Crop Breeding and Applied Biotechnology 4:43-47, 2004
Brazilian Society of Plant Breeding. Printed in Brazil

Genetic parameters in relation to the physiological quality of common bean seeds

Lourenço Viana de Souza[1], Magno Antonio Patto Ramalho[1*] and Édila Vilela de Resende Von Pinho[2]

Received 26 September 2003
Accepted 30 March 2004

ABSTRACT - *Bean breeders evaluate the water uptake (WU) capacity of lines with the aim of identifying those with the shortest cooking time. There is no information on the most likely effect of the selection for WU in the expression of traits related to germination. To obtain information in this respect, $F_{2:4}$ families of crosses between the lines CI-107 with Carioca 80 and Amarelinho were evaluated in relation to WU, germination speed index (GSI), and emergence speed index (ESI). The genetic variance was greatest in cross CI-107 x Amarelinho. The estimate of heritability for ESI was similar in both crosses and inferior to the one obtained for WU. The correlated responses in ESI to the selection practiced in WU were particularly expressive in seeds stored for 6 months. Accordingly, a selection aiming at the identification of lines with shorter cooking time should additionally contribute to a better seed germination and emergence.*

Key words: *Phaseolus vulgaris* L., water uptake, heritability, genetic correlation, physiological seed quality.

INTRODUCTION

In bean breeding programs, it is imperative that the breeding lines, at a given moment, be evaluated in relation to their cooking time. A relationship of this trait to water uptake has been confirmed: the greater the water uptake, the shorter the time needed for cooking. Owing to this fact, the evaluation of proportional grain water uptake is frequently used to identify target lines with a short cooking time (Elia et al. 1997, Costa et al. 2001).

Since the seed water uptake is indispensable for germination, it would be adequate to verify whether a selection for a greater water uptake would indirectly identify breeding lines with better germination. Among the different environmental factors, which impinge on germination, storage time has been well-documented (Monteiro 1980, Fernandes and Souza Filho 2001). An increased storage time leads to a reduced grain water uptake (Moura 1998, Rios 2000). It is, however, not known if the decreasing germination percentage during storage is consequence of the smaller water uptake under the described condition.

On this background, main goal of this study was the achievement of estimates of genetic parameters that would allow inferences on the question whether the selection directed towards a greater water uptake would have the parallel effect of increasing seed germination and emergence.

MATERIAL AND METHODS

Seeds of three common bean lines from the germplasm bank of the Federal University of Lavras (UFLA) were used, evaluated beforehand in relation to water uptake and cooking time (Costa et al. 2001, Belicuas et al. 2002). Line CI-107 presented a high, and Carioca 80 and Amarelinho a small water uptake. Of these lines, Carioca 80 has a yellow halo and must, consequently, own the dominant allele of gene J, which has a pleiotropic effect on the halo color and on uptake and similarly affects the cooking time (Leakey 1988), Amarelinho is shiny, thus owns the dominant allele of gene Asp. Although results cited in literature do not wholly agree on this aspect, gloss makes the uptake difficult. CI-107, on the other hand, has no yellow halo, and its grains are opaque, i.e., genotype j j asp asp.

[1] Departamento de Biologia, Universidade Federal de Lavras (UFLA), C.P. 37, 37.200-000, Lavras, MG, Brasil. *E-mail: magnoapr@ufla.br
[2] Departamento de Agricultura, UFLA

The following crosses were carried out: CI-107 x Carioca 80 and CI-107 x Amarelinho. F_1 and F_2 seeds were obtained in a greenhouse and those of families $F_{2:3}$ and $F_{2:4}$ under field conditions. After harvest, seeds of the 100 $F_{2:4}$ families used in the present study were sun-dried to establish a uniform moisture degree. Hereafter, water uptake (WU) and the indices of seed germination speed (GSI) and seedling emergence (SEI) were assessed. The rest of the seeds was filled into multi-layered paper bags which were stored under environmental conditions for six months; thereafter, the evaluations were repeated.

The WU was evaluated in a 4:1 proportion of distilled water and sample weight, that is, 80 g of distilled water for every 20 g bean sample. The dry matter (DM) of one seed sample of each family was determined in two replications. The samples were then put in plastic recipients with distilled water, and after four hours, the imbibed seed mass (IM) was determined. The water uptake percentage was given by the expression [(IM – DM)/DM] x 100.

