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Induced genetic variability for different quantitative characters in sesame (*Sesamum indicum*)

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Abstract
The field experiment was conducted during post-*kharif* season, 2015 and pre-*kharif* season, 2016 at the Agricultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan. Dry and homogeneous seeds of two varieties of sesame were irradiated with different doses of gamma rays viz. 250, 300, 350 and 400 Gy. Analysis of variance for different plants in M_1 generation and families in M_2 generation of each genotype of Rama and Tillotoma for different polygenic characters or parameters are carried out. The parameters investigated include days to flowering, days to 50% flowering, plant height, no. of branches per plant, no. of siliqua per plant, no. of seeds per siliqua, siliqua length, days to maturity, 1000 seed weight. In M_1 generation, mean sum of squares due to variety were, however, significant for only germination (%) and no. of siliqua per plant, while the dose × variety interaction effects were significant for germination (%), shoot length, days to 50% flowering, plant height, no. of seeds per capsule and days to maturity which indicated that varieties/genotypes responded differently to different doses of gamma rays for these characters. In M_2 generation, the mean sum of squares due to treatments were found to be significant for almost all the characters except number of primary branches per plant and 1000 seed weight in case of both Rama and Tillotoma, and for capsule length in Rama only. However, when analysis was done (considering families both from Rama and Tillotoma) in combination, were significant for all the characters except 1000 seed weight.

Keywords: *Sesamum indicum*, gamma rays, genetic variability, quantitative characters

Introduction
Sesame (*Sesamum indicum* L; 2n=26), also known as *gingelly*, or *til*, a member of the order Tubiflorae, family Pedilaceae is perhaps the oldest and traditional oilseed known to man and is valued for high quality seed oil. Sesame is described as the "Queen of oilseeds" because of its high oil content (38-54%), protein (18-25%), calcium, phosphorus, oxalic acid and excellent qualities of the seed oil and meal (Prasad,2002) [14].

India is world leader in sesame production occupying an area of 1.74 million ha with a production of 0.82 million tonnes annually (which is around 20 % to the total oilseed production) (Source: Ministry of Agriculture and Farmer's Welfare, 2014-15).

Induced mutagenesis can be efficiently employed as an alternative or supplement source to increase the variability. The variability in quantitative characters increases considerably by treating the biological materials with different mutagenic agents. The genetic variability offered by the mutagenic agents is of extreme importance in plant breeding. Improvements in quantitative characters have been achieved through accumulation of genes affecting their expression in a positive or negative direction and thus, increasing the variability. An estimation of the extent of variability induced in M_2 generation will be of great value to provide useful information for carrying out further selection. Among different methods available to detect the induced variability in the mutated population, mean and components of variance serve as a suitable statistical parameter (Scossiroli, 1977) [20].

Materials and methods
Dry, uniform, bold seeds of variety Rama and Tilottoma each weighing 150g were taken in packets. Four such packets of each genotype were used for gamma irradiations. The seeds were irradiated with four different doses of gamma rays viz. 250Gy, 300Gy, 350Gy and 400Gy (1Gray = 1 joule per kg of matter undergoing radiations = 0.1kR) from ^{60}Co source at Bhabha Atomic Research Centre, Trombay, Mumbai.

The treated seeds along with their respective controls were sown immediately in the field to raise the M_1 generation with three replications in a split plot design. Each M_1 plant was harvested individually and raised as M_2 progeny in separate rows.

The progeny of each M_1 plant constituted one M_2 family. The spacing between rows and plants were 30 and 15 cm, respectively. The treated as well as control populations were carefully screened for polygenic variability or micromutations. Data on nine quantitative characters viz. days to flowering, days to 50% flowering, plant height, no. of branches per plant, no. of siliqua per plant, no. of seeds per siliqua, siliqua length, days to maturity, 1000 seed weight from five normal looking competitve plants from each M_1 plant and M_2 family were recorded and the mean and variance interms of GCV were calculated. Genotypic coefficient of variation (GCV) was computed by using the formula given by Burton (1952).

