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RESEARCH ARTICLE

Enhanced variability due to shifts in mean created through induced mutation, hybridization and its combination in groundnut (*Arachis hypogaea* L.)

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SUMMARY

An experiment to study the effectiveness of γ-rays and ethyl methane sulphonate induced mutagenesis in bringing about shift in mean and creation of genetic variability for pod yield and its attributes in two varieties of groundnut *viz*., GPBD-4 and CTMG-1 and their F_2 and F_2M_2 generations was carried out during 2006-08, at Agricultural Research Station, Chintamani, UAS (B). The LD_{50} dose was fixed at 20 kR for gamma ray irradiation and at 0.5 per cent for ethyl methane sulphonatee (EMS). The two varieties exhibited differential response to different mutagens. In general, the overall shifts in the mean of F_2M_2 population was maximum in the desirable directions compared to any other populations followed by 20 kR irradiated M_2 population of CTMG-1. The F_2M_2 population manifested maximum heritability (96.44%) and genetic advance as per cent of mean (76.24%) and among the mutagen treated M_2 populations, maximum heritability (81.35 %) and genetic advance as per cent of mean (41.50%) was recorded in 20 kR irradiated populations of GPBD-4 for pod yield (g/plant). The mutagenic treatment with 20 kR irradiated and 0.5 per cent EMS treated GPBD-4 and CTMG-1 populations and F_2M_2 population have resulted in creation of higher genetic variations and hence serve as an excellent source material for variety development representing a more efficient source of genetic variability than gene pools conserved by nature.

Key Words : Induced mutagenesis, Shifts in mean, Genetic variability, F_2M_2 population

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Groundnut (*Arachis hypogaea* L.), is one of the most important oilseed crops, commercially popular due to its superior quality of edible oil and protein, has a wide range of adaptability in varying agro-climatic conditions and soils. The major groundnut producing states of India are Gujarat which ranks first (2.5 m.t.), followed by Tamil Nadu (1 m.t), Andhra Pradesh (1 m.t), Karnataka (0.5 m.t) and Maharashtra (0.5 m.t). Due to increase in population, increased standard of living and rapid industrialization, the demand for vegetable oil and oilseeds is increasing, the National Council of Applied Economic Research (NCAER) has projected the demand for edible oils in India to be 19.02 m.t by 2025 (Sudhakara Babu and Hegde, 2011).

Lack of sufficient genetic variability has been one of the major constraints in groundnut. Creation of variability being the essence of plant breeding programme, the approach adopted strategically to create variation plays an important role in reaching the targets. The various problems often encountered in effecting crosses, longer period in evolving a superior variety and the non-availability of parents with desirable genes has enforced a limitation on the use of hybridization. Often, hybridization involving very diverse genotypes was found to disrupt the adaptive genetic base of

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the parental genotypes by infusion of many undesirable traits which necessitate number of back crosses to eliminate them. In view of the above problems, alternate methods of generating polygenic variability have greater importance in breeding groundnut. Since spontaneous mutations occur at a very low frequency in nature, creation of variability has to be artificially enhanced either through inter-varietal hybridization or through induced mutagenesis. In this context, it would be worthwhile to examine the yield transformation that would be obtained through induced mutations. The merit of using polygenic mutation in place of recombination method can only be judged based on a direct comparison of the magnitude, distribution and breeding value of the genetic variability generated by the two methods. In addition, the method of subjecting heterozygous material (F_1 or F_2 seeds) to mutagenic treatments has opened up new possibilities in mutation breeding. Such an approach is expected to exploit the potentiality of both polygenic mutation as well as recombination in expanding the genetic variability beyond the limits set by the two methods, when applied individually.

Hence, a systematic study on the nature, magnitude and breeding value of the genetic variability generated through induced mutagenesis, hybridization and their combination would help in assessing the relative merits of each of these methods in crop improvement. Further, the involvement of both radiations and chemical mutagens to induce polygenic mutation in homozygous (pure lines) as well as heterozygous (hybrid-derived) genetic background coupled with simultaneous analysis of various polygenic traits in different generations is expected to throw light on the nature and properties of induced polygenic mutations. With these priorities in mind, the present work was taken up with an objective to assess the extent of genetic variability created by physical and chemical mutagens as well as hybridization and a combination of hybridization and mutation.

