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Variability and correlations in cowpea populations for green-grain production

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ABSTRACT - *The phenotypical, genotypical and environmental variability and correlations in cowpea were estimated, aiming at the selection of lines for green-grain production. Both parents and 62 lines (39 F_4, 16 F_3BC_1, 07 F_3BC_2) were evaluated. The experiment was conducted in Teresina, Piauí, where the following traits were evaluated: stalk length; plant height at flowering; number of nodes on the main stem; number of secondary branches; number of pods per plant; pod width, length and thickness; number of grains per pod; weight of 100 grains; and grain yield. The 14 lines of the F_4 population achieved high grain yields, with purple pods and white grains; they can be recommended for selection for green-grain production. Selection for more pods per plant may achieve a higher grain yield.*

Key-words: *Vigna unguiculata*, morpho-agronomic traits, yield components.

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is a leguminous plant of great socioeconomic, cultural and nutritional importance; it is an excellent source of proteins, carbohydrates, vitamins and minerals as well as of dietary fibers, while the fat quantity is low and cholesterol content zero (Sales and Rodrigues 1988). The crop is physiologically little demanding and adapts well to the most varied environmental conditions. It can therefore be exploited in different production systems, mainly in Northeastern Brazil, where it is most cultivated (Freire Filho et al. 2005).

According to Queiroz (2001), genetic improvement programs in the last decade gave rise to a significant increase in cowpea yield by the development of cultivars that meet consumers' expectations. The wide genetic variability in the species made this possible.

On this background, estimates of genetic parameters that determine the variability available in populations are fundamental (Gomes and Lopes 2005). Bezerra et al. (1995) and Lopes et al. (2001) both used estimates of the genetic variation coefficient to quantify variability in cowpea genotypes and stated considerable diversity; the highest value of all traits was found for grain yield (19.44 and 23.90%, respectively).

Generally speaking, the study of interrelations between traits aims to improve genotypes for a whole trait set simultaneously, rather than for separate traits

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only. The interrelations reveal how the improvement of one trait can cause alterations in others (Vencovsky and Barriga 1992). Information on these relations is particularly important when the selection of a trait is hampered by low heritability and/or to problems of measurement and identification (Cruz and Regazzi, 1994).

Studies on correlations with cowpea (Bezerra et al. 2001, Lopes et al. 2001) have tried to interpret the results and obtain support to work out adequate improvement strategies.

This study aimed to evaluate the genetic variability in cowpea lines and estimate genotypic, phenotypic and environmental correlations among the morpho-agronomic traits with a view to the selection of lines for green grain production.

MATERIAL AND METHODS

The cowpea genotypes used here were originated by crossing Capela and Costelão, derived from the Germplasm Bank of Embrapa Meio-Norte. These are local cultivars, contrasting in pod length. The pods of Costelão represent the desirable type for green grain production. In F_4, F_3BC_1 (F_3 of the backcross with Capela) and F_3BC_2 generations (F_3 of the backcross with Costelão), respectively, 39, 16 and 7 lines, totalizing 62 lines and two parental genotypes were evaluated.

The experiment was installed in an experimental area of the Centro de Ciências Agrárias, Universidade Federal do Piauí, in Teresina, state of Piauí (lat 05° 05' 05" S, long 42º05' 00" W, 72m asl), in a Fluvic Neosol, from March to June 2004.

The experiment was arranged in a randomized block design with three replications; plots consisted of 2.5 m long rows, spaced 1.50 m between rows and 0.25 m between plants. The parental was planted along the two side rows as border. The plants were not irrigated.

The traits were evaluated in randomly selected individual plants with at least 50% ripe pods for: stalk length of the main stem (SL), expressed in centimeter; plant height (PH), expressed in centimeter, from the plant base to the apex of the main stem; number of nodes on the main stem (NNMS), from the plant base to the apex of the main stem; number of secondary branches (NSB); number of pods per plant (NPP); pod width (PW), in centimeter, determined by the extension from one tip to the other of one randomly collected dry pod per plant; pod length (PL), in centimeter; pod thickness (PTh), in centimeter, measured as the distance from one surface to the other of one arbitrary dry pod per plant; number of grains per pod (NGP), determined by counting the grains in a representative pod of the genotype; weight of 100 grains (WHG); grain yield (YLD), in kilograms per hectare, after transformation of the weight into grams of the total grains of the plot.

Software GENES (Cruz 2001) was used for the statistical-genetic analyses. The analysis of variance of the individual plant data was performed for all traits except grain yield, considering the treatments effects as random.

