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Competitive ability of sweet sorghum (*Sorghum bicolor* (L.) Moench) cultivars against hairy beggarticks (*Bidens pilosa* L.)

Capacidad competitiva de cultivares de sorgo dulce (*Sorghum bicolor* (L.) Moench) contra papunga (*Bidens pilosa* L.)

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ARTICLE DATA

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ABSTRACT

Among the weeds that interfere with the growth and development of sweet sorghum, beggar ticks stands out, because it has a high competitive capacity for the available resources. This study aims to compare the competitive ability of sweet sorghum (*Sorghum bicolor* (L.) Moench) against hairy beggarticks (*Bidens pilosa* L.), as a function of cultivar and plant proportion. Experiments were conducted in a greenhouse in a completely randomized design with four replications and six treatments. Treatments were arranged in replacement series in the proportions of 100:0, 75:25, 50:50, 25:75, and 0:100% (sorghum:weed) equivalent to 20:0, 15:5, 10:10, 5:15 and 0:20 plants per pot with 8 dm^3 capacity of sweet sorghum (cultivars 'BRS 506', 'BRS 509' or 'BRS 511') against hairy beggarticks. Fifty days after emergence, plant leaf area (LA), aboveground dry mass (DM), photosynthesis (A), and transpiration rates (E) were measured. Competitive ability was analyzed by using the graphical analysis method and building diagrams based on total and relative productivity. Competitiveness, clustering coefficient, and aggressiveness were also determined. Sorghum cultivars, in general, showed losses independently of the proportion of hairy beggarticks. Statistical analysis showed small differences in competitive ability among sorghum cultivars; 'BRS 509' was also demonstrated to be slightly more competitive than 'BRS 506' and 'BRS 511' against hairy beggarticks. This, however, is unlikely to provide a competitive advantage for 'BRS 509' in production fields, and hairy beggarticks should be efficiently controlled early in the crop cycle to avoid productivity losses, independently of the sorghum cultivar.

Keywords: additive series; substitute series; plant interaction; plant proportion; plant competition.

RESUMEN

Entre las malezas que interfieren en el crecimiento y desarrollo del sorgo dulce se destaca el amor seco, especialmente por presentar alta capacidad competitiva por los recursos disponibles en el medio. El objetivo de este estudio es comparar la capacidad competitiva del sorgo dulce (*Sorghum bicolor*) frente al papunga (*Bidens pilosa*), en función de la proporción de cultivo y planta. Los experimentos se realizaron en un invernadero en un diseño completamente al azar, con cuatro repeticiones. Los tratamientos se organizaron en series de reemplazo en las proporciones de 100: 0, 75:25, 50:50, 25:75 y 0: 100% (sorgo: maleza) que correspondieron a 20:0, 15:5, 10:10, 5:15 y 0:20 plantas por maceta con volumen de 8 dm^3 de sorgo dulce (cultivares BRS 506, BRS 509 o BRS 511) contra *B. pilosa*. Cincuenta días después de la emergencia, se evaluaron el área foliar de la planta (LA), la masa seca de los brotes (MS), la fotosíntesis (A) y la transpiración (E). La capacidad competitiva se analizó utilizando el método de análisis gráfico, construyendo diagramas basados en la productividad total y relativa. También se determinaron la competitividad, el coeficiente de agrupamiento y la agresividad. Los cultivares de sorgo, en general, fueron menos competitivos en todas las proporciones de *B. pilosa* . Hubo pequeñas diferencias en la capacidad competitiva entre los cultivares de sorgo; BRS 509 demostró ser ligeramente más competitivo que BRS 506 y BRS 511 frente al *B. pilosa* a. Sin embargo, es poco probable que esto proporcione una ventaja competitiva para BRS 509 en los campos de producción, por lo que *B. pilosa* a debe controlarse de manera eficiente al principio del ciclo de cultivo para evitar pérdidas de productividad, independientemente del cultivar de sorgo.

Palabras clave: serie aditiva; serie sustituta; interacción de plantas; proporción de plantas; competencia entre plantas.

INTRODUCTION

Sweet sorghum (*Sorghum bicolor* (L.) Moench) has great potential to be cultivated in large areas in Brazil (May, 2013). Its stems are rich in fermentable sugars that can serve as raw material for ethanol production (Giancotti *et al*., 2019), and its cultivation can be accomplished in sugarcane renewal areas, during the off-season, or in regions where sugarcane is not suitable (Galon *et al*., 2016; Galon *et al*., 2018). Sweet sorghum has the potential to produce up to 6 thousand liters of ethanol per hectare (May, 2013). However, it is necessary for a proper set of management practices for the crop to express this potential, using adapted cultivars, adequate levels of fertilizers, crop rotation, and pest control, among others (Silva *et al*., 2014a).

Quantitative and qualitative losses in sweet sorghum yield are reported when weed control is inappropriate (Galon *et al*., 2018; Braz *et al*., 2019). Silva *et al*. (2014b), working with sweet sorghum cultivar 'BRS 511', observed that the lack of weed control throughout the crop cycle reduced stalk productivity by about 50%. However, the degree of weed interference with the crop is influenced by the weed species, its density and plant distribution, the period of coexistence, the cultivar, and the crop stage of coexistence (Quintero-Pertúz *et al*., 2020; Fleck *et al*., 2008; Rodrigues *et al*., 2010; Agostinetto *et al*., 2013; Cabral *et al*., 2013). Thus, identifying crop varieties with superior competitive ability against weeds becomes essential. Replacement series models are the most-used methods for this purpose (Aminpanah & Javadi, 2011; Bastiani *et al*., 2016; Quintero-Pertúz *et al*., 2020).

