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# Growth and yield parameters in gamma irradiated mutant population of $M_2$ generation in field bean [*Lablab purpureus* var. *lignosus* (L.) Prain]

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**Abstract**
An experiment was carried out at vegetable block, College of Horticulture, Anantharajupeta, Andhra Pradesh during 2019 to evaluate the elite mutant lines of the gamma irradiated population of the field bean variety TFB-2 in $M_2$ generation. Among all the mutant lines of $M_2$ generation, M2.1 recorded shorter plants whereas the mutant line M2.31 was found to be showing more branches. Mutant lines M2.10, M2.15 and M2.21 reported earliness. The better performance for pod length and seeds per pod were recorded by the mutant lines M2.2 and M2.6, respectively. The mutant line M2.24 was observed to be top performer for pod yield per plant.

**Keywords:** Gamma irradiation, $M_2$ generation, earliness, yield

## 1. Introduction

Due to changing pattern of lifestyle and food habit elsewhere, intake of low calorie and low fat vegetarian food is becoming increasingly popular. Legumes occupy a major share in an Indian diet and have been recognized as "meat of poor people" as they are naturally rich in dietary proteins, fibers, fat and carbohydrates as well as minerals including calcium, phosphorus and iron (Naeem *et al*. 2009, Bello-Perez *et. al.*, 2007) [20, 3]. Among the legumes, field bean is one of the ancient and versatile crops that are grown for its fresh pods as vegetable and dry seeds that are used as a pulse.

Field Bean [*Lablab purpureus* var. *lignosus* (L.) Prain] belongs to the family Leguminosae with diploid chromosome number of 22. Field bean is grown as a rainfed crop in Madhya Pradesh, Andhra Pradesh, Karnataka and Maharashtra (Mahadevu and Byregowda, 2005) [17]. Field bean is one of the major sources of protein in the South Indian diet. It also contains vitamins (A, C & Riboflavin) and minerals (Ca, Fe, Mg, S, Na & P) (Deka and Sarkar, 1990) [5]. It can therefore play a major role in improving the diets of vulnerable rural communities in developing countries.

Being a self-fertilized plant (cleistogamous), Field bean has limited genetic variability which affects the crop improvement programme and this can be made with inducing variability in genotype. Induced mutagenesis has been recognized as the most efficient method for induction of morphological and genetic variability in plants, especially in those with limited genetic variabilities.

Gamma rays are the most energetic form of electromagnetic radiation, and they are considered as the most penetrating compared to other radiations (Kovacs and Keresztes, 2002) [15]. Gamma radiation can be useful for the alteration of physiological characters. In the current study, an attempt has been made to know the genetic variability induced in growth and yield parameters in $M_2$ generation to select efficient and elite mutants of selected field bean var. TFB-2.

## 2. Material and Methods

Around 32 morphological variants were isolated in the $M_1$ generations which were previously gamma irradiated seeds of field bean variety TFB-2 (Tirupati Field Bean-2). The seeds of these 32 elite mutants along with TFB-2 as control were raised as $M_2$ generation (plant to progeny rows) during *Rabi*, 2019 in a Randomized Block Design.

In $M_2$ generation, 32 elite mutants of field bean var. TFB-2 were selected of which $T_{14}$ mutant line showed no germination. This led to a total of 31 elite mutant lines of $M_2$ generation along with the untreated control to be considered under present investigation. The mutant population was studied for the variability in growth and yield attributes.

At final harvest, the plant height was measured from ground level to the tip of the main axis and expressed in centimeters. Total number of primary branches which arose from the main axis of the plant was recorded at the time of final harvest. Number of days taken from sowing to the first flower appearance and days to 50 per cent of the plants flowered was recorded. Days to maturity and days to harvest were recorded by observing number of days taken from the date of sowing to the date of last pod picking at marketable stage and the stage till 90% of the pods had turned brown, respectively. Length of the pod was measured from the base of the pod to tip in ten randomly selected pods from each plant and the average pod length was expressed in centimeters. Numbers of seeds per pod were counted from ten randomly selected pods in individual plant and mean was computed. Dry pods were collected from individual plant and weight was recorded. The mean weight was worked out and expressed in grams.

