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# Stability of upland rice lines in Minas Gerais, Brazil

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**ABSTRACT** - *Prior to release, new cultivars should be tested for region-specific yield stability, which is rarely done. This study aimed to evaluate the grain yield stability of 20 lines and cultivars tested in trials of value for cultivation and use in Minas Gerais State, in 10 environments in 2004/2005 and 13 other lines used in the two growing seasons (2003/2004 and 2004/2005), which were evaluated in 18 environments. The methodologies of Lin and Binns (1988) and Annicchiarico (1992) were used. Both methodologies identified the most stable lines in 2004/2005, in decreasing order: MG1097, Curinga-3, MG1096, and MG1094. The cultivars MG1096, MG1089, BRSMG Conai, CNAs10227, and MG1094performed best in the two growing seasons. It was concluded that the two methodologies are highly consistent.*

**Key words**: *Oryza sativa*, genetic breeding, upland rice.

## INTRODUCTION

The programs of genetic breeding of rice annually create a large number of lines which, after selection in preliminary trials, are tested in trials denominated Value for Cultivation and Use (VCU), for a particular regional scope, or for one or more Brazilian states. The great difficulty breeders face, is to select lines with a good grain yield in the different environments for which they will be recommended, in other words, with minimal line x environments interaction.

The determination of the grain yield stability of lines - denominated elite lines in VCU trials - enables breeders to issue sound cultivar recommendations, in spite of the variable environmental conditions which, among other factors, include year, soil, climate, planting date, and crop diseases and management.

There are numerous methods to evaluate stability (Soares and Ramalho1993, Atroch et al. 2000, Matos 2005), which differ in the estimates and mainly in the interpretation. It is therefore up to the breeder to choose the methodology with greatest ease of interpretation that applies best to the given data.

This study evaluated the stability of lines of upland rice tested in the VCU trials of Minas Gerais in 2003/2004 and 2004/2005, using the methodologies of Lin and Binns (1988) and Annicchiarico (1992).

## MATERIAL AND METHODS

In a first evaluation of grain yield stability data of ten VCU trials were used, conducted in Minas Gerais, in 2004/2005, in Felixlândia, Lambari, Lavras, Patos de Minas, Patrocínio, Uberaba and Viçosa. At three of the

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sites two trials were installed, one in the no-tillage system (NTS) and the other in the conventional planting system (CPS) (Lambari and Lavras) and two in the CPS in Patos de Minas, but on different properties. The only trial of Uberaba was in NTS. Altogether, seven trials had a CPS and three a NTS, totaling ten distinct environments.

In all trials, 20 lines and cultivars were tested, in an experimental design of complete random blocks with three replications. Plots consisted of five rows of 5m, spaced 0.40m apart and a density of 70 seeds $m^{-1}$. Of the entire area, the central 4m of the internal rows were harvested and evaluated. The crop was fertilized with 300 kg $ha^{-1}$ of the mixture 8-28-16 + Zn(0.5%) in the planting furrow and of 200 kg $ha^{-1}$ of ammonium sulfate in application, 40 days after sowing; the usual cultural practices were applied.

Thereafter, the stability of the 13 lines/cultivars that participated, simultaneously, in the VCU trials was estimated in the last two growing seasons (2003/2004 and 2004/2005). In 2003/2004, the trials were installed at eight locations - six in the CPS and two in the NTS, totaling eight different environments. The trials were conducted in Felixlândia (2 trials), Lambari, Patos de Minas, Patrocínio, Piumhi, Viçosa, and Uberaba. In one of the trials in Felixlândia the NTS was used and in the other the CPS, while in Uberaba the NTS was used. The methodology of trial conduction in 2003/2004 was similar to that in 2004/2005, as described.

