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Biological effects of gamma irradiation in oat (*Avena sativa* L.)

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Abstract

The seeds of three oat varieties viz., JO-1, Kent and JO 03-91 were exposed to seven different doses of gamma rays *i.e*. 200 Gy, 250 Gy, 300 Gy, 350 Gy, 400 Gy, 450 Gy and 500 Gy at Nuclear Research Laboratory, IARI, New Delhi. Radiation dose of 500 Gy proved most lethal and reduced the percentage of survived plants in oat varieties JO-1 (37.36%) and JO 03-91 (43.57%). Only one variety JO 03-91 has three morphological mutations were found at different doses *i.e*. 250 Gy, 350 Gy and 450 Gy and two chlorophyll mutations namely i.e. chlorina and yellow viridis was found in JO-1 (450Gy) and Kent (250Gy) in M_1 generation respectively.

Keywords: *Avena sativa*, Chlorophyll mutations, Correlation, Fodder, Gamma rays

Introduction

Gamma irradiation has been proved to be very attractive in induction of genetic variability in many cereal crops. In mutation breeding, before induction of desirable mutations in crop plants a knowledge of the relative biological effectiveness and efficiency of various physical and chemical mutagens was very necessary (Smith, 1972). Several successful cases have been reported by different scientists to determine the most effective mutagenic treatment for the induction of desirable traits in oat (Coimbra *et al*., 2004; Mehta *et al*., 2008; Chawade *et al*., 2010).

Oat (*Avena sativa* L.) is the sixth most important cereal crop in the world after wheat, maize, rice, barley and sorghum. In India, oat is mostly used as feed for animals grown in winter in north western, central India and is now extending to the eastern region. The total area covered under oat cultivation in the country is about 5 lakh ha. The crop occupies maximum area in Uttar Pradesh (34%), followed by Punjab (20%), Bihar (16%), Haryana (9%) and Madhya Pradesh (6%) (Pandey and Roy, 2011). It has excellent growth habit, quick recovery after cutting and good quality herbage. It is a palatable, succulent and nutritious crop.

Variability in cultivated oat varieties is not high enough; it precludes the breeding process. Mutation breeding is the purposeful application of mutations in plant breeding. Unlike hybridization and selection, mutation breeding has the advantage of improving a defect in an otherwise elite cultivar, without losing its agronomic and quality characteristics (Pathirana, 2011). So, the present investigation was undertaken to evaluate the relative effectiveness and biological effects of gamma irradiation in oat.

Materials and Methods

In this investigation, three prominent oat varieties (JO-1, Kent and JO-03-91) were selected and exposed with seven doses of gamma rays (200 Gy, 250 Gy, 300 Gy, 350 Gy, 400 Gy, 450 Gy and 500 Gy) by ^{60}Co gamma source at Nuclear Research Laboratory, IARI, New Delhi. After gamma irradiation ten seeds were sown in three replications per treatment on paper towel by using distilled water and germination, root and shoot length were recorded after seven days.

Fifty seeds of each irradiated dose along with control were sown in the field at Regional Research Station, IARI, wellington, Tamil Nadu. Seedling emergence and height under field conditions was recorded at two different growth stages, *viz*., 7 and 14 DAS. The data on plant height, survival percentage and seed fertility were recorded at maturity stage. The experiment was laid out in randomized method and data were analyzed by two factorial complete randomized block design (CRBD).

Results and Discussion

***Germination (%)*:** The effect of different doses of gamma irradiation on germination (%) of three oat varieties was presented in Table 1. Seed germination decreased with the increasing gamma irradiation dose not in a linear fashion (Fig 1). Lower doses of gamma radiation showed a little effect on germination percentage. The dose of 500

Gy showed 72.89% germination in Kent followed by 76% (JO-1) and 76.67% (JO-03-91). Higher doses of gamma radiation decreased less than 80% of germination in all three varieties. The similar results were also being obtained on various crop plant species including in wheat (Wiersinski, 1984; Singh, 1993), rice (Pawan Kumar *et al*., 2013) and amaranta (Amir and Khavar, 2012).

