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Article

Interference Relationships Between Weeds and Sugarcane in the 'Plene' System

Relações de Interferência de Plantas Daninhas com Cana-de-Açúcar no Sistema 'Plene'

MOSSIN, C.B.[1]
HIJANO, N.[1]*
NEPOMUCENO, M.P.[1]
CARVALHO, L.B.[1]
ALVES, P.L.C.A.[1]

*** Corresponding author:**
<nerianeh@yahoo.com.br>

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ABSTRACT - Sugarcane is one of the most important crops planted in Brazil in that the presence of weeds in the fields has promoted significant yield reduction. The objective of this work was to evaluate the differential growth response of two sugarcane varieties cropped in the 'Plene' system as a function of the coexistence with different weed species. Treatments consisted of the coexistence of *Bidens pilosa* plus *Ipomoea quamoclit*, *Ipomoea hederifolia*, *Amaranthus viridis*, *Urochloa plantaginea*, *Panicum maximum*, and *Digitaria horizontalis* with two sugarcane varieties (RB92579 and SP80-1842) cropped in the 'Plene' system, in addition to a control without weeds. The design was completely randomized with three replicates. Dry matter accumulation of weeds was dependent of the weed species and the sugarcane variety whose coexistence was kept. The behavior of development in terms of plant height, number of green leaves, leaf area, and dry mass of stems, roots and leaves was dependent on the sugarcane variety and on the weed species whose coexistence was kept. The weed *U. plantaginea* showed the greatest potential to interfere with the growth of both sugarcane varieties planted in the 'Plene' system. *Panicum maximum* and *D. horizontalis* are also potential competitors, while *B. pilosa*, *I. quamoclit*, *I. hederifolia*, and *A. viridis* are less competitive. The sugarcane variety RB92579 is less susceptible to weed interference than SP80-1842 when planted in the 'Plene' system.

Keywords: *Saccharum officinarum*, morning glory, slender amaranth, marmalade grass, guinea grass, jamaican crabgrass.

RESUMO - A cana-de-açúcar é uma das culturas agrícolas mais importantes no Brasil, e a presença de plantas daninhas nas áreas de produção acarreta reduções significativas de produtividade. O objetivo deste estudo foi avaliar a resposta diferencial do crescimento de duas variedades de cana-de-açúcar plantadas no sistema Plene, em função da convivência com diferentes espécies de plantas daninhas. Os tratamentos constituíram-se da convivência de ***Bidens pilosa*** *+* ***Ipomoea quamoclit****,* ***Ipomoea hederifolia****,* ***Amaranthus viridis****,* ***Urochloa plantaginea****,* ***Panicum maximum*** *e* ***Digitaria horizontalis*** *com duas variedades de cultura da cana-de-açúcar (RB92579 e SP80-1842) plantadas no sistema Plene, bem como da testemunha sem planta daninha. Utilizou-se o delineamento inteiramente casualizado com três repetições. As plantas daninhas apresentaram acúmulo de massa seca dependente da espécie e da variedade de cana-de-açúcar com a qual conviveram. O comportamento do desenvolvimento em termos de altura, do número de folhas verdes, da área foliar, da massa seca dos colmos, da massa seca da raiz e da massa seca das folhas das duas variedades de cana-de-açúcar foi dependente da variedade plantada e da espécie de planta daninha cuja convivência*

[1] Laboratório de Plantas Daninhas (LAPDA), Universidade Estadual Paulista "Júlio de Mesquita Filho", FCAV/UNESP, Jaboticabal-SP, Brasil.

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foi mantida. ***U. plantaginea*** *apresentou o maior potencial de interferência sobre o crescimento das duas variedades de cana-de-açúcar plantadas no sistema Plene.* ***Panicum maximum*** *e* ***D. horizontalis*** *também são potenciais competidoras, enquanto* ***B. pilosa, I. quamoclit, I. hederifolia*** *e* ***A. viridis*** *são menos competitivas. A variedade de cana-de-açúcar RB92579 é menos suscetível à interferência que a variedade SP80-1842, plantadas no sistema Plene.*

Palavras-chave: *Saccharum officinarum*, corda-de-viola, caruru-de-mancha, capim-marmelada, capim-colonião, capim-colchão.

