Original Research Article

Productivity of dry grains of cowpea {*Vigna unguiculata* (L.)} Creole cultivar (Canupum), as a function of different planting densities.

Aims: Cowpea {*Vigna unguiculata* (L.)} is a legume of great importance, being a source of food rich in protein, being essential for human nutrition and produced during the rainy season in the semi-arid region of Brazil. In this sense, the objective was to study the efficiency of different planting densities on cowpea productivity in the Brazilian semi-arid region.

Place of Study: The experiment was conducted from September to December 2021 at the Rafael Fernandes experimental farm, in the district of Alagoinha (5º03'37 "S, 37º23'50" W), northwest of Mossoró, State of Rio Grande do Norte, Brazil, with the aim of evaluating the efficiency of different planting densities on cowpea productivity in the semi-arid region of Brazil.

Study Design and Methodology: The experimental design used was randomized complete blocks with five treatments (1.0; 2.0; 3.0, 4.0 and 5.0 plants hole^{-1}) with four replications. Each plot consisted of dimensions of 3.5 m x 4.8 m, with six rows of 4.8 m in length, with a total area of 18.2 m^2, with the useful area being the four central rows, with dimensions of 2.8 x 4.8 m, with an area of 13.44 m^2, for collecting dry grains.

Agronomic characteristics of cowpea {*Vigna unguiculata* (L.)}: Number of pods, expressed in units ha^{-1} (NV), length of pods, expressed in cm (CPV), weight of one hundred grains, expressed in grams (P100G), dry grain productivity, expressed in kg ha^{-1} (PG), number of grains pod^{-1}, expressed in units (GV), dry grain index, expressed in percentage (IGS) and pod production, expressed in grams (PV) of cowpea, Creole cultivar (canapum).

Conclusions: The highest grain productivity was influenced by planting densities, with the density of three plants per pit being the one that resulted in the highest productivity (405.8 kg ha^{-1}). For the characteristic weight of 100 dry grains, the density of one plant per hole was the one that promoted the highest average weight with a maximum value of 28.24 g.

The Creole cultivar Canapum is agronomically viable for planting in the semi-arid region.

Keywords: *Agroecological production, Agronomic efficiency and Grain productivity.*

1. INTRODUCTION

Among the crops of economic interest for the northeast region, cowpea {*Vigna unguiculata* (L.)} stands out, originally from Africa, being introduced to Brazil in the 16th century in the state of Bahia [1]. The crop has a wide ability to adapt to soil conditions and has a low production cost, standing out for its high nutritional value, being a source of proteins, mineral salts and carbohydrates. These factors are of great importance as a source of nutrients. Furthermore, culture constitutes the strengthening and consolidation of Brazilian agribusiness [2].

The largest production of cowpeas is concentrated in the north and northeast regions, the latter being responsible for 64% of production in the 2019 harvest, with emphasis on the state of Ceará, with the largest planted area (359.5 thousand ha), however, presenting the second lowest productivity (305 kg ha^{-1}) [3]. The use of a low level of technology, associated with irregular rainfall and the use of cultivars poorly adapted to growing conditions, are among the main factors that cause the low yield of cowpea in the Northeast [4].

The current trend is the increased use of high technology in culture, which has led to a greater demand for highly productive cultivars that are well adapted to climate and soil conditions, being one of the main objectives of breeding programs [5]. Furthermore, cowpea cultivation is extremely important as a source of employment and income, especially for family farmers, considering that this segment normally requires manual labor, from planting to the grain threshing process. Now, marketing is done in bulk and open-air markets, and this activity is largely linked to farmers with a low technological level [5,6].

Given the importance of cowpea cultivation in the Northeast region of Brazil by farmers who work in agricultural activities and who use this crop for consumption and retail, it is extremely important to have the ideal planting density that provides the crop its maximum agronomic efficiency.

In view of the above, work was developed to evaluate the efficiency of different planting densities on cowpea productivity in the semi-arid region of Brazil.

