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# Improvement and Selection of Gamma-ray Treated Beans

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## ABSTRACT

This work was performed at Sids Horticulture Research Station, Agriculture Research Center, Egypt, during the period from 2016 to 2017 to study the influence of gamma rays on growth and productivity in two generations ($M_1$ and $M_2$) of two bean (*Phaseolus vulgaris* L.) cultivars under normal growing conditions to improve the crop. Seeds of two commercial cultivars (Nebraska and Paulista) were subjected to five different potions of gamma rays *i.e.,* 25, 50,100, 150 and 300 Gy from cobalt–60. Significant differences between irradiated and non-irradiated plants were detected for most of the studied characters in the $M_1$ and $M_2$ generations. The seeds of both Nebraska and Paulista cultivars germinated up to 100 and 150 Gy doses, respectively. Days to germination decreased significantly at 25 Gy followed by 50 and 100 Gy as compared to control for both cultivars (with no significant differences among them in Paulista). The doses 50 and 25 Gy along with control treatments were the highest for germination percentage for both cultivars with no significant differences among. Individually selection procedure was applied in the second generation. Four promising lines were selected *i.e.*, NB-4, NB-9, NB-2 and NB-7 from Nebraska cv and five promising lines PS-4, PS-9, PS-10, PS-6 and PS-1 from Paulista population. Correlation studies generally indicated that plant height, branches per plant, both length and thickness of pod, seeds per pod, weight of 100-seeds, both number and weight of pods per plant were significantly positive correlated with dry seed yield.

***Keywords:*** Bean (*Phaseolus vulgaris* L.), gamma-rays, correlation.

## INTRODUCTION

Snap and dry bean (*Phaseolus vulgaris* L.) is one of the most important vegetable crops in Egypt for local market and exportation. There are intensive efforts, recently, for improvement of dry and snap bean productivity in Egypt through breeding procedures. Plants improvement largely based on the range of genetical variances available within the species (Umavathi *et al.* 2015). Variability of genetic is the most prerequisite for successfully crop improvement program as it tool up the variants spectrum for effective selection (Kharkwal *et al.* 2004). Khan and Wani (2005 & 2006) reported that may be resorted to develop superior genotypes with creating heritable variation in polygenic traits by induced mutations according to their direct and cumulative effect on genetic background of the biological material under study. Variance level may be less responsive in one trait and highly responsive in others (Badigannavar and Murty 2007). Induced Mutation is an important integration method for plant breeding (Mahamune and Kothekar 2011). Gamma irradiation is one of the major somatic mutagenesis in plants. the reverse effects on plant traits depended on plant species or varieties and the irradiation doses (Artk and peksen 2006). Artificial mutations facilitates the improved plants development at a faster rate (Baisakh *et al.* 2011 and Wani 2018). The mutation breeding technique can be applied for changing specific characters in good varieties by combining some useful variations in relatively shorter period of time (Wani 2019). In a mutation programme of the seed crops, there is a need to determine the suitable dose and the method of dealings the $M_1$ and $M_2$ populations because of it is expected that the mutant is recessive and can be detected only as a homozygote in the $M_2$. The dose should result in the highest spectrum of mutations. Mutants in French bean (*Phaseolus vulgaris* L.) having improved grain yield have been obtained (Hussein and Disouki 1979). Cheah and Lim (1982) stated that no significant differences in germination scores were obtained between the non-irradiated control and the seeds subjected to 10, 20, 25, 30, 35 and 40 Krads of gamma rays and the dose of 30 Krads is the most suitable level of gamma radiation using in a mutation breeding programme. Many investigators have used ionizing radiation such as gamma rays to induce useful mutations for developing new genetic variants in the same time, various studies have reported that irradiation technique is one of prime importance in agriculture for improvement the productivity of crop *i.e.*, Borkar and More (2010), Khan *et al.* (2018) and Goyal *et al.* (2019).

They thought that seed irradiation may affect some of the biochemical regulatory mechanisms involved in seed germination, plant growth and yield, especially in consequence of gamma irradiation of seeds pre-sowing and reported that the quantitative traits showed higher genetic variability in $M_2$ generation revealing that potential gain could be carried out during selection in early $M_2$ generation. In one hand, Hassan *et al.* (2000) on cowpea

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found that irradiation treatments caused decrease in shoot dry weights with the increase of gamma dose from 20 to 80 Krad. On the other hand, Soliman and Abd-el hamid (2003) irradiated the dry seeds of kidney bean (*Phaseolsus vulgaris* cv.Giza 6) with different dosages (2.5-15.0 krads) and found that the shoot length, number of lateral branches, fresh and dry weights of kidney bean shoots as well as number of pods per plant and both fresh and dry weights of pods per plant were significantly increased in response to gamma irradiation of the seeds with 2.5 and 5.0 k.rad while all preceding growth parameters and yield components showed significant reduction due to irradiating the seeds with 10.0 and 15.0 k.rad comparing with their respective controls. However, when Beltagi *et al.* (2006) exposed dry seeds of common bean (*Phaseolus vulgaris* l. cv. Nebraska) to 0, 2 and 32 Krad of gamma rays recorded that, under highest dose (32 Krad) of gamma irradiation the seedling emerged but it did not continue growth and indicated 100% lethality, the low dose (2 Krad) significantly reduced the shoot length.

