

DESEMPENHO PRODUTIVO E EFICIÊNCIA NO USO DA ÁGUA E DA TERRA EM SISTEMAS SOLTEIROS E CONSORCIADOS DE MILHO E FEIJÃO-CAUPI ESTABELECIDOS EM DISTINTAS ÉPOCAS NO SEMIÁRIDO

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RESUMO: Consórcios de milho e feijão-caupi podem otimizar o uso da água e da terra, promovendo maior estabilidade produtiva na agricultura de sequeiro no semiárido. Objetivou-se avaliar a produtividade de grãos verdes de feijão-caupi e de espigas verdes de milho, relacionando-a aos indicadores de eficiência no uso da água e da terra em sistemas de cultivo solteiros e consorciados, envolvendo feijão-caupi e dois genótipos de milho (híbrido e variedade), implantados em distintas épocas de semeadura sob condições de sequeiro no semiárido cearense. O experimento foi conduzido entre fevereiro e maio de 2025, em Iguatu (CE), utilizando delineamento em blocos casualizados, em parcelas subdivididas, com três repetições. As semeaduras ocorreram em 20 de fevereiro e 21 de março. Avaliaram-se sete sistemas: feijão-caupi solteiro (BRS Pujante), milho híbrido solteiro (PR27D28), milho variedade solteiro (BRS Caatingueiro), milho híbrido consorciado com feijão-caupi, milho variedade consorciado com feijão-caupi, feijão-caupi consorciado com milho híbrido e feijão-caupi consorciado com milho variedade. A semeadura precoce favoreceu o desempenho produtivo das culturas pela maior disponibilidade hídrica ao longo dos ciclos. O milho híbrido solteiro apresentou maiores produtividades e eficiência no uso da água, enquanto o feijão-caupi obteve melhor desempenho em cultivo solteiro, com redução nos consórcios. Os sistemas consorciados otimizaram-na.

Palavras-chaves: *Zea mays* L., *Vigna unguiculata* L. Walp., Agricultura de sequeiro.

PRODUCTIVE PERFORMANCE AND EFFICIENCY IN WATER AND LAND USE IN SOLE AND INTERCROPPED CORN AND COWPEA SYSTEMS ESTABLISHED AT DIFFERENT SEASONS IN THE SEMI-ARID REGION

ABSTRACT: Corn and cowpea intercropping can optimize water and land use, promoting greater production stability in rainfed agriculture in semiarid regions. The objective was to evaluate the productivity of green cowpea grains and green corn ears, relating it to indicators of water and land

Recebido em 05/11/2025 e aprovado para publicação em 10/12/2025

DOI: <http://dx.doi.org/10.17224/EnergAgric.2025v40p112-117>

use efficiency in single and intercropped systems involving cowpea and two corn genotypes (hybrid and variety) planted at different sowing times under rainfed conditions in the semiarid region of Ceará. The experiment was conducted between February and May 2025 in Iguatu (CE) using a randomized block design in subdivided plots with three replications. Sowing took place on February 20 and March 21. Seven systems were evaluated: single cowpea (BRS Pujante), single hybrid corn (PR27D28), single corn variety (BRS Caatingueiro), hybrid corn intercropped with cowpea, corn variety intercropped with cowpea, cowpea intercropped with hybrid corn, and cowpea intercropped with corn variety. Early sowing favored crop productivity because of greater water availability throughout the cycles. Single hybrid corn resulted in higher yields and water use efficiency, whereas single-cropping resulted in better yields and water use efficiency, with a reduction in intercropping. Intercropping systems optimized it.

Keywords: *Zea mays* L., *Vigna unguiculata* L., Walp., Rainfed agriculture.

1 INTRODUCTION

In the semiarid region of Brazil, strategies such as intercropping corn and cowpea have been adopted to optimize water and land use in the face of high climate variability (Souza *et al.*, 2004).

However, agronomic results under rainfed conditions are still inconsistent and are influenced by interactions between crops, environmental conditions, and genotypes (Ponce-Encinas). *et al.*, 2022). The sowing season, in turn, plays a decisive role in affecting water availability in the soil (Cunha *et al.*, 2019).

In this context, it becomes necessary to investigate the interactions among cropping systems, genotypes, and sowing times to achieve greater productive efficiency and resilience in semiarid regions.

Thus, the objective was to evaluate the productivity of green cowpea grains and green corn ears, associating it with indicators of efficiency in the use of water and land in single and intercropped cropping systems involving cowpea and two corn genotypes (hybrid and variety) established at different sowing times under rainfed conditions in the semiarid region of Ceará.