MATERIALS AND METHODS

The present investigation was carried out from *Kharif* 2006 up to *Kharif* 2008 at the field unit of All India Co-ordinated Research Project (AICRP) on Groundnut, Agricultural Research Station, Chintamani, representing the Eastern dry zone (Zone-5) of Karnataka. The material for the present investigation was generated from two varieties of groundnut *viz*., GPBD-4 and CTMG-1.

These two varieties were treated with different doses of gamma-rays (γ-rays) and ethyl methane sulphonatee (EMS) for determination of LD_{50} dose under laboratory conditions, after these two varieties were treated with LD_{50} dose for each mutagen g-rays and EMS concentration, the progenies of M_1 generation were advanced to M_2 generations under field conditions. In addition, the two varieties were crossed to generate F_0 seeds, 50 per cent of which were treated with 20 kR g-rays and advanced to F_2M_2 generation, while remaining 50 per cent of untreated seeds were advanced to F_2 generation under field conditions.

Indentification of LD_{50} under laboratory conditions :

One hundred viable, bold uniform sized seeds of each of the two varieties *viz*., GPBD-4 and CTMG-1 with about 12 per cent moisture were selected and packed in butter paper bags separately for each treatment and sent to Bhabha Atomic Research Centre, Trombay, Bombay for irradiating seeds with 10 kR, 20 kR, 30 kR, 40 kR, 50 kR, 60 kR, 70 kR, 80 kR, and 90 kR doses of g-rays from ^{60}Co source at gamma garden. The untreated seeds of each genotype were used as control. Similarly, One hundred bold and viable uniform sized seeds of each variety *viz*., GPBD-4 and CTMG-1 having 12 per cent moisture were treated with ethyl methane sulphonatee (EMS). Appropriate quantities of EMS were dissolved in double distilled water to get the required concentration of 0.1 per cent, 0.2 per cent, 0.3 per cent, 0.4 per cent, 0.5 per cent, 0.6 per cent, 0.7 per cent, 0.8 per cent and 0.9 per cent. The seeds of each genotype for each treatment were presoaked in double distilled water for six hours. The presoaked seeds were then soaked in EMS solutions of different concentration for eight hours at room temperature ($22^0 \pm 2^0$C) with intermittent shaking during the period of treatment. After the treatment, the treated seeds were washed to remove the residues of the chemical. The seeds that were pre-soaked in double distilled water alone for six hours were used as control for EMS treatment.

The seeds of the two varieties *viz*., GPBD-4 and CTMG-1 that were individually treated with 10-90 kR doses of (γ-rays) and 0.1 - 0.9 per cent of EMS along with their respective controls were sown in germination papers and kept in germination chamber. On the tenth day of germination, per cent germination, seedling height (cm) and seedling vigor index from each treatment of both the varieties was recorded. The procedure followed for recording observations on seedling traits in M_1 generation in the laboratory is presented below.

Germination percentage :

The germination test was conducted in the laboratory using between paper method as prescribed by ISTA, (Anonymous, 1996) utilizing non toxic germination paper as media. One hundred seeds of each treatment of two replicates each were placed on germination paper that is between paper towels and the rolled towels were incubated in germination chamber maintained at 25 ± 1^0C temperature and 85 per cent relative humidity. The seedlings were evaluated on the fourth and tenth day and percentage germination was expressed based on normal seedlings.

Seedling height (cm):

The seedling height was measured from the tip of the primary root to the tip of the primary leaf and mean of ten seedlings was calculated and expressed in centimeters.

Seedling vigour index (SVI) :

The seedling vigour index was calculated by using seedling growth parameters and expressed as a whole number as suggested by Abdul Baki and Anderson (1973).

