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Groundnut improvement: Genetic variability induction for growth aspects and pod yield in groundnut (*Arachis hypogaea* l.) through gamma irradiation

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A MUTATION breeding program on groundnut has been carried out in Cairo University, Faculty of Agriculture, Agronomy Dept., Egypt, for several years from 2014 until now. The present study aims to estimate the genetic variability of some different quantitative traits for some mutant lines resulting from two different genotypes *i.e*., Giza-6 and NC-1. During 2014 season, groundnut seeds of both genotypes (Giza-6 and NC-1) were treated with physical mutagenic agents of gamma irradiation doses (0, 100, 200 and 300 Gy). Regarding M_1 generation, A significant effect of gamma irradiation doses was detected on germination ratio, crop growth rates (CGR), pods yield and the growth traits (roots, shoots, leaves, pods and total biological yield as dry weights). The results showed significant reductions in germination ratio which reached 38.56, 33.5 and 23.39% under 100, 200 and 300 Gy, respectively as compared to a control treatment (85.0%). Regarding growth analysis, among the various doses of gamma rays treatment, the low level (100 Gy) caused an increase in crop growth rates by (25.49 and 41.8% for 1st and 2nd intervals, respectively) compared to a control treatment. Concerning M_2 generation, gamma irradiation dose at 100 Gy increased significantly the pods yield/plant in g. by 44.2% for Giza- 6 and 50.6% for NC-1as compared to the control treatment. Meanwhile, for the total biological yield plant^{-1}, there was a significant increase of 59.6% for Giza 6, and 122.7% for NC-1 at 100 Gy as compared to control treatment. On the other hand, higher dose of gamma rays (300 Gy) caused significant reduction in plant growth and pods yield and the other contributing traits. Overall generations, for all studied quantitative traits, the range of trait values were wider in irradiated materials than non-irradiated (control) and the majority of the traits in the M_2 were positively skewed especially under 100 Gy irradiation doses. Further genetic improvement through selection for yield improvement should rely on the pods yield plant^{-1}.

Keywords: Peanut, gamma rays, effective dose, growth and high-yielding ability.

Introduction

Groundnut is considered as one of the most valuable and oldest crops belonging to the family leguminous. Peanut is cultivated in about 24 million ha over the world, developing countries account for over 97.6% of the world groundnut area and 95.5 % of total production with average yield of 1522.0 kg ha^{-1} (FAOSTAT, 2010). Groundnut is considered aself pollinated diploid annual summer crop with narrow base of genetic background, so the classical or conventional methods of plant breeding are not enough to induce genetic variability. Therefore, groundnut has been exposed extensively to mutagenic treatments for variability induction through physical (Gamma-rays) and chemical (EMS) mutagens that can improve several quantitative and qualitative traits. Induced mutations are needed in the cultivated peanut to improve genetic variability as stated by Knauft and Ozias-Akins (1995). Sorour*, et al* (1999) mentioned, that ranges of trait values were wider in irradiated materials than non-irradiated controls over all generations, and the majority of traits in the M1 were positively skewed under 100 Gy irradiation doses, while the higher doses had a negative effect. Many authors mentioned that the groundnut seeds could be treated with various doses of gamma rays ranging between 100 to 300 Gy [Busolo-Bulafu, (1988), Sorour, *et a*l (1999), Shahin and Azer, (2003), Kaveri and Nadaf, 2008, Badigannavar and Mondal 2009, and Pachore *et. al*., (2012)]. Tshilenge-Lukanda, *et al* (2011) mentioned that mutation induction has been used to create new genetic variability for high yielding ability, high oil quality and biotic and abiotic resistance. On the other hand, Cheah, (1988), Ramadan et al. (2025), Abdel-Lattif, (2018) Hemeid et al. (2020) and Tshilenge-Lukanda, *et al* (2012), mentioned that morphological and yield characters of M1generation (seed germination, number of grains per plant, 100 grains weight, grain yield per plant, dry weight per plant) were significantly reduced by increasing gamma irradiation dose. The present investigation was undertaken to study the effect of different irradiation doses on germination ratio, biological growth traits, crop growth rates and pod yield during different growth stages to determine the effective irradiation dose for induce the genetic variability in order to

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confer specific improvements, such high seed yield, in agronomical important peanut varieties.

Material and Methods

Two field and one laboratory experiments were conducted during the two successive seasons 2014 and 2015 in The Faculty of Agriculture Cairo University Giza Egypt to study the effect of four different doses of gamma rays (0, 100, 200 and 300 Gy) on two different peanut genotypes (Giza-6 and NC-1). In The 2014 season two experiments were conducted, the first one in the lab and the second in the field. With respect to lab experiment, and for recording observations on germination percentage, 500 pure, uniform, healthy and dry (12% moisture) seeds for each one of the 8 treatments (two genotypes X four gamma ray irradiation doses) were subjected to the different gamma irradiation doses. The treated seeds and the control treatment were grown in sterilized Petri dishes under the laboratory conditions using split-plot arrangement in RCBD design with three replications. With respect to the field experiment in 2014 season, 120 germinated seeds were selected from each treatment of the Petri dishes and sown in field plot experiment in split plot arrangement, where the genotypes occupied the main plot and gamma ray levels in subplot using RCBD design with three replications to raise M_1 plants, each plot consisted of two ridges 0.6 m in width, 4 meter long and 0.2 m between hills, number of plants/square meter = 7.1 plant. At 40, 65 and 90 days after planting (DAP), a random sample, each of ten plants were chosen from each plot unit to estimate root, shoot, leaves, pods dry matter plant^{-1}and total biological yield (TBY) in g Growth parameter i.e., crop growth rate (CGR) in g^{-2} day^{-1} was calculated as.

