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Competition between cowpea and weeds for water: Effect on plants growth

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ABSTRACT: Water is the most important resource for agricultural production. The understanding of water competition mechanisms may lead to the development of new control strategies or coexistence with certain weed species, especially in situations where water is scarce. The objective of this work was to evaluate the competition between cowpea and weeds by water under the effect on plant growth. It was carried out experiment in greenhouse in the period from September to November 2015, in a randomized complete block design, with four replications. The treatments were arranged in factorial 5 x 2, with the first factor corresponding to the competition arrangements between the species (*V. unguiculata* + *C. benghalensis*; *V. unguiculata* + *W. indica*; *V. unguiculata*, *C. benghalensis* and *W. indica* in monoculture), and the second of water regimes (irrigated and water deficit). The water deficit reduces the growth of cowpea plants, *C. benghalensis* and *W. indica*. The competition between plants increases the effects of temporary water deficit in the soil. The *W. indica* leaf is the organ most affected by the water deficit. The weed specie *W. indica* has greater capacity competition for water with *V. unguiculata* than *C. benghalensis*.

Key words: *Commelina benghalensis*; interference; *Vigna unguiculata*; *Waltheria indica*; water stress

Competição entre feijão-caupi e plantas daninhas por água: Efeito no crescimento das plantas

RESUMO: A água é o recurso mais importante para a produção agrícola. O entendimento dos mecanismos de competição por água pode propiciar o desenvolvimento de novas estratégias de controle ou convivência com determinadas espécies de plantas daninhas, principalmente nas situações em que a água é escassa. Objetivou-se com este trabalho avaliar a competição entre feijão-caupi e plantas daninhas por água sob o efeito no crescimento das plantas. Foi realizado experimento em casa de vegetação no período de setembro a novembro de 2015, em delineamento em blocos casualizado, com quatro repetições. Os tratamentos foram arranjados em fatorial 5 x 2, com o primeiro fator correspondente aos arranjos de competição entre as espécies (feijão-caupi + trapoeraba; feijão-caupi + malva-branca; feijão-caupi, trapoeraba e malva-branca em monocultivo), e o segundo dos regimes hídricos (irrigado e déficit hídrico). O déficit hídrico reduz o crescimento das plantas de feijão-caupi, *Commelina benghalensis* e *Waltheria indica*. A competição entre plantas aumenta os efeitos do déficit hídrico temporário no solo. A folha de *W. indica* é o órgão mais afetado pelo déficit hídrico. A espécie daninha *W. indica* tem maior capacidade de competição por água com o feijão-caupi do que a *C. benghalensis*.

Palavras-chave: *Commelina benghalensis*; interferência; *Vigna unguiculata*; *Waltheria indica*; estresse hídrico

Introduction

Cowpea is cultivated under different edaphoclimatic conditions. It is one of the main crops used as a protein source in the world (Freitas et al., 2017). Some of its genotypes have tolerance to the temporary water deficit of the soil, characteristic that makes the crop one of the preferred for cultivation in periods of lower precipitation, mainly in the North, Northeast and Midwest regions of Brazil (Nascimento et al., 2011; Dutra et al., 2015). In these regions, droughts (summer) are common in the rainy season and, consequently, problems caused by water deficit, such as reduced growth and productivity, are common (Sousa et al., 2009; Freitas et al., 2014; Souza et al., 2017).

The negative effects of the water deficit can be anticipated or intensified by the occurrence of weeds in the areas of cowpea, since these plants will require the same resources as the crop for their growth, establishing a competitive relationship. Under low resource conditions such as water, competition tends to intensify and the ability of species to extract resources rapidly or continue growing even at low levels in the soil will confer greater or lesser competitive capacity (Craine & Dybzinski, 2013; Treder et al., 2016).

