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Genetic control of the number of days to flowering in common bean

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ABSTRACT – *The aim of this study was to investigate the genetic control of early flowering in common bean. Crosses were made between the parents Pérola and BRS Radiante and between ESAL 506 and Preto 60 dias. The segregating generations, F_3, F_2BC_{11} and F_2BC_{12} of each cross were evaluated in experiments with two replications. F_3 plants of both crosses were randomly taken, and $F_{3:4}$ progenies evaluated for the trait number of days to flowering. There was good adjustment to the additive-dominant model of both crosses. The dominance effect was lower than the additive effect in the trait control and, when present, it reduced the number of days to flowering. The value of realized heritability (h^2_R) was similar in both crosses and lower than the h^2 estimated for selection among $F_{3:4}$ progenies. There were indications that aside from the environmental effect on the trait expression, the genotype-environment interaction was also significant.*

Key words: Common bean, flowering, genetic improvement.

INTRODUCTION

Common bean types in Brazil have a mean cycle of 85 to 90 days. Still, there is a demand for earlier cultivars, particularly for irrigated cultivation, to reduce water consumption and facilitate rotation with other crops.

The main trait used to compare the earliness is the number of days from emergence until the occurrence of the first flowers. This period is influenced by the genotype as well as environmental factors, e.g., photoperiod and temperature. The lines differ in earliness; some are reported to reach flowering within 30 and others in more than 100 days (Blair et al. 2006).

Information on the genetic control of the number of days to the beginning of flowering has been compiled in different situations by distinct methodologies (Coyne 1978, Freire Filho 1980, Santos and Vencovsky 1985, Arriel et al. 1990, Barelli et al. 1999). However, there is no consensus on the genetic control. It is admitted that the trait has high heritability, but its expression varies widely between locations and sowing dates. In view of the importance attached to this trait by breeders, this study was carried out to obtain more details on the genetic control.

MATERIAL AND METHODS

The genetic control of the number of days to flowering in common bean was studied using four different lines. The following lines were used: Pérola,

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with carioca grain, normal cycle and type II / III growth habit; BRS Radiante, with beige and red striped grain, early maturity and type I growth habit; Preto 60 dias, which has black beans, early maturity and type I growth habit; and ESAL 506, with brown grain, normal cycle and type III growth habit.

Crosses were made between parents Pérola (P_1) and Radiante (P_2) and between ESAL 506 (P_1) and Preto 60 dias (P_2). The F_1 generation of each cross was grown in a greenhouse, Department of Biology, Universidade Federal de Lavras, in the southern region of Minas Gerais (lat 21 ° 58 ' S, long 45 ° 22' W; 910 m asl). Part of the F_1 seeds were sown for the F_2 generation and another part was used for the backcross generation (BC_{11} - the first backcross generation with parent 1 and BC_{12} - the first backcross generation with parent 2). The experiments were conducted with the segregating generations F_3, F_2BC_{11} and F_2BC_{12}. The experiment was arranged in randomized blocks and two replications. For the parents, the plots consisted of one 3-m-row with 25 plants. For the segregating populations, plots had four 3-m-rows, spaced 0.5 m apart. The regionally recommended cultural treatments were used for bean cultivation.

For each plant the opening date of the first flower was recorded. Subsequently, 47 plants were taken randomly from the F_3 generation of the cross Pérola x Radiance, and 62 F_3 plants of the cross between Preto 60 dias x ESAL 506, to obtain the $F_{3:4}$ progenies. The progenies and the parents were evaluated in the harvest of winter 2007. The experimental design used in the evaluation of $F_{3:4}$ progenies from the cross Radiante x Pérola was a 7x7 simple lattice and the progenies of cross Preto 60 dias x 506 ESAL was an 8x8 simple lattice design. The plots consisted of one 2-m-row, with a seed sowing density of 15 per meter. The management was similar as described above. The date on which 50% of plants in the plot had at least one open flower was recorded.

With the number of days from emergence to the beginning of flowering, the analysis of variance of evaluations of $F_{3:4}$ progenies was performed. The heritability (h^2) for selection in the progeny means was estimated based on the mean square expectations. The error of the h^2 estimate was obtained by Knapp et al. (1985). For the F_3 and backcross generations, the mean components were estimated using a methodology similar to that proposed by Cruz et al. (2004). For this purpose, the program MapGen was used (Ferreira and Zambaldi 1997).

With data of F_3 plants and the mean of the respective $F_{3:4}$ progenies, the realized heritability was estimated by a procedure similar to that used by Ramalho et al. (1993a).

RESULTS AND DISCUSSION

The earliness of the parents Radiante and Preto 60 dias was confirmed. The mean number of days to the beginning of flowering was lower and varied among the parents of each cross (Table 1). The mean difference between the parents Pérola and Radiante was 8.2 days and 4.2 days between Preto 60 dias and ESAL 506. This difference may seem small, but a reduction of 8.0 days in flowering, for example, corresponds to a reduction of approximately 10% of the cycle. In the studies on genetic control, the difference in the life cycle of the parents was similar to the magnitude of this study (Coyne and Mattson 1964, Coyne 1978).

