Consequences of early selection for grain type in common bean breeding

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ABSTRACT

The common bean grain color is controlled by a large number of genes, probably distributed in all the chromosomes. Therefore, early selection for this trait is likely to cause an expressive reduction in the variability of other traits such as grain yield, which is the main objective of most breeding programs. This study was carried out to verify the effect of early (F_2 generation) selection for grain type on grain yield in more advanced generations. The F_2 population from the cross between the Ouro Negro (black grains) and Pérola ("carioca" - cream with brown stripes) type grains was used. The harvest seeds were divided into two groups, one with "carioca" grains and another of mixed type, where no selection was applied. The F_3 plants of both sub-populations were individually harvested resulting in 199 families per sub-populations. These 398 $F_{3:4}$ families and the parent cultivars were assessed during the year 2000 dry season in Lavras and the $F_{3:5}$ families in the winter of 2000 in Lavras and in Patos de Minas. On average, no yield differences among the non-selected and selected for grain type family means were detected. It was also observed that the heritability estimates were high and similar. It is, therefore, inferred that early (F_2 generation) selection for grain type did not reduce the potential of the population for selection of superior inbred lines. Consequently, strong selection for grain color in the F_2 generation, to screen out undesirable types will enable breeders to concentrate their efforts on the selection of other traits in the advanced generations. Only families with commercially acceptable grain type will be submitted to selection, increasing the chances of success.

KEY WORDS: *Phaseolus vulgaris*, heritability, seed type, genetic variability.

INTRODUCTION

Seed color is one of the most important traits for commercial acceptance of a common bean cultivar. It is also essential for farming since commercialization at good prices requires that the bean color meets the demands of wholesalers and consumers.

The common bean presents enormous variability for a number of traits (Hildalgo, 1993), especially those associated with bean size and color. Several bean colors with different distribution patterns can be observed. In spite of the wide variability, consumers have some well established preferences, which vary from region to region. In Brazil, the preference is for black seeded cultivars in the southern states, in Rio de Janeiro and in some parts of Minas Gerais, while the cream buff type is favored in the Northern region. However, the "carioca" type, which is characterized by a pale cream color bean with brown stripes, without a yellow halo, is unanimously accepted throughout most of the country.

Due to the importance of this trait, breeding programs should emphasize selection for certain bean types, especially the "carioca". Selection should be carried out early in the program to prevent resources and time being wasted in assessing families whose seeds will not be commercially accepted.

Considering that this trait is controlled by many genes (Leakey, 1988; Basset, 1996), which are probably distributed in all the chromosomes, an expressive reduction in the variability of other traits is expected if early selection for seed type is carried out. This is especially true for grain yield, which is the main objective of most breeding programs. Although early selection for seed type in the F_2 generation is widely performed in common bean breeding, data on its effect on the variability released for other traits in later generations is limited.

Therefore, this study was carried out to investigate the effects of selection for seed type in the F_2 generation on grain yield, which is usually selected in advanced generations.

MATERIAL AND METHODS

The families assessed in this study are derived from the cross between the Ouro Negro and Pérola cultivars. The Ouro Negro cultivar is black seeded and resistant to the angular spot (*Phaeoisariopsis griseola*) and to anthracnose (*Colletotrichum lindemuthianum*) diseases. It is well adapted and is currently one of the highest yielding cultivars. The Pérola cultivar shows "carioca" type seeds (cream colored with brown stripes) and is resistant to *P. griseola.* It is also well adapted and is currently the most widely cropped cultivar in Brazil.

The crosses were carried out in a greenhouse and the F_1, F_2 and F_3 generations were obtained in the field. The F_3 seeds were divided into two samples: a) One was selected for cream colored seeds with brown stripes, as close as possible to the "carioca" type; b) No selection was practiced in the other sample. These two samples were sown and 199 plants were randomly collected from each sample to produce $F_{3:4}$ families.

The experiments were carried out in the year 2000 dry and winter growing season in the experimental field at the Department of Biology at the Federal University of Lavras, located at Lavras-MG, at 918 m altitude, 21º14´ S latitude and 40º17´W longitude, with mean annual rainfall of 1529.7 mm and mean temperature of 19.14ºC. In the winter growing season, the experiment was also set up in Patos de Minas (18º35´S latitude and 46º31´W longitude), which is located in the Alto Paranaíba region of Minas Gerais state.

