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RESEARCH ARTICLE

Improvement of oil content in groundnut (*Arachis hypogaea* L.) by the impacts of gamma irradiation

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Abstract

Gamma radiation dosages of 100, 200, 300, 400, 500 and 600 Gy were given to the groundnut seed variety Dharani (*Arachis hypogaea* L.). The study's goal was to look at genetic diversity, heritability and genetic advancement for seed yield and quality characteristics in M_2 generation using only a Randomized Complete Block Experiment using 3 replications from 2018 to 2019. The article's outcomes significantly enhanced the oil content of groundnut at 400 Gy to 52.44 % as compared to other dosages. For all characteristics, treated seeds displayed more variance than control seeds, particularly seed yield per plant showing the highest in GCV, PCV, H^2, GA and GAM. In most traits, 400 Gy of gamma-ray treatment generates the largest changes however, 600 Gy of gamma-ray treatment also creates equivalent conditions. The link between features demonstrated that the number of pods per plant had a significant role in rationalizing seed yield variance in the M_2 generation. These findings show that this yield component is one of the most important predictors of pod yield variations among plants and it is also favorably impacted by irradiation mutagens (gamma rays).

Keywords

Coefficient of variation, heritability, mutations, oil yield improvement

Introduction

Groundnut (*Arachis hypogaea* L.) dharani is drought tolerant, water efficient and resistant to PBND (*Peanut* bud necrosis disease) and PSND (*Peanut* stem necrosis disease) as well as stem and dry root rots. Its unique traits include a time span-100-105 days), yields of 16-26 pod, an oil content-50%, drought tolerance (withstanding a 35 days dry spell, uniform maturity, a high SMK (Sound Mature Kernel) percentage attractive pods, a moderate size and a tolerance to low light levels. On approximately 25 million ha of land around the world, the significant leguminous oil seed crop known as peanut produces 36.40 million tons annually (1). Groundnut, also referred to as peanut, is a significant agricultural and oilseed plant in many parts of the world. It is used as feeding livestock, human protein and vegetable oil, as well as farmyard manure. Groundnut seeds mainly 48% oil and 26% protein (2). Recently, activated mutations have been widely used in recent years to enhance the genetics of yearly bases oil seeds such as soybean, sesame, canola, sunflower and linseed (3, 4).

The plant characteristics that influence productivity must be identified in order to increase groundnut pod outcome in a breeding programme.

Therefore, understanding the type and plant features that impact productivity must be determined. As a result, knowing the type and extent of genetic variation and trait propagation is crucial for optimizing seed and pod yield selections. Crop improvement efforts targeted at developing high-yielding varieties must include genetic variability, as indicated by the calculation of various genetic analyses such as components of variance, genetic and phenotypes indicators of variability, heritability and genetic progress (5).

Novel genetic mutations are produced by mutation and hybridization. Growers differ in terms of mean shifts in M_2 and future generation, as well as the probability of positively or negatively generated polygenic variations (through induced mutagenesis) (6).

