Australian Journal of Crop Science AJCS

AJCS 18(06):305-309 (2024) ISSN:1835-2707
https://doi.org/10.21475/ajcs.24.18.06.pne44

Canonical correlations between morphoagronomic and production traits in traditional cowpea varieties based on genotypic values

Suzy Anne de Araújo e Silva[1], Suziane Maria Silva de Souza[2], Vanderley Borges dos Santos[3]*, Luan de Oliveira Nascimento[4], Adriele Giaretta Biase[5]

[1]Doutoranda em Produção Vegetal. Universidade Federal do Acre. Rio Branco-AC, Brasil
[2]Mestre em Produção Vegetal. Universidade Federal do Acre. Rio Branco-AC, Brasil
[3]Professor Doutor. Universidade Federal do Acre. Rio Branco-AC, Brasil
[4]Doutor em Produção Vegetal. Universidade Federal do Acre. Rio Branco-AC, Brasil
[5]Professora Doutora. Universidade Federal do Acre. Rio Branco-AC, Brasil

***Corresponding author: vanderley.santos@ufac.br**

Submitted: 11/11/2023

Revised: 25/04/2024

Accepted: 26/04/2024

Abstract: Obtaining information about the main morphoagronomic and yield components, as well as their interrelationships, is of utmost importance in cowpea breeding programs, aiming at the selection of superior genotypes. The analysis of canonical correlations allows us to predict and describe the relationship between groups of characters, allowing the indirect selection of superior genotypes. The objective of this work was to verify relationships between morphological characters and production components through the analysis of canonical correlations using genotypic values obtained via mixed REML/BLUP models in traditional cowpea varieties. The experiment was conducted in a randomized block design with three replications and 12 treatments. Traditional varieties were characterized and evaluated during the germination, seedling, flowering and harvest stages with data obtained from plants, pods and seeds. Using the genotypic correlation matrix, two sets of characteristics were established, Group I, formed by production components and Group II, formed by morphoagronomic characters. A second correlation analysis was performed to verify associations between morphoagronomic and seed traits (seed length, width and thickness). It was found that dependence between the groups evaluated and intergroup associations can be established, which allows the study of cause-effect and the practice of indirect selection between groups of variables studied. An increase in pod length, hundred-grain mass and seed size is achieved through the selection of early maturing plants, with greater width of the apical leaflet and length of the hypocotyl.

Keywords: *Vigna unguiculata*; multivariate; traditional varieties; REML/BLUP; genotypic correlation

Abbreviations: E_emergence; IF_initial flowering; HL_hypocotyl length; ALW_apical leaflet width; NB_number of branches; PL_pod length; NGP_number of grains per pod; HSW_hundred seed weight; P_productivity; SL_seed length; SW_seed width; ST_seed thickness.

Introduction

Cowpea (*Vigna Unguiculata*) is a legume of high economic and social value, standing out as an important source of protein. With its productive capacity and adaptation to unfavorable environments, it has great potential to alleviate hunger in agricultural regions that use a low level of technology (Miqueloni et al., 2018). Therefore, it is necessary to know and characterize the genetic materials available in each location, becoming a fundamental step towards conserving the genetic diversity of the crop and developing more adapted, productive and nutritious materials that meet the needs and requirements of producers and consumers (Costa et al., 2012).

Improved varieties tend to be genetically very similar to each other, which leads to the loss of genetic diversity. In this context, traditional varieties cultivated on small agricultural properties constitute an important source of variability for enriching germplasm collections and use in plant breeding programs (Costa et al., 2012; Amabile et al., 2018). In addition to improving the main characteristic, breeders seek to increase other characteristics of the plant and understanding the association between its main components is of great importance, especially when it comes to characters that are difficult to measure or have low heritability, knowledge of correlations and their

magnitudes can assist in indirect selection (Cruz et al., 2012; Costa et al., 2022).

Abreu et al. (2021), studying the associations between morphological characteristics and production components in cowpea, identified that the characters pod number per plant, pod length and type of plant, presented a high and positive magnitude, allowing to conclude that selecting individuals with greater number of pods per plant, early genotypes and architecture suitable for mechanized harvesting increase grain yield.

Essentially, the use of genotypic values must be prioritized in the study of correlations, as only they involve an association of a heritable nature, enabling greater success with selection (Cruz et al., 2012). The use of REML/BLUP mixed model procedures allows for greater precision in obtaining genotypic values and estimating variance components (Resende et al., 2016).

Additionally, the use of canonical correlations allows measuring the degree of association between two sets of variables, through linear combinations of the various characters that constitute them, allowing to group variables of interest so that the determination of associations between groups allows the indirect selection of characters (Cruz et al., 2012).

