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Weed Growth and Dry Matter Partition Under Water Restriction[1]

Crescimento e Partição de Matéria Seca de Plantas Daninhas sob Restrição Hídrica Temporária

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ABSTRACT - The capacity of a weed to adapt to the restriction of growth factors is directly related to its ability to compete for those resources with the cultivated species. An experiment was conducted to evaluate the effect of water restriction on the growth and biomass partitioning of four species of weeds. The experimental design used randomized blocks, with five replications. The treatments were arranged in a 4 x 2 factorial, with the first factor being the weed species (*Waltheria indica*, *Crotalaria retusa*, *Cleome affinis* and *Commelina benghalensis*) and the second, two water regimes: daily irrigation (Irr) and water restriction (WR). The number of leaves, leaf area, dry mass of the plant and its parts (root, stem and leaf), and the mass distribution among different organs (roots, leaves and stems) were determined. The water deficit in the soil increased the root dry matter for *C. retusa*, *W. indica* and *C. benghalensis*, however, it did not alter the mass of the stem of the weeds. *C. retusa* and *W. indica* suffered a reduction on the number of leaves, leaf area, dry matter of the leaves and the plant dry matter under water deficit. *W. indica* and *C. retusa* had a reduction on the percentage of biomass allocated to the leaves, and an increment on the percentage of the roots mass, while *C. benghalensis* and *C. affinis* had an increase only on the roots mass.

Keywords: *Waltheria indica*, *Crotalaria retusa*, *Cleome affinis*, *Commelina benghalensis*, soil water deficit.

*RESUMO - A capacidade de uma planta daninha para se adaptar à restrição de fatores de crescimento está diretamente relacionada à sua habilidade de competir por esses recursos com as espécies cultivadas. O experimento foi realizado para avaliar o efeito da restrição hídrica sobre o crescimento e partição de biomassa de quatro espécies de plantas daninhas. O delineamento experimental foi em blocos casualizados com cinco repetições. Os tratamentos foram arranjados em esquema 4 x 2, com o primeiro fator sendo as espécies de plantas daninhas [malva-branca (**Waltheria indica**), crotalária (**Crotalaria retusa**), mussambê (**Cleome affinis**) e trapoeraba (**Commelina benghalensis**)] e o segundo, dois regimes hídricos: irrigação diária (Irr) e restrição hídrica (Def). Determinou-se o número de folhas, a área foliar, a massa da matéria seca de raiz, caule, folha e total e a distribuição percentual de massa entre os diferentes órgãos (raízes, folhas e caule). O déficit hídrico no solo aumentou a matéria seca das raízes da **C. retusa**, **W. indica** e **C. benghalensis**, porém não alterou a matéria seca do caule das plantas daninhas. **C. retusa** e **W. indica** tiveram redução no número de folhas, área foliar, matéria seca das folhas e total em condições de déficit hídrico. **W. indica** e **C. retusa** reduziram percentualmente a biomassa alocada nas folhas e aumentaram a de raízes, enquanto a trapoeraba e **C. affinis** aumentaram somente nas raízes.*

Palavras-chave: *Waltheria indica, Crotalaria retusa, Cleome affinis, Commelina benghalensis*, deficit hídrico no solo.

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INTRODUCTION

Weed infestations are common on agricultural plantations, and they are responsible for economic damages when not managed correctly. Production losses of cultivated species, due to the interference of weeds, may reach 100% and have been attributed mainly to the competition for water, light and nutrients (Lemes et al., 2010).

The competition for water is the most important one on agricultural cultures, above all, in the case of dry or limited-irrigation cultures. Plants with the capacity to adapt to adverse conditions, such as a temporary water deficit on the soil, tend to have greater chances to establish on the agricultural environment (Chauhan and Abugho, 2013). Some weeds, such as *Cyperus esculentus* and *Plantago major*, develop better on moist areas; however, after having been established, they may tolerate dry conditions. Some malva species (*Malva* spp.), *Polygonum aviculare*, *Conyza* spp., *Paspalum dilatatum* and *Cynodon dactylon* are able to survive under water restriction (Roncoroni and Wilen, 2014).

