GENETIC CONTROL OF BLAST IN RELATION TO NITROGEN FERTILIZATION IN UPLAND RICE[1]

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ABSTRACT - Six upland rice cultivars were evaluated under two nitrogen levels (10 kg and 60 kg N/ha) for blast control based on slow leaf and panicle blast characteristics in field experiments conducted during three consecutive years. The criteria for measuring slow blasting resistance were area under disease progress curve (AUDPC), maximum severity during disease progress (Ymax) and the rate of increase until the disease reaches maximum ($^{r}ymax$). There was a high positive correlation among the criteria utilized. The control of leaf blast in improved rice cultivars (Cuiabana, Centro América, Guarani, Rio Paranaíba) ranged from 36 to 56% for 10 kg/ha of N and from 19 to 49% for 60 kg/ha of N over the susceptible checks (IAC 47, IAC 165). The effect of slow blasting resistance on panicle blast control was less than on leaf blast in most of the cultivars. Increasing the nitrogen level from 10 to 60 kg/ha resulted in a mean yield increase by only 12% corresponding to 258 kg/ha. The data suggest that the existing level of slow blasting resistance in the improved rice cultivars is efficient only under low nitrogen level.

Index terms: resistance, *Oryza sativa*, *Pyricularia grisea*, *Pyricularia oryzae*, slow blasting, epidemiology.

CONTROLE GENÉTICO DE BRUSONE EM RELAÇÃO À FERTILIZAÇÃO NITROGENADA EM ARROZ DE SEQUEIRO

RESUMO - Foram avaliadas seis cultivares de arroz de sequeiro sob dois níveis de nitrogênio (10 kg e 60 kg N/ha) para o controle de brusone com base em característica de progresso lento da doença nas folhas e panículas, em experimentos de campo realizados durante três anos consecutivos. Os critérios para medir o progresso lento foram área sob curva de progresso, severidade máxima durante o progresso da doença e a taxa de aumento até a doença atingir severidade máxima. Houve uma correlação alta e positiva entre os critérios utilizados. O controle de brusone nas folhas das cultivares melhoradas (Cuiabana, Centro América, Guarani, Rio Paranaíba) variou de 36 a 56%, com aplicação de 10 kg/ha, e de 19 a 49% com 60 kg/ha de nitrogênio, comparadas com as testemunhas suscetíveis (IAC 47 e IAC 165). A característica 'progresso lento da doença' no controle da brusone foi menor nas folhas do que nas panículas na maioria das cultivares. O incremento da dose de 10 para 60 kg/ha de N resultou em aumento de produtividade média somente de 12%, correspondente a 258 kg/ha. Os resultados indicaram que os graus de resistência existentes nas cultivares melhoradas de arroz de sequeiro são eficientes somente em níveis baixos de nitrogênio.

Termos para indexação: resistência, *Oryza sativa*, *Pyricularia grisea*, *Pyricularia oryzae*, epidemiologia.

INTRODUCTION

The utilization of specific and general genetic resistance in the existing upland rice cultivars for growing them under cultural practices that do not favor epidemic is important in blast disease management. Rice blast caused by *Pyricularia grisea* (Cooke) Sacc. (Rossman et al., 1990) earlier referred

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as *P. oryzae* Cav. is the major yield constraint in upland rice. Several cultivars with different degrees of resistance or susceptibility have been developed. The resistance in these cultivars is not complete and exhibit slow blasting characteristic. The term slow blasting was used as a synonym of field resistance to describe the ability of rice to reduce the rate of disease development (Villareal et al., 1980; Ahn, 1981; Marchetti & Xinghua, 1986). Slowing down an epidemic is not necessarily a characteristic of horizontal resistance and could be overcome being race specific in some cases (Browder, 1973; Johnson, 1978; Nelson, 1978). The slow blasting nature of resistance in the improved rice cultivars can be quantified and compared with commercial cultivars under similar field conditions (Shaner & Finney, 1977).

