# INTERACTION OF GENOTYPES AND ENVIRONMENT FOR GRAIN YIELD IN UPLAND RICE[1]

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ABSTRACT - With the aim to identify among some released upland rice (*Oryza sativa* L.) cultivars those best adapted to upland conditions, the genotype x environment interaction for grain yield was studied. Eight genotypes grown in 21 environments in the State of São Paulo, Brazil, were evaluated from 1974 to 1977 seasons. Both genotypes x environments interaction and the variation among the environments showed to be highly significant ($P < 0.01$ and $P < 0.001$, respectively). No significant statistical difference between cultivar yields was detected ($P < 0.05$) and none of the cultivars displayed linear regression coefficient different from unit ($P > 0.05$). The nonlinear component ($s_d$) was highly significant ($P < 0.01$) for IAC 25, 'Pratão Precoce' and 'Batatais'; and nonsignificant for IAC 47, IAC 1246, IAC 1131, IAC 5544, and IAC 5032, which are the most stable cultivars, and their response to environmental changes could be predicted. Among the eight cultivars and the ecological conditions tested, these genotypes were the most promising lines toward stable grain production.

Index terms: *Oryza sativa*, environmental stress.

## INTERAÇÃO GENÓTIPO E AMBIENTE PARA RENDIMENTO DE GRÃOS EM ARROZ DE SEQUEIRO

RESUMO - Visando identificar, das cultivares de arroz de sequeiro (*Oryza sativa* L.) recomendadas, as mais adaptadas a esta condição de cultivo, oito populações deste tipo de planta foram cultivadas experimentalmente, de 1974 a 1977, em 21 ambientes do estado de São Paulo. Tanto a interação genótipo x ambiente como a variação entre os ambientes foram altamente significativas ($P < 0{,}01$ e $P < 0{,}001$, respectivamente). Não houve, entretanto, diferença estatística no desempenho da produção de grãos das cultivares ($P > 0{,}05$), nem entre os seus coeficientes de regressão e a unidade, no mesmo nível de significância. A componente não-linear da variação ($s_d$) foi altamente significativa ($P < 0{,}01$) para IAC 25, 'Pratão Precoce' e 'Batatais' e não-significativa para IAC 47, IAC 1246, IAC 1131, IAC 5544 e IAC 5032, sendo as cinco últimas, por conseguinte, consideradas estáveis. A estabilidade permite predizer suas respostas às melhorias introduzidas no ambiente e destacá-las como as mais promissoras entre as oito cultivares estudadas nos 21 ambientes, relativamente à produtividade de grãos.

Termos para indexação: *Oryza sativa*, estresse de ambiente.

## INTRODUCTION

The wide range of environmental conditions found in uplands of the State of São Paulo and similar areas of Brazil has long been a concern to plant breeders. Temperature and rainfall patterns vary widely from year to year and from location to location within years.

Air temperature, which range from 18 to 30°C, records an average of 24°C during the rice growth season (Instituto Agronômico de Campinas 1978).

This upland area has a rainy season that begins in October and ends in March. Annual rainfall pattern varies from 1,300 mm to 1,800 mm and 70% - 80% of the rain falls during the upland rice-growing season. However, up to 10 - day drought periods, locally known as *veranicos* (Fig. 1) may occur 13 times each 20 years during January and February (Arruda et al. 1979). It often causes severe damage to the rice crop at the reproduction and ripening stages.

Soil types and fertility levels also differ throughout the region. Most of São Paulo's upland rice is sown on welldrained soils, principally highly weathered oxisols. Some alfisols and ultisols are used also. The oxisols generally have a pH between 4 and 5, aluminum saturation of more than 60%, low levels of available phosphorus, and a cation exchange capacity of 2-8 meq/100 g of soil. The

1 Accepted for publication on September 6, 1988.
Part of a Master thesis presented by the senior author to Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ) - Universidade de São Paulo (USP), Piracicaba, São Paulo State, Brazil.

