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GAMMA RAY AND EMS INDUCED POLYGENIC VARIABILITY IN M_2 AND M_3 POPULATIONS OF AROMATIC RICE

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ABSTRACT

In the present study, most of the quantitative traits were studied to screen out the useful and desirable mutants in the mutagen treated population. A sharp decline in grain yield per plant might be attributed to decrease in mean performance of these quantitative traits affecting induced polygenic variability. The present investigation clearly demonstrated the high potentials of 50kR gamma rays +0.2% EMS followed by 0.5% EMS and 50kR gamma rays in inducing variability for yield and component traits in most of the characters in both the genotypes as well as generations. Traits like plant height, days to 50% flowering, days to maturity, panicle length, number of grains per panicle, number of panicle bearing tillers per plant, 100-seed weight and grain yield per plant showed positive and negative shifts in mean in both the varieties of aromatic rice in both generations. These traits, as expected because of their positive correlation with grain yield, contributed significantly towards grain yield.

INTRODUCTION

A polygenic mutation or micro-mutation is a mutational event which causes only small modifications in a phenotype of a trait. Such mutations should be useful for improving quantitatively inherited traits (e.g., grain yield) without disturbing the major part of the genotypic and/or phenotypic architecture of the crop plants (Gaul *et al.*, 1969 and Arias and Frey, 1973). The primary objective of the mutation breeding is to enhance the frequency and spectrum of mutations and also to increase the incidence of viable mutations. The use of physical and chemical mutagens or combination of both has been an important tool for the increase of variability in agronomic traits in rice (Agrawal *et al.*, 2000; Baloch *et al.*, 2002; Domingo *et al.*, 2007; Chakravarti *et al.*, 2013). The potentiality of ionizing radiations and chemical mutagens is different and their ability to induce mutations varies from genotype to genotype in rice (Singh and Sharma, 2013). Therefore, it is desirable to have the appropriate treatment schedule before undertaking mutagenesis. Since genetic variability is a pre-requisite for any successful breeding programme, the creation and management of genetic variability becomes central base for crop improvement programme. Induced variability was observed in M_2 and M_3 generations indicated the possible selection for quantitative characters. The primary objective of this research work was to enhance the frequency and spectrum of mutations and also to increase the incidence of viable mutations.

MATERIALS AND METHODS

The two aromatic rice varieties, viz., Pusa Basmati 1 and Kalanamak were employed as experimental materials. Some of the important characteristics of cultivars are given below which may serve as useful criteria for judging the relative merits of induced mutants, if any. Pusa Basmati 1 was derived from a cross of Pusa 150 x Karnal local. It is a semi dwarf, medium flowering, long size grain, awned panicle, mildly scented, high gelatinization temperature, soft gel and intermediate amylose. Kalanamak is a non-basmati scented rice variety grown primarily in the Tarai area adjoining Nepal particularly in the districts of Siddharthnagar, Santkabirnagar and Basti and in small pockets in eastern Uttar Pradesh, and is named because its husk is black. It is a successful adapter to usar soils characterised by higher salt concentration and high ph. The name itself — 'namak', means salt signifies this quality.

Three hundred pure, uniform, healthy and dry (12% moisture) seeds for each treatment of aromatic rice Pusa Basmati 1 and Kalanamak were irradiated with gamma rays at five doses, viz., 10 kR, 20 kR, 30 kR, 40 kR and 50 kR at NBRI, Lucknow. Two hundred fifty seeds were sown in the field and remaining fifty seeds were kept for laboratory observations. EMS solution with different concentrations, *i.e.*, 0.2%, 0.3%, 0.4% and 0.5% were prepared by mixing appropriate volume of the chemical (EMS) and phosphate buffer (pH 7.0). Three hundred pure, uniform, healthy and dry seeds (12% moisture) were subjected to pre soaking in distilled water for 6 hours at room temperature. The soaked seeds were then transferred to EMS solution of different concentrations in research lab of the department. The seeds were kept in EMS solution for 6 hours and seeds were given intermittent shaking throughout the period of treatment to maintain uniformity. The mutagen solution was drained out. The treated seeds were then washed in running tap water for 1 hour to remove residual chemical from the seeds, if any.

The combination treatment of gamma rays and ethyl methane sulphonate (EMS), was also done as described earlier. For this, the gamma ray treated seeds were soaked in distilled water for six hours and then treated with EMS solution of 0.2% concentration followed by washing in running tap water for 1 hour. For each combination treatment, 300 seeds were used. The 250 washed seeds of each treatment were then sown in experimental field at Research Farm, UP College to raise M_1 generation along with control in three replications and the remaining 50 seeds were used in laboratory for observing germination and seedling height reduction (Singh and Sharma, 2013).