The estimates of the coefficients of phenotypic, genotypic and environmental correlation between the trait pairs were calculated based on the estimates of variances and covariances, according to Kempthorne (1973), by the expressions:

Phenotypic correlation (r_P)

$$r_P = \frac{MPT_{xy}}{\sqrt{MST_x . MST_y}}$$

where:

$MPT_{(xy)}$: mean product associated to the treatment effects, for the trait pair X and Y; and

$MST_{(x)}$ and $MST_{(y)}$: mean squares of the treatments, of the trait pair X and Y, respectively.

Genotypic correlation (r_G)

$$r_G = \frac{\sigma_{G\,xy}}{\sqrt{\sigma^2_{G\,x} \cdot \sigma^2_{G\,y}}}$$

where:

$\sigma_{G(x,y)}$: square component that represents the genotypic covariance between the trait pair X and Y;

$\sigma^2{}_{G(x)}$ and $\sigma^2{}_{G(y)}$: square components that represents the genotypic variability of the traits X and Y, respectively.

Environmental correlation (r_E)

$$r_E = \frac{MPE_{xy}}{\sqrt{MSE_x . MSE_y}}$$

where:

MPE (*xy*): mean product of the experimental error, for the trait pair X and Y; and

MSE(*x*) and *MSE*(*y*): mean squares of the experimental error of the traits X and Y, respectively.

The estimates of the relation between the coefficients of the genetic and experimental variation, according to Vencovsky and Barriga (1992), were obtained based on the ratio:

$$b = \frac{CV_G}{CV_E}$$, where:

$$CV_G = \frac{\sqrt{\sigma_G^2}}{\bar{X}}.100$$ the genetic variation coefficient;

and

$$CV_E = \frac{\sqrt{\sigma_E^2}}{\bar{X}}.100$$ the variation coefficient of the experimental error.

where:

σ^2 : is the variance estimate of the experimental error; and

$\bar{X}$: is the trait mean.

RESULTS AND DISCUSSION

The genotypes differed significantly (P< 0.01) in all traits evaluated, evidencing the existence of variability (Table 1). Of the families, the F_4 lines were particularly interesting with a significant effect for all traits, while the F_3BC_1 differed in stalk length, number of nodes on the secondary branch, pod length, pod thickness, number of grains per pod and grain yield. The F_3BC_2 lines showed difference for number of pods per plant, pod length, number of grains per pod and grain yield. The parental genotypes presented differences in the pod length and weight of 100 grains. With cowpea Bezerra et al. (2001) and Lopes et al. (2001) obtained results consistent results regarding plant height, number of nodes on the main stem, number of secondary branches, number of pods per plant, weight of 100 grains and grain yield; the results of Lopes et al. (2001) were significant for stalk length as well.

In general, the experimental precision indicated by the variation coefficients (CV) was satisfactory, with values classified as low and medium by Gomes (1982). For the traits pod thickness, pod width, pod length, number of grains per pod and weight of 100 grains, the

Table 1. Mean squares, variation coefficient of the experimental error (CV) , genetic variation coefficient CV_g and relation between the coefficients of genetic and experimental variation (b) of the traits: stalk length (SL), plant height (PH), number of nodes on the main stem (NNMS), number of secondary branches at maturation (NSB), number of pods per plant (NPP), pod width (PW), pod length (PL), pod thickness (PTh), number of grains per pod (NGP), weight of 100 grains (WHG) and grain yield (YLD), evaluated in 64 cowpea populations

