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Weed interference in the sweet sorghum crop

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Abstract

This is a phytosociological study which determined the critical period of weed interference in sweet sorghum crops. The experiment was a randomized block design with three replications. Treatments consisted of increasing periods of control or coexistence of weeds in different phenological stages of crop growth: 0-3 (V_3), 0-5 (V_5), 0-7 (V_7), 0-9 (V_9), 0-11(V_{11}) fully expanded leaves and 0-R_5 (harvest). The weed community was evaluated for the number of individuals and their correspondent dry mass accumulation, for each weed population in different periods of coexistence. Sweet sorghum was harvested at 101 days after emergence, when we measured plant height, stem diameter, total soluble solids (°Brix) according to the periods of coexistence between crop and weeds, besides the yield of stems. *Commelina benghalensis* and *Panicum maximum* were the two species of greater relative importance in the area. The lack of weed control, during the crop cycle, led to an increase in total soluble solids (°Brix) and reduction by 9 and 25% in plant height and stem diameter, respectively, when compared with the hoed control throughout the cycle. Accepting losses of 5% in stem yield, the critical period of weed interference corresponded to the period between phenological growth stages V_3 and $V_{11.}$

Key words: BRS 511, competition, control periods, *Sorghum bicolor.*

Interferência de plantas daninhas na cultura do sorgo sacarino

Resumo

Este trabalho teve como objetivo o estudo fitossociológico da comunidade infestante ao longo do ciclo de desenvolvimento do sorgo sacarino e a determinação do período crítico de prevenção à interferência das plantas daninhas na cultura. O delineamento experimental foi de blocos ao acaso com três repetições. Os tratamentos foram constituídos por períodos crescentes de controle ou convivência das plantas daninhas em diferentes estádios fenológicos da cultura: 0-3 (V_3), 0-5 (V_5), 0-7 (V_7), 0-9 (V_9), 0-11(V_{11}) folhas completamente expandidas e 0-R_5 (colheita). A comunidade infestante foi avaliada por meio do número de indivíduos e da massa seca acumulada correspondente, para cada população de planta daninha nos diferentes períodos de convivência. O sorgo sacarino foi colhido aos 101 dias após a emergência, quando se avaliaram altura, diâmetro, teor de sólidos solúveis totais (°Brix) em função dos períodos de convivência da cultura com as plantas daninhas, além do rendimento de colmos nos diferentes tratamentos. *Commelina benghalensis* e *Panicum maximum* foram as duas espécies de maior importância relativa na área, no momento da colheita. A ausência de controle da comunidade infestante, durante todo o ciclo do sorgo sacarino, ocasionou aumento no teor de sólidos solúveis totais (°Brix) e redução de, respectivamente, 9% e 25% na altura e diâmetro de colmo da cultura, quando comparado com a testemunha capinada durante todo o ciclo. Considerando a tolerância de 5% na redução da produtividade de colmos, observou-se que o período crítico de prevenção a interferência correspondeu ao intervalo do estádio fenológico V_3 a $V_{11.}$

Palavras-chave: BRS 511, competição, períodos de controle, *Sorghum bicolor.*

1. INTRODUCTION

Nowadays there is a growing interest in replacing energy of fossil origin with plant origin energy. Since the oil crisis in the 70's, when it was discovered that this source is exhaustible, Brazilian studies have focused on various raw materials for bioethanol production, highlighting sugar cane as the main alternative. However, in the medium and long term, the study and exploration of energy matrix has emphasized the search for new options of renewable sources with energy potential, including the use of new crops with this potential. Among these crops, sweet sorghum (*Sorghum bicolor* (L.) Moench) stands out as an alternative for ethanol production, especially in the off-season of sugarcane in plantations (Pereira Filho et al., 2013), or in places where sugarcane cultivation is not permitted by law.

