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Canonical correlation among morphological traits and yield components of cowpea

Correlação canônica entre as características morfológicas e componentes de produtividade de feijão caupi

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Abstract: The study of canonical correlation makes it possible to identify and quantify the associations of morphological and productive characters with the performance of cultures. Due to the scarcity of studies on the topic of cowpea, the selection of characters of interest for grain yield is promising. The objective of this study was to verify the associations between morphological traits and yield components in cowpea. The experiment was carried out in 2016 at experimental area of the Embrapa Agropecuária Oeste, municipality of Dourados, State of Mato Grosso do Sul. The experimental design was randomized blocks, with 14 treatments and four replications. Canonical groups were established between production components (group 1) and morphological characteristics (group 2). Canonical correlation analysis was estimated between the group consisting of primary agronomic traits (grain yield, number of pods and pod length) and the group consisting of secondary agronomic traits (beginning of flowering, plant size, value for cultivation and lodging). The data were submitted to analysis of variance at 5% probability and canonical variables. Moreover, it was determined the matrix of phenotypic correlation coefficients and the multicollinearity diagnosis. The number of pods per plant, pod length and plant size showed high and positive magnitude, allowing to conclude that, in cowpea breeding program, plants with the highest number of pods per plant, earliness and optimal plant architecture for mechanized harvesting should be selected to increased grain yield.

Keywords: *Vigna Unguiculata*. Selection Criteria. Multivariate Analysis.

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Resumo: O estudo da correlação canônica permite identificar e quantificar as associações de caracteres morfológicos e produtivos com o desempenho das culturas. Devido à escassez de estudos sobre o tema feijão-caupi, a seleção de caracteres de interesse para a produtividade de grãos é promissora. O objetivo deste estudo foi verificar as associações entre características morfológicas e componentes de produção em feijão caupi. O experimento foi conduzido na área experimental da Embrapa Agropecuária Oeste, em 2016, no município de Dourados, no estado de Mato Grosso do Sul. O delineamento experimental foi em blocos casualizados, com 14 tratamentos e quatro repetições. Os grupos canônicos foram estabelecidos entre componentes de produção (grupo 1) e características morfológicas (grupo 2). A análise de correlações canônicas foi estimada entre o grupo de variáveis constituído pelos caracteres agronômicos primários (produtividade, número de vagens e comprimento de vagens) e o grupo de variáveis constituído pelos caracteres agronômicos secundários (início da floração, tipo de planta, valore de cultivo e acamamento). Os dados foram submetidos à análise de variância a 5% de probabilidade e correlação canônica. Além disso, foi determinada a matriz dos coeficientes de correlação fenotípica e o diagnóstico de multicolinearidade. Os caracteres número de vagem por planta, comprimento da vagem e tipo de planta, apresentaram alta e positiva magnitude, permitindo então concluir que, em programas de melhoramento genético de feijão caupi, devem ser selecionadas plantas que apresentam maior número de vagem por planta, genótipos precoce e arquitetura da planta ideal para colheita mecanizada para aumentar o rendimento de grãos.

Palavra-chave: *Vigna Unguiculata.* Critérios de Seleção. Análise Multivariada.

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1 Introduction

Cowpea was introduced in Brazil in the 16th century by the Portuguese settlers and is part of the Brazilian diet (Freire Filho *et al*., 2005). It is cultivated by small farmers in the rainfed system in consortium with other crops, and it has wide genetic variability, with good adaptability in different soil and climatic conditions.

In Brazil cowpea plays a strategic role in food and nutritional security, especially for low-income populations due to the high protein content (Akande, 2007), in addition to employing familiar hand labor (Cardoso and Ribeiro, 2006).

There has been great progress in recent years in the national and international scenarios due to the increased production and market expansion, but there is still a lack of knowledge on the crop and technology transfer (Freire Filho *et al.*, 2017). According to Rocha *et al.* (2003), the identification and study of genetic parameters such as coefficient of genetic variation, heritability and correlation between traits are of great importance because by mean these the genetic variability, degree of trait expression from one generation to another, and the possibility of gains by direct or indirect selection can be understood.

