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SCIENTIFIC NOTE

Agronomic behavior of cowpea varieties in non-alluvial soils of the Peruvian Amazon

Comportamento agronômico de variedades de feijão-caupi em solos não aluviais da Amazônia Peruana

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ABSTRACT: Grain legumes in tropical areas are of great importance as a food source, especially in rural communities. Little is known about their adaptability and behavior in non-alluvial soils of the Peruvian Amazon. Our objective was to assess the agronomic behavior of cowpea varieties in non-alluvial soils. The experiment was performed in completely randomized design with four treatments and four repetitions. Each experimental unit consisted of five rows of 6 m length by 0.5 m between plants and 1 m between rows. The variables evaluated were: plant height (cm), number of pods, pod length (cm), number of grains per pod, grain length (mm), grain width (mm), and weight of 100 seeds (g). An analysis of variance and Tukey' test at 5% probability were used to determine significant differences between treatments. Results showed significant differences between varieties according to the evaluated variables. The red cowpea presented significant differences for the agronomic characteristics in plant height (62.83 cm), grain length (8.68 mm), and weight of 100 seeds (16.87g) in relation to the other varieties. The Chiclayo Olho Preto variety stood out only in grain width (5.46 mm), and the Chiclayo Vermelho in pod length (19.58 cm). The red cowpea has the potential to be cultivated preliminarily in larger-scale areas in the Yurimaguas district.

KEYWORDS
Tropical legumes
Vigna unguiculata
Climate change
Agronomic performance

PALAVRAS-CHAVE
Leguminosas tropicais
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RESUMO: *As leguminosas de grãos nas áreas tropicais são de grande importância como fonte de alimento, sendo especial para as comunidades rurais. Pouco se sabe sobre sua adaptabilidade e comportamento em solos não aluviais da Amazônia peruana. O objetivo do nosso estudo foi avaliar o comportamento agronômico de variedades de feijão-caupi em solos não aluviais. O experimento correspondeu a um Desenho Completamente Aleatório (DCA) com quatro tratamentos e quatro repetições. Cada unidade experimental foi de 5 fileiras de 6 metros de comprimento por 0,5 m entre plantas e 1 m entre fileiras. As variáveis avaliadas foram altura da planta (cm), número de vagens, comprimento de vagens (cm), número de grãos por vagens, comprimento do grão (mm), largura do grão (mm) e peso de 100 sementes (g). Uma análise de variância foi realizada e o teste de Tukey foi usado a 5% de probabilidade determinar as diferenças significativas entre os tratamentos. Os resultados indicaram que houve diferenças significativas entre as variedades de acordo com as variáveis avaliadas. A variedade do feijão-caupi vermelho apresentou diferenças significativas para as características agronômicas em altura de planta (62,83 cm), comprimento de grão (8,68 mm) e peso de cem sementes (16,87g) em relação às demais variedades. A variedade Chiclayo olho preto destacou-se apenas na largura da semente (5,46 mm) e o Chiclayo vermelho no comprimento da vagem (19,58 cm). A variedade feijão- caupí vermelho tem potencial para ser cultivada preliminarmente em áreas de agricultores em maior escala no distrito de Yurimaguas.*

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1 Introduction

Grain legumes are considered the second most valuable plant source for human nutrition *et al.*, 2019). Cowpea (*Vigna unguiculata* L. Walp), an annual herbaceous legume that belongs to the Fabaceae family (Wani *et al.*, 2016), can be used in the form of dry seeds, forage, green beans, green manure, and cover crops (Metwally *et al.*, 2021).

Cowpea is one of the most widely cultivated and consumed grain legumes, especially in tropical and subtropical areas (Kebede & Bekeko, 2020), for its high content of proteins (18-26% in seeds and between 14-21 in foliage), calcium, and vitamins. Because of its content of essential amino acids (Foyer *et al.*, 2016) and for being a plant that adapts to a wide range of soil and climate conditions, it is considered one of the best drought-resistant food crops and can, therefore, help hold the negative impact of climate change (Gonçalves *et al.*, 2016). On the other hand, it plays a fundamental role in rural and urban communities (Gondwe *et al.*, 2019), and in the sustainability of soil fertility, due to its ability to fix the atmospheric nitrogen (Gondwe *et al.*, 2019).

Specifically in the Peruvian Amazon, cowpea is still cultivated as a secondary crop, that is, mainly by small farmers. However, its easy adaptation to different ecosystems enabled its cultivation in other regions, in particular to neighboring localities of Yurimaguas, Peru.

