

Evaluation of two cowpea (*Vigna unguiculata* (L.) Walp.) genotypes under rainfed farming with low rainfall

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ABSTRACT

The sustainable agriculture in drylands depends on stored soil water, efficient use of water, prevention of soil degradation, and the use of crops that have drought tolerance. Dryland regions in the world are vulnerable ecosystems, for that reason, productive crops associated with erratic and low rainfall, and different land-use practices are fundamentals for dryland cropping systems. Cowpea (*Vigna unguiculata* (L.) Walp.) is an excellent crop for research in dryland regions due to high genetic variability, excellent nutritional value, wide adaptive capacity, high productive potential, and strategic values. We tested the productive performance of two cowpea genotypes in rainfed planting, during low rainfall (< 200mm), and on two different land-use conditions. Our results show that there are variations among the characters between Roxinho and Corujinha genotypes evaluated. Roxinho had more yield than Corujinha in rainfed farming with low rainfall. Besides that, Roxinho genotype shows a stable yield regardless of the environmental conditions evaluated. Yield and total dry mass show major contributions to genetic divergence and major heritability values. Therefore, phenotypic selection can be applied based on yield and using the number of vargem per plant as an indirect variable due to correlation among them.

Keywords: Drylands, semiarid, sustainable agriculture.

Avaliação de dois genótipos de feijão-caupi (*Vigna unguiculata* (L.) Walp.) sob cultivo de sequeiro com baixa pluviosidade

RESUMO

Agricultura sustentável em regiões de terras secas depende da água armazenada no solo, uso eficiente da água, prevenção da degradação do solo e uso de culturas tolerantes à seca. As regiões de terras secas no mundo são ecossistemas vulneráveis e, por esse motivo, culturas produtivas associadas a chuvas irregulares e baixa precipitação, bem como associados a diferentes práticas de uso da terra, são fundamentais para os sistemas de cultivo em terras secas. O feijão-caupi (*Vigna unguiculata* (L.) Walp.) É uma excelente cultura para essas regiões devido à alta variabilidade genética, excelente valor nutricional, ampla capacidade adaptativa e alto potencial produtivo. Nesse artigo, nós testamos o desempenho produtivo de dois genótipos de feijão-caupi em regime de sequeiro, durante baixa precipitação (<200 mm) e em duas condições diferentes de uso da terra. Nossos resultados mostram que há variações entre os caracteres dos genótipos Roxinho e Corujinha avaliados. Roxinho teve maior produtividade que Corujinha, em um plantio de sequeiro com baixa pluviosidade. Além disso, o genótipo Roxinho apresentou rendimento estável, independentemente das condições ambientais avaliadas. O rendimento e a massa seca total mostram grandes contribuições para a divergência genética e os principais valores de herdabilidade. Portanto, uma seleção fenotípica pode ser aplicada com base no rendimento e usando o número de vargem por planta como variável indireta devido à correlação entre elas.

Palavras-Chaves: Agricultura sustentável, semiárido, terras secas

1. Introduction

The sustainable agriculture depends on “integrated approaches which make the best use of nature’s goods and services and human technologies and practices to improve rural worker’s lives by increasing agricultural productivity” (Sheerr & McNelly, 2008; Silva & Barbosa, 2018). These practices must be frequent in semi-arid regions due to agriculture success in drylands depends on stored soil water, efficient use of water, prevention of soil degradation, and the use of crops that have drought tolerance (Peterson et al., 2006; Stewart, 2016; Stewart et al., 2006). Therefore, a strategy dryland agriculture is keeping crop yield with efficient water use in a local with rare and erratic water available.

The Caatinga is the major dryland region from South America, is located in the Brazilian northeast, and ranges 912,529 km². This region harbors about 28.6 million people, has an economy based mainly on public services and presents low indicators for human development (Silva et al., 2017). The original vegetation is composed of dry forests and woodlands (de Queiroz et al., 2017), but human and nature interactions are characterized by acute and chronic disturbances that broken ecosystems services necessities for local sustainable (Silva et al., 2017).