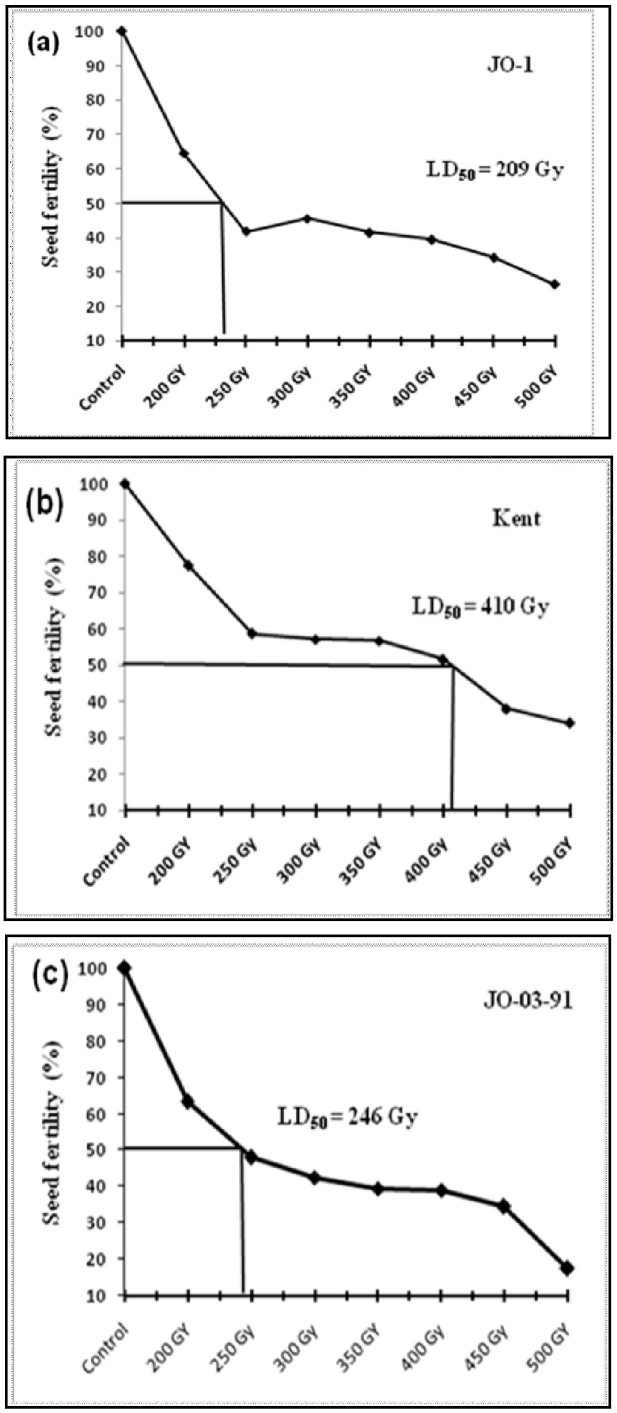

Fig 1. Effect of gamma irradiation on seed fertility (%) in M_1 generation

***Root length and Shoot length*:** In this investigation, reduction in root and shoot length of seedling occurred with each corresponding increase in gamma radiation doses not in a linear fashion (Fig 2). In contrast, the gamma rays had some stimulatory effects on shoot length in comparison to root length (Fig 2). Higher doses of gamma irradiation such as 450 Gy and 500 Gy showed drastic suppressing effect on root and shoot length in all oat varieties. Radiation doses of 450 Gy and 500 Gy for Kent and JO-03-91 and 500 Gy for JO-1 varieties of oat which showed less than 50% growth reduction (GR50) in root and shoot length of seedlings at 7 DAS. Such a conclusion gets supported by Shah *et al.* (2008) mentioned that higher doses gamma irradiation causing 20-40% reduction in shoot and root length of seedlings under the laboratory conditions.

