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# GENETIC VARIABILITY INDUCED BY GAMMA RAYS IN $M_2$ GENERATION OF SOYBEAN ( *Glycine max* (L.) Merrill)

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## ABSTRACT

**TAMS-38 variety of Indian soybean (*Glycine max* (L.) Merrill) was treated with 200, 250 and 300 gy doses of gamma rays with the objective to study the variability in $M_2$ for the qualitative and quantitative characters. The experiment was conducted in the experimental farm of Botany section, College of Agriculture, Nagpur during *kharif* and *rabi* 2016. The treated material along with untreated control planted in $M_1$ generation and individual plants were harvested separately. Harvested seeds of individual plants from $M_1$ generation were planted in non replicated field trial to raise $M_2$ generation. Observations were recorded on different yield attributing characters like days to flowering, days to maturity, plant height (cm), number of branches plant$^{-1}$, length of primary root (cm), number of pods plant$^{-1}$, 100 seed weight (g) and grain yield plant$^{-1}$ (g). In $M_2$ generation days to flowering and days to maturity increased significantly in all the treatments. Plant height, number of branches plant$^{-1}$ and length of primary root reduced significantly in all the treatments. Number of pods plant$^{-1}$ and grain yield plant$^{-1}$ significantly increased in all the treatments and 100 seed weight significantly decreased in all the treatments as compared to control. Visible macromutants like chlorophyll mutants, early flowering, late flowering, early maturing, late maturing, dwarf, tall, increased root length, increased 100 seed weight, small leaf, wrinkled leaf, viney type mutants, sterile, high yielding, more pods, more branched mutants were identified and isolated in $M_2$ generation. The economical and morphological mutants were isolated from the variety of TAMS-38. High yielding mutant with 12 g to 17 g yield as against 4.40 g in control were identified from this variety. Early maturing mutant matured 11.2 to 20.2 days earlier than control were isolated from this variety. These mutants need to be evaluated for their breeding behavior in further generation and their utilization in improvement of soybean.**

**(Key words: Soybean, gamma rays, mutation, quantitative traits)**

## INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is referred as “Golden bean’’ and “Miracle crop” of 21th century. It is one of the important oilseed as well as legume crop. It contributes more than 50% to the global production of edible oil. Soybean contain 20% oil and 40% protein. Soybean protein is rich in all essential amino acids, vitamin A, B and D; health promoting phytochemicals like isoflavones. Hence, soybean referred as “Wonder crop” or “Golden bean”. Soybean oil is used as edible oil in Indian diet. It contain low level of saturated fatty acids. Therefore, soybean oil is better for human health. Soybean is highly self pollinated crop. Taxonomically soybean belongs to the order Fabales and family “Leguminoseae” and subfamily “Papilionidae” and the genus *Glycine*.

Soybean originated in North Eastern China. It entered in India during 6th century AD. USA, Brazil, China, Argentina and India are the major soybean producing countries in the world. These countries accounts for 90% of the world production. India ranked 5th position in respect to area and production. The largest soybean producing states in India are Madhya Pradesh, Maharashtra and Rajasthan. In India, Maharashtra ranks second in area and production (Anonymous, 2016).

The concept of inducing mutation and utilizing them in plant breeding was first given by Hugo de vries (1903) for generating variability and achieving the goal of generating of new strains of cultivated crop plants. Gamma rays a ionizing physical mutagen capable of inducing mutation in plants. Gamma rays are electromagnetic radiations similar to X-rays in their physical characteristics and action on the organism they are therefore, natural X-rays but of very short wavelength by virtue of which they are more penetrating. Most of the gamma rays wavelength are of less than 0.01 $A^0$ as compared to 0.5$A^0$ of X-rays.

Keeping in view the above aspects, the present study was undertaken to create variable population and select morphologically distinct mutants from the population.