CGR (g m^{-2} day^{-1}) = $(W_2 - W_1)/(t_2-t_1)$, where
W_1, total biological yield/unit area at specific time,t_1
W_2, total biological yield/unit area at specific time, t_2

All M_1 plants from each treatment were harvested and bulked treatment wise to raise the M_2 generation. In the 2015 season the M_2 seeds along with control were sown in field experiment in a split plot arrangement in RCBD whereas, the genotypes were applied in the main plot and the gamma ray levels in sub plot with three replications. Each plot consisted of 10 ridges four meters long and 0.60 m width, the plant-to-plant distance was kept 0.20 m within the row. Recommended agronomic practices were applied. At harvest, ten guarded plants were randomly selected from each plot unit to study the different agronomic characters viz., total biological yield plant^{-1} in g and pods yieldplant^{-1}.

Statistical Analysis

Data of each experiment was subjected to statistical analysis and the mean comparisons were performed at 5% level of significance by using LSD test according to Gomez and Gomez (1984). In 2014 season (M_1generation), the data for germination%, crop growth rate (CGR) and pods yield/plant in g were analyzed as split plot design. On the other hand, theM_1 data of the three growth samples were analyzed as a split-split plot design, where genotypes (G) as main plot, gamma irradiation dose (ID) as subplots and sampling dates (SD) as sub-sub plots. In 2015 (M_2 generation), the data was analyzed as split plot design with the genotypes as main plots, and gamma irradiation doses as sub-plots. Moreover, the best fit curves of the different studied traits (total biological yield plant^{-1} in g and pods plant^{-1} in g) were drawn.

Results and Discussion

A.M_1-generation plants during 2014 season

A.1 Analysis of variance of M_1 generation

Data in Table 1 represent the mean squares for the studied traits viz., root dry weight, leaves dry weight, shoot dry weight, pods dry weight and total biological yield plant^{-1}in g as affected by factors of study (Genotypes (G), Irradiation doses (ID) and three successive growth samples (SD)). Highly significant effects of gamma rays and sampling date were recorded on the previously studied traits. Concerning the effect of genotypes, significant or highly significant differences were detected only for root dry matter and pods dry matter. With respect to the second order interaction between the three main factors (genotypes (G), irradiation dose (ID) and sampling dates (SD)), the results in Table 1 revealed, except leaves dry weight, G x ID was highly significant effect for remaining traits (total biological yield plant^{-1}, shoot dry weight plant^{-1}, pods dry weight plant^{-1}and root dry weight plant^{-1}). The G x SD second order interaction exhibited a highly significant effect only for pods dry weight plant^{-1}and root dry weight plant^{-1}. Concerning the second order interaction (ID x SD), a highly significant effect was detected for all studied traits. Concerning the three-way interaction (G x ID x SD), a significant effect was detected for roots, shoots and pods dry weight. From the above results it could be concluded, the important role of gamma irradiation dose as an important factor for variation induction in different traits of groundnut, these results are in agreement with those obtained by (Benslimani and Khelifi, 2009, Pachore *et al* 2012 and Gunasekaran and Pavadai 2015).

Data in Table 2 represents the mean square values of the analysis of variance of germination ratio, crop growth rates during two intervals and pods yield plant^{-1}. The results showed a significant effect of genotype on crop growth rate (CGR-2), and pods yield plant^{-1}(g). Except (CGR-1), highly significant effects of gamma irradiation dose (ID)were detected on germination ratio, CGR-2 and pods yield/plant. Moreover, a highly significant effect was observed for the second order interaction (G x ID) onCGR-2and pods yield plant^{-1}. From the above results it could be demonstrated the important role of gamma irradiation dose for variation induction for germination ratio, crop growth ratio and pods yield plant^{-1}.

Table 1. Mean squares of the analysis of variance for roots, shoots, leaves, pods and total biological yield plant^{-1} (TBY) of the two peanut cultivars (G) evaluated under four gamma irradiation doses (ID) through three successive samples (SD) during the 2014 season.

