Effect of γ Irradiation on Germination of Rice (*Oryza Sativa* L.)

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Abstract

The present investigation aimed at estimating the influence of γ rays, confirmed suppressive effect on germination and seedling parameters of rice compared to non-irradiated seed. Seeds of paddy (BPT 5204) were exposed to different doses of γ rays ranging from 0.40 KGy to 2.00 KGy using Co^{60} γ radiation (GC 5000) facility at Quality Control Laboratory, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad during 2010-11. The experimental results revealed that the percentage of germination decreased after irradiation and the effect became stronger with increase of γ dose. Parameters such as germination percentage, speed of germination, mean daily germination, peak value and germination value have significantly decreased with increased irradiation doses. Similarly, seedling parameters, viz. shoot length, root length and vigor index and root and shoot length ratio expressed higher reduction at higher doses as compared to untreated control. The study clearly indicated the deleterious effects of γ irradiation increased at regular intervals, with attainment of LD_{50} at a dose of 1.20 KGy.

1. Introduction

Rice is a major staple food crop of India ensuring food security to millions of people. The realized yield potential in rice is mainly achieved through genetically stable high yielding varieties. Continuous mono-cropping of rice predominated by few varieties led to narrow genetic base making the rice ecosystem highly vulnerable to external factors like radiation stress. Climate change driven radiation stress on rice not only would result in irreversible genetic changes but also interfere with establishing optimum field population by drastically reducing the germination capability of seed. The study on the effects of radiation in plants is a broad and complex field. Work is being done in many areas on a large number of plant species. Radiation has been found to affect the size and weight of plants. In many radiobiological reactions, the effect of a given dose depends on the intensity of radiation or the manner in which the total dose is fractioned. γ rays are known to influence plant growth and development by inducing cytological, genetical, biochemical and physiological changes in cells and tissues (Gunckel and Sparrow, 1961). γ radiation can be useful for the alteration of physiological characters (Kiong et al., 2008). The biological effect of γ ray is based on the interaction with atoms or molecules in the cell, particularly water, to produce free radicals (Kovacs and Keresztes, 2002). These radicals can damage or modify important components of plant cells and have been reported to affect differentially the morphology, anatomy, biochemistry and physiology of plants depending on the radiation dose (Ashraf et al., 2003). In view of the potential hazards of natural and artificial γ radiations, it becomes essential to understand the extent of damage caused to the rice system. Since rice is the most important staple food crop, the ill effects of radiation at germination level need to be thoroughly investigated. The radiation induced growth abnormalities in seedlings were mainly due to cell death and suppression of mitosis at different exposures. In the light of above facts, present study was carried out to evaluate the effect of γ rays on seed germination and various seedling parameters of *O. sativa*.

2. Materials and Methods

Rice variety Samba Mahsuri (BPT 5204), an *indica* cultivar was selected for irradiation. Sixty seeds were taken in 0.1 mm thick polythene bags of 15 x 22 cm^2 dimension and sealed. The bags were exposed to γ irradiation with doses of 0.40, 0.60, 0.80, 1.00, 1.20, 1.40, 1.60, 1.80 and 2.00 KGy at a specific activity of 3.01 KGy h^{-1}. Samples were irradiated in continuous γ sterilization plant (GC 5000, designed by Board of Radiation and Isotope Technology, Mumbai) with 444 TBq (12000Ci) and Cobalt-60 (Co^{60}) source at Quality Control Laboratory, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad, and were compared with the observations made on non-irradiated control. The material for irradiation was placed in an irradiation chamber located in vertical drawer inside the lead flask. Radiation field was provided by a set of stationary Co^{60} source placed in a cylindrical cage. The source was doubly encapsulated in corrosion resistant stainless steel pencils and was tested in accordance with international standards. Two access holes of 8 mm diameter were provided of service sleeves for gasses, thermocouple, etc. Mechanism for rotating/stirring samples during irradiation is also incorporated. The lead shield provided around the source was adequate to keep the external radiation field well within permissible limits. The quantity of absorbed dose (KGy) can be defined as the amount of energy absorbed $unit^{-1}$ mass of the matter at the point of interest. The irradiated seed along with non-irradiated control were sown in petridishes in the laboratory. The experiment was carried out as per Completely Randomized Design (CRD). Data on germination and growth parameters were recorded seven days after sowing under ambient condition. Germination percentage was calculated using the formula as per ISTA (1985). Speed of germination of the given sample was calculated according to the formula given by Maguire (1962). Similarly, other germination parameters, viz. mean daily germination, peak value (Edwards, 1934) and germination value (Czabator, 1962) were calculated. Seedling parameters like shoot and root length were measured using ten seedlings collected at random from each sample on 7th day from the seeds subjected to germination test. The shoot and root length were measured in centimeters (cm) using a scale and root/shoot length ratio was calculated using the estimates of seedling length. Vigor index was calculated using the formula given by Abdul Baki and Anderson (1972).