Results and discussion

M_1 generation

Analysis of variance (Table: 1.) for different characters studied under laboratory and field conditions revealed that mean sum of squares due to doses for all the characters indicating pronounced effect of doses in inducing genetic variability. Mean sum of squares due to variety were, however, significant for only germination (%) and no. of siliqua per plant, while the dose × variety interaction effects were significant for germination (%), shoot length, days to 50% flowering, plant height, no. of seeds per capsule and days to maturity which indicated that varieties/genotypes responded differently to different doses of gamma rays for these characters. The salient results obtained for various characters under field conditions are presented in Table: 2. and Table: 3. respectively.

Days to flowering and Days to 50% flowering

The appearance of flower was significantly delayed in both the genotypes at 400 Gy from control, 250 Gy and 300 Gy. The effect of doses at 350 Gy and 400 Gy was stastitically at par, while for the other doses (including) the effects were significantly different from each other.

However, no significant delay in days to 50% flowering was noticed in both the genotypes at each doses and also from control. Significant differences could be observed between the genotypes pooled over all the doses. Delay in flowering might be due to disturbances in biochemical pathway which assists in synthesis of flower inducing substances (Kharkwal *et al*., 2004) [8].

Plant height

Significant reduction in plant height in both the genotypes was observed at 350 Gy from control and 300 Gy. The differences were statistically at par: at doses of 350 Gy with 400 Gy and 250 Gy; at doses of 300 Gy with control; at doses of 250 Gy and 400 Gy along with control. The effects of genotype pooled over doses revealed that two genotypes were not significantly different from each other. Kumari *et al*. (2016) [9] reported that plant height was not affected much by mutagenic treatment in M_1 generation. But the shift of mean value in mutated progenies in the negative duration could be attributed due to deleterious effect of radiation.

Number of primary branches per plant

The lowest dose, 250 Gy, significantly reduced number of primary branches per plant from control and other three doses in the genotype Rama, while no significant difference could be found in Tillotoma. No significant difference could be found between control and 300 Gy; between control and 350 Gy and 400 Gy; between 300 and 350 Gy; between 350 Gy and 400 Gy in Rama. However, this response of two varieties over all doses were significantly different from each other. The negative shift in mean values of mutagenic treatment for this character was reported by Ravichandran and Jay Kumar (2014) [13] in sesame. Various explanations have been offered for reduction in primary branches due to mutagenic treatments like auxin destruction (Joshi and Gour, 1974) [7], failure of assimilatory mechanisms, inhibition of mitosis and chromosomal damage with associated physiological changes. (Riley, 1953) [19].

Number of capsules per plant

Significant increase in number of capsules per plant over the control was observed at 350 Gy and 400 Gy in both the varieties. Significant reduction over the control, however, was observed at 300 Gy in both the genotypes. The results revealed that effects of 350 Gy and 400 Gy doses over two genotypes were Significantly at par, while there was no significant diiference between control and 250 Gy. The effects of genotypes pooled over doses revealed that two genotypes were significantly different from each other. Differential response for this character over gamma rays was also observed by Anabarasan (2015) [10] and Kumari *et al*. in sesame.

Number of seeds per capsule

Significant decrease in number of seeds per capsule was observed at 400 Gy from control and 350 Gy in both the varieties of sesame. Reduction was also significant at lowest dose of 250 Gy over the control. The effects of the three doses 250 Gy, 300 Gy and 350 Gy over the two varieties were stastically at par and response of genotype over all the doses were significantly different from each other. In earlier studies in sesame Prabhakar (1985) [12], Rahman and Das (1998) [16], Ravichandran and Jay Kumar (2014) [9] reported decreasing trend at various level of gamma irradiation when compared to control. The reduction caused by mutagens in number of seeds per capsule can be attributed to high seed sterility as caused by physiological and biochemical disturbances in the development of seeds (Rangaswamy, 1973) and Prabhakaran (1992) [13].

