Quantitative Resistance of Rice to Blast Disease

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ABSTRACT

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Eighteen rice cultivars used for differentiating physiologic races of *Pyricularia oryzae* in the Philippines were repeatedly exposed in the blast nursery, and seven of them artificially inoculated with 40 single-spore isolates. The number of lesions that formed on individual cultivars was negatively correlated with the percentage of resistant reactions of each cultivar to 242 races of *P. oryzae* in the Philippines, as well as to the 69 races identified during the tests. Cultivars resistant to most races had very few lesions. Accumulation of many "vertical" or "specific" resistance genes in a cultivar against many specific races of *P. oryzae* appears to confer "horizontal" or "general" resistance to blast. Comparison of 40 single-spore isolates for pathogenicity indicated that the spore populations of the majority of the isolates were heterogeneous, consisting of many different pathogenic races, very much like that in a blast nursery.

When rice cultivars are compared for blast resistance in the field or in a disease nursery, the quantitative expression of resistance is obvious and it varies from none, to a few, to numerous lesions on the leaves. Qualitative rating for blast resistance (susceptible or resistant) is inadequate. An earlier study (8) showed that the difference in the number of lesions (quantitative) is due to the difference in the spectrum of resistance of the cultivars to the fungal races present. Cultivars resistant to many races had few lesions. This quantitative nature of resistance resembled what is commonly referred to as "horizontal" or "general" resistance, but apparently it is conditioned by the presence of several to many "vertical" or "race specific" resistance genes.

The present study explores further the quantitative nature of blast resistance in 18 "differential" rice cultivars, whose spectra of resistance to the Philippine races of the blast pathogens were previously known, under natural as well as artificial inoculation conditions.

MATERIALS AND METHODS

The 18 rice "differentials" used for the international and the Philippine race differentiation of *Pyricularia oryzae* are listed in Table 1. The International Rice Research Institute (IRRI) staff had inoculated 3,515 isolates from all parts of the Philippines on the 12 Philippine "differentials" and identified 262 races. Of the 262 races, 242 were inoculated on the international "differentials." Each of the 18 cultivars was known to be resistant or susceptible to each particular race. The relative spectrum of resistance of each cultivar was expressed as the percentage of the 242 races to which the cultivar was resistant. For instance, cultivar Zenith was resistant to 218 of the 242 races, therefore the percentage rating was 90, while Khao-tah-haeng 17 was resistant to 26 of the 242 races, the rating was 11% (Table 1). The percentage of isolates to which a cultivar is

TABLE 1. Percentages of 242 *Pyricularia oryzae* races of the Philippines to which each of 18 rice cultivars of the International Rice Research Institute is resistant

Cultivars	Resistance (%)	
	Philippine race[a]	IBN[b]
Zenith (I)[c]	90	93
Pai-kan-tao (P) (P-K-T)	81	90
NP-125 (I)	76	86
Kataktara DA-2 (P) (KAT)	74	90
Kanto 51 (I)	68	74
Dular (I)	68	72
Wagwag (P)	62	86
Chokoto (P)	63	81
CI 5309 (P)	63	80
CO 25 (P)	60	73
Raminad Str. 3 (P,I) (Ram)	43	85
Taichung T.C.W.C. (P) (T.T.C.W.C.)	41	39
Peta (P)	36	69
CI8985 (Lacrosse) (P)	36	53
Caloro (I)	33	32
Sha-tiao-tsao (s) (P,I) (S.T.T.)	31	31
Usen (I)	17	59
Khao-tah-haeng 17 (P) (KTH)	11	47

[a] Percentage of the races to which each cultivar is resistant.
[b] Percentages of resistant readings based on total number of tests; data from IRRI Annual Report for 1971.
[c] (I) = international differential cultivars, (P) = Philippine differential cultivars.

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resistant is considered to be a relative measurement of the spectrum of resistance.

