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 M₂ and M₃ 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 unirradiated 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 M₂ 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 M₂ and M₃ 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 M₂ and M₃ generations. When analysis of variance showed significant generational differences, the phenotypic variance was partitioned into its components: the genetic portion due to irradiation treatments, \( \sigma_g^2 \), and the environmental portion, \( \sigma_e^2 \); heritability, \( h^2 \); and an expected genetic gain by selection from this population, \( G_s \), were calculated (Allard 1960).

RESULTS AND DISCUSSION

Analyses of variance of protein content resulting from gamma irradiation in the M₂ and M₃ generations for the three rice varieties studied are shown in Table I. The statistical parameters are presented in Table II.

For rice of the Ratna variety, the overall CVs amounted to 11% for M₂ and 16% for M₃. The highest individual treatment CV values were associated with 15,000 R in M₂ and 5,000 R in the M₃ 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 M₂ and 12% in M₃, whereas CVs for each level of irradiation in M₂ and M₃ were never above the low value of 13% (associated with 10,000 R in M₂ and 5,000 R in M₃). Mean values of protein content were generally less than the control. The highest value of 15.71%, reported for 15,000 R in M₂, 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 M₂ and M₃ Generations of the Three Rice Varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Source of Variation</th>
<th>df</th>
<th>Mean Squares</th>
<th>df</th>
<th>Mean Squares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>for M₂</td>
<td></td>
<td>for M₃</td>
</tr>
<tr>
<td>Giza 172</td>
<td>Radiation</td>
<td>3</td>
<td>83.1816**</td>
<td>3</td>
<td>115.8354**</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>73</td>
<td>1.2323</td>
<td>78</td>
<td>0.5874</td>
</tr>
<tr>
<td>Ratna</td>
<td>Radiation</td>
<td>3</td>
<td>3.1493</td>
<td>3</td>
<td>0.6690</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>44</td>
<td>1.5034</td>
<td>32</td>
<td>3.3251</td>
</tr>
<tr>
<td>IR 480</td>
<td>Radiation</td>
<td>3</td>
<td>1.5194</td>
<td>3</td>
<td>2.7448</td>
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<tr>
<td></td>
<td>Error</td>
<td>14</td>
<td>1.9052</td>
<td>13</td>
<td>3.0467</td>
</tr>
</tbody>
</table>

\(^a^{Degrees of freedom.}
\(^{**}Significant at the \( P = 0.01 \) confidence level.

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### TABLE II
Statistical Parameters of Protein Content for M₂ and M₃ Generations of Giza 172, Ratna, and IR480

<table>
<thead>
<tr>
<th>Variety/ Radiation Dosage (R)</th>
<th>M₂</th>
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<th>M₃</th>
<th></th>
</tr>
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<td>Range</td>
<td>Mean</td>
<td>CV</td>
<td>No. of Samples</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>...</td>
<td>9.83</td>
<td>...</td>
</tr>
<tr>
<td>5,000</td>
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<td>8.66</td>
<td>14</td>
<td>49</td>
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<tr>
<td>10,000</td>
<td>13</td>
<td>12.14-8.29</td>
<td>10.30</td>
<td>5</td>
</tr>
<tr>
<td>15,000</td>
<td>30</td>
<td>12.60-8.76</td>
<td>10.13</td>
<td>27</td>
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<tr>
<td>Overall variation</td>
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<tr>
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<td>...</td>
<td>1</td>
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<tr>
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<td>13.32</td>
<td>6</td>
</tr>
<tr>
<td>10,000</td>
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<td>15.25-11.40</td>
<td>13.32</td>
<td>4</td>
</tr>
<tr>
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<td>8</td>
<td>15.71-12.16</td>
<td>14.30</td>
<td>6</td>
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<tr>
<td>Overall variation</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

*Mean values were adjusted to fix control values for the two generations.

Heritability \( h^2 \) was calculated as 0.47 and 0.71 for generations M₂ and M₃, respectively; genetic gain \( G_s \) was calculated as 1.46 and 2.06, respectively, for the M₂ and M₃ 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.

**LITERATURE CITED**


