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Effect of gamma irradiation on germination characters of amaranth seeds

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ABSTRACT

Amaranth seeds of lines D-136, K-432 and K-433 were subjected to different gamma irradiation doses (i.e. 0, 100, 150, 200 and 250 Gy) and germination characters of these lines were studied at Shahid Chamran University of Ahvaz, Iran. The experiment was designed as a split plot design with three replications. Amaranth lines and gamma-rays were allocated to main plots and sub-plots, respectively. The results revealed that seed germination percentages and seedling shoot and root length decreased with increasing dose of gamma-ray. The 250 Gy gamma-ray dose in particular had a pronounced effect on these germination parameters than others, probably because of injury it might have caused to the seed or seedling of the amaranth. Although, gamma-ray increased the germination index of amaranth seeds but the subsequent length of shoot and root of seedling were markedly decreased. There was a decrease in shoot and root length of amaranth seedling by increase gamma-ray doses. These results indicated that germination traits of amaranth lines seeds were sensitive to increase in gamma-ray, even though, its exposure to the lower doses of gamma-rays.

Keywords: Amaranth, Gamma irradiation, Seed germination, Shoot length, Root length.

INTRODUCTION

The study of the effects of Gamma Radiation (GR) on plants is a broad and complex field. Work is being done in many areas on a large number of plant species. GR has been found to affect the size and weight of plant. In many radiobiological reactions, the effect of a given dose depends on the intensity of radiation or the manner in which the total dose in fractioned (i.e. the time intensity factor) [1]. It was generally agreed that low doses of gamma rays stimulate call division and growth development in various organisms including plants and animals. This phenomenon, named "hormesis" [2]. Several workers have studied effect of gamma rays on seed germination of gymnosperms and noted that the higher exposures were usually inhibitory, whereas lower exposures were sometimes stimulatory [3]. Indeed, the morphological, structural and the functional changes depend on the strength and duration of the gamma- irradiation stress [4]. Therefore, it's pointed out that the results from one species or varieties should not be applied to others as different types of responses are to be expected in different plants or even at different stages of development in the same plant. Similarly founded that although, exposure to gamma- radiation retards seed germination but, its effect differs in varieties as well as species, and it more pronounced at higher temperatures and higher seed moisture contents [5].

Selim and El-Banna [6] concluded that irradiation with low doses of 5 to 50 Gy were the safety doses that can be used as a perfect tool for pea seed preservation and stimulating seed germination, growth and metabolic processes as well as increasing seed yield and the nutritional value of seeds. On the other side, doses of 100, 150 and 200 Gy were inhibitory doses; doses of 250 up to 400 Gy were lethal. Also, other study have shown that relatively low-doses GR on plants and photosynthetic microorganisms are manifested as accelerated cell proliferation, germination rate, cell growth, enzyme activity, stress resistance and crop yields [7]. In contrary, germination losses up to 38.1 % have been observed in wheat and sorghum at 200 to 400 Gy and in corn at 400 to 800 Gy. Gamma radiations up to 800 Gy caused retardation of shoot and root growth up to one-half to two- thirds that of the untreated seeds [8]. Results of gamma radiation studies on rice seeds shown that, the speed of germination was actually increased by exposure to GR below 100 Gy. But, stronger exposure depressed germination [9].

Amaranth (*Amaranthus* spp.) as a new crop is an ancient pseudo-cereal originating in the Americas and can be used as a high-protein grain and forage crop or a leafy vegetable. To date there is no major report stating the use of gamma irradiation on Amaranth seed. Thus, the aim of this study is investigate the effects of different doses of gamma radiation on seed germination parameters of amaranth cultivars.

