

Variety	RD_{50}	RD_{30}	Regression model
Suakoko-8 Red	377.35 Gy	266.03 Gy	Linear, $y = 117.795 - 0.17966x$; $r = 0.9606$, $r^2 = 0.9228$, SE = 12.55
Suakoko-8 White	316.90 Gy	294.45 Gy	Logistic, $y = a/(1 + (x/b)^c)$; $a = 100.342$, $b = 316.708$, $c = 11.474$; $r = 0.9987$, $r^2 = 0.9973$, SE = 3.16

The logistic model follows the Suakoko-8 White data closely (r^2 = 0.997). The linear model for Suakoko-8 Red predicts 99.8% at 100 Gy, below the observed 109.0%, so it misses the small rise in height at that dose and its RD values should be treated as approximate. This rise is not significant (Table 5) but fits the low-dose stimulation seen in other rice studies (Herdiyanti *et al.*, 2025; Wagatua *et al.*, 2022) [3,

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[8]. The RD_{50} of Suakoko-8 White (317 Gy) lies just below the 335 to 531 Gy range reported by Wagatua *et al.* (2022) [8] and is close to the values for their most sensitive variety, Komboka (335 to 351 Gy). The RD_{30} of Suakoko-8 Red (266 Gy) is at the lower end of their 267 to 426 Gy range. Overall, Suakoko-8 White behaves as a highly radiosensitive variety with a narrow response window, and Suakoko-8 Red as a moderately sensitive variety with a wider one.

The recommended practice in rice mutation breeding is to select doses between the RD_{30} and the LD_{50} (Wagatua *et al.*, 2022) [8]. Because the LD_{50} was not reached here, the RD_{30} to RD_{50} interval provides the practical working range: about 266 to 377 Gy for Suakoko-8 Red and about 294 to 317 Gy for Suakoko-8 White. These ranges should be validated in the M_1 generation, ideally with survival and fertility data.

Conclusion

Rice mutation breeding in Liberia has lacked genotype-specific radiosensitivity data, so this study set out to determine the response of two locally adapted varieties, Suakoko-8 Red and Suakoko-8 White, to gamma radiation to establish doses for mutation induction. Gamma irradiation of seeds up to 600 Gy did not significantly affect germination, seedling emergence or survival, so no LD_{50} could be estimated for either variety (>600 Gy); the varieties differed in germination percentage, with Suakoko-8 White higher than Suakoko-8 Red. Seedling height was a far more sensitive indicator: it was significantly reduced from 300 Gy in both varieties at 7 and 14 DAS and was almost entirely suppressed at 600 Gy, while no dose significantly increased it. The RD_{50} was 377.35 Gy for Suakoko-8 Red and 316.90 Gy for Suakoko-8 White, and the RD_{30} was 266.03 Gy and 294.45 Gy, respectively. Doses of about 266 to 377 Gy for Suakoko-8 Red and 294 to 317 Gy for Suakoko-8 White are therefore proposed as the working range for mutation induction. Suakoko-8 White showed a sharper threshold than Suakoko-8 Red, so dose control is more critical for this variety. Because emergence and survival were derived indirectly from shoot records, direct counts of emerged and surviving seedlings, more replicates, and validation in the M_1 generation are recommended before these doses are adopted.

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Conflict of interest

The authors declare that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author contributions

Numei Wamah: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing.
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Joseph Ndebeh: Supervision, Writing – original draft, Writing – review & editing.
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All authors have read and approved the final version of the manuscript.

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