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Genetic variability, Heritability and Genetic advance for yield and yield contributing traits in *Phaseolus lunatus* L. (lima bean)

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Abstract
To assess plant breeding, the genetic variability plays an important role which forms the basis for any crop improvement program. The statistical analysis of Genetic variability, Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), Heritability (h^2) and Genetic advance (GA) was studied for its yield and yield contributing characters like plant height, number of branches per plant, number of pods per plant, length of pod, number of seeds per pod, number of seeds per plant and 100 seed weight. Statistical analysis gives information about the character wise genetic improvement of plants through mutagenesis experiments. For the calculation of different yield and yield contributing traits in *Phaseolus lunatus* L. (lima bean), mutagenic treatments Gamma rays, EMS and combination were used to induce genetic variability. The Genetic variability observed in plants is due to the environmental influence and genetic factors. It could also be due to the interaction between these two factors.
There was positive and negative shift of mean for various traits in different mutagenic treatments. The difference between PCV and GCV values were high for parameters like number of seeds per pod and number of branches per plant in *Phaseolus lunatus* L. Higher the presence of PCV and GCV greater the variability of all the traits which indicates scope for improvement of traits by simple selection. High heritability when coupled with genetic advance is more useful in understanding the selection process.

Keywords: Genetic variability, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2) and genetic advance (GA)

1. Introduction
Induced mutation plays a very important and significant role in crop improvement of agricultural crops. It is an important and essential tool for induction of variations in quantitative and qualitative characters of plants. Pulses are a great source of proteins and hence need to increase research work on it to fulfil the high demand of protein food for human consumption and animal feed (Santalla *et al*., 2001) [35]. They have a very high and aggressive growth habit which contribute to high yield. India is one of the major producers and consumer of pulses in the world. The total area under cultivation of pulses in India is about 807.54 lakh hectare with the production about 730.07 lakh tones with productivity 904kg/ht. *Phaseolus lunatus* L. (lima bean) is a minor grain legume. It can produce up to 2000 to 8000kg of fresh seeds which depend on cultivar type and cultivation conditions. In tropical regions, in experimental conditions, climbing types grow in pure stands and may yield 750kg/ht dry seeds whereas bushy types may yield 2000-2500 kg/ht. Lima bean (*Phaseolus lunatus* L.) is a species suitable to low altitude, humid and sub humid tropical climatic conditions. It can be grown in a wide range of ecological conditions. Lima beans are cultivated throughout India particularly in Assam, West Bengal, Uttar Pradesh, and Tamil nadu, Karnataka, Maharashtra and Punjab. It is an excellent source of nutrient and protein for humans but is underexploited and a neglected legume species which makes the minor crop an important choice for research. Germplasm of lima bean is available at CIAT (Centro International de Agriculture Tropical) at Cali, Columbia, with various cultivars collected from Central and South America, Western and South Africa and some parts of Asia.
Plant breeding programs are a means by which new genetic varieties can be obtained and practically be used by humans. In a broader sense plant breeding method aims at obtaining the desired genes from more than one variety and combining them to produce a new variety which is a pure line population and more desirable than its parent type (Novak and Brunner, 1992) [27]. The ionizing radiations along with the chemical mutagens induce mutation singly or in combination in crops (Maluszynski, 2001) [25]. Mutagens are mainly grouped into physical mutagens and chemical mutagens. In this research work the study was performed by irradiation of seeds with various doses of Gamma rays and different concentrations of EMS and combination of both mutagens (Gamma rays and EMS) along with control. Research study has proved that use of different mutagens provides the tool to overcome limitations in genetic variability that occur in crops.