3. Results and Discussion

The results on germination percentage are furnished in Table 1. Significant differences were observed for germination among the doses. There was a decrease in germination in all doses with highest at irradiation dose 2 KGy (25%). The control (0.00 KGy) recorded maximum germination percentage (96) followed by radiation dose 0.40 KGy (83%). LD_{50} dose for germination was attained at 1.20 KGy (Table 1).

Speed of germination provides good reflection of seed vigor which would facilitate in categorizing the strong and weak seedlings. Differences among treatments in respect of speed of germination and mean daily germination were highly significant. However, control (0.00 KGy) recorded high speed of germination (41.80) followed by γ irradiation dose 0.40 KGy (31.60) and finally low speed of germination was recorded by γ irradiation dose 2.00 KGy (3.61), with LD_{50} dose recording a moderate value of 15.68 (Table 1)

Further, the effect of γ irradiation on mean daily germination was significant in all γ irradiation doses. The maximum mean daily germination was recorded by control (13.71) whereas, radiation dose 2.00 KGy recorded lowest mean daily germination (3.61) (Table 1).

Krishnaswamy and Seshu (1989) opined that the rate of germination was positively correlated with oxygen uptake, dehydrogenase activity by providing energy to the germinating embryo and interfering with membrane integrity and overall capacity of the metabolic machinery of the young germinating primordia. The figures presented in Table 2, indicate the percent reduction in these parameters in comparison to non-irradiated control and revealed increasing trend with increase in γ dose. The perusal of data also showed that at LD_{50} dose germination, speed of germination and mean daily germination were reduced by 47.91, 62.48 and 47.92%, respectively in comparison to control after 5 incremental doses. This magnitude of reduction was higher compared to the percentage of reduction in later doses, i.e. 1.40-2.00 KGy which recorded 73.95, 91.36 and 73.96%, respectively (Table 2).

These results are in agreement with earlier studies carried out by Hameed et al., (2008), Toker et al., (2005), who reported that percent of germination of chick pea was inversely proportional to irradiation dose. The significant effect of γ doses on germination even at low doses could be attributed to generation

Table 1: Effect of various doses of γ radiation on germination parameters of rice

Radiation dose (KGy)	Germination (%)	Speed of germination	Mean daily germination	Peak value	Germination value
0.00	96	41.80	13.71	32.00	438.86
0.40	83	31.60	11.86	16.60	196.83
0.60	80	26.42	11.43	11.42	130.61
0.80	72	22.45	10.29	10.28	105.80
1.00	60	21.01	8.57	8.57	73.47
1.20	50	15.68	7.14	7.14	51.02
1.40	46	14.06	6.57	6.57	43.18
1.60	37	13.08	5.29	5.28	27.94
1.80	33	10.12	4.71	4.71	22.22
2.00	25	3.61	3.57	3.57	12.76
GM	58.20	19.98	8.31	10.61	110.27
SED	2.20	0.09	0.03	0.02	0.02
CD*	4.60	0.19	0.06	0.04	0.04
CD**	6.27	0.26	0.09	0.06	0.06
CV%	4.64	0.58	0.48	0.27	0.030
S/NS	S	S	S	S	S

S=Significant; NS=Non-significant; GM: Grand mean; *: p=0.05; **= 0.01

of free radicals in plant system resulting in various metabolic disorders in the germinating seeds leading to inhibition of germination. Further, it was also found to affect enzyme activity since higher seed vigor is related to higher germination capacity. The inhibitory influence of γ irradiation was also reported to be associated with increased membrane permeability with seed vigor loss. Hence, increased radiation doses enhanced the membrane permeability resulting in higher loss of leachates and reduced germination percentage. This study also indicated that the germination test could be successfully applied an indirect measure of radiation sensitivity in rice crop with clear demarcation between lethal, sub-lethal and super-lethal doses of γ ray exposure. The critical response of variety samba mahsuri in terms of germination after irradiation at various doses of γ rays also revealed interesting results when plotted against time. The study of germination parameters like peak value and germination value indicated significant influence of higher doses on the progress of germination in the context of time. The data indicated that the non-irradiated control attained peak value within 3 days of sowing. However, as the dose increased from 0.60 to 2.00 KGy, the respective treatments took 7 days to attain peak values which were far more less (3.57 at 2.00 KGy) compared to the control (32.00) (Table1).

