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# Study of the interaction genotypes x environments in the selection process of upland rice

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**ABSTRACT** - *Objectives of this study were the investigation of the interactions between upland rice lines/cultivars x planting system, years and locations. The experiments were conducted in the agricultural years of 2001/02 and 2002/03 in Lavras, Uberlândia and Patrocínio in the state of Minas Gerais (MG), in two planting system: conventional and no-tillage. The treatments were 20 lines/cultivars and the evaluated traits were: plant height, flowering date, grain yield and disease incidence. The absence genotype x system interaction of grain yield indicated that cultivars recommended for sowing traditional can be utilized in the no-tillage system. The interactions genotypes x locations and genotypes x years were significant. The Cruz methodology indicated that cultivar Caiapó presented adaptation in unfavorable environments and the line CNAs 8983 showed response in the environment improvement. The Annicchiarico methodology showed that Guarani and CNAs 8989 were the most stable.*

**Key words**: no-tillage sowing, stability, breeding, *Oryza sativa.*

## INTRODUCTION

The new fine-type upland rice cultivars, due to their long fine grain type and their good commercial quality, have been the focus of preference for cultivation under no-tillage system, for economical reasons as much as for the need of crop rotation, a very important requisite for the system. It is remarkable the great expansion of rice cultivation under the no-tillage system in the upland of central Brazil, especially in recovered areas with plentiful rainy seasons and/or central pivot sprinkle irrigation. In such areas, the rice crop participates is an alternative to the maize/soybean rotation system, with expectations of high yields.

For a further expansion of the rice areas using no-tillage, it is of paramount importance to identify cultivars that adapt ideally to such conditions and which explore this crop system more efficiently and profitably. Furthermore, the selection of more adapted cultivars will make easier their adoption by growers, thus widening their usage and incrementing the total area of rice cultivation in the country.

Few studies have wit with the selection of line and

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cultivars that present good overall performance when cultivated under no-tillage planting system. In the genetic improvement it is common to evaluate genotypes under several different environments, so that the most adapted may be identified with great accuracy. In such studies it is frequently considered different environments, both locations and years, although it may also be included other sources of variation such as doses of fertilizers, sowing dates, plant density and planting systems (Vencovsky and Barriga 1992). Evaluations of line and cultivars under different planting systems, such as the non-tillage, have not been used in breeding programs. That would be advantageous since it would permit the selection of breeding lines with greater adaptation to the state. Such evaluations will make it possible to identify strains adapted to both cultivation systems or, if this is not possible, the identification of superior genotypes in each and every environment, which in turn would increase the efficiency of the rice breeder task.

As far as the rice crop is concerned, very little has been accomplished in order to attenuate the problems inflicted to the breeding programs by the genotype vs. environment interactions. A few researches exist that evaluate the best planting dates for different cultivars (Morais et al. 1989). Santos (2002) studied the effect of the interaction of segregant populations versus environments on the choice of superior populations in a breeding program. The greater emphasis has been given to the identification of more stable genotypes as they perform in regional trials of strains and cultivars under competition (Morais et al. 1981, Morais et al. 1982). Despite that, very little information is available on the performance of strains and cultivars as related to no-tillage systems in the central Brazil environment.

Objectives of this research were: to study the interactions lines/cultivars of upland rice x systems, years and locations of planting; to select upland rice lines and cultivars adapted to conventional and no-tillage systems utilizing direct and index selection.

## MATERIAL AND METHODS

The experiments were conducted in the crop years 2001/02 and 2002/03 at three locations of Minas Gerais state: Lavras, Uberlândia and Patrocínio, under two planting systems: traditional and no-tillage. All experiments comprised randomized complete-block designs with three replications. The experimental units were constituted of plots with four rows four of 4 m length spaced 0.4 m apart; the data were collected in the three central meters of the two internal rows.