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# MATERIALS AND METHODS

Dry healthy and true breeding seeds of soybean cultivar TAMS-38 was used in this study. The seeds of TAMS-38 were irradiated by gamma rays at Bhabha Atomic Research Centre, Trombay, Mumbai. Equal quantity of seeds (i.e. 500 g of each lot) were irradiated by different doses of gamma rays i.e. 200 Gy, 250 Gy and 300 Gy ($Co^{60}$ at BARC, Trombay, Mumbai).

$M_1$ generation was raised in *kharif* 2016. The treated seeds along with the control were sown immediately after treatment to raise the $M_1$ generation at Shankar Nagar farm, Botany section, College of Agriculture, Nagpur. All the recommended cultural practices and management were given to raise a good crop and maximum multiplication of seed. The $M_1$ population was studied by recording observations at different growth stages. $M_1$ generation was screened for different morphological mutants. Seeds from each $M_1$ generation harvested separately and labeled with plant number, doses and ancillary characters and stored to raise $M_2$ generation.

$M_2$ generation was raised in *rabi* 2016. By sowing seeds of each $M_1$ plants separately all the harvested seeds from each treatment were sown to raise $M_2$ population. The sowing was undertaken on the fertile and well levelled piece of land at Shankar Nagar farm, Botany section, College of Agriculture, Nagpur. The statistical analysis was done for Mean, Standard deviation (S.D.) and Coefficient of Variation (C.V.) by following standard formulas suggested by Singh and Choudhary (1985).

# RESULTS AND DISCUSSION

Data regarding the effect of gamma rays on different quantitative traits of soybean are presented in table 1. Maximum mean value for days to flowering was observed in 300 Gy treatment (69.35 days) and was statistically significant, while the minimum days to flowering was recorded in 200 Gy treatment (66.95 days) as compared to their respective controls (66.80 days). The coefficient of variation increased in all the treatments for days to flowering as compared to control. The maximum coefficient of variation was observed in 250 Gy treatment (7.90%) while the minimum in 200 Gy treatment (5.66%). The range of variation in treated population was 5.66% to 7.90%. It is observed in these study that increase in days to flowering resulted from gamma rays treatment as compared to control. Dhole (1999) also noticed that the flowering delayed significantly in gamma rays treated soybean as compared to control.

Mean value for days to maturity was observed to increase in all the treatments as compared to control. The maximum mean value was observed in 250 Gy treatment (118.59 days) and minimum in 300 Gy treatment (116.35 days). The days to maturity in control was (116.20 days). The coefficient of variation increased in all the treatments as compared to control. The maximum variation was found to be in 250 Gy treatment (5.49%) while the minimum in 200 Gy treatment (4.53%). The range of coefficient of variation was 4.53% to 5.49%. Gopinath and Pavadai (2015) also observed that in $M_2$ and $M_3$ generations mean for days to maturity increased at mutagenic treatment than control in soybean.

Plant height (cm) reduced significantly in all the treatment as compared to control. Maximum plant height was observed in 250 Gy treatment (46.13 cm) while the minimum was in 200 Gy treatment (40.34 cm) as compared to control treatment (56.20 cm). The coefficient of variation for the plant height increased in all the treatments as compared to the control. The maximum variation was noticed in 200 Gy treatment (30.81%) and 300 Gy treatment (30.74%) and minimum in 250 Gy treatment (25.28%) as compared to control treatment (13.92%) respectively. The range for the coefficient of variation was 25.28% to 30.81%. EI-Demerdash (2007) studied the effect of gamma irradiation doses of 100, 150 and 200 Gy on soybean plants and found that plant height decreased by gamma irradiation. Ellyfa *et al*. (2007) also observed that the lowest doses of irradiation (300 Gy) reduced the plant growth characters compared to the control in snapbean.

Data regarding number of branches plant$^{-1}$ revealed that the highest mean value for the character was recorded in 250 Gy treatment (4.12) and the lowest in 200 Gy treatment (3.50). In general the number of branches decreased in all the treatments as compared to their control treatment (6.00). The variability studies showed that the coefficient of variation increased against their control in all the treatments. The variation for the character ranged from 38.90% to 52.18% as compared to control treatment(26.35%). The highest variation was recorded in 200 Gy treatment (52.18%) and 300 Gy treatment (43.57%) and the lowest in 250 Gy treatment (38.90). It is revealed that gamma rays treatment resulted in decrease in number of branches plant$^{-1}$ as compared to control. EI-Demerdash (2007) studied the effect of gamma irradiation doses of 100, 150 and 200 Gy on soybean plants and observed that number of branches plant$^{-1}$ were deceased by gamma irradiation.

