Original Research Article

EFFECTS OF DIFFERENT LEVELSOF GAMMA RADIATION ON GROWTH AND YIELD CHARACTERISTICS OF GROUNDNUT

ABSTRACT

One of the key strategy for improving the crops is plant mutation breeding, which generates a large germplasm pool to improve crop characteristics. In this field experiment, the effects of different levels of gamma radiation on the growth and yield characteristics of groundnut were investigated. "Gamma chamber 1200 Cobalt-60" research irradiator was used to irradiate the groundnut seeds. Two experiments were conducted, with the first exposing the seeds to gamma radiation levels ranging from 0 to 100 Gy, and the second exposing them to levels from 0 to 500 Gy. Irradiated seeds were sown in poly bags and kept under shade. After 2 weeks, seedlings were transplanted in an open field using a Randomized Complete Block Design with five replications. Growth and yield parameters were collected, and statistical analysis was carried out using SAS 9.1 software, with treatment means compared using DMRT at 0.05 level. Results from experiment one showed no significant ($P \geq 0.05$) differences among treatments. However, in experiment two, treatments showed significant differences in the measured variables. Seeds exposed to 200 Gy had increased shoot fresh weight (123.3%), root fresh weight (69.8%), number of pods (46%), 100-seed weight (47.7%), and total yield (65.6%). The study recommends 200 Gy as a more suitable level of gamma radiation to create desirable characteristics in groundnut. In conclusion, gamma radiation can be an effective tool for inducing mutations in plants for crop improvement. The findings of this radiation study could contribute to the improvement of new cultivars of groundnut with desirable traits, such as increased yield and improved plant growth.

Keywords: Crop improvement, Gamma radiation, Survival rate, Mutational breeding

INTRODUCTION

In order to eradicate the poverty and ensures the food security for all people worldwide, agriculture is crucial. It is expected that there will be 9–11 billion of population in 2050[1]. Current crop production provides enough food for the growing population. However, because of climate change and limited land, crop productivity is continuously declining; as a result, a 60% increase in crop production would be required to meet the world's food requirement [2]. Through technological innovations and scientific breakthroughs crop productivity and sustainability can be improved to ensure food security worldwide [3]. Mutation is the process through which genes are irreversibly changed by their environment and passed on to the following generation. According to Raina et al., [4] mutations are the primary cause of genetic diversity in all living things, including plants. A significant degree of genetic diversity is created in plants by the use of chemical and physical mutagens, which is used in contemporary plant breeding [5].

Most mutations are occurred spontaneously in nature or induced by artificially. Induced mutations are created by physical and chemical mutagenic agents in plant mutation breeding. X-rays, gamma rays and neutrons are used as physical mutagens and ethyl methanesulfonate (EMS) is used as a chemical mutagen [6]. However, gamma rays are commonly used physical mutagen worldwide. Seeds and other planting materials like pollen and cuttings can be used in induced mutation breeding [7]. Mutation breeding is the best alternative practice against genetically modified organisms practice and conventional breeding methods because it is safe and affordable. Gamma rays do not produce any harm to humankind as well as the environment therefore gamma rays application should be suggested in plant breeding[8].

Among the grain legumes, groundnut is one of the important oil seed crop in the family leguminoceace. The groundnut, which is currently farmed in around 90 countries across various agro-climatic regions, it is a major food legume and oilseed crop of tropical and subtropical locations and ranks 13th among the world's economically important crops [9].

Groundnuts are self-pollinating and have limited varieties. As a result, groundnut cultivars can only be further enhanced to certain point by conventional breeding methods.Mutation breeding has the ability to provide particular enhancements without significantly altering a plant's phenotype as a source of expanding variety that supports conventional plant breeding [10]. To successfully increase genetic variety in crops like soybeans and other economically significant crops, gamma rays have been employed in plant breeding [11].

