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Importance and correlations of characters for cowpea diversity in traditional varieties[1]

Importância e correlações de caracteres para diversidade do feijão-caupi em variedades tradicionais

Márcia Silva de Mendonça[2]*, Paulo Márcio Beber[3], Francisca Silvana Silva do Nascimento[4], Vanderley Borges dos Santos[5] and José Tadeu Marinho[6]

ABSTRACT - Cowpea is a legume with ample plasticity, versatility and nutritional potential. It is a species widely used as a source of income and subsistence for small farmers in several Brazilian states, among them Acre. Due to the different varieties found in the State, it is the target of studies aiming at its genetic improvement. Thus, as one of the first stages of its improvement, it was aimed to determine the importance and correlations of characters for diversity and selection in traditional varieties of cowpea. The experiment was carried in completely randomized design, with plots consisting of four vase with capacity to 15.7 L, with one plant each and two replicates. The characteristics evaluated were: days for emergence, flowering (days), plant vigor (note), number of main stem nodes, apical leaflet length (mm), apical leaflet width (mm), length of pod (cm) and width of the pod (cm). The correlation coefficients (phenotypic, genotypic and environmental) were obtained, and the principal components analysis and the importance of the characters by the method proposed by Singh were carried out. The Singh method and principal components analysis were partially concordant in the distinction of the evaluated characters. The days for emergence, width of the apical leaflet, flowering and length of the apical leaflet were the main determinants for quantification of the genotypes and those that contributed the most to the variability of cowpea. The least discriminant characteristic by principal component analysis and recommended for discarding was plant vigor.

Key words: *Vigna unguiculata*. Phenotypic, genotypic and environmental correlations. Principal components.

RESUMO - O feijão-caupi é uma leguminosa com ampla plasticidade, versatilidade e potencial nutritivo. Trata-se de uma espécie bastante utilizada como fonte de renda e subsistência para pequenos agricultores em vários estados brasileiros, entre estes, o do Acre. Devido as diferentes variedades encontradas no Estado, é alvo de estudos visando o seu melhoramento genético. Assim, como uma das primeiras etapas do seu melhoramento, objetivou-se determinar a importância e correlações de caracteres para a diversidade e seleção em variedades tradicionais de feijão-caupi. O experimento foi realizado em delineamento inteiramente casualizado, com parcelas constituídas por quatro vasos de volume igual a 15,7 L, com uma planta cada e duas repetições. As características avaliadas foram: dias para emergência, florescimento (dias), vigor da planta (nota), número de nós do caule principal, comprimento do folíolo apical (mm), largura do folíolo apical (mm), comprimento da vagem (cm) e largura da vagem (cm). Foram obtidos os coeficientes de correlações (fenotípicas, genotípicas e ambientais), realizada a análise de componentes principais e a importância dos caracteres pelo método proposto por Singh. O método de Singh e componentes principais foram parcialmente concordantes na distinção dos caracteres avaliados. Os caracteres dias para a emergência, largura do folíolo apical, florescimento e comprimento do folíolo apical foram os principais determinantes para quantificação dos genótipos, e os que mais contribuíram significativamente para a variabilidade de feijão-caupi. A característica menos discriminante pela análise de componentes principais e recomendada para descarte foi o vigor da planta.

Palavras-chaves: *Vigna unguiculata*. Correlações fenotípicas, genotípicos e ambientais. Componentes principais.

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*Author for correspondence
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[1]Projeto de pesquisa financiado pelo CNPq
[2]Mestranda em Agronomia/Produção Vegetal, Universidade Federal do Acre, Rio Branco-AC, Brasil, marcia.mendonca2@gmail.com
[3]Doutorando em Agronomia/Produção Vegetal, Universidade Federal do Acre, Rio Branco-AC, Brasil, paulobeber@yahoo.com.br
[4]Estudante do Curso de Engenharia Agronômica, Universidade Federal do Acre, Rio Branco-AC, Brasil, sylvana.fs@hotmail.com
[5]Universidade Federal do Acre, Rio Branco-AC, Brasil, boges.v@gmail.com
[6]Embrapa Acre, Rio Branco-AC, Brasil, tadeu.marinho@embrapa.br

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is among the main legumes grown in Brazil, with great economic and socio-cultural importance. It is a rustic, versatile and nutritious species among the cultivated ones, besides being an important staple food accessible to the population and a fundamental component in the production systems, since it presents a wide flexibility in relation to the forms of use and consumption (TEÓFILO *et al*., 2008).