MATERIALS AND METHODS

The experiment was conducted in 2008 at the seed laboratory of Agricultural faculty of Shahid Chamran University, Ahvaz, Iran. Three Seeds amaranth (*Amaranthus cruentus* L.) lines included, D-136, K-432 and K-433 which kindly obtained from Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, U.S.A. were exposure to gamma radiation. Seeds were subjected to four doses of gamma-rays (i.e. 100, 150, 200 and 250 Gy) and with non- irradiation (i.e. 0 Gy) as a control. Irradiation was carried out by a ^{60} cobalt gamma source at Radiology Medical Center, Gendi-Shahpoor Medical University, Ahvaz, Iran. The experiment was laid out in split-plot design, with three replications. Amaranth lines were allocated to main plots and gamma radiation on sub-plot. Irradiated seeds (50 seeds per 9 cm diameter Petri dishes) were put on distilled water (using moist filter papers) and placed in an incubator for 7 days at 25 ^{0}C with the same condition. Emergence of radical was taken as index of seed germination. Germination parameters were recorded for both control (non-irradiated) and irradiated seeds.

The parameters taken into consideration were germination index (GI) percentage of seed germination (SG %), root and shoot lengths (mm), for all amaranth lines after 7 days from germination. Germination index was measured by following equation.

$$Gi = \frac{(7*n1)+(6*n2)+(5*n3)+(4*n4)+(3*n5)+(2*n6)+(1*n7)}{7*N}$$

Numbers: days after germination test, n1…n7: Numbers of seeds germinate on day N, N: total seed germination.

Data were subjected to arc sin transformation for variance uniformity and analyzed by MSTAT-C software and means were compared by Duncan's multiple range test.

RESULTS AND DISCUSSION

Germination index

Varieties, radiation doses and interaction between V×R affected germination index significantly (Table 1). Variation at one percent level of probability was observed due to varieties. Germination index of variety K-432 was 0.615 followed by D-136, while variety of K-433 had 0.652 germination index (Table 2).

Table 1 Analysis of variance regarding differential sensitivities of three amaranth cultivars seeds to gamma radiation

Source of variation	D.F.	Germination index	Final germination percentage	Shoot length	Root length
Blocks	3	24.86 NS	0.069 NS	30.46 NS	134649.63 NS
Varieties	2	255.95 **	54.60**	81.42 NS	1112531.75*
Error I	6	6.46	0.242	17.4	210411.62
Radiation	4	8.69*	0.377**	313.27**	215864.77*
V× R	8	0.68 *	0.139*	30.42 NS	18238.98 NS
Error II	36	2.26	0.059	26.71	80194.67

*NS: Non significantly, *: Significantly at 5 percent level of probability and **: Significantly at 1 percent level of probability.*

Table 2 Effect of gamma radiation on germination index of amaranth seeds

Radiation dose (Gy)	Variety "D-136"	"K-432"	"K-433"	Mean
0	0.630	0.608	0.645	0.627 b
100	0.631	0.610	0.648	0.630 ab
150	0.633	0.611	0.650	0.632 ab
200	0.635	0.614	0.653	0.634 ab
250	0.637	0.624	0.655	0.639 a
Collective mean	0.633 b	0.613 c	0.650 a	0.632
Irradiation mean	0.634	0.615	0.652	0.633

Values followed by same letters do not differ significantly at 1 percent level of probability Using Duncan's New Multiple Rang Test.

As for radiation treatment, seeds with 250 Gy dose had a faster germination index than seeds with zero Gy gamma radiation. Germination index remained the same from 0-15 irradiation treatments but further increase in radiation dose accelerated germination index. Some researcher founded that gamma-irradiation causes more rapid germination of seeds. This is probably due to the fact that short-waves photons (i.e. gamma-rays) are more energetic than visible light photons (> 400 nm) and, hence, have a stronger effect on the surface of plant cells. This causes the ultimate breakdown of seed coating allowing germination to accrue. But continual exposure to short-waves radiation will reduce the vegetative growth, primarily, duo to slower leaf elongation rate, which led to shorter fully expanding leaves [10].

Final germination percentage

Statistical analysis of final germination percentage (Table 3) revealed that differences among varieties and radiation doses were significant at one percent level of probability. However, V×R interaction was significant at five percent only (Table 1). Much variation in germination percent was noted duo to varieties. Variety, K-433 produced higher germination percent (Figure 1) than the rest but K-432 ranked second while the lowest germination percent were obtained by D-136.

