STUDIES ON RADIATION-INDUCED MUTATIONS IN SOME VARIETIES OF RICE

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Abstract

Dry seeds of two standard local varieties of rice namely, Dokri Basmati and Jajai-77 were subjected to different dosages of gamma-rays and fast neutron. Data on the seed fertility of the M_1 generation plants indicated that Jajai-77 is more radio-resistant than Dokri Basmati.

Chlorophyll deficient and viable mutations were scored in the M_2 generation. In general the mutation rates increased with the increase in dosages of radiations. In both the varieties, the highest frequency of chlorophyll mutations induced by either neutron or gamma-ray treatments, was obtained for albina followed by viridis type. In Dokri Basmati the spectrum of viable mutations was restricted to one type only. In Jajai-77, on the other hand, the viable mutant types included a wide variety of variants totalling to seven types.

Introduction

In many countries of the world new varieties of crop plants have been developed by radiation treatments and released as commercial varieties *e.g.*, barley (Borg *et al.* 1958), mustard (Andersson and Olsson 1954), wheat (Swaminathan *et al.* 1967) and rice (Futsuhara 1968).

A programme on rice breeding through induced mutations was initiated in 1964 at the Atomic Energy Agricultural Research Centre, Tandojam, West Pakistan. Some of the results have been published recently (1968). The present irradiation experiment with rice was undertaken in 1967 with a view to obtaining:

(*a*) Preliminary information on the frequency and spectrum of chlorophyll mutations.

(*b*) Dwarf, semi-dwarf or short-culm types with better response to heavier doses of fertilizer for a higher yield.

(*c*) Early maturing types with increased yield as compared to the mother variety.

Although the experiment is still in progress, some useful results have been obtained and are reported in this paper.

Materials and Methods

The characteristics of the rice varieties used in this investigation are as follows:

(1) Dokri Basmati: Early maturing, fine quality variety with shorter and stiff straw.

(2) Jajai-77: Medium late, fine scented variety with tall growing habit.

Neutron irradiation of seeds was done at the International Atomic Energy Agency, Vienna. For gamma-ray treatments a Co-60 source was used. The radiation doses used in this experiment are given in Tables 1 and 2.

The M_1 generation was grown in summer 1967. All the M_1 plants were harvested individually and seed fertility of the longest spike from each plant was studied.

The M_2 populations were screened for chlorophyll mutations at the seedling stage and viable mutations at the adult plant stage.

For chlorophyll mutation studies the longest spike from each M_1 plant was sown, without threshing, as an M_2 strain. Chlorophyll mutants were scored when the seedlings were 14 days old. While arranging experimental results, M_2 strains with less than 10 seedlings, were discarded. Mutation frequency was expressed as number of mutations per 100 M_1 spikes and also as number of mutants per 1000 M_2 seedlings. The segregation ratio for each treatment was pooled and expressed as a percentage of mutants in total no. of M_2 seedlings tested in mutated M_2 strains. Chlorophyll mutations were classified into 4 groups *i.e., albina* (white), *xantha* (yellow), *viridis* (light green) and others (no definite pattern of chlorophyll destruction). Chlorophyll mutation studies were carried out in a field nursery from May to July, 1968. Calculation of viable mutation rate was made on the basis of the number of M_2 plants that survived till maturity.

Results

A. *Studies in the M_1 generation*

The data on seed fertility of M_1 plants as expressed in per cent of control, are presented in the first column of Table 1. In both the varieties seed fertility decreased following neutron and gamma irradiations. But the decrease was not proportional to the increase in dosage. From the data it is apparent that Jajai-77 is more radio-resistant than Dokri Basmati.

B. *Studies in the M_2 generation*

(*a*) Chlorophyll mutations

Results of the chlorophyll mutation studies are summarised in columns 2-5 of Table 1. In the variety Dokri Basmati, mutation frequency per 100 M_1 spikes as well as per 1000 M_2 seedlings, was found to be highest in 1800 r neutron irradiation treatment, but at 1300 r the mutation frequency was lower than the 1000 r treatment. Following gamma-irradiation, both mutations per 100 M_1 spikes and mutants per 1000 M_2 seedlings increased upto 30000 r and then decreased at higher doses, though not proportional to the doses.

In Jajai-77, both the number of mutations per 100 M_1 spikes and of mutants per 1000 M_2 seedlings increased with the doses of neutron irradiation except in the highest dose (1800 r) where a remarkable reduction in mutation frequency can be observed. Following gamma irradiations, on the other hand, mutations per 100 M_1 spikes decreased with the increase in doses while the frequency of mutants per 1000 M_2 seedlings increased upto 30000 r and then decreased at higher doses.

