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Gamma irradiation effect on yield and yield attributing traits of sesame (*Sesamum indicum* L.) In M_1 generation

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Abstract
Sesame (*Sesamum indicum* L.) variety Rama and Tillotoma were exposed to different doses viz. 250, 300, 350, 400 and 450 Gy of gamma rays from Bhaba Atomic Research Centre (BARC) and grown (along with control) during pre-*kharif* 2015 in split plot design at University experimental farm Visva-Bharati, to study their effect on various characters like plant height, number of capsule per plant, number of branches per plant, days to first flower, days to 50% flower, flower duration, number of seeds per capsule, capsule length, days to maturity, 1000 seed weight (gm), and yield per plant. In M_1 generation the results revealed that there was reduction and also amplification at higher doses compared to lower doses for the studied characters. The results were obtained in the present study clearly indicate that different doses of gamma rays can be effectively utilized to create variability for various quantitative traits of the crop.

Keywords: Gamma rays, M_1 generation, Quantitative traits, Sesame.

1. Introduction
Sesame *(Sesamum indicum L.*; 2n= 26*)* also known as *til* is probably the oldest and traditional oil seed crop known to man and is valued for its high quality seed oil. Though, it is called as the 'queen' of oilseeds due to rich in oil and protein, still Sesame is a neglected crop from the plant breeding point of view. The fact that sesame is a crop of mainly developing countries with limited available research funds for long term breeding programmes, resulted in very few breeding efforts in research stations. The two most commonly used breeding approaches in sesame are selection (mostly from local landraces) and pedigree; introduction, backcross and induced mutations are less common (Ashri, 2001) [2]. A major constraint in this approach was the lack of sufficient genetic variation within the existing germplasm collections. This is where mutation techniques could offer a possible solution. In addition, when genetic variability is narrowed using traditional breeding methods for a long period, induced mutations is one of the most important approaches for broadening the genetic variation to circumvent the bottleneck conditions. Gustafsson (1947) [7] advocated that mutation approach was superior to other methods of crop improvement to create genetic variability. This technique is generally employed when low genetic variability present in a gene pool for particular trait (Fehr, 1993; Verma *et al*., 2017; Bara *et al.*, 2017) [4, 23, 3]. Mutations provide an opportunity to create hitherto unknown alleles, so that the plant breeder does not remain handicapped due to limited allelic variation at one or more gene loci of interest. Most important aspects of mutation breeding have been the quick rectification of defects in varieties and advanced breeding lines, induction of polygenic mutations and development of ideotypes for various agro-climatic conditions.

Variability in the population creates the chance of selection for desirable improvement. Many workers like Gregory (1961) [8], Kawai (1963) [9] have attempted to exploit somaclonal variation for crop improvement through physical mutagens particularly treated by gamma radiation and suggested that mutation breeding may be an alternative and supplement to hybridization as a source of variability. Today, the plant breeders have at hand, a number of effective physical and chemical mutagens capable of inducing variation when applied properly. Physical mutagens, specially the ionizing radiations have been widely and routinely used to generate genetic variability in various crop species including sesame (Tomlekova *et al*., 2010; Verma *et al*., 2014) [22, 24].

Mutations are mostly recessive and they cannot be selected until the second generation, whereas dominant mutations occur at very low frequencies and can be selected in the first generation. Although mutations are beneficial for producing variability in populations, the treatments themselves can be detrimental and can cause a reduction in germination, growth rate, and plant viguor and pollen & ovule fertility in a plant (Micke and Donini, 1993) [13].

Considering the above idea in mind the present investigation was, therefore, taken to study the different doses of gamma rays in creating variability in the M_1 population of two genotypes sesame for selecting desirable doses of gamma rays for the specific characters of plants.

2. Materials and methods

The study was carried out at Agriculture Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan ($23^0 29^/$ N latitude and $87^0 42^/$ E longitudes and at an altitude of 58.9 m above the mean sea level under sub-humid, sub-tropical, lateritic belt of West Bengal) in pre-*kharif* of 2015.

2.1 Plant materials and their basic characteristics

Two selected popular sesame genotypes from West Bengal, India had following characteristics:

The genotype "Rama": a) brown, rough, glossy seeds (1000 seed weight ~ 3.5gm), b) medium in size and maturity (92-102 days).

The genotype "Tillotoma": a) black, rough, dull seeds (1000 seed weight ~ 3.1gm), b) medium in size and maturity (90-100 days).

2.2 Gamma irradiation

Dry, uniform and healthy seeds of these two genotypes of sesame were irradiated using ^{60}Co (Cobalt 60) gamma source (Gamma Chamber 900) with different doses (250, 300, 350, 400, 450 Gy) of gamma rays at the Bhabha Atomic Research Centre (BARC), Trombay, India.