Annual and interannual climate variation and different land use and land cover represent the landscapes in Caatinga. However, the land use changed by inadequate agricultural practices provided biodiversity decreasing, soil degradation, agricultural areas decreasing, agricultural production reducing, consequences to current climate change, economical losses, and poverty increasing (Sá et al., 2010; Santana, 2007). Ecology restoration is urgent in many Caatinga areas, but the union this practice with correct dryland agricultural activities is an important strategy for environmental restoration keeping agricultural productivity. Dryland cropping systems must integrate crop choices to minimize production risk (Baumhardt & Anderson, 2006). Therefore, productive crops under erratic, low, and varied rainfall, as well as associated with different land use practices, are fundamentals for dryland cropping systems.

Cowpea (*Vigna unguiculata* (L.) Walp.) is an excellent crop for research in the semiarid regions. It has high genetic variability, excellent nutritional value, wide adaptive capacity, high productive potential, and strategic values (Freire-Filho, 2011). Besides that, cowpea shows abiotic tolerances, as temperature and low rainfall, and needs 300mm for satisfactory production in rainfed agriculture (Silva et al., 2016; Silva et al., 2018). Brazil has the third major cowpea production in the world, with 1,512.7 thousand hectares of planting areas and average yield of 469 kg.ha⁻¹ during 2018/19 (CONAB, 2018). The major planting area is in the northeastern region, with 1.194,1 thousand hectares and an average yield of 326 kg.ha⁻¹.

In this paper, we tested the productive performance of two cowpea genotypes in rainfed planting, during low rainfall (< 200mm), and on two different land-use conditions. We also evaluated genetic characteristics from genotypes to identify indicators that can be used in the genetic breeding to improve traits associated with efficient dryland agriculture.

2. Methods

The experiment was conducted in two sites from Cariri Paraibano during 2018 (Figura 1). In this region, the annual rainfall ranges from 400 to 800 mm, and over 60% of this is concentrated in February, March, and April (Alvares et al., 2013). The annual average temperature and humidity are 25°C and 65%, respectively. The planting on the degraded landscape was in the municipality of São João do Cariri, where historically occurred extensive goat farming and exploratory removal of native vegetation. Currently, this region is characterized as a desertification nucleus in Brazilian semiarid named Cariris Velhos (Perez-Marin et al., 2012; Travassos & Sousa, 2014). Another planting was at Fazenda São Paulo dos Dantas, in the municipality of Prata. Agricultural practices as the use of crop selections, mixed farming associated with crop rotations, and crop-livestock systems are frequent on this farm during the last 40 years. These activities occur about 40% of the farm, and another 60% corresponds to natural vegetation. In both localities, the experiments were done on

Luvisol. During the planting done in 2018, the rainfall was 182mm and 190mm in São João do Cariri and Prata, respectively.

We selected two cowpea genotypes used by farmers in the Cariri Paraibano locally named Corujinha and Roxinho (Figure 2). These genotypes were classified according to Freire-Filho (2011) (Table 1). The experiment was conducted in randomized blocks design with two treatments (2 genotypes and 2 environments) and eight replications. The blocks consisted of 10m long by 4m wide with four lines where plants were separated by 0.7 m. The two central lines were used in our analyses, eliminating borders, and the sampling unit was 10 plants per block. The tillage was carried out conventionally with plowing and harrowing. Sowing was performed with the use of three seeds per pit, and after 15 days was thinned. Harvesting was performed about 65 days after planting.

We analyzed the following characteristics: number of flowers per inflorescence, length of vargem, number of vargem per plant, number of grains per vargem, total dry mass, 100 dry grain mass, and yield. The results were submitted to analysis of variance using the F test, and the averages were compared by the Tukey test.