Water restriction is one of the most important environmental factors for the plant growth limitation, initially due to the stomatal closing and the resulting reduction on the CO_2 absorption (Yan et al., 2016); however, as the stress evolves, several metabolic changes occur (Suseela et al., 2015; Muscolo et al., 2015), resulting on leaf fall on deciduous species (Estomell et al., 2013)

The capacity of a weed to adapt to changing factors that affect growth is directly related to its capacity to compete for these resources with the cultivated species. Chauhan and Abugho (2013), when studying two weed species (*Amaranthus spinosus* and *Leptochloa chinensis*), observed higher mass values on branches and leaves of *A. spinosus* when subjected to a more severe water restriction. On the same study, in a comparison to a culture, both weeds were more competitive and tolerant than rice under high water restriction conditions. There are few studies with weeds regarding their water competition potential, and there is no available information that allow us to understand the competitive capability of weeds upon water restriction and daily irrigation conditions.

Information on the growth and biomass allocation of weeds under the effect of variations of essential resources are important to understand the aspects involved in the competition among plant species and the different adaptive strategies among the species and their relationship with their competitive ability (Barrat-Segretain, 2001). Considering this, the aim of this study was to evaluate the effect of water restriction on the growth and biomass allocation of four weed species.

MATERIAL AND METHODS

The experiment was conducted on a greenhouse, from March to June 2014, in Mossoró-RN. During this period, the temperature and relative air humidity means were 31.5 ^oC and 45.5%, respectively. Each experimental unit was constituted by three pots with volumetric capacity for 1.9 dm^{-3}, filled with sandy-textured Red-Yellow Latosol (Embrapa, 2013) and cultivated with one plant per pot. The results of the chemical and physical analyses were: pH ($CaCl_2$) = 6.1; Ca = 4.45 $cmol_c$ dm^{-3}; Mg = 1.3 $cmol_c$ dm^{-3}; K = 159 mg dm^{-3}; Al = 0.05 $cmol_c$ dm^{-3}; P = 174 mg dm^{-3}; organic matter = 12 g dm^{-3}; total sand = 0.76 kg kg^{-1}; silt = 0.08 kg kg^{-1}; and clay = 0.16 kg kg^{-1}.

The experimental design used randomized blocks with five replications. The treatments were arranged on a 4 x 2 factorial; the first factor was the weed species (*Waltheria indica*, *Crotalaria retusa*, *Cleome affinis* and *Commelina benghalensis*), and the second, two water regimes (daily irrigation (Irr) or water restriction (WR)).

The seeds of the studied species were collected in September 2013 (*W. indica*, *C. retusa* and *C. affinis*), near the experimental location. The seeds of *C. benghalensis* were acquired from the company Agrocosmos Produção e Serviços Rurais Ltda, located in Engenheiro Coelho/SP. The seeds underwent certain procedures to overcome dormancy, through the lopping of the seed at the opposite end of the radicle.

A previous study was conducted to determine the flowering start period for each species, with the purpose of conducting evaluations on the four species at the same growth phase (beginning of flowering). Thus, the *W. indica*, *C. retusa*, *C. benghalensis* and *C. affinis* plants were sown at different times, in order for the evaluation to occur at 92, 66, 55 and 39 days after emergence (DAE), respectively.

The sowing was conducted on trays with 128 cells, and the plants were then transplanted into pots when the first pair of leaves had completely expanded, one plant per plot. During this stage, uniform plants were selected. The irrigations were conducted daily, always at the end of the afternoon.

The plants with no water restriction (Irr) were daily irrigated, maintaining the soil humidity close to the field capacity, while, for the plants subjected to water restriction (WR), the irrigation was suspended upon flowering and maintained until the CO_2 assimilation rate of the plants, at 9 a.m., reached values near zero (LI-6400 Photosynthesis system –LI-COR Biosciences), when the irrigation was resumed. The irrigation was resumed on the fifth day after the beginning of the water stress for the *C. retusa* and *W. indica* plants; on the sixth day, for *C. benghalensis*; and on the seventh day, for *C. affinis*. The plants were subjected to growth evaluations at the end of the experiment, when the photosynthesis rates of the plants subjected to water restriction would be equal to the irrigated plants.