Excessive nitrogen level has been known to increase blast severity (Hashioka, 1950; Atkins, 1956; Volk et al., 1958; Kozaka, 1965; Soave et al., 1977). Both leaf and panicle blast have been shown to increase with increase in N level from 15 to 60 kg/ha and to decrease in grain yield in experiments conducted under upland conditions with cultivar IAC 47 (Faria et al., 1982). Further, application of N all in furrow at planting increased blast as compared to split application in upland rice (Santos et al., 1986).

Upland rice is usually grown for one or two years after clearing the savanna vegetation commonly called 'Cerrado' using low nitrogen levels to mainly reduce the cost of implanting pasture (Steinmetz et al., 1986). Now, it is widely cultivated in rotation with soybean or maize using high input technology in the favorable upland rice regions. Also, there is a growing tendency to use high nitrogen levels at the time of planting in an attempt to increase the yield level of improved rice cultivars in unfavorable upland conditions with supplementary irrigation. Grain yield of upland rice cultivars has been shown to increase in response to fertilization up to 60 kg/ha of N when the soil water content was not a limiting factor (Stone et al., 1979).

However, there is little information on the extent to which the slow blasting characteristic of the cultivar is consistently expressed in different years and effective under varying nitrogen fertilizer levels. In the present study, the performance of improved upland rice cultivars was compared to the traditional rice cultivars for slow leaf and panicle blast resistance as well as grain yield under low and high nitrogen levels.

MATERIAL AND METHODS

Cultural conditions

Three field experiments were conducted at the National Rice and Bean Research Center (CNPAF-EMBRAPA), Goianira County, Goiás State, during 1986/87, 1987/88 and 1988/89 growing seasons. A split-plot design with three replications was employed. Two nitrogen levels (10 kg and 60 kg N/ha in the form of ammonium sulphate) were used in the main plots and six cultivars (Centro América, Cuiabana, Guarani, IAC 47, IAC 165 and Rio Paranaíba) were assigned to subplots. Each subplot consisted of 11 rows 5.0 m long. Seeds were drill planted with 50 cm row spacing at the rate of 40 kg/ha, on December 4, 1986; November 17, 1987, and November 25, 1988. The soil was dark red latosol according to the Brazilian system of classification. Fertilizer was applied at the planting time at a rate of 200 kg/ha (50-30-15+Zn) of NPK in addition to 20 kg/ha of zinc sulphate. An additional 50 kg/ha of N in the form of ammonium sulphate was added in the main plots with N60 level. Three buffer rows of cultivar highly resistant to blast (Três Marias) were established around each subplot to minimize the interplot interference.

Disease and grain weight assessment

Four serial observations on leaf and panicle blast were made at three to five days intervals to plot the disease progress curves. Leaf blast was assessed on four to five fully expanded leaves on ten main tillers of randomly selected plants in the five central rows of each subplot. A 10-grade scale (0; 0.50; 1.0; 2.0; 4.0; 8.0; 16.0; 32.0; 64.0; 82.0% of leaf area affected) according to Notteghem (1981) was employed for evaluating leaf blast severity.

Panicle blast was assessed in 50 randomly selected panicles in the five central rows of each subplot at three or four days interval 93 to 106 days after seeding (d.a.s.) for early maturing and 108 to 124 d.a.s. for medium maturing cultivars. The dates of observation were different for early and medium maturing cultivars. The number of days after panicle emergence was computed taking 5% emergence as a base. The panicle blast severity was measured using a 5-grade visual rating scale (0, 5, 25, 50, 75 and 100% infected spikelets/panicle). The 100 panicle grain weight adjusted to 13% moisture was based on 50 panicles harvested in the central five rows of each subplot. The central 10.0 m^2 plot was harvested for grain yield (kg/ha) and adjusted to 13% moisture.

Data analysis

Three criteria were used for measuring the degree of resistance of cultivars to leaf and panicle blast.

