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EFFECT OF GAMMA IRRADIATION ON VARIATION IN SEGREGATING GENERATIONS OF F_2 SEEDS OF RICE

P. C. KATOCH, J. E. MASSAR AND P. PLAHA

Department of Plant Breeding & Genetics, Himachal Pradesh Krishi Vishwavidyalaya Rice Research Station, Malan 176047

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ABSTRACT

The F_2 seeds of two rice crosses, Himalaya 1 x Phul Patas 72 and Himalaya 1 x China 988, were irradiated with 25 kR gamma-rays. The mean values of F_2M_1 generation decreased as compared to F_2 for plant height, spikelet fertility and grain yield in both the crosses, and for panicle length and 100-grain weight only in the cross Himalaya 1 x China 988. On the other hand, mean values in the F_3M_2 generation for spikelet fertility and grain yield increased in both crosses as compared to F_3. However, the variance of F_3M_2 generations did not differ significantly from that of F_3 generation in both the crosses for the characters studied, except for grain yield in the cross Himalaya 1 x China 988. Estimates of heritability and genetic advance in F_3M_2 were lower than in the corresponding F_3 for all the traits in the cross Himalaya 1 x Phul Patas 72, except for plant height and 100- grain weight. However, the estimates of heritability and genetic advance in the F_3M_2 generation were higher than in F_3 generation for all characters, except 100-grain weight and grain yield in the cross Himalaya 1 x China 988. The study also revealed that irradiation has differential effect on the same character depending on the genetic background of the test/segregating material.

Key words: Rice, irradiation, variation, segregating generations.

Pure breeding homozygous genotypes have generally been used for mutation induction. Lately, the importance of mutagenesis in increasing recombination rate with a possibility of supplementing variability to that inherent in a cross has been realized and heterozygous and heterogeneous populations have been exposed to mutagens. Gregory [1] hypothesized that variation induced by radiation may be cumulative with that generated through hybridization. Thus, the combination of mutation breeding and conventional breeding methods should permit the breeder to derive the benefit of both the sources of variation to recover improved genotypes. For this, mutagenic treatments can be applied to the F_1 or F_2 seeds. The most useful application of mutagenic treatment in the segregating generation may be to a cross in which the parents are widely divergent. The present investigation was, therefore, undertaken to make a comparative assessment of the effects of gamma irradiation (25 kR) of F_2 seeds on induced variability for some quantitative traits in two rice crosses, namely, Himalaya 1 x Phul Patas 72 and Himalaya 1 x China 988.

MATERIALS AND METHODS

The experimental material comprised irradiated and unirradiated F_2 seeds of two crosses, viz., Himalaya 1 x Phul Patas 72 and Himalaya 1 x China 988.

F_2 AND F_2M_1 GENERATIONS

Samples consisting of 500 F_2 seeds of both the crosses were irradiated with 25 kR gamma-rays (F_2M_1). Seeds were stabilized at 13% moisture content. Untreated 500 F_2 seeds of each cross (F_2) and 100 seeds of each parent were used as controls. Thirty-day- old seedlings grown in a germinator were transplanted to raise F_2 and F_2M_1 generations. Observations on plant height (cm), tillers/plant, panicle length (cm), spikelet fertility (%), 100- grain weight (g), and grain yield/plant (g) were recorded on 200 plants of the four F_2 and F_2M_1 treatments, and on 20 plants from the parents.

F_3 AND F_3M_2 GENERATIONS

Seeds from randomly taken normal looking 40 plants, each of the F_2M_1 and F_2 generations of the two crosses, and bulk seed of 5 plants from each parent were sown in the nursery beds for raising seedlings of F_3, F_3M_2 and parental populations. Fifteen 30-day- old seedlings of each of the 40 F_3 and 40 F_3M_2 single plant progenies, along with 25 plants of each parent per replication were transplanted in randomized block design with three replications. The observations were recorded for the above mentioned traits in addition to heading days. Individual progenies of single plants family, i.e. F_3, F_3M_2, and parents of each cross were analysed separately.