The intensity of this water competition depends on the species involved and their survival mechanisms under water deficient conditions. Some species, such as *W. indica* and *Crotalaria retusa*, have strategies that allow the maintenance of the stomatal opening and continue to make photosynthesis even with little availability of water, to the detriment of their water status, being considered investor plants and, such as *C. benghalensis* and *Cleome affinis*, when under moderate water deficit, close their stomata to maintain their water status as a way to delay dehydration, being known as conservative plants (Lima et al., 2016).

When there is competition on the part of weeds for water, soils dry faster and the availability of this resource to the target crop is impaired, increasing the frequency and intensity of the water deficit, which affects the efficiency of utilization of the resources available in the environment, mainly the growth and distribution of dry matter (Carvalho et al., 2011; Cury et al., 2011).

The understanding of the species in the competition for water provides elements for understanding the functional mechanisms of plants when water is the limiting factor and allows the improvement of agricultural management practices aimed at optimizing crop productivity. In this sense, the objective of this work was to evaluate the competition between cowpea and weeds by water under the effect on plant growth.

Materials and Methods

The experiment was carried out in a greenhouse from September to November, 2015, in Mossoró, RN, Brazil, with each experimental unit corresponding to a plastic vessel with 10 dm³ volumetric capacity, containing a sample of

Eutrophic Haplo Plantain (Embrapa, 2013), collected in the 0-20 cm layer, with the following characteristics: pH (water) = 6.5; organic matter = 1.0 dag kg⁻¹; P, K and Na = 7.2, 64.4 and 3.2 mg dm⁻³; Ca, Mg, Al, H + Al, and effective CTC = 2.5, 1.8, 0.0, 0.0 and 4.5 cmol_c dm⁻³; sand, silt and clay = 820.0, 120.0 and 50.0 g kg⁻¹, respectively; with sand texture. The fertilization followed the recommendations of the IPA (2008), with the application in the planting of 45.50 mg dm⁻³ of the MAP. The cover fertilization was done with 33.30 and 16.67 mg dm⁻³ of urea and potassium chloride, respectively.

The experimental design was a randomized block design, with four replications. The treatments were arranged in a 5x2 factorial scheme, with the first factor consisting of the competition arrangements between the evaluated species (*Vigna unguiculata* + *Commelina benghalensis*; *Vigna unguiculata* + *Waltheria indica*; *Vigna unguiculata*, *Commelina benghalensis* and *Waltheria indica* in monoculture) and the second of the water regimes (irrigated and water deficit).

The cowpea bean cultivar was BRS Guariba, with an indeterminate growth habit, semi-weed size, and cycle of 65-70 days (Gonçalves et al., 2009). The seeds of *W. indica* and *C. benghalensis* were collected in a cowpea area and submitted to procedures to overcome dormancy (splitting at the opposite end of the wire). Before the installation of the experiment, a preliminary test was carried out to verify the emergence time of each species in the soil aiming at simultaneous emergence in the competition test.

Thinning was performed five days after plant emergence, leaving the same density of weeds and crop (one plant per pot). In the competition treatments, the cowpea seeds were placed in the center of the pot and the weeds between the center and the periphery of the container.

Irrigation was carried out daily to leave the soil with water level above 70-80% of the field capacity. The volumes of water applied were obtained from the difference between the weight of the pot in its previously determined field capacity and the weight of the pot on the day of irrigation, being done daily, following a methodology described by Sousa et al. (2015).

When the cowpea plants had the third definitive Trifolium - V4 stage (40 days after emergence), the imposition of water regimes (irrigated and water deficit) was initiated. The irrigated treatment plants continued to receive daily irrigation as described, and the plants of the water deficit treatment had their irrigation totally suspended, so the stress was the result of the gradual exhaustion of the water of the soil, maintained until the rate of assimilation of CO₂ (A) of the cowpea plants at 09:00 hours, reached values close to zero, which occurred after 11 days of irrigation suspension, at which time irrigation was resumed. The CO₂ assimilation rate was measured using an infrared gas analyzer (IRGA, portable model LI-6400, LI-COR Biosciences), according to the methodology of Lima et al. (2016). At 21 days of evaluation, when the CO₂ assimilation rate of the

plants submitted to the water deficit equaled those of the irrigated plants, the plants were harvested.

