

EFFECTS OF COMPETITION AND WATER DEFICIENCY ON SUNFLOWER AND WEED GROWTH¹

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ABSTRACT – In the agricultural environment, the occurrence of biotic and abiotic stresses, such as weed interference and soil water deficit is common. However, little is known about the effects of the interaction of these stresses on the growth of cultivated crops and weed species. Thus, the objective of this study was to evaluate the effects of competition and water deficiency on the growth of sunflowers and weeds. The experiment was performed in a randomized block design with four replications. The treatments were arranged in a 5 × 2 factorial design, with the first factor corresponding to the competition arrangements between the species (sunflower + *Waltheria indica*; sunflower + *Amaranthus spinosus*; and sunflower, *W. indica*, and *A. spinosus* in monoculture without competition) and the second factor corresponding to water regimes (irrigated and water deficit). The water deficit regime was established when the sunflower plants had six expanded leaves (V6 stage) and was maintained until the rate of CO₂ assimilation of the plants reached values close to zero (6 days), after which irrigation was resumed and maintained until 40 days after emergence, when the plants were collected and evaluated. The growth components evaluated were plant height, leaf area, dry leaf mass, dry stem mass, dry root mass, and total dry mass. Competition between plants decreased sunflower, *W. indica*, and *A. spinosus* growth. *W. indica* and *A. spinosus* aggravated the negative effects of water deficiency on sunflower growth. The water deficit regime did not affect the growth of *W. indica*. *A. spinosus* was more competitive with the sunflower than was *W. indica*.

Keywords: *Helianthus annuus*. *Amaranthus spinosus*. *Waltheria indica*. Water stress. Interference.

EFEITOS DA COMPETIÇÃO E DO DÉFICIT HÍDRICO SOBRE O CRESCIMENTO DE GIRASSOL E PLANTAS DANINHAS

RESUMO – No ambiente agrícola é comum a ocorrência de estresse de origem biótica e abiótica, como a interferência das plantas daninhas e o déficit hídrico no solo, respectivamente. Porém, pouco se conhece sobre os efeitos da interação desses estresses sobre o crescimento de espécies cultivadas e daninhas. Desta maneira, objetivou-se com este trabalho avaliar os efeitos da competição e do déficit hídrico sobre o crescimento de girassol e plantas daninhas. O experimento foi realizado em delineamento em blocos casualizados, com quatro repetições. Os tratamentos foram arranjados em fatorial 5x2, com o primeiro fator correspondente aos arranjos de competição entre as espécies (girassol + *Waltheria indica*; girassol + *Amaranthus spinosus*; girassol, *W. indica* e *A. spinosus* em monocultivo), e o segundo dos regimes hídricos (irrigado e déficit hídrico). O déficit hídrico foi estabelecido quando as plantas de girassol apresentavam seis folhas expandidas – estágio V6 e mantido até que a taxa de assimilação de CO₂ das plantas alcançasse valores próximos à zero (6 dias), quando foi retomada a irrigação, sendo mantida até aos 40 dias, momento em que as plantas foram coletadas. Os componentes de crescimento avaliados foram: altura de planta, área foliar, massa seca de folha, caule, raiz e total. A competição entre plantas reduz o crescimento do girassol, *W. indica* e *A. spinosus*. As espécies *W. indica* e *A. spinosus* agravam os efeitos negativos do déficit hídrico sobre o crescimento do girassol. O déficit hídrico não afeta o crescimento da espécie *W. indica*. O *A. spinosus* é mais competitivo com o girassol do que a *W. indica*.

Palavras-chave: *Helianthus annuus*. *Amaranthus spinosus*. *Waltheria indica*. Estresse hídrico. Interferência.

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INTRODUCTION

The sunflower (*Helianthus annuus* L.) is one of the most important oleaginous species worldwide, being cultivated in all continents (CASTRO; LEITE, 2018). Sunflower crops are mainly used to produce seed oil for human consumption and to produce biofuels (DANTAS et al., 2017). The average Brazilian yield of sunflower (average grain yield) is 1319.3 kg ha⁻¹, which is considered low when compared to other countries, such as the Ukraine with 2238.8 kg ha⁻¹ (FAO, 2016). Among the factors contributing to this result are biotic and abiotic stresses, such as weed interference and soil water deficiency.

The occurrence of water deficiency is an increasingly frequent situation in rainfed crops in Brazil and may lead to reduced growth and crop yield losses (RAHMATI et al., 2018). The sunflower is a species that is considered tolerant to temporary soil water deficit (AHMAD et al., 2014); however, factors that increase the severity of droughts may reduce the ability of this species to tolerate stressful conditions. For example, an increase in atmospheric temperature was found to intensify the negative effects of water deficiency on sorghum plants, a species recognized for its great adaptability to hot regions (LOBELL et al., 2015), and sunflower varieties that are susceptible to drought (KILLI et al., 2017).