Sweet sorghum is an annual cycle crop (90-130 days), spread by seeds, with tall size, succulent stems showing high levels of fermentable sugars (Almodares and Hadi, 2009). These characteristics, along with the need of only a few adjustments in sugarcane plants to use sorghum as a feedstock for ethanol production, makes this crop an alternative to sugarcane industries (May et al., 2012).

Meanwhile, to consolidate the expansion of the cultivated area with sweet sorghum, and to achieve satisfactory yield potential, it is necessary to properly conduct the treatments in the crop. Among them, the integrated weed management stands out as one of the main bottlenecks in the production system, because the weed control in inappropriate time may adversely affect the production cost and/or result in qualitative and quantitative losses in crop yield (Ciuberkis et al., 2007).

A major component for adopting integrated weed management is the identification the optimum time for weed control throughout the crop cycle. To this end, three periods of interference are described in the literature: critical weed free period (CWFP), critical timing of weed removal (CTWR) and critical period of weed control (CPWC). CWFP is the period when the crop can coexist with weeds without quantitative or qualitative losses; CTWR is the period after planting or emergence when the crop should be kept free from weed interference; CPWC is the period between late CWFP and late CTWR, where the coexistence of weeds and crops can cause damage (Pitelli, 1985). Periods of interference can be determined considering the phenological stage of the crop or time periods after sowing and/or emergence. To better characterize the CPWC, it is interesting to assess the behavior of the weed community throughout the crop cycle, so that it is possible to understand the existing interactions and which species are being selected by the management system and practices in the area (Adegas et al., 2010).

The lack of studies on the topic for sweet sorghum can induce the farmer to error on the best time for weed control in the crop. Thus, the development of studies that address this gap is crucial for good crop establishment.

In this context, this study aimed to evaluate the dynamics of the weed community throughout the crop cycle and determine the critical timing of weed removal on sweet sorghum.

2. MATERIAL AND METHODS

The experiment was conducted in the experimental area (11°51'37" S; 55°36'19" W) of Embrapa Agrossilvipastoril, Sinop, Mato Grosso State. The altitude is 365 m, the meteorological data during the experiment are listed in figure 1.

The soil of the experimental area was classified as dystrophic Red Yellow Latosol (Santos et al., 2006). Physical and chemical characteristics of the 0-20 cm soil layer are presented in table 1. Soil preparation was done as in the conventional system and crop management techniques followed the recommendations for the cultivation of sorghum. We used the cultivar BRS 511 sown at a spacing of 0.75 m between rows, with 09 seeds per linear meter. Sowing was done on November 6th, 2012 and the emergence took place five days later. The basic fertilization consisted of applying 450 kg ha^{-1} of the 08-28-16 formulation (N-P_2O_5-K_2O). As topdressing, we applied 200 kg ha^{-1} of ammonium sulfate at the V_5 phenological stage and 200 kg ha^{-1} of urea at the V_7 phenological stage, with applications directed to the planting row.

