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NOTE

Phenotypic correlations between combining abilities of F_2 cowpea populations

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Abstract – *Cowpea is a crop that has become socio-economically relevant, mainly in developing countries. Correlation studies are important to determine the association between quantitative traits and yield to guide the selection, i.e., choose direct or indirect selection. The objective was to estimate the correlations between six agronomic traits in cowpea as well as the correlations between the estimates of combining abilities of parents. Genotypes with high pod weight and pod length, 100-grain weight, and number of beans per pod should be used to improve grain yield in cowpea. The breeder should preferably insert plants into his group of crosses that have a high combining ability for pod length, number of grains per pod and yield per plot.*

Key words: Vigna unguiculata, *diallel, selection.*

INTRODUCTION

An annual and extremely robust crop, cowpea (*Vigna unguiculata* (L.) Walp.) is undemanding in soil fertility and tolerant to high temperatures and drought. At temperatures between 18 °C and 34 °C, considered ideal for its development, cowpea has higher yields than other crops (Passos et al. 2007, Shimelis and Shiringani 2010).

Particulalry in developing countries, cowpea has become a socio-economically relevant crop. According to Vijaykumar et al. (2010), in recent years, the crop was planted on an area of more than 12 million hectares worldwide and is cultivated in all tropical areas.

In Brazil, cowpea has been widely planted in the North, Northeast and Midwest of Brazil (Oliveira et al. 2003, Xavier et al. 2005). Most farmers grow it on small fields, mainly in the north and northeastern regions, achieving low yields due to the limited use or even absence of technological inputs. In the agribusiness and large-scale farming regions of the Midwest, in the states of Mato Grosso and Mato Grosso do Sul, for example, the crop has produced average yields that are 1,159 and 883 kg ha^{-1} higher, respectively, than the national average of 369 kg ha^{-1} (Freire Filho et al. 2011).

In breeding for yield, different traits and their interrelationships are considered in the evaluation of cultivars. The low heritability of most quantitative traits of economic interest complicates the selection process, while other traits are hard to measure and identify, making the understanding of the relationship between the traits extremely important (Cruz et al. 2004). In the selection of lines, the correlations among the target traits for crop improvement are also considered. Correlation studies are important to determine the association between grain yield and other quantitative traits, providing an orientation for the selection, i.e, whether a given trait of interest can be indirectly selected by selection for another (Mohammed et al. 2010). Work carried out by Mohammed et al. (2010) indicates that the number of pods per plant, seeds per pod and seeds per plant can be used in both direct and indirect selection for grain yield in cowpea.

High heritability estimates reflect a major contribution of the genotypic variance, which in some cases allows for the direct use of phenotypic selection, while low-heritability traits can be improved by indirect selection for other, high-heritability traits, correlated with the former (Shimelis and Shiringani 2010).

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According to Falconer and Mackay (1996), the main cause of genetic correlation is the pleiotropy, i.e, one gene influences the expression of several traits by its interference with direct or indirect metabolic pathways. If the correlation is a result of the pleiotropic effects, it is permanent. On the other hand, correlations arising from gene links, called transitory, are dispersed when crossing-over between linked genes occurs (Ramalho et al. 1993).

For cowpea few studies report associations between traits that could be useful in breeding (Lopes et al. 2001, Mohammed et al. 2010). The objective of this study was to estimate the correlations between six traits related to grain yield, in cowpea populations derived from crosses of eight genotypes, and to estimate the correlations between combining abilities between the traits for the selection of parents with high agronomic performance.

MATERIAL AND METHODS

Eight cowpea genotypes were used as parents, two of which were improved cultivars (BRS Tumucumaque and BRS Xiquexique), three were lines (TE97-304G-4, MNC05-843B-88 and MNC99-541F-15) from the cowpea improvement program of Embrapa Mid-North, two lines were provided by the International Institute of Tropical Agriculture (IITA) (IT89K-205-8 and IT97K-1042-3) and one was a traditional cultivar (Pretinho). All genotypes belong to the work collection of the cowpea improvement program of the Embrapa Mid-North.

