Dilatory Resistance to Rice Blast in USA Rice

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ABSTRACT

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Differences in dilatory resistance (slower disease development) to race IG-1 of *Pyricularia oryzae* were detectable among closely related rice lines planted in three-row by 60-cm "miniplots" separated by two buffer rows of a resistant rice line. This technique has direct application in screening large numbers of breeding lines for dilatory resistance to rice blast. It requires only a few grams of seed, and miniplots can be planted in existing blast nursery beds designed for specific resistance screening. Southern rice lines with no major-gene resistance to race IG-1 of *P. oryzae* showed various degrees of dilatory resistance, and all of them were more resistant than two lines developed in blast-free California. Most of the newer rice cultivars carry major genes for resistance to race IG-1, but many have multiple sources of dilatory resistance in their recent ancestry.

Additional key words: discriminatory resistance, general resistance, horizontal resistance, vertical resistance.

Breeding for specific or vertical resistance has proven inadequate against rice blast disease in many rice-growing areas where blast is chronic and the pathogen, *Pyricularia oryzae* Cav., is pathogenically variable (9,13). Consequently, more effort is being made to breed for general (sensu Caldwell [4]) or horizontal (sensu Vanderplank [18]) resistance, supplemented by specific resistance and chemical control (2,5,7,17). Blast is not a widespread problem in the southern USA, although occasionally a commercial planting will be severely damaged by the disease. There are several probable reasons why blast is less severe in the USA than elsewhere. All USA rice is flood-irrigated, and blast is especially devastating in upland rice. Most southern USA acreage is sown to early maturing cultivars that are mature before blast can become epidemic. Southern USA rice breeders have incorporated major gene resistance to *P. oryzae* into most new cultivars. Rice is not grown year round as it is in much of the tropics; also, it is grown in rotation with other crops. In any 1 yr, less than 10% of the Texas rice belt area is planted to rice. And for whatever reason, *P. oryzae* seems more pathogenically stable in the southern USA than in other parts of the world (12). All of these factors tend to reduce the chances of a blast epidemic. However, we also suspect that cultivars developed in the southern USA possess effective levels of general (sensu Caldwell [4]) resistance. We know from observations in the breeding nursery that exotic rice lines are occasionally attacked severely by blast when there is little or no infection in domestic lines.

In 1977, a program was initiated at Beaumont to determine the extent of general resistance to rice blast in USA cultivars and to develop an efficient method of screening breeding lines for general resistance to blast. Although rice blast is not presently a major constraint on yields in the southern USA, it could become so in the future as rice breeders intensify efforts to broaden the genetic base of southern USA rice lines and seek such traits as earlier maturity, cold and salinity tolerance, increased tillering, and higher yield potential from exotic germplasm. Specifically, my goals were to determine whether factors contributing to general resistance could be expressed adequately in "miniplots" planted in our existing compact blast nursery beds (Fig. 1), and to assess levels of general resistance in USA rice lines possessing no specific (major-gene) resistance to race IG-1, the most common race of *P. oryzae* in the USA (12). To meet the accepted definition of general resistance (3,4), resistance to race IG-1 would have to be operative against all the races, present and future. Indeed, breeders engaged in rice cultivar improvement are seeking general resistance (a *genetic* descriptor) in the strict sense, but as an acknowledgement that the nonmajor-gene resistance reported herein may be specific to race IG-1, I choose to use the *epidemiological* descriptors of Browning et al (3): dilatory resistance (that which retards the rate of disease development) and *discriminatory* resistance (that which prevents pathogenesis by some, but not all, pathotypes). Characteristically,

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discriminatory resistance is *specific*, and *general* resistance is *dilatory*. But there have been cases of *dilatory* resistance being *specific* to certain races of *P. oryzae* (6)—the so-called "undistributed middle" referred to by Robinson in his discussion of horizontal and vertical resistance (16). Ultimately we expect to determine if the dilatory resistances reported herein are operative against races other than race IG-1.