The mean value for length of primary root (cm) decreased in all the treatments of gamma rays as compared to control. The maximum mean value for the characters was observed in 300 Gy treatment (13.92 cm) and minimum in 250 Gy treatment (13.70 cm). The coefficient of variation increased in all the treatments for length of primary root as compared to control. The maximum coefficient of variation was observed in 250 Gy treatment (22.90%) while the minimum in 300 Gy treatment (16.15%). The range of coefficient of variation in treated population was 16.15% to 22.90%. It is revealed from this observation that the mean length of primary root decreased in gamma rays treatment as compared to control.

Nandanwar *et al.* (1995) reported reduction in root and shoot length as the doses of gamma rays increased in mungbean. Ellyfa *et al*. (2007) also observed that increase in dosage of gamma irradiation was accompanied with decrease in height, root length, oven-dry weight of shoot and survival of snap bean.

**Table 1. Effect of gamma rays on different quantitative traits of soybean (*Glycine max* (L.) Merrill)**

| Characters | Parameters | Irradiation dose (Gray) | | | |
|---|---|---|---|---|---|
| | | 200 Gy | 250 Gy | 300 Gy | Control |
| Days to flowering | Mean | 66.55 | 68.15 | 69.35 | 66.80 |
| | SD | 3.79 | 5.39 | 5.27 | 3.63 |
| | CV (%) | 5.66 | 7.90 | 7.60 | 5.44 |
| Days to maturity | Mean | 118.15 | 118.59 | 116.35 | 116.20 |
| | SD | 5.35 | 6.50 | 5.60 | 4.60 |
| | CV (%) | 4.53 | 5.49 | 4.82 | 3.96 |
| Plant height (cm) | Mean | 40.34 | 46.13 | 43.24 | 56.20 |
| | SD | 12.43 | 11.66 | 13.29 | 7.82 |
| | CV (%) | 30.81 | 25.28 | 30.74 | 13.92 |
| No. of branches plant$^{-1}$ | Mean | 3.50 | 4.12 | 3.69 | 6.00 |
| | SD | 1.83 | 1.60 | 1.61 | 1.58 |
| | CV (%) | 52.18 | 38.90 | 43.57 | 26.35 |
| Length of primary root (cm) | Mean | 13.83 | 13.70 | 13.92 | 14.20 |
| | SD | 2.37 | 3.14 | 2.09 | 1.92 |
| | CV (%) | 17.16 | 22.90 | 16.15 | 13.55 |
| No. of pods plant$^{-1}$ | Mean | 22.62 | 22.95 | 26.73 | 21.00 |
| | SD | 15.78 | 15.91 | 17’43 | 8.37 |
| | CV (%) | 69.77 | 59.09 | 65.23 | 39.84 |
| 100 seed weight (g) | Mean | 11.63 | 10.73 | 10.08 | 12.40 |
| | SD | 1.01 | 1.60 | 1.73 | 0.55 |
| | CV (%) | 8.66 | 14.89 | 17.17 | 4.42 |
| Grain yield plant$^{-1}$ (g) | Mean | 4.98 | 5.41 | 5.00 | 4.40 |
| | SD | 2.54 | 2.49 | 2.41 | 1.14 |
| | CV (%) | 51.02 | 46.00 | 48.17 | 25.91 |