SVI = Germination (%) x Mean seedling height (cm)

Raising of M_1, M_2 and M_3 generations

Mutagenic treatment and raising M_1 generation :

One hundred seeds of GPBD-4 and CTMG-1 were treated with 20kR of gamma-rays and 0.5 per cent of ethyl methane sulphonate along with their respective controls and M_1 generation was raised following all the recommended package of practices. In each mutagenic treatment, all those plants that survived to maturity were harvested individually and forwarded to M_2 generations as plant to row progeny.

Advancement of M_1 to M_2 generation :

The two untreated parental varieties GPBD-4 and CTMG-1 and seeds harvested from each M_1 plants were collected separately and sown in separate rows to raise M_2 generation following all the recommended package of practices.

Observations were recorded as per standard procedures on quantitative characters *viz.*, total number of pods per plant, number of matured pods per plant, pod yield per plant (g), kernel yield per plant (g),100-kernel weight (g) and oil content (%) in each treatment separately at the time of harvest along with the controls.

Hybridization and combination of hybridization and mutation:

Variability generated by hybridization alone and variability created through combination of hybridization and mutation was studied in this experiment. Crossing programme was carried out as per Norden (1973) between two varities CTMG-1 and GPBD-4. At the time of harvest, the crossed pods were collected to obtain F_0 seeds, half of which was used for raising F_1 generation. The remaining F_0 seeds were sent to Bhabha Atomic Research Centre Trombay, (BARC) Bombay for treatment with gamma-rays at 20 kR to obtain F_1M_1 generation.

Raising F_1 and F_1M_1 generation :

The irradiated crossed seeds along with untreated crossed seeds of both the parents were sown and at the time of harvest, seeds of both F_1's and F_1M_1's individual plants were harvested separately to raise F_2 and F_2M_2 generation.

Raising F_2 and F_2M_2 generation :

The F_2 and F_2M_2 populations were raised in unreplicated blocks along with their parents.

Statistical analysis :

The mean was computed for all the observations recorded for each genotype and was used for further statistical analysis. The analysis of variance was carried out following RCBD design as suggested by Panse and Sukhatme (1967).

Statistical analysis of F_2, F_2M_2 and M_2 populations :

The details of statistical procedures adopted for genetic analysis of F_2, F_2M_2 and also in M_2 populations to get inference on the magnitude of variability produced, heritability and genetic advance as percentage over mean in respect of yield and its attributing characters are presented below.

Mean :

Means in respect of all the quantitative traits were calculated for each parent F_2, F_2M_2 and M_2 populations along with their respective parents and or controls using data recorded on individual plants.

Estimation of genetic parameters :

The genetic variance was partitioned from total variance according to the method suggested by Fiuzat and Atkins, 1953 and as illustrated by Weber and Moorthy (1952). The variance of the F_2, F_2M_2 and M_2 populations is considered as the total phenotypic variance (σ^2p). The environmental variance (σ^2e) is the mean variance of the non-segregating parental populations. The genotypic variance (σ^2g) was estimated as the difference between the total phenotypic variance and environmental variance. The genotypic and phenotypic co-efficient of variation for all the characters in each of the F_2, F_2M_2 and M_2 populations, along with heritability in broad sense for all the characters was estimated as the ratio of genotypic variance to the phenotypic variance and was expressed in percentage were computed as per the methods suggested by Burton and De Vane (1953). Genetic advance expressed as per cent of mean (GAM), that is the extent of genetic advance for each character that could be expected by selecting certain proportion of the superior progeny was predicted by the formula given by Johnson *et al.* (1955).