The stability of the lines was estimated by the methodologies of Lin and Binns (1988) and Annicchiarico (1992):

**a) Methodology of Lin and Binns (1988):**

The underlying estimate of parameter $P_i$, measures the deviation from the yield of a given line in relation to the maximum in each one of the environments. The ideal line is the one with lowest $P_i$ value and lowest contribution to the line-by-environment interaction.

$P_i = \sum_{j=1}^{n} (Y_{ij} - M_j)^2 / 2n$, where:

$P_i$: stability index of line i;

$Y_{ij}$: yield of line i in environment j;

$M_j$: yield of the line with maximal response of all lines in environment j;

n: number of environments.

Partitioning of the expression:

$P_i = [\, n (Y_{i.} - \bar{M})^2 + \sum_{j=1}^{n} (Y_{ij} - \bar{Y}_{i.} - M_j + \bar{M})^2 ] / 2n$, where:

$Y_{i.} = \sum_{j=1}^{n} Y_{ij} / n$ : mean of line i;

$\sum_{j=1}^{n} = M_j / n$: mean of the lines with maximal response.

**b) Methodology of Annicchiarico (1992):**

The reliability index ($I_i$) of the performance of a given line is compared to the environment mean. This method estimates the probability that the performance of a certain line falls below the environment mean. The means of the lines are expressed as percentage of the environmental mean.

$I_i = {}_{i.} - Z_{(1-a)} * S_i$ , where:

$I_i$: reliability index (%);

${}_{i.}$: mean of line i in percentage;

Z: percentile (1-a) of the function of accumulated normal distribution;

a: significance level;

$S_i$: standard deviation from the percentage values.

## RESULTS AND DISCUSSION

The stability values of the 20 lines evaluated in the VCU trials of 2004/2005 are presented in Table 1. The methodology of Lin and Binns (1988) identified line MG 1097 as by far the most stable (Pi=412000), with a near-maximum performance in each environment. Moreover, it contributed least to the interaction (1.25%). Curinga-3 was the second most stable ($P_i$=1232000), contributing with 3.19% to the interaction. The stability of control BRSMG Conai was also good ($P_i$=2340000), with an interaction contribution of only 2.58%. The stability of CNAs 10260 was poorest ($P_i$=9245000) and the line accounted for 12.36% of the interaction. In general, the most productive lines tended to be the most stable as well (Table 1).

Annicchiarico (1992) identified the line MG 1097 as the best of all, that is, of lowest risk for the use in agriculture; in the most unfavorable of all situations, the line exceeded the environment mean by 19.12%. For Curinga-3, MG 1096 and MG 1094, the probability of attaining yields by 6.32, 5.40 and 3.99% higher than the environment mean, respectively, was 75% in the most unfavorable situation. The yield of control BRSMG Conai, in turn, was equal to the environment mean ($I_i$=99.72). The yield of the other evaluated lines/cultivars was lower than the mean of the environment. Similarly to the first, by the methodology of Annicchiarico (1992) the most productive lines also tended to be the most stable. In this particular

**Table 1.** Stability parameters estimated by the methods proposed by Lin and Binns (1988) and Annicchiarico (1992) for grain yield (kg ha$^{-1}$), of the experiments of Value for Cultivation and Use (VCU), conducted in 10 environments in the uplands of Minas Gerais, in the growing season of 2004/2005