## Table 2. Selection of mutants in $M_2$ generation from different treatments of gamma rays in soybean

| Treatments | Plant no. $M_2$ | Characters | Days to flowering | Days to maturity | Plant height (cm) | No of branches $plant^{-1}$ | Length of primary root (cm) | No of pods $plant^{-1}$ | 100 seed weight (g) | Grain yield $plant^{-1}$ (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | More pods, High yield | 68 | 119 | 33 | 3 | 12 | 85 | 12 | 12 |
| | 2 | High yield, More pods | 65 | 108 | 56 | 5 | 14 | 65 | 11 | 12 |
| | 3 | More branched, More pods, 100 SW, HY | 66 | 118 | 59 | 9 | 16 | 60 | 14 | 11 |
| | 4 | Tall, Small leaf | 66 | 124 | 64 | 4 | 16 | 42 | 12 | 9 |
| | 5 | More branched | 64 | 113 | 50 | 7 | 16 | 35 | 12 | 9 |
| | 6 | Tall, More pods | 71 | 119 | 73 | 6 | 18 | 60 | 12 | 10 |
| | 7 | Dwarf, 100 SW, HY | 63 | 112 | 24 | 4 | 12 | 35 | 14 | 11 |
| | 8 | Tall, HY | 64 | 114 | 61 | 6 | 17 | 68 | 12 | 13 |
| | 9 | Early flowered, EM, Tall | 60 | 107 | 63 | 6 | 15 | 45 | 14 | 6 |
| | 10 | Tall, 100 SW | 65 | 118 | 68 | 6 | 18 | 39 | 13 | 5 |
| | 11 | Early flowered, More branched | 60 | 115 | 38 | 7 | 11 | 46 | 10 | 7 |
| | 12 | Early matured, Small leaf | 67 | 105 | 29 | 4 | 15 | 31 | 11 | 5 |
| | 13 | Early flowered | 62 | 109 | 42 | 4 | 13 | 46 | 9 | 6 |
| | 14 | Wrinkled leaf | 71 | 124 | 47 | 5 | 14 | 47 | 9 | 7 |
| $T_1$ (200Gy) | 15 | Small leaf | 68 | 122 | 49 | 5 | 14 | 31 | 11 | 4 |
| | 16 | Dwarf | 67 | 118 | 21 | 3 | 14 | 19 | 10 | 4 |
| | 17 | More branched | 64 | 120 | 59 | 7 | 15 | 27 | 12 | 6 |
| | 18 | Early flowered, Dwarf | 62 | 113 | 25 | 5 | 11 | 25 | 11 | 5 |
| | 19 | More branched | 65 | 124 | 42 | 7 | 16 | 27 | 11 | 6 |
| | 20 | Late flowering, LM | 77 | 126 | 43 | 3 | 15 | 30 | 12 | 5 |
| | 21 | Small leaves | 65 | 118 | 36 | 3 | 15 | 25 | 11 | 4 |
| | 22 | More branched, 100 SW | 66 | 109 | 41 | 7 | 15 | 34 | 13 | 6 |
| | 23 | Dwarf | 63 | 112 | 21 | 3 | 11 | 12 | 11 | 4 |
| | 24 | Dwarf | 65 | 113 | 17 | 1 | 10 | 12 | 12 | 4 |
| | 25 | Small leaf | 65 | 118 | 36 | 3 | 15 | 25 | 11 | 4 |
| | 26 | Wrinkled leaf | 64 | 117 | 47 | 3 | 15 | 29 | 12 | 6 |
| | 27 | Viney type, Wrinkled leaf, | 68 | 120 | 34 | 0 | 13 | 8 | 10 | 3 |
| | 28 | Late flowered LM | 77 | 128 | 31 | 4 | 16 | 13 | 12 | 4 |
| | 29 | Late maturity | 74 | 127 | 46 | 6 | 13 | 17 | 11 | 4 |
| | 30 | Tall, Root length above 20 cm | 75 | 122 | 60 | 4 | 20 | 20 | 12 | 12 |
| | 47 | Dwarf | 69 | 122 | 22 | 1 | 15 | 2 | 11 | 4 |
| | 54 | Root length above 20 cm | 63 | 108 | 58 | 2 | 21 | 10 | 12 | 3 |
| | 76 | Root length above 20 cm | 64 | 124 | 33 | 5 | 22 | 11 | 12 | 5 |
| | 78 | Sterile | - | - | 48 | 4 | 15 | - | - | - |
| | 80 | Sterile | - | - | 55 | 5 | 16 | - | - | - |
| | 83 | Viney type | 68 | 119 | 44 | 0 | 13 | 12 | 12 | 3 |
| | 85 | Chlorophyll deficient | - | - | 10 | - | - | - | - | - |
| | 87 | Chlorophyll deficient | - | - | 9 | - | - | - | - | - |