SOV	Df	Roots	Shoots	Leaves	Pods	TBY
Rep	2	0.05	31.40	72.92	123.1	603.3
Genotypes (G)	1	5.82*	401.0	72.43	1063**	531.0
Error a	2	0.26	334.62	178.1	6.05	886.4
Gamma (ID)	3	5.98**	2089**	1091**	518.9**	10392**
G×ID	3	6.64**	589.0*	214.6	124.6**	2286*
Error b	12	0.36	117.28	146.16	15.0	617.0
Sample (SD)	2	54.3**	9242**	5563**	5084**	62100**
G×SD	2	3.39**	74.90	50.90	446.2**	507.8
ID×SD	6	1.51**	445.9**	168.5*	227.8**	2308**
G×ID×SD	6	1.84**	197.9*	18.93	52.08**	521.9
Error c	32	0.07	67.41	67.94	7.06	321.1

*and** indicate significant at 0.05 and 0.01 levels of probability, respectively.

Table 2. Mean squares of the analysis of variance for germination ratio, crop growth rate-1, crop growth rate-2 and pods plant^{-1} of the two peanut cultivars evaluated under four doses of gamma ray in the 2014 season.

S.O.V	d.f	Harvest sample			
		Germination %	**CGR- 1**	**CGR- 2**	**Pods yield plant^{-1}(g)**
Rep	2	46.4	178.1	1.4	186.3
Genotypes (G)	1	121.5	5.3	75.9*	3308.1**
Error a	2	20.6	46.2	3.3	11.1
Gamma (ID)	3	4481.5**	69.3	271.0**	1668.2**
G×ID	3	32.5	22.3	56.3**	385.5**
Error	22	41.4	65.3	2.2	22.2

*and** indicate significant at 0.05 and 0.01 levels of probability, respectively.

been reported by Wang et al. (2022), Mahrous et al. (2018), Xie and Kurosawa (2016), Sabreen and Mansour (2019), Ramadan et al. (2025) and Shrief et al. (2020).

A.2 Mean performance of M1 traits

A.2.1 Germination ratio of M_1 seeds

Data presented in Table 3 shows the mean values of germination ratio for the genotypes (G), four gamma irradiation doses (ID) and the interaction between (G x ID). No significant differences of germination ratio were detected between Giza 6 (47.36%) and NC-1(42.86%) over replication and gamma irradiation doses. Respecting to gamma irradiation dose, highly significant differences between the different gamma irradiation doses were detected, the highest germination ratio (85%) was obtained under control condition, by increasing the gamma irradiation dose from zero to 300 it caused A reduction in germination ratio from 85% to 23.39%, respectively. So germination ratio was reduced proportionally with the increasing gamma ray dose. Concerning the interaction between G x ID, the results in Table 3 showed that the germination ratio ranged between 22.89 % for NC-1 under 300 Gy to 86.6% for Giza 6 under control condition. Sheikh *et al*., 1980 reported that 35 % germination was observed at 90 KR gamma ray dose, a similar result was reported in soybean by Kwon *et al*., 1964. Moreover, these results confirmed the results reported by Rajput and Qureshi 1973 and Tshilenge-Lukanda *et al*., 2012.

Table 3. Means of germination ratio, crop growth rate- 1, crop growth rate- 2 and pods yield plant $^{-1}$ for genotypes, gamma ray and their interaction in 2014 season.

Genotypes	Gamma	Germination %	CGR -1	CGR- 2	pods yield plant $^{-1}$
Giza 6		47.36	9.99	14.38	27.75
NC-1		42.86	10.92	17.94	51.23
LSD0.05		**Ns**	**Ns**	**Sig.**	**Sig.**
	Control	85.00	10.71	15.02	43.75
	100	38.56	13.44	21.30	53.32
	200	33.50	12.04	21.23	45.62
	300	23.39	5.64	7.10	15.26
LSD0.05		**8.1**	**Ns**	**1.87**	**5.92**
Giza 6	**Control**	86.67	10.81	15.84	33.31
	100	44.22	14.72	22.07	47.96
	200	34.67	8.82	15.96	22.27
	300	23.89	5.58	3.66	7.46
NC-1	**Control**	83.33	10.60	14.20	54.19
	100	32.89	12.15	20.52	58.69
	200	32.33	15.26	26.50	68.97
	300	22.89	5.70	10.53	23.06
LSD0.05		**10.86**	**Ns**	**2.7**	**7.94**

A.2.2 Crop growth rate (CGR) g m^{-2} day^{-1} of M$_1$plants

Data in Table 3 represents the crop growth rates mean values (CGR) for two successive intervals (40-65 and 65-90 DAP). Concerning the first interval of CGR-1 (40-65 DAP) the results show no significant differences were detected between the two genotypes. Also, no significant difference was detected between gamma irradiation doses for CGR-1 (it ranged from 5.64 to 13.44 g m^{-2} day^{-1} under 300 and 100Gy, respectively). Respecting to the first order interaction (G x ID), the CGR-1ranged between 5.58 g m^{-2}day^{-1} for Giza-6 under 300 Gy to 15.26 g m^{-2}day^{-1} for NC-1 under100 Gy, these results show that, lower gamma irradiation dose (100 and 200 Gy) caused high degree of crop growth rate as compared to control treatment and higher dose of gamma (300Gy)

Respecting to the second interval of crop growth rate during (CGR-2, 65-90 DAP), significant differences between the two genotypes was detected, NC-1 recorded17.94 g^{-2}day^{-1}, meanwhile G-6 recorded 14.38 g^{-2}day^{-1}. Concerning gamma doses, a significant effect of gamma rays on CGR was detected; it ranged between 7.1 to 21.3 g m^{-2} day^{-1} for 300 and 100Gy, respectively. So CGR reduced proportionally with the increase in gamma ray dose. Also, respecting to the interaction of (G x ID), significant differences were detected for G x ID, the CGR-2ranged between 3.66 g^{-2}day^{-1} for Giza-6 under 300 Gy to 26.5 g m^{-2}day^{-1} for NC-1under100 Gy.

