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NOTE

Contribution of components of production on snap bean yield

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Abstract - *Aiming to estimate the path coefficients among morphological traits and effects of production components on the yield of grains and pods, thirty snap bean genotypes (27 lines and three commercial controls) were evaluated in Bom Jesus of Itabapoana-RJ. The experiments were carried out in a randomized block design, with four replications, from May to June, in 2009 and 2010. Eight traits were evaluated and the number of pods per plant, associated with high genetic correlation, is the character with the most significant direct effect on productivity. There is a high rate of genotypic association between the yields of pods and grains, as well as direct effects of high magnitude and positive signal between them, indicating that the selection for increased pod yield allows increased grain yield.*

Key words: Phaseolus vulgaris *L., genetic correlation, phenotypic correlation, path analysis.*

INTRODUCTION

Snap bean cultivation is a very important socio-economic activity in regions where vegetables have been traditionally grown. It is a good alternative for crop diversification, mainly when used in rotation with tomato crop, since, under these conditions, the tutoring structure can be used, as well as the residues of high fertilizer doses required by tomato crop. In addition, snap bean is grown mainly by small farmers, uses family labor and contributes to increased income, diversification and the maintenance of these families in the countryside.

Traditionally, little attention has been devoted to snap bean breeding in Brazil, mainly because it is a culture whose seeds are always kept by producers as they reuse their own seeds or seeds from neighbors (Mariguele et al. 2008, Cabral et al. 2011). In the Brazilian market, the private sector has dominated the development of vegetable cultivars (Marinho et al. 2011). However, few commercial cultivars of snap bean have been available by private companies. Thus, the indication of suitable snap bean cultivars to farmers depends on public breeding programs, which are scarce in Brazil (Oliveira et al. 2006, Mariguele et al. 2008, Vilela et al. 2009, Cabral et al. 2011).

It is necessary to know and explore the variability present in the accessions available in either germplasm banks or commercial materials to ensure the success of genetic breeding programs for this culture. Knowledge about the variability of traits of economic importance and their associations is very important for the selection of breeding techniques and the achievement of information on adaptability and productivity in various regions (Vieira et al. 2007, Cabral et al. 2011).

The study on the correlations among characters is not conclusive about cause and effect relations (Gonçalves et al. 2003). Therefore, when there are many explanatory variables and a basic or dependent variable, it is necessary to use analyses that consider the correlations among the explanatory variables, such as the path analysis.

Considering the path analysis for yield and related components, Hoogerheide et al. (2007) reported that knowledge on the degree of this association achieved by correlation studies, allows the identification of characters that can be used as criteria for indirect selection for productivity in breeding programs.

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This study aimed to assess, by genotypic correlation, the direct and indirect relationship between the yield of pods and of grains of snap bean, with its primary components, to assist in the selection of promising lines for the production of pods and grains (where applicable).

MATERIAL AND METHODS

The experiments were installed in the experimental field of the IFF - Instituto Federal Fluminense, Bom Jesus do Itabapoana campus, Rio de Janeiro state, in the crop years 2009 and 2010, comprising 30 genotypes of snap bean of indeterminate growth habit. Out of these, 27 lines are at an advanced stage (generations F8 and F9) of the breeding program of the Universidade Estadual do Norte Fluminense – UENF and three commercial materials are used as controls in the experiment. The experiment was arranged in a completely randomized block design with four replications. The experimental plot consisted of 12 plants, with a 1.0 x 0.5 m spacing. Ten individual plants from each plot were assessed and one plant was left at each end as borderline. The experiments were assessed from May to August in 2009 and 2010. Plants were tutored with bamboo and wire and the cultural treatments were performed according to recommendations of Filgueira (2000). Phytosanitary control and sprinkler irrigation were carried out when necessary.

The following traits were assessed: 1) height of first pod (HFP), 2) plant height (PH), by measuring the distance from the stem of each plant to the end of the main stem, on the day of the harvest, in cm; 3) number of pods per plant (NPP); 4) average number of seeds per pod (NSP), obtained by counting the number of seeds in a sample of 10 pods of each plant; 5) average length of the pod (LP), in cm, obtained by the quantification of the longitudinal length of the sample of 10 pods per plant; 6) average weight of pods (WP), obtained by the ratio between the total weight of pods and the number of plants, expressed in g; 7) 100 seed weight (SW100), expressed in g; 8) pod yield (PY) expressed in $kg.ha^{-1}$ of fresh pods, obtained by weighing the fresh pods after each harvest in each plot, and estimating productivity for 1 h; 9) grain yield (GY), expressed in kg ha^{-1} of dry grains with 13% humidity, obtained by weighing the grains produced by the plot and estimated for the area of 1 ha. The genetic-statistical analyses were performed with the Genes software (Cruz 2006).

