

Estimates of genetic and phenotypic parameters in a segregant population of rice irrigated by continuous flooding*

Patrícia Guimarães Santos¹, Antônio Alves Soares² and Magno A.P. Ramalho¹

ABSTRACT

Estimates of genetic and phenotypic parameters were obtained by using data from families of a recurrent selection program in rice. An experiment using population CNA-IRAT 4ME/1/1 was conducted at two locations (Lambari and Cambuquira) in the State of Minas Gerais, Brazil. At Lambari, families $S_{0.2}$ and $S_{0.3}$ were assessed during crop seasons 1992/1993 and 1993/1994, respectively. In the Cambuquira trial, only $S_{0.3}$ families were tested in 1993/1994. The experimental design was a 10 x 10 lattice with three replications. The following traits were assessed: grain yield (GY), mean number of days to flowering (FL), plant height (PH), and the incidence of neck blast (NB) caused by *Pyricularia grisea* and grain staining (GS) caused by *Drechslera oryzae*. This population proved to be promising for recurrent selection, as it had high average yield and genetic variability. Heritability estimates obtained using variance components were generally greater than estimates of realized heritability, and heritability obtained by parent-offspring regression.

INTRODUCTION

Genetic gain for yield in the irrigated rice crop in Brazil was fairly significant in the 1970s because of the use of modern cultivars from the International Rice Research Institute (IRRI) and other international institutions. These cultivars displayed low plant height, erect leaves, early maturity and high potential yield. However, in the 1980's there was a considerable reduction in the rate of these gains, as the differences between the yield of the elite progeny and the best controls were not significant.

One of the main reasons for the reduction of genetic gain was narrowing of the genetic base of the cultivars used (Rangel *et al.*, 1992). Another reason for the decrease in the genetic gain was the wide use, in

Brazilian rice breeding programs, of the pedigree method for segregant populations. This method, as originally proposed, depends greatly on visual selection in the first segregant populations. However, it has been shown that, for irrigated rice, visual selection is not efficient (Cutrim, 1994). Besides this disadvantage, the pedigree method does not include recombination of selected material to combine the favorable alleles of different individuals.

One method for widening the genetic base and increasing the chances of recombination in genetic improvement programs is recurrent selection in synthetic populations having a wide genetic base. An increase in the frequency of favorable alleles with minimal reduction of genetic variability within the population is expected using recurrent selection.

Thus, periodical estimates of genetic and phenotypic variance of the populations undergoing recurrent selection help plant breeders in selection and in the evaluation of genetic potential of the populations. Therefore, this research was conducted to obtain estimates of genetic and phenotypic parameters in a

* Part of a thesis presented by P.G.S. to the Universidade Federal de Lavras, in partial fulfillment of the requirements for the Master's degree.

¹ Departamento de Biologia, Universidade Federal de Lavras, Caixa Postal 37, 37200-000 Lavras, MG, Brasil.

² Departamento de Fitotecnia, Universidade Federal de Lavras, Caixa Postal 37, 37200-000 Lavras, MG, Brasil. Send correspondence to A.A.S.

segregant population of irrigated rice, in two locations within Minas Gerais State.

MATERIAL AND METHODS

Rice families were extracted from the CNA-IRAT 4ME/1/1 population supplied by the National Center for Rice and Bean Research (EMBRAPA-CNPAF). This population is derived from the CNA-IRAT 4/0/3 population (Taillebois and Neves, 1989). The families were obtained using the methodology presented by Rangel (1992).

In 1992/93, 99 families from the $S_{0,2}$ generation, and cultivar CICA 8 as the control, were tested at the EPAMIG Experimental Farm, in the county of Lambari, MG, Brazil. The seeds from these families were harvested in bulk and provided the $S_{0,3}$ generation families, which were evaluated in the following agricultural year, in Lambari and Cambuquira, MG.

A 10 x 10 lattice design with three replications was used for all the experiments. Each plot was made up of one row, two meters long, spaced at 0.30 m. Planting was done by hand sowing, using 400 seeds/m².