Germination speed was determined in two replications of 25 seeds of each family in a randomized complete block design. The seeds were sown onto previously moistened Germitest paper towels (water in a proportion of 2.5 times the paper weight), rolled up and arranged in a Mangelsdorf germinator regulated to constant temperature of 25 ^{o}C. Evaluations were carried out on the third, fifth, and tenth day, and the number of normal seedlings recorded. Seedlings with one principal root of at least four centimeters and at least three secondary roots were considered normal. The obtained data were transformed into the GSI, according to an expression suggested by Edmond and Drapala (1958).

Seed emergence was also evaluated under field conditions in an experiment conducted in a bed in a randomized complete block design. Each plot contained a 0.5 m long row with 25 seeds, rows spaced 10 cm apart. The block was represented by a 12 x 1 m and 10 cm high bed. The bed was filled with a 2:1 earth-sand mixture and irrigated daily with a constant amount of water per m^2. Seedlings were considered emerged when the cotyledons were completely above the soil surface. Emerged seedlings were counted daily, and the emergence speed index (ESI) estimated according to an expression proposed by Edmond and Drapala (1958).

Initially, variance analyses for storage time and the cross were carried out based on data of the WU, GSI and ESI. Later on, the data obtained for each cross underwent a joint analysis of variance with means obtained in the individual analyses. The family effect was considered to be random and the storage time fixed.

Based on the mean square expectations, the variance of the interaction families x times, the phenotypic variance between means of families, and the heritability for the selection of the family means were estimated by a method similar to the one presented by Vencovsky and Barriga (1992), The genetic variance among families in the joint analysis was estimated by means of the covariance between the mean performance of the families in both storage periods, i.e., genetic variance among the families without interaction (Ramalho et al. 2000a). The precision of heritability estimates was obtained by the expression proposed by Knapp et al. (1985), with a confidence of $1-\alpha = 0.95$. The genetic correlations (r_G) between the family means of the water uptake percentage and emergence speed index were estimated based on the expressions suggested by Falconer and Mackay (1996). The expected gain with direct selection in the ESI and the correlated response in the ESI with the selection carried out for WU was also estimated. In both cases, a selection intensity of 5% was assumed.

RESULTS AND DISCUSSION

In experiments of this type, one of the first steps is to find out whether the WU is defined by traits related to the tegument or to the cotyledons and the embryonic axis. This is essential because, since the cotyledons and embryonic axis have the effect of xenia and tegument is maternal tissue (Ramalho et al. 2000b), they are in different generations when families of the segregate population are evaluated, as is the case here. Despite several studies, which documented water uptake (Elia et al. 1997, Bushey et al. 2000, Hosfield and Beaver 2001, Costa et al. 2001, Bushey et al. 2002), there are still doubts in this respect. Basically, there is some evidence that the traits most strongly linked to the process are related to the tegument, underpinned by some studies which demonstrate the influence of gloss and the occurrence of certain pigments which hinder the water uptake (Bushey et al. 2002). As there is no definition in this respect, the generation that refers to the maternal tissue was chosen, i.e., tegument, in this case $F_{2:4}$ families. In the present situation, the difference is small because the families were derived from F_2 plants and, therefore, the difference between $F_{2:4}$ or $F_{2:5}$ would be restricted to segregation within the families. Since this difference was not taken into account, but only the variation among families, there is no implication at all on the obtained results.

Taking into consideration that the ESI presented better precision in the evaluation than the GSI, and that both normally present a high correlation, this trait will have to be focused on. It is important to bear in mind that the lower the ESI value, the more vigorous the seed, i.e., the quicker the germination or emergence speed (Edmond and Drapala 1958).

A significant difference ($P \leq 0.01$) was observed between the storage time and families for all traits in both crosses. The interaction families x time, however, was significant for WU in both crosses, unlike to the observed for ESI in both crosses (Table 1).

As expected, after 6 storage months the percentage of absorbed water was lower (Table 2). In cross CI-107 x Carioca 80, the reduction in the uptake was 13.8% and 16.8% in CI-107 x Amarelinho. Similar results were observed by Monteiro (1980), Rios (2000), and Fernandes and Souza Filho (2001). Moreover, it has been demonstrated that storage affects germination. The ESI after storage was 40% above the value established directly after the harvest in the cross CI-107 x Carioca 80 and 22% higher in the cross CI-107 x Amarelinho.