Days to maturity

In both the varieties significant decrease in days to maturity from the control was observed at 300 Gy and 350 Gy, while in other doses the reduction over the control was not significant. Moreover the reduction was also significant with the increase in dose.

Strength from 250 Gy to 300 Gy in both the varieties, For other doses, the effect was statistically at par with each other as well as with control. Significant differences could not be observed between two genotypes over all the doses. Similar observation was recorded by Kumari *et al*. (2016) [9] in sesame.

1000 seed weight

There was significant reduction in 1000 seed weight from the control in both the genotypes at 250 Gy. 350 Gy and 400 Gy. Significant reduction was also observed in two genotypes at 250 Gy from control and other three doses. The effect of doses at 300 Gy and control as well as at 350 Gy and 400 Gy were statistically at par. Decrease in seed yield as compared to control due to mutagenic effect was also reported by Ravichandran and Jay Kumar (2014) [17].

Table 1: ANOVA for various quantitative characters in Rama and Tillotoma in M_1 generation

Source	Degree of freedom	Mean squares													
		Germination (%)	Root length (cm)	Shoot length (cm)	Pollen fertility (%)	Survival (%)	Days to flowering	Days to 50% flowering	Plant Height (cm)	No. of pr. branches per plant	No. of capsule per plant	No. of seeds per capsule	capsule length (cm)	Days to maturity	1000 seed weight (g)
Replication	2	7.97	0.11	0.02	9.64	14.48	0.55	0.25	60.70	0.89	8.70	3.05	0.04	2.68	0.02
Vaiety (A)	1	190.16**	0.17	0.46	495.81	2.90	13.33	38.99	2.43	0.48	42.86**	28.23	0.07	0.16	0.00
Error (a)	2	9.91	0.02	0.02	82.89	21.88	0.19	1.00	29.34	0.00	0.42	13.95	0.03	0.19	0.00
Dose (B)	4	168.95**	47.26**	19.64**	23.97**	84.64**	17.98*	3.19**	4.49*	4.39*	37.78*	4.06**	66.17*	10.12**	11.70**
A×B	4	19.42**	0.12	0.06*	47.83	12.79	2.90	3.46**	3.52*	0.20	7.18	4.44**	0.23	1.83*	0.00
Error (b)	16	6.50	0.04	0.04	17.98	35.82	2.40	11.62	11.95	0.41	37.29	19.02	0.07	4.90	0.01

*Significant at 5% level of significance ** Significant at 1% level of significance

Table 2: Mean performance in respect of different characters studied in the main field in M_1 generation

3	Days to flowering			Days to 50 % flowering			Plant height (cm)			No. of pr. Branches per plant			No. of capsule per plant		
Dose variety	V1	V2	Avg	V1	V2	Avg	V1	V2	Avg	V1	V2	Avg	V1	V2	Avg
Control	30.8	34.2	32.5^{b}	43	47.1	45.0^{b}	143.1	144.71	143.9^{ab}	6.17	5.9	6^{a}	118.2	117.6	117.9^{b}
250 Gy	34.1	33.7	33.9^{b}	45.7	48.2	46.9^{ab}	140.2	139.4	139.8^{bc}	4.91	5.2	5^{b}	122.9	121.7	122.3^{b}
300 Gy	34	34.7	34.3^{b}	48.7	52.0	50.3^{a}	143.7	146.5	145.1^{a}	6.07	5.6	5.8^{ab}	104.2	103.1	103.7^{c}
350 Gy	37.4	38.9	38.1^{a}	49.6	50.4	50.0^{a}	138.3	137.7	138^{c}	6.67	6.1	6.4^{a}	140.3	137.1	138.7^{a}
400 Gy	37.7	39.2	38.5^{a}	50.4	51.0	50.7^{a}	140.1	140.1	140.1^{bc}	6.67	6.2	6.4^{a}	143.4	137.5	140.5^{a}
Avg.	36.16^{b}	34.83^{a}		49.77^{b}	47.49^{a}		141.6^{a}	141.2^{a}		6.09^{a}	5.84^{b}		125.8^{a}	123.4^{b}	
LSD	2.57			5.68			5.76			1.04			10.18		

Any two means having a common letter in the row / column of Avg are not significantly different at 5% level of significance as per Duncan's multiple range test (DMRT) or mean separation in the row / column of Avg by DMRT at 5% level.