2. MATERIAL AND METHODS

2.1 Location of the experiment installation

The experiment was conducted from September to December 2021 at the Rafael Fernandes experimental farm, in the district of Alagoinha (5º03'37 "S, 37º23'50" W), northwest of Mossoró, State of Rio Grande do Norte, Brazil, with an area of 400 hectares [7]. According to [8] and the Köppen classification, the local climate is BSwh', dry and very hot, with a dry season, often from June to January, and a rainy season from February to May, average annual precipitation of 673.9 mm and average relative humidity of 68.9%.

Before installing the experiment, soil samples were taken at a depth of 0-20 cm, which were air-dried and sieved in a 2 mm mesh, then analyzed at the Laboratory of Soil Chemistry and Fertility at UFERSA, whose results were the following: pH (water 1:2.5) = 7.7; Ca (calcium) = 2.6 cmol dm^{-3} ; Mg (magnesium) = 1.5 cmolc dm^{-3} ; K (potassium)= 56.0 mg dm^{-3} ; Na (sodium) = 10.0 mg dm^{-3} ; P (phosphor) = 4.8 mg dm^{-3}; M.O (organic matter)= 5.8 g kg^{-1} and N (nitrogen)= 0.62 g kg^{-1}.

2.2 Experimental Design

The experimental design used was randomized complete blocks with five treatments (1.0; 2.0; 3.0, 4.0 and 5.0 plants hole^{-1}) with four replications. Each plot consisted of dimensions of 3.5 m x 4.8 m, with six rows of 4.8 m in length, with a total area of 18.2 m^{2}, with the useful area being the four central rows, with dimensions of 2.8 x 4.8 m, with an area of 13.44 m^{2}, for collecting dry grains. The spacing used between rows was 0.70 m. Within the row, the spacing used was 0.40 m between pits, which resulted in 12 pits per row, corresponding to 35714; 71428; 107142; 142856 and 178570 plants ha^{-1}, at densities of 1.0; 2.0; 3.0; 4.0 and 5.0 plants hole^{-1}, respectively.

The preparation of the area consisted of weeding the bush, using a hoe, followed by marking the area, laying the hoses and digging the pits.

Planting was carried out on September 29, 2021, sowing corresponding to different planting densities. Thinning took place fifteen days after planting, and was carried out on October 14, 2021 (Figure 1).

Figure 1. Representation of the cowpea {*Vigna unguiculata* (L.)} plant area in the experimental area of the Universidade Federal Rural do Semiárido, Brazil. **Photograph:** Agricultural Engineer, Researcher and member of the Jitirana research group, Natalia Fernandes de Oliveira Alves.

Weeding was carried out regularly, as needed, to avoid competition for water and nutrients with weeds, especially in the initial phase of crop development. Irrigation was carried out via drip, with a daily irrigation shift divided into two applications (morning and afternoon).

2.2 Measurement of the Agronomic Characteristics of cowpea {*Vigna unguiculata* (L.)}

Dry beans were harvested, the first being carried out on November 25, 2021, for a total of three harvests (Figure 2).

Figure 2. Representation of the cowpea harvest on the experimental farm at the Universidade Federal Rural do Semi-arid, Brazil. **Photograph: Photograph:** Agricultural Engineer, Researcher and member of the Jitirana research group, Natalia Fernandes de Oliveira Alves.

After harvesting dry pods, they were stored in bags, identified and taken to the DCAF/UFERSA Post-Harvest laboratory, where the following characteristics were measured: Number of pods, expressed in units ha^{-1} (NV), length of pods, expressed in cm (CPV), weight of one hundred grains, expressed in grams (P100G), dry grain productivity, expressed in kg ha^{-1} (PG), number of grains pod^{-1}, expressed in units (GV), dry grain index, expressed in percentage (IGS) and pod production, expressed in grams (PV) of cowpea, Creole cultivar (canapum).

Statistical analysis

Statistical analysis was performed according to conventional methods of analysis of variance (BANZATO and KRONKA 1995), using ESTAT statistical software (Barbosa,

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Malheiros and Banzatto, 1992). The response curve fitting procedure was performed using the ESTAT Software (BARBOSA, MALHEIROS and BANZATTO, 1992).