RESULTS AND DISCUSSION

In preliminary data analyses, the homogeneity of variance of the treatments (genotypes) was verified by the Crochran and Barttlet tests, and for normality, by the Lilliefors test, for both experiments (two years). Then, the analyses of variance revealed that the effects of genotypes presented significant variations for the characters assessed in this work. For the purposes of the correlation and path analyses, the data from both environments (two years, 2009 and 2010) were assessed together, since, according to the results of the individual analysis of variance, the residual variances of the two experiments were considered homogeneous, and the ratio between the highest and lowest mean square of the residue was lower than 7, according to the criterion established by Pimentel Gomes (2000). The low influence of the environment on the expression of the characters is probably due to the fact that the experiments were installed at the same season of year (from May to August, in 2009 and 2010).

There were significant differences ($p < 0.01$) in all traits we evaluated, except to height of first pod (HFP), indicating the existence of genetic variability between genotypes (Table 1). Concerning the years, there were significant differences ($p < 0.01$) for number of pods per plant (NPP), average number of seeds per pod (NSP), average length of the pod (LP), average weight of pods (WP), pod yield (PY) and grain yield (GY), whereas for the height of first pod (HFP), plant height (PH) and 100 seed weight (SW100) no significant differences were identified. Considering the genotype by year interaction (GxY), NPP and GY were affected by significant differences

Table 1. Values and significances of the mean squares (MS) and percentage coefficients of the experimental variation, based on the mean of the treatments for nine traits, evaluated in two years in snap bean inbred lines

Sources of variation	df	Mean squares[1]								
		HFP	PH	NPP	NSP	LP	WP	SW100	PY	GY
Block/Years	6	7.5621	0.02736	132.60	0.088	0.0761	0.7474	4.3981	0.1861	0.8095
Genotypes (G)	29	7.9246	0.0953**	350.62**	1.957**	27.47**	0.5524**	31.67**	2.2431**	5.8938**
Years (Y)	1	7.2145	0.0612	2092.30**	4.641**	171.76**	20.71**	3.9254	2.2999**	3.3.854**
G x Y	29	6.4219	0.0704	172.38*	0.5395	3.46**	0.3054	4.1211	2.4773**	1.8332*
Error	174	4.0941	0.04118	91.62	0.3340	1.102	0.2401	2.5604	0.2140	0.8788
Means		8.79	2.47	55.83	7.59	15.16	2.51	34.61	1.985	2.96
CV (%)		23.01	8.21	17.14	7.61	6.92	19.51	4.62	23.31	31.83

[1] HFP = height of first pod; PH = plant height; NPP = number of pods per plant; NSP = average number of seeds per pod; LP = average length of pods; WP = average weight of pods; SW100 = 100 seed weight; PY = pod yield; and GY = grain yield.
[**, *] Significant in level of 0.01 and 0.05 of probability, respectively, by the F test.

at $p < 0.05$, while LP and PY, significant differences occurred at $p < 0.01$. For the others traits, GxY was not significant. The occurrence of significant GxY indicates a genotypic differential response to changes in the environment. Therefore, the behavior of genotypes was differentiated front the two crop years, for the most important traits (PY and GY).

Furthermore, a diagnosis of multicollinearity was performed and a degree of low severity was observed, which was less than 100, according to the criteria of Montgomery and Peck, corroborated by Cruz and Carneiro (2003). For Carvalho et al. (1999), this study is important for regression and path analyses and selection indices. Cruz and Carneiro (2003) report that the estimates of the parameters under multicollinearity can lead to unstable estimates of the regression coefficients and the overestimation of the direct effects of the explanatory variables on the main variable, which may lead to erroneous results.

The coefficient of determination reveals that 95% of pod yield and 80% of grain yield can be explained by the effect of the variables analyzed. It is important to highlight that this value is restricted to the characters under analysis, since productivity is a quantitative character, with a large number of alleles of small effect that affect the main character.

The significant phenotypic and genotypic correlations were found in several pairs of characters (Table 2). The differences between the phenotypic and genotypic correlations for most traits studied are low. This demonstrates the low magnitude of the environmental correlations and the little effect that the environment has on the variation of characters.

The phenotypic correlation measures the degree of association of two characters from environmental and genetic effects. The latter effect is the main responsible for the heritable fraction from parents to progenies. Considering than the most important traits for this crop are pod yield and grain yield, in the present work will be discussed only coefficients of genotypic correlations involving these traits with the others, emphasizing only the major correlations. These values were obtained from the following variables: pod yield and grain yield (1.0), grain yield and 100 seed weight (0.86), pod yield and number of pods per plant (0.76), grain yield and number of pods per plant (0.49). The variables NPP, SW100, LP and HFP correlated positively and significantly with the yields of pods and grains, while the variable PH correlated only with PY. The variable WP correlated only with grain yield and the variable NSP alone correlated negatively with pod yield, but positively with grain yield. This discrepancy in magnitude and direction of the estimated parameters demonstrates that the causes of genetic and environmental variation affected this character by means of different physiological mechanisms, according to reasoning reported by Falconer and Mackay (1996).

