PLANTA DANINHA

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS

<http://www.sbcpd.org>

ISSN 0100-8358 (print)
1806-9681 (online)

Article

Weed Interference Periods in Pre-Sprouted Sugarcane Seedlings

Períodos de Interferência de Plantas Daninhas em Mudas Pré-Brotadas de Cana-de-Açúcar

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ABSTRACT - The aim of this research was to determine weed interference periods in sugarcane cultivated under the system of pre-sprouted seedlings, taking into account the impact on the final plant stand, and bud yield and stalk yield. In the field, this study used a randomized block design with 14 treatments and four replications. The treatments consisted of periods of control and weed coexistence with the sugarcane crop (cultivar IACSP95-5000): 30, 60, 90, 120, 150, 180, 210 and 240 days after planting. A phytosociological survey was carried out in the experimental area, and the species *Merremia aegyptia*, *Urochloa decumbens* and *Nicandra physaloides* were found to be predominant. At the end of 240 days, regression analysis was performed according to Boltzmann's sigmoidal model and considering loss tolerance of 5% in the evaluated variables. For final plant stand, the period prior to interference was 31 days and the total period of interference prevention was 187 days. For bud yield, the period prior to interference was 23 days and the total period of interference prevention was 178 days. For stalk yield, the period prior to interference was 19 days and the total period of interference prevention was 195 days. Weed interference was detrimental to all evaluated variables, with losses of up to 100% of the sugarcane plants after 120 days of weed coexistence.

Keywords: *Merremia aegyptia*, *Urochloa decumbens*, weed competition, critical periods, PSS, *Saccharum* spp.

RESUMO - Esta pesquisa objetivou estudar a determinação dos períodos de interferência de plantas daninhas na cultura da cana-de-açúcar cultivada sob o sistema de mudas pré-brotadas, levando-se em conta os impactos no estande final de plantas e na produtividade de gemas e de colmos. No campo, utilizou-se o delineamento em blocos casualizados com 14 tratamentos e quatro repetições. Os tratamentos foram constituídos por períodos de controle e convivência de plantas daninhas com a cultura da cana-de-açúcar, cultivar IACSP95-5000: 30, 60, 90, 120, 150, 180, 210 e 240 dias após plantio. Realizou-se o levantamento fitossociológico da área experimental, determinando-se o predomínio das espécies ***Merremia aegyptia, Urochloa decumbens*** *e* ***Nicandra physaloides****. Ao final dos 240 dias, utilizando-se da análise de regressão conforme o modelo sigmoidal de Boltzmann e considerando a tolerância de perda de 5% nas variáveis consideradas, para estande final de plantas, determinou-se o Período Anterior à Interferência de 31 dias e o Período Total de Prevenção a Interferência de 187 dias. Para produtividade de gemas, determinou-se o Período Anterior à Interferência de 23 dias e o Período Total de Prevenção à Interferência de 178 dias. Já para a variável produtividade de colmos, determinou-se o Período Anterior à Interferência de 19 dias e o Período Total de Prevenção à Interferência de 195 dias. A interferência*

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Received: June 14, 2018
Approved: November 7, 2018

Planta Daninha 2019; v37:e019203772

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Doi: 10.1590/S0100-83582019370100105

das plantas daninhas foi prejudicial a todas as variáveis estudadas, com perda de até 100% das plantas de cana-de-açúcar a partir dos 120 dias de convivência com as plantas daninhas.

Palavras-chave: *Merremia aegyptia*, *Urochloa decumbens*, matocompetição, períodos críticos, MPB, *Saccharum* spp.

INTRODUCTION

Pre-sprouted seedlings (PSS) is a multiplication system for sugarcane crops based on planting of seedlings grown in tubes, resulting from sprouting of separate buds in 5 cm mini stem cuttings. These seedlings are transplanted to definitive cropping areas, generating uniform sugarcane fields which are free from pests, diseases and variety mixtures. Also, there is a reduction in the volume of plant propagation material used in crop planting (Landell et al., 2012). Despite all these advantages, there is still a need for research to fill gaps in the implementation of the PSS planting technique, particularly as far weed management is concerned (Azania et al., 2014; Amaral, 2018).

