INHERITANCE OF RESISTANCE TO PHYTOTOXICITY OF PHENYL MERCURIC ACETATE IN RICE

by

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Differences in the reaction of rice varieties (*Oryza sativa* L.) to the toxicity of phenyl mercuric acetate (PMA) have been reported by Okamoto *et al.* (1960). Japonica varieties are generally resistant whereas most indica ones are highly sensitive to the toxicity of PMA. A similar pattern of response also prevails in the japonica-type "ponlai" varieties and indica-type "native" varieties of Taiwan. The toxicity of PMA, especially on most indica varieties, was probably due to its stability on rice leaves and its strong adsorption and absorption by rice leaves (Okamoto and Hamaya, 1962).

Okamoto *et al.* (1960) reported that resistance to PMA was probably inherited as a recessive character, basing on the reaction of F_1 plants from japonica× indica crosses. The experiment conducted by the Genetics Division of the National Institute of Agricultural Sciences at Hiratsuka, Japan (1962) did not reveal the number of genes conditioning the reaction to PMA toxicity. Since sources of high resistance for the rice blast disease in the temperate zone often come from indica varieties, information with regard to the inheritance of reaction to PMA toxicity may be useful in breeding rice varieties for resistance to blast disease and PMA toxicity. Usually a variety moderately resistant to blast is considered to be commercially acceptable when chemical control is also practiced.

Studies on the inheritance of reaction to agricultural chemicals were also reported in barley (Wiebe and Hayes, 1960) and maize (Grogan *et al.*, 1963). The purpose of this experiment was to investigate the inheritance of resistance to PMA toxicity in rice.

MATERIALS AND METHODS

Japonica-type "ponlai" variety, Chianung 242, and indica-type "native" variety, Taichung Native 1, were used as parents and F_1 seeds of reciprocal crosses were obtained. F_1 plants of the cross Chianung 242×Taichung Native 1 were back-crossed to Chianung 242 (BC_1), Taichung Native 1 (BC_2), and also selfed to produce F_2 seeds. Chianung 242 is resistant and Taichung Native 1 is sensitive to the toxicity of PMA.

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F_1, F_2, BC_1, and BC_2 populations were investigated for the inheritance of resistance to PMA toxicity in the field and greenhouse. Ceresan lime, an organomercuric compound, was used as a source of PMA in this study. It contains 0.25% mercury and is widely used as a fungicide for controlling rice blast disease in Taiwan. In the field test, Ceresan lime was dusted 50 days after transplanting. Special attention was paid in dusting to cover every leaf blade evenly with dust in order to prevent possible "escapes". In the greenhouse test, seeds were planted in the clay pots and Ceresan lime was applied 30 days after sowing or 4–5 leaf stage. When symptoms developed about one week after dusting, each plant or seedling was graded for the resistance according to the following system:

0: No symptoms, leaf blades green.
1: Slight chlorosis on leaf blades.
2: Moderate chlorosis with yellowish orange color on leaf blades.
3: Yellowish to brownish orange color accompanied slight wilting of leaf blades.
4: Brownish orange color with severe wilting of leaf blades.

The statistical analysis outlined by Mather (1949) and by Hayman and Mather (1955) were used in this study for estimating the number of effective factors.

This study was conducted in the first crop of 1966 at Chiayi Agricultural Experiment Station.

EXPERIMENTAL RESULTS

1. Analysis of Means.

The frequency distributions, means, and variances of the various populations are given in Table 1.

Chianung 242 showed no symptoms, whereas Taichung Native 1, mostly of a class 4 reaction, gave mean values of 4 and 3.96 respectively for PMA toxicity in the greenhouse and field tests. Tests in the greenhouse and field were generally the same, showing that seedlings and plants responded similarly to PMA toxicity. The means of F_1 plants were 2.1 and 2.0 in the reciprocal crosses which were neer to the average of the means of the two parents, indicating that sensitivity of PMA toxicity was not completely dominant to insensitivity. The F_1 plants obtained from reciprocal crosses showed the same response, suggesting that no maternal influence was involved. F_2 seedlings and plants showed continuous segregations in their response to PMA toxicity. The mean values of F_2 populations were 2.02 and 2.03 for the greenhouse and field tests respectively, which were similar to those of F_1. The means of BC_1 and BC_2 were 1.06 and 3.06 respectively.

