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Genetic Analysis of Seed Morphological Traits and its Correlations with Grain Yield in Common Bean

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ABSTRACT

This work investigated the genetic control of seed morphological traits and its correlations with grain yield in common bean. Three crossings among bean cultivars with different growth habit and seed characteristics were analyzed. F_1 progenies gave origin to F_2, $RC_1P_1F_1$ and $RC_1P_2F_1$ generations. Random samples of seeds from F_2 generations and parents, F1 and backcrossings were sown during the season 2003/2004. Plant grain yield and seed morphological traits were determined by a sample of 150 plants from F_2 generations and 20 plants from parents, F_1 and backcrosssings. Genetic effects involved in each crossing were obtained from estimates of genetic components means and genetic and environmental components of phenotypical variance. Results showed that the seed morphological traits were controlled by a complex of genes, with additive effects predominance although dominance effects were present. High and negative correlations among seed length and thickness with grain yield suggested greater grain yield in bean plants with smaller seeds.

Key words: Genetic inheritance, shape seed, heritability, common breeding

INTRODUCTION

Brazil is the largest producer and consumer of common beans (*Phaseolus vulgaris* L.) worldwide. It is cropped annually 4,330,800 hectares with a production of 3,620,800 tonne, with a grain yield of 836 kg per hectare (CONAB, 2007). Common bean is cultivated almost all over the Brazilian territory, in different periods, utilizing production systems and diverse technology. In general, the participation of small farmers in the production is predominant in Brazil.

Common bean is the basic component of Brazilian feed, mostly in form of grains *in natura*, being considered one of the main sources of protein for people with low incomes, and also source of carbohydrate, vitamins and minerals. Nowadays, it's being consumed as functional food, because of the benefits given by its fibers, with hypocholesterolic and hypoglycemic actions (Geil and Anderson, 1994).

Among the different regions that produce beans, there's preference for color and type of grain, besides the utilization of diverse systems of production. This way, the breeding programs search the development of cultivars that display high potential of grain yield, earliness, good plant scheme and resistance to diseases, grains with

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good commercial acceptance and good technological characteristics and high nutritional quality (Dalla Corte et al., 2003; Souza et al., 2004). Grain yield, an extremely complex trait, is the result of the expression and association of several plant growth components and correlation coefficients are very useful in quantifying the size and direction of trait associations (Marega Filho et al., 2001; Bizeti et al., 2004).

The large phenotypic variability present in common bean has usually been expressed in terms of size, shape, color and brightness. A expressive number of work related to the genetic control of the skin coloration of bean seeds are available in literature and a review of the genes studied until now had been published by Basset (2004) and Tomaz et al. (2007). The comparison among the results obtained is difficult due to the different nomenclature utilized for genes and the different colorations related by the authors to a same color tone.

Few works were executed for obtaining information about the genetic control of size and shape of common bean seeds. These elements have been measured by either weight of a stable number of seeds, usually 100 or 1000 seeds or through length, width and thickness of seed. Ribeiro et al. (2000) observed great genetic variance for size and shape of grains for the groups black, carioca and colored. The results obtained also indicated that the thickness of seed had higher direct effect over weight of 100 seeds in carioca and colored groups; the black group was more influenced by the traits of length and width of seed.

Motto et al. (1978) studied the inheritance of characteristics related to the size of seeds (length, width, thickness and weight of grain). These traits were controlled by additional genetic effects with heritability in a narrow sense varying from 0.72 to 0.77. These authors found an average of at least 10 genes controlling the size of the seeds. Values in the narrow sense from 0.56 to 0.81 for seed weight were found by Nienhuis and Singh (1988).

Significant dominance effects for seed weight have been reported by Nienhuis and Singh (1986). In their studies, the general capacity of combination and specific capacity of combination were important for the weight of the seeds in the F_1 generation. Its general capacity magnitude was bigger than the its specific capacity.