Several works on bean crop found that the number of pods per plant is the character that contributes most to grain yield of common bean, since it presents the highest correlations with grain yield (Lana et al. 2003, Cabral et al. 2011). In this study, this component correlated positively and significantly with grain yield and pod yield. Moreover, this character presented the highest direct effect on pod yield, highlighting its potential for selection and identification of superior genotypes for pod yield in snap beans.

Table 3 indicates that there is a system of inter-relationships between the characters under study and that a certain variable might affect yield (of grains or pods) through another correlated trait, characterizing indirect effects of the character analyzed on productivity.

The magnitude of the direct effects of the characters analyzed on pod yield was lower than the magnitudes of the estimates of their respective correlations with pod yield, except for the variable NVP, whose direct effect on pod yield was higher than the magnitude of its correlation (1.23). Based on this information, it is possible to see in Table 3 that the NVP was the yield component that presented the highest direct effect on pod yield. It demonstrates the relevance of this component on pod yield

Table 2. Estimates of the phenotypic correlation coefficients and genotypic correlation (bold) among nine agronomic characters evaluated in snap bean

Variables	GY	HFP	PH	NPP	LP	NSP	WP	SW100
GY	-	0.26	0.18	0.54**	0.25	0.059	0.13	0.69**
HFP	**0.44***	-	0.04	0.007	0.33	0.30	0.21	0.11
PH	**0.22**	**-0.03**	-	0.09	0.28	-0.02	0.17	0.16
NPP	0.49**	0.005	**0.15**	-	-0.37*	-0.47**	-0.52**	0.34*
LP	**0.43***	**0.45****	**0.29**	**-0.46****	-	0.58**	0.72**	0.22
NSP	0.47**	0.59**	-0.02	-0.75**	**0.68****	-	0.43*	-0.26
WP	**0.35***	**0.46****	**0.16**	**-0.66****	**0.43***	**0.47****	-	0.63**
SW100	0.86**	0.02	0.10	-0.16	0.17	-0.21	**0.58****	-
PY	1.00**	0.39*	0.40*	0.76**	0.36*	-0.35*	0.23	0.35*

*, ** Significant at 1% and 5% probability, respectively, by the t test. PY and GY= yields of pods and grains, expressed in kg ha^{-1}; HFP = height of first pod insertion (cm); PH = plant height (m); NPP = number of pods per plant; LP = average length of pods (cm); NSP = average number of seeds per pod; WP = average pod weight (g); SW100 = 100 seed weight (g).

Table 3. Estimate of direct and indirect genotypic effects of the components of production on the yield of pods and grains, for snap bean crop, in two crop years (2009 and 2010)

Description of the effects		**Yields** (kg ha^{-1})	
		Pods	Grains
Direct Effect of	**HFP**	-0.060	0.5360
Indirect effect via	NPP	0.0055	-0.0096
Indirect effect via	PH	-0.0022	0.0044
Indirect effect via	WP	0.5027	-1.0372
Indirect effect via	LP	-0.1112	0.4981
Indirect effect via	NSP	-0.0005	0.5223
Indirect effect via	SW100	0.2693	-0.2847
Indirect effect via	GY	0.0469	-
Indirect effect via	PY	-	0.80724
Total		0.3908	0.4418
Direct Effect of	**PH**	-0.069	-0.1363
Indirect effect via	NPP	0.187	-0.3261
Indirect effect via	HFP	0.002	-0.1742
Indirect effect via	WP	0.171	-0.3524
Indirect effect via	LP	-0.071	0.3196
Indirect effect via	NSP	-0.0005	0.0020
Indirect effect via	SW100	-0.0214	0.2219
Indirect effect via	GY	0.047	-
Indirect effect via	PY	-	0.7343
Total		0.4545	0.2237
Direct Effect of	**NPP**	1.2308	0.1566
Indirect effect via	HFP	-0.0003	0.0031
Indirect effect via	PH	0.0105	-0.0027
Indirect effect via	WP	-0.7198	0.2881
Indirect effect via	LP	0.1147	-0.4929
Indirect effect via	NSP	-0.1816	0.5421
Indirect effect via	SW100	-0.4478	0.5317
Indirect effect via	GY	0.1037	-
Indirect effect via	PY	-	1.0133
Total		0.5582	0.4943
Direct Effect of	**LP**	-0.2474	1.1074
Indirect effect via	NPP	-0.5707	0.9908
Indirect effect via	HFP	-0.0271	0.2411
Indirect effect via	PH	0.0199	-0.0394
Indirect effect via	WP	0.9344	-1.9274
Indirect effect via	NSP	0.1649	-0.6039
Indirect effect via	SW100	-0.2213	0.1174
Indirect effect via	GY	0.0899	-
Indirect effect via	PY	-	0.6606
Total		0.3639	0.4290