We also used the genetic parameters and estimators based on analysis of variance with the following expressions:

- a) Environmental variance: $(\sigma^2 E) = QMr/k$
- b) Variance of genotypes: $(\sigma^2 G) = (QMg - QMr)/k$
- c) Variance of phenotypes: $(\sigma^2 F) = (QMg)/kl$
- d) Coefficient of genetic variation: $(CVg) = \frac{\sqrt{\sigma^2 G}}{m} \times 100$
- e) Ratio: $(CVg/CVe) = \sqrt{\frac{\sigma^2 G}{\sigma^2 E}}$
- f) Heritability: $(h^2) = \frac{\sigma^2 G}{\sigma^2 F}$

When: QMr = means square of blocks (replications); QMg = means square of genotype; k = number of replications; m = average of experiments; l = number of environments.

The relative contribution of each characteristic was evaluated according to the method proposed by Singh (1981), based on the generalized Mahalanobis distance (D^2).

Statistical analyses were performed using the Computational Genes program (Cruz, 2013).

Figure 1: Location of the study area in Cariri Paraibano, Northeast, Brazil. Estação experimental de São João do Cariri in the municipality of São João do Cariri, and Fazenda São Paulo dos Dantas in the municipality of Prata.

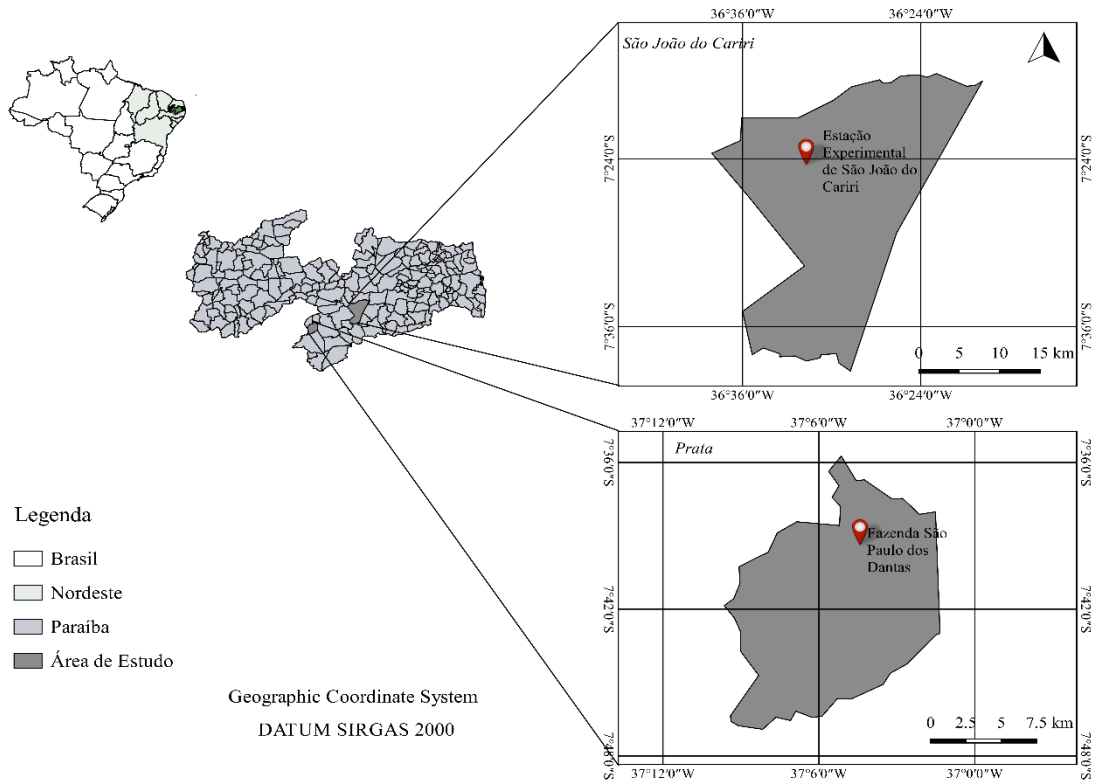


Figure 2: Seeds of cowpea (*Vigna unguiculata* (L.) Walp.) genotypes used in this work and locally named: A) Corujinha and B) Roxinho.