The field experiment was conducted at Research Farm, Udai Pratap Autonomous College, Varanasi. The M_1 , M_2 and M_3 generations seeds were sown on 19th July, 2011 ; 3rd July, 2012 and 13th June, 2013, respectively and transplanted after 21 days in the well puddled field in Randomized Block Design with three replications along with the control. The distance between and within the rows was kept as 20 cm and 15 cm, respectively. The cultural practices were performed to maintain a good plant stand. For micro mutational studies, all the M_1 plants having 60% pollen fertility or more were advanced to raise M_2 generation following the procedure adapted by Gaul, (1964). Seeds of the selected plants on the basis of pollen fertility as described above were bulked treatment wise and sown separately in the nursery bed during rainy season. For micromutational study, the data on yield and yield traits were recorded on 50 randomly selected normal looking plants from each treatment and control from each replication of both the varieties in M_2 and M_3 generations, respectively and observations were taken on nine quantitative characters, namely, plant height (cm), days to 50% flowering, days to maturity, , panicle length (cm), number of panicle bearing tillers/plant, number of grains/panicle, 100-seed weight (g) and grain yield/plant (g).

RESULTS AND DISCUSSION

The analysis of variance for all the characters revealed a significant difference between the treatments in M_2 and M_3 generations in both the varieties. The values of mean, range and coefficient of variation (CV) for the two varieties are presented in Tables 1-8.

Plant height

The data pertaining to mean, range and coefficient of variation for plant height in treated as well as control populations of Pusa Basmati 1 and Kalanamak are presented in Table 1. It is obvious from the results that there was shift in mean in both positive as well as negative directions over the control. Similarly, there was wider range in the treated populations as compared to the untreated population. The extent of variability was higher in M_2 than M_3. Invariably, the variability increased in both the generations irrespective of increase or decrease in mean values. Plant height significantly decreased in both the varieties in both the generations in few treatment doses. The shift towards reduced height was found maximum as 95.16 cm in Pusa Basmati 1 and 162.66 cm in Kalanamak in M_2 generation and 98.66 cm in Pusa Basmati 1 and 164.76 cm in Kalanamak in M_3 generation at 0.5% EMS.

Days to 50% flowering

The values of mean, range and coefficient of variation for days to 50% flowering in rice cultivars Pusa Basmati 1 and Kalanamak are presented in Table 2. The coefficient of variation increased in all the treatments as compared to the control in both the varieties in both the generations. It was evident from the table that in Pusa Basmati 1 and Kalanamak, the maximum shift towards late flowering was observed in M_2 and M_3 generations at 50 kR gamma rays + 0.2% EMS. In general, there was a wider range for days to flowering in treated populations than the control in both the varieties in M_2 and

Table 1: Mean, range and coefficient of variation (CV) for plant height in aromatic rice in M_2 and M_3 generations

Treatment	Pusa Basmati 1						Kalanamak					
	M_2 generation			M_3 generation			M_2 generation			M_3 generation		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
Control	101	90-110	5.6	102	92-109	5	166.33	160-185	6	168.33	160-180	6
Gamma rays												
10 kR	97.83**	86-126	7	101.33	89-124	6.1	165	149-187	7.9	167	152-184	7.1
20 kR	99.16	85-118	7.3	102.33	86-116	6.2	166.33	148-189	13.6	168.33	154-180	10.6
30 kR	97.66**	80-120	7.4	100.33	83-118	6.7	164.00*	146-190	12.2	166.00*	150-181	11.1
40 kR	100.16	80-116	7.7	103.66	80-116	6	167.33	142-189	17.6	169.33	148-177	16.4
50 kR	97.00**	79-115	7.9	100.00*	79-115	7	164.00*	130-186	16.8	166.00*	140-175	15.7
Ethyl methane sulphonate (EMS)												
0.20%	98.16**	86-122	7	101.66	86-122	6.2	165.66	148-185	9.9	167.66	150-180	10.1
0.30%	97.66**	85-121	7.7	101.66	85-121	6.1	165.66	150-183	10.2	167.76	155-179	9.7
0.40%	98.00**	72-117	8.6	100.00*	72-117	7.2	164.66	147-180	11.4	166.66	153-176	10,2
0.50%	95.16**	79-116	8.7	98.66**	79-116	7.4	162.66**	143-179	12	164.76**	149-170	10
Gamma rays+ EMS												
10 kR+0.2%	98.50*	84-125	7.7	101.33	84-125	7	166	151-185	12.6	168	157-180	11.4
20 kR+0.2%	98.50*	80-116	9	104.33*	80-116	7.9	166.16	148-187	14	168	150-176	12
30 kR+0.2%	97.50**	86-122	6.8	101	86-122	6	165	146-189	16	167	156-175	14
40 kR+0.2%	99.5	81-120	8	102.66	81-120	7	166.66	138-190	19.8	168.66	145-188	17.8
50 kR+0.2%	97.66**	79-120	9.6	99.33**	79-120	8.1	163.33**	135-188	20.4	165.33**	146-181	18.4
SE±	1.02			0.83			0.95			0.93		