Sources of variation	DF	Mean squares										
		SL (cm)	PH (cm)	NNMS	NSB	NPP	PW (cm)	PL (cm)	PTh (cm)	NGP	WHG (g)	YLD (kg ha^{-1})
Blocks	2	0.60	3.47	1637.23	0.87	376.21	0.01	36.81	0.05	209.22	151.53	11361.46
Genotypes	63	0.03**	2.82**	161.90**	7.40**	320.26**	0.03**	26.59**	0.03**	22.86**	114.54**	3209.88**
F4	38	0.03**	3.10**	206.58**	6.79**	314.43**	0.03**	25.54**	0.03**	23.20**	153.98**	3035.42**
F3BC3	15	0.04**	2.10	112.60	10.85**	380.51**	0.02	20.17**	0.02**	19.67**	47.10	3907.42**
F3BC4	6	0.01	1.16	15.42	3.93	293.31**	0.02	44.35**	0.01	32.24**	34.61	3437.34**
Parental	1	0.02	1.32	5.40	3.27	52.26	0.03	69.18**	0.00	22.82	166.03**	64.01
Fam vs Parental	1	0.07	9.96	160.63	0.90	155.78	0.03	49.75	0.05	41.52	94.05	4313.03
Among families	2	0.09	4.98	180.04	8.69	279.84	0.10	5.37	0.24	3.63	91.11	1612.92
Error	126	0.02	1.26	57.54	2.59	87.00	0.02	5.29	0.01	7.72	22.18	967.68
Within families	1728	0.00	0.48	22.21	0.82	32.09	0.00	2.09	0.00	3.09	10.92	363.11
Mean		0.28	1.64	17.79	2.72	12.31	0.92	18.94	0.76	12.67	20.66	67.53
CV (%)		11.50	17.14	10.56	15.48	19.03	3.69	2.98	3.02	5.05	5.14	50.02
CV g (%)		8.74	13.91	10.48	14.72	22.65	2.35	4.45	3.56	5.71	8.49	20.86
b		0.76	0.81	0.99	0.95	1.19	0.64	1.49	1.18	1.13	1.65	1.11

(**) Significant at 1% probability, by the F test.

magnitudes of CV were below 10%, while for stalk length, plant height, number of nodes on the main stem, number of secondary branches, number of pods per plant and grain yield the CV was below 20%. The highest variation coefficients were estimated for plant height (17.13%), number of pods per plant (19.03%) and grain yield (18.75%); these values were explained by the quantitative nature of the traits. The values found are similar to those cited in the literature, although the value for grain yield was lower than that reported by Bezerra et al. (2001) and Lopes et al. (2001).

The genetic variation coefficients CV_g varied from 2.35% (pod width) to 22.65% (number of pods per plant); aside from the number of pods per plant, grain yield was particularly favorable, with 20.86%. The values indicate the existence of variability in cowpea genotypes for the referred traits, indicating the possibility of selection. Estimates of CV_g in cowpea were used in studies by Bordia et al. (1973), Lakshmi and Goud (1977) and Barriga and Oliveira (1982). In a study with cowpea genotypes of erect and determinate growth, Bezerra et al. (1995) observed the highest coefficients for number of pods per plant and grain yield (19.42 and 19.44%, respectively). Lopes et al. (2001) stated wide genetic variability for most traits in cowpea lines, of which grain yield presented the best genetic variation coefficient (23.90%).

The relations b varied from 0.64 (pod width) to 1.65 (weight of 100 grains) in the traits: grain yield (1.11), number of grains per pod (1.13), pod thickness (1.18), number of pods per plant (1.19), pod length (1.49) and weight of 100 grains (1.65), the estimates of b were higher than 1, which indicates a favorable situation for selection in the populations.

With respect to the morphological traits (Table 2), line 12 (F_3BC_1) stood out with a mean stalk length of 0.37 cm. Long stalks are desirable since they make the pod yield above the leaves possible. In the F_4 lines plant height varied from 2.25 to 1.04 cm. For number of nodes on the main stem, line 56 (F_4) presented the highest mean (26.87). Working with cowpea, Lopes et al. (2001) and Bezerra et al. (2001) obtained means of 18.28 and 14.50, respectively, for this trait. Considering the mean number of secondary branches, line 8 (F_3BC1) stood out with a mean of 4.83. The traits plant height, number of nodes on the main stem and mean number of secondary branches are important for the ideotype of the cultivars designated for green bean production, where branching growth is desirable.

With regard to the qualitative traits, the pod color in the lines was purple or green and grains were white or brown; 65.62% of the lines had white grains (Table 3). Purple pods and white grains are desirable for green bean production.

For the grain yield-related traits (Table 3), the overall mean of the number of pods per plant was 13.31, exceeded by 20 lines. Oliveira et al. (2002) evaluated cowpea lines for green grain production and found a mean value of 22.50. In pod thickness and width, 56.45% and 53.23% of the lines, respectively, exceeded the overall means (0.76 and 0.92 cm, respectively). For pod length, line 11 (F_4), with purple pods and brown grain, stood out with a mean of 21.39 cm. The mean of the number of grains per pod was 12.67, exceeded by 30 lines. Line 57 (F_4), with green pods and white grain, achieved the highest weight of 100 grains, with a mean of 28.91 g. In a study with cowpea, Leite et al. (1999) found a lower mean value for pod length and a higher one for weight of 100 grains.