From the above results it could be concluded, that the highest CGR value for both intervals were obtained under 100 Gy and by increasing the gamma irradiation dose from 100 to 300 it caused significant reduction in CGR, the crop growth rate was reduced proportionally with the increase in gamma ray dose. However, the optimum gamma ray dose to obtain the high mean performance of CGR ranged between 100 and 200 Gy while the lowest value of CGR was achieved under the higher dose (300 Gy). Similar results were reported in soybean by Kwon *et al.* 1964. Moreover, Tshilenge-Lukanda *et al*, 2012 detected negative relationships between irradiation dose and plant growth

A.2.3. Pods yield plant^{-1} of M$_1$ plants in g at harvest

The result in Table 3 represents the pods yield plant^{-1} in g. Concerning the effect of genotypes, significant differences were detected between the two genotypes for pods yield plant^{-1}. The cultivar NC-1 exceeded significantly Giza-6 by 84.7% for pods yield plant^{-1}.

Respecting the effect of gamma irradiation dose on pods yield plant^{-1}, highly significant differences were detected between the different gamma irradiation doses. Pods yield plant^{-1} in g ranged between 15.26 to 53.32 g under 300 and 100Gy, respectively. Meanwhile, by using 100 Gy, it caused the highest percentage of increment of pods yield plant^{-1} (21.87%) as compared to control treatment. On the other hand, by increasing the gamma irradiation dose more than (100 and 200) to 300 Gy it caused a reduction in pods yield plant^{-1} (65.12%) as compared to control treatment. So pods yield plant^{-1} reduced proportionally with the increase in gamma ray dose. In respect to the interaction between G x ID and their effects on pods yield plant^{-1} the results in Table 3 showed that the pods yield plant^{-1} ranged between 7.46 g for Giza-6 under 300 Gy to 68.97 g for NC-1under 200 Gy. Also, from the above results it could be concluded, that the pods yield plant^{-1} was reduced proportionally with the increase in gamma ray dose. From the above results, the optimum gamma ray dose to obtain the high mean performance of the pods yield plant^{-1} ranged between 100 and 200 Gy while the higher dose (300 Gy) caused higher reduction in pods yield plant^{-1}. A similar result was reported in soybean by Kwon et al. 1964 and Tshilenge-Lukanda *et al.*, 2012.

A.2.4. Growth traits of M_1 generation plants

Data in Table 4 represent the mean of growth traits viz., root, shoot, leaves, pods and total biological yield plant $^{-1}$ in g of two genotypes Giza-6 and NC-1 through three successive samples (40, 65, 90 DAP). For all traits the results show, there is an increase in the different plant organs by time but with different ratios. Respecting the genotypic effect, theNC-1 exhibited higher values as compared to Giza-6 for root dry weight plant^{-1}, leaves plant^{-1} in g, pods plant^{-1} in g and TBY plant^{-1} during the different samples. Meanwhile, the mean values for root dry weight over the three samples are 1.62 and 2.19 g for Giza-6 and NC-1, respectively, for shoot dry weight 30.56 and 25.84 g for Giza-6 and NC-1, respectively, for leaves dry weight 23.0 and 25.0 g for Giza-6 and NC-1, respectively, for pods dry weight it ranged between 13.4 to 24.9g for Giza-6 and NC-1, respectively and for total biological yield plant^{-1} 64.21 and 69.64 g for Giza-6 and NC-1, respectively.

Concerning the effect of the four (0,100, 200, and 300 Gy) gamma irradiation doses, a significant effect was detected on different plant organs over the three successive samples, the mean values of root dry weight were 1.84, 2.35, 2.32, and1.12 g, for shoot dry weight were 25.3, 40.4, 32.14 and 14.95 g, for leaves dry weight were 22.0, 30, 30.2 and 13.9g, for pods dry weight were 20.74, 26.1, 22.15 and 7.55 g and total biological yield 63.18, 90.12, 79.46 and 34.94 g, respectively, it could be concluded, under the lower dose(100 and 200 Gy) we obtained the higher values of plant organs as compared to control and 300 Gy meanwhile, the lower values of plant organs(root, shoot, leaves, pods and total biological yield plant $^{-1}$) were achieved under 300 Gy .