2. Materials and Methods
Healthy, uniform size and dry seeds of *Phaseolus lunatus* L. (lima bean) were exposed to three mutagenic treatments i.e. physical treatment (Gamma rays), chemical treatment

(EMS) and combination treatment (Gamma radiation + EMS). Seeds were packed in polythene bags and sealed for gamma radiation. Electromagnetic ionizing radiations were applied from CO^{60} source of irradiation. To ascertain the value of LD 50 the seeds were exposed to four doses of Gamma rays i.e., 240Gy, 300Gy, 360Gy and 420Gy. The exposure of radiation was carried out at Nuclear Chemistry Division, Department of Chemistry, Savitri bai Phule University of Pune, Pune. For chemical mutagen EMS was used. Ethyl Methanesulphonate (EMS) was obtained from Spectrochem. Pvt. Ltd. Mumbai (India). Four different concentrations 0.25%, 0.50%, 0.75% and 1% of the chemical mutagenic treatment were taken. The treatments were administered at room temperature at 25±2°C. Prior to treatment the seeds were washed thoroughly and presoaked in 100ml distilled water for 4 hours. Later the seeds were kept on filter paper to remove excess moisture in them. After presoaking, the seeds were immersed in mutagenic solution for 4 hours with continuous shaking. The combination treatment 240Gy+1%, 300Gy+0.75%, 360Gy+0.50% and 420Gy+0.25% consists of both physical mutagenic treatment and chemical mutagenic treatment. First the gamma rays irradiated seeds of different doses were used. After the physical treatment the chemical treatment of EMS was conducted at room temperature, where the seeds were immersed in EMS mutagenic solution for 4 hours.

2.1 Statistical Analysis

The data was subjected to statistical analysis. Computation of quantitative and qualitative data was studied and recorded as per Standard statistical procedure and ANNOVA such as Standard error (SE), Standard deviation (SD) and Coefficient of variability (CV). The statistical data was analyzed by using a software called NPRC STAT.

$$\text{Mean} = \frac{\sum X}{N} \quad \text{Variance} = \frac{\sum X^2}{N}$$

$$\text{Standard deviation} = \frac{N}{\sqrt{\text{Variance}}}$$

$$\text{Standard error (SE)} = \frac{\text{S.D}}{\sqrt{N}}$$

$$\text{Coefficient of variation (CV)} = \frac{\text{S.D}}{\text{Mean}} \times 100$$

Critical difference (CD) = SE (d) × t e.d.f. (Error degree of freedom). Where, SE (d) = SE (difference) = SE (Mean) ×2
The Annova was calculated by using SPSS Annova software of IBM-
S.E = Standard error S. V = Source of variation D. F = Degree of freedom S. S = Sum of squares
M. S. S = Mean sum of square F = Test value

2.2 Components of variations

The phenotypic and genotypic variances were calculated using the formula given by Johanson *et al*; (1955).
Environmental variance: σ 2e=EMS

$$\text{Genotypic variance: } \sigma 2g = \frac{\text{GMS} - \text{EMS}}{\text{R}}$$

Phenotypic variance = $\sigma^2P + \sigma^2g + \sigma^2 2e$

Where, GMS= Genotypic mean sum of square EMS=Error mean sum of square
r =Number of replications

2.3 Broad sense heritability

Broad sense heritability was calculated by using the method given by Hanson *et al*; (1956)

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where, g = Genotypic variance p = Phenotypic variance

2.4 Genetic Advance: Genetic advance (at 5% selection intensity) was calculated by Johansson *et al*., (1955) formula-

$$\text{G. A} = \text{K} \frac{\sigma^2 g}{\sigma^2 p} \times \sigma^2 p$$

Where, g=Genotype variance p= Phenotypic variance K= selection differential (Lush, 1949)
At 5% selection intensity, the value of K=2.06