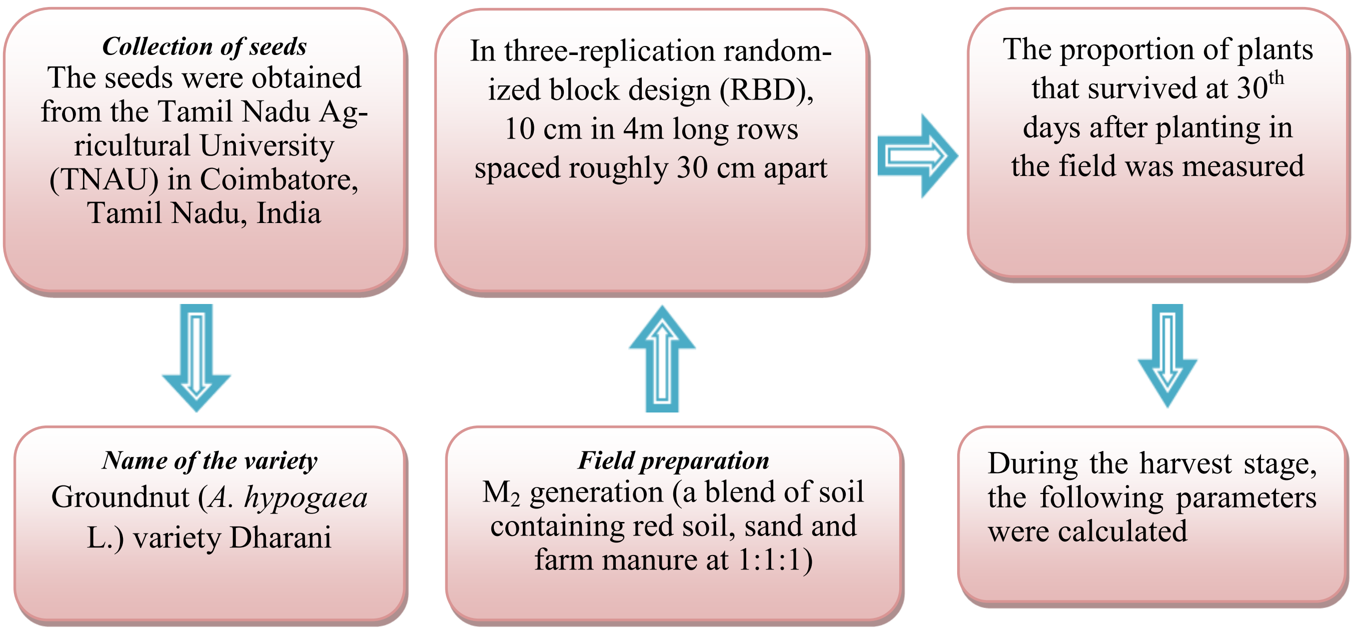
By choosing and combining features that contribute to physiological efficiency, to crop yield can be increased while increasing crop economic production. Heritability and other genetic factors must be estimated accurately in order to plan the selection process and determine where to direct the development in agricultural plant traits. Superior plant types have been generated over the years through the application of induced mutation (7). Since mutagenesis processes are considerably easier and faster than conventional hybridization. Radiation that is ionizing, such as alpha particles, cosmic rays and x-rays, has the advantage of excellent penetration, and treating seeds with these agents is the simplest and most practical technique to directly influence plant genetic structure. Because groundnut seeds include protein, fat and carbohydrates, they are susceptible to radiation-induced stress; nonetheless, modest doses of radiation have positive benefits (8).