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Understanding the association between the major components of the plant is extremely important because it shows how selection for one trait influences the expression of other traits. However, in breeding programs, in addition to the improvement of a main trait, the breeders seek the improvement of other traits of the plant (Cruz *et al.*, 2004).

As described by L'Heureux *et al*. (2015) and Rana *et al*. (2018) the purpose of biometric analysis via canonical correlations has been used effectively for data description, verification of numerical models and construction of statistical forecasting models, allowing the knowledge of which configurations tend to occur simultaneously between two or more different fields and the degree of connection between them. This study aimed to verify the associations between morphological traits and yield components in cowpea and their competence in breeding programs.

2 Material and Methods

The experiment was carried out in 2016 at experimental area of the Embrapa Agropecuária Oeste, located in the municipality of Dourados, State of Mato Grosso do Sul. The municipality is located under the coordinates 20°03′S and 55°05′W, and altitude of 407 m. According to Köppen classification, region climate is rainy tropical monsoon (Am). Soil samples were airdried, passed through 2.0 mm sieves and analyzed for granulometry and chemical attributes (Table 1).

Table 1. Chemical analysis of soil of the experimental area.

Local/Ano	pH	P	K	Ca	Mg	Al	H+Al	SB	CTC	V%
		mg								
	CaCl	dm^{-3}		cmol	dm^{-3} de	Solo			pH 7,0	
Dourados/ 2016	5,4	42	0,6	5,4	1,8	0,0	4,3	8	12	64

pH in $CaCl_2$ – ratio 1:2.5; H+Al – in calcium acetate; Al, Ca and Mg – in KCl 1N; P and K – in Mehlich; SB – sum of bases; T – capacity for ion exchange at pH 7.0; t – true CTC; V% – saturation by bases in %;

Soil was classified as dystrophic red latosol. The average temperature and precipitation accumulated during the development of the crop is shown in Figure 1.

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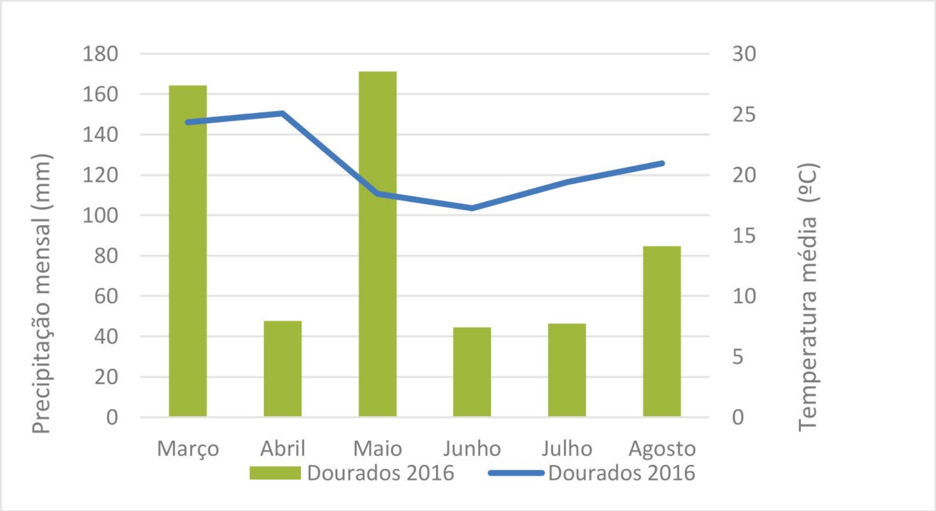
Figure 1. Precipitation (in the columns) and average temperature (in the lines) in Dourados, MS, 2016, during the development of the experiment. Source: CEMTEC (2020).