Table 2: Mean, range and coefficient of variation (CV) for days to 50% flowering in aromatic rice in M_2 and M_3 generations

Treatment	Pusa Basmati 1						Kalanamak					
	M_2 generation			M_3 generation			M_2 generation			M_3 generation		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
Control	118	106-132	5.6	118.33	106-130	5	145.66	140-158	5.1	147.66	140-158	5.1
Gamma rays												
10 kR	119.83	100-132	8.5	118.33	102-127	7.6	146.33	135-153	7.7	146.33	139-150	7.4
20 kR	121.50**	103-134	6.4	120	106-130	6.8	148.00*	132-156	9.1	148	137-153	8.5
30 kR	120.16*	106-132	5.6	118.66	108-128	5.1	146.66	130-157	11.4	146.66	134-153	10.4
40 kR	119.16	104-133	5.9	117.66	105-127	5	145.66	130-158	12.6	146.66	133-155	11.4
50 kR	122.50**	101-130	7.4	121.00*	104-126	6.9	149.00**	129-156	13.2	149	132-153	12.6
Ethyl methane sulphonate (EMS)												
0.20%	119.5	100-133	7.6	118	102-130	7.1	147.33	136-158	7.1	147.33	138-154	6.5
0.30%	120.16*	101-133	6.4	118.66	104-129	6	146.66	139-156	7.9	146.66	140-153	7.3
0.40%	121.16**	101-130	8.3	120.66*	103-127	7.9	147.66*	137-157	8.1	147.66	139-152	7.8
0.50%	120.50*	101-132	7.5	119.1	102-129	6.9	147.1	135-156	9.3	147.1	137-153	9
Gamma rays+ EMS												
10 kR+0.2%	120.50*	102-132	7.4	119.2	104-130	7	147.2	130-154	7.7	147.2	133-152	7
20 kR+0.2%	120.50*	102-131	7.3	119	105-129	6.7	147	131-157	10.1	147	134-155	9.7
30 kR+0.2%	121.50**	102-130	7.3	120	103-128	7	148.00*	130-156	11.2	148	132-152	10.4
40 kR+0.2%	119.83	100-129	8.4	118.33	103-125	7.5	146.33	128-155	13.1	146.33	130-151	12.6
50 kR+0.2%	123.83**	101-128	8.2	122.33**	102-124	7.2	150.33**	129-156	14.6	151.00**	131-150	12.3
SE±	0.95			0.97			0.93		0.86			

Table 3: Mean, range and coefficient of variation (CV) for days to maturity in aromatic rice in M_2 and M_3 generations

Treatment	Pusa Basmati 1						Kalanamak					
	M_2 generation			M_3 generation			M_2 generation			M_3 generation		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
Control	147	130-157	5	146.66	131-156	5	167.66	160-178	4.9	168.66	160-173	4.8
Gamma rays												
10 kR	147.63	125-164	7.2	146.33	128-160	7	168.33	159-180	6.4	168.33	157-180	6.2
20 kR	149.63**	127-164	5.1	148.33*	129-161	5	170.00*	153-182	6.6	170	150-180	6.3
30 kR	147.96	130-162	4.5	145.66	133-160	4.3	168.66	151-184	10.2	168.66	150-181	10
40 kR	146.96	128-163	4.6	145.66	130-161	4.3	167.66	148-187	11.7	167.66	146-177	11.2
50 kR	150.63**	125-160	6.1	149.33**	128-159	5.5	171.00**	146-185	10.1	171.00**	144-180	10
Ethyl methane sulphonate (EMS)												
0.20%	148.70*	124-156	6.3	147.33	126-155	6	169.33	157-184	6.7	169.33	155-181	6.4
0.30%	147.96	124-157	5.1	146.66	125-154	5	168.66	157-184	7.9	168.66	155-182	7.7
0.40%	148.96**	124-160	7.1	147.66	127-158	6.1	169.66*	156-186	8.2	169.66	154-185	8
0.50%	148.50*	125-162	6.2	147.2	126-160	6	169.2	152-184	9.5	169.2	150-181	9.2
Gamma rays+ EMS												
10 kR+0.2%	148.63*	126-160	6	147.33	127-158	5.6	169.33	155-185	9.2	169.33	153-183	9
20 kR+0.2%	148.3	128-161	6	147	129-159	5.8	169	144-186	10.7	169	143-182	10.2
30 kR+0.2%	149.30**	124-165	6.2	148	127-162	6	170.00**	149-188	13	170	147-185	12
40 kR+0.2%	147.63	127-163	6	146.33	129-161	5.8	168.33	145-188	17.2	168.33	143-186	16.2
50 kR+0.2%	150.63**	126-161	6	149.33**	128-158	5.6	172.33**	140-186	17.8	171.66**	140-183	16.8
SE±	0.7			0.71			0.92			0.77		