RESULTS AND DISCUSSION

The knowledge on genetic variability in the populations for different characters is a pre-requisite before initiating any breeding programme aimed at improving yield, quality and other characters under consideration. Unless a major portion of variations turns out to be heritable, attempts to improve a character by selection would become futile. Mutations is considered as a valuable tool in crop improvement, a source to increase genetic variability resources from which useful variants could be obtained either directly or after recombination. The importance of gamma-rays in evolving ideal recombination along with yield and other superior agronomic characters in groundnut was emphasized by Badigannavar *et al.* (2005). Irradiation of heterozygous material has been followed as new approach in mutation breeding. Such an approach is expected to exploit simultaneously the

potentiality of both polygenic mutations and recombination in enlarging quantitative variability beyond the limits set by the two methods when applied individually and brings about breakages of linkages of undesirable gene blocks.

Determination of LD_{50} dose in M_1 generation :

The effect of different doses of gamma-rays ranging from 10 to 90 kR and different concentrations of ethyl methane sulphonatee (EMS) ranging from 0.1 to 0.9 per cent along with control on seedling growth, germination percentage and seedling vigour index in two groundnut varieties GPBD 4 and CTMG 1 is tabulated in Table 1 and 2. The germination percentage was 51.21 per cent in GPBD-4 and 50.53 per cent in the variety CTMG-1 at 20 kR. The germination percentage was 51.13 per cent in the variety GPBD-4 and 50.25 per cent in the variety CTMG-1 at 0.50 per cent concentration.

Hence, LD_{50} dose was fixed for both gamma-rays (20 kR) as well as EMS (0.5 %) treatment. The immediate effect of treatment of seeds with mutagens is inhibition of germination. A gradual reduction in germination percentage with increase in dosage was noticed with both gamma-rays and EMS treatments. Singh and Kole (2005) reported severe reduction in germination, frequency of normal seedlings, reduction in plumule to radical length and physiological injuries of radical which indicated effective mutagenesis in mung bean. Singh and Renuka Devi (2006) also made similar observations in gamma ray treated rice bean varieties.

Mean performance of various characters recorded in M_2, F_2 and F_2M_2 generations of groundnut varieties :

Mean was computed for productivity characters of M_2, F_2 and F_2M_2 along with their control and is presented in Table

Table 1: Effect of different doses of gamma rays on germination percentage and seedling traits in M_1 generation of two varieties of groundnut

Doses of γ-rays (kR)	GPBD-4			CTMG-1		
	Germination percentage	Seedling height (cm)	Seedling vigour index	Germination percentage	Seedling height (cm)	Seedling vigour index
Control	100.00	27.54	2747.64	100.00	27.38	2736.38
10	93.37	24.36	2275.76	88.30	21.85	1946.21
20	51.21	19.60	1003.69	50.53	15.48	782.20
30	49.00	17.61	930.50	47.60	11.06	570.93
40	46.99	6.46	303.56	46.28	8.61	397.87
50	42.77	5.56	237.83	42.56	8.27	354.33
60	37.95	5.00	190.04	35.64	4.95	176.70
70	32.53	4.67	153.47	28.20	5.56	156.19
80	20.48	4.79	97.28	20.22	5.00	100.35
90	13.26	4.46	58.07	3.19	1.85	11.80
Mean	48.86	12.31	809.78	46.65	11.00	723.26
C.V. (%)	5.29	19.26	24.23	4.35	15.76	22.68
C.D.@5%	13.16	4.36	346.71	11.28	26.87	375.84

Table 2: Effect of different concentrations of EMS on germination percentage and seedling traits in M_1 generation of two varieties of groundnut

EMS Concentration (%)	GPBD-4			CTMG-1		
	Germination percentage	Seedling height (cm)	Seedling vigour index	Germination percentage	Seedling height (cm)	Seedling vigour index
Control	99.96	23.90	2390.93	99.97	28.40	2840.32
0.10	94.79	30.13	2856.99	92.72	31.31	2903.26
0.20	85.60	35.19	3010.32	88.58	28.19	2497.01
0.30	74.11	33.18	2461.78	80.81	25.23	2041.87
0.40	49.98	28.64	1429.17	48.69	17.93	873.05
0.50	51.13	17.08	873.89	50.25	16.48	828.03
0.60	37.34	11.90	444.26	39.89	7.73	308.34
0.70	16.09	8.29	137.97	13.99	7.44	102.32
0.80	8.04	13.80	110.72	9.32	11.32	104.75
0.90	0.00	0.00	0.00	0.00	0.00	0.00
Mean	51.70	20.21	1371.60	52.42	16.90	1224.59
C.V. (%)	4.02	12.29	11.84	5.82	13.67	9.45
C.D.@ 5%	2.78	17.51	286.86	14.76	18.94	327.41

