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ESTIMATES OF THE GENETIC PROGRESS OBTAINED BY THE UPLAND RICE BREEDING PROGRAM OF THE STATE OF MINAS GERAIS

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ABSTRACT

Genetic advances obtained by breeding upland rice in Minas Gerais in the 1980s were quantified and two methodologies (Vencovsky *et al., Anais do Congresso Nacional de Milho e Sorgo*, 16, pp. 300-307, 1986 and linear regression) of genetic progress estimation compared. Grain yield data of comparative trials of cultivars and pure lines of upland rice for the period 1979/80 to 1988/89 were used. There was a total genetic gain of 698.1 kg/ha by the Vencovsky *et al.* (op. cit.)method and of 713.1 ± 125.8 kg/ha by linear regression, giving an average annual gain of 77.6 kg/ha, and of 79.2 kg/ha respectively. Both average gains correspond to approximately 3.0% per year. Thus the two methods were equivalent in determining genetic improvement. The magnitude of genetic progress estimates indicate that the Minas Gerais upland rice breeding program was efficient during this period.

INTRODUCTION

Accurate estimation of the genetic advances obtained in a rice breeding program would demand a network of yield trials in various environments, involving samples of the genotypes from the periods to be compared. This method, besides being costly, would be difficult to carry out since most materials are discarded along the years or are available only in small samples in germplasm banks. Therefore, alternate methods which use data already available are desirable.

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The present upland rice breeding program to develop new cultivars for cultivation in several growing regions of the State of Minas Gerais started in 1974. The indication of cultivars for commercial planting is dyanamic and continuous, and research periodically releases new materials to substitute those less productive and less accepted commercially. Every year, a group of pure lines selected in the preliminary phases of the program is tested in various representative regions of the state in comparative trials. After several years of testing, the results allow the identification of superior lines to be released as new cultivars.

A large number of upland rice cultivars have been developed as a result of this work, among which the cultivars Rio Paranaíba, Guarani, Douradão and Rio Doce have given a significant increase in yield and have allowed the cultivation of rice in various environments.

MATERIAL AND METHODS

Grain yield of cultivars and pure lines of upland rice was evaluated in Minas Gerais from 1979/80 to 1988/89. A group of cultivars of lines which did not perform well was discarded every year and substituted with others. It was supposed that every year the new substitute genotypes were superior to those which were eliminated, providing a continuous genetic advance.

The cultivars IAC 25, IAC 47 and IAC 164 were used as controls throughout the study period.

The methodologies used to quantify genetic improvement were that described by Vencovsky *et al.* (1986) and a linear regression estimation.

Method of Vencovsky et al. (1986)

An assessment is made of the difference between the grain yield of genotypes from a particular year and those of the previous year. The common treatments, in each pair of years, are used for the estimate of the year effect, to be subtracted from the total effect.

The linear model adopted was:

$$\overline{Y}_1 = m + a_1 + \overline{g}_1 + a_1\overline{g}_1 + \overline{e}_1$$

where $\overline{Y}_1$ is the general mean of the trials of year 1; m is the general mean; a_1 is the effect of year 1, common to all the treatments: $\overline{g}_1$ is the average genotypic potential of all the materials (except the common treatments, the controls) in the trials of year 1; $a_1\overline{g}_1$ is the mean of the interactions of the genotypes with year 1 and $\overline{e}_1$ is the experimental error of the mean $\overline{Y}_1$. Similarly, for year 2,

$$\overline{Y}_2 = m + a_2 + \overline{g}_2 + a_2\overline{g}_2 + \overline{e}_2$$

The joint analysis, involving the mean of the controls and the transitory genotypes for the 10 years studied, was used to assess the genotype x years interaction. When the interaction was not significant, the following linear models were adopted:

$$\overline{Y}_1 = m + a_1 + \overline{g}_1 + \overline{e}_1 \quad \text{and}$$

$$\overline{Y}_2 = m + a_2 + \overline{g}_2 + \overline{e}_2$$

where the effects are described as above.

The main objective was to assess the difference $\overline{g}_2 - \overline{g}_1$ observed in two subsequent years. The contrast,

$$\overline{Y}_2 - \overline{Y}_1 = (a_2 - a_1) + (\overline{g}_2 - \overline{g}_1) + (\overline{e}_2 - \overline{e}_1)$$

confounds the genotypic differences with those of the environment.

