Effect of gamma rays irradiation on seed germination and seedling parameters in Sesame (*Sesamum indicum* L.)

ABSTRACT

The present investigation was carried out with the aim to understand the gamma ray sensitivity of three sesame varieties *viz.*, DS-5, DSS-9 and Swetha irradiated with ten different doses of gamma rays *ie.*, 250Gy to 700 Gy at 50 Gy intervals. Germination percentage, root and shoot length, seedling length decreased gradually in all the three varieties compared to control which is untreated. Swetha showed a maximum reduction in germination percentage (73.0 %) than DSS-9 (74.0 %) and DS-5 (76.5 %) at 700 Gy. At a higher dose of 700 Gy, root 1(.17 cm) in DS-5 and shoot (2.47 cm) length of seedlings in DSS-9 were greatly inhibited. Based on all the biological parameters studied, the mutagen sensitivity of DSS-9 is higher than DS-5 and Swetha. The overall considerations on M_1 generation effects showed that Swetha was least sensitive to gamma rays.

Keywords: Sesame, germination, seedling morphology, gamma radiation

Introduction:

Sesame (*Sesamum indicum* L.) is one of the oldest oil seed crop domesticated by mankind and is being widely cultivated in tropical and subtropical parts of the world including India (Ashri, 1998). It is a member of the family Pedaliaceae having 2n=26 chromosome number and considered to be originated in Africa as there exists diverse wild species. Sesame is commonly known as gingelly, til, simsim, benniseed etc. It is referred to as" Queen of Oil Seeds" because of its excellent oil quality offered by lignans -a natural antioxidants such as sesamolin and sesamin present in its oil (Brar and Ahuja 1979, Kamal Eldin 1993) and the seeds are also rich in minerals (calcium, potassium, phosphorus, iron, magnesium, zinc), vitamins (E, C, B complex).Sesame has wider economical, industrial, nutritional and medicinal significances thus the demand for sesame seed and oil consumption is estimated to reach about 220.46 million tons by 2030. Hence, demands the crop improvement.

Sesame is grown widely in many countries, including China, India, Ethiopia, Uganda, Nigeria and Myanmar. As per the report of FOASTAT 2020, the productivity of sesame is low in India (431 kg/ha) as compared to world's average (790 kg/ha) and it is far below as compared to China (1620 kg/ha) which is being the highest (Telku *et al.*, 2022). The crop being mainly cultivated under rainfed conditions in low and marginal soils and use of local varieties and besides susceptibility to various biotic and abiotic stresses are main factors responsible for reduced production and productivity of this crop.

Presence of genetic variation is the basic requirement in any crop for its geneticimprovement. Among various breeding tools,one of the feasible andpotential means of creation of these variations is throughinduced mutagenesis as spontaneous mutations occur in very low frequency in nature. In order to have mutations in crop plants, physical mutagens are beingused and subsequent improvement can be achievedthrough selection. Among the physical mutagens, gamma rays are commonly used mutagens that directly penetrate plant tissue.Usually radiation make cuts in the plant's DNAand errors to DNA repairs lead to induced mutations (Abdallah *et al.*, 2024). The study by Viana *et al.* (2019) states that doses of any physical mutagen that leads to 50% lethality or 50% growth reduction are considered as LD_{50} or GR_{50} respectively which helps to understand the adequate gamma irradiation dose for mutations. Further, it is also considered that the optimum mutation frequency lies in between GR_{30} and GR_{50} values (Roy *et al.*, 2019).

The degree of radio sensitivity of different genotypes and the extent of damage caused by themutagens is observed by inhibition of seed germination in M_1generation (Gaul., 1958). Previous studies (Parthasarathi et al., (2020), Boranayak et al., (2010) indicate that the mutagen is very effective at creating genetic variation in sesame also. Hence, the present study was carried out to understand the influence of gamma rays on seed germination and seedling parameters in different sesame genotypes and there by to have scientific basis for sesame mutation breeding.

Materials and Methods

The experiment was carried out at Seed Unit, University of Agricultural Sciences, Dharwad. Seeds of three promising sesame genotypes *viz.*, DS-5 and DSS-9 collected for All India Co-ordinated Project on Sesame and Niger, University of Agricultural Sciences, Dharwad and Swetha collected from Seed Unit, University of Agricultural Sciences, Raichuru were irradiated with 10 different doses of gamma rays *ie.*, 250Gy, 300Gy, 350Gy, 400Gy, 450Gy, 500Gy,550Gy,600Gy, 650Gy and 700Gy from^{60}Co at Bhabha Atomic Research Centre, Mumbai. About 100 seeds of each dose along with control of all the three genotypes were placed between moistened germination papers replicated twice for seed germination test and seedling parameters study in the laboratory at Seed Unit, UAS, Dharwad during 2023-24. Data collected was analysed through descriptive statistics.