Weeds can also act as agents causing abiotic stresses related to the unavailability of essential growth resources, such as water, light, and nutrients. This interaction is known as competition (SILVA et al., 2013). Under field conditions, competition with weeds can reduce sunflower yields by up to 70% (ALVES et al., 2013).

The intensity of the negative effects of competition from weeds with cultivated crops depends on several factors, such as the competitive characteristics of the crop and weed species. The sunflower is considered a crop with a good competitive capacity, due to its higher stature; however, it is sensitive to competition during the first weeks after planting, with a total prevention period of interference ranging from 26 to 43 days (ELEZOVIC et al., 2012; ALVES et al., 2013; SILVA et al., 2013). Weed species such as boater bush (*Waltheria indica* L.) and spiny pigweed (*Amaranthus spinosus* L.) are frequently found in agroecosystems and are considered good competitors because they can tolerate water stress conditions and have a C4 fixation mechanism, respectively (LIMA et al., 2016; ASSAD et al., 2017; OLIVEIRA et al., 2018).

Therefore, the hypothesis was proposed that competition between weeds and cultivated crops can aggravate the negative effects caused by water deficiency, with serious implications for the growth components of the species. Thus, the objective of the

present study was to evaluate the effects of competition and water deficiency on the growth of sunflower plants and *A. spinosus* and *W. indica* weeds.

MATERIAL AND METHODS

The experiment was performed in a greenhouse from April to June 2016. The experimental unit corresponded to a plastic vessel with a volume capacity of 8.5 dm³ (24 × 23 cm in diameter and height, respectively), filled with samples of a Cambisol collected from the 0–20 cm soil layer (EMBRAPA, 2013). After collection, analysis of physical and chemical attributes was performed, which revealed the following characteristics: pH (water) = 7.2; organic matter = 8.10 g kg⁻¹; P, K, and Na = 2.2, 434.6, and 49.3 mg dm⁻³, respectively; Ca, Mg, Al, H + Al and effective CEC = 11.30, 2.10, 0.00, 0.00, and 14.73 cmol_c dm⁻³, respectively; sand, silt, and clay = 0.57, 0.10, and 0.33 kg kg⁻¹, respectively; and sandy clay loam texture. The fertilization of the experiment followed the recommendations for the use of correctives and fertilizers in Minas Gerais (RIBEIRO; GUIMARÃES; ALVAREZ, 1999), applying 72.9, 52.1, and 25.86 mg dm⁻³ of monoammonium phosphate, urea, and potassium chloride, as a source of phosphorus, nitrogen, and potassium, respectively.

The experimental design was a randomized block design with four replications. The treatments were arranged in a 5 × 2 factorial design, with the first factor corresponding to the arrangements between the species (sunflower + *W. indica*, sunflower + *A. spinosus*, and sunflower, *W. indica*, and *A. spinosus* in monoculture without competition) and the second factor corresponding to the water regimes (irrigated and water deficit).

The sunflower hybrid used was Aguará 06, which was obtained commercially from the Atlântica Sementes Company. The seeds of the *W. indica* and *A. spinosus* weeds were collected from agricultural fields in the region. The seeds of these species were submitted to preliminary testing of germination and emergence with the aim to establish the sowing period of each species so that the emergence of these species was simultaneous with that of the crop.

The sowing of the sunflower and weeds was performed at the center and border of each experimental unit, respectively. The plants were thinned five days after emergence, with only one plant of each species remaining in the vessel.

Irrigation was performed daily with the aim to maintain the soil at 70% of field capacity. The water volumes applied were obtained from the difference between the mass of the vessel in its previously determined field capacity and the mass of the vessel on the day of irrigation, performed daily, following the methodology described by Sousa et al. (2015).

The water deficit regime was established once the sunflower plants had six expanded leaves (V6 stage), a period during which competition with weeds can reduce the final yield of the crop, and thus increase production costs (ALVES et al., 2013). The duration of the water deficit regime was maintained until the CO₂ assimilation rate of the sunflower plants reached values close to zero. The CO₂ assimilation rate was measured using an infrared gas analyzer (IRGA, portable model LI-6400, LI-COR Biosciences) based on the methodology described by Lima et al. (2016). The period required for the CO₂ assimilation rate to reach zero was 6 days. Then, irrigation was restored and the humidity maintained close to 70% of field capacity. At 40 days after emergence, by which time the photosynthetic rate of the plants submitted to the water deficit regime equaled those of the irrigated plants, the plants were collected and evaluated.