Description of the effects		**Yields** (kg ha^{-1})	
		Pods	Grains
Direct Effect of	**NSP**	0.2428	-0.8891
Indirect effect via	NPP	-0.9204	1.5978
Indirect effect via	HFP	-0.0354	0.3149
Indirect effect via	PH	-0.0001	0.0003
Indirect effect via	WP	0.5143	-1.0609
Indirect effect via	LP	-0.1680	0.7522
Indirect effect via	SW100	-0.0164	0.3908
Indirect effect via	GY	0.0166	-
Indirect effect via	PY	-	-0.6361
Total		-0.3504	0.4700
Direct Effect of	**SW100**	0.2945	0.9421
Indirect effect via	NPP	-0.7817	0.6735
Indirect effect via	HFP	0.0016	-0.0214
Indirect effect via	PH	-0.0112	0.1249
Indirect effect via	WP	0.6932	0.5719
Indirect effect via	LP	-0.1208	0.1600
Indirect effect via	NSP	-0.3748	-1.0218
Indirect effect via	GY	0.2065	-
Indirect effect via	PY	-	0.2920
Total		0.3849	0.8619
Direct Effect of	**GY**	0.2107	-
Indirect effect via	NPP	0.6084	-
Indirect effect via	HFP	-0.0327	-
Indirect effect via	PH	0.1542	-
Indirect effect via	WP	0.3811	-
Indirect effect via	LP	-0.1061	-
Indirect effect via	NSP	0.0192	-
Indirect effect via	SW100	0.1215	-
Total		1.07	-
Direct Effect of	PY	-	-0,4537
Indirect effect via	NPP	-	0,8960
Indirect effect via	HFP	-	-0,0029
Indirect effect via	PH	-	0,0196
Indirect effect via	WP	-	0,1413
Indirect effect via	LP	-	0,0371
Indirect effect via	NSP	-	-0,0188
Indirect effect via	SW100	-	0,0221
Total		-	0,6408
Coefficient of determination (R^2)		0.9549	0.8043
Effect of the Residual variable		0.2124	0.4423

PY and GY= yields of pods and grains, expressed in kg.ha^{-1}; NPP = number of pods per plant; HFP = height of first pod insertion (cm); PH = plant height (m); WP= average pod weight (g); LP = average length of pods (cm); NSP = average number of seeds per pod; SW100 = 100 seed weight.

for snap bean cultivation, whose commercial products are immature pods. However, there were indirect effects of negative signal between NVP and pod yield via PMV.

The most important component associated with grain yield was LP, with direct effect and magnitude of 1.11, followed by SW100, whose direct effect on productivity was 0.94, and APV, with 0.54 (Table 3). Similar results were found by Cabral et al. (2011) for the characters NPP, SW100 and NSP. The other characters did not directly affect grain yield. However, it is noteworthy that some indirect effects of high magnitude with positive and some negative signals are associated with grain yield, namely: LP via WP (-1.93); HFP via WP (-1.04); LP via NPP (0.99); LP via NSP (0.60); and HFP via NSP (0.52).

The results of this study allow us to consider the possible use of indirect selection for pod yield, using the agronomic character number of pods per plant as reference and, for indirect selection for grain yield, the characters LP, SW100, HFP and pod yield, considering the latter a primary character for grain yield.

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Contribuição de componentes de produção no rendimento de feijão-vagem

Resumo – *Com o objetivo de estimar os coeficientes de trilha entre os caracteres morfológicos e componentes da produção sobre as produtividades de vagens e de grãos, trinta genótipos de feijão-de-vagem (27 linhagens e três testemunhas comerciais) foram avaliados em Bom Jesus de Itabapoana-RJ. Os experimentos foram implantados em blocos casualizados com quatro repetições, no período de maio a junho, nos anos de 2009 e de 2010. Oito caracteres foram avaliados e o caráter com maior efeito direto sobre a produtividade de vagens foi o número de vagens por planta (NVP), associado* à *alta correlação genotípica. Existe alto* índice *de associação genotípica entre as produtividades de vagens e de grãos, bem como efeito direto de alta magnitude e de sinal positivo entre elas, indicando que ao se fazer seleção para o aumento do rendimento de vagens, consequentemente, aumenta-se a produtividade de grãos.*

Palavras-chave: Phaseolus vulgaris *L., correlação genética, correlação fenotípica, análise de trilha.*

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