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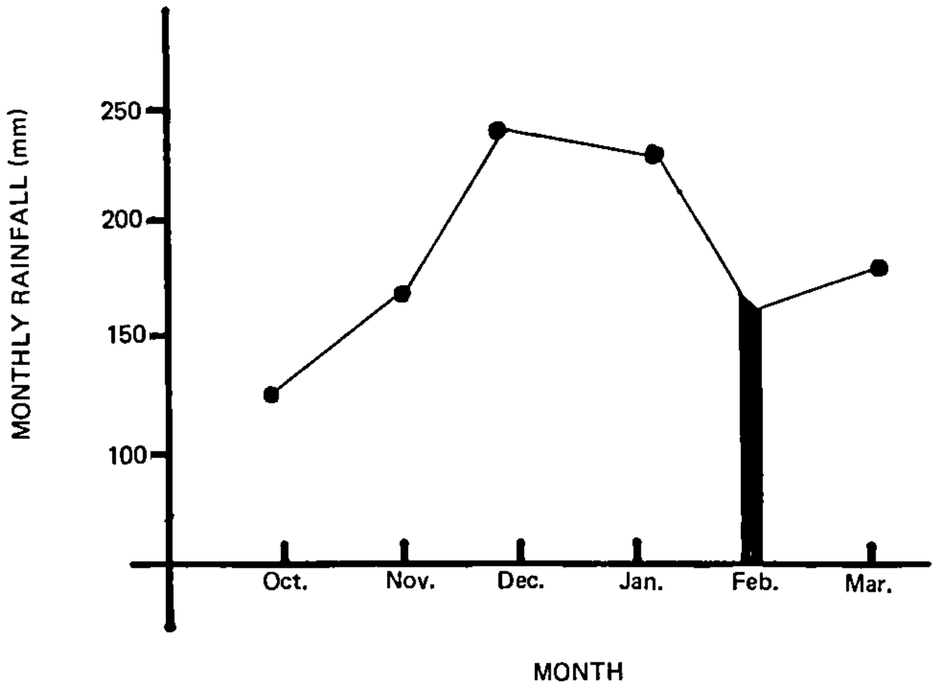


FIG. 1. Average rainfall distribution during upland rice-growing season (from 1974 to 1977) from the eight locations studied in the State of São Paulo, Brazil, and identification (shaded area) of its drought-prone period (veranico).

ultisols have kaolinitic type of lays. On oxisols and ultisols rice responds to nitrogen, phosphorus, calcium, and in some cases to zinc and iron application or supplementation. Lime is sometimes necessary depending on soil pH and rice variety, and is usually applied as calcium and magnesium fertilizer. Farmers prefer to rotate rice and pasture on alfisols (International Rice Research Institute 1975).

Because of the constraints appointed, upland rice yields in the São Paulo State during 1974/77 seasons were low, about 1.1 ton/ha (Steinmetz et al. 1979).

A study of genotype x environment interaction can lead to successful evaluation for the relatively stable genotypes which could be useful in crop production recommendations. Methods for studying the phenotypic stability have been proposed by Finlay & Wilkinson (1963), Eberhart & Russell (1966), and Perkins & Jenkins (1968). The model proposed by Eberhart & Russell (1966) has been used effectively in Brazil by Miranda Filho (1974) for corn (*Zea mays* L.), by Monteiro (1978) for eggplant (*Solanum melongena* L.), and by Bonato (1978) for soybean (*Glycine max* (L.) Merr.). No such studies, however, have been carried out for upland rice, which may suffer varied losses considering the mentioned cultivation conditions. The present investigation was undertaken to measure the relative grain yield stability of eight rice cultivars under a wide range of São Paulo's upland conditions with the purpose to search those best adapted to them.

## MATERIALS AND METHODS

The eight upland rice cultivars described in Table 1 were tested from 1974 to 1977 seasons over Campinas, Capão Bonito, Jaú, Mococa, Pindorama, Ribeirão Preto, Tatuí, and Tietê locations, making up 21 environments in the upland region of São Paulo State, Brazil.

The crop was grown as recommended by seed supplier; the field design was an 8 x 8 Latin Square.

Grain yield data adjusted to 14% moisture was obtained for each 5 m x 3 m plot and expressed as ton/ha. The statistical analysis of the data followed the proposed by Eberhart & Russell (1966).