With respect to the interaction between genotypes x irradiation dose for different studied traits (root, shoot, leaves, pods and total biological yield plant $^{-1}$ in g), for the mean values of different traits over the samples, the results in Table 4 indicated that for root dry weight plant^{-1} the highest value (3.45g) was achieved by NC-1 by using 200 GY meanwhile, the lowest value (0.87g) was recorded by NC-1 under 300 Gy . For shoot dry weight, Giza-6exhibited the highest value (50.3g) and the lowest one (13.84g) values under 100 and 300 Gy, respectively. Respecting leaves dry weight the highest value (34.69 g) was recorded by NC-1 under 200 Gy and the lowest value (13.24 g) was obtained by Giza-6 under 300 Gy. Concerning, pods dry matter plant^{-1}, NC-1 shows the highest value (28.85g) under 100 Gy, meanwhile the lowest value (3.89g) was recorded by Giza-6 under 300Gy. Concerning total biological yield plant^{-1}the highest values were achieved by Giza-6 and NC-1 under 100 and 200 Gy, respectively. On the other hand, the lowest one (31.03g) was recorded by Giza-6 under 300 Gy. So it could be concluded, the gamma irradiation dose 100 and 200 are more suitable to simulate and increase the mean performance of the different traits for the two genotypes. Tshilenge-Lukanda *et al* 2013 mentioned that, the higher doses of gamma rays (400 and 600 Gy) reduced significantly plant growth and grain yield.

Table 4. Means of growth parameters roots, shoots, leaves, pods yield and total dry mater plant^{-1} for genotypes, gamma ray, and their interaction during three successive samples (1stS, 2ndS and 3rd S) in season 2014.

Genotypes	Gamma ray	Roots				Shoot				Leaves				Pods			Total			
		1stS	2ndS	3rd S	Mean	1stS	2ndS	3rd S	Mean	1stS	2ndS	3rd S	Mean	2ndS	3rd S	Mean	1stS	2ndS	3rd S	Mean
Giza-6		0.6	1.4	2.9	**1.6**	10.4	28.4	52.9	**30.6**	10.8	20.3	38	**23**	6.7	20.1	**13.4**	21.9	57.1	113.7	**64.2**
NC-1		0.5	1.8	4.2	**2.2**	9.6	22.8	45.1	**25.8**	10.3	21.6	43.2	**25**	12.7	37.1	**24.9**	20.4	58.9	129.6	**69.6**
LSD$_{0.05}$		**GxS= 0.32**			**Sig.**	**GxS=7.9**			**Ns**	**GxS=7.9**			**ns**	**GxS=2.6**		**Sig**	**GxS=16.9**			**ns**
Control		0.6	1.5	3.4	**1.8**	8.8	24.7	42.4	**25.3**	8.9	19.2	37.8	**22**	9.9	31.7	**20.8**	18.3	56	115.2	**63.2**
100		0.8	1.8	4.5	**2.4**	14.7	35.7	70.8	**40.4**	15.1	26.9	48	**30**	13.6	38.6	**26.1**	30.6	77.9	161.9	**90.1**
200		0.6	2.1	4.3	**2.3**	11	26.7	58.7	**32.1**	11.7	25.7	53.3	**30.2**	11.2	33.1	**22.2**	23.3	65.7	149.4	**79.5**
300		0.4	1	2	**1.1**	5.5	15.4	24.1	**15**	6.6	11.9	23.1	**13.9**	4	11.1	**7.6**	12.4	32.2	60.2	**34.9**
LSD$_{0.05}$		**IDxS=0.45**			**0.44**	**IDxS=11.1**			**7.8**	**IDxS=11.2**			**8.8**	**IDxS=3.6**		**4.2**	**IDxS=23.9**			**18.1**
	Control	0.6	1.6	3.5	1.9	7.2	25.9	53.5	28.9	7.1	16.9	34.3	19.4	7.1	24.1	15.6	14.8	52.9	115.3	61
	100	1.1	1.6	3.5	2.1	18.4	45.3	87.1	50.3	18.4	30.9	51.4	33.6	12	34.8	23.4	37.9	89.8	176.8	101.5
	200	0.5	1	2.1	1.2	10.1	24.8	52.8	29.2	11	21.7	44.7	25.8	5.2	16.1	10.7	21.6	52.7	115.6	63.3
Giza-6	**300**	0.4	1.2	2.4	1.4	5.9	17.7	18	13.9	6.8	11.5	21.4	13.2	2.4	5.4	3.9	13.1	32.8	47.2	31
	Control	0.6	1.5	3.4	1.8	10.5	23.5	31.2	21.7	10.8	21.5	41.3	24.5	12.7	39.3	26	21.8	59.1	115.1	65.3
	100	0.5	2	5.4	2.7	11	26	54.5	30.5	11.8	22.8	44.5	26.4	15.2	42.5	28.9	23.3	66	147	78.8
	200	0.8	3.1	6.5	3.5	11.9	28.6	64.7	35.1	12.3	29.7.	62	34.7	17.3	50	33.7	25	78.7	183.2	95.6
NC-1	**300**	0.3	0.7	1.6	0.9	5	13	30.1	16	6.3	12.2	24.8	14.4	5.7	16.7	11.2	11.6	31.7	73.2	38.8
LSD$_{0.05}$		**GxIDxS= 0.64**			**0.37**	**GxIDxS=15.7**			**9.1**	**GxIDxS=15.9**			**9.2**	**GxIDxS=5.2**		**3.6**	**GxIDxS=33.8**			**19.5**
Average of Samples		**0.6**	**1.6**	**3.5**		**10**	**25.6**	**49**		**10.6**	**20.9**	**40.6**		**9.7**	**28.6**		**21.2**	**58**	**121.7**	
LSD$_{0.05}$		**0.15**				**4.8**				**4.7**				**Sig.**			**10.5**			