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3. RESULTS AND DISCUSSION

There was a significant effect for all characteristics evaluated at p< 0.01 probability for all characteristics evaluated in cowpea (Table 1). Interspecific competition was probably a preponderant factor in the characteristics evaluated, having a direct influence on the development of the culture.

Table 1. F values for number of pods, expressed in units ha^{-1} (NV), pod length, expressed in cm (CPV), weight of one hundred grains, expressed in grams (P100G), dry grain productivity, expressed kg ha^{-1} (PG), number of grains pod^{-1}, expressed in units (GV), dry grain index, expressed as a percentage (IGS) and pod production, expressed in grams (PV) of cowpea, Creole cultivar (canapum).

Causes of Variation	GL	NV	CPV	P100G	PG	GV	IGS	PV
Blocks	3	23.18**	0.4^{ns}	3.4^{ns}	13,2**	2.9^{ns}	2.9^{ns}	6.9**
Treatments	4	7.63**	15.6**	11.2**	14.8**	16.5**	0.9^{ns}	6.17**
Residue	12	---	---	---	---	-----	------	-----
Overall Average	----	105600	16.8	27.3	343.8	14.1	80.8	489.5
CV (%)	----	23.09	3.6	6,5	23.1	4.0	2.80	8.24

** = P<0,01; * = P<0,05; ^{ns} = not significant

There was a linear adjustment for the pod length characteristic, with the density of one plant per pit, which promoted the greatest length at 17.3 cm (Figure 3). This decrease with the increase in planting densities is probably related to the plants' nutrient requirements. [11], studying the evaluation of pod bean lines for the North and Northwest regions of Rio de Janeiro, found an average value of 13.86 cm, which is lower than this characteristic. Freitas [12], studying the morphological and agronomic characterization of cowpea accessions collected in municipalities in RN, found a general average of 20.84 cm, a value higher than that of the aforementioned research. [13] observed that the length of pods was not significantly affected by plant populations, with an average plant length of 14.99 cm for the BRS Novaera cultivar, being lower than the aforementioned research.

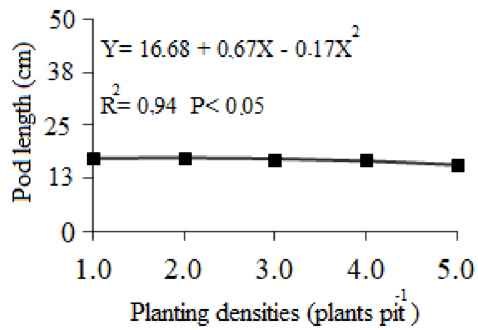

Figure 3. Cowpea pod length {*Vigna unguiculata* (L.)}, Creole cultivar (Canapum), in the semi-arid region of Brazil.

For the characteristic number of pods ha^{-1}, there was a statistical difference at the 1% probability level, with the density of four plants per pit providing the highest number of pods per hectare with a maximum value of 130,31 ha^{-1} (Figure 4). This characteristic is important because it highlights the greater grain production after threshing the pods. [14], the number of pods $plant^{-1}$ is the basic component that most relates to the grain productivity, being greatly influenced by the environment. [15], higher densities of cowpea plants result in an excessive number of plants in the line, with less availability of photoassimilates for their development.

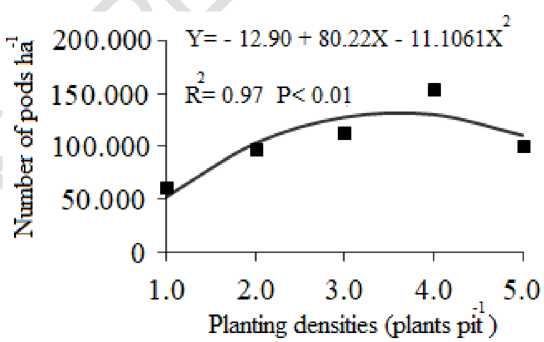

Figure 4. Number of cowpea pods {*Vigna unguiculata* (L.)}, Creole cultivar (Canapum), in the semi-arid region of Brazil.