Ten seedlings from each of the 18 cultivars were grown to the five-leaf stage in the greenhouse in plastic trays (25 × 32 × 12 cm). They were then exposed to natural infection in the blast nursery. The trays were arranged in a randomized complete block design with four replications. Exposure varied from 2 to 4 days depending on the number of airborne spores in the blast nursery. After the exposure, the plants were incubated in the greenhouse for 5 days, and the number of susceptible-type lesions was counted on the fifth leaf of five seedlings randomly picked from each replicate tray. Since the size of the leaves of different rice cultivars varies, the number of lesions was converted to number of lesions per 100 cm^2 of leaf area on the basis of average leaf area of the fifth leaf from 10 seedlings.

The experiments were repeated over a period of 6 mo. For the convenience of graphical comparison, the relative number of lesions from each cultivar was obtained by converting the highest number of lesions in any replicate per month into 100 per 100 cm^2 of leaf area. For the analysis of variance the relative number of lesions was arc sine transformed.

Correlation and regression analyses were made using the relative number of lesions as "dependent variable" and, as "independent variables," the cultivars resistant to different percentages of the 242 races reported in the Philippines or to the 69 pathogenic races identified at the time of the experiment.

For studies with artificial inoculations, seven cultivars were selected based on the range of the percentage of races to which each was resistant. Plants at the five-leaf stage were inoculated with a spore suspension containing 1.0–1.5 × 10^5 spores per milliliter, in three replications randomly arranged in the inoculation chambers. Forty single-spore isolates from 26 cultivars were used as inocula. The number of lesions was counted and data transformation and correlation and regression analyses were done as in studies with natural infection. Special inoculation chambers, made of wooden frames covered with polyethylene sheets, were used to obtain uniform deposition of spores in the inoculations.

Isolation, sporulation, inoculation, and race identification were done as described previously (7).

RESULTS AND DISCUSSION

The number of lesions on each of the 18 cultivars exposed in the blast nursery for three tests in 3 mo (Fig. 1) indicated significant differences in resistance among the 18 cultivars. The number of lesions varied monthly, and the interaction between cultivar and month was highly significant, indicating a continuous change in race composition of the fungal population in the blast nursery, as was found earlier (9). Although race composition fluctuated frequently in the blast nursery, the relative difference in quantitative resistance among the 18 cultivars was quite stable.

A high negative correlation ($r = -0.89$) was obtained between the percentage of Philippine races to which each cultivar was resistant (qualitative resistance) and the number of lesions (quantitative resistance) (Fig. 2). Cultivars resistant to many races had fewer lesions than those resistant to few races, and the relationship appeared to be linear.

Because racial population changes in the blast nursery occurred from month to month (9), it was assumed that a still better correlation might exist between quantitative and qualitative resistance of cultivars to races present during the period the quantitative resistance was assessed. To evaluate this proposition, the 18 "differentials" were inoculated artificially with 103 isolates obtained from the susceptible cultivars in one of the tests. The 103 isolates were classified into 34, 46, and 69 races based upon the reactions on three sets of differentials: international, Philippine, and a combination of both as one set of differentials, respectively (Table 2). The percentage of isolates to which each cultivar was resistant was determined. As expected, a higher negative correlation ($r = -0.92$) was observed between the number of lesions and the percentage of isolates to which each cultivar was resistant for the 69 races in the test field (Fig. 3) than for the 242 known races.

The 18 rice cultivars have been grown and evaluated for resistance in the International Blast Nursery (IBN) for 15 or more years. A correlation plotting was made in an attempt to find out the similarity or difference between the frequency of resistance of each cultivar in the Philippines and the relative resistance in the IBN (Table 1, Fig. 4). Cultivars that showed higher resistance evaluated on a worldwide basis also showed higher resistance in the