In Yurimaguas, cowpea is cultivated in small areas and mainly in alluvial soils (on the river banks, when these are in times of emptying) mostly for its use as grains and because of its ability to tolerate periods of drought. As happens to most of the countries that have Amazonian regions, Yurimaguas is currently experiencing the effects of climate change that are manifested as prolonged droughts and rainy seasons. In this part of the Peruvian Amazon, the cowpea cultivation is almost forgotten due to low yields and little consumption by the population, who just take advantage of a single campaign waiting for the rivers to lower the water level so that alluvial areas are available. Although cowpea is an important food crop for rural communities, its adaptability, productive potential, and agronomic behavior are little explored. According to Melo *et al.* (2018), it is important to identify varieties with good traits and agronomic performance for a certain region.

In this context, there are alternatives for the adaptation of these crops to non-floodable soils using well-developed agronomic techniques of good adaptability and good yield that meets the farmer's needs and becomes an excellent alternative for a large number of small producers in the region, because thanks to its short vegetative period, cowpea can be used as a crop of short-term campaign, tripling the annual campaigns. On the other hand, the productivity indexes for cowpea farmers are not the desired ones, being evident the lack of information on agronomic management and technical assistance in these crops. In this sense, there are no documented studies on the agronomic management of cowpea varieties in non-floodable soils in Yurimaguas.

The objective of this study was to evaluate the agronomic behavior of four native varieties of cowpea in Yurimaguas, in the Peruvian Amazon. The knowledge generated from this study can be used by researchers and public policy makers in the planning of feeding programs and as a basis for other studies related to the behavior of cowpea varieties in the Peruvian Amazon region.

2 Materials and Methods

The study was carried out in an area belonging to the Agrarian Experimental Station "San Ramón", Yurimaguas, of the "Instituto Nacional de Innovación Agraria" (INIA) located at 5°56′13″ S latitude and 76°07′04″ latitude, and 182 m asl, and is located on the banks of the Shanusi River, a tributary of the Huallaga River (Villacorta et al., 2021).

The climate is classified as humid tropical (Holdrige, 1967), with an annual temperature of 26.1 °C and an average rainfall of 2.200 mm (Delgado, 2017). The meteorological seasons are: rainy season (September-May) and dry season (June-August). There are well-drained and poorly-drained soils, most of them have a clayey to sandy texture in the first layer of the surface (between 10 and 15 cm deep); colors vary from black or grayish brown to yellowish red, and pH varies from 3.5 to 6.0.

The genetic material was obtained from varieties collected in municipalities belonging to the Yurimaguas district and established in the tropical legume germplasm bank of the INIA. The varieties studied were: variety 1, red cowpea, located at 5°48′42.17″ S longitude and 76°5′54.41″ W latitude; variety 2, Chiclayo Olho Preto, located at 5°48′23.85″ S longitude and 76°6′4.42″ W latitude; variety 3, Chiclayo Vermelho, located at 5°51′18.96″ S longitude and 76°9′48.07″ W latitude; and variety 4, Olho Branco, located at 5°53′10.23″ S longitude and 76°9′43.14″ W latitude. The seeds were planted and harvested during the 2020 season.

The agronomic evaluations of the four cowpea varieties were carried out in a randomized block design with four treatments and four replications. Each experimental unit was performed in five rows of 6 m in length (30 m^2) by 0.5 m between plants and 1.0 m between rows. To avoid the edge effect, the three central furrows were considered and two additional furrows of the same variety were made at the extremities.

Sowing was carried out manually, placing three seeds per hole at a depth of 4 cm. Twenty days after emerging in the field, desiccation was performed, leaving only one individual. Cleaning was done as needed during the sowing season to ensure weed-free conditions. To prevent the attack of insects and fungi on cowpea plants, we applied insecticide (cypermethrin; 30 mL/20 L of water), fungicide (carbendazine; 50 mL/20 L of water), and foliar fertilizer (Bayfolan;100 mL/20 L of water).

For the evaluation of the varieties, data were collected from ten plants randomly taken from the useful area of each experimental plot. To measure these variables, a tape measure was used from the base to the apex of the plant; the measurement was expressed in centimeters and was performed in the physiological maturation phase. At the time of harvest, the pods were collected individually for each plot and placed in properly labeled paper bags and sent to the Genetic Resources Laboratory (EEA - San Ramón) for the respective evaluations. Subsequently, the pods were opened to count the number of grains. The variables with unit of measure in cm were measured with the aid of a metal ruler graduated in centimeters, and the variables in mm were measured with the use of a Mitutoyo digital vernier caliper. Finally, for the weight of grains, a gramera digital scale was used. The variables evaluated were: plant height (cm), number of pods per plant, pod length (cm), number of grains per pod, grain length (mm), grain width (mm), and weight of 100 seeds (g).