M_3 generations. The extent of variability was higher in M_2 than M_3 generation in both the varieties.

Days to maturity

The data for mean, range and coefficient of variation for days to maturity in treated and control populations of rice cvs. Pusa Basmati 1 and Kalanamak in M_2 and M_3 generations are presented in Table 3. As evident from the data recorded from Pusa Basmati 1, the maximum shift towards late maturity was observed maximally at 50 kR gamma rays and combination treatment of 50 kR gamma rays + 0.2% EMS in both the generations. In Kalanamak days to maturity was significantly increased in few treatment doses and was found maximum at 50 kR gamma rays + 0.2% EMS in M_2 and M_3 generations. There was a wider range in the treated population as compared to the control and the coefficients of variation for all the treatments increased over control in both the generations. Days to maturity was significantly increased in both the varieties in both the generations in few treatment doses.

Panicle length

The data on mean, range and coefficient of variation for panicle length in Pusa Basmati 1 and Kalanamak in M_2 and M_3 generations are presented in Table 4. It was apparent from the results that there was shift in mean towards negative sides over the control in both the varieties. The coefficient of variation for panicle length was invariably higher in treated population. All the treatments, except few have shown negative shift in

Table 4: Mean, range and coefficient of variation (CV) for panicle length in aromatic rice in M_2 and M_3 generations

Treatment	Pusa Basmati 1						Kalanamak					
	M_2 generation			M_3 generation			M_2 generation			M_3 generation		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
Control	27	23-36	6.4	27.66	24-35	6	25.33	23-30	6.4	26	23-30	6.4
Gamma rays												
10 kR	26.00*	22-39	8.2	26.83*	24-37	8	24.50*	22-31	7.2	25.5	24-31	7
20 kR	26.66	20-36	7.9	27.66	22-35	7.5	25.16	20-31	11	26.16	22-31	10
30 kR	25.50*	20-40	10.7	26.50**	21-38	10.4	26.16	21-30	9.7	25.00*	22-30	8
40 kR	27.66	20-38	9.6	28	22-37	9.2	25.5	20-32	12.3	26.5	20-31	10.3
50 kR	26.83	20-37	9.4	27.83	22-35	9	25.33	19-31	14.8	26.33	19-30	12.4
Ethyl methane sulphonate (EMS)												
0.20%	26.33	23-37	7.4	27.33	23-36	7.2	24.83	23-29	8.8	25.83	24-29	8
0.30%	26.33	20-36	7.5	27.33	22-35	7.3	24.83	24-29	9.2	25.83	25-29	8.1
0.40%	25.83*	24-37	8.4	26.83*	24-35	8.2	24.33**	23-30	9.8	25.33	24-30	8.8
0.50%	26.5	19-36	8.2	27.5	20-34	8	24.66	23-30	10.2	27.33**	24-30	9.2
Gamma rays+ EMS												
10 kR+0.2%	26.66	20-36	8.4	27.66	21-34	8.1	24.66	21-30	10	26	22-30	9
20 kR+0.2%	26.66	21-35	8	28.83*	23-34	7.5	24.66	20-31	11.1	26	21-31	10
30 kR+0.2%	26.33	23-37	8.4	27.33	24-36	8.2	24.50*	20-32	13.6	25.5	21-32	11.2
40 kR+0.2%	26.83	21-36	8.3	27.83	22-34	8.1	25.33	19-32	16.1	26.33	20-32	15.3
50 kR+0.2%	26.5	21-37	8.5	27.5	23-35	8.2	25	18-30	16.9	26	19-30	15.1
SE±	0.38			0.36			0.33			0.41		