A good adjustment to the additive-dominant model was observed for both crosses (Table 2), since there is no epistasis for this trait, as confirmed in other studies. It was also stated that in the cross Pérola x Radiance, the additive effects estimate ("a") was approximately three times higher than the dominance effects ("d"). For the cross Preto 60 dias with ESAL 506, the magnitude of "a" and "d" were similar and not different from zero in the t test. It was inferred that dominance is less important than additive effects in the trait control and when it occurs it reduces the time until the beginning of flowering (negative "d"). Similar observations on the number of days to the beginning of bean flowering were reported by Santos and Vencovsky (1985), Arriel et al. (1990) and Barelli et al. (1999).

Table 1. Number of individuals in each population, with mean number of days to the beginning of flowering

Cross	Populations	Number of individuals	Mean
Pérola x Radiante	P_1	29	33.2
	P_2	38	25.0
	F_2BC_{11}	111	31.57
	F_2BC_{12}	111	26.98
	F_3	101	29.13
Preto 60 dias x ESAL 506	P_1	33	31.1
	P_2	37	26.9
	F_2BC_{11}	99	30.69
	F_2BC_{12}	115	28.44
	F_3	116	28.97

Table 2. Estimate of the mean components (m: mean, a: additive effects and d: dominance effects) for the trait number of days from emergence to the beginning of flowering in F_3 bean plants of the crosses Pérola x Radiante and Preto 60 dias x ESAL 506

Cross	Parameters	Estimate	Standard error	Prob.>|T|
	m	28.629	1.260	0.001
Pérola x Radiante	a	3.441	1.111	0.090
	d	-1.254	7.370	0.880
R^2	99.84			
	m	29.254	1.033	0.001
Preto 60 dias x ESAL 506	a	1.470	0.833	0.219
	d	-1.910	5.070	0.742
R^2	99.91			

Due to the absence of dominance, the expression of Wright (quoted by Ramalho et al. 1993b) was used to estimate the number of genes. The resulting value shows that the trait is controlled by one gene, in agreement with other studies (Coyne and Mattson 1964, Padda and Munger 1969, Coyne 1970, Coyne 1978, Freire Filho 1980). It should however be emphasized that there are some restrictions to the use of the expression of Wright. Thus, one can infer that the number of genes involved in trait control is monogenic or oligogenic, but the occurrence of modifiers should not be neglected in view of the commonly observed segregations.

Estimates of heritability (h^2) for the number of days to flowering of the $F_{3:4}$ progenies were high, with values of 77.09% for the cross Preto 60 dias x ESAL 506, and 60.81% for progenies from the cross Pérola x Radiante. The high h^2 values are similar to those reported in the literature by Arriel et al. (1990) and Abreu et al. (2005). Considering again that the dominance was not important in the trait expression, h^2 must be predominantly in the narrow sense (Bernardo 2002).

Considering the selection of 10% of F_3 plants with less days to flowering, the realized heritability (h^2_R) was estimated in progenies $F_{3:4}$. It was observed that the magnitude of h^2_R was similar in the two crosses (Table 3) and lower than h^2 estimated for the selection in $F_{3:4}$ progenies. This evidences that besides the environmental effect on the trait expression, the genotype-environment interaction was also significant.

Table 3. Estimates of heritability (h^2) and realized heritability (h^2_R) for selection based on the mean of the $F_{3:4}$ progenies of the crosses Preto 60 dias x ESAL 506 e Pérola x Radiante

Cross	h^2	Mean				h^2_R [3/]
		F_3		$F_{3:4}$		
		M_{0i} [2/]	M_{si} [2/]	M_{sj} [2/]	M_{0j} [2/]	
Preto 60 dias x ESAL 506	77.09 (62.30 – 86.09) [1/]	28.84	24	39.6	41.89	32.57
Pérola x Radiante	60.81 (35.49 – 76.19) [1/]	28.72	24	39.70	42.85	44.74

[1/] Upper and lower limits of the confidence interval, at 0.05% probability

[2/] M_{0i}: mean original of the F_3 population; M_{si}: mean of the plants selected in F_3; M_{sj}: mean of the progenies selected in F_3; M_{0j}: overall mean of progenies in the $F_{3:4}$ generation

[3/] Realized heritability estimated by the estimator: $\frac{\frac{M_{sj}-M_{0j}}{M_{0j}}}{\frac{M_{si}-M_{0i}}{M_{0i}}} x100$

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Controle genético do número de dias para o florescimento no feijoeiro

RESUMO – *O presente estudo objetivou obter informações sobre o controle genético do início do florescimento no feijoeiro. Foram realizados cruzamentos entre os genitores Pérola e Radiante e entre ESAL 506 e Preto 60 dias. As gerações segregantes F_3, F_2RC_{11} e F_2RC_{12}, de cada cruzamento, foram avaliadas em experimentos com duas repetições. Plantas F_3 de ambos os cruzamentos foram tomadas aleatoriamente, sendo avaliadas progênies $F_{3:4}$ para o caráter número de dias para o florescimento. Houve bom ajustamento do modelo aditivo-dominante para ambos os cruzamentos. Constatou-se menor efeito da dominância do que efeito aditivo na manifestação do caráter e, se ela ocorrer é no sentido de reduzir o tempo necessário ao início do florescimento. O valor da $h^2_{realizada}$ foi semelhante nos dois cruzamentos e de magnitude inferior a h^2 estimada para a seleção entre progênies $F_{3:4}$. Houve indícios de que além do efeito do ambiente na manifestação do caráter, a interação dos genótipos x ambientes também foi expressiva.*

Palavras-chave: Feijoeiro, florescimento, melhoramento genético.

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