The 398 families and the parents were assessed in the year 2000 dry growing season at Lavras in a 20 x 20 simple lattice design. Plots were formed by a single one-meter row, spaced at 0.5m and the plant density was 15 seeds/m. Only grain yield was assessed. All families of the previous generation were sown again in July for assessment in the year 2000 winter growing season. The experiments were carried out in Lavras and Patos de Minas. A 20 x 20 lattice design with three replications was used. Plots were formed by single two-meter rows. Row spacing and plant density were the same as in the previous experiment.

Grain yield was assessed in the two locations but bean type was only assessed in the Lavras experiment. A scale similar to that of Ramalho et al. (1998), with scores varying from 1 to 6, was used. Scores from 1 to 5 were attributed to beans belonging to the "carioca" type, with higher scores given to poorer types. Beans with a color other than the "carioca" type, such as black or brown beans, were given score 6.

Estimates of genetic and phenotypic parameters were obtained from the expected mean squares, using a procedure similar to that presented by Vencovsky and Barriga (1992). The lower and upper heritability limits were calculated by the Knapp et al. (1985) equation using the probability of 1- a =0.95.

The genetic covariance among the family means in the environments (locations or generations) were pairwise estimated for all families and, individually, for the selected and unselected families. It is important to point out that, $cov_{G_{ii'}} = s_G^2$ the covariance among the mean performance of the families in i^{th} and i'^{th} environments, corresponds to the among family genetic variance without the interaction effect (Ramalho et al., 2000).

Based on the covariance estimates, the among family means heritability was obtained using the expression: $h_i^2 = COV_{G_{ii'}} / s_F^2 = COV_{G_{ii'}}/(Q/ar)$ where: Q is the among family mean squares of the joint analysis of variance of the two generations or locations; a is the number of environments (locations or generations) and r is the number of replications.

The variance of the families x environment interaction (s^2_{GE}) was estimated by the expression: $s_{GE}^2 = (s_{G_i}^2 + s_{G_{i'}}^2)/2 - s_G^2$ where $s_{G_i}^2$ *and* $s_{G_{i'}}^2$ are the among family genetic variance in the i^{th} and i'^{th} environments (locations or generations). The (s^2_{GE}) was also partitioned according to the expression presented by Vencovsky (1987).

The expected gain from selection in each group of families (selected and unselected) was estimated by the expression G.S.(%) = ds x h^2, where ds is selection differential, that is, the difference between the mean of the selected families and the general mean of each group of families; and h^2 is the trait heritability.

RESULTS AND DISCUSSION

Many genes are involved in the genetic control of bean color (Leakey, 1988; Basset, 1996) and size (Mesquita, 1989). As the parents involved in this study are contrasting for seed type (background color, halo, stripe occurrence), a wide variation for these traits was observed already in the F_2 generation (F_3 seeds), which permitted identification of plants with seeds within the "carioca" type pattern. The two parents, Pérola and Ouro Negro, are cultivars recommended for cultivation in Minas Gerais state (Ramalho and Abreu, 1998). In this context, it should be pointed out that the two parents showed similar and high yields in the three assessments (Tables 1 and 2).

There are two possible explanations for the fact that the parents showed fairly similar grain yields: a) They have the same favorable alleles fixed for the trait in question; b) They have approximately the same number of loci with the fixed favorable alleles, but the loci are different in the two cultivars. If the first alternative is correct, the segregant population should show small variability. On the other hand, if the second alternative is correct, the derived population should express high variability level. The large variability detected among the families in all the situations shows that the parents are divergent, that is, they have approximately the same number of favorable alleles, but in different loci. Many families performed better than the mean of the parents and showed transgressive segregation, which is expected when the parents complement each other. The divergence between these two cultivars had already been studied by Machado et al. (2000).

Some literature on the common bean emphasize that genetic progress from selection for grain yield is possible only if the cross is made between parents of different races (Nienhuis and Singh, 1988; Singh et al., 1991). In studies carried out in Brazil, however, it has been observed that this is not always true. Beans, especially those of the Andean race, are not always adapted and adequate variability has been obtained even from crosses between cultivars of the same race (Abreu et al., 1999). This fact was again confirmed in this study by the among family genetic variances (Tables 1 and 2).