For the statistical analysis, we performed normality and homogeneity of variances (Kolmogorov Smirnof and Levene tests). The experiment corresponded to a completely randomized design. In this sense, data of the evaluated variables were subjected to the respective analysis of variance individually for each variable and Tukey's test was used at 5% probability to determine the significant differences between the treatments. For the statistical analysis, the R 4.0.2 (2020) programming language was used.

3 Results and Discussion

According to our results, the analysis of variance (Table 1) highlighted, in general terms, significant and highly significant differences in the evaluated varieties, except for number of pods per plant and number of grains per pod. Similar results were reported by Barros *et al.* (2013), who evaluated agronomic characteristics in eight accessions of cowpea, evidencing the existence of genetic variability between them. The assumptions of the mathematical model (independence, homogeneity of variance, additivity, and normality) of our data were satisfied, indicating that the conclusions derived from the study are reliable. These results indicate that there were differences in the traits evaluated. The quality of precision of the coefficients of variation (CV%) indicates an experimental precision within the satisfactory percentage for field trials (1.15 to 9.64; da Silva *et al.*, 2020).

For the variables evaluated in our study, the analysis of variance showed significant differences by Tukey's test at 5% probability for plant height between red cowpea and Olho Branco varieties. The variety with the highest plant height was red cowpea (62.83 cm), followed by Chiclayo Olho Preto (58.35 cm), Chiclayo Vermelho (56.99 cm), and Olho Branco (54.48 cm) (Table 2). Our results are in line with those reported by Souza *et al.* (2020), who found significant differences for the varieties Costela de Vaca (58.75 cm), Manteigão (56 cm), Arigozinho (55.65 cm), Leite (54.33 cm), Branco de Praia (52.25 cm), Ceará (51.50 cm), and Baiano (51.45 cm). These results may be due to the fact that the study areas have similar environmental characteristics (climate, altitude, etc.) (Tatis *et al.*, 2017). On the other hand, the results reported by Haro *et al.* (2019) were different for the 'INIAP463' variety with an average plant height of 74.6 cm. This difference is probably due to the type of growth habit of the varieties. In our case, the varieties studied were of low growth and those reported by these authors were of semi-erect growth.

Table 1. Analysis of variance. Expected mean squares for plant height (PH; cm), number of pods per plant (NPP), pod length (PL), number of grains per pod (NGP), grain length (GL), grain width (GW), and weight of 100 seeds (WS).

Tabela 1. Análise de variância. Quadrados médios esperados para altura da planta (AP; cm), número de vagem por planta (NVP), comprimento de vagens (CV), número de grãos por vagem (NGV), comprimento de grãos (CG), largura do grãos (LG) e peso de 100 sementes (PS).

Variation source	DF	PH (cm)		NPP		PL (cm)		NGP		GL (mm)		GW (mm)		WS (g)	
Blocks	3	4.56	Ns	0.27	Ns	0.96	Ns	0.96	Ns	0.04	Ns	0.01	Ns	0.01	*
Treatments	3	49.00	*	1.40	Ns	4.14	*	3.58	Ns	4.42	***	1.32	Ns	12.6	Ns
Error	9	12.18		0.38		0.85		2.26		0.01		0.0036		0.03	
Total	15	-		-		-		-		-		-		-	
CV (%)		6.00		7.16		4.96		9.64		1.41		1.27		1.15	

DF - degrees of freedom; CV - coefficient of variation; Ns - not significant.
*** 0.001; ** 0.01; * 0.05; Ns: 0.1
GL- graus de liberdade; CV- coeficiente de variação; Ns- não significativo.
*** 0,001; ** 0,01; * 0,05 'Ns' 0.1; Ns: 1,0

For number of pods per plant, no significant differences were found between the varieties, and the highest number was found in Olho Branco (9.1 cm) followed by red cowpea (9.08 cm), Chiclayo Vermelho (8.38 cm), and Chiclayo Olho Preto (7.88 cm) (Table 02).

