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Morphoagronomic characterization of common bean genotypes

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Abstract:

The aim of this work was to carry out morphoagronomic characterization of bean genotypes with aptitude for pod production. The experiment was carried out at the Federal University of Ceará, evaluating five bean genotypes in a randomized block design with five replications. Each experimental unit consisted of a bed with 9.6 m in length, with a spacing of 0.1 x 0.3 m. The morphoagronomic characterization of the genotypes was performed based on 15 characters. The quantitative descriptors were submitted to analysis of variance and the means were grouped using the Scott-Knott test. The dissimilarity between the genotypes was estimated based on the average Euclidean distance and the clustering performed by the UPGMA method. There were significant differences between the genotypes for all characters evaluated, except for the number of pods per plant. The Pronto Alívio genotype was the latest, however, it presented the highest yield of pods. The Pronto Alívio, Habichuela, Feijão Vagem do Panamá and Feijão-de-Metro genotypes stood out in terms of pod length and weight, in addition to presenting above-average productivity, which could be incorporated into crop improvement programs. Crossing between the varieties Feijão Vagem do Panamá and Pronto Alívio is recommended in order to obtain superior cultivars.

Keywords: *vigna unguiculata*. *phaseolus vulgaris*. multivariate analysis.

Caracterização morfoagronômica de genótipos de feijão-vagem

Resumo:

Objetivou-se com este trabalho realizar caracterização morfoagronômica de genótipos de feijão com aptidão para produção de vagens. O experimento foi realizado na Universidade Federal do Ceará, avaliando-se cinco genótipos de feijão no delineamento em blocos casualizados com cinco repetições. Cada unidade experimental foi constituída por um canteiro com 9,6 m de comprimento, com espaçamento de 0,1 x 0,3 m. A caracterização morfoagronômica

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dos genótipos foi realizada com base em 15 caracteres. Os descritores quantitativos foram submetidos a análise de variância e as médias foram agrupadas pelo teste de Scott-Knott. A dissimilaridade entre os genótipos foi estimada com base na distância Euclidiana média e o agrupamento realizado pelo método UPGMA. Verificou-se diferenças significativas entre os genótipos para todos os caracteres avaliados, exceto para o número de vagens por planta. O genótipo Pronto Alívio foi o mais tardio, porém, apresentou a maior produtividade de vagens. Os genótipos Pronto Alívio, Habichuela, Feijão Vagem do Panamá e Feijão-de-Metro destacaram-se quanto ao comprimento e peso das vagens, além de apresentarem produtividade acima da média, podendo ser incorporados aos programas de melhoramento da cultura. Recomenda-se o cruzamento entre as variedades Feijão Vagem do Panamá e Pronto Alívio visando a obtenção de cultivares superiores.

Palavras-chave: *Vigna unguiculata, Phaseolus vulgaris,* análise multivariada.

Introduction

The cowpea (*Vigna unguiculata* L. Walp.) and common bean (*Phaseolus vulgaris* L.) are leguminous species of great social and economic importance in different parts of the world, being consumed in several countries in Asia, Africa and the Americas (Silva et al., 2018). In Brazil, the cultivation of cowpea predominates in the North and Northeast regions, currently expanding in the Center-West region. Common bean production is concentrated in the Midwest, South and Southeast regions (Vale et al., 2017). Both species have important nutritional properties, representing excellent sources of iron, proteins, carbohydrates, vitamins and minerals, being considered essential foods for the diet of the Brazilian population. (Mullins e Arjmandi, 2021; Kotue et al., 2018).

Both cowpea and common bean are cultivated mainly for the sale of grains, however, the demand for green pods has increased in recent years (Gomes et al., 2016). The immature bean pod is a food rich in vitamins and carbohydrates, it also has mineral salts such as calcium, phosphorus, potassium and iron, in addition to a high fiber content (Silva et al., 2019). In order to sell the pods, they must be harvested at their maximum point of development, before they become fibrous and with protruding seeds, favoring cooking and consumption (Vale et al., 2017).