2.3 Field Experiment in M_1 generation

Irradiated seeds (M_0) along with the controls (un-irradiated) were sown in the field (treatment and variety wise) in a Split Plot Design with three replications in twelve rows plot of 5m length keeping plant to plant and row to row distance of 10 and 30 cm., respectively during pre-*kharif* season 2015. Data were taken in the field as well as in laboratory on germination (%), pollen fertility (%), seedling height (cm), root-shoot length (cm), survival (%), lethality along with yield and yield attributing traits *viz.* days to first flowering, days to 50% flowering, flower duration, plant height, no. of branches/plant, capsules/plant, days to maturity, capsule size, no. of seeds/capsule, 1000 seed weight(gm), seed yield/plant in M_1 generation.

2.4 Statistical analysis

All the data statistically analyzed for each character separately. The mean data of each genotype for different characters were used for statistical analysis. Duncan's Multiple Range Test (DMRT) was performed for all the characters to test the significant differences among the means of the genotypes following Steel and Torrie (1960) [20]. All the data were analyzed using the statistical software IBM SPSS 20 (SPSS Inc., Chicago, IL, USA). The means were separated by Duncan Multiple Range Test (DMRT) at 5% level of significance. Treatment means were compared by computing Least Significant Difference (LSD) value.

LSD = S.Em × table 't' at error degree of freedom, where, S.Em = Standard error of mean difference and 't' is tabulated value at 5% or 1% level of significance for the corresponding degree of freedom of error mean square.

3. Results and Discussion

Interaction between two sesame genotypes and different doses of radiation for different characters are discussed below.

3.1 Days to first flowering: The appearance of flower were significantly delayed in both the genotypes. Days to first flowering ranges for both genotypes from 30.87 to 39.55 days (Table 1). In Rama, similarities were observed among control, 250 and 300 Gy, but, significant differences were observed at 450Gy with 250, 300Gy and unirradiated plants. In case of genotypes, 350, 400, 450Gy treated plants were significantly different from control. Delay in flowering might be due to disturbances in biochemical pathway which assists in synthesis of flower inducing substances (Kharkwal *et al*., 2000 [11], Veni *et al.*, 2016 [25]).

3.2 Days to 50% flowering: The ranges for days to 50% flowering were recorded from 43.03 to 56.77 days (Table 1). For both genotypes, significant differences were observed in unirradiated plants with other applied doses at same genotypes except 250 Gy in Rama. In M_1 generation quantitative characters were decreased but the days to 50% flowering was increased in treated plants when compared to control. The gamma rays delayed the days to 50% flowering irrespective of treatment level in cowpea (Grija *et al*., 2013 [6]) and in black gram (Yasmin *et al*., 2016 [26]).

3.3 Flower Duration: Flower duration varied dose wise and also differed between genotypes. The ranges for flower duration were recorded from 51.57 to 73.31 days (Table 1). The highest flower duration was observed at 250 Gy (73.31) in Rama followed by 250Gy (70.31) in Tillotoma which were significantly different from 350, 400 and 450 Gy treated plants. All applied doses between two genotypes were statistically similar expect 400 Gy. Variation in flower duration at different doses may be attributed due to chromosomal aberration for induced mutagenesis. The similar results had also been proposed earlier in soybean (Pavadai *et al*., 2010) [15]; in Cowpea (Girija *et al*., 2013) [6].

3.4 Plant height: Significant reduction in plant height was observed in Rama at 450 Gy (115.00 cm) and in Tillotoma at 350 Gy (134.19 cm) from control (Table 1). Plant height ranges for both genotypes from 115.0 to 146.71 cm. The highest plant height was recorded 143.73 in Rama and 146.71 cm in Tillotoma at 300Gy of treated plants. In case of Rama, except 450 Gy; 250, 300, 350, 400 Gy treated plants were statistically similar with control, whereas, in Tillotoma, 350 Gy treated plants were statistically similar with 250, 400 and 450 Gy but not with control. Between two genotypes, 450 Gy treated plants of Rama were statistically different from each dose. Kumari *et al*. (2016) [12] reported that plant height was not affected much by mutagenic treatment in M_1 generation. The result indicated that the mutagen could cause both positive and negative genetic variability in plant height. Selection than could be made for both tall and dwarf variety.

3.5 No. of branches/plant: Number of branches/plant ranges from 3.49 to 6.67 (Table 1). The highest branches/plant was recorded 6.67 in 350Gy and 400Gy in Rama and 5.27 in 250 Gy in Tillotoma. In Rama, 250 and 450Gy treated plants were statistically different from control and other applied doses, in case of Tillotoma, 300 Gy treated plants were statistically different from control but similar to 400 Gy doses. For both genotypes, responses over all doses were significantly

different from each other. 450 Gy treated plants of Rama showed significantly dissimilar with other treatment in the same genotype, but no significant differences was observed with 300 and 400 Gy treated plants of Tillottoma. Various explanations have been offered for reduction in number of branches due to mutagenic treatments like auxin destruction (Rizwana Banu *et al.,* 2005 [19]; Ravichandran *et al.,* 2014 [17]), failure of assimilatory mechanisms, inhibition of mitosis and chromosomal damage with associated physiological changes.