For growth evaluation, leaf number per plant (NL) was determined; leaf area (LA), determined by the corrected disk method (Souza et al., 2012), using a sample of 10 numbered leaves. Afterward, the plants were fractionated in leaves, stems, and roots, packed in paper bags and placed in a greenhouse with forced air circulation at a temperature of $65 \pm 1^\circ\text{C}$ until reaching a constant mass. Afterward, each fraction was weighed in an analytical balance to obtain the dry mass. With this data, the dry mass partitioning in the different organs (leaf, stem, and root) of the plants was calculated, following the methodology of Carvalho et al. (2011).

The data were submitted to analysis of variance by the F test ($p \leq 0.05$). In the cases of significance, the growth variables were compared by the Tukey test; while for the dry mass partition the t-test was used, both at the 5% probability level.

Results and Discussion

For cowpea, there was no effect of the interaction between competition arrangements between species (S) and water regimes (R) for none of the variables studied (Table 1). The only effect of the factor isolated water regimes (R) on the analyzed variables was verified. As for the *Commelina benghalensis* specie, the factors competition arrangements between species and water regimes influenced all variables, except the root dry mass (RDM), while for the interaction (S x R), there was a statistical difference only for the stem

dry mass (SDM) and the root (RDM). For the *Waltheria indica* specie, it was observed an effect of the competition arrangement among the species for all variables analyzed. The water regimes factor influenced leaf area (LA), leaf dry mass (LDM), SDM and total (TDM) variables; while the interaction (S x R) had an effect on the number of leaves per plant (NL), LDM, SDM, and TDM.

The water deficit reduced the number of leaves per plant (NL) of cowpea in 11.2% compared to the irrigated plants (Table 2). The reduction in leaf numbers was probably caused by leaf fall, which is a common plant strategy to reduce water loss through transpiration and increase water use efficiency in response to soil water deficit (Cechin et al., 2010).

For leaf area (LA) of cowpea, there was a reduction of approximately 26.6% in plants that were under water deficit, in relation to irrigated plants (Table 2). The stress caused by the water deficit probably reduced the rate of expansion of the young leaves, besides having ceased the production of new leaves, an alternative found by the plant to reduce the leaf area and, consequently, the loss of water by perspiration, to save the limited water supply in the soil for a longer period (Díaz-López et al., 2012).

The dry matter accumulation (LDM), stem (SDM), root (RDM) and total (TDM) dry matter decreased by 29.7, 38.7, 46.3 and 36.9%, respectively, in relation to the irrigated treatment (Table 2). These negative effects of the water deficit on the growth and production of cowpea biomass were also reported by several researchers (Nascimento et al., 2011; Freitas et al., 2014; Fernandes et al., 2015; Souza et al., 2017).

Table 1. Summary of the analysis of variance for the number of leaves per plant (NL), leaf area (LA), leaf dry mass (LDM), stem (SDM), root (RDM) and total (TDM) cowpea, *Commelina benghalensis* and *Waltheria indica*, depending on the arrangement of competition between species and water regimes.