These results differ from those reported by Tatis & Camacho (2011), who found 21.1, 20, and 19.6 cm for lines L066, L002, and L019, respectively. This difference can be altered due to environmental conditions and edaphic factors that influence plant development (Tatis *et al.*, 2017) and to the lack of fertilization of plants before grain filling.

As for pod length, the highest value found was for Chiclayo Vermelho (19.58 cm), followed by Chiclayo Olho Preto (19.15 cm), Olho Branco (18.18 cm), and red cowpea (17.31cm). In the evaluation of pod length reported by de Souza *et al.* (2020), they were similar to the varieties Costela de Vaca (22.13 cm), Mudubim de Rama (21.41 cm), and Fígado de Galinha (21.11 cm). However, these results differ from those reported by Haro *et al.* (2019), who found the highest value of 24.4 cm length. According to Miranda *et al.* (1996), there are parameters for the commercialization of the cowpea crop related to the ideal pod length (average of 20 cm), which indicates that, in our study, the most similar variety is the Chiclayo Vermelho and Chiclayo Olho Preto varieties.

Regarding the number of grains per pod, there were no significant differences among the variables evaluated, but it is important to highlight as a reference that the highest value found for this variable was in the Chiclayo Vermelho variety with 16.38 cm. (Table 2). The variable number of grains per pod must be related to pod length. However, this pattern is not always observed (Valeriano *et* *al.*, 2019), i.e., there are pods with greater length, but with fewer grains (Table 2). This may be due to intraspecific competition between plants in the grain filling process (de Souza *et al.*, 2020).

Table 2. Mean values of cowpea varieties for plant height (PH), number of pods per plant (NPP), pod length (PL), number of grains per pod (NGP), grain length (GL), grain width (GW), and weight of 100 seeds (WS).

Tabela 2. Valores médios das variedades de feijão-caupi para altura da planta (AP), número de vagem por planta (NVP), comprimento de vagens (CV), número de grãos por vagem (NGV), comprimento de grãos (CG), largura do grãos (LG) e peso de 100 sementes (PS).

Treatment	PH (cm)		NPP		PL (cm)		NGP		GL (mm)		GW (mm)		WS (g)	
Red cowpea	62.83	a	9.08	a	17.31	b	14.63	a	8.68	a	4.36	c	16.87	a
Chiclayo olho preto	58.35	ab	7.88	a	19.15	ab	14.92	a	6.25	d	5.46	a	15.63	b
Chiclayo vermelho	56.99	ab	8.38	a	19.58	a	16.38	a	8.16	b	4.18	d	12.65	c
Cowpea olho branco	54.48	b	9.1	a	18.18	ab	16.42	a	7.9	c	4.88	b	15.27	b

On the other hand, the variables grain width, grain length, and weight of 100 seeds showed significant differences between the varieties. The highest values found for grain length were in the red cowpea (8.68 mm) and Chiclayo Vermelho (8.16 mm); for grain width, Chiclayo Olho Preto (5.46 mm), followed by Olho Branco (4.88 mm); and for the weight of 100 seeds, the red cowpea was significantly superior to all the other varieties, obtaining the highest value (16.87 g), followed by Chiclayo Olho Preto (15.63 g) (Table 02). These results were similar to those reported by da Silva *et al* (2020) for grain width and length of the BRS Potiguar (8.78 mm and 4.98 mm) and Conapum (8.52 mm and 6.89) varieties. However, for weight of 100 seeds, the values reported by the same authors were different for the varieties Coruja (25.50 g), Canapum (27 g), Lizão (25.66 g), Sempre Verde (28.33 g), Costela de Vaca (31.16 g), and BRS Potiguar (19.66), which were higher than ours. The variable weight of 100 seeds is one of the most important agronomic traits for obtaining the price of the product and directly influences grain yield (Bertini *et al.*, 2010) and may respond better in the field under unfavorable conditions (Haig & Westoby, 1991).

4 Conclusion

Significant differences were found between the varieties according to the variables evaluated, except for the number of pods per plant and the number of grains per pod. The red cowpea variety stood out for presenting significant differences for the agronomic traits plant height, grain length, and especially weight of 100 seeds in relation to the other varieties. The Chiclayo Olho Preto variety stood out only in grain width, and the Chiclayo Vermelho in pod length. According to the agroecological conditions presented in our study, the red cowpea has the potential to be preliminarily cultivated on a larger scale in the Yurimaguas district. New research related to agronomic behavior with other genotypes should be developed to help identify other varieties that respond positively to climatic and edaphic conditions in the region in non-alluvial soil conditions.

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