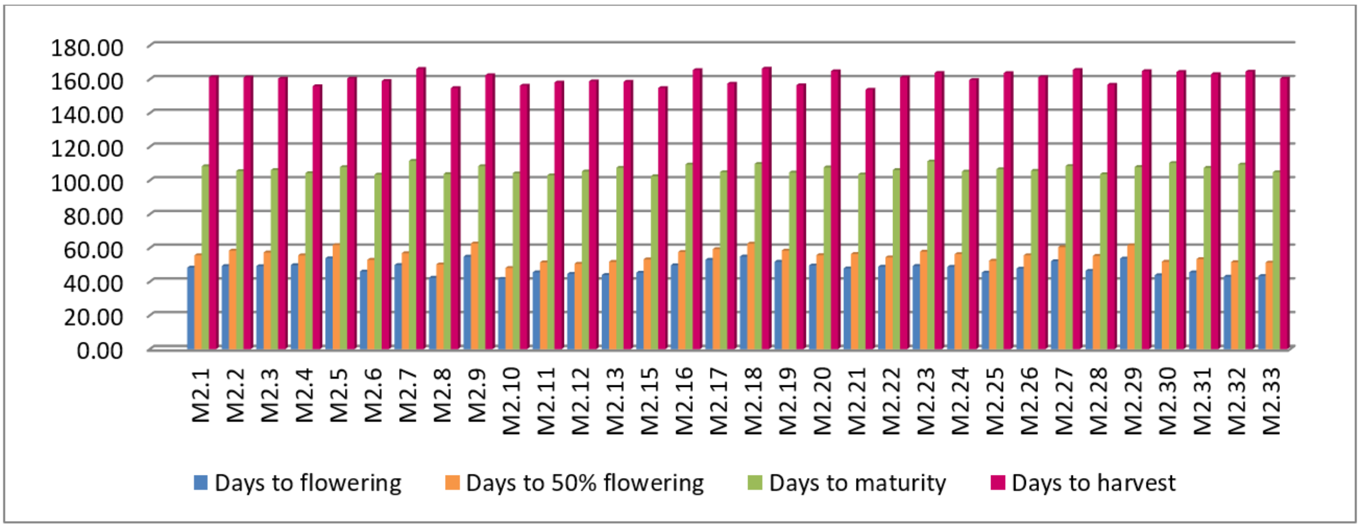
Observations were recorded and the entire recorded data was subjected to statistical analysis using WINDOWSTAT software to observe mean performance the mutant lines.

## 3. Result and Discussion

The mean performance of 31 mutant lines of field bean var. TFB-2 along with unirradiated control with respect to growth parameters and yield are described and presented in Table 1 and Graph 1.