***B.M₂-Generation plants* during 2015 season**

B.1. Analysis of variance of M_2 generation

Data in Table 5 represent the analysis of variance of the M_2 generation progeny traits viz., biological yield plant^{-1} in g and pods yield plant^{-1} in g. The results show no significant effect was recorded for the genotypes effects for both studied traits. On the other hand, the results exhibited highly significant effects of gamma irradiation doses on the two studied traits. Concerning the interaction of (G x ID), significant effect of (GxID) was detected for pods plant^{-1}. From the above results it could be concluded the important role of gamma ray irradiation as a tool for variation induction especially in M_2 generation.

Table 5. Mean squares **of the analysis of variance for biological yield and pod yield/plant of two peanut cultivars, four doses of gamma ray and the interaction (G x ID) in season 2015**

Genotypes	d.f	Biological yield /plant(g)	Pod yield/ plant (g)
Rep	2	413.8	44.3
Genotypes (G)	1	28692	103.7
Error a	2	5565	47.9
Gamma (ID)	3	11761**	4372**
G×ID	3	2053	160.7*
Error	**22**	882	36.6

*and** indicate significant at 0.05 and 0.01 levels of probability, respectively

B.2 . Mean- performance of M_2 generation

Concerning the data in Table 6 which represent the average of total biological yield plant^{-1} in g and pods yield plant^{-1} in g of the two genotypes and the 4 levels of gamma irradiation doses. Although, no significant differences were detected between the two genotypes for both traits, the NC1 exhibited the higher values for total biological yield plant^{-1} (195.5g) and pods yield plant^{-1} (44.5) g. Concerning to the mean-performance of the different studied traits under the effect of gamma irradiation dose, the low irradiation dose (100 Gy) achieve the maximum values of, the total biological yield plant^{-1}(214.64 g), pods plant^{-1}(53.1 g). On the other hand, the higher dose (300 Gy) caused the higher reduction in total biological yield plant^{-1} in g and pods yield plant^{-1} in g.

Table 6. Means of biological yield and pod yield plant^{-1}for main effects of genotypes and gamma ray in the 2015 season.

Genotypes	Gamma	Biological yield plant^{-1} (g)	Pod yield plant^{-1} (g)
Giza 6		126.39	40.36
NC-1		195.54	44.52
LSD0.05		**Ns**	**Ns**
	Control	110.79	44.52
	100	214.62	53.10
	200	174.69	39.18
	300	143.76	32.95
LSD0.05		**37.37**	**7.62**

B.3. Descriptive statistics of M_2 generation plants

B.3.1 Total biological yield plant^{-1} in g

Respecting the total biological yield plant^{-1} for M_2 plants in g, for Giza-6 the results in Table 7 indicated, that the treated plants by gamma irradiation having the highest values for biological yield as compared to control treatment, the highest mean value (162.6 g plant^{-1}) was detected under 100 Gy, meanwhile the lowest mean value (101.9 g plant^{-1}) was detected under control condition. Regarding the statistical parameters, the higher values of standard deviation(S=68.24), coefficient of variability (CV%=48.17%), skewness (SK=+1.3) and range (=299.5g) were detected under 100 and 200Gy and the lowest values of S (21.24), CV (20.84%), SK (+0.67) and range (76.5g) was detected under control treatment. In respect to the second genotype NC-1, it exhibited a higher mean-performance value of the total biological yield as compared to Giza-6 under the four gamma doses the greatest mean value of total biological yield (266.3 g) was achieved under 100Gy meanwhile; the lower one was recorded under control (119.66 g). Concerning the different statistical parameters, the higher values of S (90.63), CV% (33.99%) and the range (331.0 g) was recorded under 100 Gy. Meanwhile, the highest value of SK (+1.14) was recorded under 200 Gy. So from the above results it could be concluded, that great differences were detected between the two genotypes in biological yield under different levels of gamma irradiation. Moreover, the gamma rays doses caused a greatest effect in the mean of biological yield for both genotypes which reflected on the different statistical parameters which increase by increasing the gamma irradiation doses. Positive skewed to the weight was detected for the both genotypes under the four levels of gamma irradiation. Also, it could be add, that the two irradiation gamma dose (100 and 200 Gy) are the more usefully and efficiency for genetic variation induction, these results are confirmed with those obtained by Benslimani, and Khelifi (2009), Pachore *et al*, (2012), Bedawy et at. (2018) and Safina et al (2025).