1. The area under disease progress curve (AUDPC) was calculated for each subplot treatment according to Shaner & Finney (1977).

$$AUDPC = \sum_{i=1}^{n-1}\left[(Y_1 + Y_{i+1})/2\right](d_{i+1} - d_i)$$

where:
Y_i = leaf blast severity at the ith observation
d_i = days at the ith observation
n = total number of observations

Log transformation was used to reduce the heterogeneity of error mean square because of the observed association between mean and standard deviation. Analysis of variance (ANOVA) was made using the transformed values.

2. The maximum disease (Ymax) during the disease progress curve was used as a measure of blast severity. The data were transformed to arcsine before subjecting to ANOVA.

3. The rate of increase until the disease attains its maximum (^{r}ymax) severity during the disease progress curve was estimated.

The logit $\left[\text{Log}_e\left(\frac{y}{1-y}\right)\right]$ of proportion of panicle blast severity (PBS) was regressed on time in days according to Plank (1963), to estimate the apparent infection rate (slope of the regression line) for each cultivar at low and high nitrogen levels. Coefficient of determination was used to test the goodness of fit of regression lines. Significant differences in slopes of disease curves between low and high nitrogen levels were tested by using t-test according to Snedecor & Cochran (1978). The relationship of resistance parameters to yield data was examined by correlation analysis.

Combined analysis of variance of three years data on AUDPC, Ymax and ^{r}ymax for both leaf and panicle blast as well as grain yield was conducted to study the effect of nitrogen level, cultivar and nitrogen x cultivar interaction.

RESULTS AND DISCUSSION

The combined analysis indicated that cultivar, N level and cultivar x N level interactions were highly significant for both leaf and panicle blast severity parameters. Cultivar differences at two N levels are presented in Tables 1 and 2.

The susceptible traditional cvs. IAC 165 and IAC 47 utilized as checks exhibited significantly higher values of AUDPC, Ymax and ^{r}ymax at both N levels than the improved early maturing cultivars (Table 1). At lower N level cvs. Centro América, Guarani, Cuiabana and Rio Paranaíba differed from their respective checks. At higher level, cv. Cuiabana had lowest value of AUDPC, Ymax and ^{r}max than the rest of the cultivars. Enhanced nitrogen application significantly increased the AUDPC in all cultivars. However, the degree of resistance as measured by Ymax and ^{r}ymax was not altered by high nitrogen level only for the cv. Cuiabana. The coefficients of variation were greater for Ymax (40.9%) and ^{r}ymax (43.0%), than AUDPC (9.8%). The control of leaf blast in improved rice cultivars over local checks ranged from 36 to 56% for 10 kg N and 19 to 49% for 60 kg/ha of N based on assessment with AUDPC. In general, the percentage control of leaf blast under high N level was lower than under low N level in all improved cultivars.

The early maturing traditional cv. IAC 165 showed significantly higher panicle blast severities (PBS) than the cvs. Centro América and Guarani in all three assessment criteria (Table 2). The medium maturing cvs. Cuiabana and Rio Paranaíba did not differ statistically from the cv. IAC 47 at both low and high N levels with any of the three criteria. However, the cv. Rio Paranaíba had relatively lower values of PBS under high N level. Increased N level did not significantly alter the PBS of the medium maturing cultivars. But the PBS of early maturing ones increased under high nitrogen level. Nitrogen application at the rate of 60 kg/ha did not significantly alter the PBS of the medium maturing cultivars. But the PBS of early maturing cultivars increased with increase in N level. However, the values of AUDPC did not differ significantly for the cv. IAC 165. The cvs. Centro América and Guarani showed 26 to 29% and 13 to 16% control of panicle blast severity over the susceptible check IAC 165 considering AUDPC. The percentage control of PBS was greater with Ymax

TABLE 1. The area under disease progress curve (AUDPC), maximum disease during disease progress (Ymax) and the rate of increase until the disease attains maximum (^{r}ymax) in relation to the leaf blast resistance for six upland rice cultivars (1986-89).[1]