Table 5: Mean, range and coefficient of variation (CV) for number of panicle bearing tillers per plant in aromatic rice in M_2 and M_3 generations

Treatment	Pusa Basmati 1						Kalanamak					
	M_2 generation			M_3 generation			M_2 generation			M_3 generation		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
Control	8	18-Jun	21.3	8	16-Jul	21	6.1	11-Apr	15.3	6.3	10-Apr	15
Gamma rays												
10 kR	6.96**	15-May	23.6	8.16	13-Jun	21.6	5.03**	12-Mar	21	5.8	12-Apr	20
20 kR	7.8	15-Mar	25.5	9.00*	13-Apr	23.5	6.56	15-Mar	23.3	6.46	14-Mar	20.3
30 kR	6.30**	17-Apr	27.4	7.5	13-Apr	24.3	4.93**	16-Mar	28.4	5.30*	15-Apr	24.4
40 kR	8.13	15-Mar	23.4	9.33**	14-Apr	21.1	6.1	16-Mar	31.1	6.8	14-Mar	28.1
50 kR	7.46	17-Mar	22.2	8.66	15-Apr	20	5.36*	16-Mar	34.2	6.13	15-Apr	30.2
Ethyl methane sulphonate (EMS)												
0.20%	7.10*	17-Apr	27.9	9.16**	16-May	25.4	5.43	13-Mar	27.4	6.13	13-Apr	22.4
0.30%	7.13*	20-Mar	25.5	8.33	18-Apr	24.3	5.43	15-Mar	29.2	6.13	11-Apr	24
0.40%	6.63**	19-May	25.4	7.83	16-Apr	24.2	4.93**	16-Apr	30.6	5.63	13-Apr	26.1
0.50%	7.3	20-Mar	22.2	8.5	17-Apr	21	5.6	17-Mar	31.8	6.3	12-Apr	27.5
Gamma rays+ EMS												
10 kR+0.2%	7.63	18-Mar	28.3	8.83*	16-Mar	26.3	5.93	15-Mar	26.1	6.63	15-Mar	25
20 kR+0.2%	7.3	18-May	26.7	8.5	17-May	25.4	5.6	16-Mar	28.3	7.63**	16-Mar	26.1
30 kR+0.2%	7.00*	15-May	26.7	8.16	14-May	24.6	5.10**	14-Mar	33.2	5.96	14-Mar	31
40 kR+0.2%	7.63	15-May	27.7	8.66	15-Jun	25.6	5.93	17-Mar	34.3	6.63	17-Mar	32.1
50 kR+0.2%	7.3	18-May	24.9	8.5	16-May	23.5	5.6	16-Mar	35.1	6.3	16-Mar	32
SE±	0.36			0.37			0.34			0.37		

mean panicle length over the control. The maximum negative shift in mean panicle length over the control was observed in Pusa Basmati 1 at 30 kR gamma rays in both generations. Kalanamak also showed negative shifts in mean performance over the control and it was found maximum at.0.4% EMS in M_2 and at 30 kR gamma rays in M_3 generation. The coefficient of variation for panicle length was invariably higher in treated populations, irrespective of increase or decrease in mean values. Panicle length significantly increased or decreased in both the varieties in both the generations in few treatment doses.

Number of panicle bearing tillers per plant

The values of mean, range and coefficient of variation for number of panicle bearing tillers per plant in Pusa Basmati 1 and Kalanamak in M_2 and M_3 generations are presented in Table 5.The results revealed that there was slight change in the magnitude of range for number of panicle bearing tillers in both the varieties in M_2 and M_3 generations. Negative shifts in mean over control were observed in both the varieties in both the generations. In case of Pusa Basmati 1, negative shift for number of panicle bearing tillers per plant was found maximum at 30 kR in M_2 generation and at 40kR gamma rays in M_3 generation. In case of Kalanamak, a maximum significant reduction in number of panicle bearing tillers per plant was observed at 30 kR gamma rays and 0.4% EMS in M_2 and at 30 kR gamma rays in M_3 generations. In general, the coefficient of variation among treated population was higher than the

Table 6: Mean, range and coefficient of variation (CV) for number of grains per panicle in aromatic rice in M_2 and M_3 generations