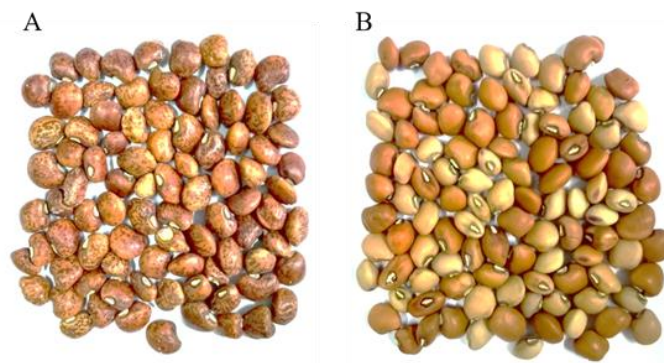


Table 1: Classification of Corujinha and Roxinho genotypes according to Freire-Filho (2011).

Genotypes	Class	Subclass	Shape
Corujinha	Colors	Corujinha	Round
Roxinho	Colors	Mulato liso	Oval

3. Results

The number of vargem per plant, total dry mass, and yield varied significantly between the two genotypes studied (Table 2). The number of vargem per plant varied between two environments but did not influence the total dry mass and yield (Table 2). In the environment and genotype interaction, total dry mass and yield variations indicate different genotype performances between the environments (Table 2). The Roxinho genotype showed variation in total dry mass but not in yield between the environments. However, the Roxinho genotype showed higher values of total dry mass and yield when compared to the Corujinha genotype regardless of the environments (Figure 3).

The number of vargem per plant, total dry mass and yield also showed heritability values (h^2) higher than 90% indicating that phenotype selection can be done based on these characters (Table 2). The ratio CV_g/CV_e for total dry mass and yield was higher than 1 supporting the possibility of the individual phenotype selection. The ratio CV_g/CV_e for the number of vargem per plant was less than 1 indicating dominance genetic interaction. However, the number of vargem per plant explains 72.5% of the yield data variation for Roxinho genotype ($R^2 = 0.725$).

The relative contribution for genetic divergence shows that yield (65%) and total dry mass (23%) had a higher contribution to explain the variability between the two genotypes. The number of flowers per inflorescence and the number of vargem per plant had lower contributions (Figure 4).

Table 2: Analysis of variance among the characters evaluated of two cowpea genotypes under rainfed planting, during low rainfall.

	DF	Characters						
		NFI	LV	NVP	NGV	TDM	DGM100	YIELD
Blocks	7	4,80	4,17	4,15	2,78	373,37	7,22	2104,37
Genotypes	1	0,25 ^{ns}	0,34 ^{ns}	72,30 ^{**}	12,74 ^{ns}	93786,72 ^{**}	51,92 ^{ns}	236306,81 ^{**}
Environments	1	4,99 ^{ns}	9,76 ^{ns}	30,69 [*]	3,38 ^{ns}	3127,02 ^{ns}	3,07 ^{ns}	393,40 ^{ns}
G × E	1	0,005 ^{ns}	0,42 ^{ns}	1,16 ^{ns}	1,77 ^{ns}	11073,32 [*]	8,92 ^{ns}	34737,47 [*]
Residuals	21	1,56	2,67	7,01	3,85	1678,18	21,12	6324,64
Tot	31	-	-	-	-	-	-	-
σ^2G	-	0	0	4,08	0,55	5756,78	1,92	14373,88
$\sigma^2G \times E$	-	0	0	0	0	1174,39	0	3551,60
σ^2 residual		1,55	2,67	7,01	3,85	1678,18	21,12	6324,64
h^2	-	0	0	90,29	69,74	98,21	59,31	97,32
CVg (%)	-	0	0	36,45	6,57	89,42	5,05	76,62
CVg/CVe (%)	-	0	0	0,76	0,38	1,85	0,30	1,51
CV	-	19,93	8,87	47,8	17,31	48,28	16,75	50,82

DF: degrees of freedom; NFI: number of flowers per inflorescence; LV: length of vargem; NVP: number of vargem per plant; NGV: number of grains per vargem; TDM: total dry mass; DGM100: 100 dry grain mass; and YIELD: yield. *: significance 5%; **: significance 1%; ns: n-significance.