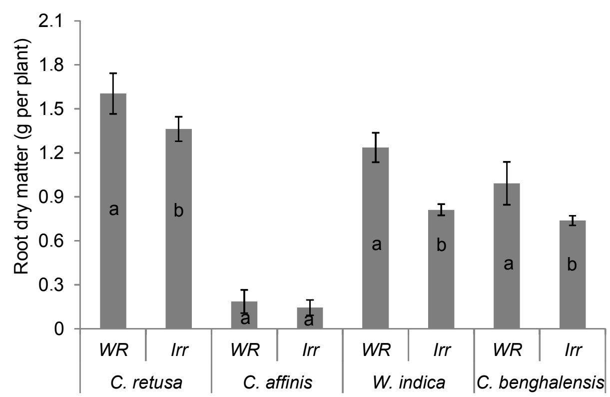
In order to evaluate the growth of the plants, the following factors were determined: number of leaves (NL) (number per plant); leaf area (LA) (cm^2), determined by the corrected disk method (Lopes et al., 2010); and dry matter of the root (RDM), stem (SDM), leaf (LDM) and total dry matter (TDM) (g per plant), obtained from a sample of three plants from the plot. The samples were collected, placed on paper bags and left to dry on a forced air circulation oven at 70 °C, for 72 hours. The percentage distribution of dry matter among the vegetable components of the different weed species were calculated, establishing the relationship between the dry matter of each organ (leaf, stem and root) to the total dry matter (Carvalho et al., 2011).

The data were subjected to the analysis of variance through the F test. Since an interaction occurred among the analyzed factors for all variables, we chose to compare the species using the confidence interval of the means at 5%. The comparison of the effect of the water regime within each species was conducted by the t test.

RESULTS AND DISCUSSION

C. retusa, *W. indica* and *C. benghalensis* plants had a higher accumulation of root dry matter (RDM) under water deficit conditions, when compared to the culture with no stress (Figure 1). The RDM of *C. affinis* did not change due to the water deficit. The increase of the RDM under water stress conditions probably occurs due to a change on the biomass partitioning of the plants in response to the water restriction, favoring the growth of the roots to the detriment of other parts of the plants. Under these circumstances, the roots tend to grow up to the more humid layer of the soil, until the water supply is exhausted on the environment (Taiz and Zeiger, 2009). This behavior is an important strategy to maintain or increase the absorbing area, in an attempt to reduce the effects of the low water availability on the soil (Kozlowski and Pallardy, 2002).

No differences were observed on the stem dry matter (SDM) between the water



Means followed by the same letter do not differ from one another according to the t test at 5% of probability for each species: *C. retusa*, *C. affinis*, *W. indica* and *C. benghalensis*. The error bars indicate the confidence intervals of the means at 5% of probability, comparing the species within each water regime.

Figure 1 - Mass of the root dry matter (RDM) on four weed species upon daily irrigation (Irr) and water restriction (WR).

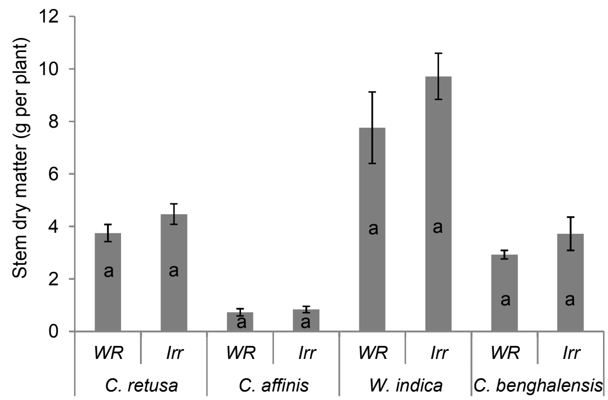
regimes, regardless of the studied weed species (Figure 2). This is probably due to the short water restriction time, which would not have been enough for the irrigated plants to produce photoassimilates in order to cause a significant increase of SDM. Usually, the water restriction initially affects the most sensitive organs, such as the leaves, inflorescences and roots, regardless of the studied species (Patterson, 1995).