Cultivar	AUDPC[2]		Ymax		^{r}ymax	
	N10[3]	N60[3]	N10	N60	N10	N60
Early maturing						
Centro América	1.83 b	2.61*b[4]	1.25 b	9.31*b	0.02 b	0.15*c
	(38.40)[5]	(22.78)	(85.74)	(59.87)	(86.66)	(61.53)
Guarani	1.79 b	2.73*b	0.95 b	8.75*b	0.02 b	0.15*c
	(35.84)	(19.23)	(89.16)	(62.28)	(86.66)	(61.53)
IAC 165 (Check)	2.79 a	3.38*a	8.77 a	23.20*b	0.15a	0.39*a
Medium maturing						
Cuiabana	1.15 c	1.66*d	0.20 b	0.79nsc	0.01b	0.01nsc
	(55.93)	(49.07)	(93.06)	(96.23)	(90.90)	(90.90)
Rio Paranaíba	1.44 c	2.34*c	0.47 b	5.49*bc	0.01b	0.09*cd
	(44.82)	(28.22)	(90.10)	(73.84)	(90.90)	(73.52)
IAC 47 (Check)	2.61 a	3.26*a	6.82 a	20.99*a	0.11 a	0.34*b
CV (%)	9.8		40.9		43.9	

[1] Data based on averages of three experiments.
[2] Transformed values ($\log_{10}$) of AUDPC.
[3] Nitrogen applied in kg/ha.
[4] Means followed by the asterisk indicates significant difference in N level according to Tukey's test at P = 0.05; ns = non-significant. Means followed by the same letter in a column do not differ significantly according to Tukey's test at P = 0.05.
[5] The values in parenthesis indicate percent genetic control compared to IAC 165 for early maturing cultivars and IAC 47 for medium maturing cultivars.

TABLE 2. The area under disease progress curve (AUDPC), maximum disease during disease progress (Ymax) and the rate of increase until the disease attains maximum (^{r}ymax) in relation to the panicle blast resistance for six upland rice cultivars (1986-89).[1]

Cultivar	AUDPC[2]		Ymax		^{r}ymax	
	N10[3]	N60[3]	N10	N60	N10	N60
Early maturing						
Centro América	2.04 b	2.60*a[4]	7.00 b	16.31*b	0.40 b	0.89*b
	(26.08)[5]	(13.33)	(66.82)	(50.90)	(63.63)	(51.09)
Guarani	1.96 b	2.53*ab	5.10 b	11.50*bc	0.26 b	0.69*bc
	(28.98)	(15.66)	(75.82)	(65.38)	(73.36)	(62.08)
IAC 165 (Check)	2.76 a	3.00nsa	21.10 a	33.22*a	1.10 a	1.82*a
Medium maturing						
Cuiabana	2.25 ab	2.25nsabc	8.93 b	12.55nsb	0.43 b	0.55nsbc
	(-6.63)	(-3.21)	(-42.88)	(-88.15)	(-30.30)	(-61.78)
Rio Paranaíba	1.94 b	1.88nsc	2.97 b	3.61nsc	0.14 b	0.18nsc
	(8.05)	(13.76)	(52.48)	(45.87)	(41.42)	(47.05)
IAC 47 (Check)	2.11 ab	2.18nsbc	6.25 b	6.67nsbc	0.33 b	0.34nsbc
CV (%)	10.9		48.2		53.1	

[1] Data based on averages of three experiments.
[2] Transformed values ($\log_{10}$) of AUDPC.
[3] Nitrogen applied in kg/ha.
[4] Means followed by the asterisk indicates significant difference in N level according to Tukey's test at P = 0.05; ns = non-significant. Means followed by the same letter in a column do not differ significantly according to Tukey's test at P = 0.05.
[5] The values in parenthesis indicate percent genetic control compared to IAC 165 for early maturing cultivars and IAC 47 for medium maturing cultivars.

was greater with Ymax and ^{r}ymax. The AUDPC, Ymax and ^{r}ymax values of cv. Cuiabana were relatively greater than those of the cv. IAC 47 even though they were not statistically significant.