Therefore, the objectives of this investigation were to Study the effect of gamma irradiation on yield and yield components of Nebraska and Paulista bean cultivars, determine the proper dose of gamma radiation for inducing beneficial genetic variability in bean and throw light on the genetic parameters under irradiated and non-irradiated plants and its impact in plant selection procedure.

## MATERIALS AND METHODS

The experiments were carried out at Sids Horticulture Research Station, Beni-Suef Governorate, Agriculture Research Center, Egypt, during three fall and summer seasons of 2016 to 2017. Two bean cultivars (*Phaseolus vulgaris* L.) were used in this study namely Nebraska and Paulista. The cultivar Nebraska used for produced dry seeds while Paulista cultivar used for produced green pods. Seeds of two commercial cultivars were exposed to five different doses of gamma–rays i.e. 25, 50,100, 150 and 300 Gy of cobalt–60 source at a dose rate of 7.03 Gy/min before sowing. The source of radiation was that installed at the Middle Eastern Regional Radioisotope Centre for the Arab Countries (MERRCAC), Dokki, Cairo, Egypt. Seeds were planted in field experiments, to evaluate the performance of the first mutant generation ($M_1$) of both cultivars in separate experiment along with untreated seeds ($M_0$ control), on the 1st of September 2016. $M_1$ plants were harvested individually at maturity to obtain $M_2$ seeds. $M_0$ (untreated seeds), $M_1$ and $M_2$ generation were raised simultaneously and data were recorded. on the 5th March 2017, seeds of $M_0$ (untreated seeds), $M_1$ and $M_2$ generation were planted. Three replications of 150-seeds each were sown for every treatment and control in each variety in a Randomized Complete Blocks design. Each plot area was 10.5 $m^2$ and which included 3 rows with 70 cm width and 5m length. Seeds were planted at 5 cm apart. Ten plants were selected from two population cultivars. The ten $M_2$ progenies showing significant negative deviation in mean values from their respective controls particularly for yield and its components were selected. In 6th of September 2017, the seeds of each of the ten selected $M_2$ progenies were grown along with untreated seeds of two cultivars in a progeny row trial with three replications to determine $M_3$.

Row to row and plant to plant distance were the same of $M_1$ and $M_2$ generations. Observations on various quantitative traits were recorded on all the plants in each treatment. Agronomic practices were employed as the recommended for the preparation of field, sowing and subsequent management of the common bean.

**Data recorded**

**Vegetative growth traits:** morphological parameters i.e., germination response after sowing (days to germination), germination percentage %, plant height and number of branches per plant were recorded.

**Yield and yield components,** in dry harvest, ten plants from each experimental plot were randomly taken to determine pod length, pod width, pod thickness, number of seed per pod, number of pod per plant and seed weight per plant.

**Statistical analysis,** the collected data were statistically analyzed according to the method described by Snedecor and Cochran (1981). Means for all generations were compared using Duncan's multiple range test as published by Duncan (1955). All statistical analyses were performed using analysis of variance technique by means of MSTATC computer software package (Freed et al., 1991). The simple correlation coefficients were calculated following Singh and Chaudhary (1985).

## RESULTS AND DISCUSSION

The effect of treatments with gamma-rays in the first ($M_1$) and second ($M_2$) generations were estimated by observing the following characteristics.

**Days to germination**

Days to germination of bean for $M_1$ generation as affected by gamma irradiation are represented in Table (1). The results show that days to germination were significantly affected by gamma irradiation. Days to germination decreased significantly at 25 Gy (10 days) followed by 50 Gy and 100 Gy (12 days) as compared to control (14 days).

For Paulista cultivar, days to germination decreased significantly at 25 Gy (10 days) followed by 100 and 50 Gy (12 days) and 150 Gy (14 days) comparing with control (14 days). Some authors found faster seed germination caused by gamma irradiation, *i.e.,* Kovacs and Keresztes (2002) and Aynehband and Afsharinafar (2012). This is probably consequent to more energetic of shortwave photons (i.e. gamma rays) than visible light photons (> 400 nm) and, therefore, have an intense effect on the cells surface of the plant causing the final breakdown of the seed coat and allowing germination to occur (Khan *et al*. 2018)