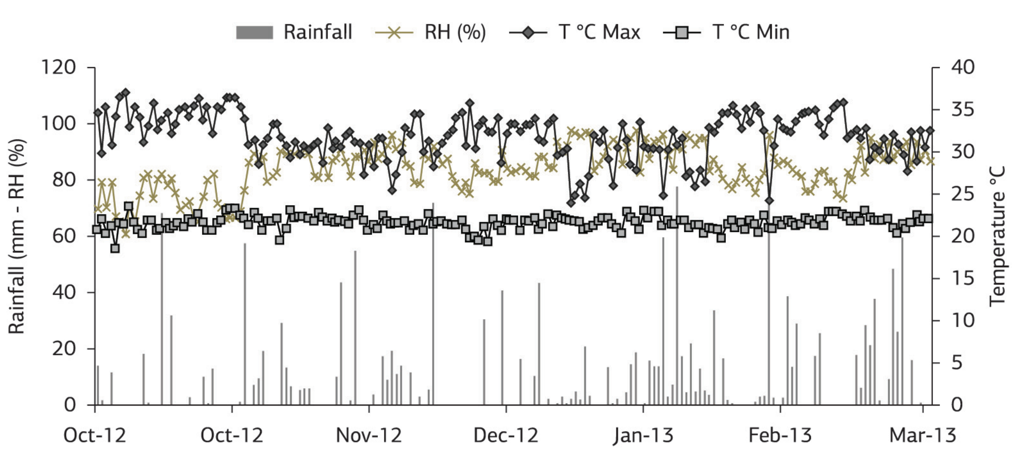

Figure 1. Climatological data in the experimental area for sweet sorghum cultivar BRS511: rainfall, maximum (T°C Max) and minimum (T°C Min) temperatures and relative humidity (RH). Embrapa Agrossilvipastoril, Sinop, Mato Grosso State, 2012/2013.

Table 1. Chemical and physical composition of soil at 0-20 cm layer from the conventional sowing system for sweet sorghum cultivar BRS511. Embrapa Agrossilvipastoril, Sinop, Mato Grosso State, 2012/2013

Conventional sowing system Physical and chemical analysis of the soil										
pH	P	K^+	H+ Al^{3+}	Ca^{2+}	Mg^{2+}	CTC total	MO	Clay	Silt	Sand
H_2O	mg dm^{-3}		-------------$cmol_c$ dm^{-3}-------------					----------- dag kg^{-1}------------		
5.22	7.28	40	4.33	1.19	0.26	5.89	1.86	43.8	22.3	33.93

CTC = cation exchange capacity and MO = organic matter.

The experiment was a randomized block design with three replications. The experimental unit consisted of six 5 m-rows. The useful area for evaluation was formed by the four central rows. It was also used one planting row at each lateral situated at 0.5 m at its closest row as boundary layers. The experimental area comprised 12 m^2 (3x4 m). The treatments consisted of two groups: in the first, crop coexisted with weeds during different cycle phases: 3 (V_3), 5 (V_5), 7, (V_7), 9 (V_9) and 11 (V_{11}) fully expanded leaves, corresponding respectively to 14, 27, 37, 47 and 56 days after emergence (DAE). After these periods, the plots were kept clean by periodic hand weeding. In the second, crop remained free from weed interference, from emergence until the end of the periods described above; weeds that emerged after the end of these periods were not controlled. There were two controls, a constantly free from weeds and other infested until harvesting the crop R_5 – 101 DAE).

Weed community was characterized at the end of each period of coexistence. These evaluations were performed with the random thrown of a metallic square frame (0.5x0.5 m) for three times in the useful area of each plot. Shoots of weeds were collected and separated by species to determine the values of density and dry mass. Plants were cut at ground level, oven-dried at 70 °C to constant mass. Besides counting the species and total individuals per sampled area, the following phytosociological parameters were calculated: relative frequency (rFr), relative density (rDe), relative dominance (rDo) and index of importance value (IV), as proposed by Concenço et al. (2013a) and Silva et al. (2005).

The evaluation of diameter, height and total soluble solids content (°Brix) of the crop was performed at 101 days after emergence (DAE) in the treatments of coexistence with weeds. The variables were measured in ten sorghum plants within the useful area of each treatment. Plant height was measured with a graduated ruler from close to the ground until the inflection of the flag leaf. The stem diameter was measured in the middle third of the plants, with a caliper. For determining the °Brix of the treatments, ten sorghum plants in each plot, were pressed in an electric low speed mill (1750 RPM) and a sample of juice was taken for reading on a digital refractometer, Brix 95° scale.

At the time of the measurements, we manually cut ten sorghum plants in the useful area of each plot, in the two treatment groups (control and coexistence). Leaves and panicles of sweet sorghum were detached and stems were weighed in the field. Stem yield data were fitted to a non-linear regression model, using the logistic equation:

$$Y = y_0 + \frac{a}{\left[1+\left(\frac{x}{x_0}\right)^b\right]} \quad (1)$$

Where: Y is the yield of stem, x is days after sorghum emergence, y is the minimum yield; a is the difference between the maximum and minimum yield, representing the yield loss; x is the time in days in which occur 50% response in stem yield; b is the slope.