The heritability estimates also demonstrated the presence of genetic variability among the families. The lower limit was positive in all the cases, indicating that the estimate has at least 95% probability of being different from zero and that there is genetic variability among the families.

It is important to point out that wide sense heritability estimates were obtained, as the genetic variance among the families contains dominance variance, besides additive variance. However, several reports showed that the additive genetic variance predominates in the control of common bean grain yield (Takeda, 1990; Nienhuis and Singh, 1988). Furthermore, the proportion of the dominance variance in the $F_{3:4}$ and in the $F_{3:5}$ generation is small (3/16 and 3/64, respectively). Therefore, the reported values are practically narrow sense heritabilities.

Table 1 - Estimates of the components of genetic and phenotypic variance of grain yield (g/m^2) obtained in the assessment of $F_{3:4}$ and $F_{3:5}$ families of common bean. Lavras, 2000.

Estimates	Selected Families	Unselected Families	Selec. + Unselec. Families
Mean $F_{3:4}$	387.49	377.62	382.56
Mean $F_{3:5}$	332.41	327.88	330.15
Mean (two generations)	359.95	352.75	356.35
Among family genetic variance $F_{3:4}$ $(\hat{\sigma}^2_{G_{F_{3:4}}})$	2795.827(759.60)	3275.880 (803.72)	3042.191 (594.94)
Among family genetic variance $F_{3:5}$ $(\hat{\sigma}^2_{G_{F_{3:5}}})$	1044.778(251.43)[1/]	1526.099 (297.92)	1283.883 (200.67)
Among family genetic variance from the joint analysis $(\hat{COV}_{F_{3:4}:F_{3:5}} = \hat{\sigma}^2_G)$	825.80 (280.63)	815.11 (303.71)	829.58 (210.85)
Among family mean phenotypic variance/$F_{3:4}$ $(\hat{\sigma}^2_{\bar{F}_{3:4}})$;	6943.985	7424.038	7190.349
Among family mean phenotypic variance/$F_{3:5}$ $(\hat{\sigma}^2_{\bar{F}_{3:5}})$;	2412.195	2983.516	2651.30
Among family mean phenotypic variance in the two generations $(\hat{\sigma}^2_{\bar{F}})$;	2751.947	2986.947	2875.205
Families x generations interaction variance $(\hat{\sigma}^2_{GE})$	1094.47	1585.87	1333.46
-simple part	211.21	165.07	186.72
-complex part	883.26	1420.80	1146.73
$\hat{\sigma}^2_{GE} / \hat{\sigma}^2_G$	1.32	1.95	1.61
Genetic correlation among the family means of the two generations $(r_{G_{F_{3:4}:F_{3:5}}})$(%)	48.3	36.4	42.0
Heritability among family means/$F_{3:4}$ $(h^2_{F_{3:4}})$	40.3 (23.0 ; 53.0)	44.1 (28.0 ; 56.0)	42.3 (29.0 ; 52.0)
Heritability among family means/$F_{3:5}$ $(h^2_{F_{3:5}})$	43.3 (28.0 ; 54.0)[2/]	51.2 (40.0 ; 62.0)	48.4 (38.0 ; 56.0)
Heritability among family means in the joint analysis (h^2)	30.0 (12.6 ; 43.0)	27.3 (9.2 ; 40.8)	28.9 (16.0 ; 39.3)
Parents average in generation $F_{3:4}$: Pérola=350.7 Ouro Negro=303.2	Parents average in generation $F_{3:5}$: Pérola=330.0 Ouro Negro=409.3		

[1/] Standad deviation;

[2/] Lower and upper heritability limits.

Table 2 - Estimates of the genetic and phenotypic variance components of grain yield (g/m²) $F_{3:5}$ common bean families. Lavras and Patos de Minas, 2000.