**Germination percentage %**

The results in Table (1) revealed that the gamma irradiation have significantly affected on germination percentage. The seeds germinated up to 100 and 150 Gy for Nebraska and Paulista cultivars, respectively. It is obvious that, no significant differences were observed between each of 0, 25 and 50 Gy doses in germination percentage of both cvs. The doses 50 Gy (98.3 and 97.0 %), 25 Gy (97.3 and 97.0 %) and the control (98.0 and 97.5%) were the highest germination percentage followed by 100 Gy (80.7 and 82.3%) for Nebraska and Paulista cultivars, respectively. The dose 150 Gy exhibited the lowest in germination percentage (67.7 %) for paulista cultivar. Germination percentage was decreased with 100 and 150 Gy doses. These results agreement with which reported by Cheah and Lim (1982) and Hameed *et al* (2008). They found that final germination percentage was decreased significantly after higher irradiation doses ranging from 800 to 1000Gy.

Germination frequency was not much affected to seeds irradiated with 5kr and control. Germination frequency was high 95.9% in control plants followed by 5 kr (95.8%), 15 kr (75.8%) and 20 kr (70.8%) and 25 kr (66.1%) in irradiated plantlets for irradiated pea seeds.

Animating causes of gamma ray on germination may be certified to RNA activation or protein synthesis during the early stage of germination after seed irradiated (Abdel-Hady *et.al.* 2008). Khan *et al.* (2018) reported that the percent of germination was insignificantly affected by gamma irradiation and germination percentage was kept maximum by all the doses compare to control (100 %) in pea.

**Table1. Days to germination and germination percentage (%) as affected by gamma irradiation for two bean cultivars.**

| Gamma irradiation doses ( Gy) | Days to germination | | Germination percentage % | |
|---|---|---|---|---|
| | Nebraska | Paulista | Nebraska | Paulista |
| 0 | 14.0 a | 14.0 a | 98.0 a | 97.5 a |
| 25 | 10.0 c | 10.0 b | 97.3 a | 97.0 a |
| 50 | 12.0 b | 12.0 ab | 98.3 a | 97.0 a |
| 100 | 12.0 b | 12.0 ab | 80.7 b | 82.3 b |
| 150 | not germinate | 14.0 a | 0.0 c | 67.7 c |
| 300 | not germinate | not germinate | 0.0 c | 0.0 d |
| Grand mean | 12.0 | 12.4 | 62.4 | 73.7 |
| C.V.% | 4.17 | 8.83 | 1.79 | 2.54 |

The results (Tables 2 and 3) show that all studied traits were significantly affected by gamma irradiation in both $M_1$ and $M_2$ generations except number of branches and both number and weight of pods per plant for $M_1$ and pod width for $M_2$ of Nebraska as well as seed yield for $M_2$ of Paulista cv. It is obvious from data that, no significant differences between 25 and 50 Gy treatments on each of plant height ($M_2$), number of branches ($M_1$ and $M_2$), pod length ($M_1$ and $M_2$), number of seeds/pod ($M_2$) of Nebraska and both number of branches ($M_1$) and pod width ($M_2$) of Paulista cv and also, between 25 and 100 Gy treatments on each of pod thickness ($M_2$), number of seeds/pod ($M_1$) of Nebraska and pod length ($M_2$) of Paulista as well as between 25 and 150 Gy treatments on the weight of pods/plant in $M_2$ generation of Paulista. Therefore, it can be considered that the dose of 25 Gy is the most appropriate to improve these traits and the most economical in the corresponding generation. On the other hand, insignificant differences between control (zero dose) and 50 Gy treatment for pod width in $M_1$ generation of Nebraska as well as number of seeds/pod ($M_1$) and both number and weight of pods/plant in $M_1$ of Paulista and between zero dose and 100 Gy on pod weight and seed yield in $M_1$ generation of Nebraska and seeds/pod count. in $M_2$ generation of Paulista were obtained. Thus, the radiation treatments used in this research have no significant consideration on pod width, pod weight and seed yield in $M_1$ generation of Nebraska as well as both number and weight of pods/plant in $M_1$ and seeds number/pod in both generations of Paulista. These results are in line with Khan *et al* (2018), where they found that gamma irradiation showed a decreasing tendency with increasing radiation doses and inhibitory effect on number of seeds/pod for pea.

On the other hand, Soliman and Abd-el hamid (2003) irradiated the dry seeds of kidney bean (*Phaseolsus vulgaris* cv. Giza 6) with different dosages (2.5-15.0 krads) and found that the shoot length, number of lateral branches as well as pods number per plant and both fresh and dry weights of pods per plant were significantly increased in response to gamma irradiation of the seeds with 2.5 and 5.0 k.rad and reduction in range of 10.0 and 15.0 k.rad comparing with controls. Low coefficients of variation (in $M_2$ generation comparing with $M_1$) for all the characters except the seed yield of Paulista, number and weight of pods of both Nebraska and Paulista in $M_2$ generation encourages the use of yield and some of its components in selection of suitable lines further improvement. Traits such as plant height and number of seeds of $M_2$ Nebraska and pod width of $M_2$ Paulista may be considered where there is need to support the yield parameters because their coefficients of variation were comparatively large (Tables 2& 3).

