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GAMMA-RAY INDUCED MUTATIONS FOR ISOLATING ECONOMIC MUTANTS IN RICE (*ORYZA SATIVA*. L) CULTIVARS ADT 39 AND CR 1009

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ABSTRACT
The two rice varieties viz., ADT 39 and CR 1009 were exposed to gamma rays at 50, 100, 150, 200, 250 and 300Gy for isolation of mutants possessing desirable economic value. In M_2 generation, chlorophyll mutants were observed in both the varieties. The spectrum of chlorophyll mutation consists of *albino, xantha, viridis*. Among the chlorophyll mutants obtained, albino mutants occurred more frequently followed by *xantha* mutants in both the varieties. Prominent viable mutants were recorded in both the varieties. The frequency of the chlorophyll and the viable mutation recorded to have dose dependent relationships. However the mutagenic effectiveness and efficiency reduced with the increase in dose. The economic mutants isolated in the present investigation included the mutants with dwarf plant type, early duration, long slender and fine grain mutants, with higher single plant yield and thus indicating the scope for improving the qualitative and quantitative traits by appropriate breeding approaches.

KEY WORDS: Mutation, Chlorophyll mutant, Viable mutant, Mutagenic effectiveness and efficiency.

INTRODUCTION
Mutation is regarded as an important tool for creating genetic variability and developing improved cultivars. One of the most important breakthroughs in the history of genetics was the discovery that mutations can be artificially induced in organisms. The application of mutagenic agents, i.e. gamma rays and other physical and chemical mutagens has generated a vast amount of genetic variability and has played a significant role in genetic improvement of cultivars. Mutation techniques have been used almost exclusively for plant breeding from 1960's. The outcome was indeed remarkable. About 2000 new varieties were developed in almost all continents except Africa, where progress was limited (Ahloowalia et al., 2004). Systematic development, characterization and collection of chemically or physically induced mutants came rather recently, when researchers started realizing the potential of such mutants in functional genomic studies (Li et al., 2001). Mutation techniques sometimes were the only way for improving overall performance while keeping the required traits unchanged, e.g., traditional varieties like Basmati in India and Pakistan (Patnaik et al., 2006).

Many mutant cultivars became the national leading variety, e.g. the rice variety Yuanfengzao in the 1970's and early 1980's, and Zhefu 802 in the late 1980's and early 1990's in China for the early season rice production (Ahloowalia et al., 2004). Several mutated genes have been integrated into most modern varieties, e.g. the two independent sd1 mutant alleles first induced in Reimei in Japan and in Calrose 76 in the US are now fully integrated into new rice varieties in these two countries (Yamaguchi, 2001).

MATERIALS & METHODS
The experiments were conducted at the Department of Rice, Centre for Plant Breeding and Genetics, Coimbatore. The seeds of rice (*Oryza sativa*) varieties viz., CR 1009 and ADT 39, which were obtained from Department of Rice, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore formed the base material of studyand their details were given in table 1. Seeds of the selected varieties were exposed to gamma irradiation (Co60 was used as source). The doses of gamma rays 50Gy, 100Gy, 150Gy, 200Gy, 250Gy and 300Gy were fixed for the treatment of rice varieties based on preliminary experiments. Well filled, uniform sized, hand picked dry seeds with 12 per cent moisture content were used. A total of 200 seeds packed in polythene bags were exposed to irradiation for each treatment. M_1 generation was raised at the Department of Rice, Coimbatore. Based on the number of seeds germinated seedlings survival on 30th day and height reduction at 30th day, the LD50 values were fixed for all the genotypes through probit analysis. The M_2 generations were raised at Department of Rice with the number families as given in table 2.