3. Result and Discussion

Genetic variability that occurs in plants is important for the improvement of cultivated crops. Genetic variability helps in variation of genes in a population which helps in biodiversity (Shah *et al*., 2015 [36]. Kumar *et al*., 2016) [20]. Inheritance of qualitative and quantitative traits are of prior importance in plant breeding programs (Shah *et al*., 2015) [36]. The quantitative characters are controlled by polygenes which are expressed as variations in plants. Polygenic mutations occurred at random and not in any particular direction. These traits are obtained and studied at the harvesting stage of the crop. In the present investigation assessment of quantitative characters such as plant height, number of branches per plant, number of pods per plant, length of pods, number of seeds per pod, number of seeds per plant and weight of 100 seeds was studied and recorded in *Phaseolus lunatus* L. These traits are yield contributing traits. Naseem *et al*., (2015) [26]. Stated that the presence of whole spectrum of phenotypes make quantitative selection of traits more difficult than that of qualitative traits. Upadhyay *et al*., (2019) [39]. observed genetic variability to be a very important and requisite factor in breeding programs due to the fact that they not only are useful in selection of useful traits but also provide data on diversity of traits. Gemechu and Gudeta (2020) [14]. reported that in plant breeding practices, the breeder must adopt simple selection methods on basis of phenotypic expression of characters.
Many researchers have observed and recorded various quantitative characters in different plants, Vidya *et al*., (2002) in Cowpea, Diriba *et al*., (2014) in Cowpea, Hakande (1992) [15]. in Wing bean, Vahidy and Yousufzai (1991) [40]. in Guar, Wojciech (2003) [45]. in Grass pea, Tah (2006) [38]. in Mung bean and Wani and Anis (2008) [42]. in Chickpea, Kulthe and Kothekar, 2011 [19]. in *Cicer arietinum* L, Shinde (2013) in cluster bean, Gaikwad (2013) [13].in cowpea, Bhosale (2014) [8]. in *Withania somnifera,* Salve (2014) in *Coraindrum sativum* Linn, Borkar (2015) *Phaseolus*

vulgaris Linn., Ramezani (2015) in *Lathyrus sativum* Linn. Gamma rays are more mutagen sensitive than EMS. EMS treatment has a less impact on the viable mutants in M2 generation but has its effect on other modifications of leaf and pod. Singh and Chaturvedi (1990) [37]. reported the increase in variability for number of pods per plant in mutagenic treatments. The increase in number of pods per plant with mutagenic treatment was also reported by Waghmare and Mehra (2000) in Grass pea. Decrease in dry weight of seeds with increasing concentrations of mutagens is due to the temperature fluctuations and nutritive contents of the plants. There was positive and negative shift of mean for various traits in different mutagenic treatments. The same was reported by Rajput *et al.*, (1974) [32]. in soya bean, Hakande (1992) [15]. In Wing bean.

1. Analysis of Genetic variability, Heritability and Genetic Advance

The statistical analysis of Genetic variability, Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), Heritability (h^2) and Genetic advance (GA) was studied for its yield and yield contributing characters like plant height, number of branches per plant, number of pods per plant, length of the pod, number of seeds per pod, number of seeds per plant and 100 seed weight. Statistical analysis gives information about the character wise genetic improvement of plants through mutagenesis experiments. To assess plant breeding the genetic variability plays an important role which forms the basis for any crop improvement program. Hence it is necessary to study genetic variability for the quantitative characters (Patil and Lokesha, 2008). Kumar *et al*., 2019 [21]. Upadhyay *et al*., 2019 [39]. stated that GCV and PCV parameters are very helpful in identifying the extend of variability in the germplasm. The relationship between yield and its components is important to understand the selection process and this can be studied by means of correlation and path coefficient analysis.

To increase the spectrum of variation, mutation breeding is a powerful tool. A superior variety is subjected to mutagenic treatment and generations are advanced to identify mutants like high yield, plant type, pod length, seed size etc. in early generations. Later these varieties are advanced and stabilized to achieve uniformity and pure lines in the families. Increasing the number of seeds per plant will increase the seed yield and hence at the time of yield selection the number of seeds per plant should be emphasized more. For the calculation of different yield and yield contributing traits in *Phaseolus lunatus* L. the mutagenic treatments Gamma rays, EMS and combination were used to induce genetic variability.