**Table 2. Effect of gamma irradiation on five traits for bean Nebraska and Paulista populations.**

| Gamma irradiation doses ( Gy) | Plant height(cm) | | Branches / plant | | Pod length (cm) | | Pod width (cm) | | Pod thickness (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $M_1$ | $M_2$ | $M_1$ | $M_2$ | $M_1$ | $M_2$ | $M_1$ | $M_2$ | $M_1$ | $M_2$ |
| Nebraska population | | | | | | | | | | |
| 0 | 44.3 c | 44.3 b | 2.8 a | 2.8 b | 11.0 b | 11.0 b | 0.82 a | 0.82 a | 0.79 a | 0.79 c |
| 25 | 49.3 b | 58.0 a | 3.0 a | 4.4 a | 14.7 a | 12.6 a | 0.73 b | 0.83 a | 0.68 b | 0.91a |
| 50 | 58.3 a | 49.5 ab | 3.3 a | 4.5 a | 14.5 a | 13.1 a | 0.82 a | 0.82 a | 0.78 a | 0.84 bc |
| 100 | 42.5 c | 43.2 b | 3.1 a | 4.5 a | 13.2 a | 12.4 ab | 0.75 ab | 0.86 a | 0.63 b | 0.87 ab |
| 150* | - | - | - | - | - | - | - | - | - | - |
| 300* | - | - | - | - | - | - | - | - | - | - |
| Mean | 48.6 | 48.8 | 3.1 | 4.1 | 13.3 | 12.3 | 0.8 | 0.8 | 0.7 | 0.9 |
| C.V.% | 3.8 | 12.2 | 8.4 | 8.8 | 5.8 | 5.6 | 3.9 | 3.3 | 5.7 | 3.9 |
| Paulista population. | | | | | | | | | | |
| 0 | 41.7 b | 41.7 c | 3.4 b | 3.4 d | 10.6 c | 10.6 b | 0.51 b | 0.51 b | 0.61 bc | 0.61 bc |
| 25 | 46.3 a | 47.8 b | 4.1ab | 4.5 b | 11.4 b | 11.7 ab | 0.51 b | 0.65 ab | 0.56 c | 0.63 bc |
| 50 | 44.4 ab | 40.9 c | 4.7 a | 3.9 c | 12.9 a | 11.7 ab | 0.58 a | 0.67 a | 0.60 bc | 0.55 c |
| 100 | 46.3 a | 52.4 a | 4.4 a | 5.3 a | 11.3 b | 12.9 a | 0.52 b | 0.62 ab | 0.70 a | 0.66 ab |
| 150 | 33.3 c | 47.4 b | 3.1 b | 4.4 b | 9.5 c | 12.1 a | 0.59 a | 0.64 ab | 0.65 ab | 0.73 a |
| 300* | - | - | - | - | - | - | - | - | - | - |
| Mean | 42.4 | 46.0 | 3.9 | 4.3 | 11.1 | 11.8 | 0.53 | 0.62 | 0.62 | 0.63 |
| C.V.% | 3.9 | 3.3 | 12.8 | 5.7 | 4.3 | 6.6 | 6.9 | 12.4 | 5.5 | 6.7 |

**Means followed by the same letters within each column do not differ significantly according to Duncan's Multiple Range test at the 5% level. * = The seeds did not germinate**