The treatments studied were comprised by 20 upland rice lines/cultivars provided by the Embrapa Arroz e Feijão (Embrapa Rice and Common Bean). The conventional soil tillage system was accomplished with a disk plow 30 days prior to sowing and leveled out with a harrow one day before. In the no-tillage plots desiccant herbicide was applied, of total action, five days before sowing. A sidedressing of 300 kg ha$^{-1}$ of the fertilizer formulation of 5-30-15 was applied in the planting furrow and 200 kg ha$^{-1}$ of ammonium sulfate spread out 40 days after planting.

The characters evaluated were: plant height (cm), flowering date (day), grain yield (kg ha$^{-1}$) and disease incidence. Such evaluations were carried over according the Rice Research Method Manual of the Embrapa Arroz e Feijão (EMBRAPA 1977).

Analyses of variance were initially run on an individual basis for the traits studied. Later a analysis of variance for the group of experiments were run, encompassing the lines/genotypes that were in common for the two growing seasons, locations and planting systems, following the statistical model proposed by Vencovsky and Barriga (1992).

To study the effect of the interaction lines/cultivars x. planting systems, an alternative procedure proposed by Cruz and Castoldi (1991) was utilized, in which aims at decomposing the interaction two by two in simple and complex component.

Once detected the genotype by environment interaction, three methods were utilized for the study of adaptability and stability, Annicchiarico (1992), Cruz et al. (1989) and Lin and Binns (1988), so that the process of evaluation would turn out safer and more efficient. The first method estimates a confidence index ($I_i$) of a certain cultivar to present performance bellow the environment average. It consists of expressing the means as a percentage of the environment average.

The methodology of Cruz et al. (1989) is based on the analysis of bi-segmented regression and uses the the mean ($b_{0i}$) and the linear response to the unfavorable environments ($b_{1i}$) and to the favorable environments ($b_{1i}$ + $b_{2i}$) as parameters of adaptability. The genotype stability is estimated through the regression deviations $\sigma^2_d$ of each line/cultivar in function of the environmental variations. The methodology proposed by Lin and Binns (1988) define as measures to estimate stability, the means square of the distance between the genotype mean and the maximum average response for all environments.

The choice of the best lines and cultivars was accomplished by observing directly the means of the traits as well as utilizing the classic selection index proposed by Smith (1936) and Hazel (1943), as a helpful tool in this process; the economic weights relative to the characters were established following recommendations. The method employed for the calculation of the classic selection index was according to Cruz and Regazzi (1994).

## RESULTS AND DISCUSSION

### Individual analyses

The analyses of variance for the characters evaluated during the two growing seasons showed that it has occurred highly significant differences ($P < 0.01$) among genotypes for the majority of the characters in the two planting systems, the three locations and the two years. Among the non-significant results, it is noticeable, the character grain yield under the conventional planting system at the locations of Patrocínio (2001/02) and Uberlândia (2002/03).

As for the coefficient of environment variation, which estimates the experimental precision, it is observed that the values varied greatly from one character to the other, and it was considered high for the trait grain yield in the experiments conducted at Patrocínio 2001/02 (37.19%).

The experiment means for the trait grain yield in the growing season 2001/02 ranged from 2396.7 kg ha$^{-1}$ in the no-tillage system at Patrocínio, to 4325.5 kg ha$^{-1}$ in the conventional crop management at Uberlândia. In this season the means for grain yield obtained in the no-tillage system were quite low at all locations and the genotypes presented short and early plants. That could be associated with the fact that in the no-tillage system there was no soil revolving which was the opposite of the traditional system. In the latter case, there were better conditions for root development and so influencing growth and flowering of the genotypes. The particular areas where the experiments were conducted did not undergo such previous preparation.

In the following growing season (2002/03), results did not present the same trend, i.e., the greatest grain yield averages for the conventional management were found only in the locations of Uberlândia (2891.7 kg ha$^{-1}$) e Patrocínio (4911.4 kg ha$^{-1}$). The no-tillage system at Lavras has lead to a better plant development with taller plants (109 cm) as well as early flowering (81.6 days), which reflected in the grain yields (4966.4 kg ha$^{-1}$). At Uberlândia, in general, the genotypes did not develop as well in both planting systems. It is relevant to point out that in this very year, the disease incidence was high and the genotypes were submitted to a low light period during their reproductive stage, which lead to low grain yields. At Patrocínio, there was an increment on mean yields in both systems as compared to the previous year; however, the flowering date means and plant heights did not vary much from one system to the other.