Estimates	Selected Families	Unselected Families	Selec. + Unselec. Families
$Mean_{Lavras}$	332.41	327.88	330.15
$Mean_{Patos}$	417.26	430.99	424.12
Mean (two locations)	374.83	379.43	377.13
Among family genetic variance in Lavras $(\hat{\sigma}^2_{G_{Lavras}})$	1044.778 (251.43)	1526.099 (297.92)	1283.883 (200.67)
Among family genetic variance in Patos de Minas $(\hat{\sigma}^2_{G_{Patos}})$	1850.568 (356.37)	1199.440 (293.48)	1564.368 (240.05)
Among family genetic variance from the joint analysis $(\hat{COV}_{Patos:Lavras} = \hat{\sigma}^2_G)$	983.97 (140.00)[1/]	561.720 (122.27)	755.330 (93.88)
Among family mean phenotypic variance/Lavras $(\hat{\sigma}^2_{\bar{F}_{Lavras}})$	2412.19	2983.52	2651.30
Among family mean phenotypic variance/Patos de Minas $(\hat{\sigma}^2_{\bar{F}_{Patos}})$	3465.00	2812.85	3177.78
Among family mean phenotypic variance in the two locations $(\hat{\sigma}^2_{\bar{F}})$	1961.03	1707.45	1834.93
Families x locations interaction variance $(\hat{\sigma}^2_{GE})$	463.70	801.04	668.79
-simple part	57.194	9.820	6.920
-complex part	406.509	791.226	661.870
$\hat{\sigma}^2_{GE}/\sigma^2_G$	0.502	1.426	0.862
Genetic correlation among the family means of the two locations $(r_{G_{Patos:Lavras}})$(%)	70.7	41.5	53.3
Heritability among family means/Lavras (h^2_{Lavras})	43.3 (28.0 ; 54.0)[2/]	51.5(40.0 ; 62.0)	48.4(38.0 ; 56.0)
Heritability among family means/Patos de Minas (h^2_{Patos})	53.4 (41.0 ; 62.0)	42.6 (28.0 ; 53.0)	49.2 (39.0 ; 57.0)
Heritability among family means in the joint analysis (h^2)	50.2 (37.9 ; 59.3)	32.9 (16.5 ; 45.1)	41.2 (30.9 ; 49.5)

Parents average in Lavras: Pérola=330.02; Ouro Negro=409.32. Parents average in Patos de Minas: Pérola=391.69; Ouro Negro=488.54

[1/] Standad deviation;
[2/] Lower and upper heritability limits.

It is difficult to compare heritability estimates once they are usually obtained using different methodologies and/or different generations, and the genotype x environment interaction, as already seen, affects the estimate of this parameter. However, the heritability values obtained in this study were similar to those reported by Abreu et al. (1999), Raposo et al. (2000) and Rosal et al. (2000).

An interesting fact observed in this study was the larger estimates of the among family means in the $F_{3:4}$ than in the $F_{3:5}$ generation. This can be partially explained by the greater magnitude of the dominance variance among the $F_{3:4}$ families than among the $F_{3:5}$ families, as already mentioned. However, dominance, if present, would be insufficient to explain such a difference. Another explanation would be deficient sampling, that is, an insufficient number of individuals used to represent a $F_{3:4}$ or $F_{3:5}$ family. Although no specific information on this matter is found in the literature, it is common in bean family assessments to use plots with a number of plants similar to that used here. A third factor, perhaps the most important, is the interaction of families X environments, which may have been of greater magnitude in the $F_{3:4}$ family assessment.

Early selection for traits such as grain yield is not efficient when assessed visually (Cutrim et al., 1997; Silva et al. 1994). It is only efficient for high heritability traits. There is no data, however, on the secondary effect that early selection for one or more high heritability traits have on the efficiency of the selective process of lower heritability traits in advanced generations. There are at least two alternatives to answer this question: a) the determination of the effect of the selection made in the F_2 generation (F_3 seeds) for bean type on the yield of the families in more advanced generations; b) the verification of the consequences of the selection on the genetic variability of these families.

These two different approaches were examined in this study. Considering the three environments, the mean of the selected families was 379.0 g/m^2 and that of the unselected families was 378.8 g/m^2 (Tables 1 and 2). This indicates that there were no significant differences in the yield of these two groups, showing that early selection for seed type did not affect family grain yield in more advanced generations.

A similar result was obtained for variability. There were practically no differences in the among family genetic variance or in the heritability estimates (Tables 1 and 2). It was hypothesized that although seed color is controlled by many genes (Leakey, 1988; Basset, 1996), probably distributed in different chromosomes, they are not linked to the genes that control grain yield, which must also be numerous and probably found in all the chromosomes.