## RESULTS AND DISCUSSION

Differences in mean environmental yield values were observed in different years. The highest yields were obtained in the 1976/77 season, and the lowest in 1974/75. The highest overall mean yields were obtained for 'Pratão Precoce', IAC 25 and 'Batatais'; IAC 1131 had the lowest yield (Table 2). The same table shows also the mean grain yields (ton/ha), the estimates of the two stability parameters (b and $s_d$), and of the genotypes x environment interaction component of variance for each season studied.

A pooled analysis of variance for grain yield in the 21 environments (Table 3) showed that genotype effect was not statisticaly significant since the performance of the cultivars was similar ($P > 0.05$) throughout locations and seasons (Table 2), whereas genotype x environment interaction was highly significant ($P < 0.01$). The variation among the environments was also highly significant ($P < 0.001$). The major contribution for the significance of the interaction came from the deviations from regression (highly significant for three of the cultivars tested), since the correspondent linear regression coefficients did not differ from unity ($P > 0.05$). A bidimensional view of the linear response of these cultivars is shown in Fig. 2.

Finlay & Wilkinson (1963) considered the linear regression coefficient as a measure of stability of performance. When $b > 1.0$, a variety is not adapted to low yielding environments, and when $b < 1.0$, a variety yields well in lowyielding environments, but is unable to exploit more favorable conditions.

**TABLE 1. Genealogy, some agronomic characters and field reaction to lodging and major disease (Blast and helminthosporium) of eight upland cultivars[1] in São Paulo State, Brazil.**

| Cultivar | Genealogy | Plant height (cm) | Growth duration (days)[2] | Reaction to | | |
|---|---|---|---|---|---|---|
| | | | | Lodging | Blast | Helminthospor. |
| IAC 25 | 'Dourado Precoce'/ IAC 1246 | 100 | 90 | MR | S | MS |
| IAC 47 | IAC 1246/IAC 1391 | 120 | 110 | MR | S | R |
| IAC 1131 | IAC 1246/IAC 1391 | 120 | 130 | R | S | S |
| IAC 1246 | 'Pratão'/'Pérola' | 130 | 120 | MR | S | R |
| IAC 5032 | 'Pratão'/'Pérola' | 125 | 130 | MR | S | MS |
| IAC 5544 | 'Pratão'/'Matão' | 120 | 120 | MR | S | MS |
| 'Batatais' | Mass selection on local variety | 100 | 90 | MR | S | MS |
| 'Pratão Precoce' | Mass selection on local variety | 100 | 90 | MR | S | MS |

Source: Coordenadoria de Assistência Técnica Integral (CATI), Campinas, São Paulo State, Brazil.

[1] All lines have long-broad grain type.

[2] From emergence to blooming.

/ First cross.

MR Moderately resistant.

R Resistant.

MS Moderately susceptible.

S Susceptible.

IAC Instituto Agronômico de Campinas, São Paulo, Brazil.

TABLE 2. Yield (ton/ha) of eight upland cultivars, estimates of genotypes x environment interaction components (G x E) and stability parameters (b and $s_d$), in são Paulo State, Brazil.