In general, segregation ratio increased with the increase in doses with the exception that in Dokri Basmati the highest segregation ratio was obtained in neutron irradiation with the 1000 r and in Jajai-77, the segregation ratio decreased remarkably at the 1800 r following neutron irradiations.

As regards the spectrum of chlorophyll mutations induced by neutron or gamma-ray treatments, the highest relative frequency was that of albina followed by viridis type in both the varieties (Table 2).

(*b*) Viable mutations

Data pertaining to the frequency of viable mutations isolated in the M_2 generation are tabulated in the last 2 columns of Table 1. In Dokri Basmati the highest viable mutation rates of 24.0‰ and 26.0‰ were obtained after neutron and gamma-ray treatments respectively. In Jajai-77, however, the highest mutation rate was 55.0‰ for neutron and 74.0‰ for gamma-ray treatments.

The spectrum of viable mutations is given in Table 3. In Dokri Basmati, the viable mutant was restricted to the short-culm type only. In Jajai-77, on the other hand, the viable mutation types included a wide variety of variants consisting of physiological mutants pertaining to maturity (like early and late) as well as morphological ones relating to changes in plant height (Fig. 1) and grain size and shape (Fig. 2) totalling to seven types. Studies on the breeding behaviour of all the viable mutants will be followed in the next generation.

Discussion

The results on seed fertility (Table 1) indicate that the effects of both neutron and gamma-irradiations are not equal in the two varieties. In their response to irradiation treatments, Jajai-77 appeared to be more resistant than Dokri Basmati. It has now been established that plants respond differently to irradiation depending on their variety. Mikaelsen and Halvorsen (1953) have found that two barley varieties responded differently to irradiation. These authors have attempted to interpret this phenomenon in terms of the physiological traits of the two varieties (because one has a longer and the other a shorter growing season) and of their respective seed sizes.

Fig. 1.—Left: Control. Right: Mutations for plant height, isolated from the irradiated progenies of rice variety Jajai-77.

Of the two estimates of mutation rate used in the present study (Table 1), the one on the M_2 seedling basis is a better estimate, as has been discussed by Gaul (1961). For this reason the mutation rate on the M_2 seedling basis is discussed here. In general both chlorophyll and viable mutation rates increased at lower doses and then decreased at higher doses. This might be due to the fact that the unadaptable mutations become eliminated at higher doses.

Most of the chlorophyll mutations are recessive, and theoretically it is expected that they will segregate in 3:1 ratio (25%). But in the present investigation the segregation ratios showed a clear deficit of recessives (Table 1). These deviations from the 3:1 ratio might be due to chromosome aberrations associated with chlorophyll mutations resulting in gametic elimination.

M_2 segregation ratios of chlorophyll mutations increased with increasing radiation doses, indicating a progressive increase in the average size of mutated sectors in M_1 spikes. This observation is in agreement with the results obtained in rice by Yamaguchi and Miah (1964) and Bekendam (1961).

Chlorophyll mutation spectrum following treatment with chemical mutagens varies from the spectrum obtained with radiation treatment in barley. Radiation

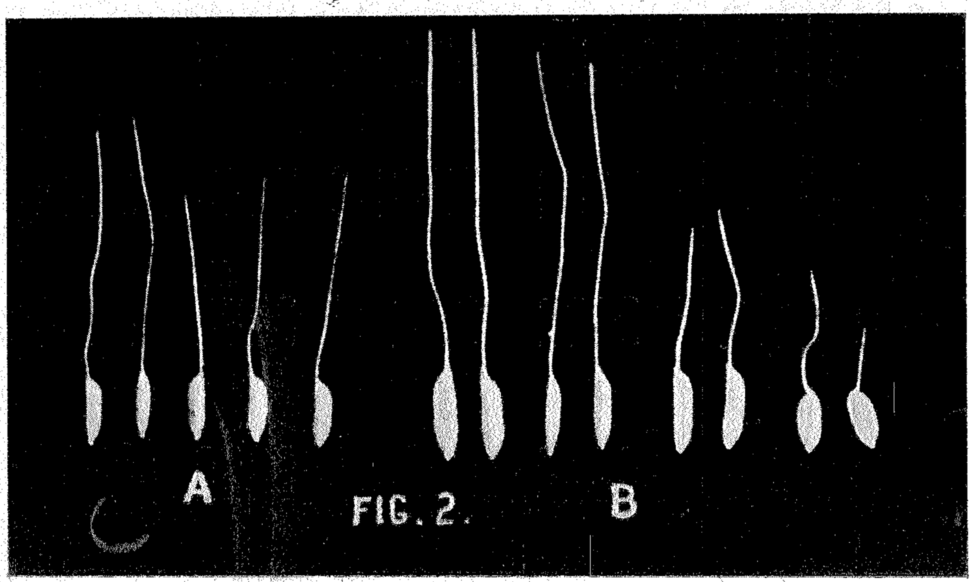

Fig. 2.—Left: Control. Right: Mutations for grain size and shape, isolated from the irradiated progenies of rice variety Jajai-77.