Conti (1985) observed that for the width and thickness of the seed, only additive genetic effects were important. For the length of seed, however, both additive and dominant effects were important.

The objective of this work was to study the genetic control of morphological traits in common bean and its correlation with grain yield, aiming at subsidies for the improvement programs in the development of early common bean cultivar with good potential grain yield and showing desirable grain traits for the consumer market.

MATERIALS AND METHODS

The materials utilized in the present study included the parents (P_1 and P_2) and the generations (F_1, F_2, $RC_1P_1F_1$ and $RC_1P_2F_1$), derived from crossings among contrasting bean harvest for shape, size of seeds, cycles and growth habit. These cultivars are adapted to Brazilian climatic conditions (Dalla Corte et al., 2002). The main traits of the parents are presented in the Table 1. In 2003, all the parents were sown in green-house.

Aiming to get F_1 generation, the following crossings were made: Goiano precoce x IAPAR 81, Carioca 1070 x IAPAR 81 and Carioca 1070 x Carioca. The crossings were manually made according to the methodology described by Bliss (1980). Indeterminate growth habit was utilized as marker gene. The F_1 seeds obtained from each crossing were sown at green-house to obtain the F_2 generation and backcrossings generations ($RC_1P_1F_1$ and $RC_1P_2F_1$). F_1 plants were utilized as male parent.

Table 1 - Common bean cultivars used as parents in respect of origin, growth habit, cycle means (days) and seeds traits.

Cultivar	Origin	Seed color	Cycle (days)	GH[1/]	W1000[2/]	Seed shape (J)[3/]	Flat grade (H)[3/]
Goiano Precoce	EMGOPA	Cream	60	I	342	Elliptical	Full
Carioca 1070	CENA-USP	Cream with brown stripes	72	I	200	Elliptical	Half full
IAPAR 81	IAPAR	Cream with brown stripes	90	II	254	Oblong/short reniforme	Half full
Carioca	IAC	Cream with brown stripes	92	III	285	Oblong/short reniforme	Flat

[1/]Growth habit: I = determinate; II e III = indeterminate; [2/]Weight of 1000 seeds; [3/]Seed shape and flat grade (J and H) (Puerta, 1961).

In the wet planting season 2003/2004, random samples of 20 seeds of each parents (P_1 and P_2), 50 seeds of the F_1 generation, 300 seeds of F_2 generation and 50 seeds of ($RC_1P_1F_1$ and $RC_1P_2F_1$) generations of each crossing were sown. The population was sown in randomized sample consisting of nine rows: one row of P_1, P_2, F_1, $RC_1P_1F_1$ and $RC_1P_2F_1$ and four rows for F_2 for each population. The rows of five meters were spaced at 0.5 meters with a density of 75 plants/row.

In the stage of physiological maturity R_9 (CIAT, 1987), 20 plants of each parent (P_1 and P_2), F_1 and backcrossing generations ($RC_1P_1F_1$ and $RC_1P_2F_1$) and 150 plants of the F_2 generation were sampled to determine the grain yield per plant (GYP). Of each selected plant the length (LS), width (WS) and thickness (TS) of 50 seeds was measured.

After getting data, a distribution of frequency from plants for the evaluated characteristics (GYP, LS, WS, and TS) was observed, calculating means and variances for each parent and generations derived from each crossing. The genetic effects involved in each crossing were obtained through the estimation of the genetic components of the means and the genetic and environmental components of the phenotypic variance. The method of analysis was a procedure known as the joint scaling test proposed by Cavali (1952), Hayman (1960) and Mather and Jinks (1982). The estimative of the heritability in the wide and narrow sense (h^2_w e h^2_n), heterosis (h), endogamy depression (% ed) and average dominance grade (adg) were done (Allard, 1999; Matzinger, 1963; Falconer, 1981). The phenotypic correlations among the evaluated characteristics were estimated as proposed by Falconer (1981).