The market for immature bean pods has potential for expansion, however, the scarcity of information regarding the morphological and agronomic aspects of cultivars suitable for pods makes it difficult to exploit the species (Lazaridi et al., 2017). The morphoagronomic characterization of genotypes consists of identifying and describing the possible differences between them. Thus, carrying out morphoagronomic characterization helps in the identification and selection of characters and genotypes of interest that meet the requirements of producers and consumers of this legume (Santana et al., 2019).

Given the above, the objective of this work was to carry out the morphoagronomic characterization of bean genotypes with attention to the production of pods.

Material and methods

Location and conduct of experiments

Five bean genotypes with potential for pod production were evaluated, one belonging to the *Phaseolus vulgaris* species and four to *Vigna unguiculata* (Table 1).

Table 1 – Evaluated genotypes and their respective origins.

Genotypes	Scientific name	Origin
Habichuela	*Vigna unguiculata ssp. sesquipedalis*	Panama
Feijão Vagem do Panamá	*Vigna unguiculata ssp. sesquipedalis*	Panama
Pronto Alívio	*Vigna unguiculata* L.	Panama
Quiura Bejuco	*Phaseolus vulgaris* L.	Panama
Feijão-de-Metro	*Vigna unguiculata ssp. sesquipedalis*	Brazil

The experiment was carried out in the Didactic Garden of the Universidade Federal do Ceará (UFC), in Fortaleza - CE (3°44’25”S, 38°34’35”O and altitude of 19.5 meters), from August to November 2019. According to the Köppen classification, the climate of the region is Aw, rainy tropical. During the conduction of the test, the average temperature and accumulated precipitation were 28.4°C and 20.8 mm, respectively.

The experimental design was in randomized blocks with five genotypes and five replications. Sowing was carried out using three seeds per hole, with thinning carried out seven days after sowing (DAS), leaving a plant in each hole. Each experimental unit consisted of a bed 9.6 m long, spaced 0.1 x 0.3 m, totaling 32 plants $plot^{-1}$.

The localized irrigation system by microsprinkler was used, being performed twice a day, early in the morning and late in the afternoon. To carry out the staking, bamboo stakes planted in the ground were used, which were arranged every three meters within the rows of cultivation. The stakes had their apexes joined by a number 20 galvanized wire at a height of 2.20 m.

For foundation fertilization, 1.2 kg of nitrogen fertilizer (urea with 45% N) were applied per bed, distributed manually along the planting line. At 20 and 40 DAS, topdressing fertilizations were carried out. Pest and weed control was carried out according to the need observed in the field.

Morphoagronomic characterization

The characterization of the genotypes was based on 15 morphoagronomic characters, six quantitative and nine qualitative. The quantitative characters evaluated were: number of days from sowing to anthesis (NDSA), plant height (PH), average length of five pods (A5P), average weight of five pods (W5P), average number of pods per plant (NPP) and yield of mature pods (YIELD. While the qualitative traits were: growth habit (GH), flower color (FC), pod position (PP), pod shape (PS), pod profile (PDF), pod color (PC), pod shape grain (PSG), grain color (GC) and leaf hairiness (LH).

The identification of the growth habit of the genotypes was based on the classification by Vilhordo et al. (1980): Type I - determinate, bushy growth habit and erect plant size; Type II - indeterminate growth habit, bushy, erect plant and sparsely branched stem; Type III - indeterminate, prostrate or semi-prostrate growth habit, with well-developed and open branching; Type IV - indeterminate growth habit, climbing; stem with strong apical dominance and reduced number of lateral branches, poorly developed.