The correlation coefficients among AUDPC, Ymax and ^{r}ymax both for leaf blast and panicle blast were positive and highly significant (Table 3). The grain weight of 100 panicles was negatively correlated to leaf and panicle blast assessment criteria. The non-significant correlation coefficients showed that leaf blast did not account for the differences in grain yield. However, the correlation between grain yield and PBS values assessed using AUDPC, Ymax and ^{r}ymax was negative and highly significant. The highest negative correlations were between AUDPC for panicle blast and 100 panicle grain weight ($r = -0.44$, $P = 0.0001$) as well as grain yield ($r = 0.42$, $P = 0.0001$).

The cultivar x N level interaction was significant for 100 panicle grain weight for one of the three cropping seasons. The grain weight differences by cultivar and N level are shown in Table 4. Increasing the application of N from 10 kg to 60 kg/ha significantly increased grain weight only in cv. Cuiabana among the medium maturing cultivars and decreased in cvs. Guarani and IAC 165 among the early maturing ones. The differences in grain weight between Guarani and IAC 165 were significant both under low and high N levels. The grain weight in cv. Guarani increased by 19% and 37% over the cv. IAC 165 under low and high N levels, respectively. There were, however, no significant differences among the medium maturing cultivars in relation to 100 panicle grain weight.

The apparent infection rates of all cultivars were greater at N60 than at N10 level (Table 5). There was, however, no consistency in relation to the infection rates of cultivars in different years within N levels. The coefficients of determination for the estimation of infection rates were over 90% in 19 out of 36 estimates. The mean panicle blast progress was lower for cv. Rio Paranaíba compared to cvs. Cuiabana and IAC 47. The cvs. Guarani and Centro América had lower infection rates over IAC 165 both at low and high N levels.

TABLE 3. Correlation (r) matrix between leaf blast (LBS) and panicle blast (PBS) severities, and parameters of 100 panicle grain weight (GW) and grain yield (GY) (1986-89)[1].

Parameters	LBS			PBS			GW	GY
	Ymax[2]	^{r}ymax[3]	AUDPC[4]	Ymax	^{r}ymax	AUDPC		
LBS								
Ymax	-	0.99 (0.0001)[5]	0.83 (0.0001)[2]	0.53 (0.0001)	0.52 (0.0001)	0.52 (0.0001)	-0.30 (0.001)	0.06 (0.52)
^{r}ymax		-	0.80 (0.0001)	0.52 (0.0001)	0.52 (0.0001)	0.51 (0.0001)	-0.33 (0.0006)	0.05 (0.61)
AUDPC			-	0.54 (0.0001)	0.55 (0.0001)	0.56 (0.0001)	-0.06 (0.52)	0.16 (0.10)
PBS								
Ymax				-	0.98 (0.0001)	0.97 (0.0001)	-0.48 (0.0001)	-0.30 (0.001)
^{r}ymax					-	0.96 (0.0001)	-0.43 (0.0001)	-0.32 (0.0008)
AUDPC						-	-0.44 (0.0001)	-0.42 (0.0001)

[1] Number of observations in the analysis = 108.
[2] Ymax = maximum disease during disease progress curve.
[3] ^{r}ymax = the rate of increase until the disease attains maximum.
[4] AUDPC = area under disease progress curve.
[5] Probability level.

TABLE 4. Effect of nitrogen (N) levels on panicle grain weight (GW) for six upland rice cultivars (1988/89)[1].

Cultivar	Grain weight/100 panicle (g)			
	N10[2]	GW(%)[3]	N60[2]	GW(%)[3]
Centro América	145.8[4]c	-10.3	131.1[ns]bc	7.2
Cuiabana	176.9abc	-15.2	203.6*ab	-2.7
Guarani	193.1ab	18.8	167.4*b	36.9
IAC 165 (Check)	162.6bc	-	122.3*c	-
IAC 47 (Check)	208.6ab	-	209.2[ns]a	-
Rio Paranaíba	227.1a	8.9	227.0[ns]a	8.5

1 Data based on one experiment during 1988-89.
2 Nitrogen applied in kg/ha.
3 Percentage increase or decrease in grain weight as compared to susceptible checks IAC 47 and IAC 165 for medium and early maturing cultivars, respectively.
4 Means followed by the asterisk indicates significant difference in N level according to Tukey's test at P = 0.05.