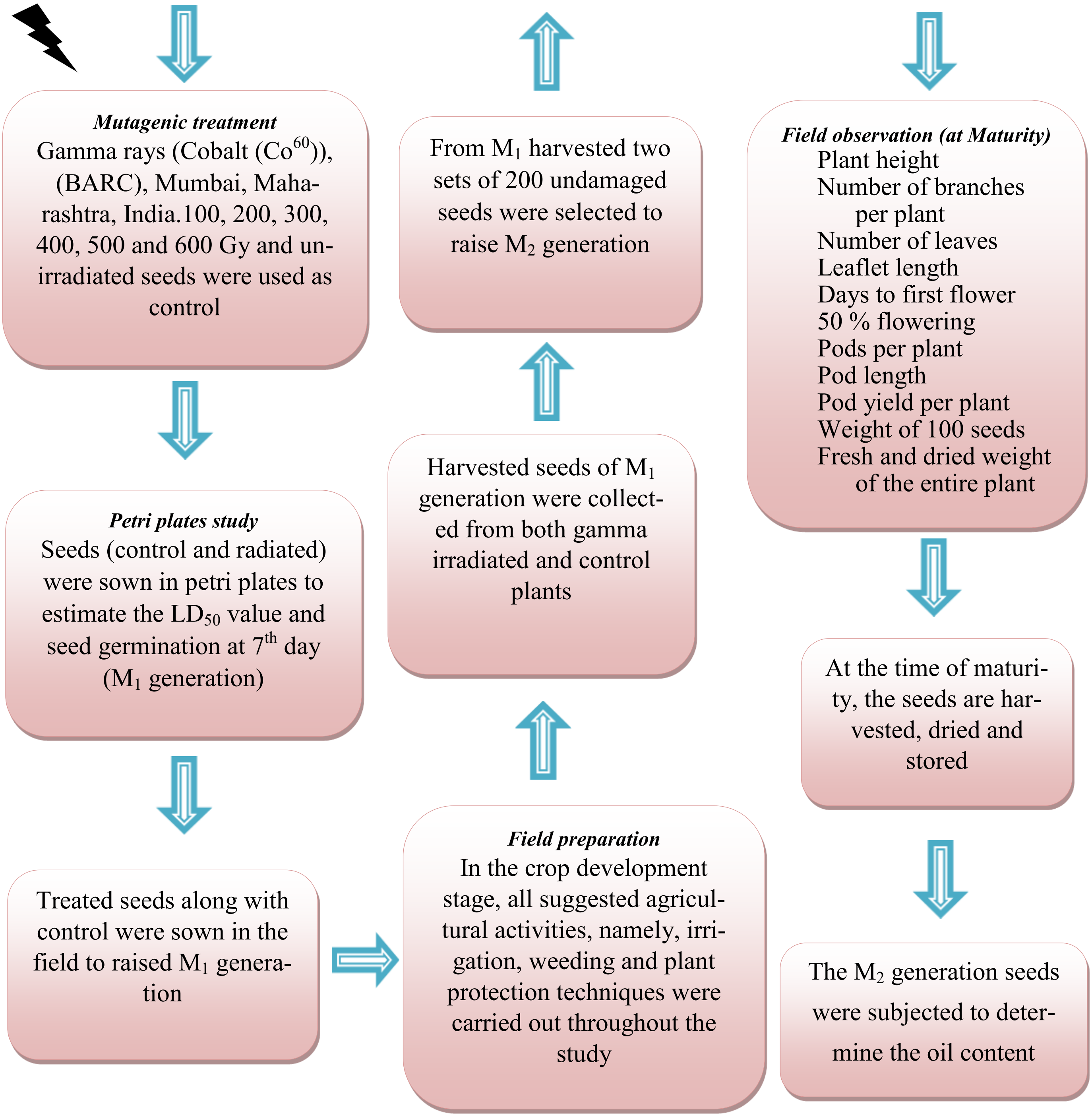
Gamma radiations effects on rice quantity and quality attributes revealed that radiation doses slightly boosted growth parameters, through a declining relationship in the analyzed attributes was found as dose rates increased (9).

When high lipid-containing materials are exposed to radiation, this can cause lipid peroxidation, which can lead to the formation of off-flavor and off-odor, as well as the loss of natural antioxidants (10). Low in saturated fatty acids but high in mono and polyunsaturated fatty acids make up groundnut oil (11). Except for research findings on peanuts exposed to significantly higher doses of radiation (12), there are currently few studies looking at the properties of oil obtained from irradiated peanut seeds. In contrast, other studies focused primarily on how irradiation affected the fatty acid components of peanut oil (13).

Mutation breeding is an alternative to traditional plant breeding as a source of growing variety and has the potential to give particular improvement without dramatically affecting the acceptable phenotype (14). Irradiation has been used in various locations to increase groundnut genetic diversity (15). Direct selection for groundnut yield enhancement is frequently deceptive. Evaluating current diversity, as well as the degree of association between yield contributing characteristics and their relative contribution to yield, is essential for creating high-yielding groundnut genotypes. The observed variation is the result of an interaction between genetic and environmental influences (16).

Information on the degree of variance in particular characteristics can be found in the genomic coefficient (GCV) and phenotypic coefficient of variance (PCV) provides information on the degree of variation in certain characteristics. As a result, an analytical study of metric properties is necessary to acquire a full and thorough idea. Since hereditary is influenced by environmental factors, heritability information alone may be ineffective in finding qualities that enforce selection (17) studied mung bean genotypes to measure genetic diversity, heritability and genetic progress for agronomic characteristics and discovered highly substantial variances for all traits, with plant height and seed weight having one of the highest degrees of heritability (18). This study investigates to examine the gamma irradiation effects on seed germination, plant survival, quantitative and qualitative characteristics in M_2 generation. Phenotypic, genotypic, heritable, genetic advance and genetic advance as percentage of mean are the factors that affect correlation coefficient of variations. The oil content of the collected seed was calculated.