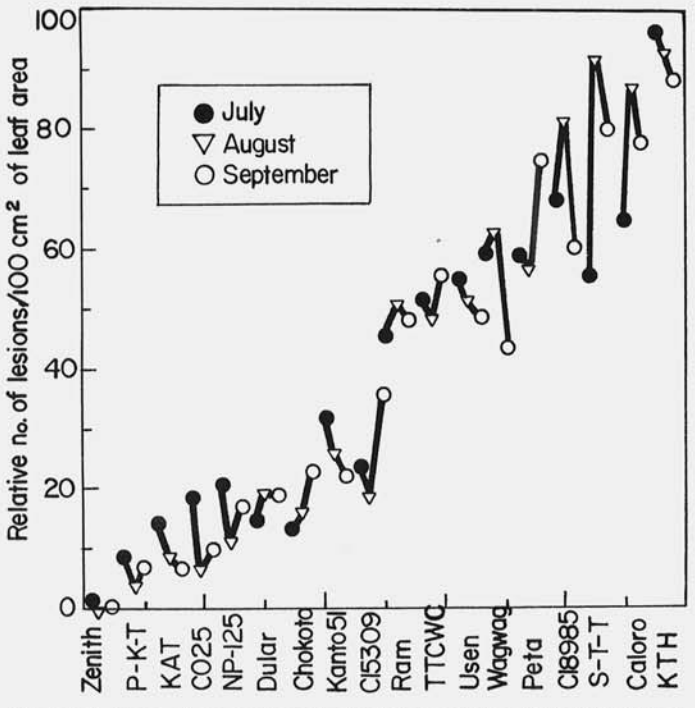

Fig. 1. Blast lesion formation on plants of 18 rice cultivars after exposure in the International Rice Research Institute blast nursery to natural infection by *Pyricularia oryzae* in three tests conducted in July, August, and September 1976.

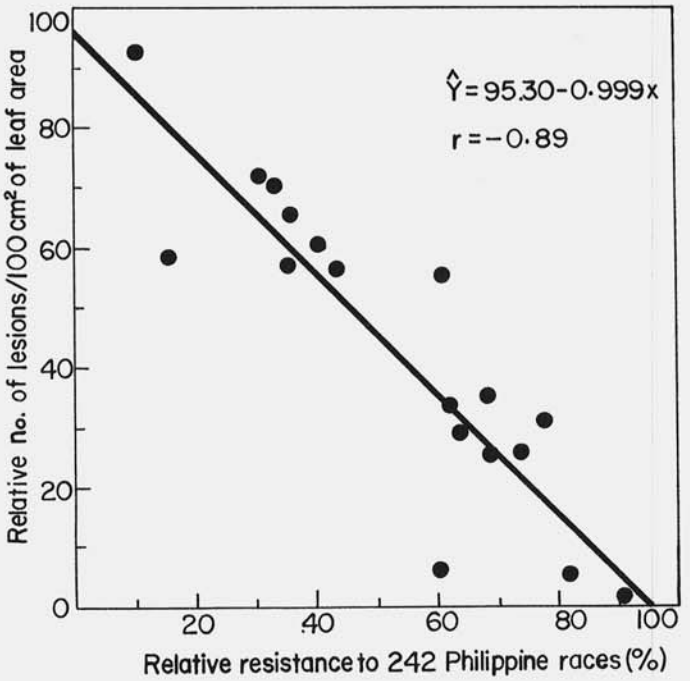

Fig. 2. Relationship between number of lesions (quantitative resistance) formed on plants of 18 rice cultivars in the International Rice Research Institute blast nursery and the percentage of 242 identified Philippine races of *Pyricularia oryzae* (qualitative) to which each cultivar was resistant. (Average number of lesions from six tests; see Table 1 for names of the cultivars).

Philippines. The disparity in this general trend observed in cultivars Peta, Wagwag, and Raminad Str. 3 might be due to the relatively larger number of Philippine races pathogenic to these native cultivars.

The results of artificial inoculation with 40 isolates obtained from 26 different cultivars also clearly demonstrated the general trend that cultivars resistant to many races develop few lesions whereas cultivars resistant to few races develop many lesions (Fig. 5).