Among the weeds of sorghum crops, hairy beggarticks (*Bidens pilosa*) may be highlighted due to its wide distribution and presence of traits that confer to this species high competitive ability against crop plants. This weed compromises the physiological, morphological, and growth of crops (Manabe *et al*., 2014), due to its high capacity to thrive in different agroecosystems (Santos & Cury, 2011). Cury *et al*. (2013) reported decreased nitrogen, phosphorus, and potassium absorption, by up to 50%, for beans competing against hairy beggarticks.

Variations in plant yield between crop and weeds should be screened since crop plant density is generally constant while weed density fluctuates, depending on the number of seeds in the soil bank or the level of local infestation (Quintero-Pertúz *et al*., 2020). Thus, it is necessary to assess the influence of not only the weed species and density on the crop but also the effect of variation in their proportion when in competition. This will most easily allow precise inferences for real production field conditions while elaborating weed control plans.

The hypotheses of the present study are: (1) sweet sorghum cultivars are most competitive than hairy beggarticks when they occur in equal proportions, with appropriate resource availability, and (2) there are differences among sweet sorghum cultivars in their competitive ability against hairy beggarticks. Therefore, this study aims to compare the competitive ability of sweet sorghum against hairy beggarticks, as a function of cultivar and plant proportion.

MATERIALS AND METHODS

Edaphoclimatic traits and experimental design. The experiments were installed into a greenhouse from November 2018 to February 2019. Plants were sown in plastic pots filled with 8 dm^3 of previously corrected and fertilized soil, classified as Red Latosol Aluminum humic (EMBRAPA, 2013). Correction and fertilization were done based on soil analysis and according to the technical recommendation for the cultivation of sorghum in Brazil (ROLAS, 2016). The chemical and physical traits of the soil were as follows: soil pH = 4.8, SOM = 35 g dm^{-3}, P = 4.0 mg dm^{-3}, K = 117.0 mg dm^{-3}, Al^{3+} = 0.6 $cmol_c$ dm^{-3}, Ca^{2+} = 4.7 $cmol_c$ dm^{-3}, Mg^{2+} = 1.8 $cmol_c$ dm^{-3}, effective cation exchange capacity ($CEC_{(t)}$) = 7.4 $cmol_c$ dm^{-3}, total cation exchange capacity ($CEC_{(T)}$) = 16.5 $cmol_c$ dm^{-3}, H+Al = 9.7 $cmol_c$ dm^{-3}, sum of bases (SB) = 6.8 $cmol_c$ dm^{-3}, base saturation (V) = 41%, and clay = 600 g dm^{-3}. In all tests, a randomized block design was used with four replications.

Species used in experiments, preliminary tests, and assessed variables. The tested species were three cultivars of sweet sorghum (‘BRS 506’, ‘BRS 509’, and ‘BRS 511’), competing against hairy beggarticks (*Bidens pilosa*). Preliminary experiments in additive series (monocultures) were carried out for all species and cultivars to identify the minimal plant density of each, in which the accumulation of biomass becomes constant and density-independent. For that, 0, 25; 49; 98; 196; 392; 587; 784; 980; 1,176; 1,372 and 1,568 plants m^{-2} were tested for each species and cultivar. Fifty days after emergence, the aboveground mass of both sweet sorghum and hairy beggarticks were harvested for assessment of the aboveground dry mass (DM) and leaf area (LA). LA was measured by using a leaf area integrator (LI-COR Li-3000C) and DM was determined by the gravimetric method after drying in a forced-air circulation oven at 72°C for a week. Through the average values of DM, the minimal density-independent plant number was established as 465 plants m^{-2} (20 plants per pot); for all species and cultivars only the final constant production of the species dry mass was shown (Figure 1) since the final constant production based on leaf area indicated the same plant densities (465 plants m^{-2} or 20 plants per pot, both for crop and weed).