Table 3 Final germination percentage of amaranth seeds as affected by gamma radiation

Radiation dose (Gy)	Variety "D-136"	"K-432"	"K-433"	Mean
0	42	51	70.3	54.4 a
100	41.6	51.3	66	53.2 abc
150	40.9	51.1	64.7	52.3 bc
200	40.4	50.4	63.6	51.5 bc
250	40.2	49.8	63.1	51.1bc
Collective mean	41.02 a	50.74 b	62.24 c	52.46
Irradiation mean	40.8	50.66	64.41	51.93

Values followed by same letters do not differ significantly at 1 percent level of probability Using Duncan's New Multiple Rang Test.

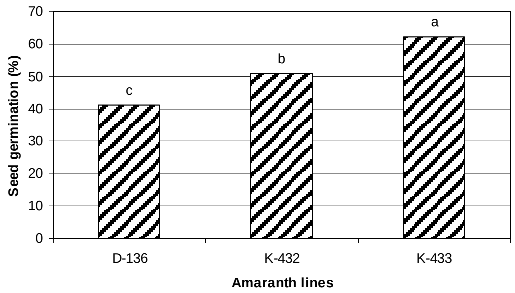

Figure 1. Germination percentage of amaranth varieties as affected by gamma radiation

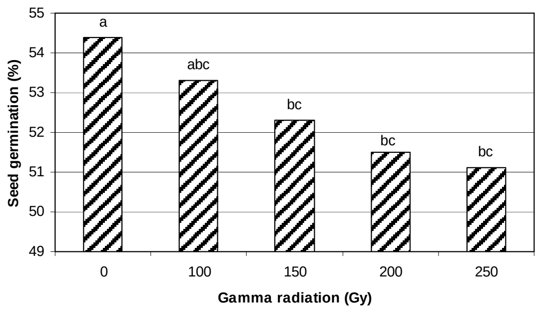

Figure 2. Germination percentage of amaranth as affected by various does of gamma rays

By comparing collective and irradiation means of all test varieties it may be concluded that the depression in germination percent in case of treated seeds is duo to radiation (Table 3). This factor is further confirmed when the irradiation mean of treatment were compared through the varieties were compared with that of untreated mean through the varieties. Gamma radiation significantly reduced the germination percent. Highest germination percent were recorded from zero and lowest from the maximum dose (Figure 2). However, control and 100 Gy of gamma radiation produced the same FGP statistically, but increase in radiation dose beyond 100 Gy reduced germination percent. Similarly, Hameed et al [11] shown that chickpea cultivars respond differentially to gamma irradiation and pointed out that inherent differences in crop varieties may be the basis for their differential germination response to gamma irradiation. For instance, substantial loss in protein content and peroxidase activity enhancement were accrued with increase in gamma radiation from 500 to 800 Gy in one chickpea cultivar, but were not seen in other cultivar. These results were also reported by Ciftici et al [12] and Zaka et al [2].

Shoot length

Radiation dose significantly affected the shoot length (Table 1). Varieties also showed differences in shoot length but these were statistically non-significant. Varieties K-432 and K-433 had the same shoot length (i.e. 36 mm) while D-136 produced shorter (i.e. 33 mm). Highest shoot length was recorded from non-irradiated seeds followed by seeds from 100 Gy of gamma-rays, but with increase in radiation the seedling shoot length decreased and reached its lowest length at the highest dose of 250 Gy (Table 4). Similarly, reported that shoot length was decreased in both Desi and Kabuli chickpea after all doses of gamma irradiation of seed [11]. They noted that shoot length of seedling was decreased gradually with increasing dose.