Materials and Methods

Co-efficient of variation

The given method was used to compute the variability of the phenotypic and genotypic coefficients (19).

$$PCV = \frac{(\text{Phenotypic variance})^{1/2}}{\text{General mean}} x100$$

$$GCV = \frac{(\text{Genotypic variance})^{1/2}}{\text{General mean}} x100$$

The range of variation was categorized by the method given by (20) and was classified as (i) more than 20 % – high, (ii) 10-20 % – moderate and (iii) less than 10 % – low.

Heritability

For each character heritability was computed by using the formula given by (21) and was categorized according to (22) as (i) more than 30 % – High, (ii) 10-30 % – Moderate and (iii) Less than 10 % - Low

$$h^2 = \frac{GV}{PV} x100$$

Where, GV- Genotypic variance, PV- Phenotypic variance

Genetic advance

Genetic Advance $=h^2$ x 6ph x K

The genetic advance (GA) for a certain characteristic was assessed using the approach proposed by (23).

Where, h^2 = Heritability, $6ph^2$ =phenotypic standard deviation, K= Selection differential 2.06 at 5 % level.

Genetic advance as % of the mean (GAM)

$$GAM = \frac{GA}{GM} x100$$

Where, GA- Genetic Advance, GM- Genetic Mean

The Genetic advance as a % of the mean was categorized as (i) More than 20 %- High, (ii) 10-20 %- Moderate and (iii) Less than 10 %- Low.

M2 generation seeds oil content

Groundnut seeds obtained from control and gamma-irradiated were ground in a pestle and mortar and motored continuously for extraction using a Soxhlet apparatus for about 8 hrs with n-hexane as a solvent by the method by AOAC (24). To obtained total lipid content by calculating the lipid % and was collected, stored at 4 °C to analyse further peroxide value.

Statistical analysis

SPSS software was used to conduct the analysis of variance for the phenotypic characteristics. The formulas were used to compute genotypic and phenotypic coefficients of variation, broad-sense of heritability (h^2), genetic advance (GA) and genetic advance as a percentage of the mean (GAM). One-way Analysis of variance (ANOVA) was carried out to define the dissimilarities in morphological parameters during yield, comparing with control.

Results

Statistical analysis was conducted on quantitative phenotypic traits, which include seed germination, survivability, days to first flowering, 50 % flowering, plant height, number of branches per plant, number of leaves per plant, leaflet length, number of pods per plant, pod length, pod yield per plant, 100 seed weight, fresh and dry weights and harvest index, to evaluate the extent of induced genetic variability and divergence generated by the mutagen. The section discusses the results of several statistical approaches used on attributes and generation.

Quantitative traits

Plant height (cm)

The findings for plant height in the M_2 generation (Supplementary Table 1 & Fig. 1) revealed maximum results were obtained in the 400 Gy treatment (81.20) when compared to control (42.85). This result had a positive variance mean value of plant height rose dramatically with increasing dosages. Calculations based on GCV % yielded the highest genotypic variation in plant 400 Gy (20.38). At 400 Gy, phenotypic variation (PCV) was reported (25.17). The greatest (H^2) heritability estimates were found in 400Gy (70.53). An examination of (GA) genetic advance estimates revealed a significant rise over the 400 Gy (18.41). Maximum (GAM) genetic advance mean values were obtained at 400 Gy (33.99) (Supplementary Table 2).