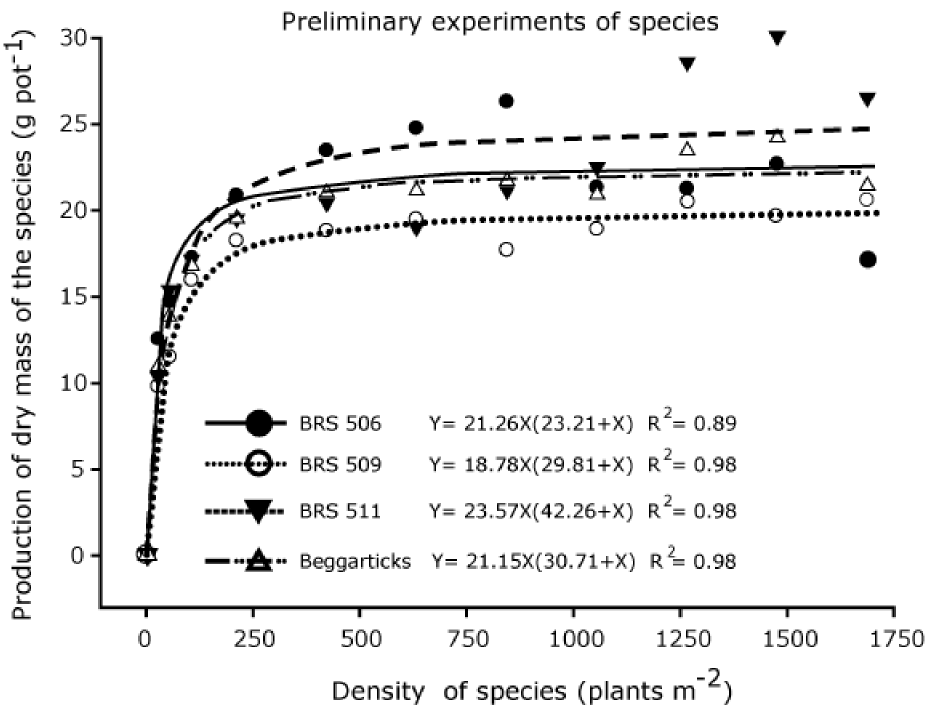

Figure 1. Constant final production of aboveground dry mass for sorghum cultivars (BRS506, 509 and 511) and the weed (hairy beggarticks) as a function of plant density (plants m^{-2}).

To test the competitive ability of sorghum cultivars against hairy beggarticks, three replacement series experiments were installed alternating plant proportions of sorghum cultivars against the weed, where the numbers of plants per pot (crop:weed) were 20:0; 15:5; 10:10; 5:15 and 0:20, while keeping the total plant density constant (20 plants pot^{-1}). Seeds were sown in plastic trays, being later transplanted to the definitive experimental units (plastic pots) five days after emergence, to ensure establishing plants with homogeneous sizes into each species. After transplanting, pots were kept for four days under 50% shading and were lightly irrigated three times a day to avoid any damage to the transplanted seedlings.

Definitive experiments installed in a substitutive series. Replacement series experiments were assessed also 50 days after emergence. Previously to plant collection, the photosynthetic (A) and transpiration (E) rates were obtained by using an infrared gas analyzer (IRGA) ADCLCA PRO (Analytical Development Co. Ltd, Hoddesdon, UK) by evaluating the middle third of the first fully expanded leaf of sorghum. Only one block of all experiments was evaluated on the same day, between 7 and 9 am so that the environmental conditions were homogeneous during the analysis of treatments in the same block. Thus, 54 days after emergence, DM and LA were quantified in the same way as for the preliminary experiments.

Experimental analysis. Data sets from replacement series experiments were analyzed by using the method of graphical analysis of variation, or relative productivity

(Roush *et al*., 1989; Cousens, 1991; Bianchi *et al*., 2006). This method builds diagrams considering the relative (PR) or total (PRT) productivity. If the PR result is a straight line, it means that the species' competitive abilities are equivalent. However, if PR results in a concave line, it means there is a loss in the growth of one or both species. On the other hand, if PR shows a convex line, there is a benefit for the growth of one or both species. If PRT is equal to 1 (straight line), competition for the same resources occurs; however, if PRT is greater than 1 (convex line), there will be no competition in the community. If PRT is smaller than 1 (concave line), there is damage to the plants involved in the competition (Cousens, 1991).

The relative competitiveness (CR), clustering (K), and aggressiveness (A) coefficients were also estimated. CR expresses the comparative growth of sweet sorghum cultivars (X) compared to the competitor hairy beggarticks (Y); K determines the relative dominance of the crop on the weed, and A indicates whether the sweet sorghum cultivars are most aggressive than the weed. In this way, CR, K, and A are indicators of the most competitive species, and their joint interpretation more accurately points out species competitiveness (Cousens, 1991). Sweet sorghum (X) is more competitive than hairy beggarticks (Y) when CR > 1, Kx > Ky, and A > 0 (Hoffman & Buhler, 2002). These coefficients were calculated by using equal plant proportions (50:50), with the equations: $CR = {}^{PRx}/_{PRy}$; $Kx = {}^{PRx}/_{(1\ PRx)}$; $Ky = {}^{PRy}/_{(1\ PRy)}$; $A = PRx - PRy$, as proposed by Cousens & O'Neill (1993).

For the procedure of statistical analysis of yield, the calculations of the differences for the PR were obtained in the proportions 25, 50, and 75%. The "t" test was used to test these differences between the hypothetical and the obtained curves (Roush *et al*. 1989). It was considered a null hypothesis to test the differences in PR and A when means were equal to zero ($H_0 = 0$); for PRT and CR, when the averages were equal to one ($H_0 = 1$); and for K, that the averages of the differences between Kx and Ky were equal to zero [$H_0 = (Kx - Ky) = 0$]. As a criterion for accepting if PR and PRT curves were different from the hypothetical lines, it was taken into account that at least two proportions (out of three) would present significant differences by the "t" test (Bianchi *et al*., 2006).

The results obtained for photosynthetic and plant transpiration rates, leaf area, and aboveground dry mass were submitted to Analysis of Variance by the F-test and, when significant, means were compared by Dunnett's test, considering monocultures as controls in these comparisons. For all statistical analyses, a significance of $p \leq 0.05$ was adopted.

RESULTS AND DISCUSSION

The graphical results show that the three cultivars of sweet sorghum showed similarity in competition against hairy beggarticks for AF and MS. The PRT values for these variables (solid lines) deviated from the expected (dashed lines), generating predominantly concave responses and mean values below 1 (Figure 2 and Figure 3).