Table 7. Mean, standard deviation (S), coefficient of variation (CV%), Skewness (SK) and the range of studied traits for Giza-6 and NC-1 in seasons 2015.

Biological yield plant^{-1} of Giza 6					Biological yield plant^{-1} of NC-1				
	0	**100**	**200**	**300**		**0**	**100**	**200**	**300**
Mean	101.91	162.60	132.25	108.79	**Mean**	119.66	266.63	217.13	178.73
S	21.24	68.24	63.70	59.91	**S**	19.21	90.63	65.38	69.83
CV%	20.84	41.97	48.17	55.07	**CV%**	16.06	33.99	30.11	39.07
Sk	0.67	0.24	1.30	0.62	**Sk**	0.25	0.94	1.14	0.88
Range	76.51	292.10	299.50	248.00	**Range**	61.03	331.00	332.00	265.00
Pod yield plant^{-1} of Giza 6					**Pod yield plant^{-1} of NC-1**				
Mean	35.32	50.93	39.35	35.83	**Mean**	36.71	55.27	39.02	30.07
S	8.22	21.18	15.44	19.87	**S**	10.48	19.22	21.95	11.34
CV%	23.28	41.58	39.24	55.45	**CV%**	19.51	34.78	56.25	37.71
Sk	0.52	0.49	0.43	0.67	**Sk**	0.59	0.56	1.50	0.51
Range	30.91	88.20	70.50	82.80	**Range**	30.83	67.00	97.00	43.00

B.3.2. Pods yield plant^{-1} in g

The results in Table 7 shows, for Giza-6 the mean values of pods yield plant^{-1} in g ranged between 35.3 g under control to 50.93 g under 100 Gy. Concerning the descriptive statistical parameters, the results show that, the highest value of S (21.18), and the range (88.2g) were recorded under 100Gy. Meanwhile, 300 Gy exhibited the highest values for CV% (55.45%) and SK (+0.67). On the other hand, the control treatment exhibited the lowest values of S (8.22), CV% (23.28%), and range (30.91 g). For NC-1 the mean values of pods yield plant^{-1} in g ranged between 30.07 to 55.27 g under 300 and 100Gy, respectively. Concerning the measures of variability, the control treatment (0 Gy) exhibited the lowest values of S (10.48), CV% (19.51%), SK (+0.59) and the range(30.83 g) on the other hand the higher values of S (21.95), CV% (56.25%), SK (+1.5)and the range (97 g) were recorded under 200Gy. From the above results it could be concluded, that a great variation was detected for pods yield plant^{-1} in g as a result of gamma irradiation as compared to control treatment. Cheah 1988 mentioned that the lower irradiation doses led to better performances than controls in terms of pods plant^{-1} and pod dry weight. On the other hand, Tshilenge-Lukanda *et al*., 2013 mentioned, that by using 100 Gy, significant increment in number of pods by (37%) was recorded.