The growth components evaluated were plant height (PH), which was determined using a graduated ruler and measured from the base of the lap to the insertion of the last fully expanded leaf and leaf area (LA), which was obtained with the corrected disk method (SOUZA et al., 2012). The sunflower plants, and *W. indica* and *A. spinosus* weeds were fractionated into leaves, stems, and roots, and were then separately packaged in paper bags and placed in a forced circulation oven at 65 ± 1°C until reaching a constant mass. Then, each part of the plant was weighed on an analytical balance to obtain the dry leaf mass (DLM), dry stem mass (DSM), dry root mass (DRM), and total dry mass (TDM).

The data were submitted to analysis of variance using the F test ($p \leq 0.05$) and, when significant, the averages were compared by Tukey's test at the 5% probability level using the statistical software program SISVAR (FERREIRA, 2011).

RESULTS AND DISCUSSION

Effects of competition and water deficiency on sunflower growth

From the analysis of variance results, interaction was observed among the competition arrangements between the species and water regimes for PH and DRM. There was an isolated effect between the competition factors and water regimes

for LA, DLM, and TDM, whereas for DSM there was only an isolated effect for the water regimes factor.

The water deficit regime affected the growth rate of sunflower plants when cultivated alone and in competition with *A. spinosus*, which resulted in plants with lower heights (Figure 1A). This could be caused by the stress related to water deficiency, which is characterized by a reduction in soil water content and, consequently, a reduction in leaf water potential, stomatal closure, loss of turgescence, and consequently there is a decrease and/or interruption in cell growth (JALEEL et al., 2009). For example, in *Abelmoschus esculentus* (okra) plants, the reduction in height under the water deficit regime might be associated with a decline in cell growth and increase in leaf senescence (BHATT; SRINIVASA RAO, 2005).

Under irrigated conditions, competition with weeds did not affect the sunflower PH, in relation to the free treatment of coexistence (Figure 1A). Thus, the presence of weeds did not cause interference to the sunflower, e.g., light competition (shading) was not enough to change the shoot growth of the crop. Lu et al. (2016) evaluated the growth of *A. retroflexus* in soybean crops and did not observe any competition influence in PH. Under water stress conditions in the present study, there was an interference effect only for *A. spinosus*, which intensified the effects of water restriction, with a severe reduction in sunflower PH compared to the isolated treatment (without the presence of weeds).

The plants under water deficit conditions had lower LA values than those in the irrigated treatment (Figure 1B). This reduction in LA might be related to reduction in the rate of expansion of young leaves, suspension of the production of new leaves, and the fall of green leaves. These stress-induced changes caused by water deficiency reduce LA and, consequently, loss of water via transpiration, promoting water savings (DÍAZ-LÓPEZ et al., 2012). Leaf abscission is mainly due to the synthesis of and sensitivity to ethylene (ABELES; MORGAN; SALTVEIT JR, 1992). Auxin and ethylene have an antagonistic relationship in the regulation of leaf abscission in many plant species, where the reduction of the auxin concentration in the leaf increases the production and sensitivity to ethylene (TAIZ et al., 2017).