TABLE 1. Characteristics of CR1009 and ADT 39

Variety	Parentage	Duration	Grain type	Percent adoption in Tamil nadu
CR 1009	Pankaj x Jagannath	160 days	Short bold	3-5
ADT 39	IR8 x IR20	130 days	Medium slender	20-25

TABLE 2. Total number of M_2 families raised in each dose

Variety	50Gy	100Gy	150Gy	200Gy	250Gy	300Gy	Total
ADT 39	66	21	53	63	31	23	257
CR1009	80	37	30	47	21	10	225

Viable mutations and chlorophyll mutations were scored periodically in different treatments from the seedling stage to maturity in M_2 generation. The frequency of mutation was calculated in terms of percentage. The effectiveness and efficiency of the mutagens in inducing mutations were estimated by adopting the formula suggested by Konzak et al. (1965). Both the estimates were expressed as percentage. The mean and variance of M_2 families were estimated for the six doses of gamma rays for the traits viz. plant height, 100 grain weight, days to maturity and yield per plant. The mean of the families was compared with the mean of the standard check varieties ADT 39 and CR 1009. The total variability observed for each of the treatment was taken as a measure of phenotypic variance (Vp) whereas the variability existing in the parents was considered as environmental variance (Ve). Genotypic variance was calculated by subtracting the environmental variance from phenotypic variance. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated by using the formulae as suggested by Burton (1952). Heritability estimate (h2) in broad sense and expected Genetic Advance (GA) at 5 per cent selection intensity were estimated through the methods devised by Lush (1949) and Johnson and Comstock (1955) and illustrated by Allard (1960).

RESULTS

Spectrum of chlorophyll mutations in M_2 generation

The frequency of chlorophyll mutations were assessed in 8318 seedlings of ADT 39 and 9606 seedlings of CR 1009 and the data are presented in table 3.

TABLE 3. Spectrum of chlorophyll mutations in M_2 generation for ADT 39 and CR 1009

Varieties	Treatment	Total no of plants observed	No of chlorophyll mutants scored	Chlorophyll mutants (%)	Spectrum of chlorophyll mutants		
					Albino %	*Xantha* %	*Viridis* %
ADT 39	Control	203	0	0.00	0.00	0.00	0.00
	50Gy	2336	10	0.43	80.00	20.00	0.00
	100Gy	1049	6	0.57	66.67	33.33	0.00
	150Gy	2158	13	0.60	84.62	7.69	7.69
	200Gy	1763	14	0. 79	50.00	50.00	0.00
	250Gy	760	NO	-	-	-	-
	300Gy	252	NO	-	-	-	-
CR 1009	Control	135	0	0.00	0.00	0.00	0.00
	50Gy	3777	10	0.26	60.00	20.00	20.00
	100Gy	1448	7	0.48	57.15	28.57	14.28
	150Gy	1897	12	0.63	83.33	16.67	0.00
	200Gy	1920	NO	-	-	-	-
	250Gy	395	NO	-	-	-	-
	300Gy	169	NO	-	-	-	-

NO-Not Observed

Albino *Xantha* *Virdis*

FIGURE 1. Chlorophyll mutant observed in M_2 generation

Three chlorophyll mutants namely *albino*, *xantha* and *viridis* were observed (Fig.1). Among the three mutants, frequency of albinos was more in both the varieties. The frequency of chlorophyll mutations in ADT 39 ranged from 0.43 to 0.79 per cent and in CR 1009 it ranged from 0.26 to 0.63 per cent. The highest frequency of 0.79 per cent chlorophyll mutation in ADT 39 was recorded in 200Gy whereas in CR 1009, it was in 150Gy with 0.63 per cent dose. Among the different types of chlorophyll mutations, albino occurred in greater proportion followed by *xantha*. The highest frequencies of albino mutants were observed at 150 Gy dose in both ADT 39 and CR 1009, their value being 84.62 per cent and 83.33 per cent respectively. In the case of *xantha* mutants, the highest frequency were noticed in the 200Gy with 50.00 per cent in ADT 39 and in CR 1009, it occurred in 100Gy (28.57 %). The *viridis* mutants occurred only in 150Gy of ADT 39 while in CR 1009, it was recorded in both 50 and 100Gy doses. The treatments 250Gy and 300Gy in both the varieties were devoid of chlorophyll mutants. In CR 1009, besides these doses, the treatment 200Gy also does not generate any chlorophyll mutants.

Spectrum of Viable mutations in M_2 generation

The frequency and types of viable mutation were recorded up to maturity in 32,340 plants for both the varieties. Aberrants possessing altered plant height, duration, grain type, plant type and presence of awns in grains were recorded (Figs. 2, 3, 4 & 5). The frequency and also spectrum of viable mutations observed for ADT 39 and CR 1009 are presented in table 4 and 5. In the variety ADT 39, the frequency of viable mutants was the highest at 150Gy (3.71 %) while for CR 1009, it was at 100 Gy (3.69 %).