**Table 1:** Mean values of the growth and yield parameters in the mutant lines of $M_2$ generation

| Mutant line | Plant height (cm) | No. of primary branches | Days to flowering | Days to 50% flowering | Days to maturity | Days to harvest | Pod length (cm) | Pod yield/ plant (g) | Seeds per pod |
|---|---|---|---|---|---|---|---|---|---|
| $M_{2.1}$ | 142.85 | 2.85 | 48.30 | 55.63 | 108.43 | 161.25 | 5.21 | 204.99 | 3.46 |
| $M_{2.2}$ | 158.06 | 2.83 | 49.28 | 58.45 | 105.60 | 161.10 | 5.32 | 159.60 | 4.52 |
| $M_{2.3}$ | 152.53 | 2.94 | 49.19 | 57.30 | 106.20 | 160.39 | 5.15 | 98.30 | 3.57 |
| $M_{2.4}$ | 150.99 | 2.24 | 49.80 | 55.60 | 104.36 | 155.87 | 4.80 | 125.04 | 4.65 |
| $M_{2.5}$ | 179.32 | 3.98 | 53.87 | 61.71 | 107.92 | 160.43 | 4.60 | 201.81 | 3.73 |
| $M_{2.6}$ | 292.62 | 3.00 | 46.00 | 52.96 | 103.48 | 158.98 | 4.70 | 272.67 | 4.68 |
| $M_{2.7}$ | 230.91 | 4.00 | 49.85 | 56.86 | 111.62 | 166.13 | 4.73 | 180.16 | 3.15 |
| $M_{2.8}$ | 185.96 | 3.00 | 42.31 | 50.23 | 103.79 | 154.80 | 4.61 | 327.68 | 4.18 |
| $M_{2.9}$ | 210.05 | 2.98 | 54.83 | 62.65 | 108.44 | 162.44 | 4.72 | 189.84 | 3.98 |
| $M_{2.10}$ | 210.89 | 2.97 | 41.66 | 48.12 | 104.21 | 156.22 | 4.72 | 167.90 | 3.91 |
| $M_{2.11}$ | 183.27 | 2.13 | 45.53 | 51.42 | 103.02 | 158.11 | 4.51 | 207.04 | 3.50 |
| $M_{2.12}$ | 161.39 | 3.02 | 44.61 | 50.61 | 105.31 | 158.81 | 4.91 | 265.77 | 3.99 |
| $M_{2.13}$ | 154.19 | 2.15 | 43.94 | 51.74 | 107.54 | 158.54 | 4.31 | 164.86 | 4.57 |
| $M_{2.15}$ | 175.33 | 2.15 | 45.31 | 53.21 | 102.53 | 154.78 | 4.60 | 138.87 | 3.46 |
| $M_{2.16}$ | 156.95 | 3.16 | 49.73 | 57.60 | 109.48 | 165.48 | 4.50 | 190.33 | 4.59 |
| $M_{2.17}$ | 261.20 | 2.13 | 52.98 | 59.31 | 104.90 | 157.40 | 4.81 | 171.73 | 4.16 |
| $M_{2.18}$ | 197.97 | 2.13 | 54.92 | 62.53 | 109.79 | 166.30 | 4.79 | 220.58 | 3.82 |
| $M_{2.19}$ | 184.97 | 2.11 | 51.80 | 58.46 | 104.70 | 156.43 | 4.90 | 183.48 | 3.72 |
| $M_{2.20}$ | 175.35 | 2.13 | 49.60 | 55.68 | 107.74 | 164.74 | 5.10 | 339.36 | 3.99 |
| $M_{2.21}$ | 175.23 | 3.16 | 47.89 | 56.42 | 103.57 | 153.81 | 4.30 | 256.09 | 3.74 |
| $M_{2.22}$ | 150.83 | 2.08 | 48.85 | 54.41 | 106.18 | 161.09 | 4.90 | 328.46 | 3.13 |
| $M_{2.23}$ | 185.74 | 2.14 | 49.32 | 57.82 | 111.27 | 163.78 | 4.81 | 156.71 | 3.31 |
| $M_{2.24}$ | 159.26 | 4.02 | 48.76 | 56.34 | 105.26 | 159.57 | 4.81 | 371.94 | 4.17 |
| $M_{2.25}$ | 175.76 | 2.17 | 45.38 | 52.43 | 106.68 | 163.68 | 4.89 | 254.32 | 3.74 |
| $M_{2.26}$ | 178.49 | 3.15 | 47.71 | 55.63 | 105.75 | 161.25 | 5.11 | 305.29 | 3.74 |
| $M_{2.27}$ | 161.96 | 2.11 | 52.15 | 60.49 | 108.54 | 165.54 | 4.31 | 191.32 | 4.00 |
| $M_{2.28}$ | 175.04 | 3.09 | 46.40 | 55.31 | 103.74 | 156.79 | 4.50 | 225.36 | 3.73 |
| $M_{2.29}$ | 187.85 | 3.05 | 53.70 | 61.58 | 107.96 | 164.80 | 4.50 | 258.10 | 3.74 |
| $M_{2.30}$ | 210.61 | 2.10 | 43.79 | 51.79 | 110.33 | 164.33 | 4.50 | 273.42 | 3.72 |
| $M_{2.31}$ | 177.54 | 4.14 | 45.50 | 53.38 | 107.51 | 163.01 | 4.80 | 185.39 | 3.40 |
| $M_{2.32}$ | 177.99 | 2.07 | 42.99 | 51.57 | 109.49 | 164.50 | 5.10 | 173.21 | 3.77 |
| $M_{2.33}$ | 241.10 | 3.69 | 43.38 | 51.31 | 104.88 | 160.38 | 4.58 | 198.06 | 4.47 |
| SE(m)± | 1.424 | 0.031 | 0.287 | 0.130 | 1.090 | 2.147 | 0.009 | 2.89 | 0.019 |
| CD 5% | 4.127 | 0.090 | 0.838 | 0.377 | 3.157 | 6.222 | 0.025 | 8.38 | 0.054 |