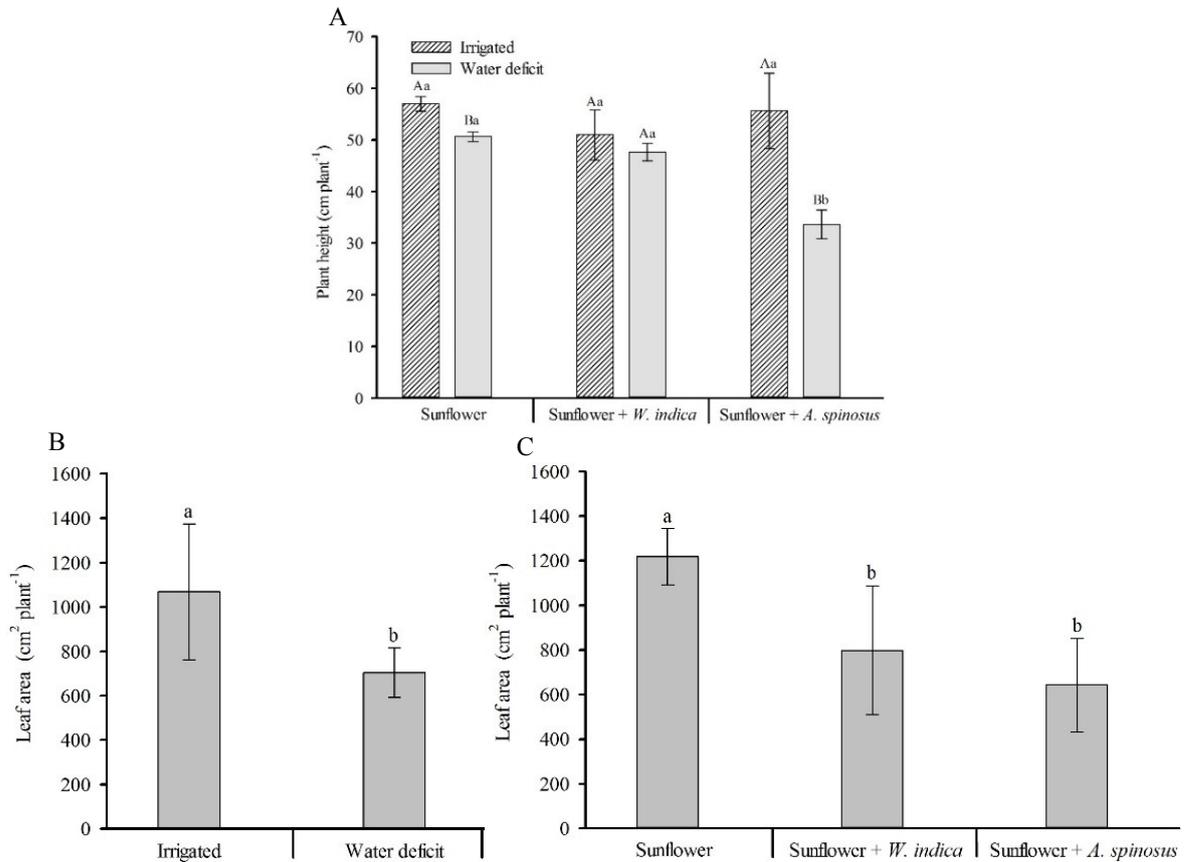


Figure 1. Plant height (A) and leaf area (B, C) of sunflower plants as a function of water regimes and competition with *Waltheria indica* and *Amaranthus spinosus*. Figure 1A: means followed by the same lowercase letter (between the competition arrangements in each water regime) and upper case (between the water regimes within each competition arrangement) do not differ at the 5% probability level by the Tukey's test. Figures 1B and C: averages followed by the same letter do not differ at the 5% probability level by the Tukey's test. Error bars indicate mean confidence interval at 95% probability.

Regarding the effect of competition on FA, independently of the weed species, the competition gave lower values than those for the sunflower plants grown in isolation (Figure 1C). This occurred because, in general, weeds present a higher growth rate during the early stages, causing them to have an initial advantage, with such small competitive advantages during the onset of growth being converted into large differences in size, and thus the capacity to intercept light (CORRE-HELLOU et al., 2011). The sunflower, which is a slow initial developmental plant (shoot growth), was probably affected during the initial stage by weed interference, due to light competition that affected the LA of the crop (SILVA et al., 2013).

The water deficit regime reduced the DLM, DSM, DRM, and TDM of sunflower plants by 42.7%, 48.5%, 44.9%, and 43.9%, respectively, compared to the irrigated treatment (Figure 2). In general, during periods of water deficiency, available soil water is decreased and, to cope with this, plants tend to have greater stomatal regulation to minimize loss via sweating. Although this response to water deficiency helps to maintain adequate water potential of the plant, there is also a reduction in the absorption of CO₂ and, consequently, reduction in the photosynthetic and respiration rates, which reduces dry mass production (URBAN; AARROUF; BIDEL, 2017).