Analyzes of fresh mass, dry mass and moisture percentage of the pods were carried out, using 50 pods of each genotype. The pods were collected manually at the ideal harvest period, being immediately weighed using a precision digital scale to measure their fresh mass. After weighing, the pods were placed in paper bags and transferred to an oven with forced air circulation at a constant temperature of 60°C for 24 hours, obtaining the dry mass of the samples. The moisture content of the pods was calculated using the following equation:

$$H = (100 \times W) / Wi$$

where: H: pod moisture percentage (%); W: weight of the initial sample - weight of the sample after oven drying (g); Wi: initial sample weight (g).

Statistical analyzes

Analyzes of variance were performed for all quantitative characters according to the following statistical model:

$$Yij = m + gi + bj + eij$$

where: m: overall mean; gi: effect of the i-th variety; bj: effect of the j-th block; eij: experimental error.

The means of the different treatments were grouped by the Scott-Knott test ($p<0.05$). With regard to qualitative traits, the data obtained were divided into classes and the genetic distances between pairs of individuals were estimated based on the average Euclidean distance. From the dissimilarity matrix, a dendrogram was constructed using the mean link between groups method (UPGMA – Unweighted Pair-Group Method using Arithmetic Avarages). To verify the fit between the dissimilarity matrix and the dendrogram, the cophenetic correlation coefficient (r) was estimated.

The statistical analyzes described were performed using the GENES program (Cruz, 2013). The dendrogram was generated using the R program (R Core Team, 2022).

Result and discussion

There was a significant difference between the genotypes, at the 1% probability level, for all quantitative traits evaluated, with the exception of the number of pods per plant (Table 2).

The coefficient of variation (CV) ranged from 1.92 to 29.83 for W5P and PROD, respectively (Table 2). The CV values found in the present research were low, indicating good experimental precision and reliability of the results. The highest values were recorded for PROD, which is considered normal because it is a variable strongly influenced by the environment.

The ratio between the genetic (CVg) and environmental (CV) coefficients of variation reflects the predominance of genetic over environmental effects for the evaluated traits. CVg/CV values above unity mean characters less influenced by the environment, which have greater potential for selection (Panchta et al., 2021; Aramendiz-Tatis et al., 2018). According to Table 2, all characters had CVg/CV ratios above 1, with the exception of the NPP variable. Such results demonstrate the possibility of obtaining genetic gains through selection for most of the characters studied.

Table 2 – Summary of analysis of variance of quantitative traits evaluated in five bean genotypes for pods.

SV	DF	NDFS	PH	L5P	W5P	NPP	PROD
Blocks	4	0.76	7.47	1.44	0.38	4.23	1.36
Genotype	4	158.66**	5188.53**	914.22**	163.26**	38.71^{ns}	34.98**
Residual	16	1.49	5.65	0.71	0.07	13.24	3.28
CV (%)		2.81	4.40	2.97	1.92	28.11	29.83
CVg(1)		12.94	59.63	47.61	40.16	17.44	41.48
CVg/CV(2)		4.60	13.54	16.02	20.91	0.62	1.39

**Significant at the 1% probability level by the F test; (1)Coefficient of genetic variation; (2)Ratio between genetic and environmental variation coefficients; NDSA: number of days from sowing to anthesis; PH: plant height; L5P: length of 5 pods; W5P: weight of 5 pods; NPP: number of pods per plant; PROD: pod productivity.

To assess precocity, one of the main descriptors used is the time elapsed between planting and the appearance of the first flowers (anthesis). The character number of days from sowing to anthesis (NDSA) had a general average of 44 days, ranging from 42 to 52 days for the FVP and Pronto Alívio genotypes, respectively (Table 3). With regard to this character, the variety Pronto Alívio stood out negatively, since it had a later onset of flowering. Based on the classification by Paiva et al. (2014) and in the grouping of means, all other genotypes were considered precocious.

Table 3 – Means of the quantitative traits evaluated in five bean genotypes for pods.