The water deficit caused a reduction on the leaf dry matter (LDM) and total dry matter (TDM) accumulation of *C. retusa* and *W. indica* (Figures 3 and 4) due to the reduction on the number of leaves (NL) (Figure 5), indicating the occurrence of leaf abscission and/or the reduction on the emission of leaves on these species.

As a response to the water deficit, a restriction on the biomass accumulation occurs (Silva, 2004), restricting both the initial growth of the plants and the posterior stages, limiting the dimensions of the individual leaves, the number of leaves and, consequently, the total leaf area and the total dry matter of the plant (Mahajan and Tuteja, 2005; Jaleel et al., 2009). Similar results were described by Santos et al. (2004), who observed that the water deficit induced the abortion of the leaves, with a 66% reduction of the leaf mass, and 60% reduction of the total dry matter on *Hyptis pectinata* after four days of water restriction.

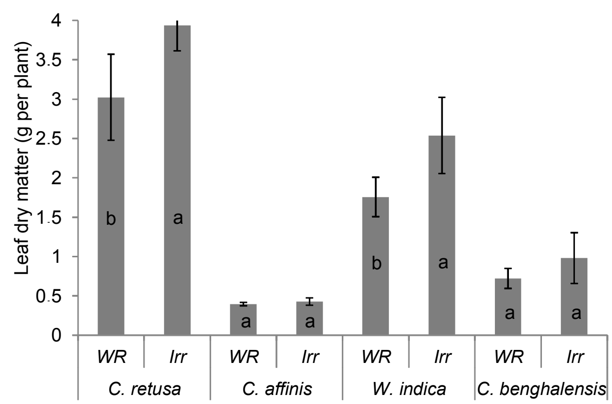
No changes were observed on LDR, TDM and Nl for *C. benghalensis* and *C. affinis* due to the water regime, probably because no leaf fall occurred, differently from the other species, indicating that *C. benghalensis* and *C. affinis* behave as a conservative species, which, as a response to water deficit, interrupt their metabolic activity, preserving most of their energy, and the the water content of the leaves, avoiding their abscission (Larcher, 2006).

In general, the water deficiency directly affects the growth of the plant as a whole, limiting the dimension of individual leaves, the number of leaves, the leaf area and the dry matter of the plant. This occurs due to a reduction of the cell expansion and formation of the cellular wall, and due to an indirect



Means followed by the same letter do not differ from one another according to the t test at 5% of probability for each species: *C. retusa*, *C. affinis*, *W. indica* and *C. benghalensis*. The error bars indicate the confidence intervals of the means at 5% of probability, comparing the species within each water regime.

Figure 2 - Mass of the stem dry matter on four weed species upon daily irrigation (Irr) and water restriction (WR).



Means followed by the same letter do not differ from one another according to the t test at 5% of probability for each species: *C. retusa*, *C. affinis*, *W. indica* and *C. benghalensis*. The error bars indicate the confidence intervals of the means at 5% of probability, comparing the species within each water regime.

Figure 3 - Mass of the leaf dry matter on four weed species upon daily irrigation (Irr) and water restriction (WR).

reduction on the availability of carbohydrates or influence of the hormonal production, therefore, causing a restriction of the biomass production (Jaleel et al., 2009; Endres et al., 2010).

The leaf area (LA) of *C. retusa* and *W. indica* was reduced due to the water restriction (Figure 5). This was related to the 14% and