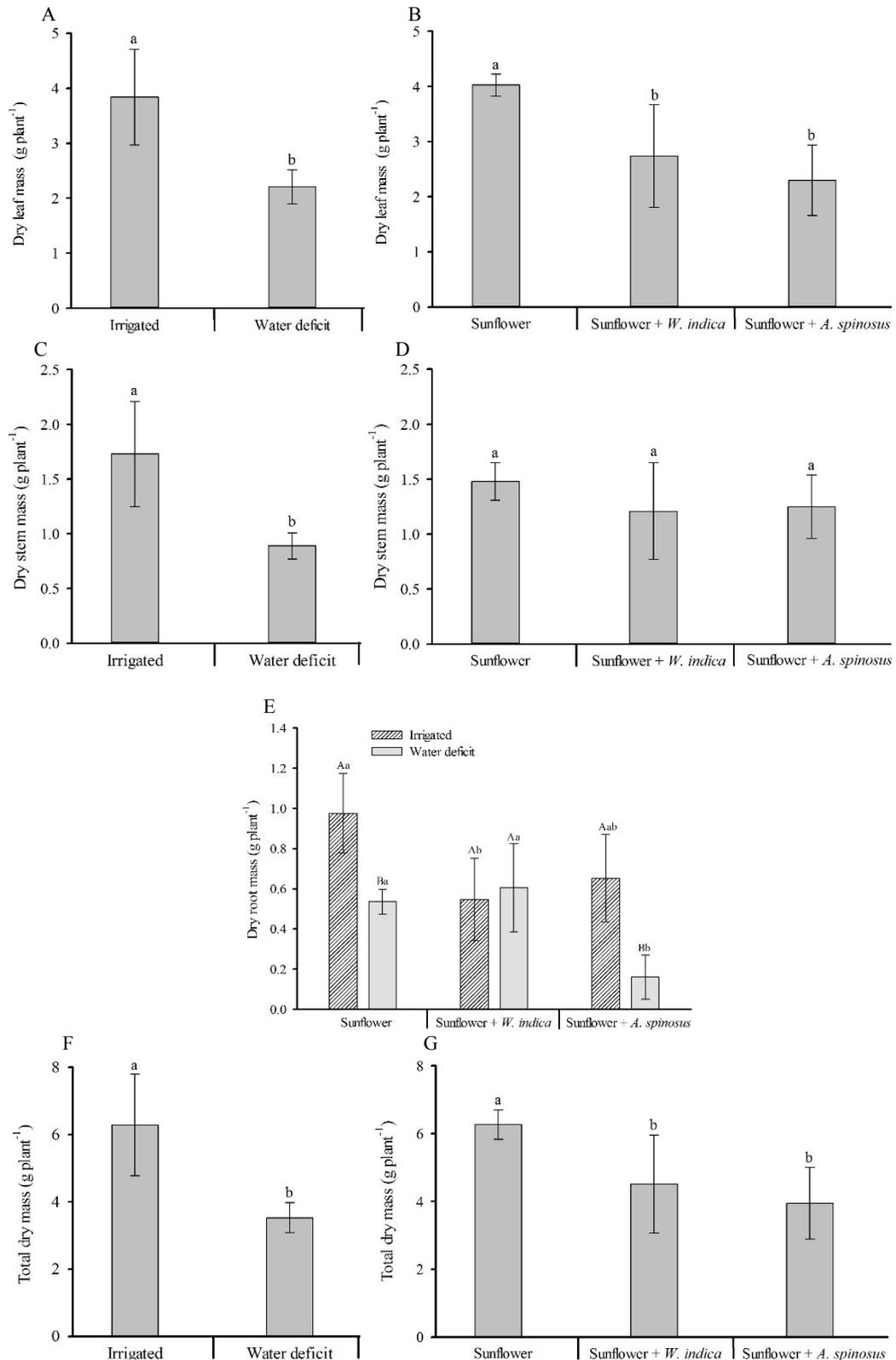


Figure 2. Dry leaf mass (A, B), dry stem mass (C, D), dry root mass (E), and total dry mass (F, G) of sunflower plants as a function of water regimes and competition with *Waltheria indica* and *Amaranthus spinosus*. Figure 2E: means followed by the same lowercase letter (between the competition arrangements in each water regime) and upper case (between the water regimes within each competition arrangement) do not differ at the 5% probability level by Tukey's test. Other figures: means followed by the same letter do not differ to the level of 5% of probability by Tukey's test. Error bars indicate the mean confidence interval at 95% probability.

When analyzing the competition effect, independently of the species, the presence of weeds with sunflower plants resulted in lower DLM (Figure 2B) and TDM (Figure 2G) than that of the treatment without interference. The reduction of these growth variables is possibly a reflection of the species response when perceiving the change in light quality due to the presence of weeds (LAGE et al., 2017). The effects of this alteration in light quality is usually noticed in the growth components, such as branching, foliar and tiller senescence, alteration of the photoassimilates partition (GOMMERS et al., 2013), LA, lower density of tillers (SZYMEZAK et al., 2016), and dry mass production (DAN et al., 2010).

In contrast, for DSM, no competition effect was observed (Figure 2D). This behavior reflects the sunflower height not being affected even under competition with weeds. Many species develop escape responses to overcrowding, which include rapid elongation of stems and the elevation of leaves towards light (FRANKLIN, 2016).

For DRM (Figure 2E), a reduction was observed when in competition with *W. indica* under irrigated conditions. Similar to the present study, Almeida et al. (2015) found a smaller increment in DRM accumulation when the soybean competed with *Urochloa brizantha* and *Bidens pilosa*. It was verified that the competition from *A. spinosus* intensified the effects of the water restriction, with an even more severe reduction in DRM for the sunflower plants. *A. spinosus* has a pivotal root system (CHAUHAN; ABUGHO, 2013) and may have explored the same region as the sunflower

plants, thus competing for available water with the crop and producing a higher DRM than that of the crop.

The lower development of the root system of the crop in the treatments with competition can result in less competitive plants by decreasing the capacity to absorb water and nutrients (ZANINE; SANTOS, 2004). In general, competition between crops and weeds is more severe when the root system, morphology, and growth habit of plants are similar (DASS et al., 2017).