**Table 3. Effect of gamma irradiation on four traits for bean Nebraska and Paulista populations.**

| Gamma irradiation doses ( Gy) | Seed number /pod | | Pod number/plant | | Pod weight/plant (g) | | Seed Weight / plant (g) | |
|---|---|---|---|---|---|---|---|---|
| | Nebraska population | | | | | | | |
| 0 | 4.6 b | 4.6 b | 14.3 a | 14.3 b | 24.8 a | 24.8 b | 16.9 ab | 16.9 b |
| 25 | 5.1 ab | 4.9 a | 17.3 a | 13.1 b | 24.0 a | 22.0 b | 12.2 b | 18.9 b |
| 50 | 5.3 ab | 5.5 a | 16.3 a | 13.4 b | 25.0 a | 26.3 b | 15.0 ab | 18.5 b |
| 100 | 5.6 a | 4.8 a | 16.2 a | 25.4 a | 26.0 a | 38.1 a | 17.2 a | 28.4 a |
| 150* | - | - | - | - | - | - | - | - |
| 300* | - | - | - | - | - | - | - | - |
| Mean | 5.2 | 4.9 | 16.1 | 16.6 | 24.9 | 27.8 | 15.3 | 20.7 |
| C.V.% | 8.5 | 11.5 | 17.5 | 20.0 | 14.9 | 16.7 | 15.0 | 10.0 |
| | Paulista population. | | | | | | | |
| 0 | 7.2 a | 7.2 a | 22.3 a | 22.3 ab | 14.0 ab | 14.0 b | 8.7 b | 8.7 a |
| 25 | 5.4 b | 5.5 b | 17.3 b | 21.2 ab | 12.6 b | 16.0 ab | 9.0 b | 10.3 a |
| 50 | 6.7 a | 5.7 b | 23.0 a | 17.0 b | 17.4 a | 14.2 b | 12.8 a | 8.6 a |
| 100 | 5.2 bc | 7.4 a | 16.4 b | 26.1 a | 12.2 b | 17.1 ab | 7.2 b | 10.7 a |
| 150 | 4.4 c | 6.0 b | 20.8 ab | 24.2 ab | 14.0 ab | 21.5 a | 8.3 b | 11.7 a |
| 300* | - | - | - | - | - | - | - | - |
| Mean | 5.8 | 6.4 | 19.9 | 22.1 | 14.0 | 16.6 | 9.2 | 10.0 |
| C.V.% | 7.7 | 6.5 | 11.5 | 19.4 | 14.1 | 21.6 | 19.4 | 28.1 |

**Means followed by the same letters within each column do not differ significantly according to Duncan's Multiple Range test at the 5% level. * = The seeds did not germinate**

**Selected lines in the 3rd generation ($M_3$) of both populations**

The selected lines mean in 3rd generation ($M_3$) are presented in Table 4. For Nebraska population, NB-2, NB-4, NB-7 and NB-9 lines were higher in number of pods/plant, pods weight/plant, seed weight/plant, pod length, number of seed/pod, pod width, pod thickness,100-seed weight and branches/plant than initial Nebraska cultivar and grand mean. NB-4 and NB-9 populations having the tallest plants and exhibited appropriate values for all traits. For Paulista population, PS-4, PS-9, PS-10, PS-6 and PS-1 lines were higher in pods number/plant, pods weight/plant, seed weight/plant, branches/plant and plant height than parent and grand mean, while were the least for 100-seed weight. PS-6, PS-9, PS-1 and PS-4 lines were higher in seed number/pod than parent and grand mean. PS-3, PS-8 and PS-10 lines were the thin in pod thickness. PS-3, PS-4, PS-6, PS-8 and PS-10 populations were the least in pod width. PS-4, PS-5, PS-9 and PS-10 populations were the tallest in pod length. Generally, four promising mutants were selected from $M_3$ generation were NB-4, NB-9, NB-2 and NB-7 populations for Nebraska population and five promising mutants were selected from $M_3$ generation were PS-4, PS-9, PS-10, PS-6 and PS-1 populations for Paulista population. These lines in two cultivars can be developing promising new lines by selection in the following generations.