### Genotype x environment interaction

The results concerning the summary of the group analysis involving crop planting systems and genotypes are presented in Table 1. For the character grain yield, the genotype-by-planting system interaction was significant only at Lavras in both years and at Patrocínio in the 2002/03 growing season. That indicates the differential performance of the genotypes in the two planting systems at those locations. In those cases. Simple and complex interactions were estimated in order to help the interpretation of the results. There was a greater predominance of the complex fraction of the interaction in the three experiments (72.80 and 89%, respectively). The presence of this type of interaction is a hindrance for the plant breeder's work that must select specific genotypes for each environment. Nevertheless, in half of the experiments, no genotype by system interaction was found, which indicates that each cultivar has shown up, in average, the same performance in both the no-tillage and conventional systems.

When grain yield averages in each location in both years were considered, it was observed that only at Uberlândia there was a reduction from the first to the second year. The lower experiment average was found at Uberlândia 2002/03 (2467.2 kg ha$^{-1}$) whereas the greatest was found at Patrocínio in the 2002/03 (4311.0 kg ha$^{-1}$) growing season.

As far as the flowering results are concerned, it was observed the occurrence of genotype-by-planting systems interactions at all locations and in both years. The genotypes flowered early at Uberlândia (2002/03) and lately at Lavras (2001/02). As for plant height, only at Lavras location in 2001/02, it was found a significant interaction and this trait was little affected by years in both planting systems.

Disease incidence was evaluated at Lavras during both crop years of study and also at Uberlândia in the 2002/03 growing season. As a general rule, it was found interactions between genotypes and planting systems for the majority of de diseases evaluated; the cultivars and lines showed higher susceptibility in the environments where the no-tillage system was utilized, which was probably associated with the greater easiness of pathogen survival in such environments (Table 2). In South Brazil

**Table 1**. Summary of joint variance analysis of characters evaluated in upland rice genotypes in two planting systems

| | | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2001/02 | | | 2002/03 | | |
| | | Lavras | | | | | |
| **Sources of variation** | **df** | **Grain yield** | **Flowering date** | **Plant height** | **Grain yield** | **Flowering date** | **Plant height** |
| Replications(Systems) | 4 | 1691547** | 0.442 | 191.583** | 903643.9 | 1.9 | 38.891 |
| Systems (S) | 1 | 21304299** | 832.133** | 2058.408** | 91445004.3** | 3864.675** | 3499.2** |
| Genotype (G) | 19 | 1071545** | 240.770** | 324.963** | 1846664.0** | 131.830** | 632.633** |
| S x G | 19 | 722979.9* | 17.221** | 100.145** | 867543.1* | 9.640** | 39.428 |
| Error | 76 | 402546.9 | 1.836 | 40.382 | 471352.6 | 0.891 | 24.453 |
| VC (%) | | 18.7 | 1.47 | 7.5 | 16.8 | 1.08 | 4.7 |
| Mean | | 3392.7 | 92.2 | 84.7 | 4093.4 | 87.3 | 104.4 |
| | | Uberlândia | | | | | |
| **Sources of variation** | **df** | **Grain yield** | **Flowering date** | **Plant height** | **Grain yield** | **Flowering date** | **Plant height** |
| Replications(Systems) | 4 | 1853464.3** | 11.083* | 85.892** | 491234 | 5.192 | 25.183 |
| Systems (S) | 1 | 17533807** | 61.633**. | 2457.075** | 1618936.3** | 874.8** | 1840.833** |
| Genotype (G) | 19 | 2336785.6** | 556.375** | 314.956** | 589361.7** | 242.720** | 323.737** |
| S x G | 19 | 373068.2 | 8.633** | 19.215 | 259227.4 | 17.449** | 46.570 |
| Error | 76 | 281013.3 | 3.189 | 22.567 | 245450.1 | 3.604 | 34.438 |
| VC (%) | | 13.5 | 2.2 | 4.9 | 20.1 | 2.4 | 7.3 |
| Mean | | 3931.5 | 83.1 | 96.0 | 2467.2 | 79.3 | 80.8 |
| | | Patrocínio | | | | | |
| **Sources of variation** | **df** | **Grain yield** | **Flowering date** | **Plant height** | **Grain yield** | **Flowering date** | **Plant height** |
| Replications(Systems) | 4 | 3353434.52** | 17.067** | 141.358** | 952830.3 | 20.167 | 157.058** |
| Systems (S) | 1 | 11249175.68** | 72.075** | 3553.408** | 43258820.0** | 297.675** | 1235.208** |
| Genotype (G) | 19 | 781390.9 | 394.636** | 168.812** | 2129763.1** | 364.534** | 349.892** |
| S x G | 19 | 1016533 | 7.303** | 29.163 | 1399022.6* | 42.692** | 45.454 |
| Error | 76 | 759514 | 2.347 | 26.016 | 679414.6 | 14.886 | 31.049 |
| VC (%) | | 32.2 | 1.8 | 7.2 | 19.1 | 4.7 | 6.5 |
| Mean | | 2702.9 | 87.4 | 70.6 | 4311.1 | 83.0 | 86.0 |