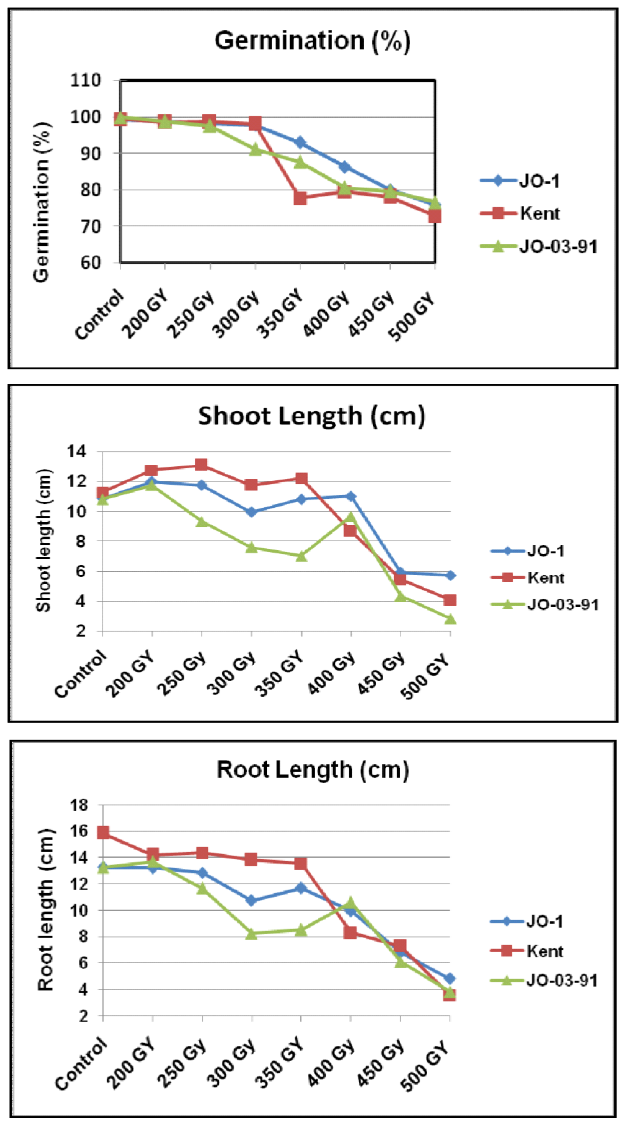

Fig 2. Effect of gamma radiation on germination (%), root and shoot length

Table 1. Mean values of germination, root length, shoot length, seedling emergence following gamma irradiation

Varieties	Treatments	Germination %	Root Length	Shoot Length	Seedling Emergence 7 DAS	Correlation (r) Dose vs. Emergence	14 DAS	Correlation (r) Dose vs. Emergence
JO-1	Control	99.33	13.23	10.83	88.67		94.33	
	200 GY	98.89	13.20	11.97	85.00		79.67	
	250 Gy	98.33	12.83	11.73	80.67		76.00	
	300 Gy	97.89	10.73	9.93	76.00	-0.72*	77.33	-0.86*
	350 GY	93.00	11.67	10.80	60.00		79.00	
	400 Gy	86.33	9.93	11.00	66.00		76.00	
	450 Gy	80.00	6.80	5.90	48.00		66.00	
	500 GY	76.00	4.80	5.73	37.00		51.00	
KENT	Control	99.51	15.84	11.26	94.00		95.33	
	200 GY	98.66	14.19	12.75	87.67		79.33	
	250 Gy	98.67	14.35	13.08	84.33		78.67	
	300 Gy	98.11	13.80	11.72	83.00	-0.80*	79.00	-0.90*
	350 GY	77.77	13.52	12.21	73.67		67.67	
	400 Gy	79.55	8.30	8.66	78.00		75.00	
	450 Gy	78.11	7.27	5.44	77.00		73.67	
	500 GY	72.89	3.58	4.10	47.33		60.33	
JO 03-91	Control	100.00	13.24	10.80	83.00		85.33	
	200 GY	98.89	13.67	11.73	84.67		83.33	
	250 Gy	97.55	11.68	9.31	79.67		76.67	
	300 Gy	91.33	8.23	7.59	81.00	-0.90*	78.33	-0.88*
	350 GY	87.67	8.53	7.03	69.33		78.33	
	400 Gy	80.67	10.60	9.67	74.33		77.00	
	450 Gy	79.67	6.09	4.35	65.33		74.67	
	500 Gy	76.67	3.84	2.85	32.00		66.13	*Significant
		A=0.668	0.960	1.277	0.854		0.926	t = 0.632 at
LSD Values 0.01		B=1.091	1.567	2.086	1.395		1.512	P = 0.05%
		AxB=1.890	2.714	N/A	2.416		2.618	