Table 3: Mean performance in respect of different characters studied in the main field

	No. of seeds per capsule			capsule length(cm)			Days to maturity			1000 seed weight(g)		
Dose variety	V1	V2	Avg	V1	V2	Avg	V1	V2	Avg	V1	V2	Avg
Control	54.30	49.43	51.87^{a}	4.76	4.32	4.54^{a}	93.50	93.53	93.52^{a}	3.27	3.21	3.24^{b}
250 Gy	45.90	45.50	45.70^{bc}	3.27	3.14	3.21^{b}	90.13	92.17	91.15^{ab}	3.42	3.25	3.33^{a}
300 Gy	48.73	47.67	48.20^{abc}	2.63	3.10	2.86^{c}	86.47	85.97	86.22^{c}	3.24	3.19	3.21^{b}
350 Gy	50.77	49.07	49.92^{ab}	2.22	2.68	2.45^{d}	89.23	88.47	88.85^{bc}	3.03	3.1	3.06^{c}
400 Gy	43.53	41.87	42.70^{c}	2.29	2.43	2.36^{d}	92.13	92.07	92.10^{a}	3.09	3.04	3.06^{c}
Avg	48.64^{a}	46.70^{a}		3.13^{a}	3.03^{a}		90.44^{a}	90.29^{a}		3.3^{a}	3.1^{a}	
LSD (Dose within variety)	5.13			0.61			2.59			0.14		

V_1, = Rama, V_2 = Tillotoma Any two means having a common letter in the row / column of Avg are not significantly different at 5% level of significance as per Duncan's multiple range test (DMRT) or mean separation in the row / column of Avg by DMRT at 5% level.

Polygenic variation in M_2 generation

Analysis of variance for different families of each genotype of Rama and Tillotoma for different polygenic characters are presented in Table: 4. and Table: 5 and in combination in Table: 6. The mean sum of squares due to treatments (genotypes = here plant to progeny family) were found to be significant for almost all the characters except number of primary branches per plant and 1000 seed weight in case of both Rama and Tillotoma, and for capsule length in Rama only (Table: 4. and 5.). However, when analysis was done (considering families both from Rama and Tillotoma) in combination, were significant for all the characters except 1000 seed weight (Table: 6). The MSS for character (s) which was found non-significant, was not considered for further statistical analysis.

Table 4: ANOVA for various quantitative characters in Rama in M_2 generation

Source	Degree of freedom	Mean squares								
		Days to flowering	Days to 50% flowering	Plant height	No. of branches per plant	No. of siliqua per plant	No. of seeds per siliqua	Siliqua length	Days to maturity	1000 seed weight
Replication	2	6.98	1.67	2.88	1.50	43.47	14.64	0.21	16.63	0.03
Treatments	39	20.27**	20.13**	104.84**	2.63	595.02**	69.80**	0.75	53.18**	0.12
Error	78	7.08	6.11	41.77	2.19	97.52	30.19	0.80	10.78	0.08

*Significant at 5% level of significance ** Significant at 1% level of significance

Table 5: ANOVA for various quantitative characters in Tillotoma in M_2 generation

Source	Degree of freedom	Mean squares								
		Days to flowering	Days to 50% flowering	Plant height	No. of branches per plant	No. of siliqua per plant	No. of seeds per siliqua	Siliqua length	Days to maturity	1000 seed weight
Replication	2	6.28	15.19	13.92	1.25	48.38	28.26	0.05	1.25	0.01
Treatment	39	15.06*	43.30**	98.31**	3.64	850.54**	104.34**	0.71**	43.70**	0.29
Error	78	8.50	7.69	51.74	2.63	97.11	55.42	0.37	15.12	0.26

*Significant at 5% level of significance ** Significant at 1% level of significance