Soil tillage consisted of plowing and harrowing 60 days before planting, and harrowing and hand levelling of the tableland the day before initiation of the experiments. At planting, 500 kg/ha of 4-14-8 fertilizer was applied. Around 60 days after seedling emergence, 200 kg/ha ammonia sulfate was applied. Flooding was started about 20 days after germination and was maintained until maturation of the latest families. Weeds were controlled by means of hand hoeing and the grain harvested at 20 to 22% moisture.

The following traits were assessed: grain yield (GY), days to flowering (FL), plant height (PH), and the incidence of neck blast (NB) caused by *Pyricularia grisea* and grain staining (GS) caused by *Drechslera oryzae*, according to the CNPAF (EMBRAPA, 1977) Manual of Rice Research Methods.

An analysis of variance was calculated for each trait assessed, considering the family effect as random. A joint analysis of variance was calculated using the two years in the same location (families $S_{0,2}$ and $S_{0,3}$), and the two locations when the $S_{0,3}$ families were assessed. The family effect was again considered random in these analyses, but the environmental effect was considered fixed. Components of variance and genetic and phenotypic parameters were estimated from the mathematical expectation of the mean squares. Parameters estimated included: genetic and phenotypic variance,

coefficient of genetic variation and broad sense heritability.

Three different estimates of the heritability coefficients were calculated: broad sense heritability, heritability by the parent-offspring regression (Smith and Kinmam, 1965) and realized heritability (Fehr, 1987; Ramalho *et al.*, 1993).

RESULTS AND DISCUSSION

In Lambari, there were highly significant differences ($P < 0.01$) among the means of the families for the traits grain yield, number of days to flowering and plant height, in the $S_{0,2}$ generation (Table I), and in the $S_{0,3}$ generation (Table II) there were significant differences among the means of the families for all traits. In the experiment at Cambuquira the means of the families differed for the grain yield, plant height and flowering (Table III). This shows that there was large variability among families for these traits.

The CVg were high, varying from about 15 to 20%, for grain yield (Tables I, II and III). These results were higher than those found by Rangel *et al.* (in press). Apparently this material retains sufficient genetic variability and is promising for selection.

The broad sense heritability estimates obtained from the components of variance were generally greater than the estimates of realized heritability and heritability obtained by parent-offspring regression (Table IV). Similar results were reported by Gonçalves (1995) and Collicchio (1995) in the assessment of bean families in the south of Minas Gerais State. This difference was

Table I - Summary of the analysis of variance of the experiments of the $S_{0,2}$ families for grain yield (kg/ha), plant height (cm), flowering (days), neck blast incidence and grain staining traits. Lambari, MG, 1992/1993.

Sources of variation	Mean squares				
	GY	PH	FL	NB	GS
Adjusted treatment	2597223.08**	87.48**	8.69**	0.34 ^{ns}	2.54*
Effective error	1005786.99	30.75	4.55	0.34	1.83
Mean	3375.90	81.8	121.4	1.2	4.1
CVe (%)	29.70	6.9	1.8	50.2	33.3
σ_G^2	530478.69	18.9	1.38	0	0.24
CVg (%)	21.50	5.3	1.0	0	12.0
Broad h^2 (%)	61.30	64.9	47.7	0	28.0

ns - Not significant; *significant at 0.05 level; **significant at 0.01 level. GY - Grain yield; PH - plant height; FL - days to flowering; NB - neck blast; GS - grain staining.

CVe - coefficient of environmental variation; CVg - coefficient of genetic variation; σ_G^2 - genetic variance; h^2 - heritability.

Table II - Summary of the analysis of variance of the experiments of the $S_{0.3}$ families for grain yield (kg/ha), plant height (cm), flowering (days), neck blast incidence and grain staining traits. Lambari, MG, 1993/1994.

Sources of variation	Mean squares				
	GY	PH	FL	NB	GS
Adjusted treatment	3888759.69**	50.9*	41.43**	5.29**	3.0**
Effective error	1803924.67	34.26	14.30	3.08	1.83
Mean	5511.5	89.6	130.8	3.5	5.7
CVe (%)	24.4	6.5	2.9	50.7	23.8
σ_G^2	694945.01	5.55	9.04	0.73	0.39
CVg (%)	15.1	2.6	2.3	24.8	11.0
Broad h^2 (%)	47.8	32.7	65.5	41.7	39.1

Abbreviations defined in Table I.