The results of weed on yield components were checked for normality and homogeneity and subjected to analysis of variance at 5% significance. In case of significance, data were subjected to regression analysis. Model selection was based on the biological phenomenon, coefficient of determination (R^2) and the significance of the regression analysis. The CPWC considered losses of 5% in stem yield in relation to plots kept clear throughout the cycle.

3. RESULTS AND DISCUSSION

Analyzing the density and the accumulation of dry mass of the weed community over the study period (Figure 2a,b), there was a contrasting behavior of the two variables, while the number of plants m^{-2} decreased linearly, the accumulation of dry mass increased. This inverse relationship indicates that the weed species remaining at the end of the study period have high competitive ability, which led to the elimination of various other species.

In the phytosociological survey of the weed community, we identified 15 species, comprising nine families (Table 2). The species that presented great number of individuals were *Digitaria insularis* (sourgrass), *Eleusine indica* (goosegrass), *Cyperus esculentus* (yellow nutsedge), *Commelina benghalensis* (tropical spiderwort) and *Panicum maximum* (guinea grass).

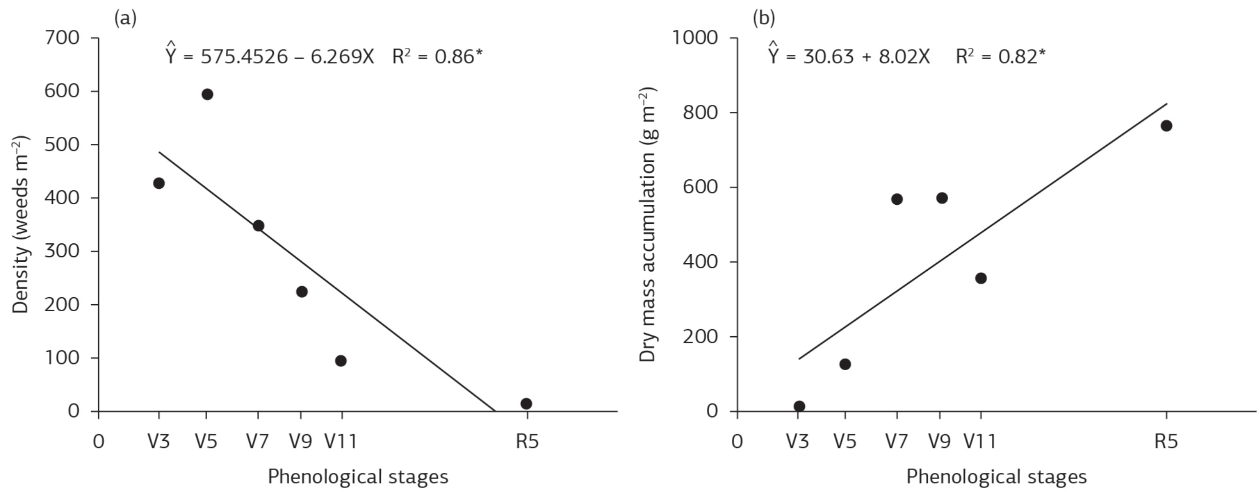

Figure 2. Density (a) and accumulation of dry mass (b) of the weed community, at the end of periods of coexistence with sweet sorghum cultivar in the phenological stages 3 (V_3), 5 (V_5), 7 (V_7), 9 (V_9), 11 (V_{11}) fully expanded leaves and R_5 (harvest). *significant at 5% probability by the F-test.