Seed germination:

The emergence of cotyledon leaf in each treatment was considered as the indication of germination. Germinated seeds count for each treatment was taken on seventh day after sowing according to ISTA (2004) rules and germination percentage was calculated.

Germination percent = [(Number of seeds germinated/ Total number of seeds taken) x 100]

Shoot length (cm):

The length of the shoot from the cotyledonary node to the tip of the shoot was measured n centimeter on ten randomly selected seedlings and averaged to get mean shoot length.

Root length (cm):

The root length from the cotyledonary node to the tip of the primary root was measured on ten randomlyselected seedlings and average root length was expressed in cm.

Seedling Vigour index:

Seedling vigour indices were calculated by using the formula suggested by Abdul-Baki and Anderson (1973).

Seedling vigour index = Standard germination (%) x seedling length (cm)

The radio-sensitivity test:

The LD_{50}, GR_{50} and is calculated using graphical analysis on Microsoft excel sheet. The standard statistical analysis was done by formulae given by Panse and Sukhatme (1985)

Results and Discussions:

In any induced mutation breeding experiments assessment of the effects of mutagens in M_1 generation is a common procedure. These biological damages caused by the mutagens is measured based on seed germination, survival reduction, plant growth reduction as well as fertility reductionor sterility. These damage caused could be considered as an indication of mutagenic effects (Gaul., 1970). Similar to aforesaid research results, different effects due to gamma rays have been studied in the present investigation amongthree sesame genotypes. The results of the present study are presented (Table1) and discussed here.

Germination percentage: In the present experiment, the results of germination test under laboratory condition revealed that the percentage of seed germination was increased progressively with the increasing dose of gamma rays at specific treatment and then decreased thereafter in all the three sesame varieties (Table 1). Many earlier workers *viz.,* Bolbhatsadashiv *et al.(*2012) in horsegram, Dhakshanamoorthy 2010) in Jatropha curcas, Khan and Wani (2005), Lavanya (2011) and Rukesh (2017) in green gram also reported similar results due to treatment of mutagens. However, in contrast to our study Boranayak *et al. (*2010) and Raut *et al*.(2021) reported the decrease in percentage of seed germination in sesame varieties. Sesame variety DS-5 recorded highest average germination percentage (87.7 %) compared to Swetha (86.1 %) and DSS-9 (85.5%).

Shoot length: Increase in gamma rays doses resulted in a considerable reduction in shoot length development among all the sesame genotypes and rate of reduction was more as the dose of gamma rays increased in present study. Lower doses *ie.,* 250 Gy, 300 Gy exhibited highest shoot length. The highest reduced shoot length was recorded at 700 Gy in DS-5(1.17cm) compared to DSS-9 (1.36 cm) and Swetha (2.27cm) (Fig. 2, 3 & 4). Similar results of reduced shoot length was reported by Kumari *et al*. (2016), Parthsarthi *et al*., (2020) and Raut *et al*.(2021) in their study.

Root length: In this study, root length of gamma irradiated plants and control plants differed significantly in all the three sesame genotypes. Shoot length also decreased progressively with increase in dose of the gamma rays mutagen. It was observed that at 700 Gy highest reduced root length as compared to other doses and shortest root length was noticed in the variety DSS-9 (2.47 cm) followed by DS-5 (2.90 cm) and Swetha (4.85cm) (Fig. 2, 3 & 4) Decreased in shoot length witnessed in the present study was also in conformity with the observation of Raut *et al*. (2021), Boranayak *et al*.(2010), Parthsarthi *et al.*, (2020) and Kumari *et al*.(2016).

Total seedling length: Wide range of variation for total seedling length was recorded. It ranged from 14.94 to 3.83cm in DSS-9 followed by DS-5 (13.79 – 4.07cm). The study also revealed thatreduction in average total seedling length of M_1 plantswith the increase in dose of gamma rays. Similar report was given by Raut et al.(2021). Among the different doses of gamma rays doses of mutagen, 700 Gy of gamma ray recorded the maximum total seedling length reduction (Table 1).In the presentinvestigation, the seed germination got delayed and the seedlings were shorter at higher dosage of mutagens which might be due to the effect of mutagens (Priyanka *et al.*, 2020).