| Lines andcultivars | Yield [1] (kg ha$^{-1}$) | $P_i$/1000 | Contribution to interaction (%) | $I_i$ [2] |
|---|---|---|---|---|
| MG 1097 | 5250 a | 412 | 1.25 | 119.12 |
| CURINGA-3 | 4935 b | 1232 | 3.19 | 106.32 |
| MG 1096 | 4782 b | 1636 | 3.53 | 105.40 |
| MG 1094 | 4579 c | 1995 | 2.25 | 103.99 |
| BRSMG Conai | 4490 c | 2340 | 2.58 | 99.72 |
| MG 1084 | 4426 c | 2582 | 2.69 | 98.64 |
| CARISMA | 4300 c | 3463 | 5.15 | 90.39 |
| CNAs 10227 | 4277 c | 3553 | 5.12 | 92.43 |
| MG 1089 | 4238 c | 3863 | 6.04 | 91.00 |
| CNAs 8957-1 | 4109 d | 4065 | 3.90 | 89.21 |
| CNAs 10217 | 4089 d | 4219 | 4.26 | 86.75 |
| CNAs 8938-1 | 4014 d | 4445 | 3.52 | 89.61 |
| CANASTRA | 3884 d | 4919 | 2.45 | 86.98 |
| MG 1078 | 3834 d | 5803 | 6.16 | 79.38 |
| JAPONÊS | 3819 d | 6152 | 7.79 | 78.87 |
| YIN LU 31 | 3696 e | 6649 | 6.61 | 72.25 |
| CAIAPÓ | 3649 e | 7008 | 7.14 | 79.77 |
| MG 1093 | 3570 e | 7376 | 6.49 | 69.22 |
| CNAs 10260 | 3429 e | 9245 | 12.36 | 57.26 |
| CNAs 8817-2 | 3137 f | 10481 | 7.47 | 61.75 |
| Mean | 4125 | | | |
| N°. of Environments | 10 | | | |

[1] Means in the column followed by the same letter did not differ by the 0.05 Scott-Knott test (UFLA 2005)
[2] Ii – Reliability index; significance level 0.25

case, the two methods of evaluating stability were highly concordant.

The overall mean grain yield of the 10 trials for all treatments is also shown in Table 1. MG 1097 was clearly the best line (mean of 5250 kg ha$^{-1}$) and outmatched the others statistically ($p \leq 0.05$), followed by Curinga-3 (4935 kg ha$^{-1}$) and MG 1096 (4782 kg ha$^{-1}$), which were statistically similar and exceeded the best controls (BRSMG Conai - 4490 kg ha$^{-1}$ and Carisma – 4300 kg ha$^{-1}$). Other valuable lines with attractive appearance in the field were: MG 1094 (4579 kg ha$^{-1}$), CNAs 10227 (4277 kg ha$^{-1}$) and MG 1089 (4238 kg ha$^{-1}$). Although productive, MG 1084 was discarded owing to a low amylose content and high gelatinization temperature that affected the culinary quality.

According to the law of cultivar protection, a novel cultivar must be evaluated in at least three locations in two growing seasons before release. A second study of stability was therefore conducted during the two last growing seasons (2003/2005), using the two above-described methods. The results for the 13 lines and cultivars tested simultaneously in the cited period are shown in Table 2. In this new group of lines, by the methodology of Lin and Binns (1988), line MG 1096 was the most stable ($P_i$=657000), contributing with only 2.44% to the interaction. MG 1089 was the second most stable, outmatching control BRSMG Conai. Other noteworthy lines were CNAs 10227, MG 1094 and MG 1084.

Considering the reliability index (Annicchiarico 1992), MG 1096 was again the most stable, in other words, in the worst of the situations, the probability of producing 7.11% more than the environment mean was 75% (Table 2). The reliability index of the other lines varied from 98.89% (MG 1089) to 61.39% (CNAs 10260) of the environment mean, and once more, the most productive lines tended to present a more stable grain yield.

The highest mean grain yield in the two growing seasons was observed in MG 1096 (4894 kg ha$^{-1}$), which exceeded ($p \leq 0.05$) all lines statistically (Table 2). MG 1089 ranked second (4614 kg ha$^{-1}$) and outmatched the other