2. Phenotypic and Genotypic coefficient of variation

PCV and GCV was estimated for height of plant, where PCV value 25.60% was recorded highest in EMS treatment and lowest value 21.33% in combination treatment. The highest value of GCV 25.46% was recorded in EMS treatment and the lowest GCV 21.01% was observed in combination treatment. The PCV and GCV estimated for the number of branches per plant, where PCV value 51.28% was recorded highest in EMS treatment and lowest value 35.26% in combination treatment. The highest value of GCV 51.25% was recorded in EMS treatment and the lowest GCV 35.12% was observed in combination treatment. The PCV and GCV estimated for the length of pod per plant, where PCV value 28.57% was recorded highest in combination treatment and lowest value 27.25% in EMS. The highest value of GCV 28.03% was recorded in combination treatment and the lowest GCV 25.91% was observed in EMS treatment. The PCV and GCV estimated for the number of seeds per pod, where PCV value 40.89% was recorded highest in Gamma rays treatment and lowest value 27.46% in combination treatment. The highest value of GCV 12.04% was recorded in Gamma rays and the lowest GCV 4.64% was observed in EMS treatment. The PCV and GCV estimated for the number of seeds per plant, where PCV value 30.65% was recorded highest in EMS treatment and lowest value 28.79% in Gamma radiation. The highest value of GCV 30.50% was recorded in EMS treatment and the lowest GCV 28.67% was observed in Gamma radiation. The PCV and GCV estimated for the weight of 100 seeds (gm), where PCV value 9.31% was recorded highest in EMS treatment and lowest value 8.43% in combination treatment. The highest value of GCV 9.31% was recorded in EMS treatment and the lowest GCV 8.42% was observed in combination treatment.

The difference between PCV and GCV values were high for parameters like number of seeds per pod and number of branches per plant in *Phaseolus lunatus* L. Higher the presence of PCV and GCV greater the variability of all the traits which indicate scope for improvement of traits by simple selection. Similar results were obtained by Rao *et al*., (2013). These observations inferred that the phenotypic coefficient of variation is higher than the genotypic coefficient of variation for all the traits. Hence it can be stated that the influence of environment was least and the genetic factors which caused variability is more. The similar results were observed in chickpea by Yucel *et al*., (2006) [46]. Gemechu and Gudeta (2020) [14]. reported that the traits in consideration are less influenced by environment when the PCV is slightly greater than the GCV.

The low degree of phenotypic correlation may be due to the environment effect on the plants which was studied by Rajanna *et al*., (2014) [33]. Furthermore, many researchers observed the similar results in different plant species like, the PCV was high in cowpea for the number of pods per plant was reported by Bhosale (2014) in *Withania somnifera*, Salve (2014) in *Coraindrum sativum* Linn, Borkar (2015) in *Phaseolus vulgaris* Linn., Ramezani (2015) in *Lathyrus sativum* Linn. It can be stated that most of the characters may be under genetic control rather than the environmental influence and the improvement of these traits can be gained through selection process. This was reported by Oyiga and Uguru (2011). More and Borkar (2016) reported that the heritability calculated was very high for quantitative characters like plant height, length of pod and 100 seed weight induced by EMS, Gamma rays and combination treatment in French bean.

The PCV and GCV values were moderate for plant height and number of seeds per plant in *Phaseolus lunatus* L. Lesley (2005) also observed similar results and inferred that the selection was less effective at high PCV and GCV. The similar trend was observed in other crops like in Black gram reported by Arulbalachandran *et al*., (2010) and in chickpea reported by Wani (2011). All the traits under observation presents a different data on variability which shows significant differences (Islam *et al*., 2011).

3. Heritability and Genetic Advance

Heritability is the phenomenon in which there is transfer of characters from the parents to their off springs. Kumar *et al*., (2016) [20]. Stated the heritability index to be important and dependable factor in transmission of traits from parents to progeny. Parmar *et al*., (2013) [30]. observed that the heritability is an indicator of advancement which is observed when selection of a population occurs. Selection of yield components which indirectly increase the yield is a common practice among the plant breeders. Hence to increase grain yield effectively, higher heritability and genetically independent analysis takes place. Genetic heritability values are less reliable because of the altercation in values which take place due to environmental and experimental factors if taken into account singly. Thus, the preference of high heritability and high genetic advance is taken into consideration for traits and are most likely controlled by additive gene action.

The Genetic variability observed in the plants is due to the environmental influence and genetic factors. The Genetic variation can be divided into heritable and non-heritable factors while the pure line selection is attributed to environmental influence. The variation due to heritability can further be divided into additive and non-additive factors. The non-additive components of genetic variance do not transfer to next generation. The heritability can also be classified into dominant and inter-allelic interaction which was suggested by Falconer (1981). Lush (1945) and Hanson *et al*., (1956) suggested that the broad sense heritability is the ratio of genetic variance to the total variance in non-segregating population. Calculation of heritability and genetic advance for all the traits help in the selection of desired genotypes.