Seedling Vigour Index: Increase in dose of gamma radiation resulted in a gradual reduction in vigour index (Table 1).Minimum vigour index was witnessed at 700 Gy of gamma rays treatment irrespective of genotypesand showed wide range values. Among the three genotypes,Swetha genotype recorded maximum vigour index (1196.9 %) followed by DS-5 (1169.2 %) while, DSS-9 (321.0 %) showed least vigour index value. These results are supported by the research finding s of Raut *et al.* (2021) and Boranayak *et al*.(2010).

The radio-sensitivity test:For any successful mutation breeding programme, it is necessary to determine the lethal dose (LD_{50}) or growth reduction dose (GR_{50}) values which serve as a baseline for the subsequent doses that can be used to treat and study a larger population.The GR_{50} value for all the three sesame genotypes were determined based on the seedling growth reduction percentage with different doses of gamma rays by adopting graphical excel analysis (Table 1 and Fig 1,2 and 3). Results of i*n vitro* experiment of the present study revealed dose dependent gradual growth reduction in sesame seedlings. The GR_{50} value was 608.1 Gy for DS-5 (Fig 1), 909.9 Gy for Swetha (Fig 2) and 585.7 Gy for DSS-9 (Fig 3) indicating that Swetha has less sensitivity to gamma rays irradiation followed by DS-5 and DSS-9 variety.These difference indicated that different genotypes of the same family can also vary considerably in their sensitivity response to gamma rays irradiation (Muhammad et al.,2021). The expected LD_{50} value for DS-5, Swetha and DSS-9 was 493.2 Gy, 670.6Gy and 584.8 Gy respectively.

Conclusion :

In the present study it was observed that, sesame variety DS-5 showed highest average germination percentage, root length, shoot length and vigour index compared to Swetha and DSS-9. The seed germination, seedling growth, root and shoot lengths were inhibited by increasing doses of gamma rays. Root length reduced drastically than shoot length irrespective of the genotypes. Root system appeared to be more sensitive than shoot. The present study showed that through gamma rays irradiation can be used effectively to induce essential economic mutations in all the sesame varieties. The results also indicate that the lower doses of mutagen are more effective than the higher doses in exploitation of desirable mutants.

Table 1. Effect of gamma rays irradiation on growth parameters (Laboratory condition)

Genotypes	Dose of Gamma rays	Germination %	Shoot length (cm)	Root length (cm)	Total Seedling length (cm)	Vigour Index
DS-5	Control	91.5	4.05	9.74	13.79	1255.1
	250 Gy	89.5	3.98	9.23	13.21	1169.2
	300 Gy	92.5	3.60	9.57	13.17	1205.3
	350 Gy	93.0	3.25	8.34	11.59	1084.0
	400 Gy	95.0	3.29	8.06	11.35	1105.9
	450 Gy	96.0	2.79	7.15	9.94	951.6
	500Gy	89.0	2.01	6.00	8.01	745.5
	550 Gy	82.5	2.26	6.15	8.41	784.7
	600 Gy	80.0	1.36	3.96	5.32	463.4
	650 Gy	79.0	1.39	4.82	6.21	513.2
	700 Gy	76.5	1.17	2.90	4.07	342.4
	Mean	87.7	2.65	6.90	9.55	874.57
	S.Em. ±	2.15	0.13	0.29	0.41	35.38
	CD@5 %	6.77	0.42	0.91	1.28	111.48
	CV %	3.33	7.13	5.94	6.04	5.72
Swetha	Control	93.0	4.80	7.83	12.63	1173.8
	250 Gy	86.5	4.85	7.54	12.39	1196.9
	300 Gy	82.0	4.34	7.13	11.47	943.7
	350 Gy	84.5	4.00	8.16	12.16	1028.2
	400 Gy	88.5	4.08	8.30	12.38	1096.7
	450 Gy	86.5	4.18	7.70	11.88	974.2
	500Gy	92.0	3.81	7.29	11.1	960.6
	550 Gy	91.0	3.13	6.69	9.82	891.8
	600 Gy	87.5	3.29	5.72	9.01	788.2
	650 Gy	82.0	3.38	6.27	9.65	890.6
	700 Gy	73.0	2.27	4.85	7.12	647.9
	Mean	86.1	3.83	7.04	10.87	962.97
	S.Em. ±	2.57	0.27	0.48	0.56	72.56
	CD@5 %	8.11	0.84	1.52	1.78	228.65
	CV %	4.11	9.81	9.68	7.33	10.66
DSS-9	Control	91.0	4.38	10.56	14.94	1359.1
	250 Gy	84.5	4.16	8.58	12.74	1076.3
	300 Gy	83.0	4.01	8.84	12.85	1066.0
	350 Gy	87.5	3.77	7.89	11.66	1019.1
	400 Gy	89.5	3.79	8.32	12.11	1082.9
	450 Gy	90.5	3.32	7.46	10.78	932.0
	500Gy	88.5	2.19	6.75	8.94	790.8
	550 Gy	86.5	2.11	7.04	9.15	818.2
	600 Gy	84.0	1.64	4.14	5.78	486.0