**Graph 1:** *Per se* performance of mutant lines for earliness in the of $M_2$ generation

### 3.1 Plant height (cm)

In M2 generation, plant height ranged from 142.85 cm to 292.62 cm with a mean of 183.26 cm. Among the mutant lines, minimum plant height (142.85 cm) was recorded in mutant line M2.1 followed by M2.22 (150.83 cm), while the maximum plant height (292.62 cm) was recorded in mutant line M2.6. The mean plant height for untreated control plants was 241.10 cm. Out of 31 mutant lines, only two mutant lines *viz.*, M2.6 (292.62 cm) and M2.17 (261.20 cm) exhibited greater height than the control whereas all the other remaining lines exhibited lower height.

The shoot meristem of the progeny of irradiated dry seeds has been observed to take deleterious mutations leading to abnormal gametogenesis and embryonic lethality (Sangsiri, 2005) [24]. The reduction in plant height can be attributed to the decrease in mitotic activity of meristematic tissues among the mutants. It might also occur as a result of the effect on few genes yielding macro mutations (Bara, 2007) [2].

The research studies are in line with the findings of Mahla *et al.* (2010) [16] in cluster bean, Masry *et al.* (2019) [18] and Xu *et al.* (2020) [27] in pea, Mohamed *et al.* (2020) [19] in cowpea and Harish Kumar *et al.* (2016) [10] in dolichos bean.

### 3.2 Number of primary branches

The number of primary branches per plant ranged from 2.065 to 4.135 with a general mean of 2.747 in M2 generation. The highest number of primary branches per plant was produced by the mutant line M2.31 (4.135) followed by M2.24 (4.018), while the lowest number of branches was produced by the mutant M2.32 (2.065). The control means recorded for primary branches per plant was 3.688. Four mutant lines *viz.*, M2.5 (3.976), M2.7 (4.000), M2.24 (4.018) and M2.31 (4.135) recorded significantly more branches than the control.

Similar findings were observed by Aruna *et al.* (2013) [1] in eggplant, Bolbhat and Dhumal (2012) [4] in horse gram, Jadhav *et al.* (2013) [12] in okra, Masry *et al.* (2019) [18] in pea and Horn (2016) [11], Gnanamurthy and Dhanavel (2014) [8] and Mohamed *et al.* (2020) [19] in cowpea.

### 3.3 Days to first flowering

In M2 generation, the data recorded for days to first flowering in untreated control showed a mean of 43.38 days. Among the irradiated plants, M2.10 showed early flowering (41 days) which was on par with M2.8 (42.31), followed by M2.32 (42.99) whereas M2.9 and M2.18 showed late flowering (54 days). Days to first flowering ranged from 41.66 to 54.92 days in the mutagenic population with a mean of 48.26. A total of 3 mutant lines *viz.*, M2.8 (42.31), M2.10 (41.66) and M2.32 (42.99) recorded less number of days to flowering than the control mean.

The data observed was in line with the reports of Jagajanantham *et al.* (2012) [13] and Elangovan and Pavadai (2015) [6] in okra, Masry, *et al.* (2019) [18] in pea and Ogidi *et al.* (2010) [22], Horn (2016) [11], Girija and Dhanavel (2013) [7] in cowpea.