This study was conducted with only one race to simplify the choice of test lines to those susceptible to race IG-1 in monocyclic greenhouse inoculations, and to reduce the chance of confounding by the cross-protection sometimes observed when rice seedlings are exposed simultaneously to inocula of virulent and avirulent races (10). The "feasibility" experiments were conducted intentionally with closely related lines, in which differences in dilatory resistance might be small, in anticipation of the probable use of the technique, ie, selecting from among related lines those most likely to have superior dilatory (and hopefully general) resistance to blast.

The planting scheme used here was a miniaturized version of that used by Bidaux in his studies of general resistance to rice blast conducted in the Ivory Coast, West Africa (1). Since our ultimate objective was to develop a technique for screening breeding lines, we needed to reduce space and seed requirements to allow evaluation of many lines including early generation lines with limited seed.

MATERIALS AND METHODS

Fifty-five F_3 lines from the cross 'Nortai'/CI9879 (=CI9545/'Northrose') (cross B7442A1) and the parental lines were evaluated for dilatory resistance to race IG-1 (isolate 74T3) of *P. oryzae* in the blast nursery. Both parents are susceptible to race IG-1 under greenhouse conditions in monocyclic inoculations; neither parent has major-gene resistance. Both parents have cultivars Tainan-iku 487 (PI215936) and Northrose in their recent ancestry, and were selected as parental material for similar superior agronomic traits. Consequently, there was little morphological diversity both within and among F_3 lines. Over many years of greenhouse testing with isolates representing eight to 10 races of *P. oryzae*, Nortai has been observed to produce fewer lesions than other susceptible lines, although lesion size and shape were typical of susceptible reactions.

Test lines were planted 12 July 1977 in three-row miniplots 60 cm long with 10-cm row spacing, ~20 seeds per row. Each test plot was separated by two rows of cultivar Labelle, a cultivar highly resistant to race IG-1, to act as a buffer between test plots to reduce confounding by alloinfection. A single row of spreader line, cultivar Calrose 76, was planted the length of the 15.2-m bed, perpendicular to the test and buffer rows, on the windward (south) side. A single row of Labelle was planted on the leeward side, parallel to the Calrose 76 spreader. Diseased rice in other beds, in which blast screening was ongoing, was the source of inoculum of race IG-1 (isolate 74T3) for this and all subsequent experiments described here.

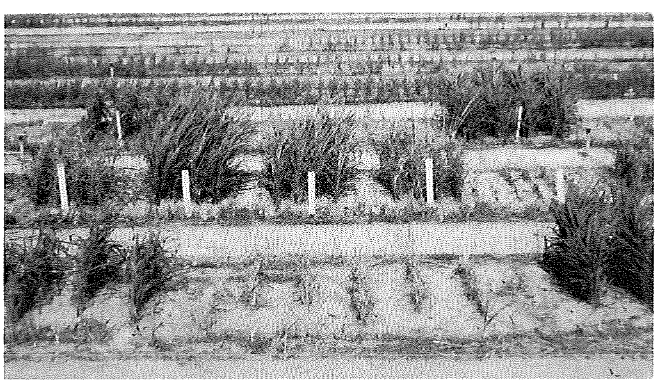

Fig. 1. Rice blast nursery beds 45 days after emergence at Beaumont, TX, 1977. The five staked miniplots (left to right) are planted to cultivars Nato, Nortai, Brazos, Starbonnet, and Calrose 76. None of the cultivars has major-gene resistance to race IG-1 of *Pyricularia oryzae*, but they represent extremes in dilatory resistance; Calrose 76 was killed, and Nortai was hardly affected. The two-row buffers between miniplots and back row of Labelle (highly resistant to race IG-1) were removed to show the miniplots clearly. In the far background are three beds of breeding lines undergoing routine screening for resistance to rice blast.