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|---|---|---|---|---|---|---|---|---|---|
| 88 | Chlorophyll deficient | - | - | 12 | - | - | - | - | - |
| 1 | High yield, More pods, More branched, EF, EM | 60 | 96 | 45 | 8 | 15 | 95 | 10 | 15 |
| 2 | More branched More pods,100 SW | 65 | 108 | 52 | 8 | 16 | 75 | 14 | 7 |
| 3 | More pods,100 SW, HY | 68 | 112 | 51 | 6 | 13 | 60 | 13 | 11 |
| 4 | Early flowered, EM, | 61 | 106 | 38 | 6 | 15 | 48 | 9 | 3 |
| 5 | Tall | 62 | 112 | 65 | 6 | 15 | 17 | 12 | 3 |
| 6 | Tall, Small leaf | 61 | 110 | 63 | 5 | 10 | 24 | 12 | 4 |
| 7 | More pods, EM | 63 | 107 | 49 | 6 | 13 | 61 | 11 | 8 |
| 8 | Wrinkled leaf | 64 | 121 | 57 | 5 | 11 | 42 | 12 | 7 |
| 9 | Dwarf , EF, EM | 58 | 102 | 21 | 4 | 11 | 18 | 12 | 4 |
| 10 | High yield, 100 SW, small leaf | 66 | 119 | 42 | 4 | 15 | 39 | 13 | 13 |
| 11 | High yield, 100 SW, Root length above 20 cm | 69 | 124 | 52 | 3 | 22 | 46 | 13 | 11 |
| 12 | High yield, 100 SW | 68 | 128 | 40 | 3 | 9 | 18 | 14 | 11 |
| 13 | More branched | 66 | 111 | 47 | 7 | 15 | 32 | 12 | 4 |
| 14 | Tall, 100 SW | 70 | 124 | 63 | 4 | 16 | 12 | 13 | 6 |
| 15 | Tall, Wrinkled leaf | 67 | 118 | 65 | 5 | 17 | 23 | 12 | 7 |
| 16 | More branched | 64 | 116 | 34 | 7 | 14 | 15 | 12 | 3 |
| 17 | Viney type | 66 | 119 | 58 | 0 | 13 | 10 | - | - |
| 18 | Late matured | 68 | 131 | 48 | 4 | 14 | 38 | 12 | 7 |
| 19 | Root length above 20 cm, | 69 | 118 | 58 | 5 | 24 | 26 | 11 | 6 |
| 20 | More branched, | 65 | 112 | 51 | 7 | 13 | 19 | 12 | 4 |
| 21 | Early flowered, More branched | 62 | 110 | 48 | 8 | 15 | 43 | 12 | 7 |
| 22 | Late flowering, LM | 91 | 130 | 45 | 3 | 10 | 19 | 11 | 4 |
| 23 | Small leaf | 72 | 120 | 54 | 0 | 14 | 32 | 12 | 5 |
| 24 | Late flowering, LM | 89 | 128 | 37 | 4 | 15 | 18 | 10 | 4 |
| 25 | Early flowering | 57 | 114 | 51 | 2 | 13 | 18 | 12 | 3 |
| 26 | Late flowering | 78 | 124 | 49 | 4 | 13 | 39 | 12 | 9 |
| 27 | Dwarf | 72 | 117 | 19 | 4 | 12 | 37 | 11 | 5 |
| 28 | Tall | 68 | 120 | 71 | 4 | 13 | 26 | 12 | 4 |
| 40 | Tall, Root length above 20 cm | 65 | 116 | 61 | 5 | 24 | 43 | 10 | 3 |
| 46 | Dwarf, small leaf | 65 | 116 | 24 | 2 | 13 | 18 | 12 | 3 |
| 49 | 100 seed weight | 70 | 124 | 52 | 5 | 14 | 10 | 13 | 7 |
| 50 | Late maturity,100 SW | 76 | 125 | 49 | 3 | 13 | 17 | 13 | 8 |
| 61 | High yielding | 65 | 118 | 43 | 6 | 14 | 40 | 10 | 13 |
| 65 | Tall, Root length above 20 cm | 63 | 110 | 43 | 7 | 26 | 45 | 8 | 5 |
| 70 | Root length above 20 cm | 66 | 119 | 41 | 4 | 22 | 27 | 9 | 6 |
| 71 | More pods, HY | 71 | 124 | 37 | 4 | 15 | 56 | 11 | 12 |
| 72 | More pods | 69 | 122 | 42 | 4 | 14 | 51 | 10 | 9 |
| 75 | More pods | 68 | 117 | 24 | 6 | 13 | 72 | 8 | 9 |
| 78 | Dwarf | 72 | 124 | 24 | 4 | 11 | 34 | 10 | 5 |
| 85 | Dwarf | 72 | 122 | 12 | 1 | 10 | 15 | 8 | 3 |