3.6 Capsules/plant: For both varieties, number of capsules/plant showed statistically similar among all the doses except 300 Gy. The highest pod number 143.46 and 137.55 was obtained through 400 Gy in Rama and in Tillotoma, respectively, and the lowest was through 300 Gy (Table 1). The range of capsules/plant was from 103.16 to 143.46. Differential response for this character over gamma rays was also observed by Anbarasan (2015) [1] in sesame.

3.7 Days to maturity: The duration for maturity ranged from 83.32 to 110.16 days (Table 1). The earliest maturity was recorded when Rama was irradiated with 400 Gy gamma ray. It was significantly different at all other doses for both genotypes except 350 Gy in Tilllotoma. Tillotoma at 250 Gy showed the longest maturity period, which showed statistically similarity with 350 and 400 Gy doses in the same genotype. On the aspect of genotypes there were significant differences for all the same doses. There are a good number of similar reports of developing early maturity mutant varieties through induced mutation in various crops, such as in chickepea (Karim *et al.,* 2008) [10], in Cowpea (Girija *et al.,* 2013) [6] and in sesame (Ghanei *et al*., 2013) [5]. The duration of maturity of all the existing varieties of sesame in West Bengal is long. Farmers are not much interested to grow long duration crops which interferes the other crops. Besides this, sesame is predominantly cultivated in West Bengal during pre-*kharif* season after harvest of paddy, rapeseed-mustard and potato. For more acceptances to the farmers for growing sesame as catch crop in rice based cropping system. Here, cropping intensity can be increased only by developing early maturity varieties through induced mutation.

Table 1: Interaction between Rama and Tillotoma at different doses of gamma rays for different characters on the basis of their mean performances

Characters/ Dose (Gy)	Days to first flowering		Days to 50 % flowering		Flower Duration		Plant height		No.of Branches/plant	
	Rama	Tillotoma	Rama	Tillotoma	Rama	Tillotoma	Rama	Tillotoma	Rama	Tillotoma
Control	30.87^{e}	34.23^{cde}	43.03^{d}	46.09^{cd}	68.41^{ab}	68.41^{ab}	143.19^{ab}	144.71^{ab}	6.17^{a}	5.13^{bc}
250 Gy	34.13^{cde}	33.70^{de}	45.70^{cd}	53.22^{ab}	73.31^{a}	70.31^{a}	140.23^{abc}	137.56^{bc}	4.91^{c}	5.27^{bc}
300	34.00^{de}	34.70^{bcde}	48.73^{bc}	53.89^{ab}	69.48^{ab}	69.48^{ab}	143.73^{ab}	146.71^{a}	6.06^{ab}	3.80^{de}
350	37.40^{abcd}	38.96^{ab}	49.60^{bc}	52.68^{ab}	61.75^{c}	63.75^{bc}	138.31^{abc}	134.19^{c}	6.67^{a}	4.57^{cd}
400	37.77^{abcd}	39.23^{a}	50.40^{bc}	51.59^{ab}	57.70^{c}	51.57^{b}	140.15^{abc}	140.12^{abc}	6.67^{a}	3.49^{de}
450	39.55^{a}	38.55^{abc}	53.16^{ab}	56.77^{a}	64.46^{b}	64.46^{bc}	115.00^{d}	141.84^{abc}	3.49^{e}	5.04^{bc}
±S.E	1.48	1.37	1.94	1.42	2.28	2.21	3.35	1.87	0.43	0.25
LSD	4.66	4.33	6.13	4.47	7.19	6.98	9.91	5.90	1.37	0.78

Table 1: Continued..