**Table 4. Mean values of ten traits for selected lines in the third ($M_3$) generation of two bean populations.**

| Population | Plant height (cm) | branches/ plant | Pod length (cm) | Pod width (cm) | Pod thickness (cm) | Seed number/ pod | 100- seed weight (g) | Pod number/ plant | Pod weight/ plant (g) | Seed weight / plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Nebraska populations ($M_3$)** | | | | | | | | | |
| NB-1 | 53.0 c | 4.8 b | 11.3 d | 0.94 a | 0.92 a | 4.4 c | 42.4 fg | 25.3 bc | 37.0 b | 27.3 bc |
| NB-2 | 53.7 c | 5.0 b | 13.1 a | 0.83 b | 0.91 a | 5.6 a | 56.4 ab | 38.0 a | 49.7 a | 36.3 a |
| NB-3 | 45.0 f | 3.9 c | 11.4 d | 0.79 b | 0.82 b | 5.2 ab | 49.7 d | 22.0 cd | 38.3 b | 25.0 cd |
| NB-4 | 62.3 a | 5.8 a | 13.0 a | 0.91 a | 0.91 a | 5.6 a | 53.3 bc | 39.3 a | 52.7 a | 36.0 a |
| NB-5 | 46.0 ef | 4.0 c | 12.3 c | 0.83 b | 0.82 b | 4.7 bc | 46.3 e | 24.3 bcd | 35.3 bc | 29.0 b |
| NB-6 | 51.0 cd | 4.9 b | 11.3 d | 0.95 a | 0.92 a | 4.4 c | 42.0 g | 26.7 b | 39.3 b | 27.0 bc |
| NB-7 | 48.3 def | 4.8 b | 13.0 a | 0.84 b | 0.85 b | 5.5 a | 56.8 a | 36.7 a | 48.0 a | 36.0 a |
| NB-8 | 48.3 def | 3.9 c | 12.0 c | 0.81 b | 0.82 b | 5.2 ab | 45.3 ef | 21.3 d | 31.7 c | 24.0 d |
| NB-9 | 58.3 b | 5.7 a | 12.8 ab | 0.90 a | 0.95 a | 5.4 a | 50.7 cd | 39.0 a | 52.7 a | 34.7 a |
| NB-10 | 49.7 cde | 3.9 c | 12.5 bc | 0.82 b | 0.84 b | 4.5 c | 46.0 e | 24.0 bcd | 34.7 bc | 28.7 b |
| Nebraska | 45.1 f | 3.8 c | 11.4 | 0.83 b | 0.78 c | 4.5 c | 49.8 d | 19.3 e | 27.8 c | 21.0 e |
| Grand mean | 51.0 | 4.6 | 12.2 | 0.86 | 0.87 | 5.0 | 49.0 | 28.7 | 40.7 | 29.6 |
| C.V.% | 4.4 | 5.4 | 2.2 | 2.2 | 3.9 | 6.6 | 3.7 | 7.0 | 6.8 | 5.2 |
| | Paulista populations ($M_3$) | | | | | | | | | |
| PS-1 | 55.7 b | 4.7 b | 12.4 c | 0.60 ab | 0.61 b | 7.2 ab | 21.1 bcd | 26.7 c | 33.0 ab | 24.7 a |
| PS-2 | 54.7 b | 5.1 ab | 11.3 d | 0.61 a | 0.61 bc | 6.4 cd | 25.2 a | 25.7 c | 28.0 de | 20.0 b |
| PS-3 | 51.0 c | 4.7 c | 11.3 d | 0.51 c | 0.55 c | 6.2 d | 24.3 a | 22.7 d | 26.7 e | 18.0 b |
| PS-4 | 60.0 a | 5.5 a | 15.0 a | 0.50 c | 0.65 ab | 7.3 ab | 20.1 d | 31.7 a | 35.3 a | 26.0 a |
| PS-5 | 53.7 bc | 4.2 c | 13.6 b | 0.56 abc | 0.62 b | 6.0 d | 23.2 ab | 26.3 c | 30.0 cd | 20.7 b |
| PS-6 | 55.0 b | 4.9 b | 12.1 c | 0.54 bc | 0.61 b | 7.4 a | 21.7 bcd | 28.3 bc | 33.0 ab | 24.7 a |
| PS-7 | 51.3 c | 5.0 b | 11.2 d | 0.60 ab | 0.62 b | 6.4 cd | 23.5 ab | 26.0 c | 27.3 e | 19.7 b |
| PS-8 | 51.3 c | 4.0 c | 11.5 d | 0.51 c | 0.55 c | 6.4 cd | 24.3 a | 23.0 d | 26.3 e | 19.0 b |
| PS-9 | 56.0 b | 5.2 ab | 14.9 a | 0.62 a | 0.68 a | 6.9 bc | 23.0 abc | 30.7 ab | 34.7 a | 25.7 a |
| PS-10 | 55.0 b | 4.1 c | 14.0 b | 0.54 c | 0.61 bc | 6.4 cd | 21.0 cd | 27.0 c | 31.7 bc | 23.7 a |
| Paulista | 48.7 d | 3.6 d | 11.6 d | 0.54 c | 0.62 b | 6.3 cd | 21.0 cd | 23.1 d | 20.0 f | 13.7 c |
| Grand mean | 53.6 | 4.6 | 12.6 | 0.56 | 0.61 | 6.63 | 22.6 | 26.5 | 29.6 | 21.5 |
| C.V.% | 3.4 | 5.5 | 2.6 | 3.3 | 3.2 | 4.2 | 5.4 | 6.1 | 4.8 | 7.7 |

**Means followed by the same letters within each column do not differ significantly according to Duncan's Multiple Range test at the 5% level.**

**Phenotypic correlation for the third ($M_3$) mutant generation**

Phenotypic correlation coefficients for all comparisons among the studied traits for the third ($M_3$) mutant generation of two bean populations are presented in Table (5) which show that seed yield/plant was positively and significantly correlated with all studied traits except pod width for two bean populations. A significant positive correlation was detected between plant height with all studied traits except with pod width, seed number/pod and 100- seed weight for two bean populations. Seed number/pod and 100-seed weight were positively and significantly correlated with pod length. On the other hand, seed number/pod and 100-seed weight were positively and insignificant correlated with plant height, branches/plant and pod thickness in two populations, while, were negatively and insignificant correlated with pod width in two bean populations. Pod length was positive and significant correlated with all studied traits except pod width and pod thickness in two bean populations. A significant positive correlation was detected between pod width with pod thickness, while were positively and insignificant with pods number/plant, seed weight/plant and pods weight/plant; and was negatively and insignificant with seed number/pod and 100- seed weight for two bean populations.