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|---|---|---|---|---|---|---|---|---|---|---|
| | 86 | Chlorophyll deficient | - | - | 8 | - | - | - | - | - |
| | 87 | Chlorophyll deficient | - | - | 11 | - | - | - | - | - |
| | 88 | Chlorophyll deficient | - | - | 9 | - | - | - | - | - |
| | 89 | Chlorophyll deficient | | | 13 | | | | | |
| $T_3$ (300Gy) | 1 | High Yield | 63 | 116 | 32 | 5 | 14 | 49 | 12 | 11 |
| | 2 | More branched, More pods, 100 SW, HY | 69 | 119 | 51 | 7 | 13 | 71 | 13 | 12 |
| | 3 | Tall, Wrinkled leaf | 71 | 128 | 53 | 7 | 13 | 44 | 11 | 6 |
| | 4 | Early flowered, EM, HY | 57 | 102 | 42 | 5 | 15 | 41 | 12 | 11 |
| | 5 | Root length above 20 cm, EM | 68 | 104 | 53 | 4 | 20 | 31 | 11 | 4 |
| | 6 | Dwarf | 74 | 119 | 24 | 2 | 9 | 17 | 8 | 4 |
| | 7 | Small leaves | 78 | 121 | 38 | 4 | 11 | 31 | 12 | 4 |
| | 8 | Late flowering, LM | 82 | 127 | 46 | 2 | 15 | 32 | 12 | 4 |
| | 9 | Early flowering, EM, Root length above 20 cm | 55 | 102 | 47 | 3 | 21 | 16 | 12 | 3 |
| | 10 | Tall | 69 | 111 | 70 | 4 | 13 | 23 | 9 | 3 |
| | 11 | Dwarf | 74 | 119 | 22 | 1 | 11 | 8 | 12 | 3 |
| | 12 | Tall | 78 | 124 | 87 | 3 | 11 | 19 | 8 | 4 |
| | 13 | High yielding | 80 | 120 | 33 | 3 | 13 | 48 | 10 | 11 |
| | 14 | Dwarf | 65 | 110 | 11 | 2 | 11 | 9 | 12 | 4 |
| | 15 | Late flowering, LM | 85 | 128 | 49 | 3 | 12 | 7 | 12 | 3 |
| | 38 | More branched, HY | 68 | 114 | 57 | 7 | 16 | 57 | 9 | 12 |
| | 44 | Dwarf | 69 | 120 | 25 | 4 | 12 | 19 | 8 | 3 |
| | 52 | Chlorophyll deficient | - | - | 13 | - | - | - | - | - |
| | 53 | Chlorophyll deficient | - | - | 11 | - | - | - | - | - |