Disease development was rated 23 days after seedling emergence. Because of the "few lesions" trait noted previously in Nortai, the female parent, two scores were recorded: a lesion density rating of 1 = few (<5 susceptible "type-4" lesions per plant) to 3 = many (>15 type-4 lesions per plant) and an overall susceptibility rating on a scale of 0 to 9 similar to the scale proposed by the International Rice Research Institute (IRRI), except that the rating scale gradations from 4 to 8 were based on relative frequencies of lesion types as defined by Latterell et al (11) rather than on percent diseased leaf area (DLA) as in the IRRI system (8). Briefly, 4 = about 2% of the lesions of the susceptible (type-4) eyespot lesion (5–20 mm long with ashen centers and brown borders), mixed with pinpoint (type 1), larger pinhead (type 2) and 1–2 mm round to slightly elongated ashen lesions with brown borders; 5 = ~10% type-4 lesions, mixed with lesion types 1, 2, and 3; 6 = 15–20% type-4 lesions; 7 = 25–50% type-4 lesions; 8 = >50% type-4 lesions; 9 = plants are killed. Our system was developed for monocyclic greenhouse screening and has worked satisfactorily under blast nursery conditions. In practice, most of the time the ratings would be similar with either system under blast nursery conditions, since the percent diseased leaf area increases as the percentage of type-4 lesions increases. Major discrepancies would arise in greenhouse ratings of lines like Nortai, which by the IRRI system would be rated 4 or 5 (2–10% diseased leaf area), but would be rated 8 by us, based on lesion type. In this experiment, the highest score (density = 3, susceptibility = 8) represented about 40% DLA. In subsequent experiments, the two-part rating was dropped in favor of a single estimate of percent DLA.

After disease was rated, the center row of each miniplot was pulled, and the plants were separated and transplanted to the field for seed production. The following year (1978), five F_4 lines from each of 11 F_3 families among those tested in 1977 were rated similarly for dilatory resistance, in order to acquire data regarding the "heritability" (in a general sense) of dilatory resistance and the reproducibility of the previous year's results in miniplots. A broad spectrum of disease ratings was represented among the 11 F_3 families. Ratings of the F_4 lines, recorded 31 days after emergence, and of the F_3 families from which they were derived were compared. At the same time, 12 F_4 bulks representing the range of the 1977 F_3 ratings, and the parental lines were evaluated in miniplots, replicated four times, for comparison with the F_3 lines from which they were derived.

From the same group of F_3 lines in the 1977 test, 34 F_4 bulks were selected and planted 4 May 1978 in a yield trial to determine if there was a relationship between dilatory resistance potential and yield potential in the absence of blast disease. Test lines, including the parental lines Nortai and CI9879, were seeded in single row, 3.7-m plots, 18 cm between rows (plots), 10 g of seed per row, in triplicate. Yields were estimated by harvesting the inner 3 m of each row-plot and weighing the grain after it was dried to 12% moisture.

In 1978, 19 rice cultivars and parental lines released or acquired during the past 55 yr of rice cultivar improvement in the southern USA and having no major-gene resistance to race IG-1 were evaluated for dilatory resistance in miniplots. Calrose 76 was included as a susceptible standard. Many of the newer cultivars could not be included because they possess major-gene resistance to IG-1, but many of the ancestral lines of the new cultivars were included. This test was planted 10 August 1978 in three-row miniplots as described previously, replicated three times, with rice lines randomized within reps. The plots were rated for percent DLA when one plot of the susceptible standard, Calrose 76, was rated 100%, which was 48 days after seedling emergence. Disease data were arc sine-square root transformed and analyzed statistically.

In the final experiment reported here, conducted in 1981, serial estimates of percent DLA caused by race IG-1 were made on miniplots of 14 rice lines sown in four replications on each of two planting dates. Among the 14 lines were three promising advanced selections each from two similar crosses (Nortai/CI9879 and Nortai//CI9545/Nova), most known ancestral lines, two southern cultivars (Nato and Brazos (= CI9545/Nova)) and two California cultivars (Calrose 76 and M101). The first planting, 22 June, was rated for disease development 21, 31, and 38 days after seedling emergence. The second planting, 28 August, was rated 18, 22, 25, 29, 32, and 36 days after seedling emergence. To reduce bias, the rater did not have access to plot identity while making disease ratings.