Many investigations have demonstrated that mutations can successfully create genetic diversity for a variety of desired characteristics, and its value in plant development programmes is widely known. The capacity to improve one or two features without altering the genotype as a whole is the primary advantage of mutant breeding [10]. Therefore, this present radiation study was carried out with the objective of to evaluate the effects of different levels of gamma radiation on the growth and yield characteristics of cultivar Indi.

MATERIALS AND METHODS

Experimental location

The field experiment was carried out at the crop farm of Eastern University, Vantharumoolai, Sri Lanka which is located in the eastern region of Sri Lanka, with a latitude of 7^0 48’ N and longitude of 81^0 35’ E. It was conducted from July to October in 2022.

Collection of seeds

Groundnut seeds of Indi cultivar were collected for the gamma irradiation since it is one of the major cultivar cultivated in eastern region of Sri Lanka.

A source

Cobalt 60 is a radioactive isotope that used to emits gamma rays, and is a common source of gamma radiation for such experiments due to its relatively long half-life and high energy output. Gamma chamber 1200 research irradiator was used to irradiate the groundnut seeds with different levels of gamma radiation. This equipment is likely a specialized device designed specifically for the purpose of irradiating plant material, and is equipped with the necessary safety features and controls to ensure safe and effective radiation exposure. The gamma irradiation facilities were obtained from Horticultural Crop Research and Development Institute

(HORDI) in Gannoruwa, Sri Lanka. HORDI is a well-known agricultural research institution in Sri Lanka, and equipped with the necessary facilities and expertise to conduct such experiments.

Experimental structure

The experimental structure of the study involved two consecutive experiments, both of which were designed as Randomized Complete Block Designs with five replications. In experiment 1, the groundnut seeds were subjected to different levels of gamma radiation, ranging from 0 Gy to 100 Gy (0, 20, 40, 60, 80 and 100 Gy). Experiment 2 was designed based on the results obtained from previous experiment to focus on an advanced range of gamma radiation levels, ranging from 0 Gy to 500 Gy (0, 100, 200, 300, 400 and 500 Gy). These different treatments were assigned specific labels, with T1 representing the control treatment of 0 Gy, and T2-T6 representing the increasing levels of gamma radiation.

Post irradiation practices

Irradiated seeds were sown in prepared poly bags containing rooting media of equal part of sand, top soil and compost. After sowing, poly bags were placed under shade house with 40% shade. Seedlings were kept under shade house to reduce shock due to the radiation process. Thereafter groundnut seedlings were transplanted in open field with the spacing of 45cm×15cm. according to the recommendation of Department of Agriculture, Sri Lanka, agronomic practices including irrigation, fertilizer application, weeding, and pest and disease management were carried out. In addition to that, 3 weeks after transplanting, 400kg/ha of gypsumwas addedalong with the earthing up practice.

Data collection

Growth parameters of germination %, survival rate, plant height, number of leaves,shoot fresh weight and root fresh weight and yield parameters of number of pods, 100 seed weight and total yield were recorded.

Statistical analysis

SAS 9.1 software was used to statistically analyze the collected data of growth and yield parameters and by using Duncan Multiple Range Test (DMRT), the mean separation within treatments was doneat 5% significant level of.

RESULTS AND DISCUSSION

Experiment 01

Germination %

Table 1. showed that, effect of different levels of gamma radiation on the germination % of groundnut. According to the results, lower levels of gamma radiation ranging from 0 Gy to 100 Gy did not significantly ($P>0.05$) change the germination % of groundnut. All the treatments from T2 (20 Gy) to T6 (100 Gy) were shown higher germination % like control treatment T1 (0 Gy). These findings are supported by the findings of Yadav et al., [12]. They reported that germination of maize seeds was unaffected significantly at lower levels of gamma radiation (<100 Gy). Furthermore these obtained results are supported by Ganesan et al., [13]and Tshilenge[14].

Survival rate

Effects of different levels of gamma radiation on survival rate of groundnut shown in table 1. The results found that, different levels of gamma radiation ranging from 0-100Gy did not significantly ($P>0.05$) influence the survival rate of groundnut.All the treatments from T2 (20 Gy) to T6 (100 Gy) were shown that higher value (100%) in survival rate similar to control treatment T1 (0 Gy). These results are on par withGunasekaran and Pavadai[14]on groundnut and Zawareet al., [15]on *Pisum sativum* L.