The gradual reduction in mean daily germination 11.86 at 0.40 KGy to 3.57 at 2.00 KGy (Figure 3) (Table 1) resulted in drastic reduction in corresponding germination value of 196.83 at 0.40 KGy to 12.76 at 2.00 KGy (Table 1).

The parameters namely peak value and germination value recorded percent reduction of 85.12 and 96.12, respectively at 2.00 KGy (Table 2) in comparison with control which recorded highest germination value 438.86 (Table 1) in view of realization of highest mean daily germination (13.71) and peak value (32.00) (Table 1). The result also clearly indicated increase in irradiation dose had not only resulted in drastic reduction in germination percentage but also prolonged the period for completion of germination process which has finally resulted in lower germination values that are important from field point of view. Similar results were reported by Akhaury and Singh (1993) and Thapa (1999) that higher exposure of γ rays may cause injury in seeds and usually show inhibitory effects on seeds of angiosperms and gymnosperms. Ajayi and Larsson (1991) reported similar observations on effects of nuclear radiation on seed germination and seedling growth in wheat, barley, etc. Abdul Majeed et al. (2010), in their study with *Lepidium sativum* indicated adverse and inhibitory effect of γ rays on root and shoot length. It was concluded that seeds exposed to higher doses produced dwarf plants with reduced root length. Further, Shakoor et al., (1978a&b), Khalil et al., (1986) attributed decreased shoot and root length at higher doses of γ rays to reduced mitotic activity in meristamatic tissues and reduced moisture content in seeds, respectively. In the present investigation also marked reduction in root and shoot length from 3.85 to 1 cm and 4.88 to 2.03 cm, respectively were noticed, while the non-irradiated control recorded a root length of 4.05 cm and shoot length of 5.08 cm (Table 3).

The gradual reduction in root and shoot length with increase in γ dose also resulted in corresponding decrease in vigor index from 724.59 at 0.40 KGy to 75.75 at 2.00 KGy. However, control recorded highest vigor index of 876.48 (Table 3).

Marginal reduction in seedling parameters including root and

Table 2: Percentage of reduction at various γ radiation doses for germination parameters

Radiation dose (KGy)	Germination	Speed of germination	Mean daily germination	Peak value	Germination value
0.40	13.54	24.40	13.56	30.83	40.21
0.60	16.66	36.79	17.65	52.41	60.36
0.80	25.00	46.29	25.01	57.16	67.88
1.00	37.50	49.73	37.49	64.29	77.68
1.20	47.91	62.48	47.92	70.25	84.50
1.40	52.08	66.36	52.07	72.62	86.88
1.60	61.45	68.70	61.48	78.00	91.52
1.80	65.62	75.78	65.64	80.37	93.25
2.00	73.95	91.36	73.96	85.12	96.12

Table 3: Effect of various doses of γ radiation on seedling parameters of rice

Radiation dose (KGy)	Root length (cm)	Shoot length (cm)	Vigor index	Root/shoot length ratio
0.00	4.05	5.08	876.48	0.80
0.40	3.85	4.88	724.59	0.79
0.60	3.59	4.62	656.80	0.78
0.80	3.36	4.39	558.00	0.77
1.00	2.50	3.53	361.80	0.71
1.20	2.02	3.06	254.00	0.66
1.40	2.00	3.03	231.38	0.66
1.60	1.85	2.88	175.01	0.64
1.80	1.72	2.75	147.51	0.63
2.00	1.00	2.03	75.75	0.49
Grand mean	2.59	3.63	406.13	0.69
SED	0.03	0.01	19.03	0.02
CD*	0.07	0.04	39.70	0.06
CD**	0.07	0.05	54.15	0.08
CV%	1.59	0.66	5.71	5.18
S/NS	S	S	S	S

S=Significant; NS=Non-significant; GM: Grand mean; *: p=0.05; **= 0.01

shoot length ratio was observed at radiation dose of 0.60KGy which had even recorded an acceptable germination of 80%, beyond which the γ rays were found to be detrimental to seed germination capacity and seedling growth attributes.

Decrease in shoot and root length of a number of crops has already been reported by Thimmaiah et al*.,* (1998), Muhammad and Afasari (2001), Al-Salhi et al*.,* (2004), Toker et al*.,* (2005), Kon et al*.,* (2007) which supports the findings of present investigations.

4. Conclusion

The research carried out during the course of this investigation clearly revealed the sensitivity of rice crop to γ radiation stress beyond 0.60 KGy which can be accepted as a threshold level for radiation stress. Further, the study also determined 1.20 KGy as the LD_{50} value for rice where in 50% reduction was observed in respect of all the germination and seedling parameters like root length and shoot length.

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