Figure 3: Variation (average: column; standard-deviation: whisker) of character values between Corujinha and Roxinho cowpea genotypes during rainfall experiment with low rainfall (< 200mm), in the Brazilian semiarid region. The letters above the bars represent the result of Tukey's tests. Capital letters show comparisons of the same genotypes between the two environments. Lower case letters show comparisons between different genotypes in the same environment.

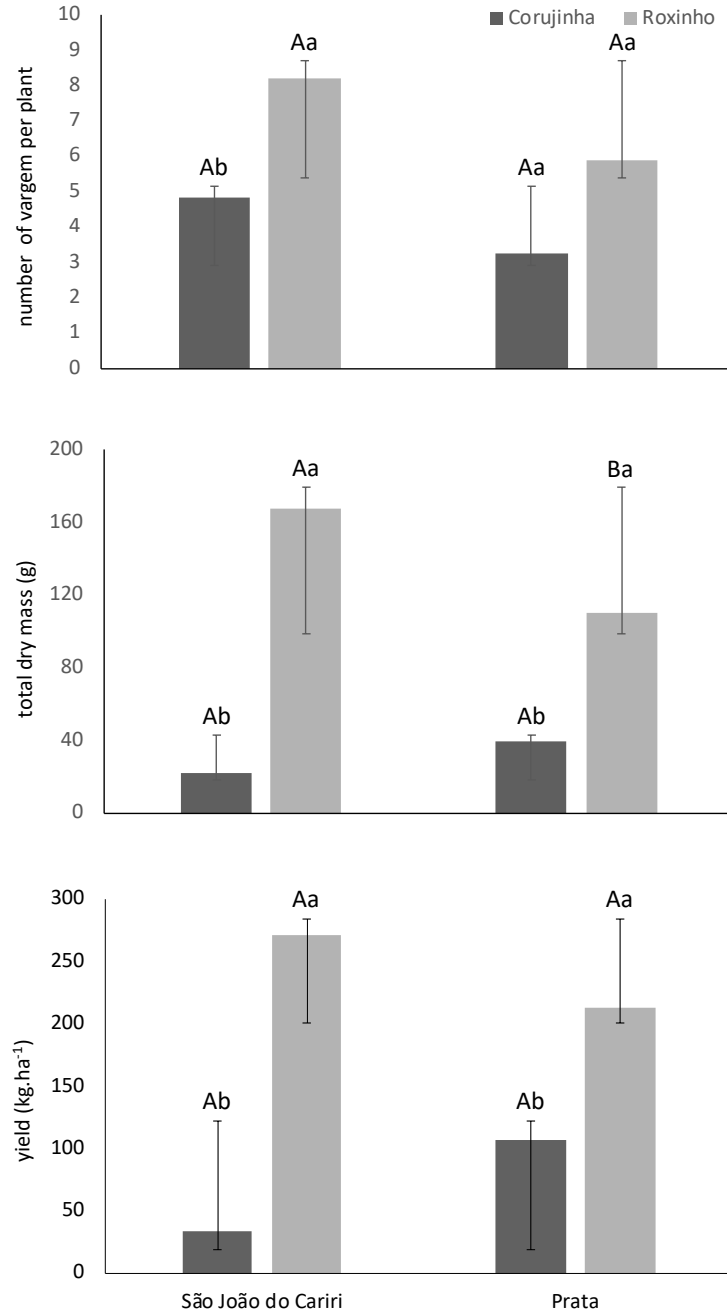
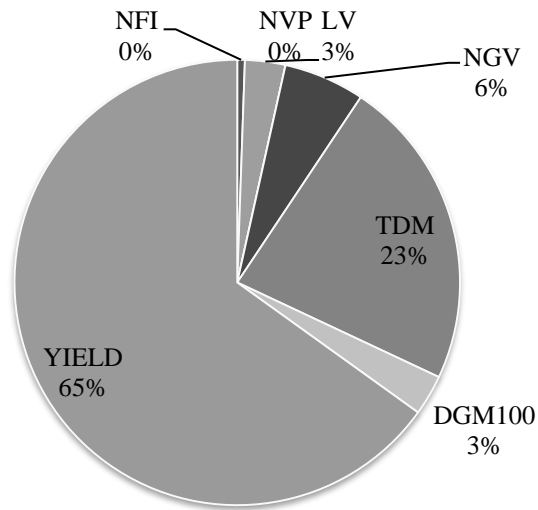


Figure 4: Relative contribution for genetic divergence of characters evaluated of two cowpea genotypes under rainfed planting, during low rainfall.