Table 2. List of weed species infesting sweet sorghum cultivar BRS511. Embrapa Agrossilvipastoril, Sinop, Mato Grosso State, 2012/2013

Family	Class	Species	Common name
	Magnoliopsida		
Amaranthaceae		*Amarantus* spp.	pigweed
Asteraceae		*Ageratum conyzoides*	goatweed
		Emilia sonchifolia	lilac tasselflower
		Melampodium spp.	plains blackfoot
		Tridax procumbens	coat buttons
Convolvulaceae		*Ipomoea* spp.	morning glory
Euphorbiaceae		*Chamaesyce hirta*	garden spurge
Fabaceae		*Senna obtusifolia*	sicklepod
Malvaceae		*Sida* spp.	arrowleaf sida
	Liliopsida		
Commelinaceae		*Commelina benghalensis*	tropical spiderwort
Cyperaceae		*Cyperus esculentus*	yellow nutsedge
Poaceae		*Brachiaria decumbens*	signal grass
		Digitaria insularis	sourgrass
		Eleusine indica	goosegrass
		Panicum maximum	guinea grass

Considering the phytosociological parameters of the main weed species along the sweet sorghum cycle (Table 3), we observed that the sourgrass, in the two initial stages of development (V_3 and V_5), was the second weed of higher IR (%). However, along the period it was suppressed until not being registered during harvesting of the crop. The loss of IR (%) of this species can be attributed to its lower competitive ability against the weed community in the area. According to Correia et al. (2010), sourgrass has slow initial growth until 45 days after emergence, so even presenting high rDe (%) and rFr (%) in the initial stages, this weed was eventually suppressed at the end of the cycle by more dominant species, such as, tropical spiderwort and guinea grass. A dominant plant is characterized by large area of ground cover, great accumulation of mass and great distribution across the area (Concenço et al., 2013a).

Tropical spiderwort and guinea grass showed the highest rDo (%), 62.05 and 37.82, respectively (Table 3). However, these two weed species had distinct behavior throughout the crop cycle. The spiderwort stood out since the first assessments, showing high IV (%), the guinea grass was more important in the final development stages of sorghum (V_9 to R_5). The late importance gain of guinea grass can be attributed to the low values of rDe (%), rFr (%) and rDo (%) in the initial periods of development (V_3 to V_7). However, these parameters increased rapidly

Table 3. Phytosociological indices of relative density (rDe), relative frequency (rFr), relative dominance (rDo) and index of importance value (IV) of the weed community at the end of periods of coexistence with sweet sorghum cultivar BRS 511, in the phenological stages 3 (V_3), 5 (V_5), 7 (V_7), 9 (V_9), 11 (V_{11}) fully expanded leaves and R_5 (harvest). Embrapa Agrossilvipastoril, Sinop, Mato Grosso State, 2012/2013

	Phenological stage V3				Phenological stage V5			
Species	rDe (%)	rFr (%)	rDo (%)	IV (%)	rDe (%)	rFr (%)	rDo (%)	IV (%)
D. insularis[1]	27.59	15.09	25.53	22.74	21.73	14.81	26.05	20.87
E. indica[2]	9.23	15.09	9.70	11.34	8.14	12.96	16.66	12.59
C. esculentus[3]	12.97	15.09	2.96	10.34	22.48	16.67	2.19	13.78
C. benghalensis[4]	15.56	16.98	37.86	23.47	16.13	16.67	37.82	23.54
P. maximum[5]	18.57	9.43	16.68	14.89	7.92	9.26	9.92	9.03
Other	16.08	28.3	7.26	17.22	23.60	29.63	7.37	20.20
Total	100	100	100	100	100	100	100	100
	Phenological stage V7				Phenological stage V9			
Species	rDe (%)	rFr (%)	rDo (%)	IV (%)	rDe (%)	rFr (%)	rDo (%)	IV (%)
D. insularis[1]	2.93	8.96	7.42	6.43	12.39	15.91	9.67	12.66
E. indica[2]	17.56	13.43	12.98	14.66	4.19	15.91	9.26	9.79
C. esculentus[3]	12.98	11.94	0.14	8.35	22.59	9.09	0.40	10.69
C. benghalensis[4]	36.77	13.43	71.85	40.68	27.87	15.91	32.90	25.56
P. maximum[5]	12.98	11.94	4.58	9.83	10.56	9.09	36.14	18.60
Other	16.79	40.30	3.04	20.04	22.40	34.09	11.63	22.71
Total	100	100	100	100	100.00	100.00	100.00	100.00
	Phenological stage V11				Phenological stage R_5			
Species	rDe (%)	rFr (%)	rDo (%)	IV (%)	rDe (%)	rFr (%)	rDo (%)	IV (%)
D. insularis[1]	0.52	3.85	0.53	1.63	0.00	0.00	0.00	0.00
E. indica[2]	11.49	19.23	22.01	17.58	2.94	8.33	0.07	3.78
C. esculentus[3]	26.11	11.54	0.15	12.60	0.00	0.00	0.00	0.00
C. benghalensis[4]	31.33	19.23	41.29	30.62	52.94	41.67	62.05	52.22
P. maximum[5]	22.45	7.69	23.25	17.80	32.35	33.33	37.82	34.50
Other	8.09	38.46	12.77	19.78	11.76	16.67	0.06	9.50
Total	100.00	100.00	100.00	100.00	100	100	100	100