Although the use and efficiency of canonical correlations are reported in the literature, with studies on different crops, such as common beans (Coimbra et al., 2000), sugar cane (Silva et al., 2007), papaya (Schmildt et al., 2011; Ferreira et al., 2012), ryegrass (Müller et al., 2012), sunflower (Nobre et al., 2018), wheat (Carvalho et al., 2015; Silva et al., 2023), maize (Crevelari et al., 2019; Ferreira et al., 2020), rice (Xavier et al., 2022), faba beans (Costa et al., 2022). Studies on cowpea culture and the use of genotypic values to investigate associations between canonical groups are still scarce.

In view of the above, the present study aimed to verify the relationship between morphological characters and production components through the analysis of canonical correlations using genotypic values via mixed REML/BLUP models in traditional cowpea varieties.

Results and Discussion

Genotypic correlations

Genotypic correlations varied in magnitude from -0.70 (SL with NGP) to 0.88 (SL, SW with HSW), showing higher values between HSW and SL and SW (0.88). At the same time, another characteristic with high and positive correlations is HL with PL (0.87), SL (0.81), ST (0.78) and HSW (0.67) (Figure 1). Therefore, the presence of high correlations reveals the possibility of selection and indirect gains for these characters.

Genetic correlation is responsible for the hereditary fraction from parents to progeny. When there is significance between the correlations of two characters, the study of cause and effect relationships through genotypic values is important for the practice of indirect selection, especially for characters whose measurement is difficult and expensive or the characteristic has low heritability (Cruz et al., 2012; Silva et al., 2023), allowing a more precise understanding, as it excludes the effects of environmental variations presented in phenotypic values.

The number of grains per pod presents a low and negative correlation with all other characteristics, indicating difficulty in making gains with indirect selection, except for seed length, which presented a high negative correlation (-0.70), indicating that pods with Longer seeds tend to have fewer seeds. In a study on the canonical correlations between traits related to the cycle and grain production in faba beans, Costa et al. (2022), also obtained negative and low magnitude values in associations with number of seeds per pod, including seed length (-0.38).

Multicollinearity diagnosis

The result for the diagnosis of multicollinearity was moderate to strong for both groups, with a number of conditions of 525 and 120 for group I and II, respectively. Multicollinearity, at levels considered moderate to severe, and the variances associated with certain estimators can assume excessively high values, generating inadequate results (Cruz et al., 2014). Considering the adverse effects of multicollinearity, the emergence and productivity variables that contributed to this problem were excluded. After exclusions, the numbers of conditions presented were 10.37 for Group I and 6.64 for Group II, indicating weak multicollinearity, according to Montgomery et al. (2012).

Canonical correlation between morphological characteristics and production components

The analysis of canonical correlations allows us to group characteristics and observe linear dependence, maximizing the relationships between groups (Costa et al., 2022). For the canonical correlation analysis between Group I (morphoagronomic traits) and Group II (production components), the first canonical pair showed a significance of 1% by the Chi-square test and correlation coefficient (r) = 0.97, suggesting an association between the groups (Table 1). The characteristics that most contributed to the association between the groups were pod length, mass of one hundred grains, hypocotyl length and apical leaflet width. The characters that contributed least were the number of grains per pod and the number of main branches.

Abreu et al. (2021), evaluating the canonical correlation between morphological and production characteristics in cowpea, obtained significance for the first canonical pair, with pod length among the characters that most contributed to the association between the groups. Costa et al. (2022), also observed the significance of the first canonical pair, with initial flowering and pod length among the most important characteristics in the study carried out between traits related to the cycle and production in faba beans.

The first pair indicated that initial flowering has a positive relationship with pod length and grain mass. Thus, the selection of earlier plants tends to also present indirect gains in the characteristics of pod size and grain mass. Likewise, estimating the relationship between the primary and secondary components of black bean grain yield through canonical correlation, Coimbra et al. (2000), observed significant intergroup associations, with a positive relationship between precocity and grain mass. In studies with faba beans, Costa et al. (2022) observed an association of plants with shorter days with longer pods for the first canonical pair.