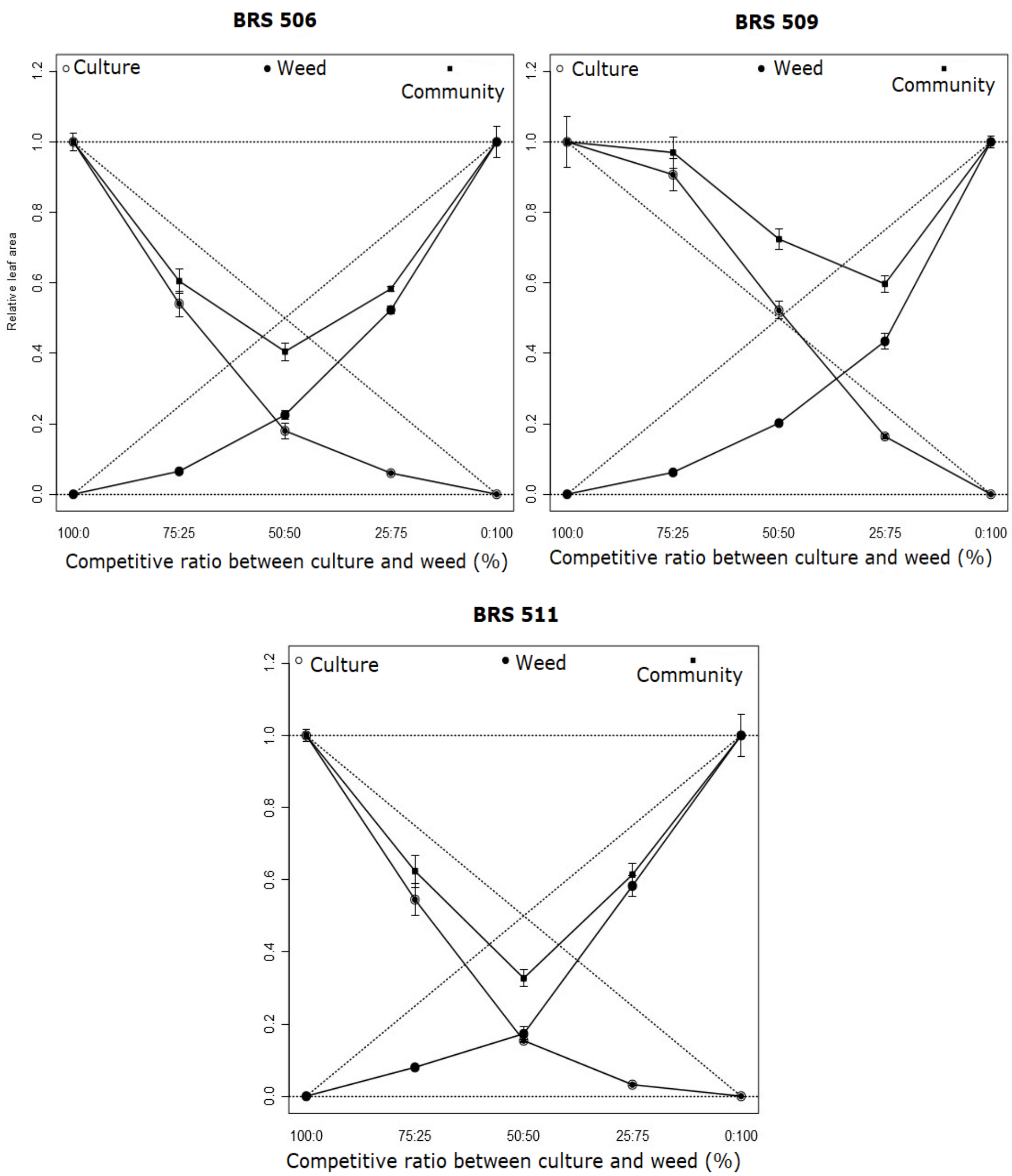

Figure 2. Relative productivity (PR) for leaf area (LA) of sorghum cultivars (○), hairy beggarticks (●) and total relative productivity (PRT) of plant community (■) as a function of plant proportion (sorghum:weed). Dashed inclined lines indicate the expected values for relative productivity in any plant proportion. Solid lines indicate the observed experimental values for relative productivity. Standard error bars are presented for treatments.

This behavior for PRT shows competition between sorghum cultivars and the weed for the same resources (Rubin *et al*., 2014). This competition culminates in quantitative and qualitative losses for both species, especially for the less competitive one. When studying the effect of Sudan grass on maize (Wandscheer *et al*., 2014) as well as ryegrass on barley (Galon *et al*., 2011), and soybean (Forte *et al*., 2017), the authors reported concave lines for the crop and the competitor, corroborating our findings. The results demonstrate losses were observed both for sorghum cultivars and for the weed (Figure 2 and Figure 3; Table 1), except for AF in 'BRS 509', in which the association was most detrimental for the weed (Figure 2).

Compared to the competition-free control, the three cultivars had significant reductions in LA during coexistence with weeds for most of the tested proportions (Figure 2; Table 1). Greater losses were verified for 'BRS 506' and 'BRS 511', with average reductions of 27.64 and 81.61%, respectively, for the proportions 75:25 and 25:75 (crop:weed). 'BRS 509', on the other hand, showed a different behavior, with LA increasing by ~ 21% in the proportion of 75:25 and a reduction of 34.58% in the proportion of 25:75. Thus, 'BRS 509' was more competitive than the others were in keeping adequate LA. Attention to this variable is justified since the leaf area is directly related to the production of photoassimilates, which therefore influences the productive and qualitative processes of the plant. For Page *et al*. (2010) light availability is one of the main limitations for the initial growth of plant communities and directly affects the productive potential of crops.