SV	Mean square values					
	NL	LA	LDM	SDM	RDM	TDM
Cowpea						
Species (S)	0.70 ^{ns}	527.91 ^{ns}	0.08 ^{ns}	1.09 ^{ns}	0.11 ^{ns}	3.12 ^{ns}
Regimes (R)	46.29*	21176.69*	10.96**	17.44**	9.19**	92.12**
S x R	18.67 ^{ns}	1380.58 ^{ns}	0.98 ^{ns}	0.16 ^{ns}	0.02 ^{ns}	4.33 ^{ns}
Block	1.68 ^{ns}	1828.03 ^{ns}	0.55 ^{ns}	1.73*	1.27*	2.43 ^{ns}
Residue	5.87	1202.26	0.36	0.48	0.29	1.61
CV (%)	9.76	13.50	15.50	19.61	22.96	13.43
<i>Commelina benghalensis</i>						
Species (S)	28985.06*	129546.00*	25.91*	52.89*	0.04 ^{ns}	157.94*
Regimes (R)	3335.06*	46235.75**	2.20*	3.47*	0.05 ^{ns}	12.83*
S x R	333.06 ^{ns}	1809.65 ^{ns}	0.15 ^{ns}	1.71**	0.30**	1.34 ^{ns}
Block	20.39 ^{ns}	12018.14 ^{ns}	0.09 ^{ns}	0.13 ^{ns}	0.10 ^{ns}	0.86 ^{ns}
Residue	85.73	7007.94	0.09	0.21	0.04	0.52
CV (%)	11.19	23.49	13.96	19.85	20.62	14.91
<i>Waltheria indica</i>						
Species (S)	1045.39*	9396.88**	9.38*	3.72*	0.88*	35.16*
Regimes (R)	44.45 ^{ns}	14083.16**	3.71*	1.51**	0.13 ^{ns}	12.46*
S x R	469.48*	7.09 ^{ns}	3.25*	0.93**	0.16 ^{ns}	10.05**
Block	11.61 ^{ns}	2058.01 ^{ns}	0.40 ^{ns}	0.18 ^{ns}	0.05 ^{ns}	1.04
Residue	26.87	1389.50	0.29	0.18	0.05	1.0
CV (%)	27.70	27.20	20.70	24.41	22.92	29.65

SV = Sources of variation; CV = Coefficient of variation; ns = not significant; **, * = Significant at 1 and 5% probability by the F test, respectively.

Table 2. Number of leaves per plant (NL), leaf area (LA), leaf dry mass (LDM), stem (SDM), root (RDM) and total (TDM) of cowpea in competition with *Commelina benghalensis* and *Waltheria indica*, under irrigated and water deficit regime.

Species	NL		Mean	LA (cm ² plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
F ¹	24.00	23.25	23.62	201.95	265.05	233.5
F + C	20.75	25.33	23.04	190.36	238.38	214.37
F + W	21.0	25.50	23.25	161.08	250.37	205.72
Mean	21.92 B	24.69 A		184.46 B	251.27 A	
Species	LDM (g plant ⁻¹)		Mean	SDM (g plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
F ¹	3.52	4.43	3.98	3.03	4.90	3.96
F + C	3.35	4.32	3.84	2.65	4.02	3.33
F + W	2.70	4.86	3.78	2.39	4.26	3.32
Mean	3.19 B	4.54 A		2.69 B	4.39 A	
Species	RDM (g plant ⁻¹)		Mean	TDM (g plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
F ¹	1.50	2.85	2.17	8.05	12.19	10.12
F + C	1.50	2.63	2.06	7.51	10.97	9.03
F + W	1.32	2.56	1.94	6.41	11.68	9.05
Mean	1.44 B	2.68 A		7.32 B	11.61 A	

F = Cowpea; C = *Commelina benghalensis*; W = *Waltheria indica*; ¹Cowpea seedlings cultivated without weed competition; Averages followed by the same lowercase letter (in the column) and upper case (in the line) do not differ for each variable at the 5% probability level by the Tukey test.

The growth of cowpea was not affected by competition with *C. benghalensis* or *W. indica* in any water regime (Table 2). This result was probably due to higher morphophysiological characteristics of the crop, such as dry shoot mass (Lamego et al., 2005), growth habit (Teixeira et al., 2009) and accumulation of nutrients (Cury et al., 2013).

The water deficit reduced the NL, LA, LDM, SDM, RDM, and TDM of *C. benghalensis* (Table 3), with decreases in the same order of 32.5, 40.1, 29.9, 33.8, 67.2 and 31.2%, compared to plants without water restriction. It was also observed a lower growth of *C. benghalensis* when it was in competition with cowpea. Cury et al. (2011) evaluated the individual-level competition between common bean (*Phaseolus vulgaris* L.) and weeds and also found that the *C. benghalensis* species was sensitive to competition with the crop, with a reduction in dry matter accumulation in all vegetative components.