2. Scaling Tests.

Since frequency distributions of the segregating populations for PMA toxicity appeared continuous, a scaling test was made to find out whether the classes of

Table 1. Frequency distribution, mean, and variance in parental varieties and hybrid populations of Chianung 242×Taichung Native 1

Population	Classes of toxicity*					Total	Statistic	
	0	1	2	3	4		Mean	Variance
	Greenhouse test							
P_1	272	—	—	—	—	272	0	0
P_2	—	—	—	—	316	316	4	0
F_2	36	161	231	169	37	634	2.02	0.982
	Field test							
P_1	56	—	—	—	—	56	0	0
P_2	—	—	—	2	52	54	3.96	0.036
$F_1(P_1 \times P_2)$	—	—	36	4	—	40	2.1	0.092
$F_1(P_2 \times P_1)$	—	--	14	—	—	14	2.0	0
F_2	31	126	216	131	38	542	2.03	0.984
BC_1	27	55	34	—	—	116	1.06	0.527
BC_2	—	—	7	18	9	34	3.06	0.481

* Frequency distribution of dusted plants and seedling in five classes. Class 4=heaviest toxicity.

grading used in this study are adequate for biometrical analysis. It is expected that if the gene effects are additive on the average in the chosen scale, the following relations would hold:

$$A=2\overline{BC}_1-\overline{F}_1-\overline{P}_1=0,\ B=2\overline{BC}_2-\overline{F}_1-\overline{P}_2=0,\ \text{and}\ C=4\overline{F}_2-2\overline{F}_1-\overline{P}_1-\overline{P}_2=0.$$

The values calculated for A, B, and C were 0.02 ± 1.48, 0.06 ± 1.43, and 0.02 ± 4.01, respectively, which were all insignificant. Hence, the scale used in this study was adequate for the analysis of the data and no transformation is needed.

3. Number of effective factors.

The number of effective factors was estimated by Mather's (1949) formula, $K_1=(\overline{P}_1-\overline{P}_2)^2/4D$. In the field test, D was estimated by simultaneous solution of the following equations:

$$V_{F2}=0.5D+0.25H+E_1=0.984$$
$$V_{BC1}+V_{BC2}=0.5D+0.5H+2E_1=1.008$$
$$F_1=0.032$$

The calculated values of D were 1.920 and 1.964 for the field and greenhouse tests, respectively. The substitution of D in the formula gave $K_1=2.045$ for the field test and $K_1=2.037$ for the greenhouse test. The results indicated that at least two effective factors conditioned sensitivity to PMA. The symbols Pma_1 and Pma_2 are tentatively designated to indicate these two alleles for high sensitivity to PMA.

4. Dominance and Interaction.

Mather's test (1949) gave the degree of dominance (h/d) at −0.130 in the field test, while dominance effect (d) calculated by the method of Hayman and Mather

(1955) gave a value of 0.193 indicating that there might be no dominance in these two pairs of alleles. The value for the additive effect of genes (a) was quite high, being 1.998 which revealed that a large part of the variation was due apparently to the fixable genetic effect. Homozygote-homozygote, homozygote-heterozygote, and heterozygote-heterozygote interactions were small and the latter two were negative, the values being 0.124, -0.016, and -0.297, respectively. No indication of the existence of epistasis between these two genes was detected.