Treatment	Pusa Basmati 1						Kalanamak					
	M_2 generation			M_3 generation			M_2 generation			M_3 generation		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
Control	136	750-150	23.9	139.83	48-148	23	128	70-160	18.25	130	124-180	17.2
Gamma rays												
10 kR	135	53-144	24.1	139	55-144	22.1	129	72-160	26.7	129	85-215	24.1
20 kR	136.33	51-153	26.8	140.3	54-150	25.1	128.33	64-165	29.1	130.33	76-222	27.4
30 kR	133.33**	40-166	26.9	138	48-161	24.2	126.66	60-170	33.2	129.33	74-230	31
40 kR	137	54-147	27.3	141	58-143	25	129	58-180	35.1	131	71-230	32
50 kR	133.66*	48-163	29	137.66*	50-160	27	125.66*	56-175	36.2	127.66*	70-225	35.1
Ethyl methane sulphonate (EMS)												
0.20%	135.66	47-148	24.9	139.66	49-145	23	127.66	60-180	27.1	129.66	74-223	25.1
0.30%	135.66	43-144	27.6	142.66**	45-140	26.4	127.66	60-185	28.2	129.66	74-220	26.3
0.40%	134.00*	42-145	31.4	138	45-141	28	126.00*	58-165	29.4	128.00*	70-230	27.2
0.50%	133.66*	41-162	32.4	137.66*	44-160	30.1	125.66*	55-163	30.8	127.66*	69-237	28.5
Gamma rays+ EMS												
10 kR+0.2%	136	44-146	30.4	140	46-143	28.1	128	60-164	29.2	132.66*	75-220	26.2
20 kR+0.2%	135.33	50-146	30.6	139.33	52-142	27.2	127.33	58-172	36.6	129.33	75-230	34.2
30 kR+0.2%	135.66	51-144	24.7	139.66	54-140	25.3	128.33	50-175	36.8	129.66	69-240	33.3
40 kR+0.2%	136.66	42-145	28.9	140.66	46-140	24.9	129	50-145	36	130.66	65-241	34
50 kR+0.2%	133.66*	50-146	29.5	137.66*	52-141	27.4	127.33	48-155	37.8	128.66	61-240	35.4
SE±	0.92			0.9			0.91			0.87		

Table 7: Mean, range and coefficient of variation (CV) for 100-seed weight in aromatic rice in M_2 and M_3 generations

Treatment	Pusa Basmati 1						Kalanamak					
	M_2 generation			M_3 generation			M_2 generation			M_3 generation		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
Control	2	2.06-2.47	4.03	2.16	2.0-2.4	4	1.5	1.7-2.0	6.8	1.6	1.7-2.0	6.6
Gamma rays												
10 kR	1.80*	1.83-2.47	5.1	1.9	1.8-2.4	5	1.4	1.6-2.1	7.2	1.5	1.7-2.0	7
20 kR	1.93	1.64-2.45	6.07	2.03	1.6-2.4	6.01	1.53	1.6-2.1	9.1	1.63	1.7-2.1	8.1
30 kR	1.66**	1.41-2.46	6.32	1.80**	1.7-2.4	6.02	1.33*	1.5-2.2	12	1.40*	1.5-2.1	11
40 kR	2.1	1.74-2.55	7.42	2.2	1.7-2.5	7.02	1.6	1.5-2.2	12.2	1.80*	1.6-2.1	10.2
50 kR	2	1.62-2.35	6.99	2.16	1.6-2.3	6.29	1.26**	1.5-2.3	13.4	1.36*	1.6-2.1	11.4
Ethyl methane sulphonate (EMS)												
0.20%	2.06	1.59-2.47	4.86	2.26	1.7-2.4	4.36	1.5	1.6-2.1	8.3	1.6	1.6-2.0	8
0.30%	2	1.64-2.44	5.62	2.1	1.6-2.4	5.52	1.46	1.6-2.1	8.9	1.56	1.6-2.1	8.2
0.40%	1.83*	1.80-2.45	6.13	1.93*	1.8-2.4	6.03	1.43	1.5-2.2	9.9	1.53	1.6-2.0	9.3
0.50%	1.66**	1.61-2.55	6.99	1.76**	1.6-2.5	6.01	1.26**	1.5-2.2	10.8	1.36*	1.6-2.1	9.5
Gamma rays+ EMS												
10 kR+0.2%	2	1.64-2.47	7.19	2.1	1.6-2.4	7.19	1.5	1.6-2.1	9.3	1.6	1.6-2.0	9
20 kR+0.2%	1.9	1.81-2.53	5.93	2	1.8-2.4	6.9	1.5	1.6-2.2	12	1.86*	1.6-2.1	10
30 kR+0.2%	1.83*	1.83-2.44	5.89	1.86**	1.8-2.4	6.89	1.36	1.6-2.2	13.1	1.46	1.6-2.0	11.1
40 kR+0.2%	1.96	1.81-2.55	4.66	2.06	1.8-2.4	5.6	1.56	1.5-2.2	13.9	1.66	1.5-2.1	11.9
50 kR+0.2%	1.80*	1.62-2.44	6.83	1.90*	1.7-2.4	7.81	1.4	1.5-2.2	14.5	1.5	1.5-2.0	12.5
SE±	0.1			0.1			0.065			0.07		

control. The results revealed that there was slight change in the magnitude of range for number of panicle bearing tillers per plant tillers in both the varieties in both the generations. Positive as well as negative shifts in mean over control were observed in both the varieties.