The negative interference imposed by these plants, which infest cultivated areas, is one of the critical points of the sugarcane production process. Weeds can compete with sugarcane plants for environmental resources such as water, light and nutrients; release allelopathic substances; inhibit their sprouting; host pests and diseases, and interfere with crop yield (Pitelli, 1985).

The model most commonly used to explain the effect of length of coexistence between weeds and cultivated plants is the one that deals with interference periods (Vidal, 2010). The study of these periods ultimately determines the period in which effective control methods must be used (Kuva et al., 2000). Pitelli and Durigan (1984) classified periods of weed interference in agricultural crops, assuming three interaction periods, namely: PPI (Period Prior to Interference): period in which, after emergence or sowing of a crop, the latter can coexist with the weed community before its yield or other characteristics are negatively changed; TPIP (Total Period of Interference Prevention) period, after emergence or sowing of the crop, in which the latter should be kept free from the presence of the weed community so that its yield or other characteristics are not negatively nor significantly altered; and CPIP (Critical Period of Interference Prevention): period that lies between the maximum limits of the other two periods mentioned; during such period, weed control is required.

Further knowledge is needed of both weed interference periods and the economic and social relevance of sugarcane cultivation. Therefore, research has been carried out in Brazil since the 1980s to determine weed interference periods in sugarcane crops planted in the conventional system. The most recent studies were conducted in the 2000s. Kuva et al. (2000, 2001) reported a 20% loss in sugarcane yield in an area infested by purple nutsedge (*Cyperus rotundus*) and an 82% reduction in crop yield resulting from interference in an area dominated by signal grass (*Urochloa decumbens*), respectively. Bressanin et al. (2016) also found a 50% reduction in sugarcane yield because of the interference of velvet bean (*Stizolobium aterrimum*), which negatively affected the quality of the harvested product.

As with sugarcane planted in a conventional system, the presence of weeds can interfere with the development of sugarcane PSS soon after their transplantation to the definitive cultivation area. Therefore, weed management is crucial to minimize costs and achieve high yield, according to the characteristics of each producing region (Silva et al., 2018).

Currently, for this type of system (PSS), it is recommended that herbicide application should occur before planting and be supplemented after the crop establishment phase, i.e., approximately at 40 days after planting (Azania et al., 2014). This recommendation has ensured selectivity of treatments for PSS; however, broader knowledge is still required of interference periods, since pre-sprouted seedlings are very sensitive to the presence of weeds. Knowledge of these periods is paramount for establishing the correct strategy to control weeds that infests crop areas in different locations (Silva et al., 2013; Amaral, 2018).

Planting pre-sprouted sugarcane seedlings brings major changes to crop management. Thus, further studies are needed to determine interference periods, so that different weed management practices can be adapted to new cultivation conditions. This way, losses and environmental impact can be reduced, especially when caused by inappropriate use of control measures (Kuva et al., 2001).

For all the reasons mentioned above, the objective of this research was to determine weed interference periods in sugarcane crops grown under the pre-sprouted seedling system, taking into account their impact on final plant stand, bud yield and stalks yield.

MATERIAL AND METHODS

The experiment was carried out from December 2016 to August 2017 in an agricultural area located in the town of Holambra, State of São Paulo; latitude was 22º39'00.3" S, longitude was 47º05'39.9"W and altitude was 622 m above sea level. The soil of the area is a medium-texture Eutrophic Latosol, with the following characteristics: pH ($CaCl_2$) of 5.7; 20 g dm^{-3} of organic matter; and contents of P = 44, K^+ = 3.13, Ca^{2+} = 48.94, Mg^{2+} = 14.09 and Al^{3+} = 0.20, expressed in $mmol_c$ dm^{-3}. Soil was prepared in a conventional manner.

The area was furrowed, with furrows spaced at 1.5 m and at a 30 cm depth. In the same operation, planting mineral fertilization was performed before planting by applying the commercial formula NPK (08-20-20) at a rate of 500 kg ha^{-1} at the bottom of the furrows. After that, the furrows were covered, and the pre-sprouted sugarcane seedlings (cultivar IACSP95-5000) were then transplanted. The main characteristics of this cultivar are its upright growth, good ratoon sprouting and good closure between rows; therefore, it is suitable for medium to favorable production environments. It is tolerant to stalk lodging and flowering and resistant to major sugarcane diseases (Landell et al., 2007).