Dwarf mutant in CR 1009 (100 Gy, F-5)


Tall mutant in ADT 39 (150 Gy, F-21)


Single tiller mutant in CR 1009 (100 Gy, F-12)

FIGURE 2. Plant type Mutant


FIGURE 3a. Early mutant CR 1009, 50Gy, F-12


FIGURE 3b. Late mutant in ADT 39, 50 Gy, F-21

FIGURE 4. Grain type mutant CR 1009


Awned grains (150 Gy, F-14)


Grain and beaks (200Gy, F-7)

Control Fine grain Mutant (150 Gy, F-3) Long slender grains (50 Gy, F-17)

FIGURE 5. Grain type mutants in ADT 39

Mutagenic effectiveness and efficiency Chlorophyll mutations

The mutagenic effectiveness and efficiency were calculated on the basis of lethality, injury and sterility data of M_2 generation are given in table 6. Effectiveness in both ADT 39 and CR 1009 decreased progressively with increasing dose of radiation. For the varierty ADT 39, it ranged from 0.86 to 0.40 where as for CR 1009, it ranged from 0.53 - 0.42. The mutagenic efficiency estimated in terms of sterility was found to be higher than those calculated on other two parameters.

Viable mutations

The effectiveness and efficiency of mutagens in inducing viable mutations were estimated and presented in table 7. Effectiveness of mutagens in inducing viable mutations was found to be dose dependent. With increase in dose, the values decreased in both the varieties. In respect of ADT 39, the effectiveness ranged from 0.63 (300Gy) to 2.82(50Gy). For CR 1009, effectiveness ranged from 0.39 (300Gy) to 4.74 (50Gy). The highest efficiency was recorded for sterility in both the varieties.

Variation in quantitative characters in M_2 generation

Plant height

The plants with height ranging from 61.31 to 92.34 cm were observed in all the treatments of ADT 39 (Table 8). However, dwarf plants with the mean value of 68.99 cm were observed in 300Gy treatment compared to 78.12 cm in the control. All the other treatments had more or less mean equaling control. A good estimate of heritability for this trait was observed in 50Gy treatment (88.40%) but the genetic advance as percent of mean was found to be lower in all the treatments. In CR 1009, a good estimate of heritability was observed in 100Gy dose (96.20 %) with low genetic advance as percent of mean. Plants in this variety had a height from 71.00 cm to 103.60 cm with the highest mean of 100.91cm in 300Gy.

100 grain weight

The 100 grain weight varied from 1.33 - 2.36 g (Table 9) in ADT 39 and the highest mean value was observed in 200 Gy (1.90g). Among all the treatments, the values of PV and GV were low whereas the values of PCV and GCV were found moderate in all the treatments except in 250Gy, which had low GCV value. A good estimate of heritability and genetic advance as percent of mean was recorded in 300Gy and 100Gy doses, their value being 85.16 percent and 30.30 percent respectively. In CR 1009, the dosage 50Gy showed the highest mean value of 2.17g. The variability parameters were low in all the treatments. A good estimate of heritability and genetic advance was observed in 50Gy whose values were 76.20 percent and 23.68 respectively.

Days to maturity

The values for mean and other variability parameters for the trait days to maturity for both the varieties were presented in table 10. For this trait, the values in each treatment ranged from 108 to 141 in ADT 39. The highest mean value was recorded in 50 Gy (128.56). However, the variability parameters were low in all the treatments except in 50 and 150Gy where high PV and GV values were discernible. In 150Gy treatment, the heritability was the highest and the value was 96 per cent. In CR 1009, the values for this trait ranged from 120 to 166 days, the mean values were more or less similar to that of control mean. However, late mutant plants with the mean value of 157.03 were also observed in 100Gy. For variability parameters, the lowest values were observed in 250Gy, whereas highest heritability was noticed in 50Gy (97.50 %).