For the number of grains per pod, the density of one plant per pit presented the highest number, with an average value of 14.6 pods, with a statistical difference in relation to the other densities (Figure 5). Freitas (2020), studying the morphological and agronomic characterization of cowpea accessions collected in municipalities in Rio Grande Norte, Brazil, found an average of 74.61 in five pods, equivalent to 14.8 grains dry $pods^{-1}$. For [16].

(2003), the component number of grains per pod is of little importance for increasing productivity, as it presents a low correlation for this characteristic. [17] states that this characteristic has high genetic heritability, being little influenced by the environment. Saraiva et al. (2020), studying productive aspects and biomass of cowpea (*Vigna unguiculata* L.) under doses of bovine biofertilizers in agroecological cultivation, found a number of grains per pod of 13.4 units, a value lower than that of the present research.

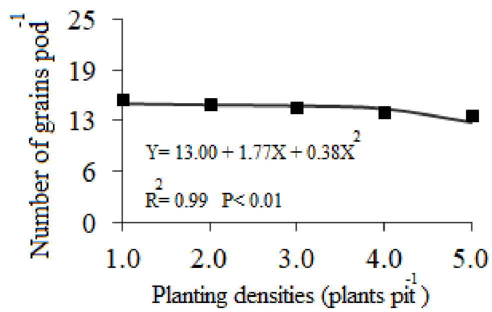

Figure 5. Number of grains per cowpea pod {*Vigna unguiculata* (L.)}, Creole cultivar (Canapum), in the semi-arid region of Brazil.

Planting density influenced the characteristic weight of 100 dry grains, where it was observed that the density of one plant per hole, presented the highest average weight of dry grains, with a maximum value of 28.24g, with a decrease due to the increase in densities of planting (Figure 6). [19], studying the yield of dry grains and production components of cowpea cultivars (*Vigna unguiculata* L.) in cultivars irrigated in the dry season in Pedro Afonso – Tocantins, found a maximum weight of 19.05g, being less than said research. This component constitutes a productivity factor, being greatly influenced by the environment [19]. Freitas (2020) found an average weight of 100 grains of 19.91g, a value below that of the aforementioned research. The decrease in the weight of 100 grains depending on planting densities is probably due to intraspecific competition. Saraiva et al. (2020), studying productive aspects and biomass of cowpea (*Vigna unguiculata* L.) under doses of bovine biofertilizers in agroecological cultivation, found a weight of 100 grains of 25.6g, a value lower than the present research.

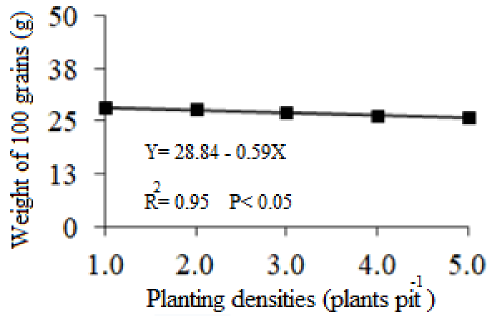

Figure 6. Weight of 100 grains of cowpea {*Vigna unguiculata* (L.)}, Creole cultivar (Canapum), in the semi-arid region of Brazil.

Grain productivity was influenced by planting densities, with the density of three plants per hole being the one with the highest productivity, with 405.8 kg ha^{-1}, with a decrease for densities of four and five plants per hole, with productivity of 396.6 and 325.4 kg ha^{-1} respectively (Figure 7). This decrease with the increase in plant population is due to interspecific competition, which is more intense in the canopy, enhancing apical dominance to the detriment of the development of lateral branches Bezerra et al. (2010).

Productivity is the most important component for farmers working in this activity, and it is important to use cowpea cultivars adapted to the region's climate and soil conditions, which can express their agronomic potential. Freitas (2020), studying the morphological and agronomic characterization of cowpea accessions collected in municipalities in Rio Grande Norte, Brazil, found an average productivity of dry pods in the second harvest of accessions A323, AC10 and AC22 of 286.51, 324.41 and 355.90 kg ha^{-1}, values lower than the aforementioned research. According to [21], the formation of pods under organic fertilizer is extremely important, in addition to the use of crop residues to supply nutrients to the soil and subsequently their availability for the crop. [21].