Number of grains per panicle

The data pertaining to mean, range and coefficient of variation for number of grains per panicle in both the varieties of aromatic rice in M_2 and M_3 generations are presented in Table 6. In case of Pusa Basmati 1, the positive as well as negative shifts in mean for number of grains per panicle were observed. The maximum reduction in this trait was observed at 30 kR gamma rays in M_2 and at 50 kR gamma rays, 0.5% EMS and 50 kR gamma rays+ 0.2% EMS in M_3 generation. Alike Pusa Basmati 1, the range and coefficient of variation in Kalanamak were significantly higher in treated population than the control. A reduction in number of grains per panicle was observed at many treatment doses and it was maximally reduced at 50kR gamma rays and 0.5% EMS in M_2 and M_3 generations. The lower doses of mutagenic treatments had least effect on number of grains per panicle, whereas higher doses of treatments exhibited reduction in the number of grains per panicle.

100-seed weight

The data on mean, range and coefficient of variation for 100-seed weight of Pusa Basmati 1 and Kalanamak are depicted in Table 7. A significant decrease in the mean values for 100-seed weight was observed in both the varieties at different

Table 8: Mean, range and coefficient of variation (CV) for grain yield per plant in aromatic rice in M_2 and M_3 generations

Treatment	Pusa Basmati 1						Kalanamak					
	M_2 generation			M_3 generation			M_2 generation			M_3 generation		
	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV	Mean	Range	CV
Control	12.16	6.0-17.5	24.5	12.2	6.5-16.5	24	10.33	11.0-16.0	16.1	10.33	11.0-14.0	15.1
Gamma rays												
10 kR	9.70**	4.7-22.1	29.9	10.20*	5.7-20.1	27.3	8.50**	6.6-17.5	28	9.00*	6.9-17.0	26
20 kR	11.13	7.0-19.7	35.1	11.53	7.5-19.0	33	9.83	5.4-19.5	28.5	10.33	5.9-19.0	26.5
30 kR	8.70**	5.8-24.5	34	9.20**	6.9-23.5	32	8.83*	5.1-20.0	30.8	9.33	5.6-19.0	30.1
40 kR	11.7	6.4-19.8	35.9	13.33	7.2-19.3	33.5	10.66	5.0-20.5	36.1	11	5.0-19.5	34.3
50 kR	9.03**	4.2-20.2	36.2	9.53**	5.4-20.0	34	7.83**	4.5-21.0	39.8	8.33**	5.5-20.0	37.5
Ethyl methane sulphonate (EMS)												
0.20%	10.03**	5.5-19.0	24	10.53	6.3-18.5	23	10.5	6.0-17.5	30.2	9.33	6.4-17.1	30
0.30%	10.36**	6.2-20.8	33.5	10.86	6.9-19.4	32.2	9.16	5.5-18.0	32.2	9.66	5.9-17.0	31.2
0.40%	10.03**	5.7-18.3	33.3	9.86*	6.4-17.1	31.1	8.83*	5.3-17.2	34.3	8.66*	5.7-16.1	32.3
0.50%	9.90**	4.1-16.0	35.8	9.53**	5.3-15.0	33.3	8.16**	5.0-16.5	37.4	10	5.4-16.0	35.4
Gamma rays+ EMS												
10 kR+0.2%	10.7	5.6-19.5	29	11.2	6.2-18.3	27	9.16	5.5-18.0	31	9.66	6.3-17.0	30.1
20 kR+0.2%	10.7	5.5-20.2	32.3	11.2	6.7-18.0	29	9.66	4.9-18.3	35.5	10.16	5.4-17.1	33.4
30 kR+0.2%	9.63**	6.4-19.0	24.1	9,80*	7.4-17.1	22.4	9.16	4.5-20.2	36.5	9.5	5.3-19.0	34.4
40 kR+0.2%	10.5	5.9-21.8	28.7	10.66	7.0-19.5	25.2	10.16	4.0-20.2	40.1	10.5	5.4-19.0	39
50 kR+0.2%	8.66**	2.7-19.0	32.5	9.00**	5.2-17.1	28	9.00*	4.1-19.6	41	8.00**	5.4-18.4	39.1
SE±	0.76			0.9			0.64			0.64		