RESULTS AND DISCUSSION

The information about the nature of the genetic effects involved in the morphological traits of common bean seeds with different cycles and growth habits were obtained through of the tests of scale and the adjusts of genetic models for the means components and genetic and environmental components of phenotypic variance. The results for the populations studied of each crossing and for each character evaluated are shown in the Table 2. The scale test utilized to detect the significance effect of the means and phenotypic variance components was the test t to level of 5% of probability. When any parameter was not significant, the same was eliminated from the model and the remaining components were again estimated. The fitness of the model to explain the genetic variability found was effectuated by running qui-square tests of conformity.

For the trait length of seed the adjustment of mean models displayed the presence of additive effects [d] for the Carioca 1070 x IAPAR 81 and Carioca 1070 x Carioca crossings. The presence of dominance effects [h] to raise the length of seeds were found on the three crossings studied. Additive x additive [i] and dominant x dominant [l] non-allelic interactions effects were detected in Goiano Precoce x IAPAR 81 crossing and additive x dominant [j] and dominant x dominant [l] non-allelic interactions in the Carioca1070 x Carioca crossing.

The width of seed also displayed dominance effect [h] for all the crossings. In Carioca 1070 x Carioca crossing the negative signal indicated the dominance in the sense of decreasing the expression of the studied trait, that is, dominance for smaller width of seed. Also, additive effects [d] was observed in Goiano Precoce x IAPAR 81 and Carioca 1070 x IAPAR 81 crossings; non-allelic interaction effects additive x additive [i] and dominance x dominance [l] in Goiano Precoce x IAPAR 81; and additive x additive [i] and additive x dominance [j] non-allelic interactions in Carioca 1070 x Carioca crossing. In this third crossing, the proposed model was not accepted according qui-square test ($p>0.05$), being inadequate or not sufficient to explain the genetic variance present among the means.

For thickness of the seed, there was additive effect [d] for the Goiano Precoce x IAPAR 81 and Carioca 1070 x IAPAR 81 crossings. The cross Goiano Precoce x IAPAR 81 also presented dominance [h], additive x additive [i] and dominant x dominant [l] non-allelic interactions. In Carioca 1070 x Carioca crossing, there were dominance effects [h] and additive x additive non-allelic interaction. The negative signal in the dominance effects [h] and of non-allelic interactions acted in Carioca 1070 x Carioca crossing to decrease the seed thickness, as well as, in dominant x dominant [l] non-allelic interaction present in the analyzed traits of Goiano Precoce/IAPAR 81 crossing.

Table 2 - Genetic parameters adjusted for seed lenght (SL), seed width (SW) and seed thickness (ST), in mm, in common bean. Means and phenotype variance of the three crosses. IAPAR, Londrina-PR, Brazil. Wet planting season 2003/2004.