TABLE 1

Fertility in M_1, frequency of chlorophyll and viable mutations in M_2 in rice, varieties Dokri Basmati and Jajai-77 following neutron and gamma-irradiations.

Variety	Treatment, dose inr	Seed fertility % of control	Mutations/ 100 M_1 spikes	Chlorophyll mutations		Segregation ratio %	Viable mutations	
				M_2 seedlings analysed	Mutants/ 100 M_2 seedlings		M_2 plants studied	Mutants/ 1000 M_2 plants
Dokri Basmati	*Control*	—	—	5468	—	—	337	—
	Neutron							
	1,000	58.0	16.4	3468	21.9	15.4	412	14.6
	1,300	42.5	8.1	2791	8.2	8.4	417	24.0
	1,500	43.5	17.0	2474	16.2	11.2	413	14.5
	1,800	36.5	26.3	2087	34.5	13.6	420	11.9
	Gamma-rays							
	20,000	74.0	22.5	1847	8.1	3.6	356	26.9
	30,000	59.4	30.6	1607	26.8	8.8	383	26.1
	40,000	48.1	15.2	1260	17.5	11.4	390	23.1
	50,000	39.6	23.2	1608	24.9	10.7	409	12.2
Jajai-77	*Control*	—	11.5	9848	1.4	1.2	385	7.8
	Neutron							
	1,000	71.3	21.2	4561	6.8	2.7	417	45.6
	1,300	52.3	32.7	5494	25.3	7.9	418	50.2
	1,500	49.2	33.0	5428	50.5	12.8	419	55.0
	1,800	58.3	19.4	6098	12.0	7.1	517	16.8
	Gamma-rays							
	20,000	75.2	35.5	6362	14.0	3.7	420	28.6
	30,000	57.9	20.0	4165	18.3	7.4	418	55.0
	40,000	55.0	16.5	3998	17.0	9.4	420	57.1
	50,000	45.0	15.1	3336	11.4	10.4	419	74.0

TABLE 2

Spectrum of chlorophyll mutations (values in % of total mutations) in M_2 in rice varieties Dokri Basmati and Jajai-77 following neutron and gamma - irradiations.

Variety	*Treatment, doses in r*	*Albina*	*Xantha*	*Viridis*	*Others*	*Total no. of mutations*
Dokri Basmati	Control	—	—	—	—	—
	Neutron					
	1,000	57.1	—	—	42.9	14
	1,300	65.2	—	30.4	4.4	23
	1,500	50.0	7.5	40.0	2.5	40
	1,800	66.7	5.6	9.7	11.0	72
	Gamma-rays					
	20,000	33.3	6.7	53.3	6.7	15
	30,000	9.3	9.3	51.2	30.2	43
	40,000	77.3	9.1	9.1	4.5	22
	50,000	30.0	7.5	45.0	17.5	43
Jajai-77	Control	57.1	—	—	42.9	14
	Neutron					
	1,000	48.4	—	32.3	19.3	31
	1,300	54.7	20.9	17.3	7.1	139
	1,500	54.0	25.9	4.7	16.1	274
	1,800	78.1	—	4.1	17.8	73
	Gamma-rays					
	20,000	10.1	15.7	55.1	19.1	89
	30,000	47.4	7.9	43.4	1.3	76
	40,000	41.2	38.2	16.2	4.4	68
	50,000	73.7	—	26.3	—	38

TABLE 3

Types and number of viable mutations isolated in M_2 in rice varieties Dokri Basmati and Jajai-77 following neutron and gamma-irradiations.

Variety	*Types of Mutations*	*Number Isolated*
Dokri Basmati	Short culm	57
Jajai-77	1. Dwarf	41
	2. Short-culm	89
	3. Long grain	10
	4. Short grain	2
	5. Slender grain	1
	6. Early	6
	7. Late	15

treatments generally produce higher proportion of albina mutations in comparison to viridis or xantha types (Ehrenberg *et al.* 1956, Swaminathan *et al.* 1962). This agrees well with our results presented in Table 2.

From the spectrum of viable mutations (Table 3), it is evident that among the viable mutations, short-culm mutant is the most common followed by dwarf type. In rice, mutations for earliness, short-culm, disease resistance, large grain and other useful characters have been induced through radiation treatments by many workers (Masima and Kawai 1958; Toriyama and Futsuhara 1962).

From the results reported here it can be concluded that both neutron and gamma-rays were highly effective in inducing mutations in rice. Some of the viable mutations isolated in the present study appear to be of economic use from the agricultural point of view.

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