Plant survival %

Maximum plant survival % in 200 Gy (90.41), minimum sur-

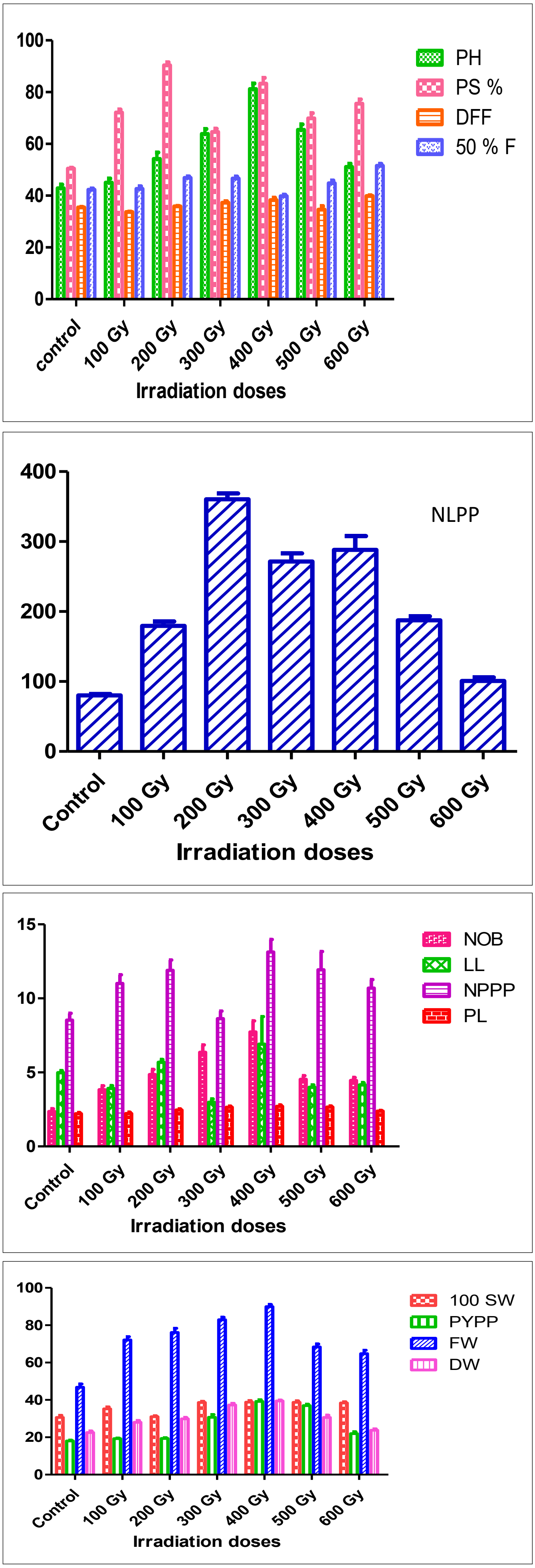


Fig. 1. Effect of gamma irradiation on agronomical traits of groundnut (*Arachis hypogaea* L.) in M_2 generation

vival % was observed in 100 Gy (72.14) when compared to control mean value (50.44). (Supplementary Table 1 & Fig. 1). The 600 Gy exhibit highest PCV (16.98), GCV (14.69), H^2 (91.78) GA (11.94), and GAM (23.20) values. Almost all treatment exhibit increasing genetic parameters (Supplementary Table 2).

Days to first flowering

In M_2 generation days to first flowering shows minimum mean values at 100 Gy (33.73) (Supplementary Table 1 & Fig. 1) in comparison to the control group plants (35.46). The maximum mean values in contrast observed in 600 Gy (39.86). The maximum coefficient alterations of genetic parameters for days to first flowering found increased in optimal dosages 400 Gy PCV (21.08), GCV (19.81) of gamma irradiation were computed in the (Supplementary Table 2).This parameter exhibit significant difference in all mutagen treatments.

50 % flowering

When compared with the control (42.33) group and other doses, the days to 50% flowering were shown to be higher mean values in 600 Gy dosage (51.50) (Supplementary Table 1 & Fig. 1). For 50% flowering, the analysis of genetic variation shown high values in 300 Gy were PCV (19.28), GCV (17.60), H^2 (67.10), GA (5.98) and GAM (12.83) (Supplementary Table 2).

Number of branches per plant

In this investigation, maximum mean value was observed for number of branches per plant characteristics in 400 Gy (7.73) (Supplementary Table 1 & Fig. 1) when compared to control (2.36) at the same time minimum mean value for these characteristics observed in 100 Gy (3.83). Genetic parameters studies revealed the maximum value in 400 Gy (Supplementary Table 2), phenotypic coefficient variation (PCV) (52.51), genotypic coefficient variation (GCV) (50.89), heritability (H^2), (93.93), genetic advance (GA) (17.85) and genetic advance mean (GAM) (31.62)for number of branches per plant among all studied characteristics.