Correlation studies generally indicated that plant height, number of branches/plant, pod length, pod thickness, number of seed/pod, 100- seed weight, number of pods/plant and weight of pods/plant were positively and significantly correlated with dry seed yield, indicating the importance of these traits as increase yield. These results are in agreement with those reported by Raffi and Nath (2004) who reported that yield was found to be positively significant correlated with number of pods/plant, number of seeds per pod, pod length and seed weight. Dursun (2007) and Sarutayophat and Nualsri (2010) stated that the highest positive significant correlation was found between the number of pods/plant and yield. Karasu and Oz (2010) and Negahi *et al.* (2014) found that correlation coefficients were positively significant between seed yield/plant with number of pods/plant, pod length, number of seeds/ pod and number of branches/plant. Galal *et al*. (2014) and Galal (2015) found that number of pods per plant and number of branches per plant were the most important contributing traits to the total yield variability pod length and number of seeds per pod were positively significant correlations with seed yield per plant. Sadeghi *et al.* (2011), Ahmed and Kamaluddin (2013), Cokkizgin *et al.* (2013), Akhshi *et al.* (2015) and Panchbhaiya *et al.* (2017) and Razvi *et al*. (2018) found positive correlations between seed yield with plant height, number of pods per plant and number of seeds per pod. Ejara *et al.* (2017) and Al-Ballat and Al-Araby (2019) reported that correlations were positive ranging from 0.60 to 0.99 between seed yield per plant and each of plant height, number of pods per plant and number of seeds per pod. Pod width had negative correlations with plant height, number of pods per plant, pod length and number of seeds per pod except with 100-seed weight, also pod length showed negative correlations with plant height, number of pods per plant, pod width and seed yield per plant.

**Table 5. Estimates of phenotypic correlation coefficients between all studied variables in the third ($M_3$) mutant generation of two bean populations.**

| Traits | Branches /plant | Pod length | Pod width | Pod thickness | Seed Number /pod | 100- Seed weight | Pod Number /plant | Pod Weight /plant | Seed Weight / plant |
|---|---|---|---|---|---|---|---|---|---|
| Nebraska population | | | | | | | | | |
| Plant height | 0.785$^{**}$ | 0.388$^{*}$ | 0.300$^{ns}$ | 0.666$^{**}$ | 0.322$^{ns}$ | 0.227$^{ns}$ | 0.696$^{**}$ | 0.670$^{**}$ | 0.538$^{**}$ |
| Number of branches/plant | - | 0.308$^{ns}$ | 0.320$^{ns}$ | 0.718$^{**}$ | 0.345$^{ns}$ | 0.314$^{ns}$ | 0.798$^{**}$ | 0.821$^{**}$ | 0.663$^{**}$ |
| Pod length | | - | -0.218$^{ns}$ | 0.557$^{**}$ | 0.604$^{**}$ | -0.735$^{**}$ | 0.684$^{**}$ | 0.578$^{**}$ | 0.792$^{**}$ |
| Pod width | | | - | 0.693$^{**}$ | -0.245$^{ns}$ | -0.278$^{ns}$ | 0.300$^{ns}$ | 0.304$^{ns}$ | 0.143$^{ns}$ |
| Pod thickness | | | | - | 0.057$^{ns}$ | 0.017$^{ns}$ | 0.566$^{**}$ | 0.567$^{**}$ | 0.381$^{*}$ |
| seed number of /pod | | | | | - | 0.723$^{**}$ | 0.618$^{**}$ | 0.635$^{**}$ | 0.535$^{**}$ |
| 100-seed weight | | | | | | - | -0.706$^{**}$ | 0.698$^{**}$ | 0.791$^{**}$ |
| pods number /plant | | | | | | | - | 0.959$^{**}$ | 0.902$^{**}$ |
| pods weigh /plant | | | | | | | | - | 0.841$^{**}$ |
| Paulista population | | | | | | | | | |
| Plant height | 0.527$^{**}$ | 0.657$^{**}$ | 0.062$^{ns}$ | 0.499$^{**}$ | 0.304$^{ns}$ | 0.342$^{ns}$ | 0.727$^{**}$ | 0.729$^{**}$ | 0.780$^{**}$ |
| Number of branches/plant | - | 0.232$^{ns}$ | 0.290$^{ns}$ | 0.601$^{**}$ | 0.341$^{ns}$ | 0.142$^{ns}$ | 0.598$^{**}$ | 0.481$^{**}$ | 0.405$^{*}$ |
| Pod length | | - | -0.076$^{ns}$ | 0.654$^{**}$ | 0.570$^{**}$ | -0.566$^{**}$ | 0.725$^{**}$ | 0.759$^{**}$ | 0.672$^{**}$ |
| Pod width | | | - | 0.431$^{*}$ | 0.028$^{ns}$ | 0.185$^{ns}$ | 0.159$^{ns}$ | 0.059$^{ns}$ | 0.087$^{ns}$ |
| Pod thickness | | | | - | 0.347$^{ns}$ | -0.343$^{ns}$ | 0.769$^{**}$ | 0.665$^{**}$ | 0.555$^{**}$ |
| seed number of /pod | | | | | - | 0.546$^{**}$ | 0.553$^{**}$ | 0.642$^{**}$ | 0.553$^{**}$ |
| 100-seed weight | | | | | | - | -0.502$^{**}$ | 0.578$^{**}$ | 0.655$^{**}$ |
| pods number /plant | | | | | | | - | 0.868$^{**}$ | 0.718$^{**}$ |
| pods weigh /plant | | | | | | | | - | 0.810$^{**}$ |