For DM (Figure 3; Table 1), reductions were observed for all cultivars in all plant proportions. DM losses in sorghum at proportions 50:50 (crop: weed) were 78.66, 46.98, and 77.18%, respectively for 'BRS 506', 'BRS 509', and 'BRS 511'. Various authors have reported losses involved in the growth of crops and weeds when they are under competition (Fleck *et al*., 2008; Rigoli *et al*., 2008; Galon *et al*., 2011).

Assuming that sweet sorghum cultivars "X" ('BRS 506', 'BRS 509', or 'BRS 511') are more competitive than hairy beggarticks "Y", (CR > 1, Kx > Ky and A > 0) (Hoffman & Buhler, 2002), and considering that Bianchi *et al*. (2006) suggests competitive superiority as the occurrence of significant differences in at least two of these indexes, for LA and DM (Table 2), all sorghum cultivars are more competitive than hairy beggarticks. Similar results of crop superiority compared to weeds were reported by Forte *et al*. (2017) for soybean and Wandscheer *et al*. (2014) for maize.

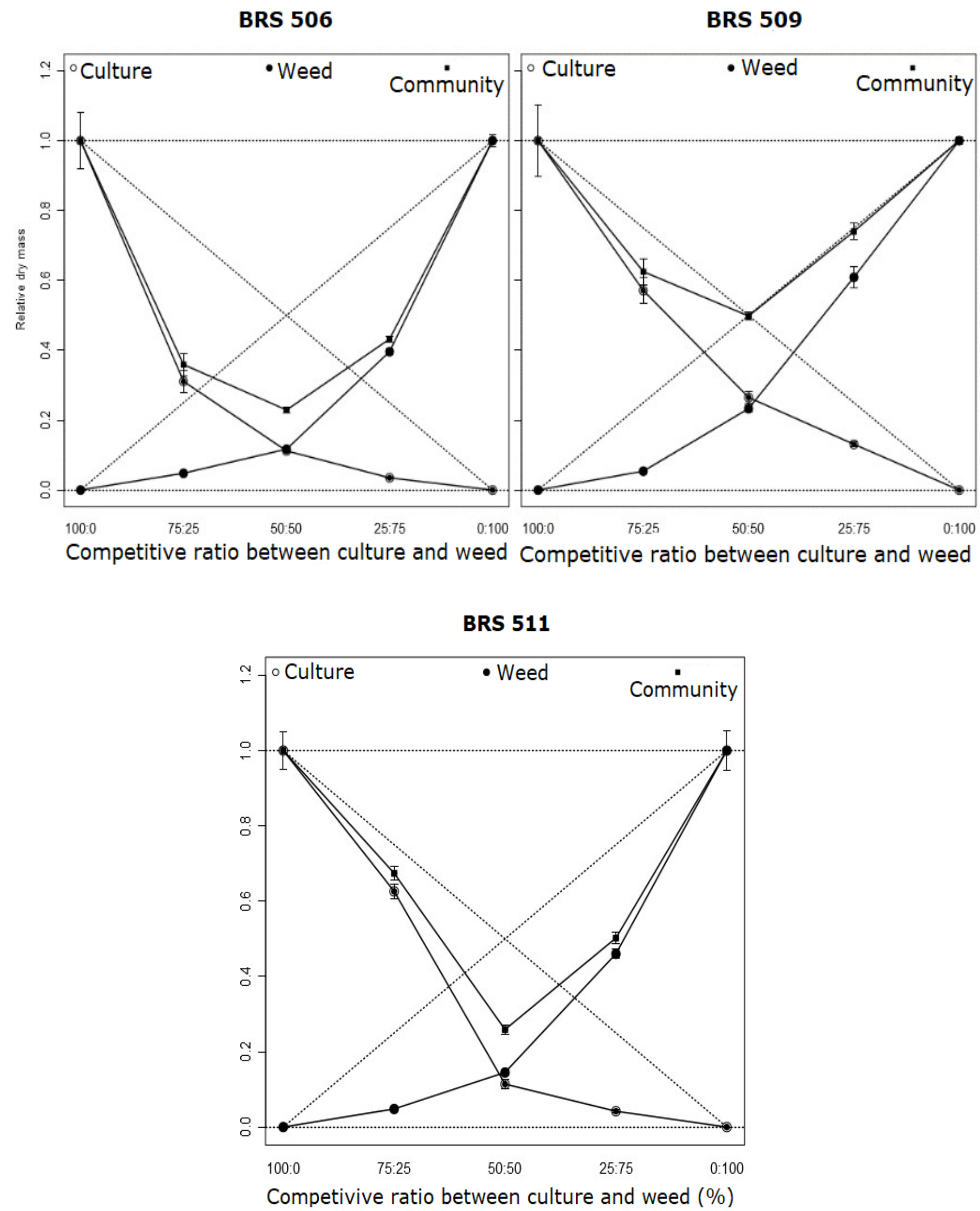

Figure 3. Relative productivity (PR) for aboveground dry mass (DM) of sorghum cultivars (○), hairy beggarticks (●) and total relative productivity (PRT) of plant community (■) as a function of plant proportion (sorghum:weed). Dashed inclined lines indicate the expected values for relative productivity in any plant proportion. Solid lines indicate the observed experimental values for relative productivity. Standard error bars are presented for treatments.