Characters/ Dose (Gy)	Capsules /plant		Days to maturity		Capsule size		No. of seed/capsule		1000 seed wt(gm)		Seed yield/plant	
	Rama	Tillotoma	Rama	Tillotoma	Rama	Tillotoma	Rama	Tillotoma	Rama	Tillotoma	Rama	Tillotoma
Control	118.26^{c}	117.64^{c}	92.88^{abcd}	93.53^{abc}	2.76^{cd}	3.32^{ab}	60.77^{ab}	62.98^{a}	3.34^{bd}	3.27^{cd}	21.53^{bcde}	26.06^{bc}
250	122.93^{c}	121.70^{c}	105.65^{b}	110.16^{d}	3.27^{ab}	3.14^{bc}	45.90^{de}	45.50^{e}	2.74^{e}	3.41b^{cd}	15.59^{g}	18.90^{defg}
300	104.23^{d}	103.16^{d}	102.19^{bcde}	95.96^{c}	2.63d^{ef}	3.09^{bc}	48.73^{cde}	47.66^{cd}	3.49^{bc}	3.23^{cd}	17.75^{efg}	15.87^{fg}
350	140.30^{a}	137.18^{ab}	97.63^{cd}	88.46^{cdef}	2.21^{f}	2.68^{de}	50.77^{cd}	49.07^{cd}	3.71^{b}	3.03^{e}	26.45^{b}	21.00^{cdef}
400	143.46^{a}	137.55^{b}	83.32^{f}	92.06^{abcd}	2.28^{ef}	2.42^{def}	43.53^{de}	41.87^{e}	3.50^{bc}	3.08^{de}	21.87^{bcde}	17.79^{efg}
450	121.88^{c}	126.02^{bc}	92.66^{abcd}	96.91^{a}	2.62d^{ef}	3.63^{a}	54.30^{bc}	49.43^{cde}	4.36^{a}	3.36^{b}	32.42^{a}	23.59^{bcd}
±S.E	4.75	3.52	2.29	1.18	0.14	0.14	2.09	2.86	0.15	0.07	2.06	0.97
LSD	14.98	11.08	7.22	3.71	0.44	0.43	6.59	9.00	0.47	0.21	6.47	3.06

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

3.8 Capsule size: Significant differences were observed between two genotypes different doses (Table 1). In Rama, all irradiated plants were significantly different with unirradiated plants, though, similarities were observed among 300, 350, 400, 450 Gy except the treated plants at 250 Gy. In Tillotoma, significant difference was observed at control with 350, 400 and 450 Gy treated plants. For both varieties gradual reduction were observed with increasing gamma radiation doses except at 250Gy treated plants in Rama. The reduced capsule sizes may be due to physiological and some other disturbances at genetic level like chromosomal damage disturbed chromosomal coiling, failure or restricted pairing etc. Girija *et al.* (2013) [6] and Yasmin *et al.* (2016) [26] also reported that in M_1 generation irradiation reduced some polygenic characters like length of capsule.

3.9 Number of seed/capsule: The range for number of seed/capsules was 41.87-62.98. The highest number was for control in Tillotoma followed by control in Rama and lowest for 400 Gy in Tillotoma (Table 1). In case of both varieties, control or unirrated plants were significantly different with other applied doses. the lowest number was recorded for Tillotoma when treated with 400 Gy, which did not show any significant differences with 250, 450 Gy treated plants of same genotype and 250, 300, 400 Gy treated plants of Rama. Number of seeds per capsule can be attributed to high seed sterility as caused by physiological and biochemical disturbances in the development of seeds (Prabhakaran, 1992) [16]. In earlier studies in sesame Rahman and Das (1998) [18], Ravichandran *et al*. (2014) [17] agreed with similar results.

3.10 1000 seed weight (gm): 1000 seed weight for two genotypes responded differently to different six doses of gamma ray including a control. It ranged from 2.74 – 4.36 gm (Table 1). The highest weight was recorded in Rama when irradiated with 450 Gy and it was significantly different with other treatments of both genotypes. The lowest 100-seed weight was recorded also in Rama when irradiated with 250

Gy which was significantly different with all other treatments except 350 and 400 Gy of Tillotoma. The two genotypes differed statistically for the same treatment. Increasing of 1000 seed weight through mutation in M_1 generation was reported by many workers. Karim *et al*. (2008) [10] irradiated some chickpea cultivars with gamma ray and observed noticeable changes in 100- seed weight.

3.11 Seed yield/plant: Seed yield/plant ranged from 15.59 to 32.42gm. The highest yield was obtained through the plants treated with 450 Gy and the lowest yield was at 250 Gy. In Rama, unirradiated seeds with 300, 350 and 400 Gy, 250 Gy and 300 Gy showed statistically similar result. 450Gy treated plants in Rama, showed significant differences with all other treatments in same genotype as well as in Tillotoma. In Tillotoma, unirradiated (*i.e.* control) seeds were significantly different with other treatments except 450Gy. Higher seed yield mutant was reported by a number of researchers, Shaikh *et al*. (1982) [21] in chickpea, Veni *et al*. (2016) [25] in urdbean, Yasmin *et al*. (2016) [26] in black gram, and Naik *et al*., (2009) [14] in Niger.

4. Conclusion

The present investigation revealed that all the quantitative traits proportionately decrease or increased with the increase in dose of gamma rays in sesame. Gamma ray was decrease or increased quantitative characters have been attributed to the physiological disturbance or chromosomal damage caused to the cells of the plants.

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