Using the means of the controls in two subsequent years in the same model, the following expressions are obtained,

$$\overline{Y}_{c1} = m + a_1 + \overline{g}_{c12} + \overline{e}_1$$

$$\overline{Y}_{c2} = m + a_2 + \overline{g}_{c12} + \overline{e}_2$$

$$\overline{Y}_{c2} - \overline{Y}_{c1} = (a_2 - a_1) + (\overline{e}_2 - \overline{e}_1)$$

The genetic advance between the years 1 and 2 (ag_{21}) is obtained by the difference between the two previous constrasts,

$$ag_{21} = (\overline{Y}_2 - \overline{Y}_1) - (\overline{Y}_{c2} - \overline{Y}_{c1}) = \overline{g}_2 - \overline{g}_1$$

since the experimental errors are random and it is assumed that they are $N(0, \sigma^2)$. Therefore, ag_{21} can be taken as the estimator of the mean genotypic change in year 2 in relation to year 1, as a result of the new materials included in year 2.

In the 10 years of study, ag_{21}, ag_{32}, ... $ag_{10,9}$ were obtained. To assess the accumulated genetic change or the total genetic gain (GT) throughout the 1980s, the genetic changes for each pair of years were added:

$$GT = ag_{21} + ag_{32} + ... + ag_{10,9}$$

The total genetic improvement represents the increase in the grain yield from the beginning to the end of the period, due to the genetic improvement of the materials throughout the years studied. The average annual increase (average yearly gain - GMA) can be obtained by dividing the GT by the number of years in the period (n - 1) or GMA = GT/(n-1). The GT and the GMA percentages can be calculated by dividing the respective values by the general mean of the first year trials.

Linear regression estimation method

Genetic improvement can be similarly assessed using the average of the controls throughout the years as a measurement of the environmental variation, using the following deviations: $d_j = Y_{ncj} - Y_{cj}$ where, Y_{ncj} is the grain yield average of the not common or transitory genotypes and Y_{cj} is the mean of the common or standard cultivars, both referring to the jth year.

From these values the estimate of the linear regression can be obtained as:

$$b = \frac{\Sigma_j (d_j - \bar{d})(a_j - \bar{a})}{\Sigma_j (a_j - \bar{a})^2}$$

- b is the stimate of the linear regression of d_j in function of the year, that is, the average annual genetic progress, which multiplied by the number of years assessed (n-1) gives the total progress estimate of the period;
- d_j is the phenotypic deviation in the jth year;
- $\bar{d}$ is the average phenotypic deviation;
- a_j is the jth year, where j = 1, 2, ... 10, and
- $\bar{a}$ is the average number of years.

RESULTS AND DISCUSSION

The overall mean of trials, the mean of the controls, the number of locations, the number of controls and total treatments of the trials in each agricultural year, and the genetic annual and total gain obtained in the period 1979/1980 to 1988/89 are presented in Table I. The trial network was increased from 1984/85 through substitution and increase of experiments (Table I). There was also a tendency to increase the number of materials included in the trials. The average materials substitution rate was 44%, showing the high vitality of the upland rice breeding program. On the other hand, the maintenance, on average, of 56% of the treatments in each pair of years assured a good reliability in the estimation of the average environmental effect, assuring greater precision in the assessment of genetic improvement. The seasons 1981/82 and 1982/83 were exceptions, with a high substitution rate (73%) and, coincidentally, negative genetic improvement (Table I).

Table I - Overall mean of trials, mean of common treatments (controls), number of locations and number of total and treatments of the trials in each agricultural years and the genetic gain obtained in the advanced comparative trials of upland rice carried out from 1979/80 to 1988/89.