The pre-sprouted seedlings were planted manually on June 12, 2016, with the help of a hand seeder, while maintaining a spacing of 50 cm between plants. On the same date, broadcast seeding was performed for the weeds hairy woodrose (*Merremia aegyptia)* and signal grass (*Urochloa decumbens),* followed by slight soil amendment with the aid of rakes to enhance the local seed bank.

The experimental used a randomized block design with 14 treatments and 4 replications, in a total of 56 plots. The experimental plot consisted of four 7 m long sugarcane rows, spaced at 1.5 m (a total of 42 m^2). The usable area of the plots for the purpose of evaluations was composed of the three central lines of the plot, disregarding the first and last meters of the plot, in a total of 22.5 m^2. The treatments consisted of two groups: control periods - sugarcane PSS were maintained without the presence of weeds ("weed-free") for increasing periods of time; and periods of coexistence - PSS were kept in the presence of weeds ("weedy") for increasing periods of time. Both periods began after the sugarcane seedlings had been planted in the experimental area. The periods determined for weed control and coexistence were: 0-30, 0-60, 0-90, 0-120, 0-150, 0-180, and 0-240 days after planting (DAP) of PSS (Table 1).

For the control group treatments (treatments 1 to 7; Table 1), during the period when the crop should remain weed-free, the plots were manually weeded with the use of hoes to eliminate weeds that emerged periodically, before there was any weed interference in the development of pre-sprouted sugarcane seedlings. After the end of each control period, weeding was suspended, allowing weeds to develop freely until harvest at 240 DAP. For the treatments of the coexistence group (treatments 8 to 14; Table 1), after the end of each period, weeding was performed in the total area of the corresponding treatment plots. Existing weeds were removed, and hand weeding was performed in the area every 14 days, on average, until harvest.

At the end of each coexistence period in the respective treatments (30, 60, 90, 120, 150, 180 and 240 DAP) and before canopy of the sugarcane plants closed completely and shaded the space between rows (130 DAP) in the control periods, a phytosociological survey of the experimental area was carried out to quantify and identify weed species that occurred in the area. The aim of this evaluation was to collect data to determine the phytosociological indices of the area, which is an important variable to analyze the impact of management systems on the growth and occupation dynamics of weed communities in agroecosystems (Pitelli, 2000).

Table 1 - Experimental treatments tested to determine the critical periods of weed interference, in number of days, in a sugarcane crop. Holambra, SP, 2017

Period	Treatment	"Weed-free" period (days)	"Weedy" period (days)
Control	1	0 – 30	30 – harvest
	2	0 – 60	60 – harvest
	3	0 – 90	90 – harvest
	4	0 – 120	120 – harvest
	5	0 – 150	150 – harvest
	6	0 – 180	180 – harvest
	7	0 – 240	-
Coexistence	8	30 – harvest	0 – 30
	9	60 – harvest	0 – 60
	10	90 – harvest	0 – 90
	11	120 – harvest	0 – 120
	12	150 – harvest	0 – 150
	13	180 – harvest	0 – 180
	14	-	0 – 240

On these dates, a quadrat (0.5 m × 0.5 m) was randomly thrown twice in the usable area of each plot of the corresponding treatments. The average between the two samples was calculated to obtain the average of the plots. The weeds present in the area of the quadrat were then collected, identified, quantified, and their aerial parts were dried in a forced air oven at 70 ^{o}C to constant weight, to determine dry weight after weighing.

These data were used for calculating the phytosociological indices of each treatment, according to the methodology established by Müeller-Dombois and Ellenberg (1974), especially the Relative Importance (IR) variable, which accurately shows the contribution of each species to yield losses, as well as other variables analyzed in the experiment (final plant stand and bud yield).

According to Pitelli (2000), relative importance (RI) is an index whereby population distribution, numbers of specimens and accumulated biomass are weighted in an area; it also shows the most important species in terms of infestation. Moreover, it relates the importance values of each weed species to the importance value of the weed community present in the area.