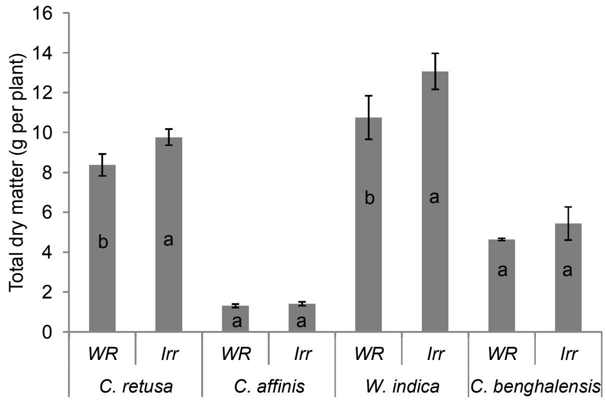


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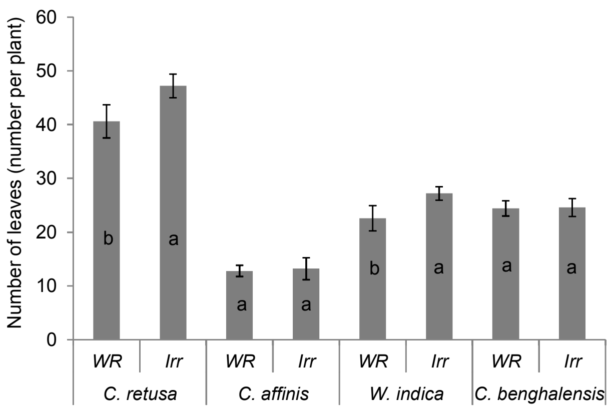
Figure 4 - Mass of the total dry matter on four weed species upon daily irrigation (Irr) and water restriction (WR).



Means followed by the same letter do not differ from one another according to the t test at 5% of probability for each species: *C. retusa*, *C. affinis*, *W. indica* and *C. benghalensis*. The error bars indicate the confidence intervals of the means at 5% of probability, comparing the species within each water regime.

Figure 5 - Number of leaves on four weed species upon daily irrigation (Irr) and water restriction (WR).

17% reduction on the number of leaves for *C. retusa* and *W. indica*, respectively (Figure 6).

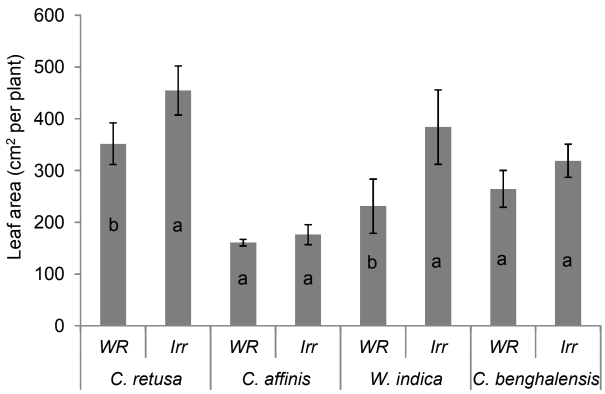
The reduction on the number of leaves and the leaf area on plants under water deficit has been observed by several authors (Tatagiba, 2006; Martins, 2010; Bortolini et al., 2011; Mar et al., 2013). The limitation on the leaf production and the reduction on the leaf area increase is considered as the first line of defense against water deficiency (Mar et al., 2013). In addition to the reduction on the emission of new leaves, the reduction of the leaf area is a consequence of the fall of green leaves, and its purpose is to reduce leaf area, and, in consequence, the water loss due to transpiration, promoting water savings (Díaz-López et al., 2012). The leaf abscission is stimulated by the accentuated synthesis and greater sensitivity to ethylene, and it is also an early adaptive response to locations where water limitation occurs (Cordeiro et al., 2009).

For the *C. affinis* and *C. benghalensis*, no differences were observed on LA between the water regimes, indicating a greater capacity of these species to maintain their leaves in comparison to *C. retusa* and *W. indica*, postponing the abscission.

The dry matter allocation of all studied weeds was modified by the water regime (Figure 7). In general, the stem was the plant compartment with higher proportion in relation to the total dry matter of the weeds. This behavior is probably associated to a reproductive strategy (Carvalho, 2011), that is, in addition to its role in supporting the leaves, the stem stores starch as a reserve for energy and carbon structures, which may be used to support the production of future shoots and roots.