### 3.4 Days to 50% flowering

Among the irradiated plants of M2 generation, M2.10 showed early flowering (48 days) followed by M2.8 (50 days) whereas M2.9 and M2.18 showed late flowering (62 days). Days to 50% flowering ranged from 48.119 to 62.652 days in the mutagenic population with a mean of 55.716. The data recorded for days to 50% flowering in untreated control showed a mean of 51.313 days. Out of 31 mutant lines, a total of 3 mutant lines *viz.*, M2.8 (50.225), M2.10 (48.119), and M2.12 (50.610) recorded less number of days to 50% flowering than the control mean.

The delay in flowering of mutant lines may be due to number of factors which are reported to induce destruction (Smith and Kerstein, 1942) [26], production of diffusible growth reducing substances *etc.*, Aruna *et al.* (2013) [1] in eggplant and Horn (2016) [11] in cowpea reported the same as the current findings.

### 3.5 Days to maturity

Days to maturity ranged from 102 to 111 days in the mutagenic population of M2 generation with a mean of 106 days. The data recorded for days to maturity in untreated control showed a mean value of 104.875. Among the irradiated plants M2.15 showed early maturity with 102 days on par with M2.2 (105.600), M2.4 (104.364), M2.6 (103.478), M2.8 (103.792), M2.10 (104.214), M2.11 (103.018), M2.12 (105.309), M2.13 (107.542), M2.17 (104.898), M2.19 (104.695), M2.21 (103.571), M2.24 (105.255), M2.28 (103.743) followed by M2.26 (105.750) whereas M2.7 and M2.23 showed late maturity (111 days). A total of 9 mutant lines recorded less number of days to maturity than the control.

The prolongation of maturation period observed in gamma rays treatment in the present investigation may be due to various factors such as inhibition of DNA synthesis, gross chromosomal changes (Sax, 1955) [25] *etc.*, The present observations was akin to Ogidi *et al.* (2010) [22], Horn (2016) [11] and Gnanamurthy and Dhanavel (2014) [8] in cowpea.

### 3.6 Days to harvest

The number of days to harvest ranged from 153 to 166 days in the mutagenic population of M2 generation with a mean of 160 days. Among the irradiated plants M2.21 recorded early harvest (153 days) on par with M2.4 (155.865), M2.6 (158.980), M2.8 (154.795), M2.10 (156.215), M2.11 (158.105), M2.12 (158.810), M2.13 (158.540), M2.15 (154.780), M2.17 (157.400), M2.19 (156.430), M2.24 (159.570), M2.28 (156.790) followed by M2.3 (160.390) whereas M2.7 and M2.18 recorded late harvest (166 days). The data recorded for days to harvest in untreated control showed a mean of 160 days. Out of 32 mutant lines, 15 mutant lines recorded less number of days to harvest than the control.

### 3.7 Pod length (cm)

Significant variation was noticed among the mutant lines of M2 generation with respect to the length of the pod which ranged from 4.295 cm to 5.324 cm with a mean value of 4.758 cm. The length of the pod was maximum in M2.2 (5.324 cm) followed by M2.1 (5.207 cm) and a minimum length of the pod was recorded in M2.21 (4.295 cm). The data recorded for the length of the pod in untreated control showed a mean of 4.582 cm. Twenty-three mutant lines recorded more pod length when compared to control.

The variation in pod length observed in the present study was in accordance with the reports of Goyal and Khan (2010) [9], Reena *et al.* (2014) [23], Ogidi *et al.* (2010) [22], Horn (2016) [11], Gnanamurthy and Dhanavel (2014) [8] in cowpea, Elangovan and Pavadai (2015) [6] and Navnath and Kulthe (2014) [21] in okra.

### 3.8 Number of seeds per pod

The number of seeds per pod across the mutant lines recorded a range of 3.133 to 4.683 with a mean of 3.864 in M2 generation. The mean of the number of seeds per pod in the control was recorded as 4.473. The maximum number of seeds per pod was recorded in M2.6 (4.683) on par with M2.4 (4.650) followed by M2.16 (4.585) and the minimum number of seeds per pod were recorded in M2.22 (3.133). Five mutant lines *viz.*, M2.2 (4.521), M2.4 (4.650), M2.6 (4.683), M2.13 (4.568) and M2.16 (4.585) recorded more number of seeds per pod than the untreated control.