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is one of the main agricultural crops produced in Brazil, and the country occupies a prominent position on the world stage as the largest producer and exporter of sugar and alcohol in the world (OECD-FAO, 2015). With the intention of making feasible the logistics of sugarcane planting, a cropping system, called 'Plene' system, was developed, which uses small 4 cm cuttings containing buds with high germinative power (Martinho et al., 2010).

The cuttings used in the 'Plene' system are produced in nurseries, ensuring sanity, traceability, genetic guarantee, cleaning and treatment, packaging for transport, providing less need for pesticides application and high yield. In conventional mechanized systems, between 18 and 20 ton of seedlings per hectare are used, while in the 'Plene' system only 1.5 to 2 ton of material per hectare are needed. The 'Plene' system can present higher productivity and longevity, but it requires more careful management from the transport of cuttings to the soil preparation (Martins et al., 2015).

Weed interference is a very important factor in the cropping system (Pitelli, 1985). Sugarcane cultivation, for example, can be reduced by up to 81% when weeds are not controlled (Kuva et al., 2001). This reduction in yield may occur due to direct factors such as competition for nutrients, light, water and space, allelopathy and parasitism, and indirect factors such as crop interference, mainly due to the presence of creeping plants that overload harvesters (Kuva et al., 2008).

It is emphasized that interference is a reciprocal phenomenon, that is, the crop itself can limit weed development. Factors that alter the balance of interference between the crop and the weed community are related to the weed community itself (specific composition, plant density, and distribution in the area), the crop (species or variety, plant population, and planting spacing), the management used in the production area, and the time and extension of the period of coexistence between weeds and the crop. All these factors are conditioned by the edaphoclimatic factors of the environment (Pitelli, 1985).

Among the different characteristics of the weed communities, the specific composition is one of the main factors that contribute with greater or lesser aggressiveness and, consequently, affect the potential to reduce crop yield. Different weed species present distinct growth potentials, nutritional requirements, and reproductive capacity, which condition their competitive potential (Carvalho et al., 2008). Kuva et al. (2001) demonstrated that losses of up to 82% were observed in areas where the predominant weed species was signalgrass, while Kuva et al. (2003) verified reductions of 40% in areas with mixed infestation of signalgrass and guinea grass. Other authors have also made similar observations for other weed species in sugarcane plantations in the state of São Paulo, whose potential yield loss varied according to the type of infestation of the area (Silva et al., 2009; Piza et al., 2016; Bressanin et al., 2016).

In this sense, the objective was to evaluate the differential growth response of two sugarcane varieties planted in the 'Plene' system as a function of the coexistence with different weed species.

MATERIALS AND METHODS

The experiment was conducted in an open area in pots, in the Jaboticabal - SP city, located at 21°14'05" South latitude, 48°17'09" West longitude, and at an altitude of 615 m. 15 L (0.14 m diameter and 0.24 m height) pots were used as experimental units, filled with Dark Red Latosol of clayey texture (clay: 428; silt: 91; fine sand: 131; and coarse sand: 350, expressed in g kg^{-1}), with the following results for chemical and physical analysis: pH ($CaCl_2$) 5.2; 18 g dm^{-3} organic matter; P = 42.0 mg dm^{-3}; K^+ = 2.5; Ca^{+2} = 25; Mg^{+2} = 12; H+Al = 31; SB = 39.5; CEC = 70.5, expressed in mmol dm^{-3}; V = 56%. Soon after the filling of the pots, fertilization was performed with formulated fertilizer 4-14-8, corresponding to 300 kg ha^{-1}.

The sugarcane varieties RB92579 and SP80-1842 were planted at the density of two sugarcane cuttings of the 'Plene' system per pot. After planting the sugarcane, weeds were sown at the density of 30 seeds per pot, regardless of the species. The species used in the research were hairy beggar-ticks (*Bidens pilosa* - BIDPI), cypressvine morning glory (*Ipomoea quamoclit* - IPOQU), scarlet morning glory (*Ipomoea hederifolia* - IPOHF), slender amaranth (*Amaranthus viridis* - AMAVI), alexandergrass (*Urochloa plantaginea* - BRAPL), guinea grass (*Panicum maximum* - PANMA), and jamaican crabgrass (*Digitaria horizontalis* - DIGHO).