The 28 hybrid combinations were analyzed together with the eight parents, totaling 36 treatments. After drying, the pods were threshed manually. The resulting hybrid seeds of each cross were wrapped separately in paper bags and refrigerated. The F_1 generation was sown in a greenhouse in March 2010, under controlled environmental conditions.

The F_2 generation was evaluated in a randomized complete block design with four replications in plots consisting of two 3-m rows spaced 0.80 m and plants 0.25 m apart, totaling 24 plants per plot. The experiment was conducted in the 2010/11 growing season on an experimental field of Embrapa Mid-North, in Teresina, Piauí, Brazil.

The following traits were evaluated: number of pods per peduncle (NPP), estimated from the arithmetic mean from a sample of 10 stalks per plot; pod weight (PW), total weight (in g) of 10 randomly chosen mature pods per plot; pod length (PL), averaged from 10 randomly chosen pods (in cm); number of grains per pod (NGP), obtained by counting the average number of grains of 10 selected randomly pods; weight of one hundred grains (W100G), weighing 100 grains, sampled after threshing the pods of each plot; yield per plot (YPlo), weighing all grains per plot; average yield per plant (YPla), estimated as the ratio between the variable YPlo and the number of plants per plot.

The combining abilities for each trait were computed using SAS 8.0, by a method proposed by Griffing (1956), in a diallel without reciprocals. The phenotypic correlations were analyzed using software Genes v. 2007.0.0 (Cruz 2001) and Spearman's correlations between the combining abilities estimated for the parents, with the same software.

RESULTS AND DISCUSSION

For all traits, the genotype effects were significant ($P \leq 0.01$), showing the existence of variability among the genotypes of the study population, indicating the possibility of selecting superior plants (Table 1). The effects of general combining ability (GCA) ($P \leq 0.01$) for all traits under study differed significantly, revealing the action of additive effects on the control of these traits. Differences in GCA, according to Ramalho et al. (1993), indicate the possibility of effective gains by selection for desirable traits.

Table 1. Summary of analyses of variance and general combining ability (GCA) for seven traits analyzed in diallel crosses of eight cowpea parent genotypes

Traits[1]	Blocks	Genotypes	GCA	Error
PL	10. 56**	13. 23**	45. 51**	2.98
PW	52.96**	121.87**	433. 26**	14. 86
NGP	3.42	10. 81**	36. 60**	2.32
NPP	0.15*	0.15**	0.39**	0.06
W100G	3.58	23. 56**	78. 89**	2.86
YPlo	32927.5	81961.3**	176208**	20786.9
YPla	251.64**	186.52**	601.31**	87.60

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

[1] PW: 10-pod weight; NPP: number of pods per peduncle; PL: pod length; W100G: 100-grain weight; NGP: number of grains per pod; YPlo: yield per plot (in g); YPla: yield per plant (in g).

Similar results were observed by Kimani and Derera (2009), under contrasting environmental conditions, for the traits weight of dry leaves and roots, date of flowering, number of seeds per plant and 100-grain weight of common bean genotypes. They reported highly significant effects of treatments and of the GCA for all genotype-environment combinations, indicating the high divergence between the genotypes and prevalence of additive genetic effects at both evaluation sites.

Nkalubo et al. (2009), who studied the genetic control of anthracnose resistance in common bean, also obtained both additive and non-additive effects related to the control of this trait, however with a slight predominance of additive genetic effects over dominance effects.

According to the estimates of phenotypic correlations between traits (Table 2) PW correlated positively and significantly ($P \leq 0.01$) with the others, except for a negative correlation with NPP. This indicates that the selection of plants with high values for pod weight can lead to gains in PL, NGP, W100G, and YPla. The trait NPP was negatively correlated with PW and W100G ($P \leq 0.01$), indicating that the greater the number of pods per peduncle, the smaller the grains of the genotypes. The trait PL was highly, positively and significantly correlated with NGP and PW, as expected, because the longer the pod, the greater the number of grains per pod, and consequently the weight of these pods, in addition to significant positive correlations with W100G and YPla. The 100-grain weight was significantly and positively correlated with YPla, PW and PL, and negatively with NPP. The NGP, in turn, correlated positively and significantly ($P \leq 0.01$) with the trait YPla.