Table 1: Effects of different levels of gamma radiations on germination % and survival rate of Groundnut

Treatments	Germination %	Survival rate
T1 (0Gy)	85^{a}	100^{a}
T2 (20Gy)	82^{a}	100^{a}
T3 (40Gy)	78^{a}	100^{a}
T4 (60Gy)	80^{a}	100^{a}
T5 (80Gy)	78^{a}	100^{a}
T6 (100Gy)	78^{a}	100^{a}
F- Test	ns	ns

The value is the average of five replicates. The letter 'ns' denotes a difference that is not significant at the 0.05 level of probability. The mean value in a column with a different letter or letters indicates that the difference is significant by DMRT at the 0.05 level of probability.

Plant height

Table 2. showed the effects of different levels of gamma radiation on plant height of groundnut. The obtained results indicated that there was no significant differences among the applied gamma radiation treatments on plant height. Applying low levels of gamma radiation ranging from 0 – 100 Gy not caused significant effect on the plant height. Further, more radiation stress can be applied to observe any different changes in the height of plant.

This results obtained since lower levels of gamma radiation promote the growth of the plant either directly through genome modifications or through regulation of cellular processes, such as hormonal signaling, increased enzyme efficiency, increased anti-oxidative potentials, modification of cell membranes, which may result in efficient cell division, a high rate of photosynthesis, and an improved ability of plants to withstand environmental stresses[17, 18]. These results supported with findings of Yadav et al., [12]who stated that, plant height of maize showed a linear enhancement up to 0.1kGy. In number of studies stated that lower levels of gamma radiation often cause germination and growth improvements of plants [15, 17]. Furthermore, Shala [19] also observed the similar observation in *Ocimumbasilicum* L.

Number of leaves

Effects of different levels of gamma radiation on number of leaves of groundnut shown in Table 2. It was showed that no any significant ($P>0.05$) differences among the tested levels of gamma radiation treatments ranging from 0 Gy – 100 Gy on the number leaves.

It is possible that low levels of gamma radiation (100Gy) have a beneficial effects on plant growth because they stimulate cell division and cell elongation which impact the phyto hormones or nucleic acids synthesis[18, 20]. This obtained results are in agreement withGunasekaran andPavadai [15], who observed that, no significance differences in growth characteristics of groundnutat 0Gy and 100Gy. Furthermore these findings are in line with findings obtained on groundnut by Ganesan et al., [13].

Not significant results on germination %, survival rate, plant height and number of leaves lead to conduct the 2nd experiment with an increased level of gamma radiation with the objectives ofto identify the LD50 of the groundnut and creating significant variations in plant growth ultimately in the yield.

Table 2 :Effects of different levels of gamma radiations on plant height and number of leaves of groundnut at 4WAP

Treatments	Plant height (cm)	Number of leaves
T1 (0Gy)	26.6 ± 0.78^a	38 ± 2^a
T2 (20Gy)	28.7 ± 1.08^a	44 ± 4^a
T3 (40Gy)	29.2 ± 1.40^a	45 ± 4^a
T4 (60Gy)	30.1 ± 1.86^a	48 ± 4^a
T5 (80Gy)	28.1 ± 1.06^a	42 ± 2^a
T6 (100Gy)	28.5 ± 1.68^a	42 ± 5^a
F- Test	ns	ns

The value is the average of five replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by DMRT at the 0.05 level of probability.