3. Maximum mean was observed for total number of pods (37.49±0.44), number of matured pods (35.02±0.42), pod yield per plant (18.37±0.43), kernel yield per plant (12.59±0.13), hundred kernel weight (42.17±0.19) and oil content (45.57±0.19) in the F_2M_2 population, whereas the mean performance of these traits was comparatively lower in F_2 population.

Among the mutagen treated M_2 populations, 20 kR irradiated CTMG-1 population recorded highest number of matured pods (34.51±0.29), pod yield per plant (14.56±0.15), kernel yield per plant (12.41±0.14), in 0.5 per cent EMS treated CTMG-1 population recorded maximum total number of pods (36.17±0.45), and hundred kernel weight (41.75±0.19) and 20 kR irradiated GPBD 4 population recorded highest mean oil content (45.94±0.13) compared to controls.

Shifts in mean performance for various characters in F_2, F_2M_2 and M_2 populations compared to control :

In M_2, F_2 and F_2M_2 populations, either positive or negative shifts for mean values in different population is revealed in Table 4. In M_2 population, most of the characters exhibited a positive shifts at 20 kR irradiated and 0.5 per cent EMS treated population of both GPBD-4 and CTMG-1 varieties. The F_2M_2 populations exhibited positive and highly desirable shifts for most of the characters. While, F_2 population was slightly better than control or at par with other mutagenic treatments.

Total number of pods, number of matured pods, pod yield per plant, kernel yield per plant, and 100-kernel weight manifested maximum positive shifts in F_2M_2 population followed by 20 kR irradiated and 0.5 per cent EMS treated M_2 population of GPBD-4 and CTMG -1. Greater positive shift was observed in 20 kR irradiated GPBD-4, F_2M_2 population and 0.5 per cent EMS treated M_2 populations of GPBD-4 for oil content. However, a marginal shift was observed in F_2 population. Positive shift in mean of different traits over control values may be attributed to the induction of a higher

Table 3 : Mean of different characters in control, M_2, F_2 and F_2M_2 populations of two groundnut varieties

Characters	Variety	Control	M_2		F_2	F_2M_2
			Gamma rays	Ethyl methane sulphonatee		
			20 kR	0.5 %		
Total number of pods	GPBD-4	23.85±0.33	31.56±0.35	33.44±0.27	26.94±0.44	37.49±0.44
	CTMG-1	25.04±0.39	35.63±0.45	36.17±0.45		
Number of matured pods	GPBD-4	18.50±0.42	26.31±0.34	29.05±0.29	21.39±0.34	35.02±0.42
	CTMG-1	19.09±0.49	34.51±0.29	34.48±0.28		
Pod yield (g/plant)	GPBD-4	10.47±0.21	10.66±0.19	11.30±0.16	12.11±0.36	18.37±0.43
	CTMG-1	11.45±0.22	14.56±0.15	14.33±0.14		
Kernel yield (g/plant)	GPBD-4	6.22±0.26	7.07±0.13	9.21±0.11	9.12±0.11	12.59±0.13
	CTMG-1	8.81±0.19	12.41±0.14	11.84±0.15		
100-kernel weight (g)	GPBD-4	30.59±0.19	33.12±0.10	33.98±0.09	32.74±0.32	42.17±0.37
	CTMG-1	32.13±0.25	41.19±0.23	41.75±0.19		
Oil content (%)	GPBD-4	41.32±0.27	45.94±0.13	45.43±0.17	44.06±0.16	45.57±0.19
	CTMG-1	42.46±0.32	45.33±0.18	45.41±0.16		