	650 Gy	82.0	1.44	4.99	6.43	539.5
	700 Gy	74.0	1.36	2.47	3.83	321.0
	Mean	85.5	2.92	7.00	9.92	862.80
	S.Em. ±	2.29	0.09	0.23	0.18	29.11
	CD@5 %	7.21	0.29	0.72	0.58	91.73
	CV %	3.74	4.53	4.59	2.61	4.77

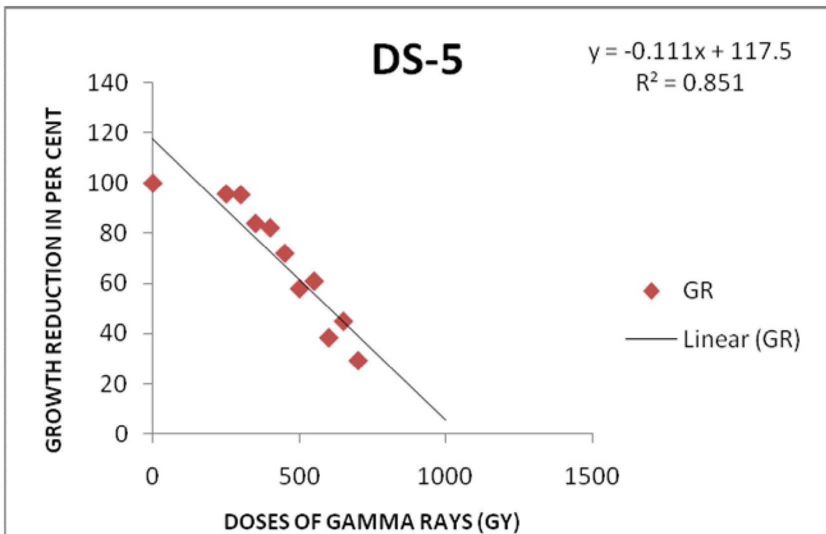

Fig.1 Effect of different doses of gamma irradiation on growth reduction in DS-5 genotype.

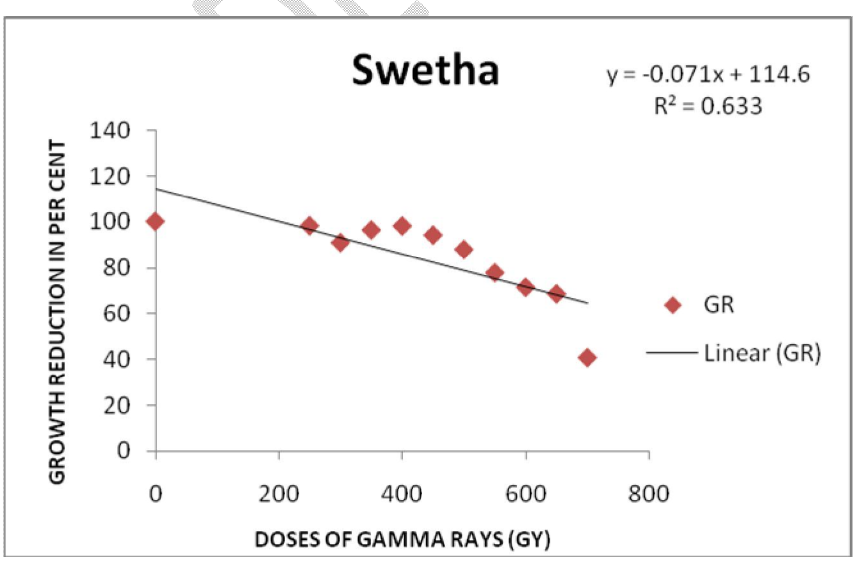

Fig.2 Effect of different doses of gamma irradiation on growth reduction in Swetha genotype