P. oryzae was reported to be very variable and to continue producing new races even from single-spore cultures (3,7). On the other hand, fairly stable strains were also reported (4). If the cultures derived from single spores consist of only one race or one virulence type, the cultivars might be expected to have no lesions or many lesions of one type. The spore population of *P. oryzae* appears to be genetically heterogeneous consisting of many pathogenic races, and rice cultivars with resistance to many races

TABLE 2. Reaction of 18 rice blast "differential" cultivars to the races of *Pyricularia oryzae* classified by three sets of "differentials" when artificially inoculated with 103 isolates

Cultivars	No. of races pathogenic to the cultivars			No. of isolates pathogenic to the cultivars (out of 103)
	Out of 34 international races[a]	Out of 46 Philippine races[b]	Out of 69 combined differentials[c]	
Pai-kan-tao	1	1	1	1
CO 25	2	2	2	2
Zenith	5	5	5	6
Kataktara DA-2	10	12	14	20
NP-125	13	16	18	22
CI 5309	13	15	20	25
Chokoto	17	19	24	29
Dular	12	21	24	30
Kanto 51	16	25	29	35
Wagwag	23	22	35	59
Raminad Str. 3	19	24	38	66
Taichung T.C.W.C.	25	25	41	75
Caloro	24	32	45	76
Peta	27	31	49	78
Usen	23	34	48	80
CI8985 (Lacrosse)	30	33	50	83
Sha-tiao-tsao (s)	30	39	61	85
Khao-tah-haeng 17	33	42	65	98

[a] Using eight international "differentials," the 103 isolates were grouped into 34 races.
[b] Using 12 Philippine "differentials," 46 races.
[c] Using all 18 "differentials," combining both as one set, 69 races.

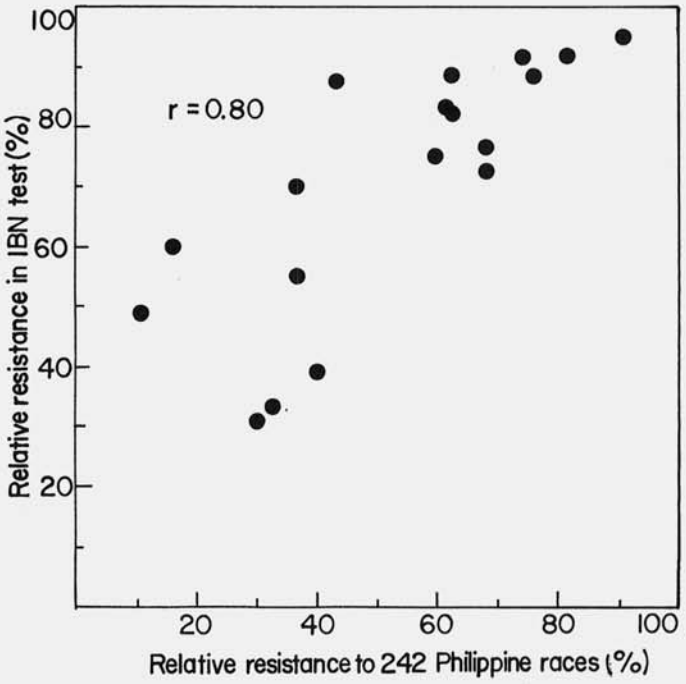

Fig. 4. Correlation between the percentage of resistant reactions of 18 cultivars to 242 Philippine races of *Pyricularia oryzae* and the percentage of resistant reaction in 302 International Rice Research Institute blast nursery tests.

