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Effect of gamma rays on germination and plant survival in sesame (*Sesamum indicum* L.)

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Abstract
In order to study the effect of mutagenesis on germination and growth in sesame, the seeds of two varieties 'AKT-101 and PKV-NT-11' were irradiated with 4 gamma radiation doses (*viz.*, 400Gy, 500Gy, 600Gy and 700Gy) at BARC, Mumbai. About 50 seeds of each dose along with control in five replications were placed for germination in laboratory and observations were recorded on percent germination, root length (cm), shoot length (cm). Besides, about 100 treated seeds per dose were grown in randomized block design with five replications at research field of agricultural botany, Dr. PDKV, Akola and observations on percent germination, plant survival, and reduction in plant survival over control were recorded. In laboratory condition, the germination (%), shoot length and root length decreased progressively with increasing doses of gamma rays in both varieties. LD_{50} was observed between 500 and 600 Gy in both varieties. Under field conditions, the highest survival reduction over control in both the varieties was recorded in 700Gy (84.41 in AKT-101 and 86.40 in PKV-NT-11). The maximum percent survival of M_1 plants in variety AKT-101 was observed in 500Gy dose (64.63%) and for variety PKV-NT-11, it was 400Gy dose (68.67%) respectively. Higher doses of gamma radiations caused considerable reduction in all parameters.

Keywords: Gamma rays, Germination, LD_{50}, mutagenesis, sesame

Introduction
Sesame (*Sesamum indicum* L.) is an ancient crop and one of the earliest domesticated oil crops in the world (Ashri, 2007) [3]. It is commonly known as gingelly, til, benniseed, simsim. It is a member of the order Tubiflorae, family Pedaliaceae with a chromosome number 2n=26, thought to have originated in Africa, due to presence of diverse wild species. Sesame is an important source of high quality oil and protein. Roughly this has excellent stability due to the presence of natural antioxidants such as sesamolin and sesamin (Brar and Ahuja 1979, Kamal – Eldin 1993) [5, 11]. In 2018, the productivity of sesame is low in India (431 kg/ha) as compared to world's average (512 kg/ha) and it is far below as compared to China (1393 kg/ha) being the highest (FOASTAT 2020) [8]. This evidently indicates the potentiality of the crop for improvement in yields.
Genetic variability is the basic requirement for genetic improvement of any crop. Induced mutagenesis is an effective and potential method to create variability in a crop. Among physical mutagens, gamma rays directly penetrate the plant tissue and are partially ionizing. The mutagen is very efficient for creating genetic variability in the natural gene pool of *Sesamum indicum* L. Seed germination, seedling growth, and plant survival are some of the commonly used criteria for studying gamma rays effect on crop plants.

Material Methods
The experiment was conducted on two varieties of sesame AKT-101 and PKV-NT-11, developed by Dr. PDKV, Akola. The healthy, dry and uniform colored seeds of both varieties were irradiated with four gamma ray doses *viz.*, 400Gy, 500Gy, 600Gy and 700Gy from cobalt-60 source at Bhabha Atomic Research Centre, Mumbai, to create variability.
Germination test was carried out in laboratory condition. In order to study the effect of different doses of mutagens on germination and seedling growth, about 50 seeds of each dose along with both controls were taken for germination testing with five replications. The observations were recorded after 7 days on percent germination, root length (cm), shoot length (cm).

Raising M_1 generation
To raising M_1 generation, about 100 treated seeds of each treatment were sown at the research field of agricultural botany, Dr. PDKV, Akola in Randomized Block Design with five replications. The row to row and plant to plant spacing were kept at 30 cm and 10 cm, respectively. Standard cultural and agronomic practices were followed to raise the crop and maintain good plant growth. The observations on percent germination, plant survival, reduction in plant survival over control were recorded at appropriate stages of crop growth in the M_1 generation.

Standard Germination Test
Germination percentages were calculated by expressing the number of seedlings in a replicate that emerged 7 days after planting as a percentage of the number of seeds planted.
Germination percent% = [(Number of seeds germinated/ Total number of seeds taken) x 100]
Plant survival (%) = [(Number of plants survived /Total number of seeds germinated) x 100]

Seedling length (cm)
Ten normal seedlings were randomly selected from each replication of both the varieties and their length was measured in cm. Average length of these seedlings were calculated.

Seedling Vigour indices
Seedling vigour indices were calculated by using the formula suggested by Abdul-Baki and Anderson (1973) [1].
Seedling vigour index = Standard germination (%) x seedling length (cm)

Results and Discussion
The experimental finding is present in two heading as Lab observations and field observations as follow:

Laboratories observation
The effects of physical mutagens on various parameters of plant growth such as germination, root length, shoot length, seedling injury and seed vigour index in sesame are presented in Table 1.

Germination percentage
According to the experiment conducted on germination under laboratory conditions, in both the varieties, there was reduction in germination percentage at each dose over the control. From Table 1 significant reduction in germination percentage was observed in AKT-101 at 700 Gy (40.60%) over control (94.60%), similarly in PKV-NT-11 significant reduction was recorded at 700 Gy (36.20%) over control (94.00%). It can be observed that germination was more affected with higher doses of gamma rays. Emrani *et al.*, (2011) [7] also observed significant effect of mutagen doses on seed germination. The LD_{50} was observed between 500 and 600 Gy in both varieties.