[1]sourgrass, [2]goosegrass, [3]yellow nutsedge, [4]tropical spiderwort, [5]guinea grass.

from V_9, suggesting a later emergence of this species, which reflected directly in the IV (%). High IV (%) values indicate plants better adapted to the environment evaluated, presenting large number of individuals and good distribution in the area, rapid early growth, favoring the use of photosynthetically active radiation and consequently contributing to the suppression of neighboring species (Concenço et al., 2013b).

Species of the genus *Commelina* are annual plants, with semi-prostate growth habit, and propagation by seed and stem rooting (Lorenzi, 2008). The growth habit and form of propagation of the tropical spiderwort, associated with high rDe (%) and rFr (%) and soil and climatic conditions favorable to its development, contributed to the rapid spatial distribution in the area, with great accumulation of mass and suppression of less competitive species. Also, guinea grass propagates by seed and vegetatively, but unlike tropical spiderwort are large perennial plants. Being a tall plant with rapid accumulation of dry mass, as observed by the increase of rDo (%) and IV (%), in short time, demonstrates the competitive ability of guinea grass.

In turn, yellow nutsedge and goosegrass lost importance with the advance of the cycle, i.e., these species were suppressed by tropical spiderwort and guinea grass. Yellow nutsedge at the V_9 stage of sorghum, even having the second highest rDe (%) 22.59, showed low rDo (%) - 0.40 – that is, there was a great number of individuals, but with low dry mass accumulation. At harvest, there were few plants of goosegrass and none yellow nutsedge plant.

The coexistence of sorghum crop with weeds caused an increase in total soluble solids (°Brix) of sweet sorghum (Figure 3). Juice Brix can be influenced by several factors such as day length, global radiation, fertilization or soil fertility (Kumar et al., 2008). Albuquerque et al. (2012) analyzed the effect of seeding rate on yield components of sweet sorghum and observed that increasing number of plants per linear meter increased the content of soluble solids. According to the authors, the increase in intraspecific competition may have adversely affected the efficiency of water absorption, resulting in increased concentrations of soluble solids in the juice. Thus, the results indicate that the concentration of sugars in sorghum juice can be influenced by both biotic and abiotic factors.

The lack of weed control during the crop cycle negatively affected the plant height of sorghum (Figure 4a), with a reduction of approximately 9% compared to the clean control. A similar result was found for stem diameter when plant coexisted with weeds (Figure 4b). The lack of weed control throughout the cycle caused a reduction of approximately 25% in the stem diameter. Reducing this variable can make plants more susceptible to lodging and breaking, adversely affecting the harvesting and thereby reducing yield and final product quality.