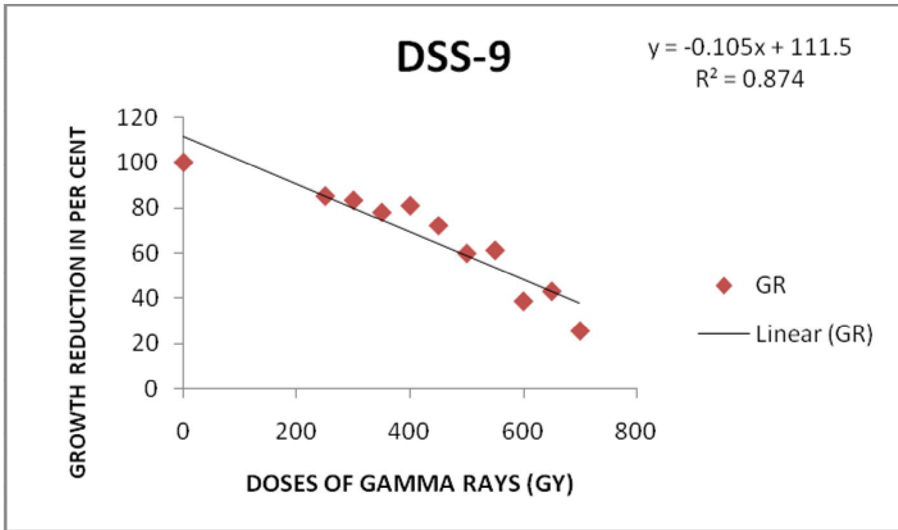

Fig.3 Effect of different doses of gamma irradiation on growth reduction in DSS-9 genotype

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

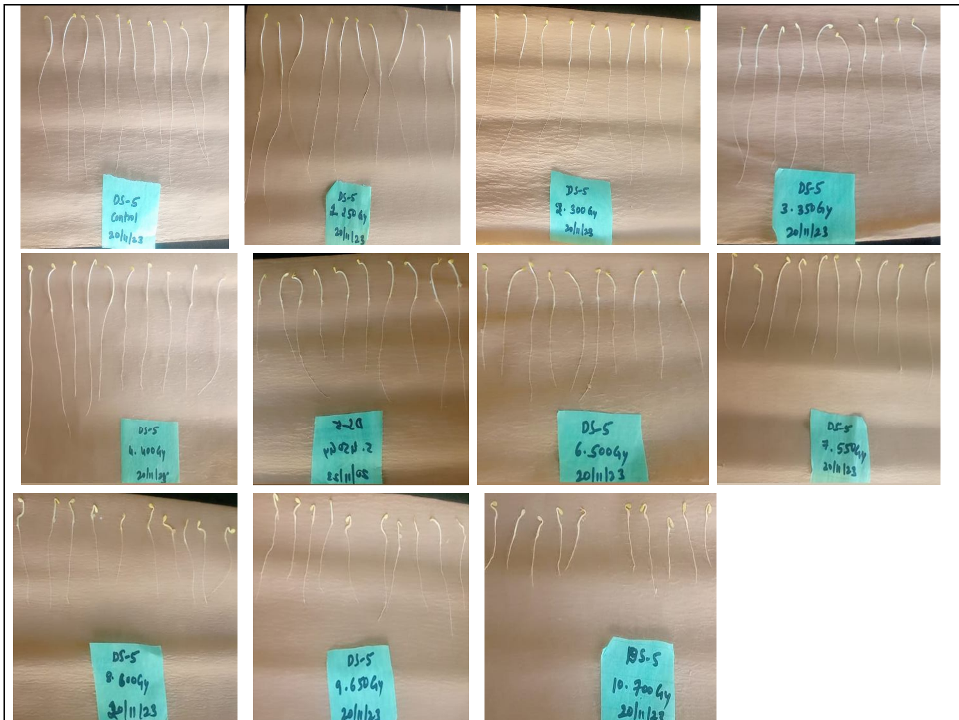

Fig. 2 Effect of gamma rays on seedling parameters in DS-5 genotype.

Fig. 3 Effect of gamma rays on seedling parameters in Swetha genotype.

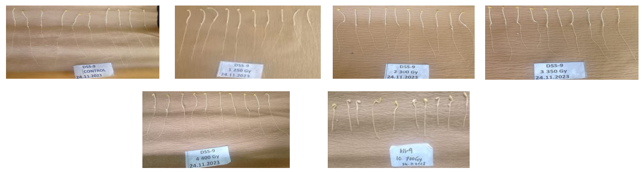

Fig. 4 Effect of gamma rays on seedling parameters in DSS-9 genotype.

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