Table 2. Phenotypic correlations by Spearman's method among six agronomic traits of cowpea

Traits[1]	PW	NGP	NPP	W100G	YPla
PL	0.875 **	0.844 **	-0.415	0.381 **	0.464 **
PW	-----	0.721 **	-0.514 **	0.614 **	0.508 **
NGP		-----	-0.173	0.109	0.524 **
NPP			-----	-0.596 **	0.311
W100G				-----	0.292 **

** Significant at 1% probability by the t test.

[1] See code on Table 1

These results agree with Lopes et al. (2001), who analyzed the different traits of cowpea and also found a positive correlation between estimates of PW, PL, W100G, and grain yield. Romanus et al. (2008) also reported positive and significant correlation values ($P \leq 0.01$) between PL, NGP and yield of seven cowpea lines.

Estimates of the effects of GCA of parental genotypes were used to estimate the correlation coefficients among six traits with YPlo (Table 3). The additive effects for PL were positively correlated with the effects obtained for PW, NGP, YPlo and YPla. The additive effects of PW correlated positively with the effects of NGP ($P \leq 0.05$) and the effects of NGP positively with YPlo and YPla. For number of pods per peduncle, a negative correlation was observed with the effects of 100-grain weight. Therefore, to concentrate the greatest possible number of favorable genes and induce an increase in pod weight, lines with high GCA for PL can be selected, which is also valid to obtain a high NGP.

Table 3. Coefficient of correlation for the effects of the GCA between seven agronomic traits of cowpea

Traits[1]	PW	NGP	NPP	W100G	YPlo	YPla
PL	0.928**	0.976**	-0.452	0.476	0.809*	0.785*
PW	----	0.904*	-0.476	0.642	0.738	0.619
NGP		----	-0.333	0.380	0.785*	0.809**
NPP			----	-0.761*	-0.571	-0.452
W100G				----	0.428	0.309
YPlo					----	0.880**

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

[1] See code on Table 1

Yield per plant was positive, high and significantly correlated ($P \leq 0.01$) with its GCA effects and the effects of yield per plot. This high significant estimate between GCA and YPlo and YPla was expected, since YPla was estimated by the simple ratio of YPlo by the number of plants per plot.

Interestingly, the correlations of the GCA effects of NPP were negatively correlated with all other estimates, of which only the correlation with W100G was significant. Thus, to increase the factors related to grain weight, parental genotypes with low NPP should be preferred.

The trait yield per plot can be increased by selecting genotypes as parents that have a high GCA for NGP and PL (Table 3). Rainey and Griffiths (2005) studied yield components in 10 common bean genotypes based on a complete diallel scheme, and also obtained significant positive correlations between the GCA estimates for NGP and grain yield-related traits.

The traits PL, PW, W100G, and NGP can be considered in addition to YPla in breeding for grain yield, as they contribute significantly to its improvement. To increase the number of progenies that generate lines with a high ability of combining with high-yielding genotypes, the breeder can include parents with high GCA for pod length, number of grains per pod and yield per plot in the group of crosses.

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Correlações fenotípicas entre as capacidades de combinação em populações F_2 de feijão-caupi

Resumo - *A cultura do feijão-caupi vem desempenhando um forte papel socioeconômico, principalmente em países em desenvolvimento. Os estudos de correlação são importantes para determinar a associação entre caracteres quantitativos e a produtividade, de forma a direcionar a seleção, ou seja, seleção direta ou seleção indireta. Objetivou-se estimar as correlações fenotípicas entre seis caracteres agronômicos em feijão-caupi, assim como as correlações entre as estimativas das capacidades de combinação dos genitores. Genótipos com elevado peso e comprimento de vagem, elevado peso de cem grãos e número de grãos por vagem devem ser usados para melhorar a produtividade de grãos em feijão-caupi. O melhorista deve preferencialmente inserir em seu grupo de cruzamentos, indivíduos com alta capacidade de combinação para comprimento de vagens, número de grãos por vagem e produção por parcela.*

Palavras-chave: Vigna unguiculata, dialelo, seleção.

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