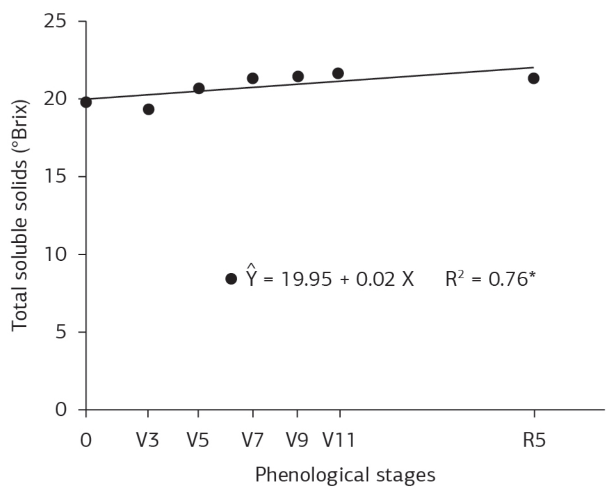

Figure 3. Total soluble solids of sweet sorghum crop, cultivar BRS 511, according to increasing periods of coexistence with weeds: 3 (V_3), 5 (V_5), 7 (V_7), 9 (V_9), 11 (V_{11}) fully expanded leaves and R_5 (harvest). Embrapa Agrossilvipastoril, Sinop, Mato Grosso State, 2012/2013. *significant at 5% probability by the F-test.

The interference imposed by weeds throughout the crop development cycle decreased the yield of around 50% (Figure 5). The slow initial growth of sweet sorghum makes it susceptible to weed competition in the early stages of development, since weeds exhibit rapid germination and emergence, promptly using environmental resources (Zegada-Lizarazu and Monti, 2012). This observation is reflected in the short period that such crop can live with weeds without the occurrence of qualitative and/or quantitative losses.

Moreover, CWFP was extended to the V_3 growth stage (14 DAE) (Figure 5). The end of this period was suitable for weed control because weeds were in early development, with high density and low dry mass accumulation, which are desirable from a technical point of view for weed control. The CTWR continued until the V_{11} growth stage (58 DAE), i.e., weeds that emerged after this period caused no further damage to the crop. Thus, under the conditions in which the work was conducted the CPWC was between the V_3 and V_{11} growth stages, or from the 14 to 58 DAE.

According to Andres et al. (2009), under temperate conditions and in lowlands, the optimal period for weed control in forage sorghum crops is between the emergence of the third and seventh leaf of the plant. On the other hand, Cabral et al. (2013) conducted a research with grain sorghum in Goiás State and found that the optimum period to perform the control is between the emergence of the fifth and ninth leaf. The different CTWRs verified reflect the different ecophysiological traits of these types of sorghum,