TABLE 5. The apparent infection rates (r) of panicle blast progress under two nitrogen (N) levels and grain yield for six upland rice cultivars.

Cultivar	Apparent infection rates (r)[1]						Mean		Grain yield (kg/ha)
	1987		1988		1989		N10	N60	
	N10[2]	N60[2]	N10	N60	N10	N60			
IAC 47	0.22 (0.85)[3]	0.27 (0.87)	0.12 (0.77)	0.15 (0.98)	0.22 (0.54)	0.18 (0.55)	0.18	0.20	2819 a[4]
Rio Paranaíba	0.18 (0.93)	0.21 (0.70)	0.10 (0.99)	0.13 (0.95)	0.19 (0.71)	0.17 (0.75)	0.15	0.17	2757 ab
Cuiabana	0.14 (0.60)	0.18 (0.36)	0.15 (0.97)	0.17 (0.98)	0.25 (0.96)	0.26 (0.98)	0.18	0.20	2164 bc
IAC 165	0.33 (0.91)	0.34 (0.94)	0.29 (0.95)	0.33 (0.84)	0.29 (0.84)	0.31 (0.93)	0.30	0.32	1319 d
Guarani	0.20 (0.80)	0.26 (0.82)	0.16 (0.97)	0.23 (0.79)	0.24 (0.97)	0.28 (0.95)	0.22	0.25	2665 ab
Centro América	0.24 (0.79)	0.27 (0.73)	0.16 (0.99)	0.29 (0.90)	0.26 (0.96)	0.29 (0.91)	0.22	0.28	1852 cd

1 The apparent infection rate (r) per year, cultivar and N level is the regression coefficient (b) of logit plotted against time; number of observations in the analysis = 4.
2 Nitrogen applied in kg/ha.
3 The values in parenthesis represent coefficients of determination (R^2).
4 Means followed by the same letter in a column do not differ significantly according to Tukey's test at P = 0.05.

The cultivar x N level interaction for grain yield was not significant. The mean grain yield at low and high N levels were 2,133 and 2,391 kg/ha, respectively. The yield increased by 12% corresponding to 258 kg/ha.

The cvs. IAC 47 followed by Rio Paranaíba and Guarani gave significantly higher mean grain yields over the rest of the cultivars (Table 5). The cv. IAC 165 had the lowest yield.

Increasing the amount of nitrogen from 10 to 60 kg/ha, applied all at the time of planting increased both leaf and panicle blast severities. Similar results were obtained in earlier investigations made under upland condition using cv. IAC 47 (Faria et al., 1982; Santos et al., 1986). The significant interaction obtained in this study between nitrogen levels and cultivars both for leaf and panicle blast is important for identifying slow blasting nature of resistance. Three criteria were utilized to compare the slow blasting of six rice cultivars. Among the three criteria, AUDPC data had shown low coefficient of variation both for leaf and panicle blast. It is a product of both disease severity and time (Plank, 1963). The advantage of using this method is that disease observations need not be taken at the same time in different years as long as initial and final disease observation dates are maintained constant. The drawback in this method is that AUDPC fails to distinguish early light and late severe infections (James et al., 1972). The parameter Ymax represents peak disease severity during the epidemic. The maximum disease level in different cultivars may be attained at different times. It may not indicate the slow blasting ability of cultivar but it furnishes data on observed disease severity levels. The blast assessment with ^{r}ymax measures the rate of increase till the disease attains the peak severity. Because two cultivars with different disease onsets may have the same rates as in the case of apparent infection rate estimation by regression method, all treatments were compared starting from zero disease level. It may not be independent of Ymax but has discriminated the treatments. All the three methods were highly correlated both for leaf and panicle blast. But the magnitude of differences in the percentage control over the susceptible checks was greater with Ymax and ^{r}ymax than AUDPC. The AUDPC was shown to be a better criterion for measuring slow mildewing in wheat as compared to the infection rate and the time required to reach 10% disease level (Shaner & Finney, 1977). The mean apparent infection rates for panicle blast showed consistently increased rates under high N level in all cultivars but did not differ from the low N level significantly, according to t-test due to differences in dates of disease onset in different cultivars and lack of goodness of fit in most of the progress curves. The present study showed that it is necessary to use more than one assessment criteria for identifying slow blasting in cultivars. Both AUDPC and ^{r}ymax may be utilized because of the ease with which they can be calculated with three to four sequential observations.