Number of leaves per plant

Maximum means value for more number of leaves per plant were noted in 200 Gy (360.53) (Supplementary Table 1 & Fig. 1) when compared to the control mean value (80.06). Minimum mean value was noted in 600 Gy (100.93). Both the phenotypic variation PCV of 400 Gy (37.05) and the genotypic variation GCV (35.86) were high, indicating a high level of genetic variation (Supplementary Table 2).

Leaflet length

The highest mean value of 400 Gy (6.91) and the lowest leaflet length recorded in 300 Gy (2.98) (Supplementary Table 2) when compared to the control range (4.98) in which this characteristic feature plays a significant role for photosynthesis in groundnut (Supplementary Table 1 & Fig. 1). When compared to other dosages, in 400 Gy the maximum PCV (45.32) and GCV (40.14) values were observed for leaflet length.

Number of pods per plant

In this studied M_2 generation for number of pods per plant increased when compared to the control (8.53) and other treatments, in 400 Gy we noted (13.13) maximum mean value for this character. Minimum mean value for this studied character noted in 300 Gy (8.63) (Supplementary Table 1 & Fig. 1). All the studied genetic parameters were documented maximum in the 400 Gy (Supplementary Table 2) and significant value for number of pods per plant for PCV (56.33) and GCV (52.28) when compared to other applied doses.

Pod length

In M_2 generation the pod length mean value observed maximum in 400 Gy (2.70) when compared to control mean value (2.21) (Supplementary Table 1 & Fig. 1). The PCV (37.78) and GCV (33.80) had a favorable and very significant relationship with pod length (Supplementary Table 2) in 400 Gy.

Pod yield per plant

In control mean value for pod yield per plant (18.06) was observed minimum when compared to 400 Gy which exhibit highest mean value (39.22) the least mean value for pod length exhibited in 100 Gy (19.26) (Supplementary Table 1 & Fig. 1).Coefficient variations for the phenotype (27.26), genotype (26.34), heritability (93.31), genetic advance (16.07) and genetic advances mean (32.41) was observed in the 400 Gy (Supplementary Table 2) when compared to other doses.

100 seed weight (g)

In analyzing mean values for the probability of high-yielding plants among the applied doses the maximum value was noted for 100 seed weight in 400 Gy (38.79) when compared to control (30.60), lowest 100 seed weight of groundnut was observed in 200 Gy (31.07) (Supplementary Table 1 & Fig. 1). Genetic parameter shows highest values in 400 Gy such as PCV (23.42), GCV (20.70) when compared to other applied doses (Supplementary Table 2).

Fresh weight

In the current investigation, substantial variability was detected for the feature of fresh weight, increased mean value seen in 400 Gy (89.93) (Supplementary Table 1 & Fig. 1) and the lowest mean values recorded at (46.78) when compared to the control (46.78). Coefficient variations for the phenotype (15.93), genotype (13.97), heritability (39.21), genetic advance (9.79) and genetic advances mean (12.87) was observed in the 400 Gy when compared to other doses (Supplementary Table 2).

Dry weight

In this study, the total yield of plant dry weight mean values rose in 400 Gy (39.43) as compared to the control (22.54) and less mean values was computed in 600 Gy (23.78) (Supplementary Table 1 & Fig. 1). At 400 Gy, the diversity in (GCV) genotypic coefficient variation, (PCV) phenotypic coefficient variation, (H^2) heritability, (GA) genetic advance and (GAM) genetic advance mean significantly increased compared to other gamma irradiation dosages (Supplementary Table 2).

Correlation

The analysis of variance revealed that maximum significant differences across genotypes for all variables except oil content, indicating a high level of genetic variability in the plant material studied. The correlation studies for all the above morphological characters deliberate statistically significant $P \leq 0.01$ (Supplementary Table 3).

ANOVA

The results of (ANOVA for RBD) variance analysis exhibited the highest improvement in the yield enhanced character for number of leaves per plant range (248.46), mean (360.53), mean square (2870.69) (Supplementary Table 4) for improvement of agronomic value, when compared with other studied characters.