Table 4 : Shifts in the mean of pod yield and its component characters in M_2, F_2 and F_2M_2 population over respective control in groundnut

Characters	Variety	M_2		F_2	F_2M_2
		Gamma rays	Ethyl methane sulphonatee		
		20 kR	0.5 %		
Total number of pods	GPBD-4	7.71	9.59	3.09	13.64
	CTMG-1	10.59	11.13	1.90	12.45
Number of matured pods	GPBD-4	7.81	10.55	2.89	16.52
	CTMG-1	15.42	15.39	2.30	15.93
Pod yield (g/plant)	GPBD-4	0.19	0.83	1.64	7.90
	CTMG-1	3.11	2.88	0.66	6.92
Kernel yield (g/plant)	GPBD-4	0.85	2.99	2.90	6.37
	CTMG-1	3.60	3.03	0.31	3.78
100-kernel weight (g)	GPBD-4	2.53	3.39	2.15	11.58
	CTMG-1	9.06	9.62	0.61	10.04
Oil content (%)	GPBD-4	4.62	4.11	2.74	4.25
	CTMG-1	2.87	2.95	1.60	3.11

proportion of desirable mutations.

Increase in mean values for certain characters was also observed following mutagenic treatment indicating that mutagenic treatment was successful in bringing about rare combinations to result in superior segregants which otherwise were not seen in the hybridized populations. Further, it could be concluded that increase in mean value of these characters may be due to occurrence of more polygenic mutations in positive directions. The results obtained in the present investigations are in conformity with the earlier reports of Dutta *et al.* (1987) and Siddappagoudar (1996). All these above findings are in accordance with the hypothesis of Brock (1965) who proposed that mutational events shift the mean away from the previous selections history. These results are in confirmation with the reports of Veena and Ravikumar (2003) who compared the mean in F_2, $4M_2$ and $4F_2M_2$ populations and indicated shifts in both the directions compared to control due to mutagenesis of hybrid. The direction of shifts varied with genotype, mutagen and character. The changes in mean in the mutagen treated populations were followed by changes in variance for all the characters.

Genetic variation :

In the present investigation, the values of the phenotypic and genotypic co-efficients of variability along with heritability and genetic advance as per cent of mean of various populations were compared to know the efficiency of mutagenesis and hybridization as well as combination of hybridization and mutation in enlarging polygenic variability.

Variability parameters *viz*., heritability, genetic advance as per cent of mean of various characters in F_2M_2, F_2 and M_2 generations of groundnut varieties is presented in Table 5. The F_2M_2 population recorded highest range for total number of pods (16.0-49.0), number of matured pods (14.0-44.0), widest range was observed for pod yield (g/plant) (3.2-27.8) and oil content (34.5-49.8). The F_2 population showed highest range only for 100-kernel weight (g) (20.5-45.7). Among the mutagen treated M_2 populations, 20 kR irradiated populations as well as 0.5 per cent EMS treated population of CTMG-1 showed widest range for total number of pods (20.0-45.0 and 21.0-46.0, respectively). The GPBD-4 population with 0.5 per cent EMS treatment recorded highest range for number of matured pods (19.0-37.0) and pod yield (g/plant) (5.8-16.2). Widest range was observed for kernel yield per plant (8.7-15.5) and hundred kernel weight (34.6-45.5) in 20 kR irradiated CTMG-1 population and 0.5 per cent EMS treated population of CTMG-1 for oil content in (40.3-49.2).

Highest GCV and PCV were recorded for pod yield (g/plant) (39.72 and 40.36 per cent, respectively) and high GCV and PCV for total number of pods (21.91 and 23.19 per cent, respectively) by F_2M_2 population. High GCV and PCV were recorded by 20 kR irradiated population of GPBD-4 (21.92 and 26.17 per cent, respectively) for kernel yield per plant. Moderate GCV and high PCV values were observed in F_2 population (19.98 and 20.71 per cent, respectively) for number of matured pods.