The percent DLA values were analyzed statistically after arc sine-square root transformation. Areas under disease progress curves (AUDPC) were calculated and analyzed, as were apparent rates of disease increase (r), for the second planting. The r-values were determined for each plot for the 18 days (Δt) between the initial and final disease ratings (except for those plots where disease ratings reached 100% at an earlier date, in which cases Δt was reduced accordingly), using the logistic equation:

$$r = \left\{\log_e[x_2/(1 - x_2)] - \log_e[x_1/(1 - x_1)]\right\}/\Delta t$$

in which x_1 = initial disease rating, x_2 = final disease rating, and the $(1 - x)$ terms correct for decreasing healthy leaf area remaining that can become diseased with increasing disease (18).

RESULTS

The 55 F_3 lines from the Nortai/CI9879 cross were differentiated into 11 lesion density-susceptibility classes, some lines being rated more susceptible or more resistant than both parents (Table 1). The disease ratings of the 12 F_4 bulks and their respective F_3 progenitors was highly correlated ($r^2 = 0.83$). The correlation between disease ratings of five F_4 lines from each of 11 F_3 families and their respective F_3 progenitors was lower, but still high ($r^2 = 0.58$). Segregation of resistance genes within F_4 families probably accounts for the lower correlation coefficient between ratings of F_4 lines and F_3 progenitors.

There were significant differences ($P = 0.01$) in yield among the 34 Nortai/CI9879 F_4 bulks, with average yields ranging from 3.3 to 8.9 MT/ha. When the 34 F_4 bulks were grouped according to lesion density (densities 1, 2, or 3) or susceptibility (classes 3–4, 5–6, or 7–8) rating, there were no significant differences ($P = 0.05$) in yield among groups, indicating that in this cross there was no relationship between yield potential and dilatory resistance potential. The average yields of the lesion density and susceptibility groups ranged from 6.2 to 6.6 MT/ha. All but five of the F_4 bulks outyielded both parents, with five lines yielding over 8 MT/ha.

There were significant differences ($P = 0.05$) in percent DLA among the 19 cultivars and parental lines evaluated for dilatory resistance 48 days after seedling emergence in miniplots in 1978

TABLE 1. Distribution of 55 F_3 rice lines from the cross Nortai CI9879 (B7442A) by lesion density-susceptibility class in an evaluation for dilatory resistance to race IG-1 of *Pyricularia oryzae* in blast nursery miniplots rated 23 days after seedling emergence at Beaumont, TX, in 1981. (Ratings of parental lines are indicated by sex symbols)

Lesion density[a]	Susceptibility rating[b]						Total
	3	4	5	6	7	8	
1 (few)	1	10(♀)	5				16
2		5	7	4	4(♂)		20
3 (many)			1	9	8	1	19
Total	1	15	13	13	12	1	55

[a] Lesion density ratings: 1 = <5 susceptible 'type-4' lesions per plant, 3 = >15 type-4 lesions per plant, estimated.

[b] Susceptibility ratings: 3 = no type-4 lesions, a mix of type-1 (pinpoint necrotic flecks) to type-3 (1–2 mm, round to slightly oblong, ashen lesions with brown borders) lesions; 4 = 2% type-4 lesions, the rest types 1 to 3; 5 = 10% type-4 lesions; 6 = 15–20% type-4 lesions; 7 = 25–50% type-4 lesions; 8 = >50% type-4 lesions.