Genotypes	NDSA (days)	PH (cm)	L5P (cm)	W5P (g)	NPP (unt)	PROD (t ha^{-1})
Habichuela	43 a	25.7 d	38.5 a	18.2 a	11	6.5 b
FVP	42 a	25.9 d	37.5 a	17.9 a	11	6.5 b
Pronto Alívio	52 b	67.4 b	19.6 b	15.6 b	18	9.2 a
Quiura Bejuco	43 a	48.5 c	8.8 c	4.3 c	13	1.8 c
Feijão-de-Metro	43 a	102.5 a	37.6 a	15.0 b	12	6.1 b
Overall average	44	54	28.4	14.2	13	6.2

Means followed by the same letter belong to the same group, according to the Scott-Knott test ($p<0.05$); NDSA: number of days from sowing to anthesis; PH: plant height; C5V: length of 5 pods; P5V: weight of 5 pods; NPP: number of pods per plant; PROD: pod productivity.

Regarding plant height (PH), the genotype that stood out the most was Feijão-de-Metro, with an average of 102.5 cm (Table 3). Next came the Pronto Alívio and Quiura Bejuco varieties. The prominence of these genotypes was already expected due to their indeterminate growth habit, with apical dominance and continuous growth (Vilhordo et al., 1980).

One of the most relevant characters in works of this nature is the length of the pods (L5P), since the size of the product is a strong attraction for the consumer. Regarding this factor, the best results were recorded for the Habichuela, FVP and Feijão-de-Metro genotypes, with values above the general average (28.4 cm) (Table 3). The Quiura Bejuco variety showed low performance regarding the length of its pods, with an average of only 8.8 cm. Demonstrating a direct relationship with pod length, the Habichuela and FVP genotypes also stood out in terms of pod weight (P5V), with averages above 17 g. Superior results were obtained by Savithiri et al. (2018) who, evaluating 62 snap bean genotypes in the conditions of Tamil Nadu, India, found an overall average of 22.6 g.

With regard to pod productivity (PROD), there was a range of 1.8 to 9.2 t ha^{-1} for Quiura Bejuco and Pronto Alívio genotypes, respectively. The overall average for this character was 6.2 t ha^{-1}, similar to the result found by Gomes et al. (2016), who evaluated the agronomic performance of three bush snap bean genotypes in two environments in the state of Parana (Tamarana and Londrina), and found an average productivity of 6.82 t ha^{-1}.

Table 4 presents the estimated qualitative characteristics for the five bean genotypes. As for growth habit (GH), the genotypes were classified into three types: Habichuela (Type I); FVP and Instant Relief (Type III); Quiura Bejuco and Subway (Type IV).

Table 4 – Characters in five bean genotypes for pods.

Qualitative Characters	Genotypes				
	Habichuela	Feijão Vagem do Panamá	Pronto Alívio	Quiura Bejuco	Feijão-de--Metro
Growth Habit (GH)	I	III	III	IV	IV
Flower color	ViBr	ViBr	Vi	Br	Vi
Pod position	Af	Af	Df	Df	Df
Pod shape	Actd	Actd	Arrd	Actd	Actd
Pod profile	Rc	Rc	Ar	Sar	Re
Pod color	VrdC	VrdC	VrdE	VrdC	VrdE
Grain shape	El	Rm	Rm	Rl	El
Grain color	Brown	Vinegar	Vinegar	Vinegar	Brown
Leaf hairiness	Absent	Absent	Absent	Present	Absent

Flower color: Br - white, Vi - violet and ViBr - violet with white; Pod position: Af - above the foliage and Df - inside the foliage; Pod shape: Actd - flattened and Arrd - rounded; Pod profile: Re - straight, Ar - arched, Sar - semi-arched and Rc - curved; Pod color: VrdC - light green and VrdR - dark green; Grain shape: El - elliptical, Rm - medium kidney-shaped and Rl - long kidney-shaped.