Experiment 02

Germination %

Figure 1 showed that effects of different levels of gamma radiation on seed germination % of groundnut. The results showed that seed germination % of groundnut was significantly ($P<0.05$) influenced by the different levels of gamma radiation. The higher value in germination of seeds was recorded in the treatment T1 (0Gy) and it was followed by T2 (100Gy) and T3 (200Gy). The reduction in seed germination % was observed with the increase in gamma radiation levels. Treatments T4 (300Gy), T5 (400Gy) and T6 (500Gy) were recorded that lower values in germination %. Different levels of gamma radiation treatments of T2 (100Gy), T3 (200Gy), T4 (300Gy), T5 (400Gy) and T6 (500Gy) were shown that gradual reduction in germination % by 10.5%, 23.5%, 33.3%, 42.2% and 44.4% respectively when compared with control.

Higher levels of gamma radiation causes reduction in germination percentage due to the higher levels produce the harmful effects on early cell division [13]. These obtained findings are in line with findings on groundnut by Ganesan et al.,[13] and Tshilenge[14]. Furthermore these obtained results are supported with results obtained by Zawareet al.,[16] on *Pisum sativum* L. and Yadav et al., [12]on maize.

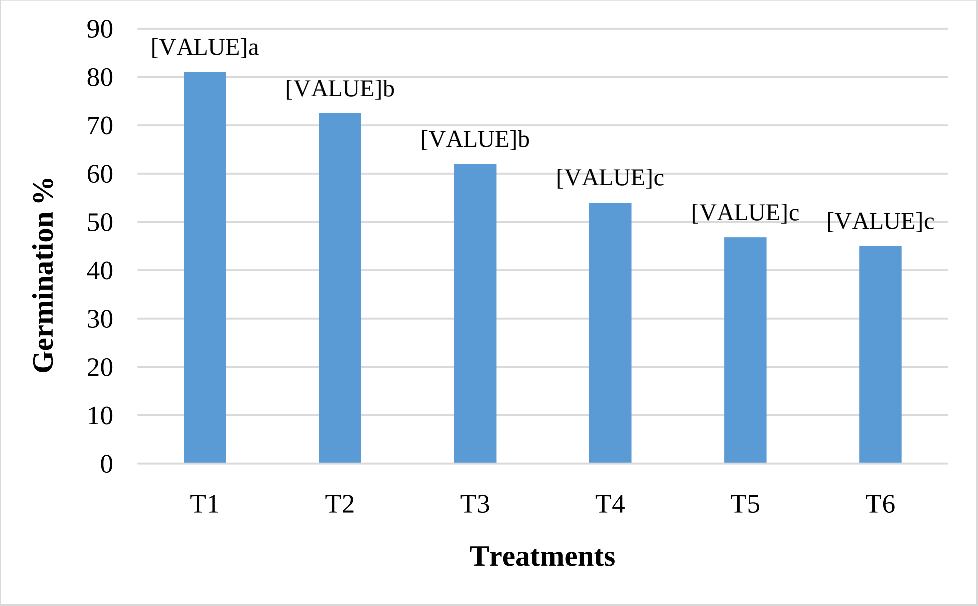

Figure 1: Effects of different levels of gamma radiation on germination % of Groundnut

Survival rate

Figure 2. showed that effects of different levels of gamma radiation on survival rate of groundnut. The findings indicated that different levels of gamma radiation significantly (P<0.05) influenced the survival rate of groundnut. The higher values (100%) in survival of seedlings were recorded in the treatments T1 (0Gy), T2 (100Gy) and T3 (200Gy). It was followed by the applied higher levels. The reduction in survival rate was observed with the increase in levels of gamma radiation. It has proved that, application of mild levels of gamma radiation is producing the plants with higher survival ability when compared with higher levels.