(Table 2). The pedigrees of the test cultivars are summarized in Table 2 to allow comparisons between some cultivars and their ancestral lines. CI9879 had significantly less disease than either parental line. Nortai had less disease than either parent, although the difference between Nortai and Tainan-iku 487 was not significant. Brazos had significantly more disease than one parent, Nova, and almost significantly less than CI9545. Plants of the

TABLE 2. Mean percentage of rice blast diseased leaf area (DLA) among USA cultivars and parental lines with no major-gene resistance to race IG-1 of *Pyricularia oryzae*, rated 48 days after seedling emergence in blast nursery miniplots at Beaumont, TX, in 1978

Line	Symbol	Pedigree[x]	DLA[y] (%)
Nova	NOVA	LACR//ZNTH/NIRA	3 a
Bluebonnet 50	BB50	*RXOR*/FRTA[z]	4 ab
Bluebelle	BBLE	9214//*CP31*/9122	6 ab
Belle Patna	BLPT	9122/*RXOR*	7 ab
PI331581	3-81	*BBLE*6*/TN-1[z]	12 abc
Nortai	NTAI	*NROS*/*T487*	13 abc
CI9879	9879	*9545*/*NROS*	18 bc
Tainan-iku 487	T487	Taiwan Introd.	22 bc
Starbonnet	STBN	*CP31*/BBNT	27 cd
Magnolia	MGNL	IMBR/FRTA[z]	27 cd
Texas Patna 49	TP49	TXPT//*RXOR*/7689	32 cde
Brazos	BRAZ	*9545*/*NOVA*	32 cde
Rexoro	RXOR	Philippines Introd.	33 def
Northrose	NROS	LACR/AROS	50 def
CI9545	9545	9214/*T487*	53 ef
Nato	NATO	*RXOR*/PRLF//*MGNL*	57 f
Century Patna 231	CP31	TXPT//*RXOR*/SBLR	57 f
PI325893	3-93	PETA/*T487*	73 g
Calrose 76	CR76	Irrad. CLDY*2/CALO	98 h

[x] Italicized ancestors in pedigrees were among lines rated for dilatory resistance in this experiment.

[y] Means of three replications. Analysis of variance and Duncan's multiple range test performed after arc sine-square root transformation of the data. Values followed by the same letter are not significantly different ($P = 0.05$).

[z] Cultivars Fortuna (FRTA) and Taichung Native 1 (TN-1) originated in Taiwan.

TABLE 3. Percentage of rice blast diseased leaf area (DLA) and rankings in two plantings of 14 rice lines in an evaluation for dilatory resistance to race IG-1 of *Pyricularia oryzae* in blast nursery miniplots. Beaumont, TX, in 1981

Rice line	DLA (%)[v]		Rank	
	First planting[w]	Second planting[x]	First planting	Second planting
Nortai	9 a	8 a	1	1
7442a[y]	18 ab	8 a	2	1
7442b	20 abc	16 ab	3	3
Tainan-iku 487	30 abcd	19 ab	4	4
7439c[z]	30 abcd	33 bc	4	5
Brazos	30 abcd	50 cde	4	7
7439b	40 bcde	39 bcd	7	6
7442c	48 cde	69 de	8	10
Nato	55 def	63 de	9	9
7439a	60 ef	74 e	10	12
9545	65 ef	61 de	11	8
Northrose	78 f	71 de	12	11
Calrose 76	95 g	95 f	13	13
M101	99 g	97 f	14	14

[v] Means of four replications. Statistical analyses performed on arc sine-square root transformed data. Values in the same column followed by the same letter are not statistically different ($P = 0.05$), according to Duncan's multiple range test.

[w] Planted 22 June and rated 21 days after emergence.

[x] Planted 28 August and rated 29 days after emergence.

[y] 7442a, b, and c are advanced lines from the cross Nortai/CI9879 (= CI9545/Northrose).

[z] 7439a, b, and c are advanced lines from the cross Nortai//CI9545/Nova.

California cultivar Calrose 76 had more disease than any of the southern cultivars.