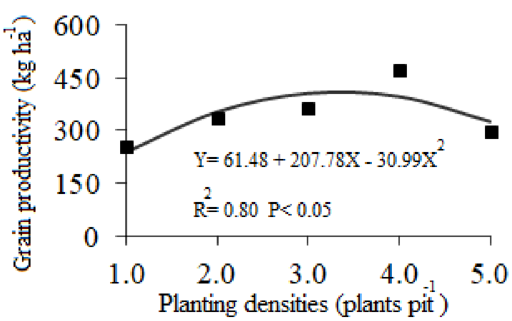

Figure 7. Grain productivity of cowpea {*Vigna unguiculata* (L.)}, Creole cultivar (Canapum), in the semi-arid region of Brazil.

The highest pod productivity was obtained at a density of three plants per pit, with a maximum value of 643.48 kg ha^{-1}, with a decrease at the highest densities, with values of 593.39 and 389.34 kg ha^{-1} at densities of four and five plants per hole, respectively (Figure 8). Freitas (2020), studying the morphological and agronomic characterization of cowpea accessions collected in municipalities in Rio Grande do Norte, Brazil, found productivity of dry pods in the first harvest of 514; 520; kg ha^{-1} for accessions AC13 and AC19, values lower than the aforementioned research. This decrease with the increase in the plant population is due to interspecific competition, which is more intense in the canopy, which enhances apical dominance to the detriment of the development of lateral branches Bezerra et al. (2010).

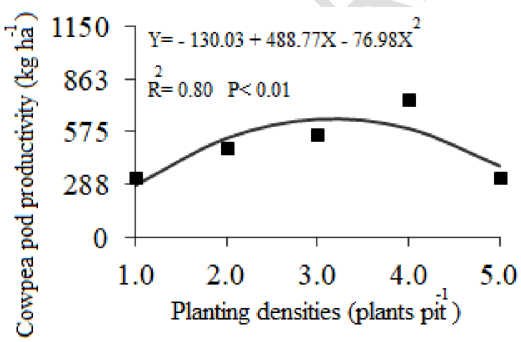

Figure 8. Cowpea pod productivity {*Vigna unguiculata* (L.)}, Creole cultivar (Canapum), in the semi-arid region of Brazil.

CONCLUSION

The highest grain productivity was influenced by planting densities, with the density of three plants per pit being the one that resulted in the highest productivity (405.8 kg ha^{-1}).

For the characteristic weight of 100 dry grains, the density of one plant per hole was the one that promoted the highest average weight with a maximum value of 28.24 g.

The Creole cultivar Canapum is agronomically viable for planting in the semi-arid region.

REFERENCES

1. FREIRE Filho FR, Ribeiro VQ, Rocha MM, Silva KJD, Nogueira MSR, Rodrigues EV (2011). Cowpea in Brazil: production, genetic improvement, advances and challenges. Teresina: Embrapa Meio-Norte, 2011, 84p.

2. Freire Filho FR, Ribeiro VQ, Alcântara J dos P, Belarmino Filho J, Rocha M de M, Marataiã (2005). New cowpea cultivar with evergreen grain. Ceres Magazine, 52(303):771-777.

3. CONAB, National Supply Company. MONITORING OF THE BRAZILIAN GRAIN CROP. v. 8 - 2020/21 harvest n.2 - Second survey, November 2020.

4. Matos Filho CHA, Gomes RLF, Rocha MM, Freire Filho FR, Lopes ACL (2009). Productive potential of cowpea progenies with erect plant architecture. Ceres Magazine, 39(2):348-354.

5. Freire Filho FR, Ribeiro VQ, Rodrigues JELF, Vieira PFMJA (2017). Culture: socioeconomic aspects. In: VALE, J. C. do; BERTINI, C.; BORÉM, A. (eds.). Cowpea: from planting to harvesting. Viçosa: Ed. UFV, chap. 1, 9-34.