According to Almeida et al. (2014), genotypes with type III and IV GH have continuous vegetative development, with a long period of flowering and fruiting, allowing for multiple harvests throughout the year. It is precisely for this aspect that a large part of small producers in northeastern Brazil adopt indeterminate growth cultivars. On the other hand, medium and large producers whose crops are mechanically harvested prefer cultivars with type I and II GH.

Regarding flower color, two genotypes showed a violet color (Pronto Alívio and Feijão-de-Metro), while two others presented a white color with violet (Habichuela and FVP), and only the Quiura Bejuco genotype showed completely white flowers (Table 4). Regarding the position of the pods on the plant, the Pronto Alívio, Quiura Bejuco, and Feijão-de-Metro varieties had pods positioned within the foliage, while the Habichuela and FVP genotypes had pods above the leaves. Genotypes with pods positioned above the foliage facilitate harvesting, whether manual or mechanical, but their pods are more exposed to biotic and abiotic external agents.

In terms of pod shape, only the Pronto Alívio variety had rounded pods, while the others had a flattened shape (Table 4). Regarding pod curvature, four different types were found: recurved (Habichuela and FVP), arched (Pronto Alívio), semi-arched (Quiura Bejuco), and straight (Feijão-de-Metro). Almeida et al. (2014), characterizing bean pods according to this descriptor, found a predominance of semi-arched (50%) and straight (46%) profiles. The same authors stated that pod curvature is not a stable trait since a plant can have pods with different profiles, although one type predominates.

Regarding pod color, all varieties had primary green coloration, with variations in shade (Table 4). In general, consumers prefer pods with a green color throughout their profile, mainly because the green color is associated with the freshness and quality of vegetables and similar products, although some markets may prefer cultivars that produce a reddish-colored pod (Ha et al., 2010).

Two descriptors were used for grain characterization: color and shape. Genotypes were classified into three groups according to grain shape: elliptical, medium kidney-shaped, and long kidney-shaped. Habichuela and Feijão-de-Metro varieties had grains with an elliptical shape, FVP and Pronto Alívio had grains with a medium kidney shape, and only Quiura Bejuco had long kidney-shaped grains (Table 4). The vinegar grain color was the most common among the evaluated genotypes, being found in the grains of FVP, Pronto Alívio, and Quiura Bejuco. The Habichuela and Feijão-de-Metro varieties had brown-colored grains.

Regarding leaf hairiness, only the Quiura Bejuco variety presented leaves with trichomes, contributing significantly to differentiate it from the other varieties (Table 4). Trichomes are uni- or multicellular extensions of the epidermis of the above-ground plant part that can assume different shapes, structures, and functions, including protection against insect and pathogen attacks, reduction of water loss, and increased tolerance to abiotic stress conditions (Taiz et al., 2017). However, to claim that the leaf hairiness of a particular cultivar constitutes a commercial advantage over another, more in-depth studies on their trichomes and functions in the variety in question are needed.

The determination of humidity is one of the most important measures used in food analysis and is related to the stability, quality, and composition of these products, directly affecting storage time, packaging, and subsequent processing (Zambrano et al., 2019). According to Table 5, the estimated moisture content ranged from 88.54 to 90.65% for the Quiura Bejuco and FVP varieties, respectively. Similar results were found by Carnib (2017) who evaluated the proximate composition, minerals, and sensory acceptance of 10 cowpea genotypes for consumption in the form of salad and obtained moisture content of pods ranging from 86.1 to 90.8% for the 3950 and Feijão-de-Metro varieties, respectively.

For the commercialization of cowpea pods, they should be harvested before physiological maturity, at a stage when the seeds are still poorly developed (beginning of grain filling) (Peixoto and Cardoso, 2016), therefore it is normal and desirable for the pods to have high moisture content at the time of harvest.