Agricultural year	Number of locations	Overall mean (kg/ha)	Control mean (kg/ha)	Treatment number		Genetic gain (kg/ha)
				Total	Control	
1979/80	5	2601.9	2664.6	12	8	69.3
1980/81	3	2275.5	2268.9	10	8	
1980/81	3	2275.5	2345.1	10	8	85.0
1981/82	4	2215.5	2200.1	11	8	
1981/82	4	2215.5	2276.3	11	3	-222.6
1982/83	5	3651.7	3935.1	21	3	
1982/83	5	3651.7	3802.3	21	8	180.5
1983/84	4	1744.3	1714.4	20	8	
1983/84	4	1744.3	1892.6	20	7	81.8
1984/85	6	2310.6	2377.1	20	7	
1984/85	6	2310.6	2346.8	20	13	74.9
1985/86	5	2229.3	2190.6	20	13	
1985/86	5	2229.3	2273.5	20	12	161.2
1986/87	7	3264.4	3147.4	16	12	
1986/87	7	3264.4	3386.7	16	10	166.0
1987/88	7	2106.8	2063.1	12	10	
1987/88	7	2106.8	2132.5	12	8	102.0
1988/89	6	2292.9	2216.6	12	8	
Total genetic improvement						698.1 (26.8%)
Average annual gain						77.6 (3.0%)

The higher yield of the controls in relation to the general average (Table I) was the main cause of this negative gain. There was adequate rainfall in the agricultural year 1982/83 favoring high productivity, especially of the cultivars IAC 47 and IAC 164, which were favored by the low disease (blast) pressure due to the favorable climate. Also, the large number of treatments (21) that participated in the trials of 1982/83 compared to 11 for the previous agricultural year, contributed to a decrease in the precision of the field trials.

The joint analysis of variance proposed by Cochran and Cox (1957) was used to verify the existence of interaction between the means of the controls and those of the transitory genotypes with the ten years considered in the present study. The results are shown in Table II. The treatment x year interaction was not significant, therefore, the controls adequately represented the environmental fluctuations of the transitory genotypes. The use of a simplified linear model for the calculation of genetic improvement in the method of Vencovsky *et al.* (1986) was adequate because of the non-significance of the treatments x year interactions during the 1980s.

Table II - Joint analysis of variance of the means of common versus transitory genotypes (treatments), from all the locations, in each year, and the ten years of the study, obtained from the comparative trials of upland rice, from 1979/80 to 1988/89.

Source of variation	DF	SS	MS	F
Treatments (T)	1	886,911	886,911	5.25*
Years (A)	9	32,282,778	3,586,975	21.20**
T x A	9	1,520,863	168,985	1.67
Error	(42)	-	101,138	
Total	103	34,690,552		

* and ** indicates significance at 5% and 1% level of probability, respectively.

The results were not very different when the linear regression method was used. Total genetic improvement was 713.1 ± 125.8 kg/ha, with an average annual gain of 79.2 ± 14.0 kg/ha (Figure 1). The total gain and annual percentage were 27.4% and 3.0%, respectively. The high r^2 value indicated that the means obtained by the difference between the transitory genotypes and the controls fitted the regression equation well. Thus it is possible to estimate the genetic gain in the intermediate years with a satisfactory safety margin.

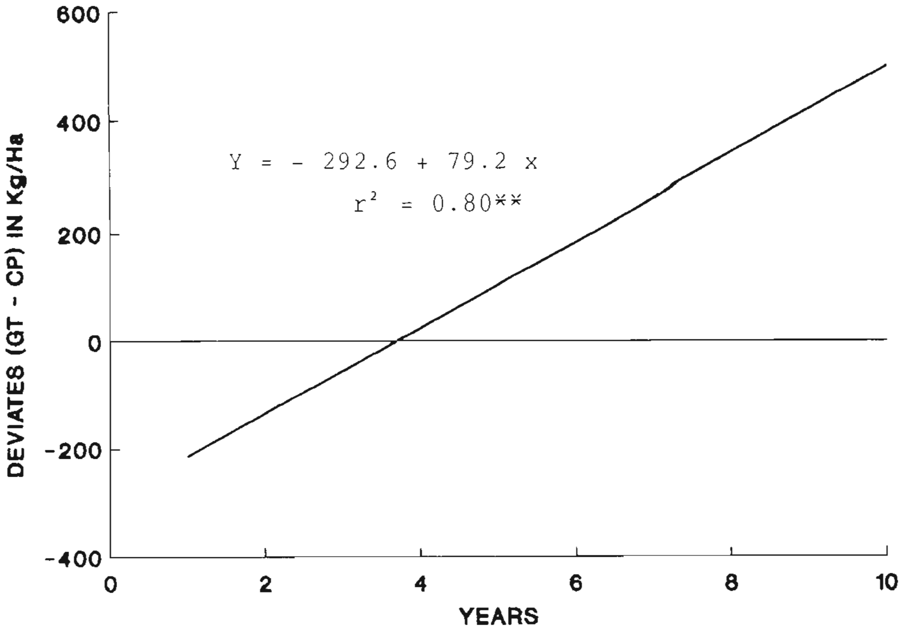

Figure 1 - Minimum square regression of the difference (deviates) between the annual grain yield means of transitory (GT) and common genotypes (CP) over years, during the 1980s. Means obtained from data of the advanced comparative trials of upland rice carried out by EPAMIG. **Significant at 1%.