In the state of Acre, the plantation of cowpea is an important source of viable alternative income for traditional populations and family farmers. Recognized as a subsistence crop, it integrates an important part of the local productive system, due to its high plasticity to edaphoclimatic conditions. The cultivars used in the region are of Creole basis and mixed with seeds distributed by governments long ago. Therefore, knowledge of the characteristics of this crop is important and desirable to identify and select genotypes favorable to the specific environment where it is grown (CARMO; PAULINO; RAGAGNIN, 2013) and with potential for genetic improvement based on local diversity.

The understanding of this genetic potential provides a premise for the identification of divergent individuals, aiding in the selection of favorable and promising combinations, allowing to obtain superior genotypes. In this sense, the improvement has contributed to aggregation of value and conquest of new markets (FREIRE FILHO *et al*., 2011).

The clarity of the association between the main components of the plant, obtained by the phenotypic, genotypic and environmental correlations, is important because it indicates how selection for one character influences the expression of other characters, which can be associated in different directions and magnitudes (SILVA; NEVES, 2011).

Other resources used for the study of variability have been the techniques of multivariate analysis, which are based on multiple information. According to Moreira *et al*. (2009), the use of these techniques is feasible since it allows multiple combinations of information through the discrimination of the genotype relative to a complex variable with analysis of the discriminatory power and their contribution together. The principal components technique has the advantage of allowing the evaluation of the importance of each character studied on the total variation available among the evaluated genotypes, allowing the discarding of characters that contribute least to the differentiation of the genotypes. The use of these techniques also allows quantifying the contribution of each character, as proposed by Singh (1981), which measures the contribution of the variables of greater and less importance in the study of diversity.

The estimates obtained are used by the breeder to define the appropriate strategies to obtain superior genotypes based on the most important characters. In this way, the selection of a certain characteristic has its efficiency increased as one obtains knowledge about the correlations of characters, which contributed to help the breeder and increase the success of the genetic improvement in this crop. In this context, correlations and methods of principal components and Singh are important because they are plant selection indicators, allowing to diagnose superior genotypes to be inserted in the local productive system (CARPENTIERI-PÍPOLO *et al*., 2012) or base for crossing and generation of variability.

Given the need to increase knowledge about this species, it is essential to acquire knowledge about the genetic base referring to the characteristics of cowpea, associating the interaction of the plant characters. Thus, the objective was to determine the importance and correlations of characters for diversity and selection in traditional varieties of cowpea in Acre.

MATERIAL AND METHODS

The experiment was carried out in 2014, under greenhouse conditions, at the Federal University of Acre, Rio Branco, AC. The climate of the region is classified according to Köppen as Am2 (hot and humid with an annual dry period of 3 months) (COSTA *et al.*, 2012). Average temperatures, maximum and minimum temperatures of 31.7 °C and 21.4 °C, respectively, mean relative humidity of 84.3% and mean annual rainfall of 2,018 mm, according to the average of the years 2005 to 2015 (INMET, 2017).

The 11 traditional varieties of cowpea cultivated in Acre were obtained from producers and in the local market (Table 1), and evaluated in a completely randomized design, two replicates and plots consisted of four vessels with a volume equal to 15.7 L, with one plant each.