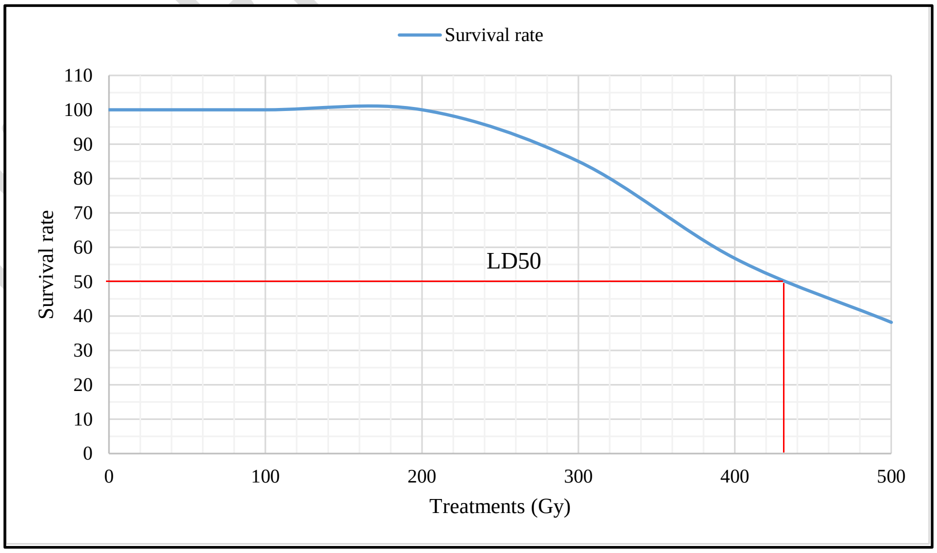

Figure 2: Effects of different levels of gamma radiation on survival rate of Groundnut

Higher levels of treatments T4 (300Gy), T5 (400Gy) and T6 (500Gy) were shown a gradual reduction in survival rates by 15%, 43.2% and 61.8% respectively compared with the control. The results obtained due to higher levels result in genomic damage, the generation of reactive oxygen speciesand free radicals, which negatively impact germination and growth factors and cause arrested germination and survival, and growth abnormalities [16, 17]. Furthermore, LD50 was recorded in level of 430Gy gamma radiation. The Radio Sensitivity experiment on groundnut varieties was conducted by Tshilenge[14] is also supported with this study. The 50% lethal dose (LD50) has been used frequently throughout history. It can be claimed that LD50 is quite arbitrary and may cause different changes in any plant. This may even result in the loss or omission of advantageous mutations as a result of poor agronomic performanceor higher plant mortalitydue to the mutagenesis [11].

Shoot fresh weight

Effects of different levels of gamma radiation on shoot fresh weight of groundnut was shown in Table.3. It was stated that, shoot fresh weight of groundnut showed the significant ($P<0.05$) differences among the applied different levels of gamma radiation. The highest value of shoot fresh weight was recorded in treatment T3 which irradiated with 200 Gy. It was followed by treatments T2 (100 Gy), T1 (0 Gy), T4 (300 Gy) and T5 (400 Gy). The lowest value of fresh weight of shoot was noted in treatment T6 which irradiated with 500 Gy.

It was revealed that 123.3% of significantly increased shoot fresh was noted in T3 (200Gy) when compared with the control. Followed by T4 (300Gy), T5 (400Gy) and T2 (100Gy) were noted increased shoot fresh weight by 23%, 21.5% and 15.5%. Furthermore, treatment T6 (500Gy) was shown reduced shoot fresh weight by 39.4%.

Higher levels of gamma radiation might reduce the shoot fresh weight since they produced minimum number of leaves, less leaf size and minimum plant height. The results could have been caused by the biological activities of plants being negatively impacted by increasing the mutagen level. Higher mutagen levels may have resulted in these impacts by causing cells to become inactive as a result of mitotic disturbances or chromosomal abnormalities, which ultimately caused a reduction in overall plant vegetative growth [21]. These obtained findings are similar to the findings of Tshilenge[14],who reported that, increasing levels of gamma radiation causes the slow shoot growth in different species of groundnut. Similar observation was found on groundnut by Gunasekaran and Pavadai [15], who observed the reduced shoot fresh weight and shoot dry weight in groundnut when increase the level of gamma radiation.