The increase due to breeding, of approximately 700 kg/ha in ten years, over the average yield of upland rice in the state (about 1200 kg/ha) was expressive. The performance of the upland rice breeding program in Minas Gerais can also be assessed by comparing the average annual gain with that of maize in Brazil during 20 years (1964/84), obtained by Vencovsky *et al.* (1986), which was 2.2% for populations and 1.7% for commercial hybrids; with that of soybean in Paraná State in the period from 1981 to 1986, which was 1.8% and 1.3% for the early and semi-early maturing genotypes, respectively (Toledo *et al.*, 1990); with that of the common bean in Minas Gerais, during 17 years (Abreu *et al.*, in press) which was 1.9% and with that of sorghum in Brazil, from 1974/75 to 1987/88, which was 1.2% (Rodrigues, 1990).

According to EMBRAPA-CNPAF (1988), quoted by Teixeira and Sanint (1989), the average rice productivity of the State during the forty years of 1947 to 1987 showed a tendency to decline (0.02% per year). When the period 1947/87 was analyzed in two steps, 1947 to 1977 and 1977 to 1987, an average annual increase of 0.31% was observed in the last ten years. This data shows that breeding did not have a good performance during the first thirty years of the study, contributing to the stagnation of rice yield in Minas Gerais. On the other hand, part of the increase of 0.31% observed in the 1980s can be attributed to breeding programs, though agricultural policy factors have prevented the adoption of better technologies and limited the expression of the genetic potential of the newly introduced cultivars.

The breeding of upland rice in Brazil made use mainly of Brazilian germplasms until the middle of the 1970s, which restricted the genetic base. The majority of the germplasms used in crossings had low blast resistance, a disease which limits grain production in many areas. A study of the genealogy of the main cultivars planted in the 1960s and 1970s showed a certain relationship between them (Morais *et al.*, 1979). Therefore, the low genetic variability available limited a greater progress through breeding.

From the mid 1970s, after EMBRAPA and many state companies had been set up, the rice breeding program in Brazil, especially of upland rice, was considerably modified. First, new germplasms were introduced, mainly from Africa, to widen the genetic base and even for direct use by farmers. The materials were not adequate for direct use by producers, but were extremely important parents for crossings with Brazilian genotypes. As a result, a large number of pure lines adapted to Brazilian conditions, i.e., tolerant to blast and drought, were developed.

Of the two methods applied, that proposed by Vencovsky *et al.* (1986) is of more general application, since it does not require the same controls throughout the period. It depends only on the existence of a reasonable number of common cultivars in each pair of years. Therefore, it is more flexible and makes the assessment program of cultivars more dynamic.

RESUMO

Visando quantificar o avanço genético obtido pelo programa de melhoramento de arroz de sequeiro em Minas Gerais, na década de oitenta e comparar duas metodologias (Vencovsky *et al.*, *Anais do Congresso Nacional de Milho e Sorgo*, 16, pp. 300-307, 1986 e a da regressão linear) para esse fim, empreendeu-se o presente estudo, utilizando os dados de rendimento de grãos dos ensaios comparativos avançados de cultivares e linhagens de arroz de sequeiro no período de 1979/80 a 1988/89. Os resultados mostraram que ocorreu um ganho genético total de 698,1 kg/ha pelo método de Vencovsky *et al.* (op. cit.) e de 713,1 ± 125,8 kg/ha, utilizando a regressão linear, proporcionando um ganho médio anual de 77,6 kg/ha e de 79,2 kg/ha, respectivamente. Em termos percentuais, ambos os ganhos médios foram aproximadamente de 3,0%. Logo, os dois métodos foram equivalentes na determinação do avanço genético. A magnitude da estimativa do progresso genético indica que o referido programa de melhoramento de arroz foi bastante eficiente no período considerado.

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