Table 4 Effect of gamma radiation on shoot length (mm) of amaranth seedling

Radiation dose (Gy)	Variety			Mean
	"D-136"	"K-432"	"K-433"	
0	37.6	45.95	40.94	41.52 a
100	33.42	35.92	37.6	35.67 b
150	33.42	34.25	36.76	34.84 bc
200	31.75	32.58	36.76	33.67 bc
250	30.08	31.24	24.4	30.08 c
Collective mean	32.5 a	36.09 a	36.76 a	35.17
Irradiation mean	32.16	33.58	35.67	33.58

Values followed by same letters do not differ significantly at 1 percent level of probability Using Duncan's New Multiple Rang Test.

Maximum decrease in shoot length was accorded in both chickpea cultivars after irradiation dose of 800 Gy. Also, Kon et al [1] reported that germination percentage, root and shoot length and root and shoot dry weight of long Bean seedling decreased with increasing dose of gamma ray. The 800 Gy gamma ray dose in particular had a pronounced effect on these morphological characteristics probably because of injury it might have caused to the seeds. As a result, poor growth and development was noticed.

Root length

Both radiation doses and varieties affected root length significantly (Table 5). However, interaction between V × R was not significant (Table 1). Variation in seedling root length was recorded for varieties. Variety, K-433 was on the top in respect of root length which was 39.5 mm followed by D-136 and K-432 35.6 and 32.2 mm, respectively. Root length decreased significantly with increase in radiation doses in all the varieties. An inverse relationship between root length and radiation doses was observed. Higher root length was recorded from non-irradiated seeds. With increasing radiation dose, root length decreased and it was lowest when seeds were treated with 250 Gy of gamma rays. This decrease in root length may be due to the radiation damage was the same as decrease in shooting length. Similarly, Jacks and Thapa [3] reported that in two pinus species, at early stage of growth, root and hypocotyls elongation were inhibition by gamma-rays exposures. This inhibition increased as the dose of exposure increased. In fact, in one species more than 50% root elongation inhibition was induced by 100 Gy exposures of gamma-rays but this exposure was not lethal. However, in another species 100 Gy exposures proved to be lethal exposure for root elongation. Also, reported that root length decreased after all doses of irradiation as compared to non-irradiated control in all chickpea cultivars. But the gamma dose which induced maximum decrease in root length was differed between cultivars [11-3].

Table 5 Effect of gamma radiation on root length (mm) of amaranth seedling

Radiation dose (Gy)	Variety			Mean
	"D-136"	"K-432"	"K-433"	
0	39.2	39.73	46.11	41.68 a
100	36.18	34.05	39.37	38.31 ab
150	35.82	30.68	38.84	35.12 bc
200	34.76	29.62	38.84	34.41 bc
250	32.1	27.31	34.41	31.21 c
Collective mean	35.65 ab	32.28 b	39.55 a	36.18
Irradiation mean	34.76	30.33	37.6	34.76

Values followed by same letters do not differ significantly at 1 percent level of probability Using Duncan's New Multiple Rang Test.

CONCLUSION

Generally, retardation of seedling growth parameters is one of the most common responses of plant subjected to ionizing radiation. Therefore, variations in radio sensitivity of plants at interfamily, interspecific and intraspecific levels are reported [7]. The results agree with Hameed et al [11] and Zaka et al [2] who reported that gamma radiation decrease the root length. According to these results, its reveal that the germination index was significantly increased in the three amaranth liens with increase the gamma doses, while the germination percentage was significantly decreased with increased gamma doses. In all gamma-rays, the highest and lowest germination percent were belonged to K-433 and D-136 lines, respectively. In addition, in all lines, gamma-rays decreased the shoot and root length of amaranth seedling. In all gamma-rays, variety of K-433 had the highest germination percentage value while variety of D-136 had the lowest. Also, different in germination index mainly attributed to genetically differences of amaranth seed lines. Base on collective data of this study it seem that both inherent differences in amaranth varieties and gamma doses more influencing on amaranth seed germination parameters. Therefore, it seems that amaranth seeds were sensitive to increasing in gamma-rays even though to the lower doses of gamma irradiation. Furthermore, degradation of ozone layer, which causes increased ionize irradiation (e.g. gamma-ray) seem to be damaging for amaranth seed germination and seedling establishment.

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