Table 3: Effects of different levels of gamma radiations on shoot fresh weight and root fresh weight of Groundnut

Treatments	Shoot fresh weight (g)	Root fresh weight (g)
T1 (0Gy)	86.89 ± 15.52^{bc}	3.94 ± 0.22^{bc}
T2 (20Gy)	100.33 ± 11.44^{b}	4.42 ± 0.39^{b}

T3 (40Gy)	194.08 ± 28.38^{a}	6.69 ± 0.30^{a}
T4 (60Gy)	106.88 ± 18.13^{b}	4.75 ± 0.06^{b}
T5 (80Gy)	105.57 ± 12.49^{b}	3.80 ± 0.80^{bc}
T6 (100Gy)	52.63 ± 7.77^{c}	2.83 ± 0.59^{c}
F- Test	*	*

The value is the average of five replicates. The letter 'ns' denotes a difference that is not significant at the probability level of 0.05. The mean value in a column with a different letter or letters indicates that the difference is significant by DMRT at the 0.05 level of probability

Root fresh weight

Effects of different levels of gamma radiation on root fresh weight of groundnut was shown in table 3. The results indicated that different levels of gamma radiation significantly ($P<0.05$) influenced the root fresh weight of groundnut.

It was revealed that, the maximum root fresh weights was recorded in treatment T3. It was followed by treatmentsT4 (300 Gy), T2 (100 Gy), T1 (0 Gy), and T5 (400 Gy). The lowest value of fresh weight of root was noted in treatment T6 which irradiated with 500 Gy. The treatment T3 (200Gy) showed that 69.8% of increased root fresh weightcompared with the control. Followed by T4 (300Gy) and T2 (100Gy) recorded increased root fresh weight by 20.5% and 12.2%. Furthermore, treatments T5 (400Gy) and T6 (500Gy) were shown reduced root fresh weight by 3.5% and 28.1%.

These results are on par with results obtained by Atteh and adeyeya[22], who stated that lower levels of gamma radiation cause the better root growth in broad bean, soy bean and pea. The findings presented here align with Tshilenge's research on groundnut [14], which indicated that elevated gamma radiation levels hindered root growth across various groundnut species. This observation is consistent with the work of Gunasekaran and Pavadai [15], who noted a decrease in the root fresh weight of groundnut with increasing gamma radiation levels. Moreover, Badr et al. [23] reported that heightened gamma radiation levels led to the inhibition of root growth.

Number of pods per plant

Table 4 showed the effects of different levels of gamma radiation on number of pods per plant of groundnut.It was indicated that number of pods per plant was showed the significant ($P<0.05$) differences among the applied gamma radiation levels. The highest number of pods was recorded in treatment T3 (200 Gy). It was followed by treatments T1 (0 Gy), T4 (300 Gy), T2 (100 Gy), and T5 (400 Gy). The minimum number of pods was recorded in treatment T6 (500 Gy).

The treatment T3 which is irradiated with 200 Gy, recorded that significantly maximum number of pods by 46% compared with the control. Furthermore, other treatments of T4 (300Gy), T2 (100Gy), T5 (400Gy) and T6 (500Gy) were shown 4%, 13%, 83% and 92% of reduced number of pods, respectively.These obtained findings are supported with results obtained on cowpea by Sankaret al., [24], who stated that, the highest number of pods was recorded at 200 Gy in cowpea. According to the research studies of Ganesan et al., [25]and Gunasekaran and Pavadai [15]higher levels of gamma radiation reduces the pods production of groundnut. Furthermore, Barela et al., [26]stated that total pods formation per plant was affected by higher levels of gamma rays exposure in pea.

100 seed weight

Effects of different levels of gamma radiation on 100 seed weight of groundnut was shown in Table 4. It was reported that100 seed weight of groundnut showed the significant ($P<0.05$) differences among the different levels of gamma radiation. It was found that the maximum 100 seed weight was noted in treatment T3 (200 Gy). It was followed by treatments T2 (100 Gy), T1 (0 Gy), T4 (300 Gy) and T5 (400 Gy). The minimum 100 seed weight was recorded in treatment T6 (500 Gy).