Heritability was observed for all seven quantitative characters in *Phaseolus lunatus* L. after the mutagenic treatments Gamma rays, EMS and combination. Heritability was maximum for plant height (98.90%) in EMS, number of branches (99.85%) in EMS, number of pods per plant (93.08) in Gamma radiation, length of pod per plant (96.23%) in combination treatment, number of seeds per pod (17.14%) in combination treatment, number of seeds per plant (99.16%) and weight of 100 seeds (99.99%) in EMS treatment. High heritability is found to be very helpful in selecting superior genotypes on the basis of their superior phenotypic performance in their respective quantitative characters. According to Idahosa (2010) if the heritability is high then the selection of traits is very easy because of the relation between phenotypes and genotypes and thus there is very less contribution of environmental factors on the phenotypes of the population. Gemechu and Gudeta (2020) [14]. observed intermediate heritability in plant height. The similar result was obtained by Borkar (2015) in *Phaseolus vulgaris* and Ramezani (2015) in *Lathyrus sativus*. Heritability was coupled with genetic advance for few traits which indicate the role of additive genes and phenotypic selection. Additive gene action is responsible for the improvement of traits when there is mass selection in a population.

The term Genetic advance can be described as the improved mean genotypic value or the measure of genetic gain of the selected plants. Genetic advance mainly depends of genetic variability and heritability of the selected population under scan (Allard 1960) [1]. High heritability was combined with moderate genetic advance in many quantitative characters. Genetic advance was maximum in *Phaseolus lunatus* L. for the following quantitative characters, plant height (31.05%) in EMS, number of branches per plant (29.54%) in EMS, number of pods per plant (9.91%) in EMS, length of pod per plant (4.86%) in gamma radiation, number of seeds per pod (0.38%) in combination treatment, number of seeds per plant (26.52%) in combination and weight of 100 seeds (13.74%) in gamma radiation. The similar results were reported by Parmar *et al.*, (2013) [30]. GA was highest in *Phaseolus lunatus* L. for plant height trait. When genetic advance is high, the additive genes come into play and if the value is low the non-additive genes play their role.

Table 1: Effect of Gamma rays, EMS and combination (Gamma rays + EMS) treatment on height of plant in *Phaseolus lunatus* L.

Mutagens	Range	Mean height of plant	Shift in Mean	Mean	CV	SE	PCV	GCV	h2	GA	GS
Control	32.5-39.3	35.33		58.47	2.67	0.90	24.18	24.04	98.78	28.77	49.21
Gamma Rays 240Gy	66.8-74.6	70.00	34.67								
Gamma Rays 300Gy	63.0-71.0	67.67	32.33								
Gamma Rays 360Gy	52.0-58.0	55.33	20.00								
Gamma Rays 420Gy	61.0-69.0	64.00	28.67								
EMS 0.25%	66.0-77.0	71.67	36.33	59.53	2.68	0.92	25.60	25.46	98.90	31.05	52.15
EMS 0.50%	68.0-74.0	71.33	36.00								
EMS 0.75%	51.5-57.6	54.67	19.33								
EMS 1%	61.0-68.0	64.67	29.33								
Combination (240 Gy+ 1%)	57.0-61.8	59.67	24.33	53.93	3.70	1.15	21.33	21.01	96.99	22.99	42.63
Combination (300 Gy+ 0.75%)	58.0-63.0	60.00	24.67								
Combination (360 Gy+ 0.50%)	48.0-53.0	51.00	15.67								
Combination (420 Gy+ 0.25%)	60.0-65.0	63.67	28.33								

Table 2: Effect of Gamma rays, EMS and combination (Gamma rays + EMS) treatment on number of branches in *Phaseolus lunatus* L.