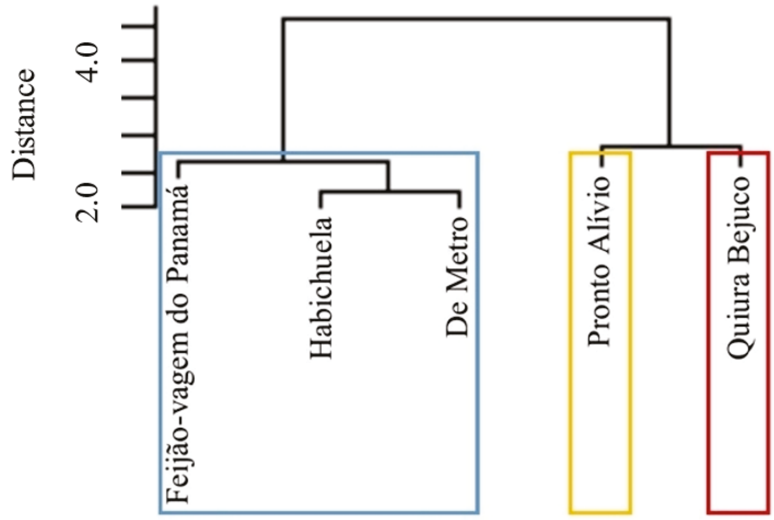
Table 5 – Fresh mass, dry mass and humidity of pods estimated in five bean genotypes for pods.

Genotypes	Fresh mass (g)	Dry mass (g)	Humidity (%)
Habichuela	7.97	0.74	90.64
Feijão Vagem do Panamá	7.23	0.67	90.65
Pronto Alívio	5.80	0.67	88.46
Quiura Bejuco	2.49	0.28	88.54
Feijão-de-Metro	7.57	0.76	89.91
Overall average	6.21	0.62	89.64

Although there was a slight variation in pod moisture among the genotypes, they may differ in perishability. El-Mogy and Kitinoja (2019) argue that the difference in perishability in foods with similar moisture content is due to the unavailability of water for microbial growth and reactions, and is related to the solid constituents of the food.

Genetic divergence among the varieties was obtained through the average Euclidean distance, standardized due to different measurement scales. The maximum distance was obtained between the FVP and Quiura Bejuco genotypes (dii' = 4.28), while the minimum was estimated between the Habichuela and Feijão-de-Metro pair (dii' = 2.24) (Figure 1). The five genotypes studied were separated into three groups. Group I consisted of the Habichuela, FVP, and Feijão-de-Metro varieties, belonging to the sesquipedalis cultigroup; Group II was comprised of the Pronto Alívio genotype (Vigna unguiculata L.); and Group III was integrated by the Quiura Bejuco variety (Phaseolus vulgaris L.).

Figure 1 – Dendrogram obtained by the UPGMA method, from dissimilarity measurements between five bean-to-pod genotypes, based on the mean Euclidean distance.



Dissimilarity studies serve specific purposes for breeders by providing information about the degree of similarity or difference between two or more genotypes, helping to identify parents that can produce progenies with higher heterotic effect (Al-Ashkar et al., 2020; Ashinie et al., 2020). In the present work, the highest genetic dissimilarity, as mentioned, was found between the FVP and Quiura Bejuco varieties (Figure 1). However, although it exhibited early maturity, the latter genotype showed low performance in the other evaluated traits, such as L5P, W5P, and PROD (Table 3). In this case, the genetic divergence found cannot be considered the main factor for the indication of the parent for future crosses. Therefore, it is recommended that the breeder selects parents that already have desirable traits and possess the greatest dissimilarity possible. Thus, it is recommended to cross the FVP and Pronto Alívio varieties. The former stood out in terms of early maturity, pod length and weight, while Pronto Alívio showed the highest productivity.

To verify the ability of the dendrogram to reproduce the dissimilarity matrices, the cophenetic correlation coefficient (CCC = 0.73) was estimated. According to Carvalho et al. (2019), CCC values closer to unity indicate better representation of the data set. Based on this, it was observed that there was adequacy between the original matrix and the resulting matrix from the clustering process, proving the reliability of the dendrogram.