Table 1. Differences between mixed and isolated species of sorghum cultivars (BRS 506, BRS 509 or BRS 511) and hairy beggarticks.

Plant proportion Sorghum: Beggarticks	Sorghum cultivar		
	BRS 506	BRS 509	BRS 511
	Leaf area (cm^2 pot^{-1})		
	BRS 506	BRS 509	BRS 511
100:0 (C[A])	5381.36	1974.80	5931.64
75:25	3879.52*	2389.25*	4306.62*
50:50	1932.28*	2061.49	1826.01*
25:75	1296.88*	1291.82*	751.41*
CV (%)	13.90	12.60	12.90
Plant proportion Sorghum: Beggarticks	Aboveground dry mass (g pot^{-1})		
	BRS 506	BRS 509	BRS 511
100:0 (C)	59.99	25.52	41.69
75:25	23.59*	19.42*	34.81*
50:50	12.80*	13.53*	9.51*
25:75	8.04*	13.40*	7.04*
CV (%)	23.00	19.50	13.00
Plant proportion Sorghum: Beggarticks	Photosynthesis rate (A - μmol m^{-2} s^{-1})		
	BRS 506	BRS 509	BRS 511
100:0 (C)	11.85	10.29	11.13
75:25	12.16	11.72	11.01
50:50	10.31	8.94	12.32
25:75	8.61*	10.93	8.94
CV (%)	18.80	12.10	9.90
Plant proportion Sorghum: Beggarticks	Transpiration rate (E - mol H_2O m^{-2} s^{-1})		
	BRS 506	BRS 509	BRS 511
100:0 (C)	1.36	1.31	1.24
75:25	1.30	1.28	1.33
50:50	1.09	1.34	1.35
25:75	0.96*	1.23	1.32
CV (%)	20.80	12.70	17.33

* Means differ from the control © according to Dunnett's ($p \leq 0.05$). [A] = control treatment (isolated species).

According to Vilá *et al*. (2004), when crops are planted in weed-infested areas, normally the crop has advantages in relative productivity under equivalent densities, thus demonstrating that intraspecific competition exceeds the interspecific competition in importance.

Interpreting the graphical analyzes of relative variables and their significance relative to the equivalent values (Figure 2, Figure 3, Figure 4, and Figure 5; Table 1) and the competitiveness coefficients (Table 2), in general, negative interaction was found between species. Cultivars, in general, showed reductions in traits whatever the proportion of hairy beggarticks. Concerning competitiveness (Table 2), the behavior of sorghum cultivars was different for some variables, with 'BRS 509' being more competitive than 'BRS 506' and 'BRS 511' against hairy beggarticks. This weed, if not controlled when infesting sorghum, will cause losses due to its high ability to interfere with this crop's growth. This information is important for the decision-making to control this weed as early as possible in a way not to cause negative interference on the crop.

Table 2. Competitiveness coefficients for sorghum cultivars (BRS 506, BRS 509, BRS 511) in equal plant proportions (50:50), expressed by relative competitiveness (CR), clustering coefficient (Kx/Ky) and aggressivity (A).

Sorghum cultivar	CR	Kx (sorghum)	Ky (hairy beggarticks)	A
Leaf area (cm^2 pot^{-1})				
BRS 506	2.86 (±0.38)*	0.40 (±0.06)	0.20 (±0.07)	0.23 (±0.03)*
BRS 509	5.07 (±0.50)*	0.83 (±3.15)	0.19 (±0.02)	0.48 (±0.03)*
BRS 511	2.27 (±0.17)*	0.41 (±0.06)	0.26 (±0.02)	0.20 (±0.03)*
Aboveground dry mass (g pot^{-1})				
BRS 506	2.13 (±0.20)*	0.15 (±0.02)	0.15 (±0.05)	0.11(±0.02)*
BRS 509	3.56 (±0.27)*	0.45 (±0.06)*	0.17 (±0.01)	0.27(±0.02)*
BRS 511	4.39 (±0.22)*	0.56 (±0.05)*	0.15 (±0.03)	0.32(±0.01)*
Photosynthesis rate (A - µmol m^{-2} s^{-1})				
BRS 506	1.48(±0.26)	1.95(±0.95)	0.66(±0.09)	0.15(±0.07)
BRS 509	1.28(±0.12)	2.52(±0.89)	0.89(±0.10)	0.11(±0.04)
BRS 511	0.97(±0.03)	0.97(±0.08)	1.03(±0.05)	0.02(±0.07)
Transpiration rate (E - mol H_2O m^{-2} s^{-1})				
BRS 506	1.10(±0.06)	0.86(±0.08)	0.84(±0.06)	0.04(±0.03)
BRS 509	0.78(±0.03)*	0.95(±0.15)	1.34(±0.02)	0.13(±0.02)*
BRS 511	0.99(±0.05)	1.54(±0.30)	1.13(±0.04)	0.08(±0.03)

* Significant difference in the column for each individual result according to t-test ($p \leq 0.05$). Values into brackets represent the standard error of the mean.