Oil content

Nearly 80% of India's groundnut harvest is pulverized for oil extraction. As a result, plant breeders and millers are interested in improving oil output and quality. The most significant quality criteria for groundnut as an oil source

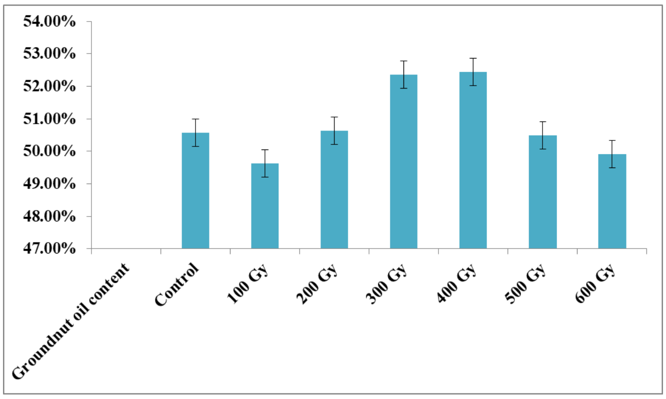


Fig. 2. Effect of gamma irradiation in groundnut analysis of oil content in M_2 generation seeds

noted high in a 400 Gy (52.44), minimum oil content was also noted in 100Gy (49.62) when compared to control (50.57) and other dosages (Fig. 2).

Discussion

The significant proportion of groundnut agronomic factors has favorable yield correlations. The mean value due to genotypes demonstrated a significant difference in all 13 quantitative parameters. Field survival %, days to 50% flowering, days to first flower, plant height (cm), branches per plant, leaves per plant, leaflet length, pod production per plant (g), pod length, 100-seed weight (g), seed yield per plant, fresh weight, dry weight were all evaluated in the present investigation of groundnut plant. Similar results with the peanut crop show the mean sums of squares of the genotypes chosen were genetically with a high degree of variance among them (25).

In the present study plant height of groundnut discrepancies can be linked to genetic diversity detected across the genotypes tested, these findings reveal (26, 27) substantial variations in plant height. Plant height is a significant feature that has been widely investigated in prior peanut research (28-30).

The characteristics of groundnut pod and kernel size of this investigation have undergone significant selection pressure during groundnut domestication. These findings were supported by the earlier studies stated the physical and genetic basis of these properties has been uncovered to improve them (31).

As a result, the phenotypic selection is enough for exercising selection in these traits. The differences in PCV and GCV predictions are higher in 400 Gy among the other studied doses of the present findings. This was supported by the reports stating, minor magnitude discrepancies in GCV and PCV estimations for variables including plant height, number of branches per plant, leaves per plant, leaflet length and pod yield per plant showed that these traits are largely regulated by genetic determinants, with minimal environmental effect on their phenotypic expression (32).

High heritability was observed in generation studies of this present study, for days to 50% flowering, together with modest genetic advancement as a percentage of mean, suggesting the dominance of non-additive gene action in the inheritance of these characteristics. A similar discovery was made with peanuts of the previous literature study (33). The pod production per plant decreased with this generation as well. Similar results have been discovered for kernel yield per plant (34).

Moderate heritability shows that there is still a possibility to use additive gene activity through selection (35) but low genetic advance implies a preponderance of non-additive gene action and so selection may not be advantageous for low genetic advance characteristics.

The number of mature peanut plants had the greatest direct impact on seed yield per ha followed by nut size, days to 50% flowering, and days to maturity (36) also similar findings with chickpeas. On the other hand, the number of immature nuts per plant, seed size, plant height and number of branches per plant had a direct negative influence on seed production per ha demonstrating that pod yield in groundnut could be raised by selecting the plant with the more number of nuts, bigger nut size, higher shelling percentage, early days to 50% flowering, and days to maturity, similar effects were found in the case of peanuts (37, 38). To boost groundnut yield, sufficient attention should be made to the aforementioned attributes.