Similar findings were observed by Goyal and Khan (2010) [9], Ogidi *et al.*, (2010) [22], Gnanamurthy and Dhanavel (2014) [8] and Reena *et al.*, (2014) [23] in cowpea.

### 3.9 Pod yield per plant (g)

Pod yield per plant ranged from 98.30 g to 371.94 g with a general mean of 219.02 g in M2 generation. The mutant line M2.24 recorded the highest pod yield per plant (371.94 g) followed by M2.20 (339.36 g) while the pod yield per plant recorded by the mutant line M2.3 (98.30 g) was the lowest. The mean pod yield per plant of untreated control was recorded as 198.06 g. Sixteen mutant lines recorded high pod yield per plant than the control.

The shift of yield and its components depends on the favourable association between the components in response to mutagenic treatments (Khan and Qureshi, 2006) [14]. The trend observed in the present study was in line with the reports of (Bolbhat and Dhumal, 2012) [4] in horse gram, Jadhav *et al.*, (2013) [12] in okra and Aruna *et al.*, (2013) [1] in eggplant.

## 4. Conclusion

The results on the mean performance of mutant lines in the M2 generation revealed significant variability for all the observations

Among all the mutant lines of M2 generation, M2.1 recorded shorter plants whereas the mutant line M2.31 was found to be showing more branches. Mutant line M2.10 observed lesser days taken for flowering and 50% flowering. Minimum days to maturity were observed in the mutant line M2.15. The mutant line M2.21 recorded lesser days taken to harvest. The better performance for pod length and seeds per pod were recorded by the mutant lines M2.2 and M2.6, respectively. The mutant line M2.24 was documented to be a better performer for pod yield per plant.

The better performing mutant lines can be selected for further evaluation to be used as donor parents for the respective characters.

## 5. References


1. Aruna J, Prakash M, Sunil kumar B. Effect of mutagens on induced variability in eggplant (*Solanum melongena*). Indian Journal of Agricultural Sciences. 2013;83(11):1269-76.
2. Bara BM. Gamma rays effect on frequency and spectrum of chlorophyll mutation in chickpea (*Cicer arietinum* L.). Journal of Pharmacology and Phytochemistry. 2007;6(3):590-591.
3. Bello-Perez LA, Sayago-Ayerdi SG, Chavez-murillo CE, Agama-Acevedo E, Tovar J. Proximal composition and in vitro digestibility of starch in Lima bean (*Phaseolus lunatus*) varities. J Sci. Food. Agri. 2007;87:2570-2575.
4. Bolbhat S, Dhumal K. Effect of mutagens on quantitative characters in M2 and M3 generation of horsegram (*Macrotyloma uniflorum* Lam. Verdc). International Journal of Science Research. 2012;2(10):1-2.
5. Deka RK, Sarkar CR. Nutrient composition and anti-nutritional factors of *Dolichos lablab* L. seeds. Food chem. 1990;38:239-246.
6. Elangovan R, Pavadai P. Effect of gamma rays on germination, morphological and yield characters of bhendi (*Abelmoschus esculentus* L. Moench). Horticultural Biotechnology Research. 2015;1:35-38.
7. Girija M, Dhanavel D. Effect of gamma rays on quantitative traits of cowpea in $M_1$ generation. Int. J. Res. Bio. Sci. 2013;3(2):84-87.
8. Gnanamurthy S, Dhanavel D. Effect of EMS on induced morphological mutants and chromosomal variation in Cowpea (*Vigna unguiculata* L. Walp). International Letters of Natural Sciences. 2014;17:33-43.
9. Goyal S, Khan S. Induced mutagenesis in Urd bean (*Vigna mungo* (L.) Hepper): A Review. International Journal of Botany. 2010;6:194-206.
10. Harish Kumar, Ghawade SM, Manoharlal M, Shivaputra. Mutagenic effect of gamma radiations on seed germination, plant growth and mortality of dolichos bean (*Lablab purpureus* L.) in $M_2$ generation. Progressive Research – An International Journal. 2016;11(7):4844-