B.4. Relative frequency distribution of M_2 plants

B.4.1. Total biological yield plant^{-1}

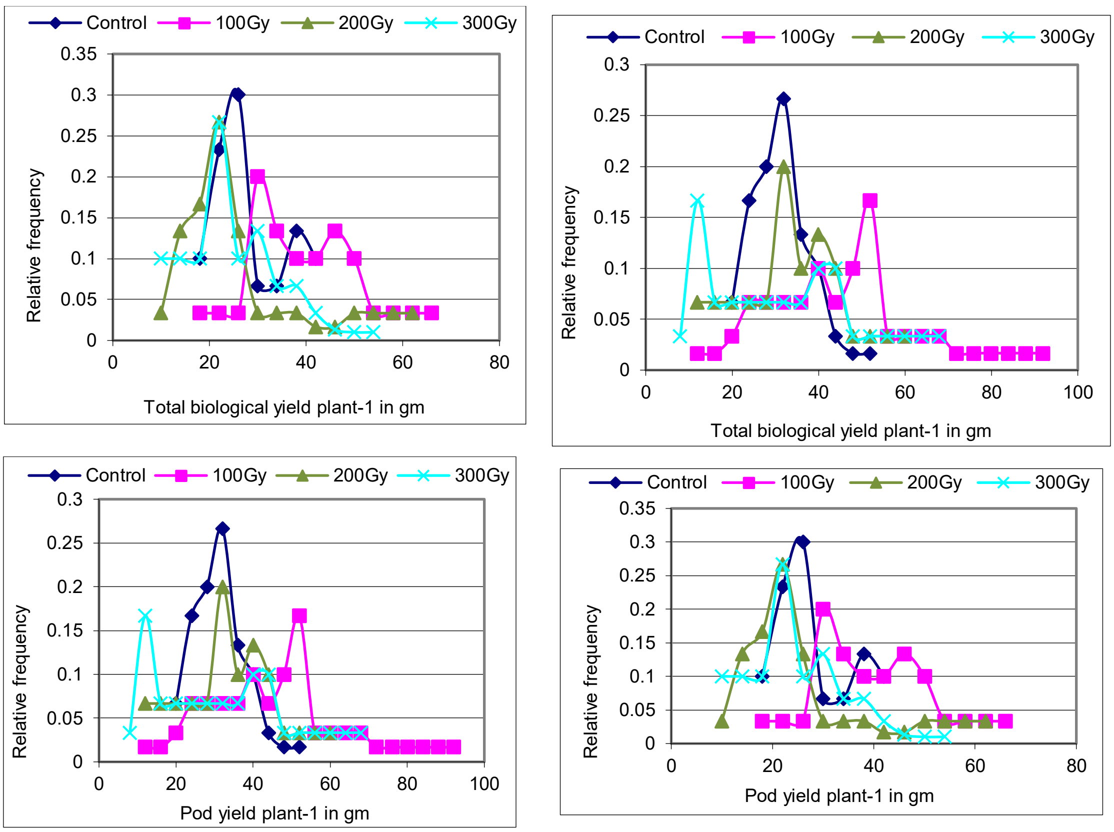
The relative frequency distribution (Fig.1) for total biological yield plant^{-1} of the two genotypes under different gamma irradiation dose for M_2 plants showed that, the total biological yield plant^{-1}for Giza 6, ranged between 66.5 to 143.02, 27.9 to 320.0 , 50.5 to 350 and 20.0 to 268.0 g under 0, 100, 200, 300 Gy, respectively concerning to NC-1the range of the total biological yield plant^{-1} was 89.5 to 150.5, 154.0 to 485.0, 88.0 to 420.2 and 90.0 to 355.0 g under 0, 100, 200, 300 Gy, respectively. Also, the results in Table (8) exhibited the highest ratio of superior mutated plants 80.6% (compared to the mean of control) and 68.3% (compared to the highest value of control) was resulted under 100 Gy for Giza 6. Respect to NC-1, the high ratio of superior mutated plants (100%) as compared to the mean value of control and (83.2%) compared to the highest value of control was resulted under 100 Gy. Moreover, greatest genetic variability was detected between the both genotypes, so, NC-1 exceeded Giza-6 for biological yield under different gamma irradiation treatments. From the above results it could be concluded, that the irradiation treatment caused a high degree of variability for biological yield plant^{-1} which reflected on the maximum and minimum values as compared to control treatment. Moreover, the highest degree of mutated plants could be obtained as a result of treatment of 100 Gy (Fig.1 and Table 8).

Table 8. Percentage (%) of superior mutated plants as compared to the mean and the highest values of control for studied traits of the two genotypes under different irradiation doses (ID).

G	Giza-6				NC-1			
ID	Mean value of control	% of mutated plants >mean value	Highest value of control	% of mutated plants >highest value	Mean value of control	% of mutated plants >mean value	Highest value of control	% of mutated plants >highest value
Biological yield plant^{-1} (g)								
100	101.9	80.6	143.02	68.3	119.66	100	180.5	83.2
200		56.3		40.2		93.2		73.1
300		40.9		26.5		75.2		30.3
Pods dry weight plant^{-1} (g)								
100	35.32	54.2	53.4	46.2	53.7	43.1	72.3	23.5
200		50.2		23.2		23.5		10.6
300		43.1		20.1		6.3		0.0

B.4.2. Pods yield plant^{-1} in g

Fig 1 represents the relative frequency distribution for pods yield plant^{-1} of M_2 generation plants of the two genotypes under different gamma irradiation doses. For Giza 6, the results showed that, the pods yield plant^{-1}, ranged between 22.5 to 53.4 g under control treatment, 15.9 to 104.1g under 100 Gy, 9.5 to 80.1 g under 200 Gy, and 6.8 to 88.5 g under 300 Gy, concerning to NC-1 the range of pods yield plant^{-1} was 41.2 to 72.3 g under control treatment, 29.1 to 96.5 g, under 100 Gy, 13.5 to 110.5 g under 200 Gy and 12.3 to 55 g under 300 Gy. Also, the results in Table (8) exhibited, for Giza6 the highest ratio of superior mutated plants (54.6%) as compared to the mean of control and 46.3% (compared to the highest value of control) were resulted under 100 Gy. With Respect to NC-1, the highest ratio of superior mutated plants (43.1%) as compared to the mean value of control and (23.1%) compared to the highest value of control were resulted under 100 Gy . From the results in Fig1 and Table 8 it could be concluded that, by increasing gamma irradiation dose, it caused a greatest reduction in percentage of superior mutated plants as compared to mean and the greatest value of control treatment. Moreover, greatest genetic variability was detected in the interaction between the both genotypes and different gamma irradiation dose, 100 Gy consider the optimum dose that cause maximum of mutation with minimum of damage to the plant meanwhile, 300 Gy caused the greatest reduction in the percentage of beneficial mutation plants.



Giza 6 **NC-1**

Fig. 1. Relative frequency distribution of total dry matter plant^{-1} and pods yield plant^{-1} for Giza 6 and NC-1 as affected by 4 gamma ray doses.

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