The evaluated characteristics were: days for emergence - DPE, obtained from the count of the days elapsed between the planting and the emergence of the cotyledons; flowering - FLOR, with the number of days comprised between emergence up to 50% of flowering plants; plant vigor - VP, based on the width and height of the plant between 3-4 weeks, assigning the following graduation: 3 not vigorous (height less than 37 cm and width less than 75 cm), 5 intermediate (height greater than 37 cm or width less than 75 cm), 7 vigorous (height greater than 37 cm and width greater than 75 cm) and 9 very

Table 1 - Identification of cowpea genotypes (*Vigna unguiculata* (L.) Walp.) collected in different municipalities of Acre and used in the present study

Genotypes	Origin
Baiano	Sena Madureira - SM (09º03’ S and 68º39’ W)
Corujinha	Sena Madureira - SM (09º03’ S and 68º39’ W)
Caupi Roxo	Sena Madureira - SM (09º03’ S and 68º39’ W)
Quarentão	Cruzeiro do Sul - CZS (07º37’ S and 72º40’ W)
Quarentão	Mâncio Lima - ML (07º36’ S and 72º53’ W)
Quarentão Praia Grande	Cruzeiro do Sul - CZS (07º37’S and 72º40’ W)
Barrigudinho	Sena Madureira - SM (09º03’ S and 68º39’ W)
Manteigão	Sena Madureira - SM (09º03’ S and 68º39’ W)
Manteiguinha	Cruzeiro do Sul - CZS (07º37’ S and 72º40’ W)
Manteiguinha	Rodrigues Alves - RA (07º44’ S and 72º38’ W)
Caupi Preto	Cruzeiro do Sul - CZS (07º37’ S and 72º40’ W)

vigorous (height greater than 50 cm and width greater than 100 cm); number of main stem nodes - NNCP, obtained by the average number of nodes present in the main stem between 3-4 weeks of planting; length of apical leaflet - CFA (mm), referring to the distance between the base and the apex of the apical leaflet; width of the apical leaflet - LFA (mm), from the distance between the lateral ends of the apical leaflet; pod length - COMPV (cm), referring to the average length of ten mature pods taken at random, using a ruler graduated in centimeters; and pod width - LV (cm), from the average of ten mature pods taken at random, using a ruler graduated in centimeters.

The averages, phenotypic (rF), genotypic (rG) and environmental (rE) correlation coefficients were calculated for all characteristics evaluated. The principal components of standardized data technique was used, where the eigenvalues (variance associated with each main component) were estimated by the characteristic roots of covariance, and the eigenvectors (set of weighting coefficients of the principal components) were estimated by the corresponding characteristic vector elements. The feasibility of its interpretation was considered with the concentration of variability among the first variables above 80% (CRUZ; REGAZZI; CARNEIRO, 2012). The relative contribution of the characters was quantified using the criterion proposed by Singh (1981). Statistical analyzes were performed with the aid of Genes software (CRUZ, 2013).

RESULTS AND DISCUSSION

The results were of good concordance of the signs, with some discrepancy of intensity between phenotypic (rF) and genotypic (rG) correlations with environmental (rE) correlations. It can be observed that genotypic correlations presented higher values than their corresponding phenotypic and environmental correlations (Table 2), which is desirable by the breeder, since this will be inherited. However, it is important to emphasize that for a practical value of selection, it is necessary for the variables to be genotypically (OLIVEIRA *et al*., 2011) and phenotypically correlated, since the selection is made based on the phenotype (FERREIRA *et al*., 2007).

There were significant and high magnitude phenotypic (rF) and genotypic (rG) correlations between the pairs of characters (Table 2): DPE x LFA, DPE x NNCP, VP x NNCP, VP x CFA, VP x LV, CFA x LFA, CFA x COMPV, NNCP x CFA, NNCP x LV, LFA x COMPV, and COMPV x LV. According to Andrade *et al*. (2010), high phenotypic (rF) correlations present a high genetic component in their phenotypic expressions and lead to gains via visual selection when it is accompanied by the genotype correlation also high and in the same direction. Cruz, Regazzi and Carneiro (2012) and Hallauer, Carena and Miranda Filho (2010) emphasize the importance of distinguishing and quantifying the degree of genetic and environmental association among the evaluated characteristics, since the genetic causes of correlation are inheritable and can assist in guiding the breeding program from the indirect selection of characters that present difficulties due to low heritability and / or obtaining problems.