| Cultivar | Seasons | | | Mean and order of merit | b | $s_d$ |
|---|---|---|---|---|---|---|
| | 1974/75[1] | 1975/76[2] | 1976/77[3] | | | |
| IAC 25 | 2.29 ± 0.33 | 1.77 ± 0.37 | 2.92 ± 0.60 | 2.33 ± 0.56 a | 0.92 | 0.83** |
| 'Pratão Precoce' | 2.05 ± 0.32 | 1.57 ± 0.33 | 2.90 ± 0.60 | 2.19 ± 0.44 a | 1.08 | 0.79** |
| 'Batatais' | 2.09 ± 0.26 | 2.07 ± 0.29 | 2.79 ± 0.69 | 2.15 ± 0.46 a | 0.99 | 0.83** |
| IAC 47 | 2.04 ± 0.42 | 2.40 ± 0.25 | 1.85 ± 0.51 | 2.09 ± 0.43 a | 0.99 | 0.55 |
| IAC 5032 | 1.88 ± 0.41 | 2.09 ± 0.30 | 1.78 ± 0.53 | 1.92 ± 0.39 a | 1.01 | 0.46 |
| IAC 5544 | 1.81 ± 0.43 | 2.03 ± 0.29 | 1.86 ± 0.55 | 1.90 ± 0.42 a | 1.08 | 0.50 |
| IAC 1131 | 1.69 ± 0.55 | 2.15 ± 0.32 | 1.84 ± 0.51 | 1.89 ± 0.51 a | 1.06 | 0.53 |
| IAC 1246 | 1.73 ± 0.41 | 2.07 ± 0.28 | 1.79 ± 0.51 | 1.86 ± 0.41 a | 1.04 | 0.46 |
| Mean | 1.95 ± 0.39 | 1.96 ± 0.30 | 2.22 ± 0.56 | 2.08 ± 0.45 | 1.00 | |
| (G x E) | 19.82** | 9.35** | 23.33** | | | |
| SE | 0.027 | 0.021 | 0.018 | 0.015 | | |

** Significant at $P < 0.01$.
b values are not different from unity at $P < 0{,}05$.
Means followed by a common letter are not different at $P < 0.05$ (Duncan's Multiple Range Test).
1 - 2 and 3 are average yeilds from 7 - 8 and 6 locations, respectively.
IAC: Instituto Agronômico de Campinas, São Paulo, Brazil.

TABLE 3. Pooled analysis of variance for grain yield (kg/ha) in eight upland rice cultivars evaluated in 21 environments of São Paulo State, Brazil, according to the model of Eberhart & Russell (1966).

| Source | df | MS |
|---|---|---|
| Genotype (G) | 7 | 412861,50 |
| Environments (E) | 20 | 8708591,06*** |
| Gen. x Env. (G x E) | 140 | 446832,25** |
| Env./G x Env. E/(G x E) | 160 | 1479544,23*** |
| Env. (linear) | 1 | 174171788,50*** |
| G x E (linear) | 7 | 94289,50 |
| Pooled deviations | 152 | 407205,84** |
| IAC 25 | 19 | 693022,94** |
| IAC 47 | 19 | 298067,61 |
| IAC 1246 | 19 | 212674,07 |
| IAC 1131 | 19 | 283046,38 |
| IAC 5544 | 19 | 248041,76 |
| 'Pratão Precoce' | 19 | 620015,04** |
| 'Batatais' | 19 | 693397,59** |
| IAC 5032 | 19 | 209381,30 |
| Pooled error | 882 | 214334,00 |

** Significant at $P < 0.01$.
*** Significant at $P < 0.001$.

The b values for the eight upland rice varieties studied are reproduced in Table 2 and Fig. 2. It should be noted that they show a near-average grain stability (b = 1.0) with a high mean yield across all environments and a high mean yield potential to the environments concerned. However, they may show bad yields if extremely adverse environmental conditions will occur. Eberhart & Russell (1966), however, suggested that both linear (b) and nonlinear ($s_d$) components of genotype x environment interaction should be considered, if the phenotypic stability of a genotype is evaluated. Subsequently, Breese (1969), Samuel et al. (1970), and Paroda & Hayes (1971) emphasized that linear regression should be considered as a measure of the response of a particular genotype, while the deviation from the regression line may be interpreted as a measure of stability. Genotypes with the nonsignificant deviation from regression are the most stable and vice-versa.

According to the deviations from regression, the eight upland rice varieties (Table 2) can be divided into two main groups: IAC 25, 'Pratão Precoce', and 'Batatais' (all of short growth duration), which showed highly significant ($P < 0.01$) varia-