The experimental design was in randomized blocks, with 14 treatments and four replications. The experimental plot consisted of four lines with 5 m of length, spaced 0.50 m apart, considering the two central lines as useful area. The genotypes evaluated were: Bico-de-ouro 1-5-11; Bico-de-ouro 1-5-15; Bico-de-ouro 1-5-19; Bico-de-ouro 1-5-24 Pingo-de-ouro 1-5-26; Pingo-de-ouro 1-5-4; Pingo-de-ouro 1-5-5; Pingo-de-ouro 1-5-7; Pingo-de-ouro 1-5-8; Pingo-de-ouro 1-5-10; Pingo-de-ouro 1-5-11; Pingo-de--ouro 1-5-14; BRS Tumucumaque, and BRS Imponente. Consisting of 12 lines and two cultivars, from the cowpea breeding program of Embrapa Meio-Norte.

The experiments were implemented in March, one week after seedling emergence, manual thinning was carried out, leaving eight seedlings per meter. The sowing and covering fertilization was not carried out. The pest control was carried out with the application of insecticide Chlorpyrifos (480 g / L), in the dose of 0.6 L / ha of the commercial product. The application of fungicides, via leaf or at sowing was not done. The pods were harvested manually in July. The evaluated variables were: beginning of flowering (FL), measured by presence of at least one open flower in 90% of the plants; plant size (PS): upright, semi-upright, semi-prostrate and prostrated; value for cultivation (VC): was carried out at the beginning of pod maturation, based on the general appearance of the plant; pod length (PL): five pods were measured from each plot with a millimeter ruler; number of pods (NP): quantified in two plants of each plot; lodging (LOD): reading was carried out at the pod maturity, taking into account lodged plants and with the main branch broken; grain yield (GY): determined by total grain yield in the plot area converted from g plot^{-1} to kg ha^{-1}.

The experimental data were found in the analysis of variance (ANOVA), after verifying the assumptions of the Bartlett test (homogeneity of the variance of the errors), Lilliefors normality test (normality of the estimated error distribution) (Marques, 1999) and the Multicollinearity Diagnosis by means of the condition number (Montgomery and Peck, 1981). All available features meet ANOVA's prerequisite. This result reveals, in general, that mathematical assumptions required to perform the analysis of variance and further study were examined. Statistical analyzes were performed using the application Computational GENES (Cruz, 2013).

3 Results and Discussion

The multicollinearity diagnosis was performed for the yield components. The condition number (NC) analysis was 7.95, which characterizes weak colinearity. For the morphological characteristics, the NC was 39.87, which also characterizes weak colinearity. Thus, was chosen to perform canonical correlation analysis considering all traits (Toebe and Cargnelutti Filho, 2013) being that, when the multicollinearity criterion is met, it exerts a greater effect than the multivariate non normality, and, therefore, it generates greater reliability of the estimates (Carvalho *et al*., 2015).

The summaries of the analysis of variance for the morphological traits and yield components are, respectively, in Tables 2 and 3. It is observed that there was a significant effect for all traits, except for LOD.

Table 2. Summary of analysis of variance for the yield components. Dourados, MS, 2016.

	MS		
Sources of variation	**PL**	**NP**	**GY**
Genotypes	0.001398 **	0.115778 **	0.195516 **
Error	1.645	8473.645	37522.749
Mean	16.4542	284.0892	483.8571
CV%	7.56	32.40	40.03

(PL) pod length; (NP) number of pods; (GY) grain yield. * P value < 0,05; ** P value < 0,01; ns = non--significant;

Table 3. Summary of analysis of variance for the morphological traits. Dourados, MS, 2016.