The 'Plene' cuttings were planted in the center of the pots, 8 cm deep, spaced 6 cm apart. Weed seeds/diaspores, purchased from a specialized company, were randomly sown at about 10 cm from the cuttings and at a depth of 1 cm.

The final population of the sugarcane crop was 2 plants pot^{-1}, as well as that of weeds. The final weed stand was established after thinning the excess seedlings, which was done 30 days after weed emergence. At 75 days after planting (DAP), cover fertilization was applied, depositing 600 kg ha^{-1} of the formula 4-20-20 and 200 kg ha^{-1} of urea per pot.

The experimental design was a completely randomized design with three replicates. The treatments were arranged in a 2 x 7 factorial scheme, with the factors consisting of the two varieties and seven coexistence situations of sugarcane varieties with weeds, including plants without coexistence (controls). The treatments are described in Table 1.

Table 1 **-** Experimental treatments adopted in the assay

Treatment	Weed	Code
Control	No weeds	
T1	*Bidens pilosa* (hairy beggar-ticks) and *Ipomoea quamoclit* (cypressvine morning glory)	BIDPI + IPOQU
T2	*Ipomoea hederifolia* (scarlet morning glory)	IPOHF
T3	*Amaranthus viridis* (slender amaranth)	AMAVI
T4	*Urochloa plantaginea* (alexandergrass)	BRAPL
T5	*Panicum maximum* (guinea grass)	PANMA
T6	*Digitaria horizontalis* (jamaican crabgrass)	DIGHO

At the end of the experimental period, at 108 DAP, growth characteristics in sugarcane plants and weeds were evaluated. The following crop characteristics were evaluated: height (distance between the base of the plant close to the ground and the last visible ligule, in cm), number of green and dry leaves, leaf area (Li-Color, LI-3100 A, in cm^2), and dry matter of leaves, stems and roots (after drying the materials in a forced air oven at 70 °C for at least 96 hours, in g). In the weeds, the dry matter of shoots (g) was determined.

The data were submitted to analysis of variance by the F test, and the means were compared by the Scott-Knott test, at 5% probability. When the interaction between the factors was significant, the unfolding of the degrees of freedom was performed, and then the comparison of means. In the case of non-significance of the interaction, the Scott-Knott test was presented on the values of each variety as a function of the means of weeds, and of each weed as a function of the means of varieties. Statistical analyses were performed using the statistical software SISVAR (UFV, version 5.1, Brazil).

RESULTS AND DISCUSSION

Weeds

For the dry matter of weeds shoots, the analysis of variance of the interaction between sugarcane and weeds species was significant ($P<0.01$), indicating that a differential response was observed between the weeds species as a function of the sugarcane variety maintained in coexistence during 108 DAP.

The dry matter of shoots of *A. viridis*, *P. maximum* and *D. horizontalis* was 45%, 54.6%, and 64.3% lower, respectively, when coexistence was established with the sugarcane variety SP80-1842 compared to RB92579 (Table 2). This indicates a potential for differentiated interference between sugarcane varieties in relation to weeds. On the other hand, the dry matter of weeds was also different depending on the species within each sugarcane variety, which may reflect their competitive capacity, since a greater mass accumulation reflects greater use of resources of the environment, such as water and nutrients, mainly (Carvalho et al., 2008). *U. plantaginea* was the one that accumulated more dry mass when coexisting with both varieties (Table 2), evidencing its potential of interference and yield reduction if there is coexistence in the production areas in the 'Plene' system. The coexistence of *B. pilosa* plus *I. quamoclit* with both sugarcane varieties resulted in the lowest accumulation of dry matter of shoots of weeds, evidencing that both varieties presented an interference potential greater than these weeds.