High heritability coupled with high genetic advance as per cent of mean was observed in F_2M_2 population (86.48 and 38.51%, respectively), 0.5 per cent EMS treated population of CTMG-1 (87.87%) and 20 kR irradiated population CTMG-1 (87.84%) for total number of pods. Heritability was maximum in F_2M_2 population (96.80%) followed by F_2 population (92.98%) for number of matured pods. The F_2M_2 population manifested maximum heritability (96.44%) and genetic advance as per cent of mean (76.24%) and among the mutagen treated M_2 populations, maximum heritability (81.35 %) and genetic advance as per cent of mean (41.50%) was recorded in 20 kR irradiated populations of GPBD-4 for Pod yield (g/plant). The highest heritability was observed in 0.5 per cent EMS treated CTMG-1 (74.50%) followed by F_2M_2 population (71.28%) for kernel yield per plant. Among the mutagen treated populations, 20 kR irradiated population of CTMG-1 (80.31%) showed higher heritability for 100-kernel weight (g). The F_2M_2 population recorded maximum heritability (76.09%) and genetic advance as per cent of mean (10.28%) for oil content.

High heritability coupled with high genetic advance as per cent of mean along with high GCV indicating the involvement of additive gene action and offers good scope for further improvement in advance generation if these characters are subjected to mass progeny or family selection. Economically important characters showing low to moderate heritability along with high genetic advance and high GCV suggested that these characters should largely be under the control of additive gene action and lower estimates of heritability may be due to larger influence of environmental factors. In some instances high estimates of heritability were not associated with the high values of genetic advance and *vice-versa*. This might be due to lower or higher values of phenotypic standard deviation which determines the value of genetic advance. In such a situation, variability in base populations would be more useful than the magnitude of heritability alone for selecting better genotype. (Meta and Monpara, 2010)

The importance of mutagenesis in increasing recombination rate with a possibility of adding induced variability to that inherent in the cross has been realized in both heterozygous and heterogeneous genotype of different crop species (Virk *et al*., 1978 and Katoch *et al*., 1991). Highest variability for pod yield and number of matured pods *via* irradiation of hybrid rather than irradiation or hybridization alone was observed by Viswanathan *et al*. (1999). These results are in accordance with the reports of Govindarasu and Ramamoorthi (2000), who recorded an increase in genetic variability in the F_2M_2 population over F_2's of all the crosses for different traits like seed yield, number of branches, number of capsules, seed number/ capsule and 1000 seed weight of sesame. Rangaswamy (1980) also recovered superior groundnut segregants from double crosses with mutagenesis

Table 5 : Variability parameters for various yield components in M_2, F_2 and F_2M_2 populations of groundnut varieties