According to the results obtained, the number of grains per pod presents negative values and low magnitude in the association between groups, indicating difficulty in gaining from indirect selection through morphological characters for this characteristic. In studies with faba beans, Costa et al. (2022), also found low magnitude values in the associations

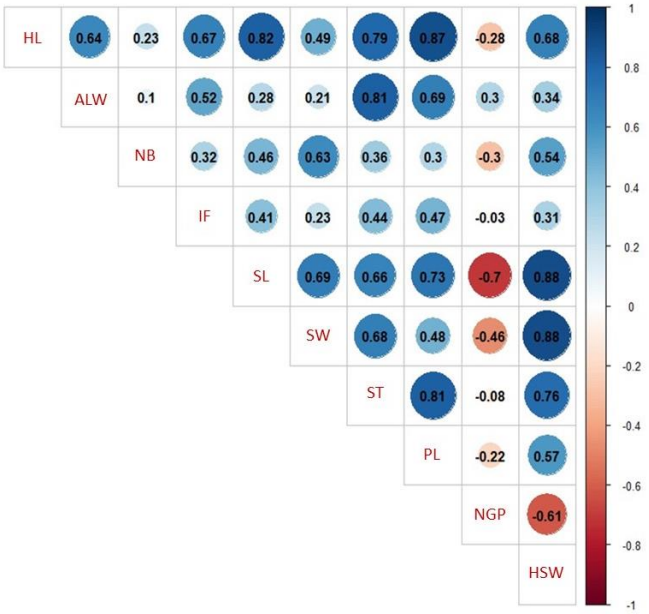

Figure 1. Pearson genotypic correlation estimate between 10 traits evaluated in 12 traditional cowpea varieties. HL: hypocotyl length, ALW: apical leaflet width, NB: number of branches, IF: initial flowering, SL: seed length, SW: seed width, ST: seed thickness, PL: pod length, NGP: number of grains per pod, HSW: hundred seed weight.

Table 1. Canonical correlations and estimated canonical pairs between morphological traits (group I) and production components (group II) in 12 cowpea varieties.

Characteristics	Canonical Pairs		
	1º	2º	3º
		Group I	
PL	0.9382	-0.0046	0.3461
NGP	-0.2295	0.9733	0.0112
HSW	0.7771	-0.4387	-0.4514
		Group II	
ALW	0.7419	0.6612	0.0747
NB	0.4300	-0.2837	-0.8061
IF	0.4925	0.1194	0.1376
HL	0.9113	-0.1170	0.3219
r	0.97^{**}	0.72^{ns}	0.34^{ns}

1°, 2° e 3° canonical pair; PL: pod length; NGP: number of grains per pod; HSW: hundred seed weight; ALW: apical leaflet width; NB: number of branches; IF: initial flowering; HL: hypocotyl length; ** significant at 1% by the Chi-square test (χ^2); ^{ns}: not significant.

between groups for number of seeds per pod, number of pods per plant, pod width, pod thickness.

The results differ from those obtained by Abreu et al. (2021), who evaluated the canonical correlation between morphological characteristics and productivity components of cowpea, based on phenotypic values. According to the authors, the characters number of pods per plant showed a high and positive correlation, concluding that to increase grain yield, plants must be selected that have a greater number of pods per plant, early genotypes and ideal plant architecture for harvesting. mechanized.

In the present study, the results indicate that the selection of earlier plants can be used to indirectly obtain superior individuals in terms of pod size and grain mass, important characteristics linked to grain productivity in cowpea. Furthermore, larger pods make manual harvesting easier and with higher yields (Públio Júnior et al., 2017). In collaboration, Mendonça et al. (2018), studying the phenotypic, genotypic and environmental correlations in cowpea varieties, state that the width of the apical leaflet, pod length and initial flowering should be considered in the selection aiming at more productive and early cultivars, according to the authors, It is necessary to deepen these studies by correlating them with the grains to better utilize these variables in the reproductive phases of the species.

Canonical correlation between morphological and seed characteristics

The canonical correlation analysis between the groups of morphological and seed characteristics showed significance at 1% using the Chi-square test for the first canonical pair with a correlation coefficient r = 0.97, indicating that the groups are not independent (Table 2). The characteristics seed thickness, hypocotyl length and apical leaflet width were those that most contributed to the association between the groups.

The width of the apical leaflet and the length of the hypocotyl are highly and positively related to the length and thickness of seeds, also showing a positive relationship, but to a lesser extent, with seed width, indicating that the selection of individuals with greater width of the apical leaflet and hypocotyl length would lead to indirect gains in obtaining larger cowpea grains.

Table 2. Canonical correlations and estimated canonical pairs between seed traits (group I) and morphological (group II) traits in 12 cowpea varieties.