* $P < 0.05$ and ** $P < 0.01$

researches demonstrate that the occurrence of diseases on rice under no-tillage planting may limit the yields of this crop (Reis 1999, Costamilan 1999).

The summary of the analysis of variance of the group of experiments involving the genotypes evaluated under the two planting systems, the two years and three locations is presented in Table 3. The genotype-by-location interactions have occurred in both growing seasons. Such type of interaction is normally very much accentuated when rice genotypes are under evaluation and this is an indication that they present inconsistent performance from one location to the other, thus causing the cultivar recommendation to be specific for each growing site.

The genotypes in common in both years of testing were grouped and the analysis of the group of experiments was proceed for the characters under evaluation in both planting systems, three locations and two years. The results are displayed in Table 4. For grain yield, the first-order significant interactions were Y x L, Y x S, L x S, Y x G and L x G. In general, the genotypes presented differential performance during the two years and at the three locations, whereas the G x S was not significant, that is, the genotypes presented consistent responses in each of the planting system.

For flowering dates, all interactions turn out to be significant and this character was much affected by the environments tested in this research. The majority of the interactions for plant height was significant, which also demonstrate the effect of the environments over this trait.

## Adaptability and stability

**Table 2**. Summary of joint variance analysis of disease incidence in the upland rice genotypes evaluated in two planting systems

| Sources of variation | df | Brown spot | Leaf scald | Leaf blast | Neck blast | Grain staining |
|---|---|---|---|---|---|---|
| | | **Lavras 2001/02** | | | | |
| Replications(Systems) | 4 | 0.267 | 1.6 | 0.833 | 6.933** | - |
| Systems (S) | 1 | 2.7** | 19.2** | 12.03** | 2.13 | - |
| Genotype (G) | 19 | 0.370 | 4.414 ** | 2.77** | 14.765** | - |
| S x G | 19 | 0.525 | 1.446 | 1.01** | 2.274 | - |
| Error | 76 | 0.337 | 1.109 | 0.377 | 1.530 | - |
| VC (%) | | 47.7 | 28.5 | 40.49 | 35.7 | - |
| Mean | | 1.2 | 3.7 | 1.5 | 3.5 | - |
| | | **Lavras 2002/03** | | | | |
| Replications(Systems) | 4 | 1.3* | 2.9** | 0.433 | 1.1 | 1.767** |
| Systems (S) | 1 | 58.8** | 14.7** | 0.833 | 0.3 | 5.633** |
| Genotype (G) | 19 | 1.467** | 1.633** | 0.412* | 1.563* | 3.387** |
| S x G | 19 | 1.467** | 1.437** | 0.412* | 1.282 | 1.423* |
| Error | 76 | 0.493 | 0.619 | 0.223 | 0.749 | 0.468 |
| VC (%) | | 41.3 | 26.7 | 43.4 | 59.69 | 23.2 |
| Mean | | 1.7 | 2.9 | 1.1 | 1.45 | 2.9 |
| | | **Uberlândia 2002/03** | | | | |
| Replications(Systems) | 4 | 24.533** | - | - | 0.933 | 2.133 |
| Systems (S) | 1 | 56.033** | - | - | 9.633** | 16.133** |
| Genotype (G) | 19 | 5.788** | - | - | 8.651** | 1.614 |
| S x G | 19 | 1.858 | - | - | 3.107** | 4.274* |
| Error | 76 | 1.586 | - | - | 0.968 | 2.028 |
| VC (%) | | 50.7 | - | - | 43.1 | 61.0 |
| Mean | | 2.4 | | | 2.3 | 2.3 |