Table 6: ANOVA for various quantitative characters in Rama and Tillotoma in M_2 generation

Source	Degree of freedom	Mean squares								
		Days to flowering	Days to 50% flowering	Plant height	No. of branches per plant	No. of siliqua per plant	No. of seeds per siliqua	Siliqua length	Days to maturity	1000 seed weight
Replication	2	0.87	4.80	5.13	2.74	90.50	8.59	0.20	4.62	0.02
Treatment	79	22.43**	33.76**	101.73**	3.47*	713.91**	88.69**	0.88*	49.62**	0.21
Error	158	7.85	6.97	46.3150	2.38	96.10	42.70	0.58	12.95	0.17

*Significant at 5% level of significance ** Significant at 1% level of significance

The mean, variance for all the above-mentioned characters (except non-significant one) are presented separately (Table 7. to Table: 8.). The detailed results for individual characters are presented in the fore going pages:

Days to flowering

In both the varieties, except at this lowest dose (250 Gy), the means increased significantly with the increase in dose in all the treated population. The range in mean was widened at 400 Gy, while there were significant increase in variance at 400 Gy in Rama and at all three doses (300Gy, 350Gy, 400Gy) in Tillotoma. The results were in agreement with the earlier findings by Sheeba and Ibrahim *et al*. (2004) [21], Raghuwanshi (2005) [15], Birara *et al.* (2013) [2].

Days to 50 % flowering

With the increase in doses, the mean and variance for the character increased significantly in both the genotype indicating further scope of improvement through selection. The increase in variability with increase of doses was also reflected in coefficient of variation. Similar results were also reported earlier by several authors working with sesame.

Plant Height

Differential response with respect to different doses was noticed in two different genotypic background. Significant decrease in plant height was noticed in Rama, while no significant change in height was observed in Tillotoma. Variance increased in treated population over the control (significant being at 350 Gy in Rama, and 350 Gy & 400Gy in Tillotoma), the result in the present study were in agreement with Babu *et al.* (2004) [21], Muduli and Misra (2008) [10], Ravichandran *et al*. (2014) [17], and Animasaun *et al*. (2014) [1].

Number of capsules per plant

The mean of the character was significantly less at 300Gy in Rama and Tillotoma, whereas at other doses the no. of capsules increased significantly. Change in variance (as compared to control) either in positive and negative direction was not significant at all the doses in both the genotype.

Number of seeds per capsule

There was a significant decrease in the number of seeds per capsule with the increase in dose of Tillotoma, while the significant decrease in Rama was noticed in 400 Gy only. The number of seeds per capsule was found to be the lowest at the highest dose (400Gy) in both the varieties. The shift in variance in positive direction was significant at 300Gy, 350Gy and 400Gy. The results are in agreement with Muduli and Misra (2008) [10], Chowdhury *et al*. (2010) [3].

Capsule length

In Tillotoma, highly significant increase in mean for this character was found at all the doses of gamma rays, highest being at 350 Gy. Significant increase in variance for the character was noticed only at 250 Gy.

Days to maturity

Except at 250 Gy, the mean of the character was found to be increased significantly over control at all the treated population of both the genotypes. Variances of the characters in all the treated populations were found to be significant. Significant increase in variability was observed at all the doses in both the population which was evident from the increase in variance as well as in coefficient of variation and also from the wider range than the control. The doses of 300 Gy and 350 Gy were found to be most effective for inducing variability for this character in both the varieties. Similar observations were found by Animasaun *et al*. (2014) [1], Ravichandran *et al*. (2014) [17] and Iqbal *et al.* (2016) [6].

From the results obtained in the present investigation, it was observed that variances for economically important traits at different doses of gamma rays (250 Gy, 300 Gy, 350 Gy and 400 Gy) in the M_2 generation of both the cultivars had increased over their respective Control, whereas the means have been shifted either towards positive or negative direction in comparison to the control. Changes in the mean performance of mutagenised populations were not expected to result from either stimulation or inhibitory effects of the mutagenic treatment of seed. Instead, these changes in quantitative characters resulted from a multitude of mutations described as 'polyamidations' (Gustafsson 1969) or 'micromutations' (Gaul, 1965) [4].