Regarding the *W. indica* specie, the water deficit imposed reduced the NL, LDM, SDM, and TDM in the cultivated plants without competition with the cowpea, with decreases of 43.6, 67.4, 65.1 and 63.8%, respectively, in relation to plants that were not under water deficit (Table 4). For the LA, it was observed, on average, a reduction of 61% in the plants submitted to the water deficit, in comparison to the plants of the irrigated regime. While, for the RDM, there was no effect of the water deficit verified. Plants of *W. indica* submitted to competition with cowpea had lower growth, compared to plants absent from competition.

The reduction of water availability possibly caused stress to the plants, affecting several physiological processes, such as stomatal opening, decreasing stomatal conductance, perspiration, and photosynthesis, consequently leading to the decline of biomass production (Cechin et al., 2015; Mota & Cano, 2016).

Table 3. Number of leaves per plant (NL), leaf area (LA), leaf dry mass (LDM), stem (SDM), root (RDM) and total (TDM) of *Commelina benghalensis* in competition with cowpea, under the irrigated regime and of water deficit.

Species	NL		Mean	LA (cm ² plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
C ¹	98.0	136.0	117.0 a	261.04	347.28	304.16 a
C + F	22.0	41.75	31.87 b	59.81	188.59	124.19 b
Mean	60.0 B	88.87 A		160.42 B	267.93 A	
Species	LDM (g plant ⁻¹)		Mean	SDM (g plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
C ¹	2.94	3.88	3.41 a	3.31 aB	4.90 aA	4.10 a
C + F	0.59	1.14	0.86 b	0.33 bA	0.61 bA	0.47 b
Mean	1.76 B	2.51 A		1.82 B	2.75 A	
Species	RDM (g plant ⁻¹)		Mean	TDM (g plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
C ¹	0.56 aA	0.41 aA	0.48	6.82	9.19	8.0 a
C + F	0.19 bB	0.58 aA	0.38	1.11	2.33	1.72 b
Mean	0.37	0.49		3.96 B	5.76 A	

F = Cowpea; C = *Commelina benghalensis*; ¹*Commelina benghalensis* absent from competition with cowpea; Averages followed by the same lowercase letter (in the column) and upper case (in the line) do not differ for each variable at the 5% probability level by the Tukey test.

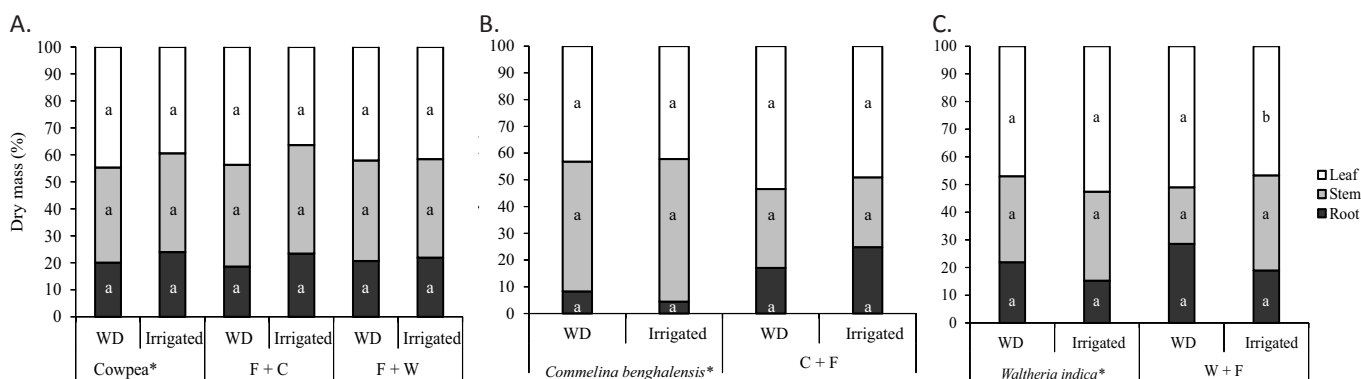
Table 4. Number of leaves per plant (NL), leaf area (LA), leaf dry mass (LDM), stem (SDM), root (RDM) and total (TDM) of *Waltheria indica* in competition with cowpea, under the irrigated regime and of water deficit.