The highest genotypic estimates (Table 2) were between DPE x NNCP (0.995), DPE x LFA (0.964) and FLOR x VP (-0.995); all of them considered to be high, with emphasis on the last one that was negative, showing that the genotypes that showed the most time for flowering had the lowest plant vigor, since the negative correlations

Table 2 - Estimates of the phenotypic (rF), genotypic (rG) and environmental (rE) correlation coefficients of 11 traditional varieties of cowpea (*Vigna unguiculata* (L.) Walp.) in the state of Acre

Characters		FLOR	VP	NNCP	CFA	LFA	COMPV	LV
	rF	-0.049	0.101	0.454	0.535	0.644*	0.332	0.317
DPE	rG	0.151	0.234	0.995++	0.921+	0.964++	0.457	0.507
	rE	-0.334	-0.382	-0.649+	-0.092	-0.034	0.065	0.124
	rF		-0.851**	-0.537	-0.394	-0.031	-0.117	-0.169
FLOR	rG		-0.995++	-0.893	-0.568	-0.104	-0.146	-0.420
	rE		-0.071	-0.142	-0.043	0.115	-0.036	0.133
	rF			0.645*	0.641*	0.311	0.373	0.548
VP	rG			0.806	0.712	0.352	0.437	0.751
	rE			0.664++	0.453	0.178	-0.321	0.273
	rF				0.562	0.375	0.191	0.501
NNCP	rG				0.782	0.588	0.335	0.897
	rE				0.305	0.111	-0.082	0.167
	rF					0.842	0.696*	0.418
CFA	rG					0.889	0.953+	0.462
	rE					0.729++	-0.355	0.386
	rF						0.428	0.262
LFA	rG						0.638	0.216
	rE						-0.448	0.350
	rF							0.599*
COMPV	rG							0.941+
	rE							-0.044

Days for emergence - DPE, flowering - FLOR (days), plant vigor - VP (note), number of main stem nodes - NNCP, apical leaflet length - CFA (mm), apical leaflet width - LFA mm), length of the pod - COMPV (cm), width of the pod - LV (cm); *, **: significant at 5% and 1%, respectively, by the t test; ++ + : significant at 1 and 5%, respectively, by the bootstrap method with 5000 simulations

indicate that the magnitudes of the characters correlate inversely. This latter correlation is not normally expected and may have been caused by the pot in which the plants were grown, which eventually limited vegetative growth.

The pod length characteristic (COMPV) presented a high, positive and significant correlation with pod width (LV) and a positive and significant correlation with the apical leaflet length (CFA). In general, the pod length (COMPV) is related to production variables as found by Romanus, Hussein and Mashela (2008), who obtained values of positive and significant correlation with the number of seeds per pod, grain yield and days to flowering, when evaluating seven lines of cowpea of the Department of Crop Science at the University of Nigeria, Nsukka.

The results on the genetic basis and correlations between the characters studied in this study suggest that, although relatively complex, apical leaflet length (CFA), apical leaflet width (LFA), pod length (COMPV), pod width (LV), number of main stem nodes (NNCP) and flowering (FLOR) should be considered in the selection of the parents, aiming the generation of variability to obtain new cultivars with higher grain yield, plant architecture (facilitating manual or mechanized harvesting) and genotypes with greater precocity. However, it is necessary to deepen these studies, correlating them with the grain or pod yield (according to purpose) for better use of these variables in the breeding stages of the species.

The knowledge of the correlations between the variables facilitates the decisions to be made in the selection of the genotypes of interest. Matos Filho *et al*. (2009), evaluating progenies of cowpea with erect plant architecture in the city of Teresina-PI, in 2004, verified that plants with the highest number of main stem nodes are the most productive, despite the low magnitude value, that would be a problem in the selection if the objective is the obtaining of plants for the mechanized harvest, since the greater number of nodes usually leads to the greater length (height) of the main branch. Nogueira *et al*. (2012), conducting track analysis and correlations between characters in soybean cultivated at two sowing times also found that the number of main stem nodes is correlated with higher productivity. Machado *et al*. (2008), seeking out select genotypes of precocious cowpea in Teresina-PI, found a high and positive correlation between flowering and grain yield, which may hinder selection, aiming at precocity and high productivity.