There were significant differences in the percent DLA among the 14 rice lines evaluated for dilatory resistance in miniplots in each of two plantings in 1981 (Table 3). The rankings of the lines in the two

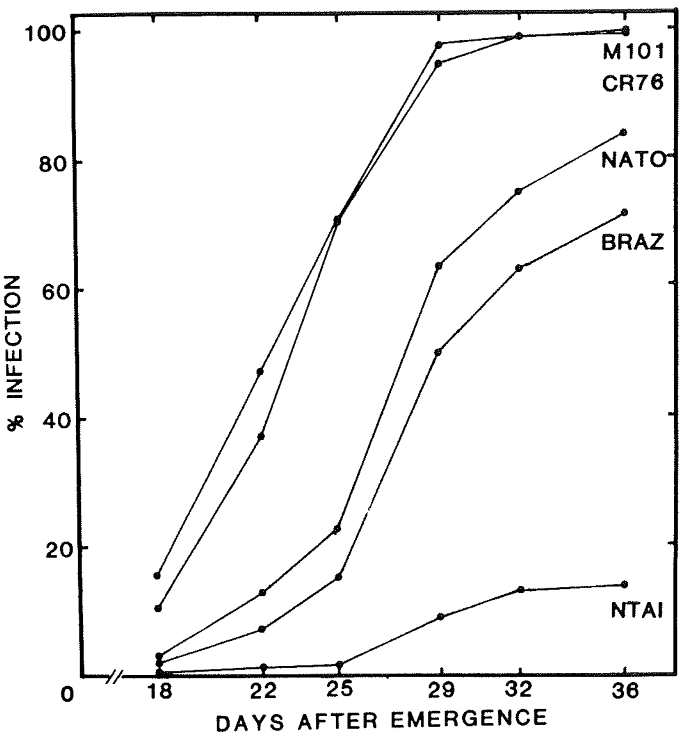

Fig. 2. Rice blast disease progress curves for cultivars M101 and CR76, which were bred in the absence of rice blast disease in California, and three southern cultivars, infected by race IG-1 of *Pyricularia oryzae* in blast nursery miniplots planted 10 August 1981 at Beaumont, TX.

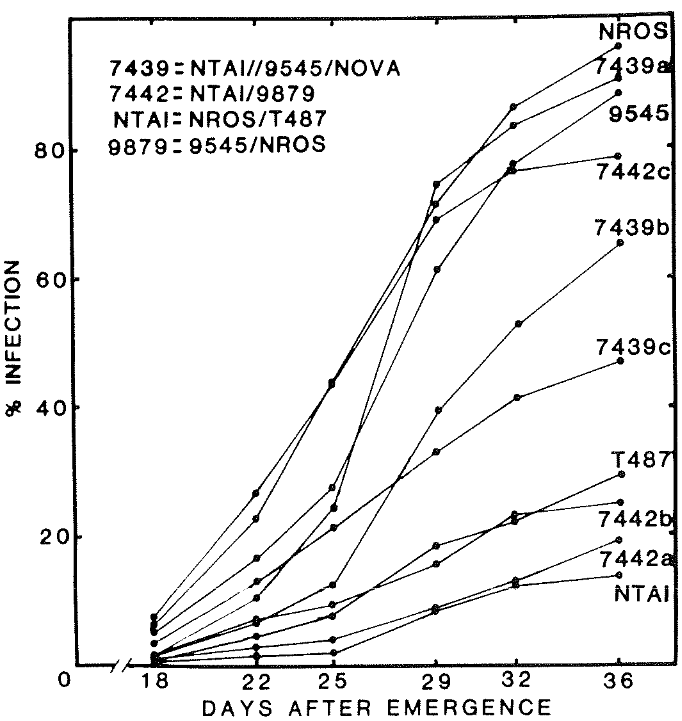

Fig. 3. Rice blast disease progress curves for six rice lines from similar crosses and their ancestral lines infected by race IG-1 of *Pyricularia oryzae* in blast nursery miniplots planted 10 August 1981 at Beaumont, TX. Ancestral lines NOVA and CI9879, not included in this study, can be compared to NROS, NTAI, and CI9545 in the 1978 study (see Table 2).

plantings, some 9 wk apart, were similar, though not identical. The disease ratings (arc sine-square root transformed) between plantings were highly correlated ($r^2 = 0.90$).