The overall grain yield mean was 67.53 kg ha^{-1} and 27 lines outmatched the mean. Line 6 of the F_3BC_1 population stood out with 112.55 kg ha^{-1}, with purple pods and brown grain.

The estimates of the phenotypic, genotypic and environmental correlation coefficients for most of the trait pairs were similar in signal, direction, levels of significance and magnitude; these were considered low when the values were below 0.4; medium between 0.4 and 0.7; and high with values of over 0.7 (Table 4). The genotypic were generally higher than the environmental and phenotypic correlations, demonstrating a higher contribution of the genetic than the environmental factors to the expression of these traits.

The morpho-agronomics traits plant height and number of nodes on the main stem were significantly correlated; the phenotypic, genotypic and environmental coefficients were high and positive, as expected. Stalk length presented significant correlations - positive with number of pods per plant and number of grains per plant, and negative with weight of 100 grains. When studying cowpea, Lopes et al. (2001) found similar results regarding the number of grains per plant and inconsistent results for

Table 2. Means of the traits: stalk length (SL), plant height (PH), number of nodes on the main stem (NNMS) and number of secondary branches (NSB), evaluated in 64 cowpea populations

Moments	Traits			
	SL (cm)	**PH** (m)	**NNMS**	**NSB**
Mean	0.28	1.63	17.79	2.72
Minim	0.21	1.04	13.90	1.97
Maxim	0.37	2.25	26.87	4.83
Range	0.16	1.21	12.97	2.86
Skewness	0.14	-0.05	0.90	1.66
Curtosis	0.09	-0.94	2.44	5.21
C.V. (%)	11.72	18.76	13.06	18.25
Standard Deviation	0.03	0.31	2.32	0.50

Table 3. Means of the traits: number of pods per plant (NPP), pod thickness (PTh), pod width (PW), pod length (PL), number of grains per pod (NGP), weight of 100 grains (WHG) and grain yield (YLD). evaluated in 64 cowpea genotypes

Moments	Traits						
	NPP	**PTh** (cm)	**PW** (cm)	**PL** (cm)	**NGP**	**WHG** (g)	**YLD** (kg ha^{-1})
Mean	12.31	0.76	0.92	18.94	12.67	20.66	67.69
Minim	4.27	0.67	0.84	16.41	10.53	16.46	39.78
Maxim	20.13	0.83	0.99	21.39	14.43	28.91	112.55
Range	15.86	0.16	0.15	4.98	3.90	12.45	72.77
Skewness	0.30	-0.12	-0.27	-0.12	-0.09	1.33	0.32
Curtosis	-0.02	0.30	0.09	0.47	-0.56	4.35	-0.64
C.V. (%)	26.54	4.14	3.42	4.97	6.89	9.46	24.96
Standard Deviation	3.27	0.03	0.03	0.94	0.87	1.95	16.89

the number of pods per plant and weight of 100 grains. Stalk length, an important morphological trait for the cultivar ideotype, can therefore be used in the indirect selection for yield increase.

For the pod-related traits, a high, positive and significant genotypic correlation was estimated between thickness and width. Pod length presented significant genotypic and environmental correlations with number of pods per plant, number of grains per pod and weight of 100 grains, similar to results found by Lopes et al. (2001) and Jindal and Gupta (1984) in studies with cowpea. The genetic and environmental correlations of the number of pods per plant with plant height, pod width and number of grains per pod were significant and positive. The results indicate the possibility of selecting lines with desirable pod traits, which is an important component in the sale of green beans.

The genotypic correlations of grain yield were positive and significant: high for the number of pods per plant, and medium for number of grains per pod. The number of pods per plant is therefore a trait that can be considered in the indirect selection for higher yield in segregating cowpea populations. Unlike in normal improvement programs, this allows the identification of potentially productive lines in early generations (F_3 and F_4). These results are consistent with those of Jindal and Gupta (1984), Oliveira et al. (2003) and Singh and Mehndiratta (1969) who evaluated cowpea, and Ribeiro et al. (2001) who worked with common bean, suggesting that the number of pods per plant can actually be used as selection criterion for higher grain yield in cowpea.

CONCLUSIONS

1. There is genetic variability in the populations for all traits studied, indicating the possibility of significant gains with line selection.

2. Line 14 derived from the F_4 population obtained particularly favorable results in grain yield, and has pods of purple and grains of white color as well.