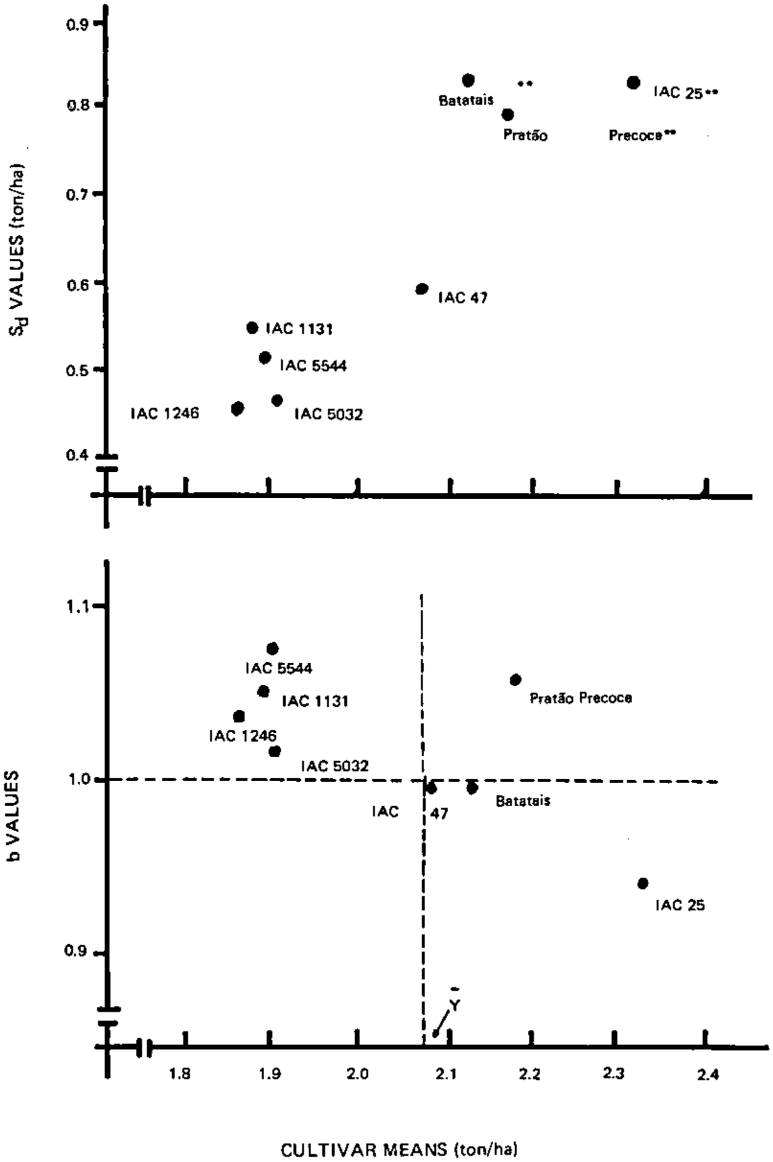


FIG. 2. Mean grain yield of eight upland rice cultivars and their stability parameters, b and $s_d$.

**Significant at P < 0.01; $\hat{\bar{Y}}$.. - General mean.

tion around the regression line, are phenotypically unstable. Considering also the means and the slopes, the five stable lines, namely IAC 47, IAC 1246, IAC 1131, IAC 5544, and IAC 5032 (all of medium growth duration) seem to be promising. Excluding 'Pratão Precoce', the three varieties that showed higher deviation were the ones with high yields and lower slopes (Table 2); probably their short cycle contributed to reduce the damage of the *veranico* or blast disease incidence on the grain yield. However, their greatest deviation from regression line makes its performances, in a given environment, less predictable.

Except for IAC 47 and IAC 1131, the other phenotypically stable cultivars were relaeased from lines screened from crosses between the local varieties 'Pratão', 'Pérola', and 'Matão' (Table 1). This may have contributed to their better adaptability to environmental fluctuations, including rainfall patterns of the region (Fig. 1). Therefore, the judicious exploitation of these upland rice cultivars is a correct way to obtain high grain yields in São Paulo State.

## ACKNOWLEDGEMENTS

The authors thank Professors Paulo Silveira Jr. and Élio Paulo Zonta, from Universidade Federal de Pelotas, for help during statistical analysis; Professor João Gilberto Corrêia da Silva, from Brazilian Agricultural Research Organization (EMBRAPA), for reading and criticizing the manuscript; Typist Rosane Maria M. Guidotti, for typewriting the text, and the Instituto Agronômico de São Paulo for supplying the climatological and experimental field data.

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