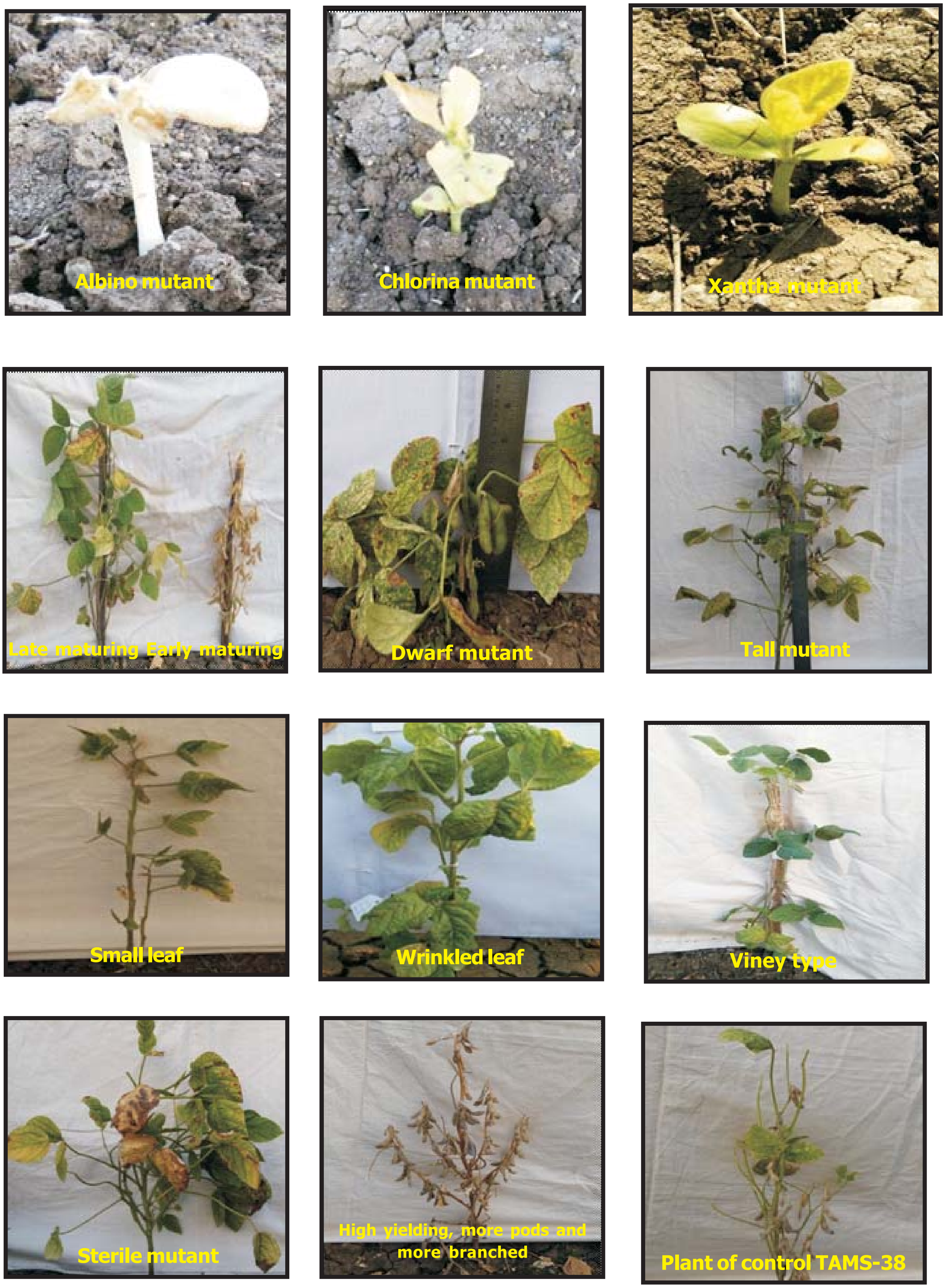


**Plate 1.Different types of mutant observed in $M_2$ generation**

Data on number of pods plant$^{-1}$ revealed that the mean value ranged from 200 Gy treatment (22.62) to 250 Gy treatment (26.95). The coefficient of variation for the characters increased in all the treatments as compared to the control. The highest coefficient of variation was noticed in 200 Gy treatment (69.77%) and the lowest in 250 Gy treatment (59.09%). The variation for the character ranged from 59.09% to 69.77%. It is revealed that the mean number of pods plant$^{-1}$ increased in gamma rays treatment as compared to control. Waghmare and Mehra (2000) observed that the mean number of pods plant$^{-1}$ were considerably reduced in higher doses than lower doses of gamma rays in grass pea. Soliman and Hamid (2003) also reported that the number of pods plant$^{-1}$ was significantly increased by 147.3% and 133.6% over the corresponding control by irradiation with 2.5 and 5.0 k rad respectively.

Data regarding 100 seed weight revealed that the 100 seed weight decreased in all treatments as compared to control. The highest mean value for the character was in 200 Gy treatment (11.63 g) and lowest in 300 Gy treatment (10.08 g) as compared to their control treatment (12.40 g). The variations for the character were found to be increased in all the treatments. Maximum variation was observed in 300 Gy treatment (17.17%) followed by 250 Gy treatment (14.89%) and the minimum variation in 200 Gy treatment (8.66%) as compared to controls treatment (4.42%). It was found in this study that mean of 100 seed weight in general, reduced in gamma rays treatment. Waghmare and Mehara (2000) also observed the significant reduction of 100 grain weight in grass pea irradiated with gamma rays.

Data regarding grain yield plant$^{-1}$revealed that the maximum grain yield plant$^{-1}$was observed in 250 Gy treatment (5.41 g) and minimum in 200 Gy treatment (4.98 g). The variability studies showed that coefficient of variation increased in all the treatments. The maximum coefficient of variation was noticed in 200 Gy treatment (51.02%) followed by 300 Gy treatment (48.17%) and the minimum was in 250 Gy treatment (46.00%). The variation for this parameter ranged between 46.00% to 51.02%. It is revealed that mean value of grain yield plant$^{-1}$ in general, increased in gamma rays treatment as compared to control. Khan *et al.