The data further indicated the slow leaf blasting resistance of Guarani and Centro América among the early maturing cultivars and Rio Paranaíba and Cuiabana among the medium maturing ones by comparison with IAC 165 and IAC 47, respectively. The question arises to as how far the slow blasting of these cultivars is effective under high N level. Only the slow leaf blasting of cv. Cuiabana was not significantly altered considering two of the three assessment criteria. The differences in panicle blast severity of Cuiabana under low and high N levels were not significant and also did not differ from IAC 47. The relative level of resistance of leaf and panicle blast of certain rice cultivars have been shown to differ (Willis et al., 1968; Ahn, 1981; Bonman et al., 1989; Prabhu & Bedendo, 1991). The slow leaf and panicle blast resistance of cvs. Guarani and Centro América were altered by high N level, indicating the imminent need to further improvement. The cv. IAC 165 had lowest yield when averaged across years and N levels possibly due to high mean leaf and panicle blast severities. Despite high disease levels, highest yield response was shown by IAC 47. The small differences in slow blasting ability of the existing cultivars have little use in breeding unless they are further improved for a relatively higher degree of slow blasting resistance.

CONCLUSIONS

1. The genetic control obtained by slow leaf blasting resistance is altered by high nitrogen level.

2. The slow panicle blast resistance of improved early maturing cultivars is adequate only at low nitrogen levels.

3. The degree of slow blasting resistance required for upland rice cultivars at high nitrogen level has to be further improved by breeding to exploit their full yield potential.

REFERENCES

AHN, S.W. The slow blasting resistance. In: SYMPOSIUM ON RICE RESISTANCE TO BLAST, 1981, Montpellier. **Proceedings**. Montpellier: IRAT-GERDAT, 1981. p.343-370.

ATKINS, J.G. An outlook of *Pyricularia* on rice in 1955. **Plant Disease Reporter**, St. Paul, v.40, p.372-373, 1956.

BONMAN, J.M.; ESTRADA, B.A.; BANDONG, J.M. Leaf and neck blast resistance in tropical low land rice cultivars. **Plant Disease**, St. Paul, v.73, p.388--390, 1989.

BROWDER, L.E. Specificity of *Puccinia recondita* f. sp. *tritici*: *Triticum aestivum* "Bulgaria 88" relationship. **Phytopathology**, St. Paul, v.63, p.524-528, 1973.

FARIA, J.C.; PRABHU, A.S.; ZIMMERMANN, F.J.P. Efeito de fertilização nitrogenada e pulverização com fungicida sobre a brusone e produtividade do arroz de sequeiro. **Pesquisa Agropecuária Brasileira**, Brasília, v.17, n.6, p.847-852, 1982.

HASHIOKA, Y. Studies on the mechanism of prevalence of the rice blast disease in the tropics. **Taiwan Agricultural Research Institute Technical Bulletin**, Taichung, v.8, p.1-237, 1950.

JAMES, W.C.; SHIH, C.S.; HODGSON, W.A.; CALLBECK, L.C. The qualitative relationship between late blight of potato and loss in tuber yield. **Phytopathology**, St. Paul, v.62, p.92-96, 1972.

JOHNSON, R. Practical breeding for durable resistance to rust disease in self-pollinating cereals. **Euphytica**, Dordrecht, v.27, p.529-540, 1978.

KOZAKA, T. Control of rice blast by cultivation practices in Japan. In: INTERNATIONAL RICE RESEARCH INSTITUTE. **The rice blast disease**. Baltimore: Johns Hopkins, 1965. p.421-438.