Table 2 **-** Dry matter of shoots (g) of weeds maintained in coexistence with two sugarcane varieties up to 108 days after planting

Weed	Sugarcane varietie	
	RB92579	SP80-1842
BIDPI + IPOQU	1.5 Ad	1.4 Ac
IPOHF	2.8 Ad	4.5 Ab
AMAVI	8.9 Ac	4.0 Bb
BRAPL	18.6 Aa	18.5 Aa
PANMA	11.9 Ab	6.5 Bb
DIGHO	8.4 Ac	5.4 Bb

Obs. Result of the unfolding of the degrees of freedom. Means followed by the same letter do not differ by Scott-Knott's test at 5% probability (uppercase in the line and lowercase in the column).

Sugarcane

The analysis of variance of the interaction between sugarcane varieties and weed species was significant for plant height ($P<0.01$), number of green leaves ($P<0.03$), leaf area ($P<0.05$), dry matter of stems ($P<0.05$), dry matter of roots ($P<0.01$), and dry matter of leaves ($P<0.01$); on the other hand, for the number of dry leaves, there was no interaction between the factors ($P>0.05$), that is, only for the number of dry leaves there was no differential response between the sugarcane varieties as a function of the weed species maintained in coexistence during 108 DAP.

The sugarcane variety SP80-1842 presented a height 25.4% higher than the variety RB92579 when kept free from coexistence with weeds (Table 3). A similar result was observed when it coexisted with *B. pilosa* and *I. quamoclit*, with a difference of 20.1%. Notwithstanding, when coexisting with *U. plantaginea*, SP80-1842 had a 34% lower height than RB92579. In the other coexistence situations, there were no differences between the varieties. Analyzing the varieties within the coexistence situation, RB92579 had a higher height when coexisting with *I. hederifolia*, *A. viridis*, and *U. plantaginea*, while the variety SP80-1842 had its height reduced when coexisting with *U. plantaginea*, *P. maximum* and *D. horizontalis* in comparison to the other situations (Table 3).

Table 3 **-** Number of green leaves and leaf area of two sugarcane varieties kept in coexistence with several weeds up to 108 days after planting

Weed	Height (cm)		Green leaves per plant		Leaf area (cm^2)	
	RB92579	SP80-1842	RB92579	SP80-1842	RB92579	SP80-1842
CONTROL*	16.9 Bb	21.2 Aa	13.8 Aa	8.7 Ba	513.4 Aa	524.9 Aa
BIDPI + IPOQU	17.9 Bb	21.5 Aa	13.7 Aa	9.5 Ba	421.1 Ab	417.6 Ab
IPOHF	21.1 Aa	20.7 Aa	13.8 Aa	5.2 Bb	418.8 Ab	277.7 Bc
AMAVI	20.0 Aa	19.7 Aa	10.2 Ab	7.8 Aa	320.2 Ac	228.5 Bc
BRAPL	20.6 Aa	13.6 Bb	7.7 Ab	1.5 Bc	80.9 Ad	22.1 Ae
PANMA	18.3 Ab	15.9 Ab	8.2 Ab	3.7 Bb	120.9 Ad	85.4 Ad
DIGHO	16.2 Ab	15.2 Ab	7.8 Ab	3.8 Bb	160.4 Ad	137.5 Ad

Obs.: Result of the unfolding of the degrees of freedom. Means followed by the same letter do not differ by Scott-Knott's test at 5% probability (uppercase in the line and lowercase in the column). * Without coexistence.

RB92579 showed a higher number of green leaves than SP80-1842 whether coexisting or not with weeds, except for *A. viridis*, in which no difference was observed between the varieties (Table 3). Analyzing the varieties within the coexistence situation, *A. viridis*, *U. plantaginea*, *P. maximum* and *D. horizontalis* reduced the number of green leaves of RB92579, whereas for SP80-1842 the reduction occurred with *I. hederifolia*, *U. plantaginea*, *D. horizontalis* and *P. maximum*.

Thus, it was not possible to establish a relationship between the variety planted and the interference potential of the weed species for the characteristics plant height and number of green leaves; the response of the varieties was different according to the weed with which the coexistence was maintained. This indicates that height and leaf emission are probably not reliable variables to evaluate the differential response of the studied varieties. The highest leaf emission of the variety RB92579 and the highest height are likely to be characteristics intrinsic to the variety.