6. Santos JAS, Soares CMG, Corrêa AM, Teodoro PE, Ribeiro LPE, Abreu HKA (2014). Agronomic performance and genetic dissimilarity among cowpea (Vigna unguiculata (L.) Walp.) genotypes. Global Advanced Research Journal of Agricultural Science, 3(1):271-277.

7. Rêgo LGS, Martins CM, Silva EF, Silva JJA, Lima RNS (2010). Pedogenesis and classification of soils in an experimental farm in Mossoró, Rio Grande do Norte, Brazil. Revista Caatinga,2016;29(4):1036-1042.

8. Carmo Filho F and Oliveira OF 1995. Mossoró: a municipality in the semi-arid northeast, climatic characterization and floristic aspect. Mossoró: ESAM, (Mossoroense Collection, Series B) 62p.

9. Banzatto DA, Kronka SN. Agricultural experimentation. 3rd ed. Jaboticabal: FUNEP, 1995:245p.

10. Barbosa JC, Malheiros EB, Banzatto D. A. ESTAT: A system for statistical analysis of agronomic trials. Jaboticabal: Unesp, Version 2.0. 1992.

11. FRANCELINO, F. M. A.; GRAVINA, G. A.; MANHÃES, C. M. C.; CARDOSO, P. M. R. Evaluation of snap bean lines for the North and Northwest regions of Rio de Janeiro. Agricultural Science Magazine, v. 42, no. 2, p. 554-562, 2011.

12. FREITAS, S.Q. Agronomic characterization of cowpea accessions collected in municipalities in the state of Rio Grande do Norte. 2010. 39f. Monograph (undergraduate) – Federal Rural University of the Semi-Arid (UFERSA), Mossoró, 2020.

13. Martins, C. M.; Martins, S. C. S.; BORGES, W. L. Acidity correction, fertilization and biological fixation. In: Vale, J. C.; Bertini, C.; Borém, A. Cowpea from planting to harvest. Viçosa: UFV, 2017. Ch.5, p.89-112.

14. Silva AO, Lima EA & Menezes HEA (2007) Yield of bean grains (Phaseolus vulgaris L.), cultivated at different planting densities. Revista das Faculdades Integradas de Bebedouro, 3:1-5

15. Martins CM, Martins SCS, Borges WL (2017). Acidity correction, fertilization and biological fixation. In: Vale, J. C.; Bertini, C.; Borém, A. Cowpea from planting to harvest. Ch.5: 89-112.

16. Oliveira FJ, Anunciação Filho CJ, Bastos GQ, Reis OV, Teófilo EM (2003). Agronomic traits applied in the selection of cowpea cultivars. Agricultural Science Magazine, 34(2):5-11.

17. Lopes ADA S, Oliveira GQ De, Souto Filho SN, Goes RJ, Camacho MA (2011). Irrigation and nitrogen management in common bean grown in a direct planting system. Agricultural Science Magazine, 42(2):51-56.

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18. Saraiva KR, Oliveira KR, Marques Filho F, Silva Fs, Silva FS, Sales JRS (2020). Productive aspects and biomass of cowpea (Vigna unguiculata) under doses of bovine biofertilizer in agroecological cultivation. Family Agriculture: Research, Training and Development, 14(1): 184-198.

19. Carvalho CDM, Francelino FMA, Manhães CMC, Silva MPS, Ribeiro EC, Bueno JAR (2020). Dry grain yield and production components of cowpea cultivars (Vigna unguiculata L.) in irrigated cultivation in the dry season in Pedro Afosno – To. Scientific Initiation and Extension Day. Federal Institute of Tocantins. P. 1-8.

20. Bezerra AAC, Távora FJAF, Freire Filho FR, Ribeiro VQ (2010). Canopy and yield characteristics in erect cowpea at different densities. Brazilian Agricultural Research, 44(10):1239-1245.

21. Davari M, Sharma SN, Mirzakhani M (2012). Residual influence of organic materials, crop residues, and biofertilizers on performance of succeeding mung bean in an organic rice-based cropping system. International Journal of Recycling of Organic Waste in Agriculture, 1(1):14.