MARCHETTI, M.A.; XINGHUA, L. Screening techniques to identify slow blasting rice lines. In: INTERNATIONAL UPLAND RICE RESEARCH CONFERENCE, 2., 1985, Jakarta. **Proceedings...** Los Baños: International Rice Research Institute, 1986. p.317-326.

NELSON, R.R. Genetics of horizontal resistance to plant diseases. **Annual Review of Phytopathology**, Palo Alto, v.16, p.359-378, 1978.

NOTTEGHEM, J.L. Cooperative experiment on horizontal resistance to rice blast. In: BLAST and upland rice: report and recommendations from the meeting for international collaboration in upland rice improvement. Los Baños: International Rice Research Institute, 1981. p.43-51.

PLANK, J.E. van der. **Plant disease**: epidemics and control. New York: Academic Press, 1963. 349p.

PRABHU, A.S.; BEDENDO, I.P. Avaliação de resistência horizontal à brusone em cultivares de arroz. **Fitopatologia Brasileira**, Brasília, v.16, p.34-39, 1991.

ROSSMAN, A.Y.; HOWARD, R.J.; VALENT, B. *Pyricularia grisea*; the correct name for the rice blast fungus. **Mycologia**, Bronz, v.82, n.4, p. 509-512, 1990.

SANTOS, A.B.; PRABHU, A.S.; AQUINO, A.R.L.N.; CARVALHO, J.R.P. Épocas, modos de aplicação e níveis de nitrogênio sobre brusone e produtividade de arroz de sequeiro. **Pesquisa Agropecuária Brasileira**, Brasília, v.21, n.7, p.697-707, 1986.

SHANER, G.; FINNEY, R.E. The effect of nitrogen fertilization on the expression of slow-mildewing resistance in knox wheat. **Phytopathology**, St. Paul, v.67, p.1051-1056, 1977.

SNEDECOR, G.W.; COCHRAN, W.G. **Statistical methods**. 6.ed. Ames: Iowa State University Press, 1978. 592 p.

SOAVE, J.; FURLANI, P.R.; AZZINI, L.E. Relação entre estado nutricional do arroz (*Oryza sativa* L.) e a suscetibilidade a *Pyricularia oryzae* Cav., agente causal da brusone. **Summa Phytopatologica**, Piracicaba, v.3, p.117-123, 1977.

STEINMETZ, S.; MORAIS, J.F.V.; OLIVEIRA, I.P.; MORAIS, O.P.; MOREIRA, J.A.; PRABHU, A.S.; FERREIRA, E.; SILVEIRA FILHO, A. Upland rice environments in Brazil and the fitness of improved technologies. In: INTERNATIONAL UPLAND RICE RESEARCH CONFERENCE, 2., 1985, Jakarta. **Proceedings...** Los Baños: International Rice Research Institute, 1986. p.15-24.

STONE, L.F.; OLVEIRA, A.B.; STEINMETZ, S. Deficiência hídrica e resposta de cultivares de arroz de sequeiro ao nitrogênio. **Pesquisa Agropecuária Brasileira**, Brasília, v.14, n.3, p.295-301, 1979.

VILLAREAL, R.L.; MACKENZIE, D.R.; NELSON, R.R.; COFFMAN, W.R. Apparent infection rates of *Pyricularia oryzae* on different rice cultivars. **Phytopathology**, St. Paul, v.70, p.1224-1226, 1980.

VOLK, R.J.; KAHN, R.P.; WEINTRAUB, R.L. Silicon content of the rice plant as a factor influencing its resistance to infection by the blast fungus *Pyricularia oryzae*. **Phytopathology**, St. Paul, v.48, p.179-184, 1958.

WILLIS, G.M.; ALLOWITZ, R.D.; MENVIELLE, E.S. Differential susceptibility of rice leaves and panicles to *Pyricularia oryzae*. **Phytopathology**, St. Paul, v.58, p.1072, 1968.