A greater percentage of mean water uptake was verified in the cross CI-107 x Carioca 80 (Table 2). One of the reasons is that the line Amarelinho has a lower water uptake capacity compared to Carioca 80. Belicuas et al. (2002), observed that the mean cooking time of cross CI-107 x Carioca 80 was shorter than that of CI-107 x Amarelinho, thus confirming the results of the present study. This can be explained by the presence of gloss in the tegument of this parent. Seeds with this phenotype imbibe less water and cook slower than seeds with an opaque tegument (Bushey et al. 2002). In the case of ESI, differences were not as accentuated as for WU. It is therefore concluded that it is probably not only the difference in the water uptake that affects the seed vigor.

Table 3 presents the estimates of the genetic variance per period (σ^2_G) and in the joint analyses ($\sigma^2_{G_E}$). The genetic variance released between the families for WU was greatest in the cross CI-107 x Amarelinho. This fact proves that in this cross the number of segregant loci in the trait control must be higher. The difference in the estimates of the genetic variance in both crosses for ESI was expressive, even though it was not as high as for WU. In the joint analysis, for example, it was 1.8 times higher.

The same comments made about genetic variance are valid for the heritabilities (h^2). The h^2 of WU were somewhat superior to those obtained for ESI. Nevertheless, the values were, in all cases, relatively high with a small associated error (Table 3). Information on h^2 estimates for traits related to the germination of bean plants is rare. In one of the few reports (Von Pinho 1990), the h^2 estimate was 80% for the ESI, evaluating pure lines. In the case of WU, there are more estimates available in literature. The h^2 values were also high, above 90% (Elia et al. 1997, Costa et al. 2001). These results allow the conclusion that selection for these traits would be successful.

The variance of the interaction families x times was particularly expressive, in relation to the genetic variance for WU in the cross CI-107 x Carioca 80 (Table 3). However, it is worth emphasizing that the estimate of the genetic correlation of the family performance was high in both periods. This fact underlines that although the interaction was expressive; it was predominantly simple, interfering a little with the classification of the families in both periods. Considering that differences aggravate during storage, it is advisable to evaluate and select this trait at some postharvest moment. In the case of the ESI,

Table 1. Summary of the joint variance analyses of the water uptake (WU), germination speed index (GSI), and emergence speed index (ESI), obtained by the evaluation of $F_{2:4}$ families of the crosses CI-107 x Carioca 80 and CI-107 x Amarelinho

Crosses	Trait	Mean squares				Mean	VC(%)
		Families (F)	Time (T)	F x T	Mean error		
CI-107 x Carioca 80	WU	189.70 **	15807.03**	61.93**	4.46	84.82	2.49
	GSI	0.4351**	31.142**	0.1645	0.1917	4.01	10.92
	ESI	0.499**	652.6**	0.2700	0.2625	7.66	6.69
CI-107 x Amarelinho	WU	1428.75**	11333.41**	132.28**	25.33	57.79	8.71
	GSI	1.5095**	233.17**	0.8223**	0.2911	5.04	10.70
	ESI	0.8440**	301.66**	0.4426	0.3832	7.50	8.25

** $P \leq 0.01$, by the F test.

Table 2. Means of the water uptake (WU), emergence speed index (ESI), and germination speed index (GSI) of $F_{2:4}$ families of the crosses CI-107 x Carioca 80 and CI-107 x Amarelinho, immediately after harvest and after six storage months

Trait	Storage months	CI-107 x Carioca 80	CI-107 x Amarelinho
WU	0	91.1	63.1
	6	78.5	52.5
	Mean	84.8	57.8
ESI	0	6.3	6.6
	6	8.9	8.4
	Mean	7.7	7.5
GSI	0	3.7	4.3
	6	4.3	5.8
	Mean	4.0	5.0

the interaction families-times was not significant. In view hereof, the same observations expressed earlier are applicable here.