At 240 days after planting, crop yield evaluations were performed using biometrics, based on the methodology proposed by Landell and Bressiani (2010).

Data on yield (t ha^{-1}), final stand (number of stems per meter of furrow) and bud yield (number of buds per hectare) were analyzed in two blocks. Control period data and coexistence data were analyzed separately, but they all underwent regression analysis according to the parameters of Boltzmann's sigmoidal model (Origin Pro 9.0 software, Origin Lab), adapted by Kuva et al. (2000):

$$Y = \frac{(A1 - A2)}{1 + e^{(X - Xo)/dx}} + A2$$

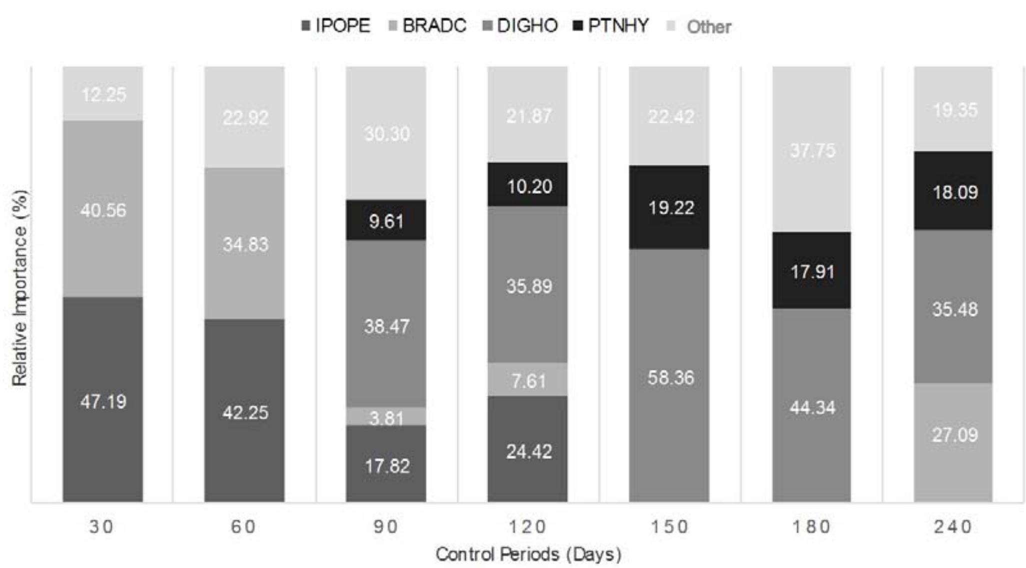
where Y is the variable evaluated in sugarcane (agricultural yield (t ha^{-1}), final stand (tillers m^{-1}), bud yield (number of buds ha^{-1})) according to the control or coexistence periods; X is the upper limit of the control or coexistence period (days); A1 is the maximum yield found on the "weed-free" plots throughout the cycle (t ha^{-1}); A2 is the minimum yield found on the "weedy" plots throughout the cycle (t ha^{-1}); (A1 - A2) is yield loss (t ha^{-1}); X0 is the upper limit of the control or coexistence periods, which corresponds to the intermediate value between maximum and minimum yield; and dx is the variable that indicates speed of yield loss or gain (tg α at point X0).

The limits of the interference periods were determined while tolerating a 5% reduction in the value of the evaluated variable in comparison to the treatment maintained in the absence of weeds throughout the experimental period. According to Parreira et al. (2014), this is the most common level of loss reported in publications about periods of weed interference in agricultural crops.