**Table 2.** Stability parameters estimated by the methods proposed by Lin and Binns (1988) and Annicchiarico (1992) for grain yield (kg ha$^{-1}$), of the experiments of Value for Cultivation and Use (VCU), conducted in 18 environments in the uplands of Minas Gerais, in the growing season of 2003/2004 and 2004/2005

| Lines andcultivars | Yield [1] (kg ha$^{-1}$) | $P_i$/1000 | Contribution to interaction (%) | $I_i$ [2] |
|---|---|---|---|---|
| MG 1096 | 4894 a | 657 | 2.44 | 107.11 |
| MG 1089 | 4614 b | 1436 | 4.47 | 98.89 |
| BRSMG Conai | 4452 c | 1877 | 4.70 | 96.90 |
| CNAs 10227 | 4435 c | 1973 | 5.08 | 94.68 |
| MG 1094 | 4404 c | 2462 | 8.30 | 96.33 |
| MG 1084 | 4389 c | 2030 | 4.46 | 97.11 |
| CARISMA | 4190 d | 3396 | 10.23 | 88.26 |
| CNAs 10217 | 4176 d | 2744 | 4.56 | 90.38 |
| MG 1093 | 3928 e | 4069 | 7.29 | 74.34 |
| CANASTRA | 3927 e | 4431 | 10.16 | 83.46 |
| MG 1078 | 3818 e | 5157 | 12.04 | 77.71 |
| CAIAPÓ | 3655 f | 5960 | 12.01 | 77.98 |
| CNAs 10260 | 3433 f | 7463 | 14.26 | 61.39 |
| Mean | 4178 | | | |
| N° of Environments | 18 | | | |

[1] Means in the column followed by the same letter did not differ in the 0.05 Scott-Knott test (UFLA 2004, UFLA 2005)
[2] Ii – Reliability index, significance level 0.25

lines as well. BRSMG Conai (4452 kg ha$^{-1}$) was statistically ($p \leq 0.05$) equal to the lines CNAs 10227 (4435 kg ha$^{-1}$), MG 1094 (4404 kg ha$^{-1}$) and MG 1084 (4389 kg ha$^{-1}$) which, in turn, surpassed the seven least productive lines/cultivars.

Based on the results of grain yield, plant height, cycle, resistance to important diseases, dimensions of brown rice grain and of rough rice grain yield, the lines MG 1096 and MG 1094 were selected for release in the entire state of Minas Gerais. This study of stability contributed significantly to the reliability of the recommendations for a regional scope regarding the performance of the above lines, since both performed extremely well with respect to grain yield stability (Tables 1 and 2).

## CONCLUSIONS

1) The grain yield of the most productive lines tended to be more stable;

2) The cultivars BRSMG Conai and Carisma and lines MG 1096 and MG 1094, to be released for Minas Gerais, have a good grain yield stability.

3) The methodologies of Lin and Binns (1988) and Annicchiarico (1992) are consistent for evaluation of grain yield stability of upland rice lines.

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# Estabilidade de linhagens de arroz de terras altas avaliadas em Minas Gerais

**RESUMO** - *O estudo da estabilidade de linhagens antes do lançamento como novas cultivares para uma determinada região é prática pouco utilizada pelos melhoristas, apesar de sua importância. O presente trabalho objetivou avaliar a estabilidade*

*de produção de grãos das 20 linhagens e cultivares testadas nos ensaios de Valor de Cultivo e Uso de Minas Gerais, conduzidos em dez ambientes em 2004/2005 e dos 13 materiais comuns aos dois anos agrícolas (2003/2004 e 2004/2005) avaliados em 18 ambientes. Para tanto, utilizaram-se as metodologias de Lin e Binns (1988) e Annicchiarico (1992). Os resultados mostraram que, em 2004/2005, as linhagens mais estáveis, considerando as duas metodologias, em ordem decrescente, foram: MG1097, Curinga-3, MG1096 e MG1094. Considerando os dois anos agrícolas (2003/2005), os maiores destaques foram: MG1096, MG1089, 'BRSMG Conai', CNAs10227 e MG1094. Conclui-se ainda que as duas metodologias de avaliar estabilidade foram altamente concordantes.*

**Palavras-chave**: *Oryza sativa*, melhoramento genético, arroz de sequeiro.

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