treatment doses. In few cases, an increased 100-seed weight was obtained. In case of Pusa Basmati 1, the results showed that increase and decrease in the mean 100-seed weight values in treated population over the control were observed and it was reduced maximally at 30kR gamma rays and 0.5% EMS in M_2 and at 0.5% EMS in M_3 generation. In case of Kalanamak, the maximum range was observed at 50 kR gamma rays while coefficient of variation was observed maximum at 50kR gamma rays+0.2% EMS. Reduction in mean seed weight was found maximum at 50 kR gamma rays and 0.5% EMS in M_2 and at 0.5% EMS M_3 generations. A significant decrease in the mean values for 100-seed weight was observed in both the varieties in both the generations at many treatment doses. In few cases, 100-seed weight increased significantly also.

Grain yield per plant

The data related to mean, range and coefficient of variation for grain yield in treated as well as control populations of Pusa Basmati 1 and Kalanamak in M_2 and M_3 generations are presented in Table 8. The results obtained clearly indicate that the mutagenic treatments reduced the yield significantly at many treatment doses in both the varieties in M_2 generation. In Pusa Basmati 1, the maximum increase in yield was observed at 40 kR gamma rays in M_3 generation whereas in Kalanamak at 40 kR gamma rays in M_2 and M_3 generations respectively. In Pusa Basmati 1, the maximum decrease in yield was observed at 50 kR gamma rays + 0.2% EMS in M_2 and M_3 generations and in Kalanamak, the maximum decrease in yield was observed at 50 kR gamma rays in M_2 generation and at 50 kR gamma rays + 0.2% EMS in M_3 generation. The maximum coefficient of variation in Pusa Basmati 1 was obtained at 50 kR gamma rays and in Kalanamak at 50 kR gamma rays + 0.2% EMS in M_2 and M_3 generations, respectively.

Mutations affecting quantitative characters can be inferred by the estimates of ranges, mean, coefficient of variation and other genetic parameters in the mutagen treated population. A large number of characters have been reported to be improved by combining the mutagenic treatments and selection (Micke, 1975). The mean performance showed improvement in most of the mutagenic treatments in M_3 generation as compared to corresponding treatments of M_2 generations. There was wider range in the treated population as compared to the untreated population. The magnitude of coefficient of variation in treated population was generally higher as compared to the control for most of the characters in both the generation for both the varieties. The observed changes in CV values revealed that the magnitude of variability declined from M_2 to M_3 generation. Several workers also noted similar results after mutagenic treatment in rice (Siddiqui and Singh, 2010; Chakravarti *et al.*, 2014). The higher doses of mutagens were comparatively effective in inducing variability. The differential genotypic response to different treatments was noted in present case; the genotype Kalanamak showed more variability than those recorded in Pusa Basmati 1 for plant height, days to maturity, panicle bearing tillers per plant and grain yield per plant, while more or less similar or low of variability was noted in both the genotypes for other traits (Siddiqui and Singh, 2010; Chakravarti *et al.*, 2014).

In general, mutagenic treatments had resulted in decreased mean coupled with enhanced variability in both genotypes and generations as compared to their respective control, though the magnitude of shift in mean varied with the treatment, genotype and trait. The present investigation clearly demonstrated the high potentials of 50kR gamma rays +0.2% EMS followed by 0.5% EMS and 50kR gamma rays in inducing variability for yield and component traits in most of the characters in both the genotypes as well as generations. Traits like plant height, days to 50% flowering, days to maturity, panicle length, number of grains per panicle, number of panicle bearing tillers per plant, 100-seed weight and grain yield per plant showed positive and negative shifts in mean in both the varieties of aromatic rice in both generations. These traits, as expected because of their positive correlation with grain yield, contributed significantly towards grain yield. The decline in means of treated population was demonstrated in rice (Jan and Roy, 1973; Awan *et al.,* 1980).The unidirectional variability towards positive side for grain yield and its component traits, as noted in the present case, were of great significance. This had yielded large number of mutants with improved grain yield per plant as well as other component traits irrespective of genotypes. Several workers also noted similar results after mutagenic treatment in rice (Singh and Singh, 2003, Siddiqui and Singh, 2010; Chakravarti *et al.*, 2014).

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