RESULTS AND DISCUSSION

In the evaluations of the weed community, at the end of the control and coexistence periods, 14 weed species were found, belonging to seven botanical families: *Merremia aegyptia* (L.) Urban e *Ipomoea nil* (L.) – Convolvulaceae; *Nicandra physaloides* (L.) Pers. – Solanaceae; *Digitaria insularis* (L.) Fedde, *Urochloa decumbens* (Stapf) R.D. Webster, *Cynodon dactylon* (L.) Pers., *Digitaria horizontalis* Willd., *Cenchrus echinatus* L. e *Eleusine indica* (L.) Gaertn – Poaceae; *Amaranthus viridis* L. – Amaranthaceae; *Parthenium hysterophorus* L. e *Bidens pilosa* L. – Asteraceae; *Cyperus rotundus* L. – Cyperaceae; and *Commelina benghalensis* L. - Commelinaceae. Of the 14 species found, 57% were monocotyledons and 43% were eudicotyledons. The predominant families in number of species were Poaceae (42.8%), Convolvulaceae (14.2%) and Asteraceae (14.2%), followed by Solanaceae, Amaranthaceae, Cyperaceae and Commelinaceae (7.2% each). Species occurring in different locations should be recognized, and further knowledge is needed of their growth habit, as well as their competing ability and the risks that they may offer, in order to devise the most efficient and economical strategy for their control, because any area that is infested or invaded by weeds has very little value, especially if these species are perennial (Meirelles et al., 2009).

Regarding the treatments of control periods, Figure 1 shows that the species *Merremia aegyptia* was predominant in the treatments with 30 and 60 days of control, with 47.19% and 42.25% of relative importance, respectively, followed by the species *Urochloa decumbens*, with 40.56% and 34.83%.



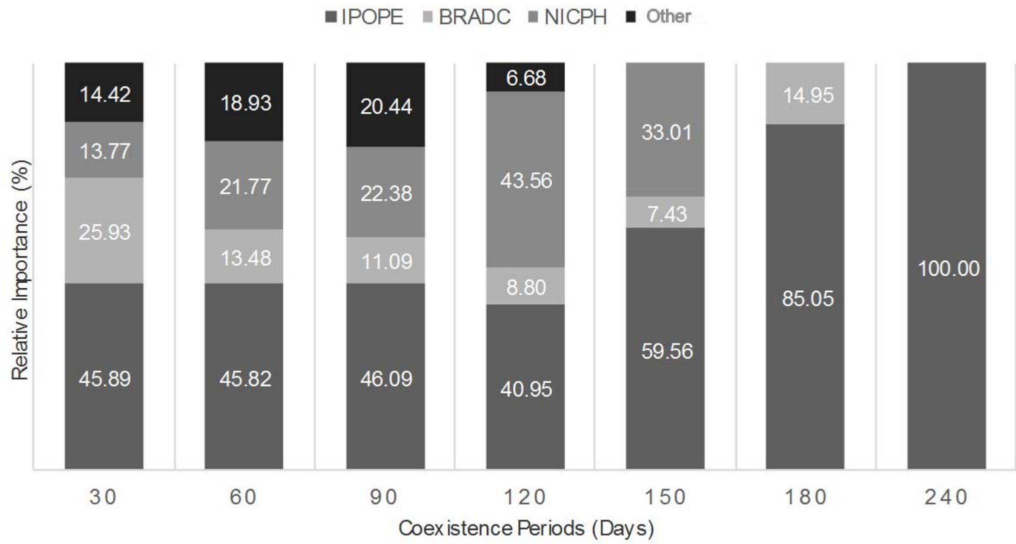
IPOPE = *Merremia aegyptia*; BRADC = *Urochloa decumbens*; DIGHO = *Digitaria horizontalis*; PTNHY = *Parthenium hysterophorus*.

Figure 1 - Relative importance of the main weed species found in the experimental area, according to the control periods, at 130 DAP. Holambra, SP, 2017.

However, after 90 DAP and with the help of frequent weeding, relative importance decreased for the species that were sown, that is, species which did not exist in a large amount in the seed bank of the experimental area, as opposed to the increased relative importance of crabgrass (*Digitaria horizontalis)*, which was already present in the seed bank of the area, although with low infestation rates, by the end of the evaluations, at 240 DAP.

Figure 2 shows the relative importance of the main species that occurred in the area, in the treatments of coexistence periods.

The species *Merremia aegyptia* and *Urochloa decumbens,* which were sown in the experimental area on the same date of transplantation of sugarcane PSS, and *Nicandra physaloides*, which was already present in the seed bank of the area, were predominant in the treatments of coexistence periods. After 150 days of coexistence, the species *Merremia aegyptia* began to prevail and compete with the other species of the weed community and the sugarcane crop. At 240 DAP,



IPOPE = *Merremia aegyptia*; BRADC = *Urochloa decumbens*; NICPH = *Nicandra physaloides*.