Mutagens	Range	Mean number of branches	Shift in Mean	Mean	CV	SE	PCV	GCV	h2	GA	GS
Control	11.0-14.0	13.00		24.07	3.22	0.45	50.95	50.85	99.60	25.16	104.54
Gamma Rays 240Gy	38.0-45.3	42.67	29.67								
Gamma Rays 300Gy	26.5-31.7	29.00	16.00								
Gamma Rays 360Gy	19.3-24.8	21.67	8.67								
Gamma Rays 420Gy	12.1-15.9	14.00	1.00								
EMS 0.25%	46.0-53.0	49.00	36.00	28.00	1.96	0.32	51.28	51.25	99.85	29.54	105.49
EMS 0.50%	32.5-38.3	35.00	22.00								

EMS 0.75%	23.0-27.0	25.00	12.00								
EMS 1%	16.0-19.0	18.00	5.00								
Combination (240 Gy+ 1%)	39.0-43.0	41.00	28.00								
Combination (300 Gy+ 0.75%)	27.0-32.5	29.00	16.00	29.00	3.08	0.52	35.26	35.12	99.23	20.90	72.07
Combination (360 Gy+ 0.50%)	31.0-35.0	33.00	20.00								
Combination (420 Gy+ 0.25%)	27.0-31.0	29.00	16.00								

Table 3: Effect of Gamma rays, EMS and combination (Gamma rays + EMS) treatment on number of pods in *Phaseolus lunatus* L.

Mutagens	Range	Mean number of pods	Shift in Mean	Mean	CV	SE	PCV	GCV	h2	GA	GS
Control	13.0-16	13.67									
Gamma Rays 240Gy	18.0-26	21.67	8.00								
Gamma Rays 300Gy	20-25.7	24.33	10.67	20.53	5.33	0.63	20.28	19.56	93.08	7.98	38.88
Gamma Rays 360Gy	21-24	22.33	8.67								
Gamma Rays 420Gy	17-23	20.67	7.00								
EMS 0.25%	23-26.6	25.67	12.00								
EMS 0.50%	24.0-28	26.00	12.33	23.27	9.43	1.27	24.34	22.44	84.98	9.91	42.61
EMS 0.75%	24-27.5	25.33	11.67								
EMS 1%	25-26.7	25.67	12.00								
Combination (240 Gy+ 1%)	20-23.7	22.00	8.33								
Combination (300 Gy+ 0.75%)	19-21.3	20.33	6.67	20.87	6.31	0.76	22.29	21.38	91.99	8.81	42.24
Combination (360 Gy+ 0.50%)	21-25	22.33	8.67								
Combination (420 Gy+ 0.25%)	22-28	26.00	12.33								

Table 4: Effect of Gamma rays, EMS and combination (Gamma rays + EMS) treatment on length of pods in *Phaseolus lunatus* L.

Mutagens	Range	Mean length of pod	Shift in Mean	Mean	CV	SE	PCV	GCV	h2	GA	GS
Control	4.1-5.6	4.87									
Gamma Rays 240Gy	6.1-9.9	9.27	4.40								
Gamma Rays 300Gy	9.6-12.1	10.53	5.67	8.91	5.68	0.29	27.65	27.07	95.79	4.86	54.57
Gamma Rays 360Gy	7.2-11.1	8.87	4.00								
Gamma Rays 420Gy	8.9-12.0	11.03	6.17								
EMS 0.25%	5.1-10.7	9.07	4.20								
EMS 0.50%	8.7-10.2	9.03	4.17	8.20	8.43	0.40	27.25	25.91	90.42	4.16	50.76
EMS 0.75%	6.2-8.5	7.47	2.60								
EMS 1%	8.8-11.1	10.57	5.70								
Combination (240 Gy+ 1%)	7.1-8.6	7.83	2.97								
Combination (300 Gy+ 0.75%)	9.1-11.0	10.07	5.20	8.41	5.55	0.27	28.57	28.03	96.23	4.77	56.64
Combination (360 Gy+ 0.50%)	6.7-9.1	8.27	3.40								
Combination (420 Gy+ 0.25%)	9.8-11.7	11.03	6.17								

Table 5: Effect of Gamma rays, EMS and combination (Gamma rays + EMS) treatment on number of seeds per pod in *Phaseolus lunatus* L.