Single plant yield

The data recorded on single plant yield are presented in table 11. The values for single plant yield ranged from 11.95 to 40.13 g in ADT 39 and 12.20 to 43.35 g in CR 1009. Among the irradiated population of ADT 39, the 250Gy dose showed the highest mean value of 23.70 g. This treatment 250Gy had also given the moderate values for the variability parameters viz., PV, GV, PCV and GCV, the actual values being 29.38, 27.46, 22.87 and 22.11 respectively. The highest value for heritability was recorded in 250Gy (93.47 %). However, the genetic advance was low in all the treatments. The highest mean value of single plant yield in CR 1009 was observed in 100Gy (24.97g). Among all the treatments, the highest values of PV, GV, PCV, GCV and heritability were recorded in 150Gy with the values of 49.67, 48.09, 28.53, 28.07 and 96.82 percent respectively. The genetic advance, as percent of mean was low in all the treatments.

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TABLE 4. Spectrum of viable mutants in M_2 generation for ADT 39 population

Types of mutants	Doses (Gy)											
	50		100		150		200		250		300	
	No	%	No	%	No	%	No	%	No	%	No	%
Plant type												
Dwarf	9	0.12	3	0.24	2	0.06	4	0.11	5	0.27	12	0.87
Tall	3	0.04	2	0.16	25	0.79	4	0.11	4	0.22	2	0.14
Single tiller	-	-	-	-	10	0.31	-	-	-	-	-	-
Grain type												
Long slender	12	0.16	3	0.24	5	0.16	18	0.48	2	0.11	2	0.14
Fine grain	-	-	-	-	12	0.38	-	-	-	-	-	-
Awned grain	20	0.27	2	0.16	4	0.13	8	0.21	4	0.22	-	-
Duration												
Early (108-120days)	13	0.17	5	0.40	20	0.63	12	0.32	4	0.22	5	0.36
Late (130-141 days)	29	0.39	2	0.16	12	0.38	15	0.39	13	0.70	-	-
Sterility												
Completely sterile (> 70%)	8	0.11	6	0.48	3	0.09	2	0.05	1	0.05	-	-
Partially sterile (20-70%)	10	0.14	10	0.79	25	0.79	20	0.53	8	0.43	5	0.36
Total	104	1.41	33	2.62	118	3.71	83	2.19	41	2.20	26	1.88
Total number of plants studied	7380		1260		3180		3780		1860		1380	

TABLE 5. Spectrum of viable mutants in M_2 generation CR 1009 population

Types of mutants	**Doses (Gy)**											
	50		100		150		200		250		300	
	No	%	No	%	No	%	No	%	No	%	No	%
Plant type												
Dwarf	8	0.17	12	0.54	5	0.28	1	0.04	2	0.16	-	-
Tall	5	0.10	5	0.23	6	0.33	4	0.14	3	0.24	6	1.00
Single tiller	-	-	3	0.13	-	-	5	0.18	2	0.16	-	-
Grain type												
Long slender	20	0.42	9	0.41	3	0.17	9	0.32	1	0.08	-	-
Medium slender	5	0.10	3	0.13	7	0.39	10	0.35	3	0.24	-	-
Grains with beaks	1	0.02	-	-	-	-	4	0.22	-	-	-	-
Awned grain	8	0.17	5	0.23	4	0.22	12	0.43	-	-	-	-
Duration												
Early (120-151 days)	48	1.00	21	0.94	6	0.33	5	0.18	4	0.31	-	-
Late (160-168 days)	5	0.10	17	0.77	-	-	-	-	1	0.08	1	0.17
Sterility												
Completely sterile (> 70%)	4	0.08	1	0.04	1	0.05	2	0.07	-	-	-	-
Partially sterile (20-70%)	10	0.21	6	0.27	5	0.28	4	0.14	-	-	-	-
Total	113	2.37	82	3.69	37	2.05	56	1.98	16	1.27	7	1.17
Total number of plants studied	4800		2220		1800		2820		1260		600	

TABLE 6. Mutagenic effectiveness and efficiency based on chlorophyll mutations in M_2 generation for ADT 39 and CR1009