Considering each evaluation period separately, an expected selection gain for ESI (SG_y) was estimated by the expression $SG_y = i\hat{\sigma}^2_{G_y} / i\hat{\sigma}^2_{F_y}$ (Falconer and Mackay 1996), and the correlated response in ESI by the selection carried out in WU ($CR_{y/x}$), given by the expression $CR_{y/x} = ih_x h_y r_G \hat{\sigma}_{F_y}$, where x refers to trait WU and y to ESI; i is the differential of the standardized selection, calculated value; $\hat{\sigma}^2_{G_y}$ is the genetic variance among families, $\hat{\sigma}_{F_y}$ is the phenotypic deviation among the families; h_x and h_y are square roots of the heritability of the traits x (WU) and y (ESI), respectively; and r_G is the genetic correlation between WU and ESI. Table 4 shows that the estimates of the genetic correlation, especially when evaluated directly after the harvest, were of small magnitude. Nonetheless, the estimates of the correlated response in ESI were expressive. Compare how the indirect response to selection after 6 storage months, for both crosses, was even superior to the gain with direct selection for the trait. According to Falconer and Mackay (1996), this happens when the product $r_G h_x$ is higher than h_y. The conclusion can be drawn that the selection bean breeders use to identify lines with a shorter cooking time would contribute to improve seed germination and emergence as well.

Table 3. Estimates of the genetic variance among the families ($\hat{\sigma}^2_G$) and heritability (h^2) for water uptake (WU), germination speed index (GSI), and emergence speed index (ESI), obtained in the crosses CI-107 x Carioca 80 and CI-107 x Amarelinho, in two evaluation periods

Cross	Storage time	Estimate	Traits		
			WU	GSI	ESI
CI-107 x Carioca 80	0	$\hat{\sigma}^2_G$	19.707	0.033	0.081
		h^2	92.695	27.172	50.910
	6	$\hat{\sigma}^2_G$	96.284	0.075	0.0415
		h^2	94.526	42.172	18.360
	joint	$\hat{\sigma}^2_G$	31.940	0.070	0.055
		[1] $\hat{\sigma}^2_{GE}$	28.740	0.000	0.004
		h^2	67.000 (51-78)[2]	62.200 (44-75)	45.930 (20-64)
		r_G	0.73	-	1.00
CI-107 x Amarelinho	0	$\hat{\sigma}^2_G$	316.450	0.092	0.098
		h^2	94.750	39.210	56.830
	6	$\hat{\sigma}^2_G$	409.577	0.780	0.163
		h^2	94.830	83.898	34.560
	joint	$\hat{\sigma}^2_G$	324.120	0.170	0.100
		$\hat{\sigma}^2_{GE}$	53.480	0.266	0.030
		H^2	91.000	45.500	47.600
		r_G	0.91	-	0.79

[1] $\hat{\sigma}^2_{GE}$: Variance of the interaction families x periods. [2] Confidence interval of the h^2 estimates.

r_G : Genetic correlation of the performance of the families in two environments

Table 4. Estimates of the genetic correlation (r_G) between the water uptake (WU) and emergence speed index (ESI), expected gain with selection in ESI (SG_y), and correlated response ($CR_{y/x}$) in ESI by the selection realized in WU, after 0 and 6 months of seed storage, obtained with families of the $F_{2:4}$ generation of the crosses Carioca 80 x CI-107 and Amarelinho x CI-107

Cross	Storage months	r_G	SG_y	$CR_{y/x}$	$CR_{y/x}$ / SG_y (%)
CI-107 x Carioca 80	0	-0.287	0.418	0.162	39
	6	-0.515	0.1800	0.2104	116
CI-107 x Amarelinho	0	-0.512	0.488	0.322	66
	6	-0.650	0.490	0.5228	107

Parâmetros genéticos associados com a qualidade fisiológica de sementes de feijão

RESUMO - *Melhoristas de feijão avaliam a capacidade de absorção de água (AA) das linhagens visando a identificação das que possuem menor tempo de cozimento. Contudo, não se tem informação sobre o provável efeito da seleção para AA na expressão de caracteres associados à germinação. Para obter tais informações foram avaliadas famílias* $F_{2:4}$ *com relação a AA, índice de velocidade germinação (IVG) e índice de velocidade e emergência (IVE), do cruzamento entre a linhagem CI-107 com as linhagens Carioca 80 e Amarelinho. A variância genética foi maior no cruzamento CI-107 x Amarelinho. A estimativa da herdabilidade para o IVE foi semelhante nos dois cruzamentos e inferior a obtida para AA. Respostas correlacionadas no IVE pela seleção realizada em AA foram expressivas, particularmente nas sementes armazenadas por 6 meses. Assim, a seleção visando a identificação de linhagens com menor tempo de cozimento deverá também contribuir para melhor germinação e emergência das sementes.*

Palavras-chave: *Phaseolus vulgaris* L., absorção de água, herdabilidade, correlação genética, qualidade fisiológica de sementes.