NFI: number of flowers per inflorescence; LV: length of vargem; NVP: number of vargem per plant; NGV: number of grains per vargem; TDM: total dry mass; DGM100: 100 dry grain mass; and YELD: yield.

4. Discussion

Our results show that there are variations among the characters between Roxinho and Corujinha genotypes cowpea. Roxinho had more yield than Corujinha in rainfed farming with low rainfall (< 200mm) and in landscapes with different land-use. Besides that, Roxinho genotype shows a stable yield (about 242.40 kg/ha) regardless of the environmental conditions evaluated. Yield and total dry mass show major contributions to genetic divergence and major heritability values. Therefore, phenotypic selection can be applied based on yield and using the number of vargem per plant as an indirect variable due to correlation among them.

The occurrence of the variation between Roxinho and Corujinha genotypes cowpea is essential to performance genetic breeding design and can accelerate conventional breeding (Mendonça et al, 2018). Variation among the cowpea characters have been shown by some authors (Gerrano et al., 2015; Barroso et al., 2017; Sharma et al., 2017; Mendonça et al., 2018), but our results demonstrated the variation importance to development of crop in a dryland condition with low rainfall (< 200mm) and in locals with different land-use practices. Therefore, it is possible to invest in research to select advanced cowpea genotypes using traditional germplasms with a focus on yield and dry tolerance. Breeders are interested in advanced genotypes with high genetic potential and sufficient divergence to generate variability in segregating populations (Elias et al., 2007). The Roxinho genotype was more productive than Corujinha in the different environmental conditions analyzed and, consequently, it is suggested that Roxinho be selected.

The high heritability values for the number of vargem per plant, total dry mass, and yield are related to selection gains. When heritability values are high, there is more chance of strategy success of selection (Gatut; Wahyu et al., 2014). Our results show selection by phenotype can be used because of the heritability values were higher than 80%, the ratio CV_g/CV_a was higher than 1, and the contribution values for divergence were high. For that reason, the number of vargem per plant, total dry mass, and yield are characters point out as indicators for selection.

The number of vargem per plant can be used as a practical surrogate character to initial selection by local farmers. When a character is hard to measure, as total dry mass and yield in the field, the indirect selection can be recommended by a character with high heritability value and easy evaluation (Krishna, et al., 2007; Cruz et al., 2012; Nascimento, 2015). The number of vargem per plant explained 72.5% of the yield data variation for the Roxinho genotype. Therefore, this character can be easily used in the field by local farmers. The reference values of an ideal number of vargem per plant are between 8 and 10 (Ramos et al., 2014).

The Roxinho genotype yield was 271.8 kg.ha⁻¹ in the municipality of São João do Cariri and 212,96 kg.ha⁻¹ in the municipality of Prata. Higher yields, until five times, were seen in the Caatinga region with irrigation conditions (eg. Silva & Oliveir,1993; Santos et al., 2009). However, our results are similar to the average yield of all state of Paraíba during 2018 (234 kg.ha⁻¹) (CONAB 2018). Different from irrigation or higher rainfall conditions, our results show yield during low rainfall (< 200 mm). For that reason, the Roxinho yield represents strategic stability when there is low water available and different land-use in a landscape.

5. Conclusion

The Roxinho genotype yield is indicated to dryland agriculture when rainfall is low, and the number of vargem per plant can be used to select individuals more productive focusing on initial selection. Therefore, this genotype is a strategic crop to production and research when erratic and low rainfall occurs, as well as when there are different land-use practices in the dryland landscapes.

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Informações adicionais

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