Effect of competition and water deficiency on weed growth

For *W. indica*, interaction between competition factors and water regimes on DLM was observed. There was an isolated effect of water regimes on LA, DLM, DSM, DRM, and TDM; however, for ALT there was no significant effect, with a general mean of 46.16 cm plant⁻¹. For *A. spinosus*, interaction was observed between the competition factors and water regimes for DLM and TDM. There was an isolated effect of competition and water regimes for DLM, DSM, DRM, and TDM. Conversely, a single effect of the competition factor was observed for FA, whereas for ALT no significant effect was observed, with a general mean of 65.12 plant⁻¹.

Regarding LA of *W. indica* (Figure 3), the weeds that were in coexistence with the sunflower crop had lower mean values than that of the weeds in the treatment without competition.

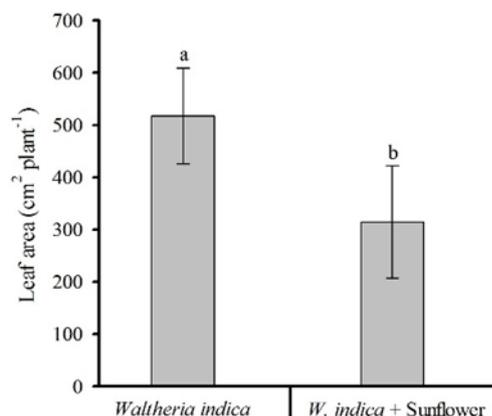


Figure 3. *Waltheria indica* leaf area as a function of competition with sunflower. Means followed by the same letter do not differ at the 5% probability level by the Tukey's test. Error bars indicate the mean confidence interval at 95% probability.

The water deficit regime did not reduce the dry mass of *W. indica*, except for the DLM (Figure 4A). This could be related to the fact that *W. indica* is a species with an investing mechanism in response to water deficiency, i.e., it maintains root water absorption and photosynthetic activity as the soil

dries to the detriment of its water state (OLIVEIRA et al., 2018). The reduction in DLM might be due to a decrease in leaf thickness, a strategy that maximizes transpiration, and thus increases the capacity of the plant to absorb soil water in more negative potentials (FANG; XIONG, 2015).