Conclusions

There was sufficient variability for the selection of superior genotypes for all evaluated traits, except for the number of pods per plant.

The genotype Pronto Alívio was the latest to mature, but had the highest average pod yield.

The genotypes Pronto Alívio, Habichuela, Feijão Vagem do Panamá, and Feijão-de-Metro out for their pod length and weight, as well as for their above-average productivity compared to the general mean of the evaluated genotypes.

It is recommended to cross the varieties Feijão Vagem do Panamá and Pronto Alívio in order to obtain superior cultivars.

References

Al-Ashkar, I.; Alotaibi, M.; Refay, Y.; Ghazy, A.; Zakri, A.; Al-Doss, A. 2020. Selection criteria for high-yielding and early-flowering bread wheat hybrids under heat stress. PLoS One, 15(8), e0236351. Doi: https://doi.org/10.1371/journal.pone.0236351.

Almeida, S. N. C.; Thiebaut, J. T. L.; Gravina, G. D. A.; Araújo, L. C.; Daher, R. F. 2014. Avaliação de características morfológicas e agronômicas de linhagens de feijão-de-vagem em Bom Jesus do Itabapoana-RJ, com potencial de recomendação. Vértices, v.16, n.1, p.39–50. Doi: http://dx.doi.org/10.5935/1809-2667.20140003.

Aramendiz-Tatis, H.; Cardona-Ayala, C.; Espitia-Camacho, M.; Arrieta-Puche, D.; Barba, A. G. 2018. Estimation of genetic parameters in white seed cowpea (Vigna unguiculata (L) Walp). Australian Journal of Crop Science, 12(6), 1016–1022. Doi: https://doi.org/10.21475/ajcs.18.12.06.p1105.

Ashinie S. K.; Tesfaye B.; Wakeyo G. K.; Fenta B. A.; Assefa E.; Greliche N.; Machuka E. M.; Yao N. K. D. 2020. DArTSeq SNP-based markers revealed high genetic diversity and structured population in Ethiopian cowpea [Vigna unguiculata (L.) Walp] germplasms. PLOS One. 12;15 (10). Doi: https://doi.org/10.1371/journal.pone.0239122.

Carnib L. P. A. 2017. Caracterização da composição centesimal, minerais e aceitação sensorial de genótipos de feijão-de-metro (Vigna unguiculata ssp sesquipedalis) [dissertação de mestrado]. Teresina: Universidade Federal do Piauí. 76 p.

Carvalho, P. R.; Munita, C. S.; Lapolli, A. L. 2019. Validity studies among hierarchical methods of cluster analysis using cophenetic correlation coefficient. Braz J Radiat Sci, 7(2), 1–14. https://doi.org/10.15392/bjrs.v7i2.501.

Cruz, C. D. 2013. GENES - a software package for analysis in experimental statistics and quantitative genetics. Acta Sci. Agron., 35(3), p.271–276. Doi: http://dx.doi.org/10.4025/actasciagron.v35i3.21251.

El-Mogy, M. M.; Kitinoja, L. 2019. Review of best postharvest practices for fresh market green beans. PEF White Paper No. 19-01. La Pine, Oregon, USA: The Postharvest Education Foundation; 19 p.

Gomes, G. R.; Moritz, A.; Freiria, G. H.; Furlan, F. F.; Takahashi, L. S. A. 2016. Desempenho produtivo de genótipos de feijão-vagem arbustivo em dois ambientes. Scientia Agricola, 73(2) 85–92. Doi: http://dx.doi.org/10.17224/SCiAGR.2016v7n2.p85-92.