Disease progress curves for the second planting are presented, comparing the two California cultivars with three southern cultivars (Fig. 2) and comparing several closely related lines with some of their ancestral lines (Fig. 3). The two California cultivars, Calrose 76 and M101, were developed in one of the few (if not the only) blast-free rice growing areas of the world; they were more susceptible than the southern cultivars. Nato, the most blast-susceptible of the major southern cultivars, has been a leading medium-grain cultivar in the south since 1959.

Disease progress curves for closely related advanced rice lines and ancestral lines are shown in Fig. 3. It was an unfortunate oversight that CI9879 was not included in this experiment, since it was significantly more resistant that its parental lines, CI9545 and Northrose, in the 1978 test (Table 2), and CI9879 is the male parent of the '7442' test lines.

There were significant differences among lines in areas under disease progress curves (AUDPC) and in apparent rates of disease increase (r) (Table 4). The AUDPC differences among lines were more discreet and more representative of the actual disease development observed in the miniplots, than were the r-values. Although the most susceptible California cultivars scored the highest r-values, the best lines for dilatory resistance did not necessarily score the lowest r-values.

DISCUSSION

The high correlations between ratings of replicated F_4 bulks or F_4 lines and those of their respective F_3 progenitors in the first experiment are evidence that the differences among the 55 F_3 lines were genetically based. The lesion density-susceptibility scoring system was an attempt to identify the "few lesions" trait of Nortai in F_3 lines from the Nortai/CI9879 cross. About a quarter of the F_3 lines were rated as having few lesions, suggesting that the trait is simply inherited. The few lesions trait would contribute to dilatory resistance and, if simply inherited, should be easily incorporated into improved rice cultivars. Inheritance of the few lesions trait is being investigated.

The southern cultivars presented a broad range of dilatory resistance to race IG-1 of *P. oryzae*. Even so, they were derived from a relatively narrow genetic base, as illustrated by the

TABLE 4. Areas under rice blast disease progress curves (AUDPC) and apparent rates of disease development per day (r) of 14 rice lines evaluated for dilatory resistance over 18 days beginning 18 days after seedling emergence in blast nursery miniplots at Beaumont, TX, in 1981

Rice line	AUDPC[w]	$r^{w,x}$
Nortai	1.09 a	0.260 abc
7442a[y]	1.33 a	0.260 ab
Tainan-iku 487	2.45 a	0.252 abc
7442b	2.52 a	0.215 ab
7439c[z]	4.53 b	0.165 a
7439b	5.28 b	0.310 abc
Brazos	6.13 bc	0.325 abc
Nato	7.75 cd	0.468 cd
CI9545	8.27 cd	0.325 abc
7439a	8.55 d	0.423 bcd
7442c	9.21 d	0.245 abc
Northrose	9.90 d	0.373 abc
Calrose 76	12.64 e	0.603 d
M101	13.24 e	0.603 d

[w] Means of four replications. Values followed by the same letter are not significantly different ($P = 0.05$), according to Duncan's multiple range test.

[x] The r-values were calculated over 18 days except in miniplots in which diseased leaf area was 100% at some earlier rating. In these cases r was calculated for the interval between the initial ratings and the 100% ratings.

[y] 7442a, b, and c are advanced lines from the cross Nortai/ CI9879.