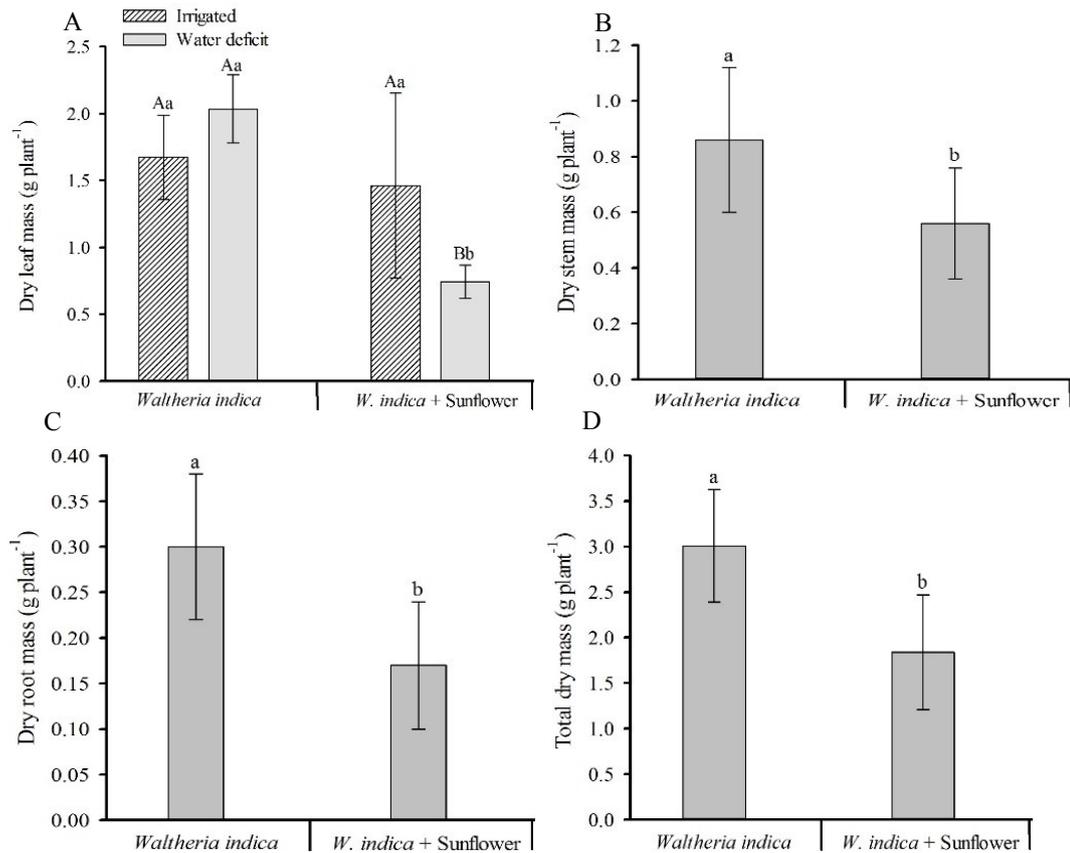


Figure 4. Dry leaf mass (A), dry stem mass (B), dry root mass (C), and total dry mass (D) of *Waltheria indica* as a function of water regimes and competition with sunflower. Figure 4A: means followed by the same lowercase letter (between the competition arrangements in each water regime) and upper case (between the water regimes within each competition arrangement) do not differ at the 5% probability level by the Tukey's test. Other figures: means followed by the same letter do not differ at the level of 5% of probability by the Tukey's test. Error bars indicate the mean confidence interval at 95% probability.

For DLM of *W. indica* (Figure 4A), competition with sunflower plants produced values that were 63.7% lower under the water deficit regime than that of the treatment without competition. Lower means of DSM (Figure 4B), DRM (Figure 4C), and TDM (Figure 4D) were found in *W. indica*

weeds that grew together with the crop.

Similar to *W. indica*, competition had an isolated negative effect on the AF of the *A. spinosus* weeds (Figure 5), with 37.4% lower values than that of the treatment without coexistence.

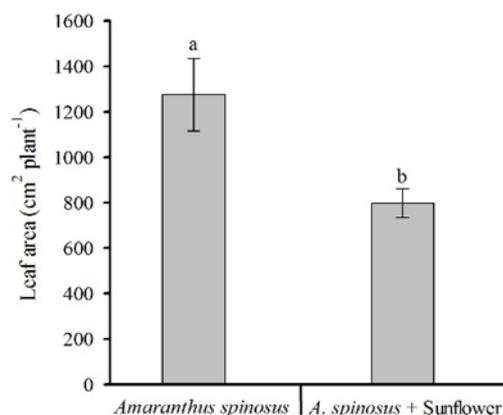


Figure 5. *Amaranthus spinosus* leaf area as a function of the competition effect with sunflower. Means followed by the same letter do not differ at the 5% probability level by the Tukey's test. Error bars indicate the mean confidence interval at 95% probability.

The water deficit regime negatively influenced the DLM, DSM, DRM, and TDM of *A. spinosus* weeds, with losses of approximately 22.3%, 17.5%, 19.2%, and 22.7%, respectively, compared to the irrigated treatment (Figure 6).

The reduction in dry mass for *A. spinosus* weeds under a water deficit regime can be justified by the inhibition of cell expansion. This occurs due to the reduction of turgescence in plant cells (cell dehydration) under water deficiency (DODD;

RYAN, 2016). Under conditions of water restriction, *Amaranthus* plants can suspend transpiration by reducing the stomatal opening, which saves the water supply in the plant for a longer period (ASSAD et al., 2017). This mechanism of adaptation allows the plant to survive; however, its yield is compromised (TAIZ et al., 2017). For example, in *A. cruentus* plants, biomass was reduced by 50% under a water deficit regime (MLAKAR et al., 2012).