For all evaluated weeds, it was observed that, upon water deficit, a higher percentage of root dry matter occurred, in relation to the respective control treatment (Figure 7). Several authors report that plants under water deficit accumulate photoassimilates on the root system to the detriment of the shoot growth, thus, representing an attempt to make up for the water deficiency through a larger absorption area on the soil (Silva et al., 2008). According to Grieu et al. (2001), plants with higher growth and greater development of root mass are, in general, more competitive, above all, due to their capacity to extract water from greater depths.

The *C. retusa* and *W. indica* species, cultivated under daily irrigation, accumulated a larger amount of dry matter on the leaves in relation to the plants subjected to water deficit, with 40% and 36% for *C. retusa*. and 20% and



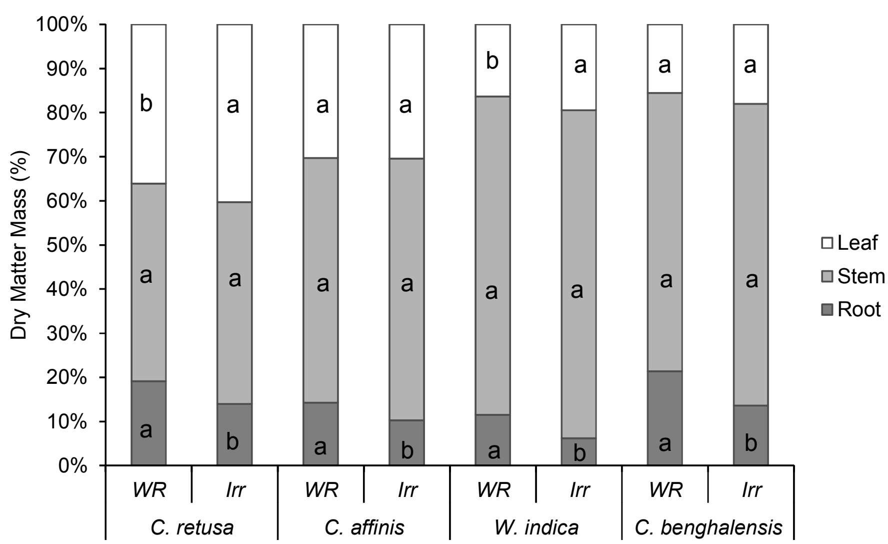
Means followed by the same letter do not differ from one another according to the t test at 5% of probability for each species: *C. retusa*, *C. affinis*, *W. indica* and *C. benghalensis*. The error bars indicate the confidence intervals of the means at 5% of probability, comparing the species within each water regime.

Figure 6 - Leaf area on four weed species upon daily irrigation (Irr) and water restriction (WR).

16% for *W. indica*, respectively (Figure 7). This may be explained by the relationship between the amount and size of the leaves and the amount of water available on the soil. Therefore, on a dry soil or with low water availability, small leaves are produced, mainly due to the lower cellular growth (Zhou et al., 2015). Under these conditions, the balance between the production of assimilates and the demand to develop the reproductive organs is severely affected by the reduction on the leaf area that is photosynthetically active and, consequently, the dry matter accumulation on the shoot (Scalon et al., 2011).

It is possible to infer that the *C. retusa* and *W. indica* species had lower toleration to water deficit, since both presented a lower accumulation of total dry mass under water deficit, in comparison to the control treatment of these species.

The different adaptation relationships to water deficit show that each species has a wide variation of the dry matter partitioning on the vegetative organs. In general, the water deficit on the soil stimulated the increase of the root dry matter on *C. retusa*, *W. indica* and *C. benghalensis*, however, it did not cause changes to the biomass of the stem on these weeds. *C. retusa* and *W. indica* suffered a reduction on the number of leaves, leaf area, dry matter of the leaves and total dry matter under water deficit conditions. *W. indica* and *C. retusa* had a reduction of the allocated biomass on the leaves and had the root biomass increased, while *C. benghalensis* and *C. affinis* had an increase only on the roots mass.



Means followed by the same letter do not differ from one another according to the t test at 5% of probability for each species: *C. retusa*, *C. affinis*, *W. indica* and *C. benghalensis*.

Figure 7 - Mean percentage distribution of dry matter among the vegetable components of different weeds upon daily irrigation (Irr) and water restriction (WR).

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