Various variability parameters, viz., genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (H) and genetic advance (GA) expressed as percentage of mean, were calculated only in the treatments and characters exhibiting significant variance.

RESULTS AND DISCUSSION

F_2 AND F_2M_1 GENERATIONS

In the treated generation (F_2M_1) of the cross Himalaya 1 x Phul Patas 72, the mean values decreased significantly for plant height, spikelet fertility and grain yield, whereas in the cross with China 988 all the characters, except tiller number, showed significant reduction

Table 1. Mean values for different characters in the F_2 and F_2M_1 populations of two rice crosses

Cross and generation	Plant height (cm)	Tillers per plants	Panicle length (cm)	Spikelet fertility (%)	100-grain weight (g)	Grain yield per plant (g)
Himalaya 1 x Phul Patas 72:						
F_2	96.5 $\pm$ 1.6	4.5 $\pm$ 0.2	22.6 $\pm$ 0.2	6.0 $\pm$ 2.0	2.2 $\pm$ 0.0	6.7 $\pm$ 0.4
F_2M_1	91.0 $\pm$ 1.6*	5.0* $\pm$ 0.2	22.4 $\pm$ 0.3	32.8** $\pm$ 2.5	2.3 $\pm$ 0.0	2.3** $\pm$ 0.2
Himalaya 1 x China 988						
F_2	81.2 $\pm$ 1.4	5.9 $\pm$ 0.2	21.7 $\pm$ 0.2	50.9 $\pm$ 2.3	2.4 $\pm$ 0.0	5.6 $\pm$ 0.4
F_2M_1	66.2 $\pm$ 1.2**	6.0 $\pm$ 0.3	20.4** $\pm$ 0.2	32.3** $\pm$ 0.0	2.3* $\pm$ 0.0	1.6** $\pm$ 0.2

**,*Significant increase/decrease of F_2M_1 over F_2 at $P \leq 0.01$ and $P \leq 0.05$, respectively.

from F_2 generation (Table 1). The decline in height may be either due to physiological damage or chromosomal aberrations caused by irradiation. Reduction in plant height after irradiation of the F_2 seeds in rice was also reported by [2, 3]. A similar explanation may be valid for the decline in mean values of other characters. The study has also revealed that irradiation has differential effect on the same characters depending on the genetic background of the test material. Regarding the effect of irradiation on induction of variability in the M_1 generation of F_2 seeds (Table 2), it has been observed that in both the crosses, the variance for plant height and grain yield decreased as compared to unirradiated F_2 generation, however, this decrease was significant only for grain yield. On the other hand, variation increased significantly for spikelet fertility and 100- grain weight in the treated F_2 generations of both crosses as compared to the respective untreated generations. Gregory [1] also reported that in terms of standard deviation, there was more variation generated in the irradiated hybrids than the unirradiated ones. It has been advocated that the M_1 plants are chimeric in nature and the immediate change in the genetic composition and physiological disturbances comprise the phenotypic expression of M_1 plants. However, the effect of physiological disturbances are eliminated almost completely in the subsequent generations.

Table 2. Variance for different characters in the F_2 and F_2M_1 of rice crosses

Cross and generation	Plant height	Tillers per plant	Panicle length	Spikelet fertility	100- grain weight	Grain yield per plant
Himalaya 1 x Phul Patas 72:						
F_2	266.3	2.99	5.66	411.4	0.20	18.2
F_2M_1	250.4	3.37	7.05	623.9*	0.30*	5.4**
Himalaya x China 988:						
F_2	188.5	5.82	4.52	539.1	0.06	16.0
F_2M_1	148.6	8.05	4.32	770.8*	0.11*	3.1**

**,*Significant increase/decrease in F_2M_1 over F_2 at $P \leq 0.01$ and $P \leq 0.05$, respectively.

F_3 AND F_3M_2 GENERATIONS

Significant differences were observed within the F_3 and F_3M_2 progenies of both the crosses for all characters, except fertility in the cross Himalaya 1 x China 988. This indicates presence of sufficient genetic variability for different traits in the treated as well as untreated segregating generations.