* P < 0.05 and ** P < 0.01

**Table 3**. Summary of joint variance analysis of upland rice genotypes evaluated in two planting systems

| | | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2001/02 | | | 2002/03 | | |
| **Sources of variation** | **df** | **Grain yield** | **Flowering date** | **Plant height** | **Grain yield** | **Flowering date** | **Plant height** |
| Replication | 12 | 2299482.1** | 9.531** | 139.611** | 782569.4 | 9.086 | 73.711** |
| Locations (L) | 2 | 45518179.3** | 2476.319** | 19356.144** | 121836616** | 1896.008* | 18406.975** |
| Systems (S) | 1 | 49264022.0** | 680.625** | 7961.803** | 923045.7 | 1849.6** | 119.025* |
| L x S | 2 | 411629.9 | 142.608** | 53.544 | 77699857.5** | 1593.775** | 3228.108** |
| Genotype (G) | 19 | 1517002.5** | 1124.85** | 690.79** | 1398555.6** | 648.88** | 1163.441** |
| GxL | 38 | 1336359.5** | 33.466** | 58.969** | 1583616.6** | 45.099** | 71.411** |
| GxS | 19 | 572039.4 | 13.192** | 48.276* | 639145.5 | 25.618** | 41.709 |
| GxLxS | 38 | 770270.9* | 9.982** | 50.123** | 943323.8** | 22.082** | 44.871* |
| Error | 228 | 481024.7 | 2.457 | 29.655 | 465405.8 | 6.460 | 29.980 |
| VC (%) | | 20.7 | 1.7 | 6.5 | 18.8 | 3.1 | 6.1 |
| Mean | | 3342.4 | 87.5 | 83.8 | 3623.9 | 83.2 | 90.4 |

* P < 0.05 and ** P < 0.01

The results concerning the study of adaptability and stability of the genotypes for the trait grain yield are displayed in Table 5. The estimates of the $\hat{b}_1$ parameter, which corresponds to the linear response of genotypes to the unfavorable environment variations, varied from 0.66 to 1.21. Only the cultivar Caiapó presented adaptability at unfavorable environments ($\hat{b}_1 < 1$), all other genotypes presented $b_1=1$, an evidence of wide adaptability. Considering the response to favorable environments, the genotypes Carisma and CRO 97505 presented $\hat{b}_1 + \hat{b}_2 < 1$, indicating that they did not respond to the environmental improvement. The line CNAs 8983 was the only genotype that showed response to the environment improvement ($\hat{b}_1 + \hat{b}_2 > 1$). The other genotypes with values $\hat{b}_1 + \hat{b}_2 = 1$, respond in a proportional manner to the environmental changes. As far as stability was concerned none of the cultivars tested as well as line CNAs 9019, presented predictable performance. It is important to notice that the predictability level should not interfere negatively with the recommendation of cultivars, when the estimate of $R^2$ is higher than 80%. This parameter indicates that there was a good adjustment of the data to the straight line regression (Cruz et al. 1989). The ideal cultivar as proposed by Cruz, which encompasses all attributes such as a high average, $\hat{b}_1 < 1$, $\hat{b}_1 + \hat{b}_2 > 1$ and the variance of regression deviations close or equal to zero, was not found amongst the cultivars and strains evaluated in the present study.