DISCUSSION

It was observed in this experiment that the F_1 plants gave predominately clase 2 reaction which is intermediate between the insensitive parent (class 0) and the sensitive parent (class 4). The result was slightly different from that of Okamoto *et al.* (1960). They reported that the type of symptom and the grade of toxic effect on the F_1 plants between a resistant japonica parent and another sensitive indica parent were the same as those of the sensitive indica parents. The difference in results may be caused by the difference in the grading system used for evaluating the degree of leaf reaction to PMA phytotoxicity. The levels of sensitivity of parent varieties to PMA and the stability of the varietal reactions may also influence the degree of sensitivity. The parental varieties used for the present study exhibited extremely good contrasting symptoms and stable reactions.

It was found that two plants of Taichung Native 1 were classified as class 3, though most of them were of class 4; whereas four class 3 plants were found in the F_1 plants which were predominately of class 2. The former may be attributable to insufficient dusting of Ceresan lime and the latter, to overdusting. The leaf blades of these F_1 plants were found to be of dark green color and with tender tissues, showing that nutritional status may also be a factor affecting the degree of resistance. These observations suggest that a similar situation could happen in the segregating generations, and there is a possibility of misclassification in the F_2 and backcross data. Thus, progeny test in the F_3 generation or selfed progeny of the backcross plants appear necessary. In the progeny tests, readings are made on the basis of the whole line rether than a single plant. Therefore, more accurate data may be available.

Interest in developing new varieties from indica-japonica crosses has increased in recent years, and varieties or lines of various combinations of the two types are being selected. As a result, classification of the newly developed varieties into a distinct type has become increasingly difficult. PMA reaction may, therefore, serve as an additional criterion for the classification, since indica and japonica types seem to be associated with differences in PMA reaction.

The reaction of PMA toxicity was found to be not related to rice blast resistance (Okamoto *et al.*, 1960), and varieties resistant to both PMA toxicity and blast disease could be developed. Chang *et al.* (1965) reported that in Taiwan, very few selections resistant for rice blast developed by various experiment stations in the past years had been successfully released as commercial varieties simply because most of the resistant selections were associated with one or two poor agronomic traits. Therefore, it would appear practical to breed a high yielding variety with a moderate level of blast resistance. Resistance to PMA toxicity is usually not considered during the process of selection under the present breeding program. Therefore, it is highly likely that varieties resistant to rice blast with different degrees of PMA tolerance can be selected, since it was observed that multiple genes control the reaction to PMA toxicity. At present, PMA remains to be the most effective chemical for blast disease control in Japan, Korea, and Taiwan, and organomercuric compounds of lesser toxicity to rice plants currently available are undesirable as far as their effectiveness in blast disease control are concerned (Yamamoto and Okamoto, 1964). Obviously, a total control could be achieved if the commercial varieties are also insensitive to the chemical. Thus, selection for PMA resistance may be of practical value in the future breeding programs especially when one PMA-sensitive variety is used as a parent.

SUMMARY

The inheritance of the marked differences between rice varieties in response to phenyl mercuric acetate (PMA) dust was investigated in the first crop of 1966 at the Chiayi Agricultural Experiment Stations. The resistant japonica-type variety, Chianung 242, was crossed with a sensitive indica variety, Taichung Native 1, and their F_1, F_2, BC_1, and BC_2 plants were used in the testing. The individual seedlings or plants were classified for resistance to PMA toxicity based on an arbitrary scale devised by the authors. The observed data agreed with the hypothesis that sensitivity to PMA toxicity is controlled by at least two pairs of alleles, Pma_1 and Pma_2. The possible implication of tolerance to PMA toxicity on the future rice breeding program is also discussed.

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水稻抗有機汞殺菌劑藥害之遺傳

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摘　　要

本試驗以分析水稻品種抗有機汞殺菌劑藥害之遺傳現象爲目的。供試材料爲抗藥害品種嘉農242號與感受品種臺中在來1號，其 F_1, F_2, BC_1 及 BC_2。分別在溫室及田間噴施西樂生石灰，並按各個體藥害之輕重分級歸類，由此分析結果得知，水稻抗有機汞殺菌劑藥害之性狀，至少受兩對遺傳因子 Pma_1 與 Pma_2 所支配。