Mutagen dose	Survival reduction % (L)	Height reduction % (I)	Seed fertility reduction % (S)	Mutation frequency (M)	Effectiveness	Efficiency		
					M x 100 / Gy	M x 100 / L	M x 100 / I	M x 100 / S
ADT 39								
50Gy	86.62	97.19	1.92	0.43	0.86	0.50	0.44	22.40
100Gy	73.94	95.77	5.07	0.57	0.57	0.77	0.60	11.24
150Gy	52.11	89.08	10.40	0.60	0.40	1.15	0.67	5.77
200Gy	36.62	87.42	22.89	0.79	0.40	2.16	0.90	3.45
250Gy	23.94	86.08	30.56	NO	-	-	-	-
300Gy	11.27	85.4	82.61	NO	-	-	-	-
CR1009								
50Gy	89.73	97.47	4.07	0.26	0.53	0.29	0.27	6.39
100Gy	80.82	93.56	4.76	0.48	0.48	0.59	0.51	10.08
150Gy	59.59	91.98	35.14	0.63	0.42	1.06	0.68	1.79
200Gy	50.00	88.7	42.31	NO	-	-	-	-
250Gy	28.77	89.01	47 .31	NO	-	-	-	-
300Gy	15.07	85.87	93.75	NO	-	-	-	-

NO-Not Observed.

TABLE 7. Mutagenic effectiveness and efficiency based on viable mutations in M_2 generation for ADT 39 and CR1009

Mutagen dose	Survival reduction % (L)	Height reduction % (I)	Seed fertility reduction % (S)	Mutation frequency (M)	Effectiveness	Efficiency		
					M x 100 / Gy	M x 100 / L	M x 100 / I	M x 100 / S
ADT 39								
50Gy	86.62	97.19	1.92	1.41	2.82	1.63	1.45	73.44
100Gy	73.94	95.77	5.07	2.62	2.62	3.54	2.74	51.68
150Gy	52.11	89.08	10.40	3.71	2.47	7.12	4.16	35.67
200Gy	36.62	87.42	22.89	2.19	1.10	5.98	2.51	9.57
250Gy	23.94	86.08	30.56	2.20	0.88	9.19	2.56	7.20
300Gy	11.27	85.40	82.61	1.88	0.63	16.68	2.20	2.28
CR1009								
50Gy	89.73	97.47	4.07	2.37	4.74	2.64	2.43	58.23
100Gy	80.82	93.56	4.76	3.69	3.69	4.57	3.94	77.52
150Gy	59.59	91.98	35.14	2.05	1.37	3.44	2.23	5.83
200Gy	50.00	88.70	42.31	1.98	0.99	3.96	2.23	4.68
250Gy	28.77	89.01	47.31	1.27	0.51	4.41	1.43	2.68
300Gy	15.07	85.87	93.75	1.17	0.39	7.76	1.36	1.25

TABLE 8. Mean and of variance for plant height in M_2 generation

Treatment	Range	Mean	PV	GV	PCV	GCV	h^2	GA%
ADT39								
Control	76.45 - 80.22	78.12	1.87	-	-	-	-	-
50Gy	74.28 - 92.34	80.02	16.04	14.18	5.01	4.71	88.40	2.66
100Gy	72.13 - 82.62	77.22	4.55	2.69	2.76	2.12	59.01	1.84
150Gy	71.38 - 82.35	78.30	5.83	3.96	3.08	2.54	67.99	2.09
200Gy	71.28 - 85.14	76.30	6.28	4.41	3.28	2.75	70.28	2.22
250Gy	75.16 - 81.22	78.21	2.85	0.98	2.16	1.27	34.55	1.06
300Gy	61.31 - 70.92	68.99	2.46	0.86	2.27	1.34	34.83	1.17
CR1009								
Control	90.20 - 94.60	92.71	1.95	-	-	-	-	-
50Gy	88.20 - 99.40	94.97	3.81	1.86	2.06	1.44	48.73	1.25
100Gy	71.00 - 98.6	89.17	50.76	48.81	7.99	7.83	96.20	2.63
150Gy	76.45 - 94.10	92.80	18.18	16.23	4.59	4.34	89.25	2.34
200Gy	89.60 - 98.80	95.02	5.43	3.48	2.45	1.96	64.04	1.64
250Gy	89.20 - 96.23	92.63	2.75	0.80	1.79	0.97	29.06	0.76
300Gy	98.23 - 103.60	100.91	3.32	1.37	1.81	1.16	41.18	0.99