The leaf area of the two sugarcane varieties was similar when there was no coexistence with weeds (Table 3). However, *I. hederifolia* and *A. viridis* reduced the leaf area of RB92579 by 33.7% and 28.6%, respectively, when compared to SP80-1842, while for the other species there was no difference between the varieties. Analyzing the effect of coexistence within the variety, it was verified that whenever there was coexistence with weeds, the leaf area of both varieties was reduced. For RB92579, the reduction varied between 18% (*B. pilosa* plus *I. quamoclit*) and 84.2% (*U. plantaginea*); *U. plantaginea*, *P. maximum* and *D. insularis* promoted the greatest reductions in the leaf area of this variety. For SP80-1842, the weeds caused a reduction between 20.4% (*B. pilosa* plus *I. quamoclit*) and 95.8% (*U. plantaginea*) (Table 3).

For the characteristic number of dry leaves, no significant interaction between the factors was observed. SP80-1842 presented a greater number of dry leaves than RB92579 regardless of the coexistence situation. There was no effect of coexistence with weeds, regardless of the variety (Table 4).

Table 4 - Number of dry leaves of two sugarcane varieties maintained in coexistence with several weeds up to 108 days after planting

Cause of variation	Number of dry leaves
Variety	
RB92579	3.4 b
SP80-1842	4.2 a
Weed	
Control*	3.9
BIDPI + IPOQU	3.4
IPOHF	3.7
AMAVI	3.0
BRAPL	4.5
PANMA	3.6
DIGHO	3.9

Obs.: Means followed by the same letter do not differ by Scott-Knott's test at 5% probability. * Without coexistence.

The dry matter of leaves of both varieties was similar when there was no coexistence with weeds (Table 5). Nonetheless, when the coexistence occurred with *I. hederifolia*, SP80-1842 had a lower dry matter of leaves when compared to RB92579. Analyzing the variety within the coexistence situation, RB92579 had the dry matter of leaves reduced when maintained in coexistence with *A. viridis*, *U. plantaginea*, *P. maximum*, and *D. horizontalis*, whereas SP80-1842 had a reduced dry matter of leaves when coexisting with any of the weed species (Table 5), showing a greater susceptibility of the variety SP80-1842 to the interference imposed by the weeds.

The two sugarcane varieties also showed a similar dry matter of stems when they were kept without weed coexistence (Table 5). Notwithstanding, for all coexistence situations, except for *A. viridis*, RB92579 showed a higher dry matter accumulation in the stems, evidencing that this variety was less affected by the interference imposed by weeds than SP80-1842. RB92579 did not have the dry matter of stems reduced when kept in coexistence with weeds, and even presented a greater accumulation of dry matter in relation to the control when coexisting with *B. pilosa* plus *I. quamoclit* and with *I. hederifolia* (Table 5). In contrast, SP80-1842 had the dry matter of stems reduced when coexisting with *A. viridis*, *U. plantaginea*, *P. maximum* and *D. horizontalis*, by 45, 70, 67 and 67%, respectively, again showing a greater susceptibility of this variety to interference imposed by weeds.

The dry matter of roots of both varieties was also similar when there was no coexistence with weeds (Table 5). However, when living with *I. hederifolia*, *U. plantaginea*, and *P. maximum*, SP80-1842 had the dry matter of roots reduced by 37, 62, and 66%, respectively, when compared

Table 5 **-** Dry matter of leaves, stems and roots of two sugarcane varieties kept in coexistence with several weeds up to 108 days after planting

Weed	Dry matter (g per plant)					
	Leave		Stem		Root	
	RB92579	SP80-1842	RB92579	SP80-1842	RB92579	SP80-1842
Control*	5.3 Aa	6.6 Aa	2.7 Ab	3.3 Aa	6.8 Ab	7.8 Aa
BIDPI + IPOQU	5.6 Aa	5.2 Ab	3.8 Aa	2.9 Ba	7.2 Ab	6.8 Aa
IPOHF	6.4 Aa	4.4 Bb	3.7 Aa	2.2 Ba	9.2 Aa	5.8 Ba
AMAVI	4.5 Ab	4.2 Ab	2.1 Ab	1.8 Ab	5.3 Ab	5.6 Aa
BRAPL	2.8 Ab	1.8 Ad	2.1 Ab	1.0 Bb	4.8 Ab	1.8 Bb
PANMA	3.8 Ab	3.0 Ac	2.1 Ab	1.1 Bb	6.2 Ab	2.1 Bb
DIGHO	3.7 Ab	3.5 Ac	2.0 Ab	1.1 Bb	6.4 Ab	4.9 Aa