Ha, T. J.; Lee, M. H.; Park, C. H.; Pae, S. B.; Shim, K. B.; Ko, J. M.; Shin, S. O.; Baek, I. Y.; Park, K. Y. 2010. Identification and characterization of anthocyanins in yard-long beans (Vigna unguiculata ssp. sesquipedalis L.) by high-performance liquid chromatography with diode array detection and electrospray ionization/mass spectrometry (HPLC-DAD--ESI/MS) analysis. Journal of Agricultural and Food Chemistry, 58(4), 2571–2576. Doi: http://dx.doi.org/10.1021/jf904286y.

Lazaridi, E.; Ntatsi, G.; Savvas, D.; Bebeli, P. J. 2017. Diversity in cowpea (Vigna unguiculata (L.) Walp.) local populations from Greece. Genetic Resources and Crop Evolution, 64, 1529–1551. Doi: http://dx.doi.org/10.1007/s10722-017-0522-2.

Mullins, A. P.; Arjmandi, B. H. 2021. Health benefits of plant-based nutrition: focus on beans in cardiometabolic diseases. Nutrients, 13(2), 1–16. Doi: http://dx.doi.org/10.3390/nu13020470.

Paiva, J. B.; Freire Filho, F. R.; Teófilo, E. M.; Ribeiro, V. Q. 2014. Feijão-caupi: melhoramento genético no Centro de Ciências Agrárias. Fortaleza: UFC.

Panchta, R.; Arya, R. K.; Vu, N. N.; Behl, R. K. 2021. Genetic divergence in cowpea (Vigna unguiculata L. Walp) - an overview. Ekin Journal of Crop Breeding and Genetics, 7(1), 1–20. Doi: https://doi.org/10.29333/ejcbg/8967.

Peixoto, N.; Cardoso, A. I. I. 2016. Feijão-vagem. In: Nascimento, W. M. (ed.). Hortaliças leguminosas. Brasília: Embrapa, 61–86.

R Core Team. 2022. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/.

Santana, S. R. A.; Medeiros, J. E.; Anunciação Filho, C. J.; Silva, J. W.; Costa, A. F.; Bastos, G. Q. 2019. Genetic divergence among cowpea genotypes by morphoagronomic traits. Revista Caatinga, 32(3), 841–850. Doi: https://doi.org/10.1590/1983-21252019v32n320rc.

Savithiri, N.; Beaulah, A.; Thingalmaniyan, K. S.; Rajeswari, S.; Kumar, R. 2018. Study on genetic variability for yield and quality of different genotypes of yard longbean (Vigna unguiculata sub sp. sesquipedalis (L.) Verd.). International Journal of Current Microbiology and Applied Sciences, 7(9), 3613–3617. Doi: https://doi.org/10.20546/ijcmas.2018.709.448.

Silva, A. C.; Santos, D. C.; Teixeira Junior, D. L.; Silva, P. B.; Siviero, R. C. S. A. 2019. Cowpea: a strategic legume species for food security and health. In J. C. Jimenez-Lopez & A. Clemente (Eds.), Legume Seed Nutraceutical Research, 47–65. Doi: https://doi.org/10.5772/intechopen.85348.

Silva, M. B. O.; Carvalho, A. J.; Rocha, M. M.; Batista, P. S. C.; Santos Júnior, P. V.; Oliveira, S. M. 2018. Desempenho agronômico de genótipos de feijão-caupi. Revista de Ciências Agrárias, 41(4), 1059–1066. Doi: https://doi.org/10.19084/RCA18046.

Vale, J. C.; Bertini, C.; Borém, A. (2017). Feijão-caupi: do plantio à colheita. Viçosa: UFV.

Vilhordo, B. W.; Muller, L.; Ewald, L. F.; Leão, M. L. 1980. Hábito de crescimento em feijão (Phaseolus vulgaris L.). Agronomia Sulriograndense, 16(1), 79–98.

Zambrano, M. V.; Dutta, B.; Mercer, D. G.; MacLean, H. L.; Touchie, M. F. 2019. Assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: A review. Trends in Food Science & Technology, 88, 484–496, 2019. Doi: https://doi.org/10.1016/j.tifs.2019.04.008.