The Use of Gamma Irradiation for Inducing High-Protein Rice

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ABSTRACT

This study investigated the possibility of using gamma irradiation to improve protein content in the rice breeding program in Egypt. Brown rice samples from M_2 and M_3 mutants of three varieties, Giza 172, Ratna, and IR480, were irradiated at three doses of cobalt 60 gamma rays. Protein content of the irradiated samples was compared with an unradiated control. Coefficients of variation were compared to elucidate which varieties might contain genetic material capable of increasing protein content. The results indicated that considerable improvement in protein content could be achieved by breeding selections of Giza 172; in M_3 it reached 13.31% protein after irradiation at 10,000 roentgen, an increase of 47% over the control. Materials from IR480 showed the least variability, and hence, least potential for improvement.

Protein content of brown rice ranges from about 5 to 17% (Juliano et al 1968, Cruz et al 1970). An increase in protein percentage, whether caused by genetic or environmental factors, will have similar effects on the amino acids composition of rice protein (Beachell et al 1972). A plant breeder must identify high-protein sources from all possible materials and concentrate or enforce their genetic factors for protein, along with those for high yield, in new hybrids. This is the classical method by which the International Rice Research Institute (IRRI 1973) was able to breed a rice variety with 18–23% more protein than the check variety IR8 without any significant difference in grain yield.

Recent breeding methods use mutations to realize these objectives. These methods use chemical and physical agents to induce valuable mutants. Hag et al (1971) successfully used gamma radiation to obtain three rice mutants having higher protein than their parents; however, more study on radiosensitivity of rice varieties is still needed. The study reported here investigated the possibility of using gamma irradiation in improving protein content in the rice breeding program in Egypt.

MATERIALS AND METHODS

Brown rice samples from M_2 and M_3 mutants were obtained from the Rice Research Section, Agricultural Research Center, Cairo. Three varieties, Giza 172, Ratna, and IR480, were irradiated at three doses of cobalt 60 gamma rays: 5,000, 10,000, and 15,000 roentgen (R). Protein content of the samples was determined by an AOAC procedure (AOAC 1970).

The effect of radiation was evaluated through estimating the coefficients of variation (CV) for each treatment and for the overall treatments in both M_2 and M_3 generations. When analysis of variance showed significant generational differences, the phenotypic variance was partitioned into its components: the genetic portion due to irradiation treatments, σ_g^2, and the environmental portion, MS_e; heritability, h^2; and an expected genetic gain by selection from this population, *Gs*, were calculated (Allard 1960).

RESULTS AND DISCUSSION

Analyses of variance of protein content resulting from gamma irradiation in the M_2 and M_3 generations for the three rice varieties studied are shown in Table I. The statistical parameters are presented in Table II.

Variation between irradiation levels was significant only for Giza 172. The highest coefficients of variation obtained were for Giza 172, being 21% and 24% for the M_2 and M_3 generations, respectively (Table II). However, the highest CVs relative to irradiation dose did not exceed 16 and 18% for 15,000 R in M_2 and 10,000 R in M_3, respectively.

Because mutation occurs randomly, and mutants are determined by screening large numbers of individuals, it may be important to check the extreme values for the ranges shown in Table II. The highest protein in M_2 of Giza 172 was associated with the highest dosage (15,000 R). It amounted to 12.60%, about 29% more than the control (Giza 172). In M_3 it reached 13.31% at 10,000 R, an increase of 47% over the control.

These results indicate that considerable improvement in protein content could be achieved by breeding selections of Giza 172. By selecting 5% of the best genotypes, improvement by an increment of 1.46 for the M_2 generation mean and 2.06 for the M_3 generation mean could be expected.

For rice of the Ratna variety, the overall CVs amounted to 11% for M_2 and 16% for M_3. The highest individual treatment CV values were associated with 15,000 R in the M_2 and 5,000 R in the M_3 generations, respectively. At 17 and 19%, they seem to result from the extremes at both levels. The first showed a high protein value of 14.76%, an excess of 20% over the control; the second showed 17.54% protein, an excess of 43%. This indicates the existence of valuable genotypes, at the lowest doses, which may be raised in frequency when a larger sample size is used.

Materials from IR480 showed the least variability. The overall CV was 10% in M_2 and 12% in M_3, whereas CVs for each level of irradiation in M_2 and M_3 were never above the low value of 13% (associated with 10,000 R in M_2 and 5,000 R in M_3). Mean values of protein content were generally less than the control. The highest value of 15.71%, reported for 15,000 R in M_2, did not add more than 9% to the control. These results show no successful response to be expected by irradiating IR480. Because this variety reported the highest control protein content (14.48%), it seems to be at maximum capacity in respect to its genotypic constitution, which probably had undergone breeding for its protein content.

In general, a cultivar that has undergone little or no breeding for protein, such as as Giza 172, is more likely to produce gains from irradiation than those already bred on this basis, or having higher protein, such as Ratna and IR480.

TABLE I
Analysis of Variance of Protein Contents for M_2 and M_3 Generations of the Three Rice Varieties

Variety	Source of Variation	M_2 df[a]	M_2 Mean Squares[b]	M_3 df[a]	M_3 Mean Squares[b]
Giza 172	Radiation	3	83.1818**	3	115.8354**
	Error	73	1.2235	78	0.5874
Ratna	Radiation	3	3.1493	3	0.6690
	Error	44	1.5034	32	3.3251
IR 480	Radiation	3	1.5194	3	2.7448
	Error	14	1.9052	13	3.0467

[a] Degrees of freedom.
[b] **, Significant at the $P = 0.01$ confidence level.

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TABLE II
Statistical Parameters of Protein Content for M_2 and M_3 Generations of Giza 172, Ratna, and IR480

Variety/ Radiation Dosage (R)	M_2				M_3			
	No. of Samples	Range	Mean[a]	CV	No. of Samples	Range[a]	Mean	CV
Giza 172[b]								
Control (0)	1	···	9.83	···	1	···	9.83	···
5,000	33	···	8.66	14	49	13.04–6.61	9.65	4
10,000	13	12.14–8.29	10.30	11	5	13.31–8.31	10.98	18
15,000	30	12.60–8.76	10.13	16	27	11.86–9.87	10.81	12
Overall variation				21				24
Ratna								
Control (0)	1	···	12.29	···	1	···	12.29	···
5,000	18	13.30–10.16	11.83	1	16	17.54–10.30	13.15	19
10,000	19	13.84–10.10	12.17	9	14	17.04–10.54	13.46	17
15,000	10	14.76–8.91	10.99	17	5	14.39–11.08	12.99	12
Overall variation				11				16
IR480								
Control (0)	1	···	14.48	···	1	···	14.48	···
5,000	5	15.40–11.30	13.32	12	6	14.86–11.59	12.77	13
10,000	4	15.25–11.40	13.32	13	4	14.73–12.36	13.69	10
15,000	8	15.71–12.16	14.30	1	6	14.54–10.81	12.61	12
Overall variaton				10				12

[a] Mean values were adjusted to fix control values for the two generatiosn.
[b] Heritability (h^2) was calculated as 0.47 and 0.71 for generations M_2 and M_3, respectively; genetic gain (Gs) was calculated as 1.46 and 2.06, respectively, for the M_2 and M_3 generations.

The study shows, also, the possibility of inducing considerable variation in protein content to be utilized in raising the nutritional value of rice grains.

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