**ns, *, ** insignificant, significant and highly significant correlation coefficient, respectively.**

## CONCLUSION

Gamma irradiation significantly affected vegetative growth (plant height and number of branches/plant), yield and its component (pod length, pod width, pod thickness, number of seed/pod, number of pods/plant, weight of pods/plant and seed yield/ plant) in some of $M_1$ and $M_2$ generations of bean. This supports the idea of irradiation effectiveness in the induction of new genetic variation which could be helpful for the plant breeder to successfully improve the important traits by selection in these irradiated populations. Also, low coefficients of variation for all the characters except the seed yield of Paulista, number and weight of pods of both Nebraska and Paulista in $M_2$

generation encourages the use of yield and some of its components in selection of suitable lines further improvement. Traits such as plant height and number of seeds of $M_2$ Nebraska and pod width of $M_2$ Paulista may be considered where there is need to support the yield parameters because their coefficients of variation were comparatively large. Therefore, nine promising lines were selected in $M_3$ generation of both populations,*i.e.*,NB-4, NB-9, NB-2 and NB-7 were derived from Nebraska population and the others five lines, *i.e.*, PS-4, PS-9, PS-10, PS-6 and PS-1 from Paulista population. These lines of two cultivars can be developing promising new lines by selection in the following generations.

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## التحسين والانتخاب فى الفاصوليا المعاملة بأشعة جاما

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اجريت التجارب في محطة بحوث البساتين بسدس - مركز البحوث الزراعية -مصر خلال الفترة من 2016 إلى 2017 لدراسة تأثير اشعة جاما على النمو والإنتاجية في جيلين ($M_1$ و $M_2$) فى صنفين من الفاصوليا زرعت تحت ظروف النمو الطبيعية لتحسين المحصول عن طريق الطفرات حيث تم تعريض بذور صنفين تجاريين من الفاصوليا (نبراسكا وبوليستا) لخمسة جرعات مختلفة من أشعة جاما 25، 50، 100، 150، 300 جراى راد. تمت دراسة ارتفاع النبات وعدد الفروع/النبات وطول القرن الجاف وعدد القرون الجافة/النبات وعدد البذور الجافة/القرن ووزن البذورالجافة ومحصول البذورلكل نبات . اظهرت النتائج وجود فروق معنوية بين النباتات المعاملة بالاشعاع وغير المعاملة بالنسبة لمعظم الصفات المدروسة في الأجيال الاول والثانى . لم تنبت البذور المعاملة بالاشعاع بالجرعتين 150، 300 جراى راد وذلك فى الصنف نبراسكا والمعاملة بالجرعة 300 جراى راد فى الصنف بوليستا. انخفضت أيام الإنبات بشكل ملحوظ عند الجرعة 25 جراى راد تليها الجرعة 50 جراى راد مقارنةً بالبذورالغيرمعاملة في كلا الصنفين. كانت الجرعتان 25، 50 جراى راد الأعلى في نسبة الإنبات لكلا الصنفين. تم انتخاب عشر نباتات من الجيل الثانى من كل صنف على حدة وتم تقييمها مع الاباء الغير معاملة فى الجيل الثالث ($M_3$). تم انتخاب أربعة عشائر واعدة من الجيل الثالث $M_3$ فى الصنف نبراسكا وهى NB-4, NB-9, NB-2, NB-7 وخمس عشائر من الصنف بوليستا هى PS-4, PS-9, PS-1, PS-6 PS-10 ويمكن من هذه العشائر انتخاب سلالات مبشرة جديدة عن طريق الانتخاب فى الاجيال التالية. أشارت دراسة معامل الارتباط إلى أن صفات ارتفاع النبات وعدد الفروع / النبات وطول القرن وسمك القرن وعدد البذو/القرن ووزن 100 بذرة وعدد القرون/النبات ووزن القرون/النبات كانت مرتبطة بشكل إيجابي ومعنوية بمحصول البذورالجافة على النبات وهذا يبين أهمية هذه الصفات فى تحسين الانتاجية فى الفاصوليا. توضح هذه الدراسة إلى أن يمكن احداث الطفرات وتحسين الصفات المختلفة فى الفاصوليا من خلال استخدام أشعة جاما.