Since the genotypic correlation coefficients were bigger than the corresponding phenotypic correlation coefficients, all pairs of characteristics show that the environmental influence suppressed the connection at the phenotypic level, demonstrating that both environmental and genotypic correlation work in the same direction and finally optimize their expression at the phenotypic level. Except for plant height and shelling percentage, the seed production plant showed a highly significant and positive relationship with all of the metrics. Plant height and shelling percentage had an inverse and non-significant association with yield per plant. The pod yield plant had a highly significant and positive link with nut size, the number of nut plants, pod size, and days to 50% flowering. Except for days to 50% flowering and maturity (39) noticed a similar pattern of relationship in the case of yield per plant with the aforementioned criteria. As a consequence, these traits proved to be the most critical components of pod yield. Plant height and kernel weight both had a fairly positive direct effect on pod yield. The greatest direct benefit on pod yield per plant was also proven by (40-42) The highest and most beneficial direct advantages have been demonstrated to be pod yield per plant, biological yield per plant, and harvest index (43, 44).

The data demonstrated that the patterns of genotypic and phenotypic linkage were almost the same across all variables. Estimates of genotypic correlation were somewhat higher than estimates of phenotypic correlation. At both the genotypic and phenotypic levels, dry pod yield per plant was positively and significantly related to pod production per plant, the number of pods per plant, and plant height. A similar positive link exists between pod production per plant, kernel yield per plant (45) and mature pods per plant (46). In the present study, measurement of genotypic parameters indicated that the phenotypic coefficient of variation was seen for traits such as days to maturity (GCV and PCV), plant height (GCV and PCV), showing that all genetic characteristics are translated into phenotype without much environmental effect.

Grain yield was connected to plant height, the number of pods per plant, shelling %, 100 seed weight and several main branches. Previous research has discovered comparable correlations (47, 48). These positive connections suggest that selecting for these characteristics would also help to boost yield. The strong positive association between grain yield and pod count per plant might imply that the two measures share some genes (49, 50).

The previous findings in groundnut plant results exhibit the mean, range, variance estimates of components broad range of variability for all the studied characters except plant height and days to 50% flowering supported by (51) were in agreement of our studies in groundnut plants for mean, mean square and range (one-way ANOVA) shows highest improvement for number of leaves per plant.

Due to the obvious positive link between grain yield and plant height, tall genotypes may have a stronger potential to gather photo-assimilates, leading to higher yields. This is vital for breeding programmes since height should be a factor in yield selection. The implication is that selection based on these significantly positively related traits might enhance groundnut yield.

Conclusion

The current study discovered that in the M_2 generation, selection done on numerous pods per plant and 100-seed weight to increase pod productivity and seed yield per plant in groundnut. When compared to other dosages and control, the greatest values for all agronomical characteristics were obtained at 400 Gy. As a result, these features should be regarded essential yield attributing factors when breeding for high pod and seed output per plant in groundnut. Selection based on these crucial characteristics will aid in increasing groundnut oil yield. The relationship between plant height and sound mature seed percentage and yield and other yield-related variables varies with M_2 generation. As a result, these characteristics should be used with caution as selection indices. Treatment with 400 Gy of gamma rays, on the other hand, produced mutants with the greatest mean values of morphological and quantitative features. Such polymorphisms might be exploited to increase agronomic metrics and oil composition in peanuts.

The evaluated parameters were shown to have a very significant relationship in this study, with the majority of attributes having a direct and indirect effect on dry pod yield.

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Authors contributions

GA and DA conceptualized and planned the experiments. GA and SL conducted experiments and examined the data. Reagents/materials/analytical instruments were donated by GA and DA. The research paper was written by GA and DA.

Compliance with ethical standards

Conflict of interest: The researchers have indicated that they have no conflicts of interest.

Ethical issues: None

Supplementary data

Supplementary Table 1. Effect of gamma irradiation on agronomical traits of groundnut (*Arachis hypogaea* L.) in M_2 generation

Supplementary Table 2. Effect of gamma rays in coefficient of variation, heritability (h^2), genetic advance and genetic advance mean (%) of groundnut (*Arachis hypogaea* L.) M_2 generation

Supplementary Table 3. Correlation studies among yield contributing characters of groundnut in M_2

generation

Supplementary Table 4. One-way ANOVA Mean square, range, means all the agronomic traits for groundnut (*Arachis hypogaea* L.)

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