Mutagens	Range	Mean number of seeds per pod	Shift in Mean	Mean	CV	SE	PCV	GCV	h2	GA	GS
Control	2-4	3.00									
Gamma Rays 240Gy	2-4	3.67	0.67								
Gamma Rays 300Gy	2-5	4.33	1.33	3.87	39.08	0.87	40.89	12.04	8.67	0.28	7.30
Gamma Rays 360Gy	3-6	4.00	1.00								
Gamma Rays 420Gy	4-5	5.00	2.00								
EMS 0.25%	3-5	4.67	1.67								
EMS 0.50%	2-5	3.00	0.00	3.93	39.93	0.91	40.20	4.64	1.33	0.04	1.10
EMS 0.75%	1-5	4.00	1.00								
EMS 1%	4-5	5.00	2.00								
Combination (240 Gy+ 1%)	2-5	3.33	0.33								
Combination (300 Gy+ 0.75%)	2-4	3.00	0.00	3.93	25.00	0.57	27.46	11.37	17.14	0.38	9.70
Combination (360 Gy+ 0.50%)	4-6	5.67	2.67								
Combination (420 Gy+ 0.25%)	3-5	3.67	0.67								

Table 6: Effect of Gamma rays, EMS and combination (Gamma rays + EMS) treatment on number of seeds per plant in *Phaseolus lunatus* L.

Mutagens	Range	Mean number of seeds per plant	Shift in Mean	Mean	CV	SE	PCV	GCV	h2	GA	GS
Control	18-24	21.00									
Gamma Rays 240Gy	38-42	41.00	20.00								
Gamma Rays 300Gy	35-42	38.00	17.00	39.13	2.64	0.60	28.79	28.67	99.16	23.02	58.82
Gamma Rays 360Gy	43-46	44.67	23.67								
Gamma Rays 420Gy	48-55	51.00	30.00								
EMS 0.25%	47-49	48.00	27.00	41.40	3.06	0.73	30.65	30.50	99.01	25.88	62.52

EMS 0.50%	35-42	37.67	16.67								
EMS 0.75%	47-50	47.67	26.67								
EMS 1%	49-54	52.67	31.67								
Combination (240 Gy+ 1%)	47-53	49.00	28.00	42.93	2.82	0.70	30.25	30.12	99.13	26.52	61.77
Combination (300 Gy+ 0.75%)	53-56	55.00	34.00								
Combination (360 Gy+ 0.50%)	43-47	44.67	23.67								
Combination (420 Gy+ 0.25%)	44-46	45.00	24.00								

Table 7: Effect of Gamma rays, EMS and combination (Gamma rays + EMS) treatment on weight of 100 seeds in *Phaseolus lunatus* L.

Mutagens	Range	Mean weight of 100 seeds	Shift in Mean	Mean	CV	SE	PCV	GCV	h2	GA	GS
Control	61.2-65.0	62.17		72.86	0.12	0.05	9.16	9.16	99.98	13.74	18.86
Gamma Rays 240Gy	71.8-82.5	78.17	16.00								
Gamma Rays 300Gy	77.9-78.2	74.33	12.17								
Gamma Rays 360Gy	70.1-73.2	71.23	9.07								
Gamma Rays 420Gy	78.1-80.1	78.40	16.23								
EMS 0.25%	60.3-64.5	63.80	1.63	69.31	0.11	0.04	9.31	9.31	99.99	13.29	19.17
EMS 0.50%	76-80.1	78.10	15.93								
EMS 0.75%	68.1-72.6	71.60	9.43								
EMS 1%	66.5-74.3	70.90	8.73								
Combination (240 Gy+ 1%)	68.5-72.2	70.90	8.73	71.99	0.17	0.07	8.43	8.42	99.96	12.49	17.35
Combination (300 Gy+ 0.75%)	73-2-76.8	74.90	12.73								
Combination (360 Gy+ 0.50%)	75.1-79.2	78.10	15.93								
Combination (420 Gy+ 0.25%)	71.5-75.3	73.90	11.73								

Conclusion

It can be concluded that there is still a need for inducing new mutants and targeting specific genes of desired interest in a functional way and those that are equivalent to other normal genes. The isolated mutants aim at objectives that help the crops to grow under adverse climatic conditions and different stress along with increased yield. In the present investigation, the physical mutagen Gamma rays and chemical mutagen EMS and combination (Gamma rays + EMS) were succeeded in inducing superior genotypes in plant progeny. They can be used to induce genetic variability in different morphological variants.

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