Species	NL		Mean	LA (cm ² plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
W ¹	18.33 aB	32.5 aA	25.41 a	61.57	122.24	91.90 a
W + F	13.0 aA	15.50 bA	14.25 b	14.43	72.44	43.43 b
Mean	15.66	24.0		38.0 B	97.34 A	

Species	LDM (g plant ⁻¹)		Mean	SDM (g plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
W ¹	0.90 aB	2.76 aA	1.83 a	0.59 aB	1.69 aA	1.14 a
W + F	0.27 aA	0.33 bA	0.30 b	0.11 aA	0.24 bA	0.17 b
Mean	0.58 B	1.54 A		0.35 B	0.96 A	

Species	RDM (g plant ⁻¹)		Mean	TDM (g plant ⁻¹)		Mean
	Water deficit	Irrigated		Water deficit	Irrigated	
W ¹	0.42	0.80	0.61 a	1.90 aB	5.25 aA	3.57 a
W + F	0.15	0.13	0.14 b	0.52 aA	0.70 bA	0.61 b
Mean	0.28	0.46		1.21 B	2.97 A	

F = Cowpea; W = *Waltheria indica*; ¹*Waltheria indica* absent from competition with cowpea; Averages followed by the same lowercase letter (in the column) and upper case (in the line) do not differ for each variable at the 5% probability level by the Tukey test.



WD = Water deficit; F = Cowpea; C = *Commelina benghalensis*; W = *Waltheria indica*; * = Plants grown without competition; Means followed by the same letter, in each variable (plant organ), do not differ among themselves by the t-test at 5% probability.

Figure 1. Partition of the dry mass of cowpea (A), *Commelina benghalensis* (B) and *Waltheria indica* (C) in competition, under the irrigated regime and water deficit.

Similar results were described by Cerqueira et al. (2013) when evaluating the effects of the water deficit and the competition of two drought-tolerant highland rice cultivars with the *Spermacoce verticillata* specie, showing that competition and/or water deficit reduced leaf area and dry mass of the vegetative components (shoot, root and total) of rice and weed cultivars.

In general, species adapted to low-resource systems often exhibit features associated with resource conservation, such as growth reduction (Funk, 2013). This reduction in cowpea and weeds, under conditions of water deficiency in the soil, confirms the reaction of these plants to maintain survival.

Such information was also verified by Lima et al. (2016) when evaluating, in the greenhouse, the ecophysiological behavior of these same weeds under conditions of water deficit. In general, they verified a reduction of the growth and alteration of the dry mass of *C. benghalensis* and *W. indica* in conditions of temporary water deficit in the soil. The same authors also found a higher dry mass allocation in the roots of the weed species submitted to the water deficit, a strategy to overcome the loss of biomass in the aerial part.

Regarding the percentage distribution of dry mass among the different vegetative organs, except for the leaf of the weed *W. indica* (Figure 1C), there was no effect of the water deficit and/or competition. There was a greater relative accumulation of dry mass in the leaf of the plants under water deficit, with 51%, in relation to the irrigated treatment. This result indicates that the species presents a more investigative strategy, with aggressive competition for water under conditions of temporary water restriction, allocating most of the photoassimilates in the leaves to maintain metabolic activity.

Conclusions

The water deficit reduces the growth of cowpea plants, *C. benghalensis* and *W. indica*.

Competition between plants increases the effects of temporary water deficit on the soil.

The *W. indica* leaf is the organ most affected by the water deficit.

The *W. indica* specie has a greater water competition capacity with cowpea than *C. benghalensis*.

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