	Goiano Precoce x IAPAR 81	Carioca 1070 x IAPAR 81	Carioca 1070 x Carioca	Goiano Precoce x IAPAR 81	Carioca 1070 x IAPAR 81	Carioca 1070 x Carioca	GoianoPrecoce x IAPAR 81	Carioca 1070 x IAPAR 81	Carioca 1070 x Carioca
		SL			**SW**			**ST**	
		Means[1]			**Means[1]**			**Means[1]**	
m	9,68±0,44	10,81±0,04	10,51±0,07	5,37±0,23	6,35±0,02	6,72±0,06	3,62±0,25	4,78±0,01	5,15±0,07
[d]	...	0,46±0,04	0,24±0,07	0,18±0,03	0,16±0,02	...	0,51±0,04	0,73±0,03	...
[h]	4,18±1,21	0,18±0,08	0,81±0,27	3,67±0,63	0,17±0,05	-0,49±0,08	4,40±0,70	...	-0,32±0,10
[i]	1,65±0,44	...	...	1,49±0,22	...	-0,56±0,07	1,58±0,25	...	-0,37±0,08
[j]	...	...	-0,76±0,30	...	...	-0,19±0,11	...	...	...
[l]	-2,03±0,78	...	-0,75±0,25	-2,06±0,42	...	...	-2,54±0,47	...	...
x^2	$1,2^{NS}$	$6,3^{NS}$	$0,02^{NS}$	$0,88^{NS}$	$3,81^{NS}$	$7,15^{*}$	$1,16^{NS}$	$8,51^{NS}$	$1,79^{NS}$
gl	2	3	1	1	3	2	1	4	3
		Variance[2]			**Variance[2]**			**Variance[2]**	
D	0,86±0,13	0,38±0,07	0,19±0,09	0,21±0,04	0,89±0,02	0,21±0,51	0,13±0,04	0,04±0,02	0,12±0,03
H	...	...	...	...	...	0,24±0,08	...	...	...
F	...	...	...	...	...	...	...	...	...
E_1	0,23±0,07	0,85±0,16	0,24±0,06	0,19±0,01	0,35±0,01	0,06±0,01	0,31±0,01	0,04±0,01	0,05±0,01
E_2	0,16±0,05	...	0,09±0,03	0,63±0,02	...	0,03±0,01	0,11±0,03	...	...
E_3	0,04±0,01	...	...	...	...	...	...	...	...
x^2	$0,32^{NS}$	$5,44^{NS}$	$5,77^{NS}$	$3,35^{NS}$	$7,32^{NS}$	$4,45^{NS}$	$0,63^{NS}$	$1,99^{NS}$	$2,34^{NS}$
gl	2	4	3	3	4	2	3	4	4

^{NS} no significant at the level of 5% probability. * significant at the level of 5% probability. [1/]Means genetic components: m: means; [d]: aditive effect; [h]: dominant effect; [i]: aditive x aditive interation effect; [j]: aditive x dominant interation effect; [l]: dominant x dominant interation effect. [2/]Genetic and environment component of phenotype variance: D: aditive effect in phenotype variance components: H: dominant effect in phenotype variance components; F: aditive x dominant interation effect in phenotype variance effect; E1: environment effect in phenotype variance components; E2 e E3: genotype x micro environment interaction effect in phenotype variance components.

The absence of additive variability [d] in some adjusted models did not mean that the same was not present in these crossings, but that could be occurring due gene dispersion in the parents. Additive (D) and environmental (E_1) effects were observed for the adjusted models of the components of phenotypic variance for all the traits studied in all crossings. The effect of the genotype x micro-environmental interaction (E_2 and E_3) was also observed in the Goiano Precoce x IAPAR 81 and Carioca 1070 x Carioca crossings. Dominance effect was only present in Carioca 1070 x Carioca for the trait width of seed.

The predominance of additive effect on controlling the seed morphological traits studied in these crossings using cultivars of different cycles, habit of growth, shape and size of seeds was observed. The presence of environmental effects and genotype x micro environment interaction also influenced the expression of the studied traits.

There was no dominance (H) in the models of variance for length, width and thickness of the seed, indicating that the magnitude of dominance was not larger than that from additive effects, and because there was effect of [d] and [h] in the average models, apparently there was gene dispersion. Though the means models displayed the importance of the dominance effects, the adjusted for variance did not reinforce it. The means models indicated a strong influence additive x additive [i], additive x dominant [j] and dominant x dominant [l] non-allelic interactions in the expression of seed morphological traits in the crossings.

The results showed a gene complex, with predominance of additive effects for the seed morphological traits studied, although the effects of dominance were present and were detected in the genetic means components models. The effects of several genes were related through non-allelic interactions fully present in the crossings studied.

The results in the present study agreed with the results obtained by Conti (1985) who found additive effects in the control of width and thickness of seeds, where length additive and dominant effects were present in the genetic control. Nienhuis and Singh (1986) also detected dominance effects for the weight of bean grain. Motto et al. (1978) too observed additive effect with at least ten genes controlling the size of seed.