Some environmental correlations between the characters showed differences in magnitude and sign in relation to the respective genotypic correlations and revealed that the environment favored one character to the detriment of the other, and that the causes of genetic and environmental variation present different physiological mechanisms, making selection difficult (ALMEIDA; PELUZIO; AFFERRI, 2010).

The coefficient of genetic variation (CV_g) was 3.25 (FLOR) and 34.24% (VP) (Table 3). The highest estimates for the CV_g were presented by the characters of plant vigor (34.24%), pod width (12.91%), pod length (12.57%) and days for emergence (11.80%), indicating that among all the characters studied, these showed greater variability, making possible the selection in these variables. The lowest estimates of CV_g were for the characters of flowering (3.25%), apical leaflet length (6.49%), number of main stem nodes (7.20%) and apical leaflet width (8.23), showing less variability among the genotypes for these characters.

The low value of CV_g found in days for flowering (3.25%) was also obtained by Bemvindo *et al*. (2010) with a value of 1.62%, when evaluating seventeen lineages and three semi-prostrate cowpea cultivars in relation to grain yield potential and components related to the cycle and the plant architecture in rainfed and irrigated cultivation, in Teresina-PI. These results can be explained by the work of Matos Filho *et al*. (2009) that by evaluating the potential of progenies of cowpea with erect plant architecture, estimated coefficient of genotypic determination of 25.29% for the character days for flowering, evidencing strong presence of environmental effects in the expression of this character.

The heritabilities were of medium to high magnitudes (44.52% and 93.59%) (Table 3), being considered adequate according to the nature of the characters evaluated, indicating good possibilities for the selection of these variables. Machado *et al*. (2008) found values of 94% for flowering and 79% for number of nodes of main branch, values much higher than those found in this work, 63 and 44%, respectively.

The coefficients of experimental variation (Table 3) were within acceptable values (good experimental precision) with higher value for pod width (LV), which presented 19.4%, indicating good experimental quality. By analyzing the values of the CV_g/CV_e ratio, the characters plant vigor (VP), apical leaflet length (CFA), apical leaflet width (LFA) and pod length (COMPV) presented values above 1, indicating high variability and favorable situation for selection.

The relative contribution of the characters evaluated for diversity (Sj) and their percentage values, which are the measure of the relative importance of variable j for the study of genetic diversity, are presented in Table 4, where it is verified that the number of nodes of the main stem (9.60%) and pod width (9.70%) presented the smallest contribution and are recommended for disposal. However, the characters that presented the

Table 3 - Estimates of the coefficient of genetic variation (CV_g) and heritabilities (H^2), coefficient of experimental variation (CV_e) and CV_g/CV_e ratio referring to the characters days for emergence (DPE), flowering (FLOR), plant vigor (VP), number of main stem nodes (NNCP), length of apical leaflet (CFA), width of apical leaflet (LFA), pod length (COMPV) and pod width (LV) of 11 varieties of cowpea (*Vigna unguiculata* (L.) Walp.) in the state of Acre

Characters	CVg (%)	H2 (%)	CVe(%)	CVg/CVe RATIO
DPE	11.80	54.02	15.4	0.76
FLOR	3.25	63.00	3.5	0.92
VP	34.24	93.59	12.6	2.70
NNCP	7.20	44.52	11.3	0.63
CFA	6.49	70.80	5.9	1.10
LFA	8.23	70.66	7.5	1.09
COMPV	12.57	89.41	6.1	2.05
LV	12.91	46.92	19.4	0.66

Table 4 - Relative eight-character contribution for genetic divergence in 11 varieties of cowpea (*Vigna unguiculata* (L.) Walp.) in the state of Acre, according to Singh (1981) criterion

Variables	Sj	Value %
Days for emergence - DPE	13.87	16.17
Apical leaflet width - LFA	12.14	14.16
Flowering - FLOR	11.67	13.61
Plant Vigor - VP	11.06	12.89
Apical leaflet length - CFA	10.64	12.41
Length of the pod - COMPV	9.79	11.42
Width of the pod - LV	8.32	9.7
Number of main stem nodes - NNCP	8.23	9.6

greatest relative contribution to dissimilarity were: days for emergence (DPE), flowering (FLOR), apical leaflet width (LFA) and plant vigor (VP), responsible for 56.83% of variation existing among the evaluated genotypes, indicating that these characteristics need to be taken into account in the diversity studies, helping in the selection of divergent genotypes for crosses with greater possibility of variability generation.