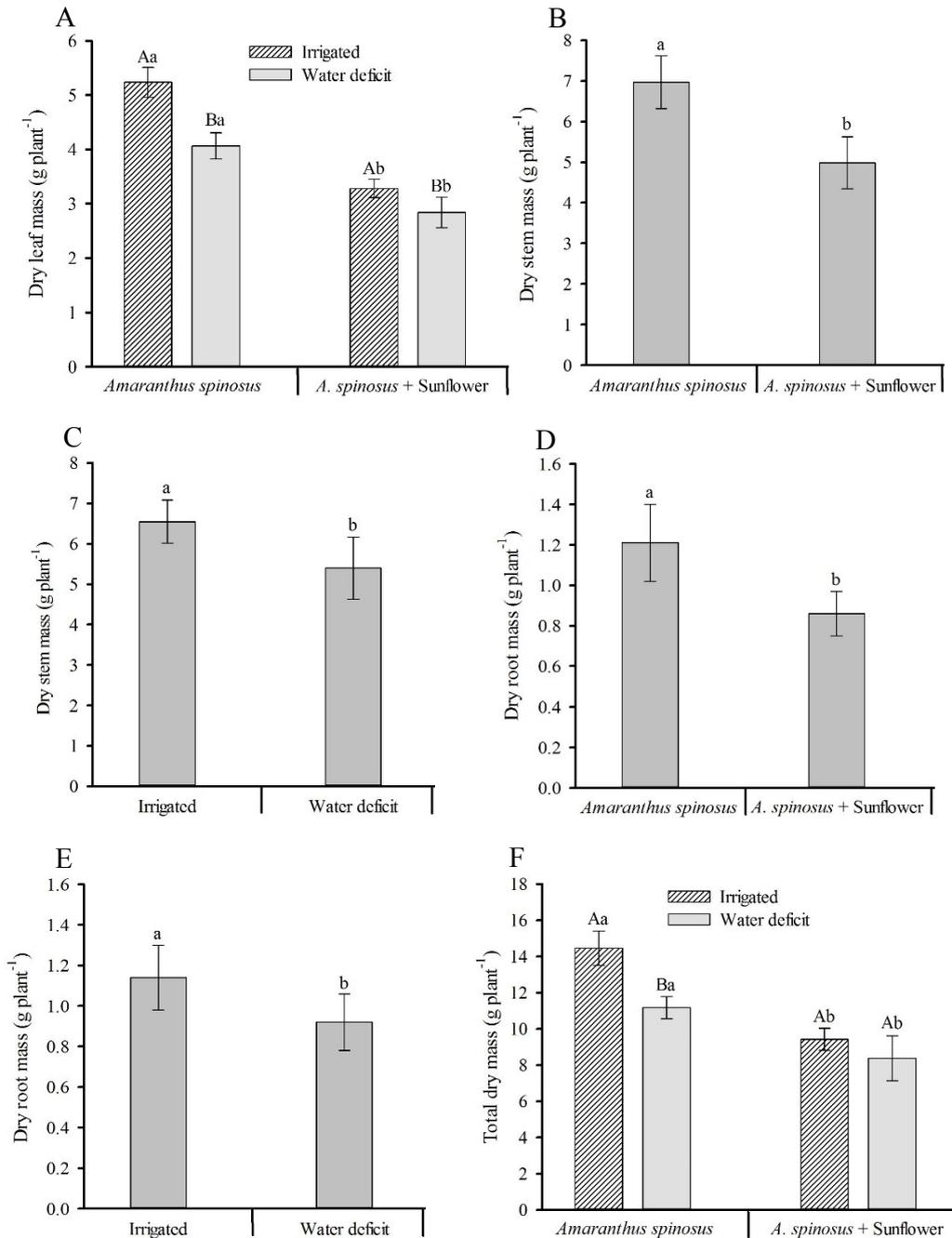


Figure 6. Dry leaf mass (A), dry stem mass (B, C), dry root mass (D, E), and total dry mass (F) of *Amaranthus spinosus* as a function of water regimes and competition with sunflower. Figure 6A and 6F: means followed by the same lowercase letter (between the competition arrangements in each water regime) and upper case (between the water regimes within each competition arrangement) do not differ at the 5% probability level by the Tukey's test. Other figures: means followed by the same letter do not differ at the level of 5% of probability by the Tukey's test. Error bars indicate mean confidence interval at 95% probability.

Competition with the sunflower crop reduced the DLM, DSM, DRM, and TDM of *A. spinosus* weeds (Figure 6). A similar reduction was found in a study by Qasem (2018) who evaluated the competition of *A. retroflexus* with tomato cultivars. This author verified a lower dry mass of *A. retroflexus* when in coexistence with the crop. In terms of DLM and TDM, competition intensified the negative effects of water deficiency, resulting in lower values, with 2.84 and 8.37 g plant⁻¹, respectively.

Therefore, competition reduced the growth of both species (crop and weeds), indicating competition for the same resources (FRANCO et al., 2017). In most cases, the crop may have a greater competitive ability than the weed alone because the weed effect is not caused by its individual competitive capacity, but rather by the total population of the weed community (VILÀ; WILLIAMSON; LONSDALE, 2004). Reductions in weed growth components have also been found in *Eleusine indica* in association with soybean crops (FRANCO et al., 2017) and in *Commelina benghalensis* and *W. indica* in coexistence with cowpeas (OLIVEIRA et al., 2018).

W. indica and *A. spinosus* showed different behaviors under water deficient conditions and under competitive conditions with the sunflower crop. Some of these growth differences between species can be attributed to different water absorption capacities and mechanisms of adaptation to water deficit conditions (CHAVES, 2002).

The combined effect of competition with *W. indica* and *A. spinosus* weeds and the stress caused by water deficiency impaired sunflower growth. Thus, it is important to adopt control measures of these weeds during the early stages of crop production to avoid competition and save the available water in the soil for the cultivated plants.

CONCLUSIONS

Interspecific competition reduced the growth of sunflower plants, and *Waltheria indica* and *Amaranthus spinosus* weeds.

Waltheria indica and *Amaranthus spinosus* aggravated the negative effects of water deficiency on sunflower growth.

Water deficiency did not affect the growth of *Waltheria indica*.

A. spinosus was more competitive with the sunflower than was *W. indica*.

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