***Seedling emergence and height*:** Seedling emergence decreased with increase gamma irradiation dose not in a linear fashion in all three varieties at 7 DAS. In case of at 14 DAS seedling emergence decreased approximately linear fashion with increasing gamma radiation doses is in agreement with results of Siddiq and Swaminathan (1968). However seedling emergence increased at 14 DAS in comparison with at 7 DAS. The correlation coefficient between seedling emergence and radiation dose was found to be significant (p>0.05) and negative in all varieties (Table 1).

Seedling height reduced with increase gamma radiation doses in an approximately linear fashion in all three varieties at 7 and 14 DAS. Radiation doses 450 Gy and 500 Gy showed Less than 50% growth reduction (GR50) in seedling height at 7 DAS whereas 500 Gy at 14 DAS in all three varieties. Analysis of variance revealed no significant effect of (p>0.01) dose x variety interaction for seedling height was observed at 7 DAS (Table-2). Variations found in seedling emergence and seedling height at two different growth stages, *viz*., 7 and 14 DAS. It may be due to temporary shock of irradiation after treatment. A linear dependency of seedling height on the dosage of physical and chemical mutagens has been reported by Mikaelsen *et al.* (1968), Siddiq and Swaminathan (1968), Ando (1970), Katoch *et al.* (1992) and Wang *et al.* (1995).

***Plant height, survival (%) and seed fertility at maturity stage*:** Plant height, survival (%) and seed fertility recorded at maturity are presented in Table 2. Maximum reduction in plant height was found at 500 Gy in all three varieties. There was no significant difference in plant height reduction at different radiation doses within each variety. All the varieties responded similarly with increasing doses of irradiation. Similar results have been reported in *Vigna sesquipedalis* (Kon *et al*., 2007) and

Table 2. Mean values of seedling height, plant height, plant survival and seed fertility following gamma irradiation

Varieties	Treatment	Seedling Height (cm) 7 DAS	Seedling Height (cm) 14 DAS	Plant Height at Maturity	Plant Survival at Maturity	Correlation (r) Dose vs. Survival	Seed Fertility
	Control	4.80	19.93	129.33	93.67		79.80
JO-1	200 GY	3.50	18.63	124.20	74.67	-0.96*	51.63
	250 Gy	3.23	17.47	120.90	70.00		33.29
	300 Gy	2.60	17.13	119.27	66.67		36.41
	350 GY	2.70	15.43	116.87	70.00		33.14
	400 Gy	2.50	14.43	111.50	64.00		31.53
	450 Gy	2.07	11.80	99.27	59.33		27.32
	500 GY	1.07	9.60	94.80	35.00		21.16
	Control	4.59	19.10	132.40	94.00		83.19
KENT	200 GY	3.67	13.73	128.97	73.67	-0.92*	64.40
	250 Gy	3.53	15.17	124.83	74.67		48.80
	300 Gy	3.47	14.40	121.30	72.67		47.66
	350 GY	3.40	14.33	119.73	74.33		47.27
	400 Gy	2.87	13.47	117.83	65.67		42.98
	450 Gy	2.77	12.33	106.77	64.00		31.65
	500 GY	2.17	9.57	98.60	59.00		28.43
	Control	5.50	21.23	134.83	85.67		89.15
JO 03-91	200 GY	4.20	19.70	134.50	75.67	-0.909*	56.43
	250 Gy	3.80	19.00	130.93	76.33		42.87
	300 Gy	3.60	18.13	130.83	65.33		37.84
	350 GY	2.75	17.12	126.10	60.33		35.31
	400 Gy	2.63	16.40	120.93	53.00		34.95
	450 Gy	2.67	13.20	112.93	46.33		30.77
	500 Gy	1.73	10.23	106.40	37.33		15.57
		A=0.242	0.437	0.701	0.627	*Significant	1.173
LSD Values 0.01		B=0.396	0.713	1.145	1.023	t = 0.632 at	1.916
		AxB=N/A	1.236	1.983	1.772	P = 0.05%	3.318