Table III - Summary of the analysis of variance of the experiments of the $S_{0.3}$ families for grain yield (kg/ha), plant height (cm), flowering (days), neck blast incidence and grain staining traits. Cambuquira, MG, 1993/1994.

Sources of variation	Mean squares				
	GY	PH	FL	NB	GS
Adjusted treatment	4599547.44**	69.97**	33.15**	0.79*	2.16 ^{ns}
Effective error	2331962.03	20.58	10.29	0.57	1.68
Mean	4598.3	90.2	113.3	1.3	5.9
CVe (%)	33.2	5.0	2.8	57.3	22.0
σ_G^2	755861.81	16.46	7.62	0.08	0.16
CVg (%)	19.0	4.5	2.4	21.0	6.8
Broad h^2 (%)	49.3	70.6	69.0	28.6	22.4

Abbreviations defined in Table I.

Table IV - Broad sense heritability estimates (%) of the $S_{0.2}$ generation realized heritability (%) and heritability by parent-offspring regression (%), obtained from the assessment trials of the $S_{0.2}$ and $S_{0.3}$ generation families, for grain yield (kg/ha), plant height (cm), flowering (days), neck blast incidence and grain staining. Lambari, MG, 1992/1994.

Methods used	Traits				
	GY	PH	FL	NB	GS
Broad h^2	61.3	64.9	47.7	0	28.0
$h^2_{2.3}$ realized	34.8	45.0	52.9	0	23.0
$h^2_{2.3}$ regression	64.74	38.76	-	0	18.66

Abbreviations defined in Table I.

expected as the estimate of broad sense heritability had, in the numerator of the ratio, the sum of $(1 + F) \sigma_A^2$, $(1 - F) \sigma_D^2$, $4FD_1$ and FD_2 , where F is inbreeding coefficient, σ_A^2 is additive variance, σ_D^2 is dominance variance, D_1 is the covariance between the dominance effects of the homozygotes and the additive effects of the alleles

comprising the corresponding homozygotes, and D_2 is the variance of these same homozygous dominance effects. A positive bias was expected because it was not possible to isolate these estimates. Normally the components of variance have high errors, which also affect the heritability estimates (Vello and Vencovsky, 1974). A last possibility, although it was not significant in this study, is the effect of interaction of families x years, which inflates the estimate of the genetic variance. This does not happen with the same intensity in the other estimates.

Among the three methods used to obtain the heritability estimates, the most important is the realized inheritance, as it best reflects what the breeder really obtained with selection. In this study, the heritability estimates obtained in $S_{0.3}$ by selection carried out in the $S_{0.2}$ generation may be considered medium to high, except for the incidence of neck blast. Using grain production as a reference, the heritability was 34.8%. This value is higher than those reported by Morais (1992) and Morais *et al.* (1995), but lower than those found by Rangel *et al.* (in press). These comparisons should be considered with caution as the heritability estimate depends on the method used and the population under selection.

No significant genotypes x location interaction was found in this study (Table V). It was concluded that the family behavior was similar in the two locations. Thus, the material may be selected based on the mean. If this result is confirmed, the future assessment of families in this region may be restricted to trials carried out in only one of the locations.

Highly significant interaction ($P < 0.01$) among genotypes and years was obtained only for flowering and neck blast incidence (Table VI), indicating that these traits behaved differently in the two years of assessment. This was not observed for the other traits, especially in grain production, suggesting that only one assessment of the families in the recurrent selection program would be sufficient. However, more information should be obtained in the region to confirm whether the participation of the genotypes x years interaction in the phenotypic variation is important.

The accuracy of the experiment data evaluated by the coefficient of variation differed among the traits (Tables I, II and III). The obtained CVe for grain yield was higher than 24%. These values were higher than those normally obtained in line assessment experiments carried out in the region (Soares, 1992). They were also higher than those found by Rangel *et al.* (in press) when assessing the same $S_{0.2}$ families from this study in Goiânia (State of Goiás) and in Formoso do Araguaia (State of Tocantins).

Table V - Summary of the joint analysis of the experiments at Lambari and Cambuquira. Grain yield (kg/ha), plant height (cm), flowering (days), neck blast incidence and grain staining of the S_{0.3} generation, 1993/1994.