Characters	Parameters	Variety	M_2		F_2	F_2M_2
			Gamma rays	Ethyl methane sulphonatee		
			20 kR	0.5 %		
Total number of pods	Range	GPBD-4	23.0-40.0	23.0-40.0	13.0-43.4	16.0-49.0
		CTMG-1	20.0-45.0	21.0-46.0		
	GCV(%)	GPBD-4	14.30	9.65	19.58	21.91
		CTMG-1	16.42	16.20		
	PCV(%)	GPBD-4	15.40	11.06	21.68	23.19
		CTMG-1	17.51	17.28		
	Heritability(bs)	GPBD-4	86.09	76.00	81.59	86.48
		CTMG-1	87.84	87.87		
	GAM (%)	GPBD-4	27.31	17.32	36.44	38.51
		CTMG-1	31.69	31.28		
Number of matured pods	Range	GPBD-4	17.0-34.0	19.0-37.0	9.0-31.0	14.0-44.0
		CTMG-1	26.0-40.0	28.0-42.0		
	GCV(%)	GPBD-4	15.42	11.00	19.98	18.44
		CTMG-1	8.64	8.15		
	PCV(%)	GPBD-4	17.67	13.49	20.71	18.73
		CTMG-1	11.71	11.34		
	Heritability(bs)	GPBD-4	76.14	66.45	92.98	96.80
		CTMG-1	54.61	51.64		
	GAM (%)	GPBD-4	27.72	18.47	39.67	41.35
		CTMG-1	13.17	12.06		
Pod yield (g/plant)	Range	GPBD-4	6.5-15.8	5.8-16.2	3.5-20.9	3.2-27.8
		CTMG-1	10.6-17.6	11.0-17.0		
	GCV(%)	GPBD-4	22.34	16.18	37.42	39.72
		CTMG-1	11.33	9.97		
	PCV(%)	GPBD-4	24.77	19.03	38.81	40.36
		CTMG-1	14.01	13.05		
	Heritability(bs)	GPBD-4	81.35	71.98	92.81	96.44
		CTMG-1	65.23	58.45		
	GAM (%)	GPBD-4	41.50	28.21	74.20	76.24
		CTMG-1	18.83	15.71		
Kernel yield (g/plant)	Range	GPBD-4	3.9-10.5	6.5-12.5	6.5-12.5	8.7-15.5
		CTMG-1	8.7-15.5	8.8-15.5		
	GCV(%)	GPBD-4	21.92	11.18	10.42	13.11
		CTMG-1	12.59	15.48		
	PCV(%)	GPBD-4	26.17	15.74	15.57	15.57
		CTMG-1	15.23	17.91		
	Heritability(bs)	GPBD-4	69.77	50.71	45.27	71.28
		CTMG-1	67.97	74.50		
	GAM (%)	GPBD-4	37.61	16.45	14.52	22.86
		CTMG-1	21.32	27.48		

Table 5: Contd……..

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100-kernel weight (g)	Range	GPBD-4	30.46-35.6	30.2-36.3	20.5-45.7	27.8-52.8
		CTMG-1	34.6-45.5	36.8-45.7		
	GCV(%)	GPBD-4	2.72	2.60	9.67	12.12
		CTMG-1	6.79	5.34		
	PCV(%)	GPBD-4	4.14	4.00	12.86	13.78
		CTMG-1	7.57	6.30		
	Heritability(bs)	GPBD-4	43.09	42.16	56.55	77.23
		CTMG-1	80.31	72.13		
	GAM (%)	GPBD-4	3.67	3.48	14.98	21.92
		CTMG-1	12.53	9.36		
Oil content (%)	Range	GPBD-4	42.4-48.9	41.2-48.8	36.8-47.8	34.5-49.8
		CTMG-1	40.5-48.8	40.3-49.2		
	GCV(%)	GPBD-4	2.01	3.85	3.65	5.73
		CTMG-1	4.26	3.57		
	PCV(%)	GPBD-4	3.74	5.02	4.95	6.56
		CTMG-1	5.36	4.82		
	Heritability(bs)	GPBD-4	28.62	59.07	54.76	76.09
		CTMG-1	63.44	55.11		
	GAM (%)	GPBD-4	2.21	6.11	5.58	10.28
		CTMG-1	7.01	5.48		

compared to untreated double crosses for productivity characters.

Conclusive evidence could be elucidated by maintenance of highest variability for number of matured pods and pod yield *via* irradiation of hybrid rather than irradiation or hybridization alone. Irradiation of hybrid seeds produced wide variability in F_2M_2 for most of the traits like total number of pods, number of matured pods, pod yield per plant, kernel yield per plant, hundred kernel weight and oil content in groundnut crosses that were subjected to 20 kR dose of ã-rays. Further, the superiority of irradiations over hybrid was seen by the increased variability in M_2 compared to F_2 population for all the characters. When genetic variability produced by irradiation of hybrid seeds was compared with the variability produced by irradiation in parents, the variability in F_2M_2 population was more than M_2 population for all the characters. Thus, combination of hybridizations and mutation could be adopted by resorting to treating F_1 hybrid with gamma irradiation for obtaining higher proportion of superior recombinants. In treated population, there is a scope for shuffling of genes in the segregating generation and hence increased possibility of realizing superior segregants.

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