Characteristics	Canonical Pairs		
	1º	2º	3º
		Group I	
PL	0.5610	0.8269	0.0401
SW	0.3984	0.6032	- 0.6910
ST	0.9399	0.1801	- 0.2902
		Group II	
HL	0.8184	0.4804	0.2627
NB	0.1694	0.5068	- 0.7826
ALW	0.9353	-0.3014	-0.0406
IF	0.4705	0.2007	0.1730
r	0.97^{**}	0.91^{ns}	0.52^{ns}

1°, 2° e 3° canonical pair; PL: pod length; SW: seed width; ST: seed thickness; HL: hypocotyl length; NB: number of branches; ALW: apical leaflet width; IF: initial flowering. ** significant at 1% by the Chi-square test (χ^2); ^{ns}: not significant.

Initial flowering also has a positive relationship with all characteristics, with the possibility that the selection of earlier individuals provides indirect gains in grain size. The number of main branches presents a positive, but low relationship with the others, reflecting a lesser importance of this characteristic for the selection of superior individuals in terms of the size of their grains.

Materials and Methods

Location and plant materials

The data were collected from an experiment carried out in 2015, at the experimental unit of the Federal University of Acre (09° 58' 29'', 67° 48' 36'', at 153 meters altitude). The soil at the site is classified as plinthic red-yellow Argisol. The climate in the region is type Am according to the Koppen classification. With an average temperature of 24.5 ºC, average relative humidity of 84% and precipitation of 1700 mm to 2,400 mm in 2015.

The treatments consisted of twelve traditional varieties of cowpea (white beach beans, plain manteiguinha, quarentão, white beans, string beans, purple manteiguinha, chicken liver, mudubim de rama, owl, milk beans, baiano, cowpea black). Traditional varieties were chosen based on their nutritional importance and their potential as sources of genes of interest in crop improvement.

Experimental characterization

A randomized block design with three replications was used. Each experimental plot consisted of two rows 5 m long, spaced 1.00 m x 0.50 m between plants with 10 plants each. To prepare the experimental area, the 0-20 cm layer was harrowed using a microtractor. Fertilization was carried out in accordance with soil analysis and recommendations for the crop. For crop management, only manual weeding was necessary to control invasive weeds.

The data were obtained through measurements carried out on plants, pods and grains. Ten plants were randomly selected from each plot and the characteristics were evaluated according to the descriptors for Vigna unguiculata: emergence (E), initial flowering (IF), hypocotyl length (HL), apical leaflet width (ALW), number of branches (NB), pod length (PL), number of grains per pod (NGP), hundred seed weight (HSW), productivity (P), seed length (SL), seed width (SW) and seed thickness (ST).

Statistical analysis

The data were submitted to REML/BLUP and the predicted genotypic values (BLUP) were obtained to estimate the genotypic correlation coefficients, according to Resende et al. (2016). Genotypic correlation analysis was carried out between the twelve morphoagronomic, productive and seed characteristics, estimated using Pearson linear correlation coefficients (Cruz et al., 2012).

Using the genotypic correlation matrix, two sets of characteristics were established, Group I, formed by production components (pod length, number of grains per pod, mass of one hundred grains and productivity) and Group II, formed by morphoagronomic traits (hypocotyl length, initial flowering, emergence, apical leaflet width and number of main branches). A second correlation analysis was performed to verify associations between characteristics of Group I and Group II.

Each group was subjected to a multicollinearity diagnosis with condition number (CN) and variance inflation factor (VIF) used as indicators of severity levels, according to Montgomery et al. (2012). Verification of significance between character groups was assessed based on the Chi-square statistic (Cruz et al., 2014).

For genetic-statistical analyses, the programs Selegen - REML/BLUP (Resende, 2006), Genes (Cruz, 2013) and R software version 4.0.2 (R Core Team, 2020) were used.

Conclusions

Canonical correlations reveal dependence between groups of morphoagronomic, productive and seed traits, enabling the study of cause-effect and the practice of indirect selection in traditional cowpea varieties.

The selection of early maturing plants allows for an increase in pod length, hundred seed weight and seed size, associated with greater width of the apical leaflet and length of the hypocotyl.

References

Abreu HK, Fachinelli AR, Ceccon G (2021) Correlação canônica entre as características morfológicas e componentes de produtividade de feijão caupi. Agrarian. 14: 314-322.

Amabile RF, Vilela MS, Peixoto JR (2018) Melhoramento de plantas: variabilidade genética, ferramentas e mercado. Brasília DF: Sociedade Brasileira de Melhoramento de Plantas. 108.

Carvalho IR, Souza VQ, Nardino M, Follmann DN, Schmidt D, Baretta D (2015) Correlações canônicas entre caracteres morfológicos e componentes de produção em trigo de duplo propósito. Pesquisa Agropecuária Brasileira. 50: 690-697.