Estimates of inheritance (h^2_w e h^2_n), heterosis (%H), endogamic depression (% ed) and average dominance grade (adg) for the studied traits are presented in the Table 3. Inheritance values in the wide and narrow sense for the traits of the studied seeds ranged from 0.183 to 0.750; from 0.204 to 0.560 and from 0.236 to 0.545 for length, width and thickness of seed, respectively. Average values were: 0.433 for the SL; 0.421 for the SW and 0.371 for the ST. These values were considered medium. Hence, these traits could be selected in F_2 generation or latter.

The heterosis values varied from 0.00 to 43.18 for length of seed, from – 7.29 to 68.34% for width of seed and from -6.21 to 12.10% for thickness of seed. Heterosis showed bigger contribution to increase the length, width and thickness of seed in Goiano precoce x IAPAR 81, in which the cultivars utilized as parents were very different contributing to the heterosis. Goiano Precoce cultivar presented cream colored seeds, elliptical and full shape, and IAPAR 81 displayed cream color with brown stripes, Carioca type, elliptical and semi-full.

Table 3 - Estimate of wide and narrow sense heritability (h^2_w e h^2_n), heterosis (% H), endogamic depression (% ed) and average dominance grade (adg) for seed length (SL), seed width (SW) and seed thickness (ST) of crosses Goiano Precoce x IAPAR 81, Carioca 1070 x IAPAR 81 and Carioca 1070 x Carioca. Wet planting season 2003/2004.

	Goiano Precoce x IAPAR 81	**Carioca 1070 x IAPAR 81**	**Carioca 1070 x Carioca**
		SL	
h^2_w	0,750	0,183	0,365
h^2_n	0,750	0,183	0,365
% H	43,18	1,66	7,71
% ed	15,08	0,82	3,58
adg	0,000	0,391	3,375
		SW	
h^2_w	0,204	0,560	0,500
h^2_n	0,204	0,560	0,786
% H	68,34	2,67	-7,29
% ed	20,30	1,30	-3,39
adg	20,389	1,063	0,000
		ST	
h^2_w	0,236	0,333	0,545
h^2_n	0,236	0,333	0,545
% H	12,10	0,00	-6,21
% ed	27,43	0,00	-3,35
adg	8,628	0,000	0,000

Endogamy depression contributed to reduce the length width and thickness of seed, but it was not so clear. The depression values varied from 27.33 to –3.35%. Thus, it was impossible to conclude that the effects of heterosis or endogamy depression were not present, having as basis the absence of significant effects of [h] in means component models utilized in the estimate. The negative signal found in the endogamy depression and heterosis for width and thickness of seed in the Carioca 1070 x Carioca suggested endogamy depression and heterosis backwards effects. In

other words, the heterosis contributed to reduce the width and thickness of seed in this crossing and the endogamy depression to increase.
The values for means grade of dominance displayed partial dominance in the Carioca 1070 x IAPAR 81 and overdominated in the Carioca 1070 x Carioca for the increase of length of seed. To increase the trait width of seed the average dominance grade calculated indicated over-dominance in Goiano Precoce x IAPAR 81 and Carioca 1070 x IAPAR 81 and over-dominance for the thickness of seed in the Carioca 1070 x IAPAR 81.
The average dominance grade estimated for the seed morphological traits indicated, in general, over-dominance effect. Probably, the [d] was sub-estimated due to gene dispersion that stipulated the expression of these traits studied in the parents. Some valuations of means grade of dominance weren't able to be calculated because of the non-significance of additive effect [d] in the proposed model.
The phenotypic correlations obtained through the valuations done in the F_2 generations among the seed morphological traits and grain yield per plant are shown in the Table 4. Significant and negative correlations between length, width and thickness of seed and grain yield were observed. High and negative correlations between width of seed and grain yield and between the seed thickness and grain yield in the Carioca 1070 x Carioca crossing were found.
The negative correlations, although low in most of it, were high in the Carioca 1070 x Carioca crossing, which involved determinate and indeterminate growth habit, respectively, suggesting a bigger production of grains in common bean pods that had smaller seeds and tended to indeterminate growth habit. The growth habit is a trait of monogenic inheritance, with dominance for indeterminate growth habit (Kornegay et al., 1992; Leakey, 1988; Singh, 1982). Kornegay *et al.* (1992) related the association between increasing of grain yield with increase of indeterminate growth habit expression type III to creeper type, with smaller size seeds. The authors gave more emphasis on inter relations between the growth habit, size of seeds, maturity and pool gene acting in the expression of these traits in the breeding programs to develop new common bean cultivars.