Regarding photosynthetic and transpiration rates, the graphical results (Figure 4 and Figure 5) indicate that, in general, the three cultivars behaved distinctly. The PRTs for A and E, in general, deviated from the expected (dashed line), generating predominantly concave lines and average values below 1 for photosynthetic rate (A) and predominantly convex lines and average values greater than 1 for transpiration rate (E), with the exception for 'BRS 506'. Concave lines for PRT indicate competition between sorghum and hairy beggarticks for the same environmental resources. Opposite, when PRT is predominantly convex, it indicates that the two species benefited from the coexistence. In this case, however, while higher A means a positive trait (higher photosynthesis rates), higher E (higher transpiration rates) indicates more water lost for the same photosynthesis rate. Thus, for E, smaller is better and 'BRS 506' was the most economical for water use.

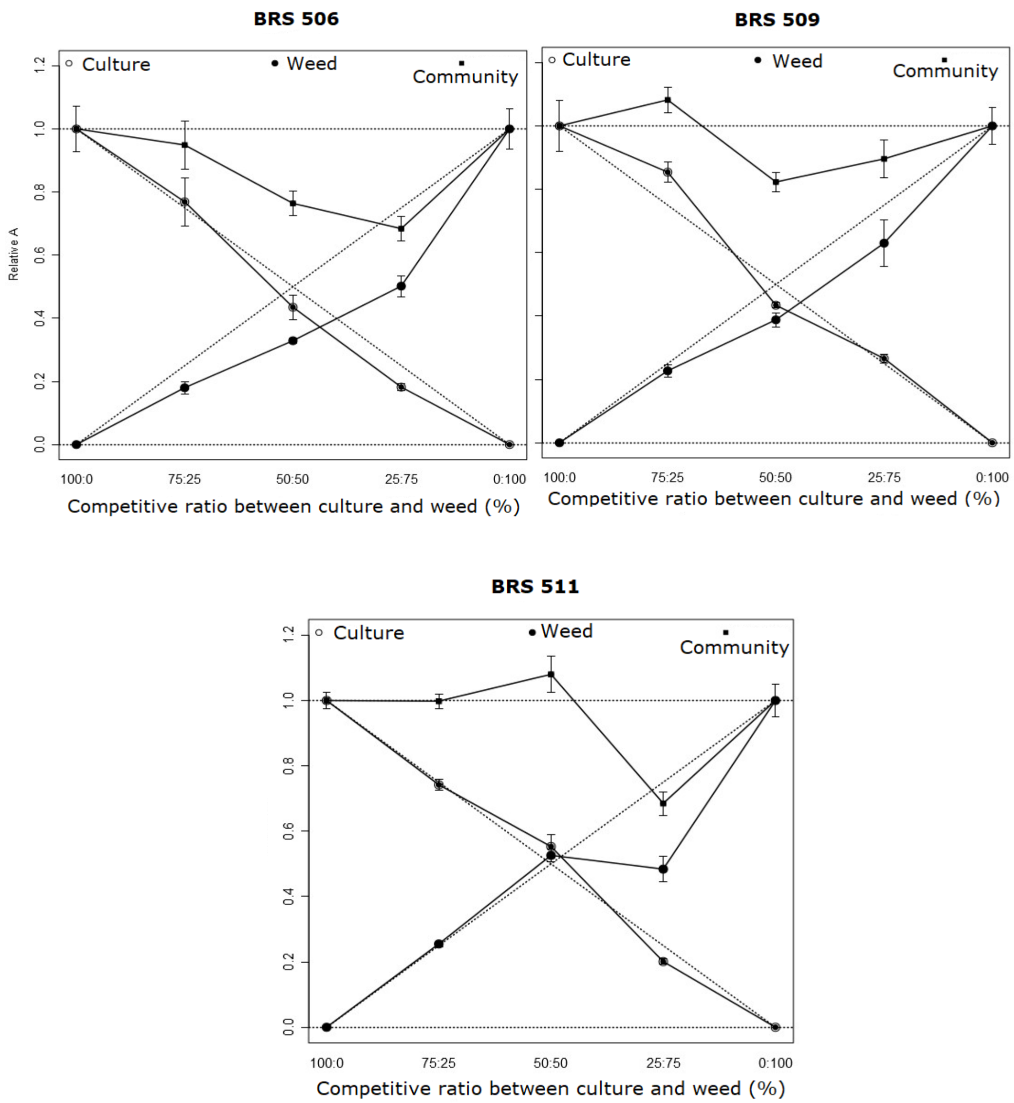

Figure 4. Relative productivity (PR) for photosynthesis rate (A) of sorghum cultivars (○), hairy beggarticks (●) and total relative productivity (PRT) of plant community (■) as a function of plant proportion (sorghum:weed). Dashed inclined lines indicate the expected values for relative productivity in any plant proportion. Solid lines indicate the observed experimental values for relative productivity. Standard error bars are presented for treatments.