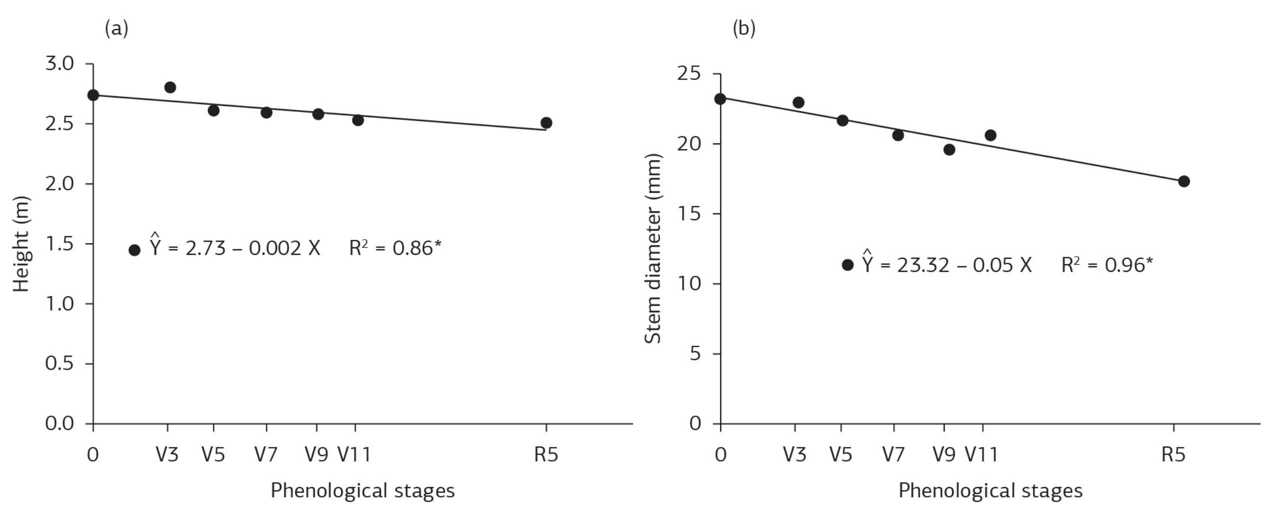

Figure 4. Plant height (a) and stem diameter (b) of sweet sorghum, cultivar BRS 511, according to increasing periods of coexistence with weeds: 3 (V_3), 5 (V_5), 7 (V_7), 9 (V_9), 11 (V_{11}) fully expanded leaves and R_5 (harvest). Embrapa Agrossilvipastoril, Sinop, Mato Grosso State, 2012/2013. *significant at 5% probability by the F-test.

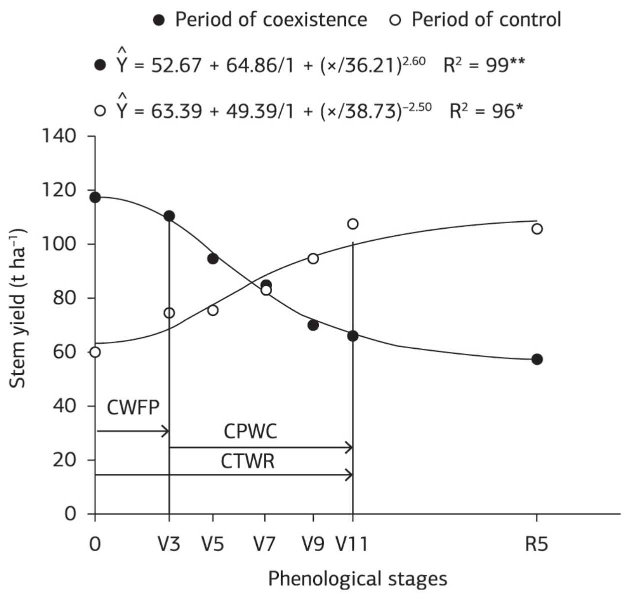

Figure 5. Stem yield of sweet sorghum, cultivar BRS511, according to increasing periods of coexistence and control of weeds, in the different phenological stages 3 (V_3), 5 (V_5), 7 (V_7), 9 (V_9), 11 (V_{11}) fully expanded leaves and R_5 (harvest). Critical weed free period (CWFP), critical timing of weed removal (CTWR) and critical period of weed control (CPWC). Embrapa Agrossilvipastoril, Sinop, Mato Grosso State, 2012/2013. ** and *significant at 1% and 5% probability by the F-test.

besides the implementation and management of the crop in different seasons and locations, as abovementioned mainly in relation to the local environmental conditions, composition of weed community and level of infestation of the area.

4. CONCLUSION

Phytosociological parameters of weed species vary over the sorghum cycle. *Commelina benghalensis* (tropical spiderwort) and *Panicum maximum* (guinea grass) have greater competitive ability than other weeds in the area, under the soil and climatic conditions of the study.

The critical timing of weed removal for the sweet sorghum cultivar BRS 511, grown under the soil and climatic conditions, in the municipality of Sinop (Mato Grosso State), corresponds to the interval between the third and eleventh fully expanded leaf (V_3 to V_{11}) or from the 14 to 58 DAE.

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