[z] 7439a, b, and c are advanced lines from the cross Nortai//9545/Nova.

recurrence of certain cultivars such as 'Rexoro' in many of the pedigrees. This is especially true of the newer cultivars, particularly Texas long-grain cultivars: Labelle (Belle Patna/Dawn), Lebonnet (Bluebelle/Belle Patna/Dawn), and the new semidwarf, Bellemont (Bluebelle//Belle Patna/Dawn/3/Bluebelle*6/Taichung Native 1). Many newer cultivars carry major-gene resistance to race IG-1 and other races of *P. oryzae*. But all except one ('LA110') are susceptible to at least one race, and, therefore, can be evaluated for dilatory resistance. Nortai and Calrose 76 have no major genes for resistance to any known USA race of *P. oryzae*; they could be included as standards for comparison. There is circumstantial evidence that the new rice cultivars, particularly the Texas long-grain cultivars, possess dilatory resistance: there has been no major outbreak of blast in the new cultivars, even though one of them, Labelle, has occupied at least 80% of the Texas rice acreage and considerable acreages in Louisiana and Arkansas since 1976 (14,15); and cultivars apparently possessing high levels of dilatory resistance (Table 2) (eg, Bluebonnet 50, Belle Patna, and Bluebelle) are in the pedigrees of the newer cultivars.

The range of dilatory resistance in closely related lines suggests polygenic control. If this is the case, then the observed resistance is more likely to be general than race-specific. Additional study is needed to better substantiate the genetic nature of this resistance and its effectiveness against other races. There is evidence of transgressive segregation in the relative susceptibilities of CI9879 and its parental lines, CI9545 and Northrose, both of which were rated significantly more susceptible than CI9879. Nortai was rated more resistant than both parents in each of three replicated experiments, although the differences between Nortai and one parent, Tainan-iku 487, were never statistically significant ($P = 0.05$).

The apparent rates of disease increase, 'r,' were not indicative of the final effects of blast on the 14 rice lines evaluated in 1981, although the two most susceptible cultivars, Calrose 76 and M101, had the highest rs. More "accurate" rs might have been calculated had there been disease ratings early enough to record perhaps less than 1% DLA among the more susceptible lines, and had the lower disease levels (<2% DLA) been *measured* rather than estimated visually. Under the high inoculum-density environment of the blast nursery, the initial DLA from alloinfection probably was greater than 5% among the more susceptible lines; and accuracy beyond visual estimation was not practical within the scope of my objectives. The difference between an estimated inital 1% DLA and an actual 0.1% DLA, or vice versa, would have no effect on the decision to keep or eliminate a line and would have little impact on the AUDPC; but such a difference in x_1 of the logistic equation would change r considerably. In practice, the lines that look the least diseased at the time of evaluation will be favored in a breeding program, regardless of the calculated r. In a screening of many early generation lines, there probably will be no replication; those that are rated the worst will be eliminated (unless the breeder sees overriding desirable traits). Of those that remain, many will be eliminated by the breeder for agronomic reasons, and the survivors will be retested in later generations.

There are two other factors that could have biased r away from an "expected" r. First, is the effect of alloinfection under blast nursery conditions. The proportion of new infections due to alloinfection should have been greater in the more-resistant than in the less-resistant lines. This would tend to increase r disproportionately for the more resistant lines. However, alloinfection seems not to have masked the innate dilatory resistances enough to prevent selection of more resistant lines in this study. Second is the differentially increasing resistance with aging of plants, a phenomenon observed routinely in greenhouse and blast nursery screening tests, but never quantified here. This could have contributed to a leveling off of some of the disease progress curves, eg, Nortai, 7439c, and 7442c (Fig. 3).

Improved blast resistance may rarely, if ever, be a primary objective of rice cultivar improvement in the southern USA. In most cases, lines selected for other traits, such as higher yield potential, better milling quality or lodging resistance, will be evaluated for blast resistance, rather than vice versa. The technique will enable breeders to select parental lines with the better dilatory resistance and ultimately raise the overall frequency of dilatory resistance genes in breeding populations. For the purpose of comparing lines, it appears that timing disease ratings according to 95–100% infection of a susceptible standard, such as M101 or Calrose 76, will give a meaningful comparison among test lines. The miniplot technique minimizes three of the greatest drawbacks to screening for dilatory resistance in cultivar improvement programs: space, seed, and time.

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