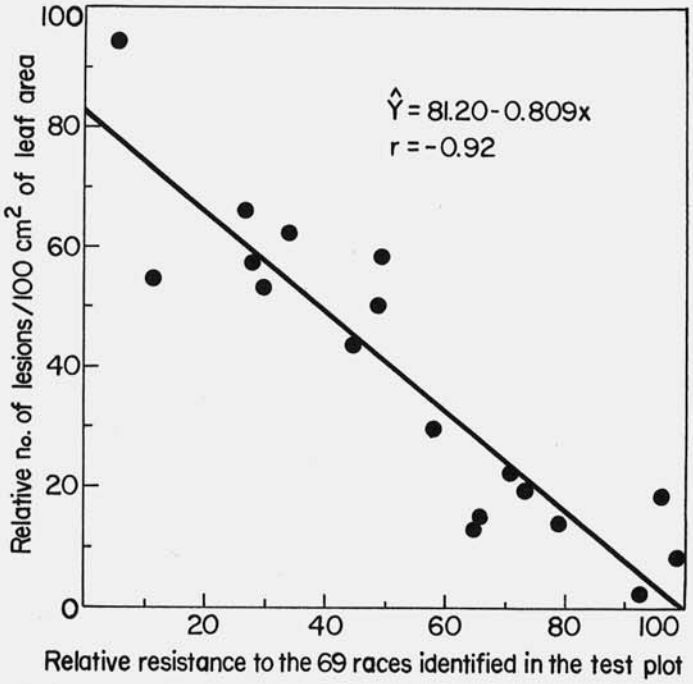

Fig. 3. Relationship between lesion number from natural infection in the International Rice Research Institute blast nursery and percentage of 69 races of *Pyricularia oryzae* detected in the nursery to which each rice cultivar was resistant.

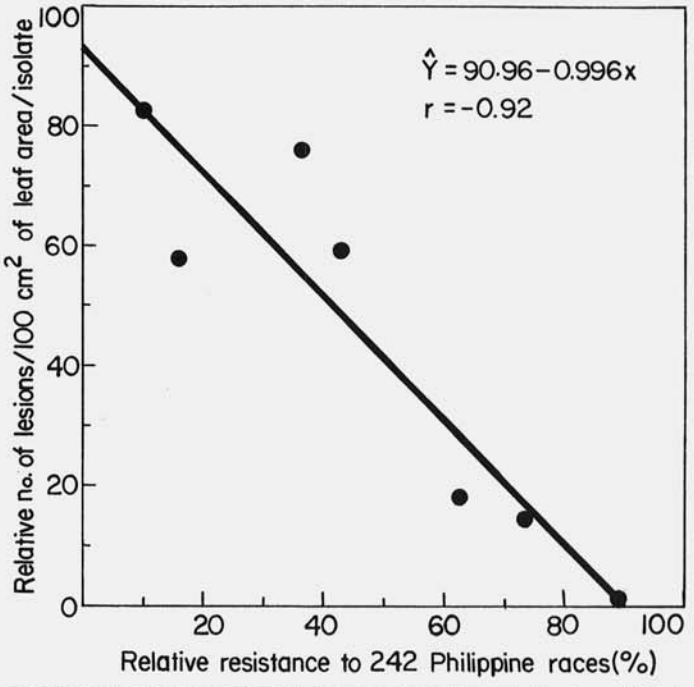

Fig. 5. Number of lesions formed on seven rice cultivars following artificial inoculation with 40 isolates of *Pyricularia oryzae* and percentage of 242 Philippine races to which each cultivar was resistant.

may appear to have horizontal or general resistance even though the relationship between the blast fungus and the rice plant is basically race-specific (= differential or vertical). The reaction of a cultivar is, therefore, the total result of interaction between the different genes for pathogenicity in fungal population and various combinations of genes for resistance in the cultivar. Thereby, the gene-for-gene relationship discovered by Flor (2) as a complementary genic system can still exist in blast fungus-rice plant system, although it appears to be expressed as a quantitative trait.

The nature of disease resistance is complex, and many terms have been used to describe the observations (1,10). Of the terminology generally used to describe resistance, none seemed to be able to describe precisely the observations of the host-parasite relationship in the rice blast disease. The observations seem to fit the statement of Nelson (5,6) that accumulation of vertical resistance may contribute to or confer horizontal resistance and that "several genes collectively conditioning HR (horizontal resistance) individually condition VR (vertical resistance) and single genes controlling VR collectively condition HR."

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