TABLE 9. Mean and of variance for 100 grain weigth in M_2 generation

Treatment	Range	Mean	PV	GV	PCV	GCV	h^2	GA%
ADT39								
Control	1.64 - 1.98	1.86	0.01	-	-	-	-	-
50Gy	1.61 - 2.36	1.88	0.05	0.04	12.06	10.91	81.78	27.87
100Gy	1.33 - 2.08	1.76	0.06	0.05	13.41	12.23	83.15	30.30
150Gy	1.33 - 2.26	1.68	0.04	0.03	12.05	10.57	77.00	29.45
200Gy	1.71 - 2.34	1.90	0.06	0.05	13.20	12.17	85.00	28.70
250Gy	1.49 - 2.13	1.75	0.04	0.03	11.25	9.79	75.81	27.77
300Gy	1.42 - 2.23	1.75	0.04	0.04	12.00	11.07	85.16	28.47
CR1009								
Control	2.06 - 2.36	2.09	0.01	-	-	-	-	-
50Gy	1.63 - 2.48	2.17	0.05	0.04	10.14	8.85	76.20	23.68
100Gy	1.64 - 2.39	2.07	0.02	0.02	7.50	6.18	67.91	20.04
150Gy	1.85 - 2.48	2.11	0.02	0.01	6.96	5.57	64.14	18.55
200Gy	1.64 - 2.49	2.12	0.03	0.02	8.29	7.18	74.99	21.59
250Gy	1.83 - 2.39	2.13	0.03	0.02	8.02	6.87	73.35	21.09
300Gy	1.76 - 2.35	2.10	0.03	0.02	8.54	7.44	75.87	22.11

TABLE 10. Mean and variance for days to maturity in M_2 generation

Treatment	Range	Mean	PV	GV	PCV	GCV	h^2	GA%
ADT39								
Control	124 - 128	126.50	1.39	-	-	-	-	-
50Gy	115 - 141	128.56	26.16	24.77	3.98	3.87	94.70	1.65
100Gy	121 - 130	125.43	5.66	4.27	1.90	1.65	75.45	1.35
150Gy	108 - 132	123.49	34.91	33.52	4.78	4.69	96.00	1.74
200Gy	120 - 132	124.92	5.59	4.20	1.89	1.64	75.16	1.35
250Gy	118 - 127	124.06	4.33	2.94	1.68	1.38	67.92	1.22
300Gy	121 - 128	124.61	3.34	1.74	1.47	1.06	52.09	0.97
CR1009								
Control	151 - 155	152.80	1.51	-	-	-	-	-
50Gy	120 - 158	148.10	57.26	55.82	5.11	5.04	97.50	1.48
100Gy	140 - 168	157.03	35.25	33.82	3.78	3.70	95.90	1.38
150Gy	143 - 158	150.23	17.91	16.40	2.82	2.70	91.56	1.39
200Gy	131 - 157	150.91	39.60	38.09	4.17	4.09	96.18	1.46
250Gy	148 - 156	151.95	6.75	5.24	1.71	1.51	77.61	1.17
300Gy	147 - 156	151.90	7.43	5.92	1.79	1.60	79.67	1.20

TABLE 11. Mean and variance for single plant yield in M_2 generation

Treatment	Range	Mean	PV	GV	PCV	GCV	h^2	GA%
ADT39								
Control	18.45 - 23.14	21.54	1.92	-	-	-	-	-
50Gy	11.95 - 32.45	21.39	16.39	14.47	18.93	17.78	88.29	10.01
100Gy	12.79 - 26.68	21.51	6.82	4.90	12.14	10.29	71.84	8.10
150Gy	17.09 - 30.16	22.59	12.48	10.56	15.64	14.39	84.62	9.08
200Gy	15.67 - 25.56	19.52	6.12	4.20	12.67	10.49	68.60	8.52
250Gy	16.31 - 40.13	23.70	29.38	27.46	22.87	22.11	93.47	9.56
300Gy	18.23 - 25.47	20.15	3.66	2.23	9.49	7.41	61.00	6.82
CR1009								
Control	22.34 - 25.92	23.92	1.58	-	-	-	-	-
50Gy	16.89 - 38.22	24.20	10.61	9.03	13.46	12.42	85.13	8.12
100Gy	17.34 - 36.78	24.97	16.53	14.95	16.28	15.48	90.46	8.36
150Gy	12.08 - 43.35	24.71	49.67	48.09	28.53	28.07	96.82	9.05
200Gy	18.34 - 27.84	23.90	7.41	5.84	11.39	10.11	78.72	7.60
250Gy	12.34 - 33.45	22.68	29.29	27.72	23.87	23.21	94.62	9.63
300Gy	20.13 - 26.02	22.16	4.73	3.15	9.81	8.01	66.63	6.94