A perusal of data in Table 3 reveals that, in general, means of the F_3M_2 and F_3 generations were in close proximity for most of the traits, implying that mutations with plus and minus effects might have occurred in equal frequency in both directions. However, there were exceptions, like decrease in grain yield and spikelet fertility in F_3M_2 generation as compared to F_3 families both crosses. This is possible because of the occurrence of more polygenic mutations in minus direction.

Genotypic coefficients of variation (GCV) for the cross Himalaya 1 x China 988 in the F_3M_2 generation exhibited increase over the F_3 for all the traits except 100-grain weight and grain yield. In the cross Himalaya 1 x Phul Patas 72, GCV in the F_3M_2 increased only per plant height and 100- grain weight and decreased for tillers per plant and spikelet fertility as compared to the respective F_3 families. For the remaining traits, GCV of the F_3M_2 generation was almost the same as in F_3.

Phenotypic coefficients of variation in F_3M_2 increased over F_3 for plant height and grain yield in the cross Himalaya 1 x China 988, and for 100-grain weight in Himalaya 1 x Phul Patas 72. However, PCV for grain yield in F_3M_2 exhibited a decline over the corresponding F_3 in the cross with Phul Patas 72. Phenotypic coefficients of variation were similar in both treated and untreated generations for the remaining traits.

Heritability in broad sense in the F_3M_2 generation increased over the F_3 for plant height, 100-grain weight, and grain yield in the cross Himalaya 1 x Phul Patas 72. Substantial increase in heritability in the treated generation over untreated was also observed for plant height, tiller number, panicle length and days to heading in the cross with China 988. On the other hand, heritability decreased for tiller number, panicle length and spikelet fertility in the cross Himalaya 1 x Phul Patas 72, and for 100-grain weight and grain yield in the F_3M_2 of Himalaya 1 x China 988.

Estimates of genetic advance, expressed as percentage of mean in F_3M_2 exhibited substantial increase over F_3 for plant height in both crosses, and for days to heading in Himalaya 1 x China 988 only. However, genetic advance in F_3M_2 decreased for grain yield in the cross Himalaya 1 x China 988 and for spikelet fertility in Himalaya 1 x Phul Patas 72. For the remaining traits, genetic advance was of same magnitude in the treated and untreated generations.

Table 3. Mean performance, range and genetic parameters for different traits in F_3 and F_3M_2 generations of two rice crosses