4847.
11. Horn LN. Breeding cowpea (*Vigna unguiculata* [L.] Walp) for improved yield and related traits using gamma irradiation. Ph.D. thesis. University of Namibia, Pietermaritzburg, Republic of South Africa, 2016.
12. Jadhav PA, Kalpande HV, Arbad SK, Mali AR. Induced mutagenesis in okra (*Abelmoschus esculentus* L. Moench) by gamma rays and ethyl methane sulphonate. Vegetable Science. 2013;40(2):223-224.
13. Jagajanantham N, Dhanavel D, Pavadai P, Chidambaram AA. Growth and yield parameters using gamma rays in bhendi (*Abelmoschus esculentus* (L.) Moench) var. Arka Anamika. International Journal of Research in Plant Science. 2012;2(4):56-58.
14. Khan MR, Qureshi AS. Induced genetic variability in quantitative traits of kabuli chickpea (*Cicer arietinum* L.). Proceedings of the Pakistan Academy of Sciences. 2006;43(2):87-94.
15. Kovacs E, Keresztes A. Effect of gamma and UV-B/C radiation on plant cells. Micron. 2002;33(2):199-210.
16. Mahla HR, Shekhawat A, Kumar D. A study on EMS and gamma mutagenesis of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. Plant Mutation Reports. 2010, 2(2).
17. Mahadevu P, Byregowda M. Genetic improvement of Dolichos bean (*Lablab purpureus.* L) Through the use of exotic and endogenous germplasm. Indian J Plant Genet. Res. 2005;(18):1-5.
18. Masry AI, Fayad AM, Dalia IT. Genetic improvements in Pea (*Pisum sativum* L.) through irradiation by gamma rays. J of Plant Production. 2019;10(12):1089-1093.
19. Mohamed YSK, Kumar KSNP, Prabakaran S, Suresh S. Ethyl methane sulphonate (EMS) induced mutations in $M_1$ generation of cowpea (*Vigna unguiculata* (L.) Walp). Journal of Pharmacognosy and Phytochemistry. 2020;9(2):1545-1547.
20. Naeem M, Khan MMA, Moinuddin Siddiqui MH. Triacontanol stimulates nitrogen-fixation, enzyme activities, photosynthesis, crop productivity and quality of hyacinth bean (*Lablab purpureus* L.). Scientia Horticulturae. 2009;121(4):389-396.
21. Navnath GK, Kulthe MP. Effect of physical and chemical mutagens on pod length in Okra (*Abelmoschus esculentus* L. Moench). Science Research Reporter. 2014;4(2):151-154.
22. Ogidi EGO, Omosun G, Markson AA, Kalu M. Effects of gamma ray irradiation on the metric traits of vegetable cowpea (*Vigna unguiculata* L.) Walp) in umudike southern Nigeria. Asian journal of Science and Technology. 2010;5:086-090.
23. Reena N, Anoop KM, Sudhakar PM. Correlation studies in $M_2$ and $M_3$ generation of cowpea [*Vigna ungiculata* (L.) Walp] treated with gamma rays and EMS. International Journal of Tropical Agriculture, 2014, 32(3-4).
24. Sangsiri C, Sorajjapinun W, Srinives P. Gamma radiation induced mutations in mungbean. Sci. Asia. 2005;31:251-255.
25. Sax K. The effect of ionizing radiation on plant growth, Am. J. Bot. 1955;42:360-64.
26. Smith GF, Kerstein H. Auxins and calines in seedlings from X-rayed seeds. American Journal of Botany. 1942;29:785-792.
27. Xu D, Yao Z, Pan J, Feng H, Guo Z, Lu X. Study on the multiple characteristics of $M_3$ generation of pea mutants obtained by neutron irradiation. Nuclear Science and Techniques. 2020;31:67.