Sources of variation	Mean squares				
	GY	PH	FL	NB	GS
Genotypes					
x location	2208141.41 ^{ns}	30.70 ^{ns}	15.23 ^{ns}	2.43 ^{ns}	2.06 ^{ns}
Mean error	2067943.35	27.42	12.30	1.82	1.75
Mean	5054.4	89.8	121.5	2.4	3.5
CVe (%)	28.45	5.83	2.89	56.21	37.80
$\sigma_{G \times L}^2$	23366.34	0.547	0.488	0.101	0.052
σ_G^2	702079.63	10.44	7.944	0.303	0
Broad h ² (%)	67.07	69.54	79.49	49.88	0

Abbreviations defined in Table I.

$\sigma_{G \times L}^2$ - Genetic variance of the genotypes x location interaction.

Table VI - Summary of the joint analysis of the S_{0.2} and S_{0.3} generation for grain yield (kg/ha), plant height (cm), flowering (days), neck blast incidence and grain staining. Lambari, MG, 1992/1993 and 1993/1994.

Sources of variation	Mean squares				
	GY	PH	FL	NB	GS
Genotypes					
x year	1544633.82 ^{ns}	34.93 ^{ns}	15.41 ^{**}	3.02 ^{**}	2.29 ^{ns}
Mean error	1404855.75	32.51	9.43	1.71	1.83
Mean	4444.3	85.6	125.8	2.3	4.9
CVe (%)	26.67	6.67	2.44	56.86	27.61
$\sigma_{G \times Y}^2$	23296.35	0.405	0.997	0.218	0.077
σ_G^2	589466.15	11.808	4.081	0.15	0.237
Broad h ² (%)	71.57	68.55	72.21	34.41	43.72

Abbreviations defined in Table I.

$\sigma_{G \times Y}^2$ - Genetic variance of the genotypes x year interaction.

An important factor contributing to experimental accuracy is the size of the plot. In rice cultivation it is common to use a plot of four to six five-meter rows (Soares, 1992). In this study the plot was made up of a single two-meter row, therefore with much smaller dimensions than commonly used. It was impossible to use large plots because of seed limitations. In some species, such as the common bean (Bertolucci, 1990) and soybean (Carnielli, 1989), it has been possible to obtain experimental accuracy similar to the standard plot using micro plots. Vieira (1996) reported on the possibility of working with two or three two-meter row plots in upland rice without a significant loss of experimental accuracy. Therefore, although the plot size may have

contributed to the low experimental accuracy in this work, it was probably not the main factor.

Disease assessment can also affect evaluation accuracy. The occurrence of diseases is normally not uniform, and this contributes to a reduction in the accuracy of trait assessment. Traits are assessed by an integer scale, which is subjective, varying from one to nine. There are normally problems in the variance analysis under these conditions. The square root transformation was also applied to the disease data. However, it did not reduce the coefficient of the environmental variation, hence the original data were used.

It may be inferred from the results obtained in this study that the population which is being used in the recurrent selection program, coordinated by the Nation Center for Rice and Bean Research, has a high potential for selection. However, these results emphasize the need for greater concern about experimental accuracy. This is especially true in a recurrent selection program where only the best families should be recombined.

ACKNOWLEDGMENTS

We thank the Fundação de Amparo à Pesquisa de Minas Gerais (FAPEMIG) for financial support received for the execution of this study.

RESUMO

Estimativas de parâmetros genéticos e fenotípicos foram obtidas utilizando famílias do programa de seleção recorrente da população de arroz irrigado CNA-IRAT 4ME/1/1 conduzida em duas localidades (Lambari e Cambuquira) do Estado de Minas Gerais. Em Lambari, avaliaram-se 99 famílias S_{0.2} e S_{0.3} e uma testemunha nos anos agrícolas 1992/1993 e 1993/1994, respectivamente. No ensaio de Cambuquira, testaram-se apenas as famílias S_{0.3} em 1993/1994. O delineamento utilizado foi um látice 10 x 10 com três repetições. Os caracteres avaliados foram: produção de grãos, altura de plantas, número de dias para floração e incidência de brusone do pescoço e mancha de grãos. Esta população mostrou ser promissora para a continuidade do programa de seleção recorrente, em função da sua produção média e da variabilidade disponível para a seleção. As estimativas da herdabilidade, de modo geral, a partir dos componentes de variância foram superiores às obtidas pela herdabilidade realizada e pela regressão genitor-descendente.