DISCUSSION

The effect of mutagens, which is the result of complex interactions among many factors, starts expressing from M_2 generation onwards. This has been regarded as a reliable and easy index by different investigators in mutation research (Mackey, 1951; Gaul, 1960). Visible effect of the mutation in the nearest vicinity is the occurrence of chlorophyll mutants. Most of the studies taken up in rice have indicated that this chlorophyll - deficit mutant trait is under the control of a recessive nuclear gene. Till date, about 80 chlorophyll deficit genes have been reported and more than 30 genes have been mapped on the rice chromosome by using classical genetic methodology and 11 genes by using molecular markers (Xiaoqun et al., 2008). Besides the observation on frequency of occurrence of chlorophyll deficit mutants, they have been utilized for testing even the varietal purity in rice. A *xantha* mutant induced by gamma rays irradiation of a CMS maintainer line II 32 B, designated as Mgt-1 possessing a low gelatinization temperature was backcrossed with CMS II 32A and a new line Huangyu A (B) was developed. Genetic analysis of this *xantha* mutation showed that expression of *xantha* colour is under single recessive locus (Zhou et al, 2006). It is worthy to mention that in the present study 43 chlorophyll mutant plants from the ADT 39 variety and 29 mutants from CR 1009 were observed and the chlorophyll mutant albinos were found to be more prevalent than *xantha* and *viridis*. Frequency of occurrence of albinos was high at 150Gy dose in both ADT 39 and CR 1009 varieties and similar results were obtained by Cheema and Atta 2003. The occurrence of more chlorophyll mutants in the variety ADT 39 indicates that this variety is more mutable than CR 1009.

Plant dwarfism is one of the most important phenotypes used in plant breeding, Dwarfism arises from various types of defects, but two major factors attributed are gibberellin (GA) and brassinosteroid (BR). Numerous dwarf mutants are deficient in the biosynthesis or perception of these phytohormones (Mandava, 1988; Clouse and Sasse, 1998 and Fujioka and Yokota, 2003). In rice GA-related mutants are typically dwarf with deep green, rough leaves, but it doesn’t exhibit other abnormal morphologies (Sakamoto et al., 2004). Though there had been a report of more than 60 dwarfing and semi dwarfing mutants in rice, useful source of rice dwarfing genes were found to originate from a single recessive gene, the new semi dwarf gene (*sd 1*). Attempts have been initiated to identify certain dominant dwarf or semi dwarf mutants as well (Qin et al., 2008). Bhat et al. (2007) have recorded slender grain type mutants from Abhilesh, a variety with long and medium bold grains. A dose of 25Kr was used in their study. In the present study long slender grains were recovered in both the CR 1009 and ADT 39 varieties and fine grain mutants were isolated from 150Gy treated population of ADT 39. There was a tendency among the consumers to prefer the medium slender rice grains possessing good cooking qualities during the recent periods and these mutants may prove useful once their quality parameters are evaluated and found suitable.

The proper choice of a mutagenic treatment and a suitable method for selecting mutants are of primary importance in mutation breeding. The former determines the mutation rate per cell at the time of treatment, and the latter influences the proportion of target mutants in M_2 or later generations. In the present study, effectiveness in both ADT 39 and CR 1009 decreased progressively with increasing dose of radiation which was also witnessed by Yankulav et al. (1980), Reddi and Rao (1988) in rice. Similarly, the effectiveness of mutagens in inducing viable mutations was also found to be dose dependent with an inverse relationship between dose and effectiveness in both the varieties. The highest mutagenic effectiveness for chlorophyll and viable mutant was observed in 50Gy of ADT 39 and CR 1009, whereas the highest efficiency was recorded for sterility in both the varieties in Chlorophyll and viable mutants.

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REFERENCES

Ahloowalia, B.S., Maluszynski, M. and Nichterlein, K. (2004) Global impact of mutation- derived varieties. Euphytica, 135, 187-204.