REFERENCES

Belicuas PR, Ramalho MAP and Abreu AFB (2002) Controle Genético da Capacidade de Cozimento dos Grãos de Feijão. In: **XV Congresso de iniciação científica da UFLA – CICESAL**. UFLA, Lavras, p.65.

Bushey SM, Hosfield GL and Beninger CW (2000) Water Uptake and its relationship to pigment leaching in black beans (*Phaseolus vulgaris* L.). **Bean Improvement Cooperative 43**:104-105.

Bushey SM, Owens S and Hosfield GL (2002) The epicuticular wax layer and water uptake in black beans. **Bean Improvement Cooperative 45**:159-160.

Costa GR, Ramalho MAP and Abreu AFB (2001) Variabilidade para absorção de água nos grãos de feijão do germoplasma da UFLA. **Ciência e Agrotecnologia 25**:1017-1021.

Edmond JD and Drapala WS (1958) The effects of temperature, sand and acerone in germination of okra seed. **Proceedings of American Society for Horticultural Science 71**:428-434.

Elia FM, Hosfield GL and Uebersax MA (1997) Genetic analysis and interrelationships between traits for cooking time, water absorption, and protein and tannin content of Andean dry beans. **Journal American Society for Horticultural Science 122**:512-518.

Falconer DS and Mackay TFC (1996) **Introduction to quantitative genetics**. 4th ed., Longman, Malaysia, 464p.

Fernandes GMB and Souza Filho BF (2001) **Armazenamento de sementes de feijão na pequena propriedade**. PESAGRO, Rio de Janeiro, 32p. (Comunicado Técnico 254)

Hosfield GL and Beaver JL (2001) Cooking time in dry bean and its relationship to water absorption. **Bean Improvement Cooperative 44**:157-158.

Knapp SJ, Stroup WW and Ross WM (1985) Exact confidence intervals for heritability on a progeny mean basis. **Crop Science 25**:192-194.

Leakey CLA (1998) Genotypic and phenotypic markers in common bean. In: Gepts P (ed.) **Genetic resources of Phaseolus beans: their maintenance, domestication, evolution and utilization.** Kluwer Academic Publishers, Netherlands, p.245-327.

Monteiro MR (1980) **Conservação de sementes de feijão (*Phaseolus vulgaris* L.) em diversos recipientes, sob condições de ambiente**. MSc. Thesis, Escola Superior de Agricultura de Lavras, Lavras, 67p.

Moura ACC (1998) **Análises físico-químicas, químicas e enzimáticas antes e após armazenamento em grãos de feijão (*Phaseolus vulgaris* L.) submetidos a diferentes tipos e tempos de secagem**. MSc. Thesis, Universidade Federal de Lavras, Lavras, 70p.

Ramalho MAP, Ferreira DF and Oliveira AC (2000a) **Experimentação em genética e melhoramento de plantas**. UFLA, Lavras, 326p.

Ramalho MAP, Santos JB and Pinto CABP (2000b) **Genética na agropecuária**. 2nd ed., UFLA, Lavras, 472p.

Rios AO (2000) **Avaliação da época de colheita e do armazenamento no escurecimento e digestibilidade de três cultivares de feijão (*Phaseolus vulgaris* L)**. MSc. Thesis, Universidade Federal de Lavras, Lavras, 59p.

Vencovsky R and Barriga P (1992) **Genética biométrica no fitomelhoramento**. Revista Brasileira de Genética, Ribeirão Preto, 496p.

Von Pinho RG (1990) **Tolerância do feijoeiro (*Phaseolus vulgaris L.*) a baixas temperaturas na fase de germinação e emergência**. MSc. Thesis, Universidade Federal de Lavras, Lavras, 86p.