chickpea (Khan and Wani, 2005; Toker *et al*., 2005). Apparently, reduction in plant height could be due to the inhibition of DNA synthesis or other physiological damage after mutagenic treatments. Micke and Wohrmann (1960) have reported that there are critical phases during plant development at which lethal effects are more prominent.

The number of surviving plants decreased with increase radiation doses in an approximately linear fashion in all varieties. Radiation dose of 500 Gy proved most lethal and reduced the percentage of survived plants in oat varieties JO-1 (37.36%) and JO 03-91 (43.57%) followed by 450 Gy in JO 03-91 (54.07 %) and 400 Gy (< 68.5%) in all three varieties. Reduction in plant survival due to mutagenic treatments is a common phenomenon in induced mutation experiments (Toker and Cagirgan, 2004; Khan and Wani, 2005; Toker *et al*., 2005). Analysis of variance revealed highly significant differences (p>0.01) among varieties as well as among different treatment doses regarding plant survival (Table 2). Highly significant effects of dose x variety interaction for plant survival were observed. The coefficient correlation between plant survival and radiation dose was found to be significant (p>0.05) and negative in all varieties. The number of surviving plants and plant height linearly decreased with the increase radiation dose in treated populations. Similar results have been reported in rice (Sarawgi and Soni, 1993; Cheema and Atta, 2003; Shah *et al*., 2012).

Seed fertility decreased with increase in gamma irradiation dose (Table 2) in an approximately linear fashion in all the three varieties. Fifty percent fertility reduction occurred at 209 Gy, 246 Gy and 410 Gy in JO-1, JO-03-91 and Kent respectively (Fig 1: a, b, c). Therefore, it is concluded from this experiment variety JO-1 and JO 03-91 appeared to be more radio sensitive to gamma rays than Kent. Miyahara (1997) reported 250 Gy of gamma rays dose at which seed fertility was halved in rice. Matsuo and Onozawa (1961) stated that decrease in fertility of rice after irradiation is considered to be due to chromosomal aberrations. A large part of M_1 sterility is caused by physiological damage and consequently not transferred to M_2. In this study, induced floret sterility increased with increasing doses of gamma radiation. These results are in agreement with those of Siddiq and Swaminathan (1968), in which it was reported that gamma rays treatments induced high levels of sterility in M_1 rice plants. The induction of > 76% sterility with the 200 Gy gamma treatment compared to the maximum of 20.2% sterility in the untreated control indicated the high mutagenic potency of gamma irradiation in oat.

Morphological and chlorophyll mutations in M_1 generation: Some seedling showed morphological and chlorophyll mutations in all three varieties at different doses in M_1 generation. The chlorophyll mutations (yellow viridis and chlorina) were found in Kent (250 Gy) and JO-1 (450 Gy). Most of chlorophyll mutations died prematurely. Similar results were also reported in black gram by Bhosale and Hallale (2011). Only one variety JO 03-91 has three morphological mutations [laxatum (lax) and erctoides (ert)] were found at different doses i.e. 250Gy, 350 Gy and 450 Gy in M_1 generation respectively.

Conclusion

From this investigation we concluded that gamma irradiation has a negative effect on biological traits of oat. In contrast, gamma rays had some stimulatory effects on shoot length in comparison to root length in all three varieties. The variety JO-03-91 and JO-1 have to be found more sensitive to gamma radiation. The results indicated that low and intermediate radiation doses have small biological effects on oat.

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