Table 1: Effect of mutagens on different parameters in M_1 seeds (Laboratory)

Varieties	Treatments	Germination (%)	Root length (Cm)	Shoot length (Cm)	Seedling height (cm)	Seedling Injury (%)	Seed vigour index
AKT-101	Control	94.60	7.26	7.96	15.22	-	1439.76
	400	76.60	6.84	7.70	14.54	4.59	1116.58
	500	58.20	5.38	6.80	12.18	20.02	714.10
	600	50.80	4.14	4.44	8.58	43.61	437.78
	700	40.60	3.68	4.08	7.76	48.29	316.42
PKV- NT-11	Control	94.00	7.04	7.04	14.08	-	1324.36
	400	70.40	4.80	5.16	9.96	26.31	702.52
	500	57.80	3.88	4.44	8.32	36.18	483.28
	600	47.20	2.42	3.88	6.30	51.26	301.10
	700	36.20	2.30	2.50	4.80	64.16	172.82
	Mean	62.64	4.77	5.40	10.17	36.80	700.87
	SE (m)	0.90	0.26	0.23	0.38	3.61	29.57
	CD@5%	2.58	0.73	0.66	1.08	10.46	84.80

Root length (cm): Root length of gamma irradiated plants and control plants differ significantly in both the genotypes of sesame. From table 1, it is observed that in variety AKT-101 treatment 400 Gy (6.84 cm) showed highest root length as compared to other doses. Similar results were observed in the variety PKV-NT-11 (4.80 cm). The shortest root length was observed in the treatment 700 Gy in both the varieties (3.68 cm and 2.30 cm respectively). Similar results of reduced root length in gamma rays treated plants of sesame was reported by Kumari *et al.* (2016) [12].

Shoot length (cm)
The shoot length was also decreased causing seedling injury progressively with increase in dose of the mutagen. The highest reduced shoot length was observed in the treatment 700 Gy in both the varieties (4.08 cm and 2.50 cm respectively). Lower doses of mutagen exhibited higher shoot length. Decreased in shoot length was observed in the present study, was also in conformity with the observation of Boranayaka *et al.* (2010) [4] and Kumari *et al.* (2016) [12].

Seedling Injury over control: The maximum seedling injury over control was observed in 700 Gy dose in both varieties (48.29% in AKT-101 and 64.16% in PKV-NT-11), while the minimum seedling injury was recorded in 400 Gy in both varieties (4.59% in AKT-101 and 26.31% in PKV-NT-11).

Seedling Vigour Index
In the variety AKT-101 maximum seedling vigor index was found in 400 Gy (1116.58) among other doses, similarly in variety PKV-NT-11 it was high in 400 Gy (702.52). In both varieties minimum seedling vigor index was found in 700 Gy (316.42 in AKT-101 and 172.82 in PKV-NT-11).

Field Observations
The effects of physical mutagens on various parameters of plant growth such as germination, percent survival, reduction in survival in sesame are presented in Table 2.

Table 2: Effect of mutagenic treatments on various parameters in M_1 generation (Field condition)

Varieties	Treatments	Total No of seeds sown	% of germination	% of survival	Reduction in survival over control
AKT-101	Control	500	92.00	93.71	-
	400	500	70.49	62.32	49.21
	500	500	59.37	64.63	55.15
	600	500	48.16	58.47	68.37
	700	500	36.00	36.95	84.41
PKV-NT-11	Control	500	89.88	91.80	-
	400	500	68.49	68.67	43.03
	500	500	55.31	53.03	64.78
	600	500	42.70	50.06	74.19
	700	500	32.00	35.00	86.40
	Mean		59.44	61.46	65.69
	SE (m)		1.21	1.49	1.05
	CD@5%		3.46	4.27	3.03

Germination (%)

The seed germination percent decreased with the increase in radiation. The lowest germination was found in 700 Gy in both the varieties (36.00% in AKT-101 and 32.00% in PKV-NT-11). Reduction in seed germination might have been due to the effect of mutagens on meristematic tissues of the seed. The decrease in seed germination at higher doses of the gamma rays may be attributed to disturbances at the cellular level. Reduction in seed germination in mutagen treated population of sesame may be either due to the delay or inhibition in physiological and biological processes necessary for seed germination.

Percent Plant survival

The maximum percent survival of M_1 plants in variety AKT-101 was observed in 500 Gy dose (64.63%), while the lowest percent survival was recorded in 700 Gy (36.95%). Similarly in variety PKV-NT-11 the maximum percent survival of M_1 plant observed in 400 Gy dose (68.67%), while lowest percent survival 700 Gy (35.00%). Table 2 also reveals that highest dose of gamma rays showed high decrease in plant survival thus has hazardous effect. The similar observation has been recorded by the researchers (Anbarasan *et al.* 2013, Diouf *et al.* 2010, Ghulam *et al*. 2008 and Yingzhong, 2003) [2, 6, 9, 13]. In both the varieties, the highest survival reduction was recorded in 700 Gy (84.41 in AKT-101 and 86.40 in PKV-NT-11). Earlier studies on the effect of mutagens on M_1 parameters have reported similar results in different crops including soybean, sesame and pigeon pea. Thus, the survival rates of treated seeds and M_1 plants are reduced probably due to genetic aberrations caused by higher doses of the mutagen. However, the lower doses of mutagens used in the present study can be successfully utilized for enhancing genetic variability in sesame.

Conclusion

In the present investigation, it was concluded that, the survival rates of treated seeds and M_1 plants were reduced probably due to high genetic aberrations caused by higher doses of the gamma ray. The seed germination, survival rate, seedling growth, root length and shoot lengths were inhibited by increasing doses of mutagens. The survival reduction in higher doses reveals the highest mutagenic response can be obtained by gamma rays. Thus the gamma rays found highly effective for modifying majority traits of the sesame crop plant.

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