According with the method by Lin e Binn, the ideal genotype must present the smaller deviation possible ($P_i$) in relation to the maximum performance. In this case, one may detect as much stable genotypes the cultivars Guarani e Conai as walls the lines CNAs 8989 and CNAs 8983. On the other hand, cultivars Carisma, Primavera and Caiapó presented a great contribution to the interaction, which demonstrate high instability. It is important to comment the performance of cultivar Guarani that in several researches has shown up as a much stable genotype. In spite of being a genotype that does not present the phenotype known as fine long grains, it may be utilized in rice breeding programs as a parental for obtaining more stable genotypes.

With the methodology proposed by Annicchiarico and observing the I(i) values, the only genotypes that present 65% probability of, in the worst hypothesis, producing 0.6% and 0.1% respectively higher than the environmental average, are Guarani and CNAs 8989. Such genotypes are therefore more stable in relation to the environmental fluctuations. Such results were coincident with the ones obtained when utilizing the previous methodology for the genotypes Guarani and CNAs 8989 (Table 5).

**Direct selection and selection index**

The final genotype averages, common to both years of study are displayed in Table 6. The direct selection on the traits was based on the their averages and the objective was to select genotypes with high grain yield, early-flowering and intermediate plant height. Among the cultivars, Guarani should be highlighted and among the lines CNAs 8983, CNAs 8989 and CNAs 9019 were the ones that fulfill the proposed requirements.

A selection index is characterized by the combination of all traits of interest in only one index (value) for each individual. Selection is then practiced on individual index values and indirect responses expected for the original traits are so evaluated. Specifically for the rice crop, it has been adopted the classical index developed by Smith (1936) and Hazel (1943). Applying this index and attributing an economic weight of 30 for grain yield, 1 for flowering dates and 1 for plant height, the selected genotypes were Canastra, Caiapó, Carisma and CNAs 8983. It is noticeable that the index selection has produced different results from the ones obtained by direct selection, but for the line CNAs 8983, selected by both procedures.

## CONCLUSIONS

The absence of genotype by planting system interaction as a result of this study for the trait grain yield, allows the conclusion that the genotypes recommended for cultivation under conventional system may be the same as for the no-tillage system. The present research covered three different regions of the state of Minas Gerais, Brazil (Triângulo Mineiro - the extreme West, Alto Paranaíba river valley and South), hence the results may be extrapolated to the whole state, since those regions represent it quite well. Another observation worth noticing is about the conduction of regional varietal tests using both planting systems. If one considers only the trait grain yield, the absence of interaction has demonstrated that the evaluations in only one of the planting systems would suffice. When the characters flowering and plant height are considered, the presence of the interaction lead to the conclusion that the genotypes did not perform in an analogous manner when grown under the two systems. Hence, depending on the objectives set by the breeder, one should take into consideration those results and other factors such as funds availability.

The genotype by location and genotype by year interactions were of quite high magnitude in this research

**Table 4**. Summary of joint variance analysis of upland rice genotypes evaluated in two planting systems at the three locations and two agricultural years