3. The selection for a higher number of pods per plant could increase gains in grain yield.

Table 4. Estimates of phenotypic (r_F), genotypic (r_G) and environment correlation coefficients (r_E) among the traits: stalk length (SL), plant height (PH), number of nodes on the main stem (NNMS), number of secondary branches at maturation (NSB), number of pods per plant (NPP), pod thickness (PTh), pod width (PW), pod length (PL), number of grains per pod (NGP), weight of 100 grains (WHG), and grain yield (YLD), evaluated in 64 cowpea genotypes

Traits [(1)]	**r**	**PH** (m)	**NNMS**	**NSB**	**NPP**	**PTh** (cm)	**PW** (cm)	**PL** (cm)	**NGP**	**WHG** (g)	**YLD** (kg ha^{-1})
SL	r_F	0.18**	0.11**	0.03**	0.03**	0.05**	0.06**	0.05**	0.02**	-0.05**	0.03**
	r_G	0.29**	-0.16**	0.11**	0.23**	-0.02	0.27**	0.15**	0.31**	-0.08**	0.18**
	r_E	0.24**	-0.09**	0.09**	0.17**	-0.01	0.19**	0.09**	0.19**	-0.10**	0.10**
PH	r_F		0.81**	0.12**	0.07**	0.06**	0.04**	0.04**	0.02**	-0.04**	0.06**
	r_G		0.71**	0.42**	0.24**	0.21**	0.16**	0.05**	0.23**	-0.15**	0.14**
	r_E		0.74**	0.33**	0.18**	0.17**	0.12**	0.04**	0.14**	-0.11**	0.10**
NNMS	r_F			0.14**	0.07**	0.07**	0.03**	0.05**	0.02**	-0.01**	0.06**
	r_G			0.41**	-0.05**	0.13**	0.08**	-0.08**	0.03*	-0.05**	-0.09**
	r_E			0.33**	-0.02	0.11**	0.06**	-0.03**	0.01	-0.04**	-0.05**
NSB	r_F				0.11**	0.04**	0.00	0.03**	0.04**	0.01**	0.12**
	r_G				0.03	-0.12**	0.06**	-0.07**	0.18**	-0.12**	0.07**
	r_E				0.04**	-0.08**	0.05**	-0.06**	0.13**	-0.08**	0.06**
NPP	r_F					0.03**	0.04**	0.15**	0.19**	0.02**	0.79**
	r_G					-0.43**	-0.24**	0.10**	0.36**	-0.46**	0.89**
	r_E					-0.29**	-0.17**	0.12**	0.31**	-0.32**	0.85**
PTh	r_F						0.44**	0.18**	-0.08**	0.12**	0.04**
	r_G						0.73**	0.14**	-0.36**	0.67**	-0.28**
	r_E						0.64**	0.18**	-0.27**	0.51**	-0.17**
PW	r_F							0.27**	0.03**	0.11**	0.04**
	r_G							0.40**	0.07**	0.65**	0.03
	r_E							0.38**	0.04**	0.49**	0.03**
PL	r_F								0.55**	0.13**	0.21**
	r_G								0.42**	0.23**	0.31**
	r_E								0.44**	0.19**	0.27**
NGP	r_F									0.03**	0.26**
	r_G									-0.32**	0.48**
	r_E									-0.19**	0.40**
WHG	r_F										0.09**
	r_G										-0.15**
	r_E										-0.07**

**, * significant at 1and 5% probability, respectively, by the t test.

Variabilidade e correlações em populações de feijão-caupi com potencial para produção de grãos verdes

RESUMO – *Estimou-se a variabilidade e as correlações fenotípicas, genotípicas e ambientais, em feijão-caupi, visando-se posterior seleção de linhagens para produção de grãos verdes. Foram avaliadas 62 linhagens (39 F_4, 16 F_3BC_1, 07 F_3BC_2) e os dois genitores. O experimento foi conduzido em Teresina, Piauí, e os caracteres avaliados foram: comprimento de pedúnculo; altura da planta; número de nós no ramo principal; número de ramos secundários; número de vagens por planta; largura, comprimento e espessura de vagem; número de grãos por vagem; peso de cem grãos; e rendimento de grãos. A linhagem quatorze da população F_4 revelou elevado rendimento de grãos, exibindo cor roxa para vagens e branca para grãos, podendo ser recomendada para seleção visando a produção de grãos verdes. A seleção para o aumento do número de vagens por planta pode proporcionar ganhos para o rendimento de grãos.*

Palavras-chave: *Vigna unguiculata*, caracteres morfo-agronômicos, componentes de produção.

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