2 MATERIALS AND METHODS

The experiment was conducted in the experimental area of the Federal Institute of Ceará–Iguatu Campus (6°39' S, 39°26' W; 218 m altitude) in Iguatu, CE, during the rainy season of 2025 (February to May). The climate

is hot semiarid (BSh), and the soil is classified as an Argisol with a sandy loam texture (0–0.20 m).

A randomized block design with 2×7 split plots was used, corresponding to two sowing dates and seven cropping systems involving cowpea and two maize genotypes (hybrid and variety) in monoculture and intercropping, with three replications, totaling 42 experimental units. Each plot measured 15 m², with a spacing of 0.75 m between rows and 0.20 m between plants, with a density of five plants per linear meter. The sowing dates were February 20 and March 21, 2025.

The treatments included (1) cowpea alone (BRS Pujante), (2) hybrid maize alone (PR27D28), (3) maize variety alone (BRS Caatingueiro), (4) hybrid maize intercropped with cowpea, (5) maize variety intercropped with cowpea, (6) cowpea intercropped with hybrid maize, and (7) cowpea intercropped with maize variety.

The soil was prepared by plowing and harrowing, followed by manual sowing, with fertilization according to soil analysis. During cultivation, all necessary management practices were employed.

The productivity of fresh green corn ears and green cowpea grains was evaluated 69 days after sowing in the usable area of each unit and expressed in kg ha⁻¹. Crop evapotranspiration (ET_c) was estimated by multiplying the reference evapotranspiration (ET_o) calculated using the FAO Penman–Monteith method. based on specific crop coefficients (K_c) for each crop and growth stage, allowing the calculation of supplemental

water requirements (SWR) and relative water satisfaction (RWS).

Rainwater productivity was obtained as the ratio between grain and/or green ear productivity and the total accumulated precipitation between sowing and harvesting, expressed in $\text{m}^3 \text{ ha}^{-1}$, according to Gebremedhin *et al.* (2023). Land use efficiency (LUE) was estimated on the basis of the methodology of Willey (1979).

The data were analyzed using analysis of variance and compared using Tukey's test at a 5% probability level with ASSISTAT software.

3 RESULTS AND DISCUSSION

Analysis of variance (not shown) revealed a significant effect of sowing time on grain yield (cowpea) and green ear yield (maize genotypes) (PGEV) and water productivity (PAGEV) but not on land use efficiency (UETGEV). Treatments (cropping systems and genotypes) also significantly influenced grain yield (cowpea) and green ear yield - maize genotypes - (PGEV) and water productivity (PAGEV), whereas the interaction between sowing time and treatments was not significant for any of the variables evaluated.

During both sowing seasons, the different maize genotypes evaluated and the cowpea presented relative water satisfaction (RWS) greater than 100%, demonstrating that the effective rainfall was sufficient to meet the water demand of the crops, even under rainfed conditions (Table 1).

Table 1. Effective precipitation (PPT, mm period⁻¹), crop evapotranspiration (ETc, mm period⁻¹), supplemental water requirements (NSA, mm period⁻¹) and relative water satisfaction (%) in cowpea and maize genotypes (hybrid and variety) in monoculture and intercropped under rainfed conditions at two sowing times during the rainy season of 2025, Iguatu, CE.

Cultures	Season 1				Season 2			
	PPT	ETc	NSA	Mrs.	PPT	ETc	NSA	Mrs.
	(mm period ⁻¹)			(%)	(mm period ⁻¹)			(%)
Hybrid and variety corn	366.47	284.39	-82.08	128.86	332.60	317.66	-14.94	101.56
Cowpea	372.15	244.02	-128.13	152.51	361.59	285.26	-76.33	126.76

Source: Prepared by the author (2025)

In both periods, compared with the maize genotypes, the cowpea genotypes presented greater water surplus (negative NSA) and, consequently, greater SRA, especially in Period 1, indicating a lower water requirement for this legume. In Period 2, the reduction in rainfall was accompanied by a higher water demand (ETc) for cowpea, resulting in less excess available water compared with that in Period 1.

These variations reflect the effects of rainfall distribution on the water balance of

crops and reinforce the importance of choosing the right sowing time as a management strategy for annual crops in semiarid regions (Table 1).

The results presented in Table 2 show that compared with Season 2, the first sowing season resulted in a higher overall average productivity of green cowpea grains and green corn ears, higher water productivity, and greater land use efficiency, although no significant differences were detected between the seasons for the UETGEV variable.

Table 2. Overall average values and productivity of green cowpea grains and green corn ears (PGEV, kg ha^{-1}), water productivity (PAGEV, km m^{-3}) and efficient land use (UETGEV, dimensionless) in single and intercropped cropping systems with cowpea and corn genotypes (hybrid and variety) under rainfed conditions during two sowing seasons, i.e., during the rainy season of 2025, in the municipality of Iguatu, CE.