Allard, R.W. (1960) Principles of Plant Breeding. John Wiley and Sons, Inc., New York. p.485.

Bhat, R.S., P. Surendra, N.G. Hanumaratti and G.V. Nayak (2007). AM3- an induced rice mutant with improved grain size and yield. Int Rice. Res. Newsl., 32(1): 18-19. Burton, G.N. (1952). Quantitative inheritance in grasses. Proceedings of 6th International Grassland. Congress, 1: 277-283.p10

Cheema, A.A. and B.M. Atta (2003) Radiosensitivity studies in basmati rice. Pak. J. Bot. 35(2), 197-207.

Clouse, S.D. and J.M. Sasse. (1998) Brassinosteroids: essential regulators of plant growth and development. Annu. Rev. Plant Physiol. Plant Mol. Biol. 49, 427-451.

Fujioka, S. and T. Yokota. (2003) Biosynthesis and metabolism of brassinosteroids. Annu Rev. Plant Biol. 54, 137-164.

Gaul, H. (1960) Critical analysis of methods for determining the mutation frequency after seed treatment with mutagens. Genetica Agraria. 12, 297-318.

Johnson, H.W. and R.E. Comstock. (1955) Genotypic and phenotypic correlation in soybeans and their implications in selections. Agron. J. 47, 477- 483.

Konzak, C.F., R.A. Nilan, J. Wagner and R.J. Foster. (1965) Efficient chemical mutagenesis. In: The Use of Induced Mutations in Plant Breeding, Pergamon Press, pp 49-70.

Li, X., Q. Lu, F. Wang, C. Xu and Q. Zhang. (2001) Separation of two locus inheritance of photoperiod sensitive genic male sterility in rice and precise mapping the *pms 3* locus. Euphytica,119, 343-348.

Lush, J.L. (1949) Heritability of quantitative characters in farm animals. Hereditas, (Lund) 35 (Suppl.): 356- 375.

Mackey, J. (1951) Neutron and X-ray experiments in barley. Hereditas, 37, 421-464.

Mandava, N.B. (1988) Plant growth-promoting brassinosteroids. Annu. Rev. Plant Physiol.Plant Mol. Biol. 39, 23–52.

Patnaik, A., D.Chaudhary, and G.J.N.Rao. (2006) Genetic Improvement of Long Grain Aromatic Rice through Mutation Approach. Plant mutation reports, 1, 11-15.

Qin, R., Y. Qiu, Z. Cheng, X. Shan, X. Guo, H. Zhai and J. Wan. (2008) Genetic analysis of a novel dominant rice dwarf mutant 986083D. Euphytica, 160, 379-387.

Reddi, T.V.V.S. and D.R.M. Rao. (1988) Relative effectiveness and efficiency of single and combination treatments using gamma rays and sodium azide in inducing chlorophyll mutations in rice. Cytologia, 53, 491-498.

Sakamoto, T., K. Miura, T. Tatsumi, M. Ueguchitanaka, K. Ishiyama, M. Kobayashi, K. Agrawal, S. Takeda, K. Abe, A. Miyao, H. Hirochika, H. Kitano, M. Ashikari and M. Matsuoka. (2004) An overview of gibberellin metabolism enzyme and their related mutants in rice. Plant Physiol. 134, 1642-1653.

Xiaoqun, H., W. Pingrong, Z. Haixin and D. Xiaojian. (2008) Genetic analysis and molecular mapping of novel chlorophyll- deficit mutant gene in rice. J. Rice sci. 15(1), 7-12.

Yamaguchi, I. (2001) Forty Years of Mutation Breeding in Japan Research and Fruits. Gamma Field Symp., 40, 1-11.

Yankulav, M.T., S.M. Isasi and A.S. Ferrer. (1980) Some aspects of sensitivity and mutability of two French bean varieties under the influence of gamma irradiation from ^{60}CO and ethyl methane sulphonate. Cinecias de la Agriculture, 7, 59-69.

Zhou, X.S., S.Q. Shen, D.X. Wu, J.W. Sun and Q.Y. Shu. (2006) Introduction of a xantha mutation for testing and increasing varietal purity in hybrid rice. Field crops Res. 96, 71-79.