The implications of these results are very favorable to Brazilian common bean breeding programs, since, as already mentioned, the main factor for cultivar adoption is bean type. Efficient early selection can be practiced because bean type has high heritability and, therefore, breeders can concentrate efforts on assessing individuals or families with commercially acceptable seeds when practicing selection for grain yield, which is carried out on more advanced generations based on family mean performance. This implies a lower number of families for assessment thus reducing the amount of work, even if the breeder chooses to use more replications and/or locations to improve experimental accuracy. The advantage of early selection was evident in this study. Among the 199 unselected families for seed type, only seven were within the commercial standard, that is, showed scores $\leq$ 2.5. In other words, 192 families were assessed in three environments, with hardly any practical return for the breeder. Among the 199 selected families 105 were within commercial standards.

When the selection of the seven highest yielding families, on average in the Lavras and Patos de Minas experiment, was simulated regardless of seed quality, the expected genetic gain was similar between the two family groups, although the seed quality score of the selected families was much smaller (2.3) than that of the unselected families (4.9) (Table 3). However, considering the selection of the seven highest yielding families among those which obtained scores of up to 2.5, the expected gain was much greater in the selected families (9.3% against 1.8%). This reinforces the previous comments on the importance of carrying out early selection for seed type and postponing selection for yield to more advanced generations.

Table 3 - Estimates of expected genetic gain from selection of the seven highest grain yielding (g/m²) $F_{3:5}$ families in the average of the two locations (Lavras and Patos de Minas).

	Type of selection	
Unselected families	Regardless of the seed score	Only among families with seed scores lower than 2.5
General mean (g/m²)	379.8	379.8
Mean of the selected families (g/m²)	463.6	396.4
G.S./m (%)[1/]	9.2	1.8
Mean seed scores	4.9	1.9
Selected families	Regardless of the seed score	Only among families with seed scores lower than 2.5
General mean (g/m²)	374.8	374.8
Mean of the selected families (g/m²)	463.6	458.5
G.S./m (%)[1/]	9.9	9.3
Mean seed scores	2.3	2.0

[1/] In the genetic gain from selection estimate, the mean heritability of the selected and unselected families ($h^2 = 41.6\%$) was considered.

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RESUMO

Implicações da seleção precoce do tipo de grão no melhoramento genético do feijoeiro-comum

Como a cor dos grãos do feijoeiro é controlada por grande número de genes, provavelmente distribuídos em todos os cromossomos, espera-se que na seleção precoce desse caráter ocorra uma expressiva redução na variabilidade dos outros caracteres, como a produtividade de grãos, objetivo primordial da maioria dos programas de melhoramento. Assim, este trabalho teve como objetivo verificar o efeito da seleção efetuada na geração F_2 do caráter tipo de grãos sobre a produção de grãos, cuja seleção é efetuada em gerações mais avançadas. Para isso, foi utilizada a geração F_2 do cruzamento entre as cultivares Ouro Negro, de grãos pretos, e Pérola, de grãos tipo carioca - creme com listras marrons. As sementes colhidas foram divididas em duas partes, selecionando-se em uma delas os grãos do padrão carioca, enquanto na outra não se fez nenhuma seleção. As plantas F_3 de ambas as subpopulações foram colhidas individualmente, obtendo-se 199 famílias por subpopulação. Essas 398 famílias $F_{3:4}$ e as cultivares genitoras foram avaliadas na seca de 2000 em Lavras e as famílias $F_{3:5}$ no inverno de 2000 em Lavras e Patos de Minas. Considerando a produtividade de grãos, constatou-se que, na média, não ocorreram diferenças entre as famílias selecionadas e as não-selecionadas quanto ao tipo de grãos. Observou-se também que as estimativas da herdabilidade foram altas e semelhantes. Infere-se, então, que a seleção precoce do tipo de grãos na geração F_2 não reduziu o potencial da população quanto à extração de linhagens superiores. Fica assim evidenciado que a estratégia de promover rigorosa seleção do tipo de grãos na geração F_2 possibilita

aos melhoristas concentrar os seus esforços na seleção de outros caracteres, apenas nas famílias com grãos comercialmente aceitáveis, ampliando a chance de sucesso.

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