Coimbra JLM, Guidolin AF, Carvalho FIF, Azevedo R (2000) Correlações canônicas: II - análise do rendimento de grãos de feijão e seus componentes. Ciência Rural. 30: 31-35, 2000.

Costa AM, Spehar CR, Sereno JRB (2012) Conservação de recursos genéticos no Brasil. Brasília, DF: Embrapa. 628.

Costa GAL, Medeiros AM, Silva VB, Lopes ÂCA, Candido WS, Gomes RLF (2022) Canonical correlations between cycle and grain production traits in lima bean. Revista Caatinga. 35: 877-883.

Crevelari J, Durães NNL, Santos PR, Azevedo FHV, Bendia LCR, Preisigke SC, Gonçalves GMB, Ferreira Junior JÁ, Pereira MG (2019) Canonical correlation for morphoagronomic and bromatological traits in silage corn genotypes. Bragantia. 78: 337-349.

Cruz CD (2013) Genes - a software package for analysis in experimental statistics and quantitative genetics. Acta Scientiarum Agronomy. 35: 271-276.

Cruz CD, Regazzi AJ, Carneiro PCS (2012) Modelos biométricos aplicados ao melhoramento genético. 4 ed. Viçosa: Editora UFV. 514.

Cruz CD, Regazzi AJ, Carneiro PCS (2014) Modelos biométricos aplicados ao melhoramento genético. 3 ed. Viçosa: Editora UFV. 668.

Ferreira JP, Schmildt O, Schmildt ER, Piantavinha, WC, Cattaneo LF (2012) Correlações entre características morfo-agronômicas de acessos de mamoeiro. Enciclopédia Biosfera. 8: 246-257.

Ferreira LL, Dalbosco LE, Carvalho IR, Carnevale AB, Moura NB, Lautenchleger F (2020) Multivariate and canonical models applied to corn: benefits of green manure with *Vigna unguiculate*. Holos. 7: 1-15.

Mendonça MS, Beber PM, Nascimento FSS, Santos VB, Marinho JT (2018) Importance and correlations of characters for cowpea diversity in traditional varieties. Revista Ciência Agronômica. 49: 267-274.

Miqueloni DP, Santos VB, Lima SR, Mesquita DN, Furtado SSF (2018) Descrição e discriminação de variedades crioulas de feijão-caupi na Amazônia Ocidental brasileira. Acta Iguazu. 7: 49-61.

Montgomery DC, Peck EA, Vinigin GG (2012) Introdução à análise de regressão linear. 5 ed. Nova York: John Wiley & Sons. 642.

Müller L, Manfron PA, Medeiros SLP, Rigão MH, Bandeira AH, Tonetto CJ, Dourado-Neto D (2012) Correlações de Pearson e canônica entre componentes da matéria seca da forragem e sementes de Azevém. Revista Brasileira de Sementes. 34: 86-93.

Nobre DAC, Silva FCS, Guimarães JFR, Resende JCF, Macedo WR (2018) Análise de trilha e correlação canônica nos componentes do desempenho de girassol. The Journal of Engineering and Exact Sciences. 4: 364-369.

Públio Júnior E, Morais OM, Rocha MM, Públio APPB, Bandeira AS (2017) Características agronômicas de genótipos de feijão-caupi cultivados no sudoeste da Bahia. Científica. 45: 223-230.

R Core Team (2020) Uma linguagem e ambiente para computação estatística (versão 4.0.2) [Software]. R Foundation for Statistical Computing, Viena, Áustria.

Resende MDV (2006) O software Selegen-REML/BLUP. Campo Grande: EMBRAPA. 305.

Resende, MDV (2016) Software Selegen-REML/BLUP: uma ferramenta útil para o melhoramento

de plantas. Crop Breeding and Applied Biotechnology, 16: 330-339.

Schmildt O, Silva CA, Ferreguete GA, Schmildt ER, Czepak MP (2011) Correlação canônica entre caracteres vegetativos e de capacidade de brotação em mamoeiro. Enciclopédia Biosfera. 7: 255-262.

Silva CM, Lima GW, Mezzomo HC, Signorini VS, Oliveira AB, Nardino M (2023) Canonical correlations between high and low heritability wheat traits via mixed models. Ciência Rural. 53:1-8.

Silva JW, Soares L, Ferreira PV, Silva PP, Silva MJC (2007) Correlações canônicas de características agroindustriais em cana-de-açúcar. Acta Scientiarum Agronomy. 29: 345-349.

Xavier MCG, Araújo JC, Menezes BRS, Damasceno Júnior PC (2022) Canonical correlations between morphological and production traits in special types of rice. Revista Caatinga. 35: 764-771.