| Sources of variation | df | Grain yield | Flowering date | Plant height |
|---|---|---|---|---|
| Replication(Y*L*S) | 24 | 1455884.3** | 4.549 | 79.428** |
| Year (Y) | 1 | 5110597.6** | 2268.75** | 2780.593** |
| Locations (L) | 2 | 10270511.5** | 2523.322** | 9663.840** |
| Y x L | 2 | 88209017.8** | 7.590 | 11901.183** |
| Systems (S) | 1 | 24006422.6** | 1430.083** | 3804.454** |
| Y x S | 1 | 11940407.5** | 92.593** | 2465.333** |
| L x S | 2 | 23581395.5** | 706.674** | 1055.669** |
| Genotypes (G) | 11 | 1003829.2* | 2322.966** | 1999.417** |
| Y x G | 11 | 2416907.1** | 78.376** | 81.209** |
| L x G | 22 | 2458146.4** | 58.857** | 121.749** |
| S x G | 11 | 866012.3 | 25.780** | 80.878** |
| Y x L x S | 2 | 29893603.4** | 249.683** | 956.521** |
| Y x L x G | 22 | 1338848.6** | 29.974** | 52.678* |
| Y x S x G | 11 | 633488.9 | 16.724** | 18.434 |
| L x S x G | 22 | 1463164.5** | 13.037** | 37.548 |
| Y x L x S x G | 22 | 744412 | 21.814** | 72.137** |
| Error | 264 | 488443.9 | 3.157 | 30.406 |
| VC(%) | | 19.87 | 2.1 | 6.3 |
| Mean | | 3517.0 | 85.5 | 87.4 |

* P < 0.05 and ** P < 0.01

**Table 5**. Estimative of mean and adaptability and stability parameters of upland rice lines/cultivars, for grain yield, evaluated in three locations, two planting systems and two agricultural years

| Line/cultivars | Mean | B1 | B1 + B2 | Deviation variance | R % | Pi | Contribution for interaction | Ii[1] |
|---|---|---|---|---|---|---|---|---|
| Guarani | 3804.9 a2 | 1.15 | 1.21 | 1882103 | 5.6 | 100.6 | 172942.9* | 81.02 |
| Carisma | 3496.9 a1 | 0.77 | 0.38* | 3525025 | 12.2 | 94.4 | 366288.8** | 50.46 |
| Primavera | 3476.3 a1 | 0.96 | 1.33 | 3513852 | 11.3 | 87.6 | 979787.6** | 50.63 |
| Caiapó | 3586.1 a2 | 0.66* | 0.86 | 3875924 | 19.4 | 92.5 | 1344037** | 26.01 |
| Canastra | 3293.4 a1 | 0.92 | 0.90 | 3947052 | 7.9 | 86.0 | 568325.7** | 55.25 |
| Conai | 3603.0 a2 | 1.16 | 1.22 | 2517515 | 5.6 | 96.2 | 101078.8 | 84.67 |
| CRO 97505 | 3366.5 a1 | 0.97 | 0.13** | 3738996 | 9.0 | 90.8 | 83616.16 | 76.59 |
| CNAs 8989 | 3739.5 a2 | 1.15 | 1.21 | 2083684 | 5.7 | 100.1 | 116886.9 | 83.80 |
| MG 1066 | 3265.8 a1 | 1.04 | 1.16 | 3709705 | 4.1 | 88.4 | -79066.4 | 93.55 |
| CNAs 8983 | 3606.7 a2 | 0.84 | 1.63* | 2656535 | 7.2 | 98.1 | 12749.09 | 86.98 |
| CNAs 9019 | 3565.8 a2 | 1.21 | 1.23 | 3011720 | 9.4 | 93.5 | 222346.1* | 80.39 |
| CNAs 9026 | 3399.3 a1 | 1.15 | 0.74 | 2986842 | 2.5 | 91.9 | -66866.1 | 92.79 |

*, ** Significantly different of 1, for $b_1$, $b_1+b_2$, P < 0.05 and P < 0.01, respectively, by t test and different of zero by F test
[1]significance level = 0.35
I(i): confidence index
$b_1$, $b_1+b_2$, deviation variation and $R^2$ - Cruz et al. method
Pi and Contribution for interaction - Lin and Bins method
Ii - Annicchiarico method