REFERENCES

- Bertolucci, F.L.G. (1990). Tamanho de parcela para avaliação de progênies do feijoeiro. Master's thesis, UFLA, Lavras, MG.

- Carnielli, A.** (1989). Representatividade de parcelas com tamanho reduzido para avaliação de caracteres agrônomicos de soja (*Glycine max* L.). Master's thesis, ESALQ, Piracicaba, SP.
- Collicchio, E.** (1995). Associação entre o porte da planta do feijoeiro e o tamanho dos grãos. Master's thesis, UFLA, Lavras, MG.
- Cutrim, V.A.** (1994). Eficência da seleção visual na produtividade de grãos de arroz (*Oryza sativa* L.) irrigado. Master's thesis, UFLA, Lavras, MG.
- Empresa Brasileira de Pesquisa Agropecuária.** (1977). Manual de métodos de pesquisa em arroz. 1ª aproximação. CNPAF, Goiânia, GO.
- Fehr, W.R.** (1987). Heritability. In: *Principles of Cultivar Development: Theory and Technique* (Fehr, W.R., ed.). MacMillan Publishing Company, New York, pp. 95-105.
- Gonçalves, P.R.** (1995). Obtenção de linhagens de feijoeiro (*Phaseolus vulgaris* L.) com grão tipo carioca e resistentes a antracnose e mancha angular. Master's thesis, UFLA, Lavras, MG.
- Morais, O.P.** (1992). Análise multivariada da divergência genética dos progenitores, índices de seleção e seleção combinada numa população de arroz oriunda de intercruzamentos, usando macho-esterilidade. Doctoral thesis, UFV, Viçosa, MG.
- Morais, O.P., Castro, E. da M. de and Sant'ana, E.P.** (1995). Seleção recorrente em arroz de sequeiro no Brasil. In: *I Taller Internacional sobre Seleção Recorrente em Arroz, 1, Goiânia, 995. Anais.* CNPAF/EMBRAPA, Goiânia, pp. 166-195.
- Ramalho, M.A.P., Santos, J.B. and Zimmermann, M.J.** (1993). *Genética Quantitativa em Plantas Autógamas: Aplicações ao Melhoramento do Feijoeiro.* UFG, Goiânia, pp. 271.
- Rangel, P.H.N.** (1992). La selección recorrente mejora el arroz brasileño. *Arroz en las Américas* 13: 4-5.
- Rangel, P.H.N., Zimmermann, F.J.P. and Neves, P. de C.F.** (1992). El CNPAF investiga: decresce en Brasil el rendimiento del arroz de riego? *Arroz en las Américas* 13: 2-4.
- Rangel, P.H.N., Zimmermann, F.J.P. and Neves, P. de C.F.** Aumento do potencial produtivo do arroz irrigado através de seleção recorrente. *Pesqui. Agropecu. Bras.* (in press).
- Smith, J.D. and Kinman, M.L.** (1965). The use of parent-offspring regression as an estimator of heritability. *Crop Sci.* 5: 595-596.
- Soares, A.A.** (1992). Desempenho do melhoramento genético do arroz de sequeiro e irrigado na década de oitenta em Minas Gerais. Doctoral thesis, UFLA, Lavras, MG.
- Taillebois, J.E. and Neves, P.C.F.** (1989). CNA - IRAT a new indica rice population. *Int. Rice Res. Newsl.* 14: 5-6.
- Vello, N.A. and Vencovsky, R.** (1974). Variâncias associadas às estimativas de variância genética e coeficiente de herdabilidade. In: *Relatório Científico.* Escola Superior de Agricultura "Luis de Queiroz", Piracicaba, pp. 238-248.
- Vieira, N.** (1996). Tamanho e forma de parcela experimental para avaliação de genótipos de arroz de sequeiro. Master's thesis, UFG, Goiânia, GO.

(Received June 17, 1996)