Generation	Mean ± SE	Range	GCV (%)	PCV (%)	h^2bs (%)	GA (%)
	Days to heading					
F_3 (Himalaya 1 x Phul Patas 72)	97.08 ± 0.60	87.2–109.0	4.7	6.5	52.4	6.81
F_3M_2 (Himalaya 1 x Phul Patas 72)	97.13 ± 0.53	89.9–109.2	4.6	6.8	46.2	6.03
F_3 (Himalaya 1 x China 988)	92.24 ± 0.60	86.3–101.4	2.9	6.0	23.9	2.79
F_3M_2 (Himalaya 1 x China 988)	92.91 ± 0.61	82.1–101.8	3.9	5.8	44.2	5.15
	Plant height					
F_3 (Himalaya 1 x Phul Patas 72)	82.68 ± 1.16	62.2–103.1	9.09	16.1	32.0	8.77
F_3M_2 (Himalaya 1 x Phul Patas 72)	78.89 ± 1.21	56.9–101.9	12.72	16.5	59.6	16.17
F_3 (Himalaya 1 x China 988)	78.14 ± 1.19	51.6–92.7	12.58	15.4	66.5	16.51
F_3M_2 (Himalaya 1 x China 988)	74.14 ± 1.28	51.0–91.0	16.64	18.6	80.2	22.76
	Tillers per plant					
F_3 (Himalaya 1 x Phul Patas 72)	4.99 ± 0.12	3.3–8.4	17.39	25.5	46.5	1.22
F_3M_2 (Himalaya 1 x Phul Patas 72)	5.61 ± 0.12	4.0–8.0	15.46	24.0	41.3	1.15
F_3 (Himalaya 1 x China 988)	6.64 ± 0.13	4.6–8.5	8.36	19.9	17.6	0.48
F_3M_2 (Himalaya 1 x China 988)	5.98 ± 0.12	3.2-7.8	11.26	20.4	30.6	0.77
	Panicle length					
F_3 (Himalaya 1 x Phul Patas 72)	21.37 ± 0.12	19.8–23.7	2.54	5.1	24.7	0.56
F_3M_2 (Himalaya 1 x Phul Patas 72)	21.24 ± 0.11	19.5–23.2	2.42	5.8	17.5	0.44
F_3 (Himalaya 1 x China 988)	20.91 ± 0.11	19.3–22.7	2.36	5.5	18.8	0.44
F_3M_2 (Himalaya 1 x China 988)	21.02 ± 0.11	18.9–22.6	3.52	5.5	41.0	0.98
	Spikelet fertility					
F_3 (Himalaya 1 x Phul Patas 72)	50.32 ± 0.81	31.8–62.6	12.01	17.3	47.9	8.62
F_3M_2 (Himalaya 1 x Phul Patas 72)	47.67* ± 0.85	33.2–62.7	7.82	18.6	17.7	3.23
F_3 (Himalaya 1 x China 988)	52.10 ± 0.77	42.2–62.7	NS	NS	NS	NS
F_3M_2 (Himalaya 1 x China 988)	51.95 ± 0.72	34.3–66.2	NS	NS	NS	NS
	100-grain weight					
F_3 (Himalaya 1 x Phul Patas 72)	2.25 ± 0.02	1.75–2.70	7.81	11.2	48.7	0.25
F_3M_2 (Himalaya 1 x Phul Patas 72)	2.24 ± 0.03	1.73–2.92	9.08	12.7	50.8	0.32
F_3 (Himalaya 1 x China 988)	2.69 ± 0.02	2.24–3.06	5.57	9.1	37.6	0.17
F_3M_2 (Himalaya 1 x China 988)	2.40 ± 0.02	2.00–2.85	5.53	9.9	31.0	0.15
	Grain yield/plant					
F_3 (Himalaya 1 x Phul Patas 72)	6.43 ± 0.17	3.47–9.87	19.47	28.3	48.8	1.83
F_3M_2 (Himalaya 1 x Phul Patas 72)	6.21 ± 0.15	4.28–10.39	18.43	26.2	49.4	1.66
F_3 (Himalaya 1 x China 988)	7.22 ± 0.18	4.48–12.68	24.46	27.3	80.0	3.26
F_3M_2 (Himalaya 1 x China 988)	6.11* ± 0.16	2.87–9.99	24.79	28.2	76.5	2.73

*Significant reduction in F_3M_2 over the respective F_3 at $P \leq 0.05$. NS—nonsignificant.

It can be visualized that the estimates of genetic parameters are of the same order in the treated as well as untreated segregating generations for complex traits like 100-grain weight and yield, whereas the treated generations had greater variability for plant height, tillers/plant, panicle length, and spikelet fertility, which have relatively simple inheritance. Probably the effect of irradiation on the segregating populations in producing heritable mutations appear to be balancing out with no net gain or loss of the total phenotypic variability as observed in the unirradiated segregating generations particularly for complex characters like 100-grain weight and yield [3]. However, the treatments of heterozygous and heterogeneous F_2 material allows mutational events to occur at both heterozygous and homozygous loci. Hence variations in the treated hybrids may be caused in one or a set of characters by point mutations, by enhancing the recombination rate and/or by chromosomal damage so as to release the total variability in blocks of linked genes. This offers the same advantage as generally expected from intermating in early segregating generations.

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