The treatments T3 (200Gy) and T2 (100Gy) were shown that increased 100 seed weight by 47.4% and 2.4% compared with the control. Treatments T4 (300Gy), T5 (400Gy) and T6 (500Gy) shown 5.3%, 39.1% and 65.0% of reduced 100 seed weight. This results obtained due to higher gamma radiation levels caused the negative impacts on plants' biological processes which have been caused by cell inactivation [11].These obtained results are supported with results foundon groundnut by Tshilenge [18] and Gunasekaran and Pavadai [15], who observed that higher levels of gamma radiation cause the reduction in 100 seed weight of groundnut. Furthermore, Sankar et al.,[24] stated that, higher value of 100 seed weight of cowpea was recorded in 200 Gy. Furthermore, Badr et al.,[23]indicated that higher levels of gamma radiation such as 300 Gy caused the severely reduced growth and yield characteristics.

Total yield

Effects of different levels of gamma radiation on total yield of groundnut was shown in Table 4. It was revealed that, total yield of groundnut showed the significant ($P<0.05$) differences among the different levels of gamma radiation. It was found that highest total yield was notedin treatment T3 (200 Gy). It was followed by treatments T2 (100 Gy), T1 (0 Gy) and T4 (300 Gy). The lower values of total yield were recorded in treatments T5 (400 Gy) and T6 (500 Gy).

According to the results, treatments T3 (200Gy) and T2 (100Gy) were shown that increased total yield by 65.6% and 15.8%, respectively compared to the control. Furthermore, other treatments such as T4 (300Gy), T5 (400Gy) and T6 (500Gy) were shown 30.8%, 76.6% and 91.3% of reduced total yield when compared with control. These obtained results are on par with Yadav et al., [12]who have found that reduced yield in maize. These findingsobtained because of lower levels of gamma radiation might improve the interactions of growth hormones and promote the antioxidant potentialsin irradiated cells, which might enhance the faster growth [17].Mudibuet al., [27]revealed that the maximum grain yield was recorded in soy bean exposed with 200Gy of gamma radiation. According to the research findings of Tshilengeet al.,[18]higher levels of gamma radiation reduces the total yield of groundnut.

Table 4: Effects of different levels of Gamma radiation on Number of pods per plant, 100 seed weight and Total yield of Groundnut at 12WAP

Treatments	Number of pods	100 seed weight (g)	Total yield (kg/ha)
T1 (Control)	24 ± 3^{b}	41.8 ± 0.79^{b}	1381.6 ± 28.05^{c}
T2 (100Gy)	21 ± 3^{b}	42.8 ± 1.85^{b}	1600.0 ± 94.60^{b}
T3 (200Gy)	35 ± 5^{a}	61.6 ± 1.20^{a}	2288.3 ± 68.69^{a}
T4 (300Gy)	23 ± 3^{b}	39.6 ± 3.05^{b}	955.0 ± 48.91^{d}
T5 (400Gy)	4 ± 1^{c}	25.2 ± 4.11^{c}	323.3 ± 49.14^{e}

T6 (500Gy)	2 ± 1^{c}	14.6 ± 1.28^{d}	120.0 ± 22.14^{e}
F- Test	*	*	*

The value is the average of five replicates. The letter 'ns' denotes a difference that is not significant and '' represents significant at the 0.05 level of probability. The mean value in a column with a different letter or letters indicates that the difference is significant by DMRT at the 0.05 level of probability.*

CONCLUSIONS

In conclusion, the present study highlights the significant influence of gamma radiation on the growth and yield characteristics of groundnut. The results demonstrate that lower levels of radiation do not have any significant effects, while higher levels lead to a reduction in growth and yield. Application of 200Gy showed the most promising results, with significant increases in various growth and yield characteristics, including shoot fresh weight, root fresh weight, number of pods, 100 seed weight, and total yield. The LD50 was observed at 430Gy, indicating the level of radiation at which 50% of the plants would not survive. Overall, this study suggests that gamma radiation can be used to create desirable characteristics in groundnut with 200Gy being the most suitable treatment future breeding programme.

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