Sowing seasons	PGEV (kg ha^{-1})	PAGEV (km m^{-3})	UETGEV (dimensionless)
Season 1	8,881.51 ^a	1.71 ^a	1.57 ^a
Season 2	6,578.95 ^b	1.32 ^b	1.41 ^a

Tukey's test at the 5% probability level.

Source: Prepared by the author (2025)

These differences reflect the better water conditions observed in Period 1 (Table 2), where higher effective rainfall and higher relative water satisfaction rates were observed for both crops. The superiority of Period 1 indicates that earlier sowing favored crop development and the use of available soil water, resulting in higher yields and better efficiency in the use of natural rainfall and available area resources.

These results reinforce the importance of proper planting time management as a strategy to maximize the productivity and sustainability of rainfed agricultural systems in semiarid regions.

³ show that corn, both hybrid and variety, achieved the highest green ear yield (GYE), ranging from 10,621.50 to 11,903.50 kg ha^{-1} , regardless of whether it was grown alone or intercropped with cowpea. There were no statistically significant differences between these cropping systems (alone and/or intercropped) in which corn was used. However, the intercropping of hybrid corn with cowpea resulted in the highest green ear yield (11,903.50 kg ha^{-1}), followed by hybrid corn alone (11,048.36 kg ha^{-1}), a variety of corn with cowpea (10,951.67 kg ha^{-1}), and a variety of corn alone (10,621.50 kg ha^{-1}).

Table 3. Average values of the green grain productivity of cowpea and/or green ears of corn (PGEV, kg ha^{-1}), water productivity (PAGEV, kg m^{-3}) and efficient land use (UETGEV, dimensionless) in single and intercropped cropping systems with cowpea and corn genotypes (hybrid and variety) under rainfed conditions during the rainy season of 2025 in the municipality of Iguatu, CE.

Variable	Treatments						
	Single cowpea	Single hybrid corn	Single variety corn	Hybrid corn with cowpea	Corn variety with cowpea	Cowpea with hybrid corn	Bean cowpea with corn variety
PGEV (kg ha^{-1})	4,312.60 ^b	11,048.36 ^a	10,621.50 ^a	11,903.50 ^a	10,951.67	2,340.30 ^b	2,933.70 ^b
PAGEV (kg m^{-3})	0.84 ^b	2,174 ^a	2.09 ^a	2.34 ^a	2.15 ^a	0.45 ^b	0.57 ^b
UETGEV (-)	-	-	-	1.65 ^a	1.97 ^a	0.52 ^a	1.82 ^a

Tukey's test at the 5% probability level.

Source: Prepared by the author (2025)

The green grain yields of cowpea were generally significantly lower than the green grain yields of cowpea, with values of 4,312.60 kg ha^{-1} in monoculture, 2,933.70 kg ha^{-1} in intercropping with a variety of maize, and 2,340.30 kg ha^{-1} in intercropping with hybrid maize. However, no statistically significant differences were observed. These results show that compared with maize, maize, especially hybrid maize, has higher grain yields, whereas compared with maize, cowpea has lower green grain yields and is more favorable when cultivated, especially in monocultures.

With respect to efficient land use (UETGEV), compared with monocultures, all intercropping systems presented values greater than 1, indicating an advantage in land use. The highest index was recorded for the intercropping of the maize variety and cowpea (1.97), followed by the intercropping of the maize variety and cowpea (1.82), although the difference was not statistically significant.

4 CONCLUSIONS

The sowing season directly influences the productive performance of corn and cowpea under rainfed conditions in semiarid regions, with better results obtained with earlier sowing (February) associated with greater water availability.

Corn, both hybrid and variety, presented the highest yields of green ears and high water use efficiency, regardless of whether it was grown alone or intercropped with cowpea, indicating that intercropping with cowpea did not compromise corn performance.

Cowpea showed better productive and water performance when it was grown alone and was significantly affected when it was intercropped with corn. On the other hand, the values for efficient land use were greater in the intercropping systems, especially for the intercropping of a variety of corn and cowpea, demonstrating greater utilization of the available space in the production environment in this cultivation configuration.

5 ACKNOWLEDGEMENTS

We would like to express our gratitude to the NESAS – Center for Studies in Agricultural Systems of the Semi-Arid Region, for their support, partnership, and scientific contributions throughout the development of this work, as well as to the Federal Institute of Ceará (IFCE), Iguatu Campus, for the infrastructure, encouragement of research, and quality academic training that made this study possible.

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