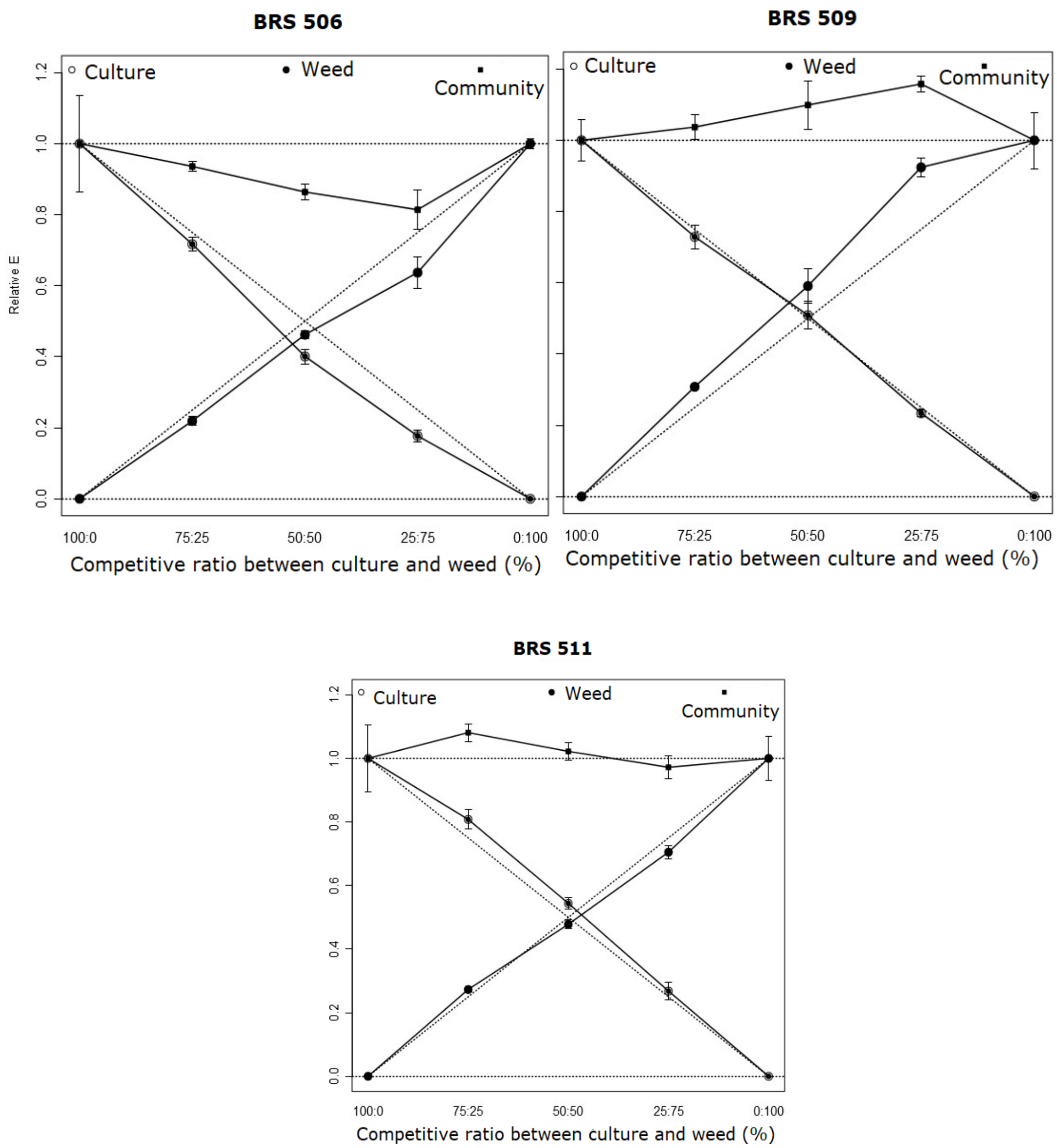

Figure 5. Relative productivity (PR) for transpiration rate (E) of sorghum cultivars (○), hairy beggarticks (●) and total relative productivity (PRT) of plant community (■) as a function of plant proportion (sorghum:weed). Dashed inclined lines indicate the expected values for relative productivity in any plant proportion. Solid lines indicate the observed experimental values for relative productivity. Standar error bars are presented for treatments.

When analyzing differences between sorghum associated or not with the weed for the physiological variables (Table 2), one can verify statistical differences in general only for 'BRS 506', even so, not for all variables and proportions. Still, when significant differences are observed, as a rule, there is a reduction in the values of the response variables whenever the proportion of competitor plants increases. In terms of competitive coefficients (Table 2), for the physiological variables, the three sorghum cultivars are more competitive than hairy beggarticks, as they were superior to the weed in at least two of the coefficients (CR > 1, Kx > Ky and A > 0).

Interpreting jointly the graphical analysis of relative variables (Figure 2 and Figure 5), their significance (Table 1), and the competitiveness coefficients (Table 2), in general, negative interaction was found between species. However, the crop is more competitive than the weed when in similar plant densities. In field conditions, however, where resource availability may be below the ideal and where the weed is in a higher plant density, it will surely affect sweet sorghum development based on the impacts of the weed on the crop reported in the present study.

The coexistence of species in a community and the study of competition for the resources of the environment such as water, light, and nutrients is very important to evaluate the effect of this interference on crops of agricultural interest, as can be seen in Figure 6 (A and B), where sweet sorghum and hairy beggarticks in the absence of competition have much greater growth and development than when they are living together (Figure 6 C). Thus, studies related to investigating the competitive ability between cultivars of a crop and weeds become important, especially this information can be used in the adoption of integrated management of weeds in crops.

CONCLUSIONS

Sweet sorghum cv. 'BRS 509' was demonstrated to be slightly more competitive than 'BRS 506' and 'BRS 511' against hairy beggarticks in experimental conditions. Field experiments should follow to test if this superiority is kept also under field conditions.

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Figure 6. Sweet sorghum (A) and hairy beggarticks (B) free from competition, and (C) when they are part of the same plant community.

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