* (2005) also observed similar result and reported that the gamma rays irradiation increased the grain yield significantly as compared to control. Mudibu *et al.* (2012) studied the effects of 0.2 kGy and 0.4 kGy irradiation in $M_2$ populations and observed significant increase of grain yield and yield components in all the three soybean varieties cvs. Kitoko, Vuangi and TGX814-49D. Gopinath and Pavadai (2015) also reported that the yield parameters like number of seeds plant$^{-1}$, grain yield plant$^{-1}$, recorded the moderate and high mean value in the 50 kR of gamma rays, 0.5% of EMS and 0.4% of DES treated population when compared to control plants in soybean.

From different treatments of gamma rays on soybean the economical and morphological mutants were isolated from the variety of TAMS-38 (Table 2). Visible macromutants like chlorophyll mutants, early flowering, late flowering, early maturing, late maturing,dwarf, tall, increased root length, increased 100 seed weight, small leaf, wrinkled leaf, viney type mutants, sterile, high yielding, more pods, more branched mutants were identified and isolated in $M_2$ generation. Maximum number 82 mutants were identified in 200 Gy treatment out of which only 27 were economical mutants. It was followed by 250 Gy treatment in which 92 number of mutants were observed of which 24 were economical. High yielding mutants yielded 12 to 17g as against 4.40 g in control. Similarly early maturing mutant matured in 11.2 to 20.2 days earlier than control.

It is inferred form the study that the gamma rays had the potential to induce variability in yield contributing characters of soybean. It was observed that gamma rays had significant effect on days to flowering, days to maturity, plant height (cm), number of branches plant$^{-1}$, length of primary root (cm), number of pods plant$^{-1}$, 100 seed weight (g) and grain yield plant$^{-1}$ (g). The economical mutants identified needs to be observed for their breeding behavior in further generations and their utilization in improvement of soybean.

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