Obs.: Result of the unfolding of the degrees of freedom. Means followed by the same letter do not differ by Scott-Knott's test at 5% probability (uppercase in the line and lowercase in the column). * Without coexistence.

to RB92579. Analyzing the variety within the coexistence situation, RB92579 did not have a reduced dry matter of roots when maintained in coexistence with the different weed species, and even presented a greater accumulation of dry matter in the roots when coexisting with *I. hederifolia* compared to the control. On the other hand, SP80-1842 had the dry matter of roots reduced when coexisting with *U. plantaginea* and *P. maximum*, by 77 and 73%, respectively, again showing a greater susceptibility of this plant to the interference imposed by weeds.

In general, coexistence with morning glories (*I. quamoclit* and *I. hederifolia*) had less influence on the dry matter accumulation of sugarcane, mainly for RB92579. Piza (2016) reported interference of *I. hederifolia* from 76 days after emergence, reducing crop yield by 17.5%, but this species presents a small accumulation of dry matter and macronutrients at the beginning of its cycle, being intensified at 63 days after emergence, with maximum accumulation at 139 and 140 days, for *I. hederifolia* and *I. quamoclit*, respectively, so that it can be inferred that the most intense competition can occur only at the most advanced stage of development of the crop (Carvalho et al., 2009; Guzzo et al., 2010). This contrasts with what was observed for velvet bean, which also has a climbing habit, whose interference starts at 50 days after sprouting and lasts up to 188 days, reducing yield by 50% (Bressanin et al., 2016). On the other hand, coexistence with grasses *U. plantaginea*, *P. maximum* and *D. horizontalis* generally provided the greatest reductions in the growth of sugarcane, mainly for variety SP80-1842. Therefore, these species may be the most problematic weeds for control, since the use of selective herbicides will be difficult because the crop is also grassy. However, it is known that the herbicides diuron+hexazinone+sulfometuron-methyl and amicarbazone+isoxaflutole are efficient in the control of *P. maximum* and *B. decumbens*, and diuron+hexazinone and amicabazone are selective to sugarcane in the 'Plene' system (Giancotti et al., 2012; Bertolino and Alves, 2014). Paula (2015) reported the grasses *B. decumbens* and *P. maximum* as the most aggressive species to the initial development of sugarcane plants from meristematic seedlings when compared to the species *I. hederifolia* and *D. horizontalis*; at 90 days of coexistence, the presence of 2 plants pot^{-1} of these species caused a reduction in dry matter accumulation of approximately 55%, 47%, 50%, and 24%, respectively.

Except for the number of dead leaves, all other growth characteristics of the sugarcane varieties were affected differently as a function of the weed with which the coexistence was maintained, agreeing with the potential of growth and interference of the weeds. Notwithstanding, it can be observed that, on average, there was a greater dry matter accumulation by RB92579 than by SP80-1842 when kept in coexistence with weeds. This fact was not expected, as the greater dry matter accumulation of weeds also occurred when coexistence was maintained with RB92579, in addition to greater dry matter accumulation in SP80-1842 maintained without weed coexistence. These results show that the variety RB92579 presented greater potential of interference against weeds than SP80-1842, although its growth potential was lower.

The weed *U. plantaginea* showed the greatest interference potential among the weed species maintained in coexistence with the two sugarcane varieties planted in the 'Plene' system. Other grasses, such as *P. maximum* and *D. horizontalis*, are also potential competitors, whereas dicotyledons (*B. pilosa*, *I. quamoclit*, *I. hederifolia* and *A. viridis*) are less competitive.

Sugarcane varieties planted in the 'Plene' system respond differently to weed coexistence, with RB92579 being less susceptible to interference than SP80-1842, which shows greater growth reduction when kept in coexistence with weeds.

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