	MS			
Sources of variation	**FL**	**PS**	**VC**	**LOD**
Genotypes	0.002372 **	0.001398 **	0.115778 **	0.195516 **
Error	2.736	1.645	8473.645	37522.749
Mean	45.6785	16.4542	284.0892	483.8571
CV%	3.62	7.56	32.40	40.03

(FL) begining of floration; (PS) plant size; (VC) value for cultivation; (LOD) lodging. * P value < 0,05; ** P value < 0,01; ns = non-significant;

Canonical correlations between the yield, number of pods and pod length with the beginning of flowering, plant size, value for cultivation and lodging were high and significant only for a canonical pair (Table 4), desired situation in the selection of traits aiming the plant breeding. It was possible to verify that the first canonical pair (u1 and v1), presented a high and positive magnitude for GY (0.87), NP (0.99) and LOD (0.73), thus making the inference that the more numbers of pods the plant has, the higher the yield and consequently the presence of lodged plants. Whereas Araujo (2019) observed the combination of yield with weight of one hundred grains and stand should not be used when it is desired to select cowpea lines with good performances for the sets of yield characteristics with lodging, pod length and number of days for flowering. It is worth mentioning that the effects of lodging are highly related to the plant's genotype, as well as to the chemical and physical properties of the soil, to climatic conditions and to the cultural practices adopted (Krysczun, 2016).

Table 4. Correlations and canonical pairs estimated between morphological traits and yield components in cowpea.

	Canonical pairs		
Traits	**1**	**2**	**3**
GY	0.8741	-0.4416	0.2022
NP	0.9978	-0.0652	0.0002
PL	0.5609	0.7313	0.3878
FL	0.0840	-0.5464	-0.1122
PS	0.0474	-0.1655	0.7294
VC	0.4267	-0.5317	-0.4909
LOD	0.7349	0.4679	-0.1527
Correlation (r)	0.9634	0.7497	0.4998
Prob.(%)	0.07469*	12.3824ns	27.4242ns

(GY) grain yield; (NP) number of pods; (PL) pod length; (FL) begining of floration; (PS) plant size; (VC) value for cultivation; (LOD) lodging. * *Significant at 1% probability by the chi-square test.

According to Teixeira *et al*. (2007), obtaining information on the main morpho-agronomic yield components is of paramount importance in the cowpea breeding programs, aiming to increase grain yield. There is agreement that several components, such as grain number per pod, pod length and weight of one hundred grains are strongly correlated with grain yield.

Souza (2016), noted that the number of cowpea pods is related to the climatic conditions caused during the growing period of the plants, in which a greater water deficit was observed at the time during flowering, thus leading to favoring abortion or unfeasibility of flowers. A study carried out by Frasca (2019), affirms that productivity in common bean culture, is highly correlated to production components, such as mass of 100 grains, number of pods per plant and number of grains per pod. In the second canonical pair (u2 and v2), the CV (0.73) presented a high and positive magnitude, but making negative inference on FL (-0.54) and VC (-0.53), making possible the inference that the increased beginning of the flowering and value for cultivation will influence in the decrease of the pod length or in an inverse way.

An important trait in the selection of superior genotypes in cowpea breeding is the beginning of flowering, since it allows to obtain genotypes with higher earliness and high grain yield (Silva *et al*., 2014), corroborating with results obtained in this study. Lastly, in the last canonical pair (u3 and v3), a positive correlation was verified, but a high magnitude only for PS (0.72), evidencing that the plant type has a positive influence on pod length.

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In order to choose a particular cultivar, it is important to consider architecture, pod and grain traits, since these characteristics are related to high grain yield. According to Silva and Neves (2011), the smaller pods are indicated for mechanized harvest, because they are lighter, and the pods are less subject to touch the ground, consequently reducing the losses by rotting.

4 Conclusions

The canonical relationships between the morphological characters and the components of the production of cowpea beans (*Vigna unguiculata* (L). Walp.) depend on the management and edaphoclimatic conditions in which the genotypes are submitted.

The characters number of pods, beginning of flowering and type of plant are morphological characters that should be prioritized in the selection of cowpea genotypes superior in terms of grain yield.

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