Furthermore, in the present study, it was found out that the shift in mean was not dose dependent and at the same time independent of the genotypic background. For example, in Tillotoma, mean days to 50 % flowering had shifted significantly towards the negative direction at all the doses except 400 Gy, while it shifted significantly towards positive direction at all the dose in Rama. This could be due to the occurrence of polygenic mutations with equal frequencies in both plus and minus direction (Oka et al.,1958) [11]. In the present investigation, the findings revealed that the manifestation of variability may vary from character to character. Significant increase in the variance at treated populations over the corresponding untreated controls indicated a possibility of improving these characters by further selection.

Table 7: Variances of different yield parameters of the two varieties at different doses of gamma rays.

Variety with dose	Days to flowering	Days to 50% flowering	Plant height	No. of capsules per plant	No. of seeds per capsule	Capsule Length	Days to maturity
Rama							
Control	6.63	3.89	44.44	118.95	51.89		5.86
250Gy	6.63	6.87**	45.41	118.50	32.97		8.50**
300 Gy	7.55	9.56**	46.67	123.39	39.34		14.72**
350 Gy	7.28	9.90**	65.24**	121.23	55.25		20.57**
400 Gy	8.75*	9.68**	48.35	116.74	39.13		15.68**
Tillotoma							
Control	6.63	6.87	45.41	118.50	32.97	0.96	8.50
250Gy	5.38	10.94**	33.76	87.89	39.40	1.30*	19.44**
300 Gy	10.32**	16.40**	55.17	111.61	57.67**	0.08	26.15**
350 Gy	10.42**	23.54**	58.34*	146.43	53.71**	0.03	22.70**
400 Gy	14.42**	17.84**	99.65**	61.43	41.16*	0.04	17.79**

** Significant at 1% level of significance * Significant at 5% level of significance

Table 8: Mean ± SD values of different yield parameters of the two varieties at different doses of gamma rays.

Variety with dose	Days to flowering	Days to 50% flowering	Plant height	No. of capsules per plant	No. of seeds per capsule	Capsule length	Days to maturity
Rama							
Control	30.87 ± 0.47	43.00±0.366	143.19±1.24	118.27±2.03	54.30±1.34		83.85 ± 0.31
250Gy	34.13 ± 0.478	45.70±0.48**	140.23± 1.25**	122.70 ± 2.02**	45.90±1.07		93.50 ± 0.45
300 Gy	34 ± 0.51**	58.77±0.57**	143.73±1.27	104.23±2.06*	48.73±1.16		90.13 ± 0.54**
350 Gy	37.4 ± 0.50**	59.60±0.58**	138.31±1.50**	140.30±2.04**	50.77±1.38		86.47 ± 0.71**
400 Gy	37.77 ± 0.54**	50.40±0.57**	140.15±1.29*	143.47±2.01**	43.53±1.16*		89.23 ± 0.84**
Tillotoma							
Control	34.23±0.47	57.13±0.48	144.71±1.25	117.64±2.021	49.43±1.07	2.32 ± 0.18	82.13 ± 0.74
250Gy	33.70±0.43**	48.23±0.61**	139.40±1.08	121.70±1.741	45.50±0.82**	3.14 ± 0.21**	93.54 ± 0.54*
300 Gy	34.70±0.59**	52.00±0.75**	146.50±1.38	103.17±2.433**	47.67±1.84*	3.10 ± 0.05**	92.17 ± 0.82*
350 Gy	38.97±0.59**	50.47±0.90**	137.74±1.42	137.18±2.247**	49.07±1.89	3.68 ± 0.03**	85.97 ± 0.95**
400 Gy	39.22±0.70**	59±0.78**	140.12±1.85	137.55±1.455**	41.87±0.81**	2.43 ± 0.04**	88.47 ± 0.88**

**Significant at 1% level of significance *Significant at 5% level of significance

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