The relative contribution values found in the literature are quite varied and dependent on the characteristics and the group of evaluated genotypes. Bertini, Teófilo and Dias (2009) verified that pod length was the variable that contributed the most to the genetic diversity of accessions of the germplasm bank of cowpea of the Federal University of Ceará with 69.04%, while, in this work, it was the third that contributed least. Considering only the morphological characters, Passos *et al.* (2007) also found pod length (36.64% for prostrate genotypes and 28.56 for erect) with higher contribution.

By analysis of principal components, it was verified that the first three components (CP_1, CP_2 and CP_3), concerning the eight agronomic characters considered, explained practically all the existing variability 83.39% (Table 5).

Among the variables of greater weight in these components, we can mention the number of main stem nodes (NNCP), days for emergence (DPE), pod width (LV), pod length (COMPV), flowering (FLOR) and apical leaflet length (CFA). These characters contributed significantly to the variability, being the most important characters for the selection (Table 6). It is identified that the character of the apical leaflet length (CFA) was the most influential in the formation of the first component. The least discriminant characteristic, and therefore likely to be discarded by this analysis, was plant vigor (VP), which is contrary to Singh's method and the value of CV_g.

The use of principal component analysis (NOGUEIRA *et al*., 2012; VIANNA *et al*., 2013) has been successfully used to identify variables of greater influence on the differentiation and grouping of genotypes. This technique has gained space even in different areas of genetic improvement, such as the work of Barbosa *et al.* (2013), which concluded that the principal components technique is an efficient tool to discriminate batches of soybean seeds.

Table 5 - Variance of each main component and its importance in relation to the total variance of eight characters evaluated in 11 traditional varieties of cowpea (*Vigna unguiculata* (L.) Walp.) in the state of Acre

Component	Variance	Variance (%)	Cumulative Variance (%)
CP1	4.0720	50.9011	50.9011
CP2	1.6276	20.3451	71.2463
CP3	0.9716	12.1454	83.3917

Table 6 - Principal components (CP), Eigenvalues (Av_1) and Eigenvectors (Av_2) of the characters days for emergence (DPE), flowering (FLOR), plant vigor (VP), number of main stem nodes (NNCP), length of apical leaflet (CFA), width of apical leaflet (LFA), pod length (COMPV) and pod width (LV) of 11 varieties of cowpea (*Vigna unguiculata* (L.) Walp.) in the state of Acre

Variable	CP^1		CP^2		CP^3	
	Av_1	Av_2	Av_1	Av_2	Av_1	Av_2
DAE	-0.5947	-0.2947	0.5480	-0.3929	-0.7927	-0.374
FLOR.	0.5244	0.411	0.7472	0.5856	-0.5654	-0.4432
VP	-0.3543	-0.3595	0.1968	0.1997	0.0581	0.059
NNCP	0.3187	0.3746	0.1702	0.2001	-0.1235	-0.1452
CFA	0.3599	0.5967	-0.2561	-0.4247	-0.0911	-0.151
LFA	-0.1188	-0.2508	0.0734	0.1549	-0.1496	-0.3158
COMPV	-0.0236	-0.1933	-0.0504	-0.4134	-0.0445	-0.3649
LV	-0.0054	-0.1355	-0.0143	-0.3579	-0.0242	-0.6074

CONCLUSIONS

1. Genotypic correlations have higher values in relation to phenotypic correlations;
2. The method proposed by Singh and principal components are partially concordant in the distinction of the evaluated characters;
3. The characters days for emergence (DPE), apical leaflet width (LFA), flowering (FLOR) and apical leaflet length (CFA) are the main determinants for differentiation and those that contribute most significantly to variability of cowpea, being indicated as selection criterion for crossing.

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