**Table 6**. Mean of characters of upland rice line/cultivars evaluated in two planting systems, three locations and two crop years (2001/02 and 2002/03)

| Genotypes | Grain yield | Flowering date | Plant height |
|---|---|---|---|
| Guarani | 3804.9 a2 | 80.5 | 96.4 a5 |
| Carisma | 3496.9 a1 | 91.8 | 80.8 a1 |
| Primavera | 3476.3 a1 | 85.0 | 95.0 a5 |
| Caiapó | 3586.1 a2 | 100.8 | 102.3 a6 |
| Canastra | 3293.4 a1 | 98.8 | 87.4 a3 |
| Conai | 3603.0 a2 | 77.8 | 78.8 a1 |
| CRO 97505 | 3366.5 a1 | 81.3 | 85.6 a3 |
| CNAs 8989 | 3739.5 a2 | 84.7 | 81.4 a2 |
| MG 1066 | 3265.8 a1 | 77.0 | 91.4 a4 |
| CNAs 8983 | 3606.7 a2 | 90.2 | 83.0 a2 |
| CNAs 9019 | 3565.8 a2 | 81.5 | 86.6 a3 |
| CNAs 9026 | 3399.3 a1 | 78.0 | 79.9 a1 |

Means followed by the same letter are not significantly different at a level of P < 0.05 by Scott and Knot test

hence one should proceed a specific analysis about the performance of genotypes in such environments.

During the 2001/02 growing season, the genotypes that presented the best performance in the location Lavras were the advanced lines CNAs 8989, CNAs 8824 and CNAs 8983 when it was considered the characters grain yield, flowering, plant height and disease incidence. At Patrocínio, in the same year, it was not detected differences among genotypes, and so selection relied only in the traits flowering and plant height. At the location Uberlândia, the lines CRO 97505, CNAs 8989, CNAs 9019, CNAs 9021, CNAs 9026 and CNAs 9027, and the cultivar Primavera performed the best, although the latter has presented some lodging and its recommendation should be done with reservations in favorable environments.

During the following growing season, 2002/03, at Lavras, the cultivar Carisma as well as the lines CNAs 10260 and CNAs 10255 have the best performances in relation to the characters grain yield, flowering and plant height, also exhibiting resistance to the diseases under evaluation. At Patrocínio, cultivars Caiapó and Canastra as well as the line MG 1077 were the most productive and early-flowering genotypes. At Uberlândia, where disease incidence was also evaluated, the highlights went to the genotypes Carisma, Primavera, Caiapó, MG 1081, CNAs 8983 and MG 1074.

In general, the adaptability and stability study permitted the making of some inferences about the behavior of the genotypes. By using the methodology proposed by Cruz, cultivar Caiapó is to be noticed by presenting adaptation to unfavorable environments whereas line CNAs 8983 has shown response to environmental improvement. With the method by Annicchiarico, the most stable genotypes were cultivar Guarani and strain CNAs 8989. All the genotypes highlighted were considered as promising when the characters grain yield, earliness and intermediate plant height were the focus of the previous direct selection.

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# Estudo da interação genótipos x ambientes no processo de seleção de arroz de terras altas

**RESUMO** - *O objetivo deste trabalho foi estudar a interação entre linhagens/cultivares de arroz de terras altas com sistemas, anos e locais de plantio. Os ensaios foram realizados nos anos agrícolas de 2001/02 e 2002/03 em Lavras-MG, Uberlândia-MG e Patrocínio-MG sob dois sistemas de plantio: convencional e direto. Os tratamentos foram constituídos de 20 linhagens/cultivares em que se avaliaram os caracteres: altura de planta, florescimento, produtividade de grãos e incidência de doenças. A ausência de interação entre genótipos x sistemas, para produtividade de grãos, indicou que os materiais recomendados para o sistema convencional podem ser indicados para o sistema de plantio direto. As interações significativas ocorreram entre genótipos x locais e genótipos x anos. Pela metodologia de Cruz, a cultivar Caiapó destacou-se por apresentar adaptação à ambientes desfavoráveis e a linhagem CNAs 8983 mostrou resposta à melhoria do ambiente. Pela metodologia de Annicchiarico os genótipos mais estáveis foram a cultivar Guarani e a linhagem CNAs 8989.*

**Palavras-chave**: plantio direto, estabilidade, melhoramento**,** *Oryza sativa.*

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