Table 4 - Estimates of phenotype correlations among common bean traits seed length (SL), seed width (SW) seed thickness (ST) and grain yield per plant (GYP), in the crosses Goiano Precoce x IAPAR 81, Carioca 1070 x IAPAR 81 and Carioca 1070 x Carioca. Wet planting season 2003/2004.

	Goiano Precoce x IAPAR 81	**Carioca 1070 x IAPAR 81**	**Carioca 1070 x Carioca**
SL/SW	0,615*	0,116*	0,068*
SL/ST	0,477*	0,091*	0,103*
SL/GYP	-0,460*	0,181*	-0,189*
SW/ST	0,469*	0,050*	0,266*
SW/GYP	-0,008^{ns}	0,141*	-0,703*
ST/GYP	-0,468*	0,233*	-0,923*

ns: not significant; * significant at the level of 5% probability (test t).

The results found in the present study were favorable to selection for the type of smaller size grain indicating that new cultivars of high grain yield, Carioca type and small grains could be developed in the breeding programs. The agriculturists preference and consumers from determined regions of Brazil is for the Carioca type of common beans. Carioca Type has the following characteristics: elliptical shape and semi full flat grade, medium size (22 to 24g per 100 seeds), cream color with brown stripes (Mendonça et al., 1998; Ribeiro et al., 2000). There is an great genetic variability in the common bean genotypes adapted to tropical conditions for size and shape of grains (Ribeiro et al., 2000; Dalla Corte et al., 2003). Consequently, it's possible to obtain success in the breeding program for common bean of high grain yield and grains of good commercial acceptance.

CONCLUSIONS

The seed morphological traits were controlled by a gene complex, with predominance of additive effects, although the effects of dominance were present in the studied crossings.

High and negative correlations between the width and thickness of seed with grain yield suggested bigger grain yield in common bean that had smaller seeds.

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RESUMO

Este trabalho estudou o controle genético de características morfológicas de sementes e suas correlações com a produtividade de grãos em feijoeiro comum. Para tanto, foram efetuados três cruzamentos entre cultivares de feijoeiro com diferentes características de sementes. As progênies F_1 deram origem às gerações F_2, $RC_1P_1F_1$ e $RC_1P_2F_1$. Uma amostra aleatória de sementes das gerações dos parentais, F_1, F_2 e retrocruzamentos foram semeadas na safra das águas de 2003/2004. Na maturação fisiológica foram amostradas 150 plantas das gerações F_2 e 20 plantas dos parentais, F_1 e retrocruzamentos, nas quais foram determinados a produtividade de grãos por planta e as seguintes características morfológicas de sementes: comprimento, largura e espessura. Os efeitos genéticos envolvidos em cada cruzamento foram obtidos por meio das estimativas dos componentes das médias e variâncias fenotípicas. As características morfológicas de sementes foram controladas por um complexo de genes, com predominância de efeitos aditivos, embora os efeitos de dominância foram presentes. Correlações altas e negativas entre a largura e espessura de semente com produtividade de grãos sugeriram maiores produtividades de grãos em feijoeiros que possuem sementes menores.

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