Figure 2 - Relative importance of the main weed species found in the experimental area, according to the coexistence periods.

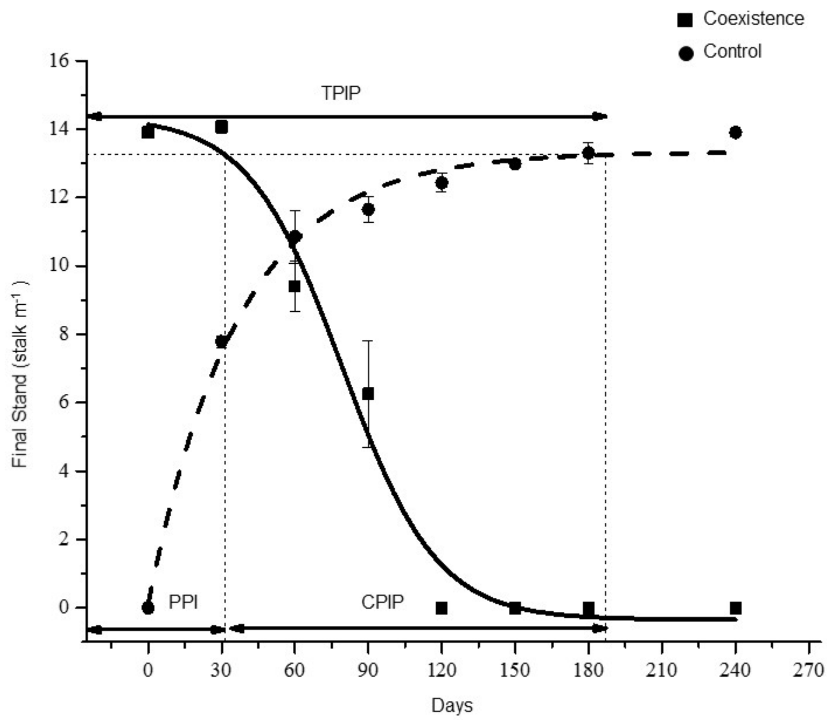
relative importance of this species was 100%, and the losses found in the parameters analyzed in this treatment can be attributed entirely to the interference of the weed species in question. For Meirelles et al. (2009), in conventionally planted sugarcane fields, the weeds that had the most relative importance during coexistence periods were buffalo grass (*Panicum maximum)*, bristly starbur (*Acanthospermum hispidum)* and sanguinaria (*Alternanthera tenella)*, by virtue of relative density and dominance. Kuva et al. (2007), when studying the phytosociology of weed communities in mechanically harvested sugarcane, without previous burning of straw, found that *Cyperus rotundus* was the main weed species in terms of relative importance (RI).

In this type of sugarcane production agroecosystem (PSS), species of the Convolvulaceae family (as is the case of *Merremia aegyptia*) are favored, since their climbing growth habit allows their volatile stems and branches to wrap around the stalks of the crop and reach the apex of sugarcane plants, hindering the absorption of light, with consequent damage to the photosynthesis of the crop (Azania et al., 2009). This climbing growth habit also hampers the effects of cultural control, since climbing species can overcome the effects of shading between rows, keeping their aerial part in the canopy of the sugarcane crop.

Figures 3, 4 and 5, respectively, show the behavior of PSS with respect to the analyzed variables – final stand, bud yield and agricultural yield – according to the periods of control and coexistence with the study weeds. The solid line curve in the three figures represents the behavior of the variable analyzed in sugarcane plants for the increased periods of crop-weed coexistence. The dashed line curve represents the behavior of the variable analyzed in sugarcane plants in relation to the increased weed control periods. The dotted line parallel to the “x” axis is drawn from the “y” axis, from the maximum value obtained in the analyzed variable, minus 5% of tolerated loss. This dotted line determines PPI when crossing over the solid line curve, and determines TPIP when crossing over the dashed line. The interval between the two periods cited and plotted in the graph is called the critical period of interference prevention (CPIP).

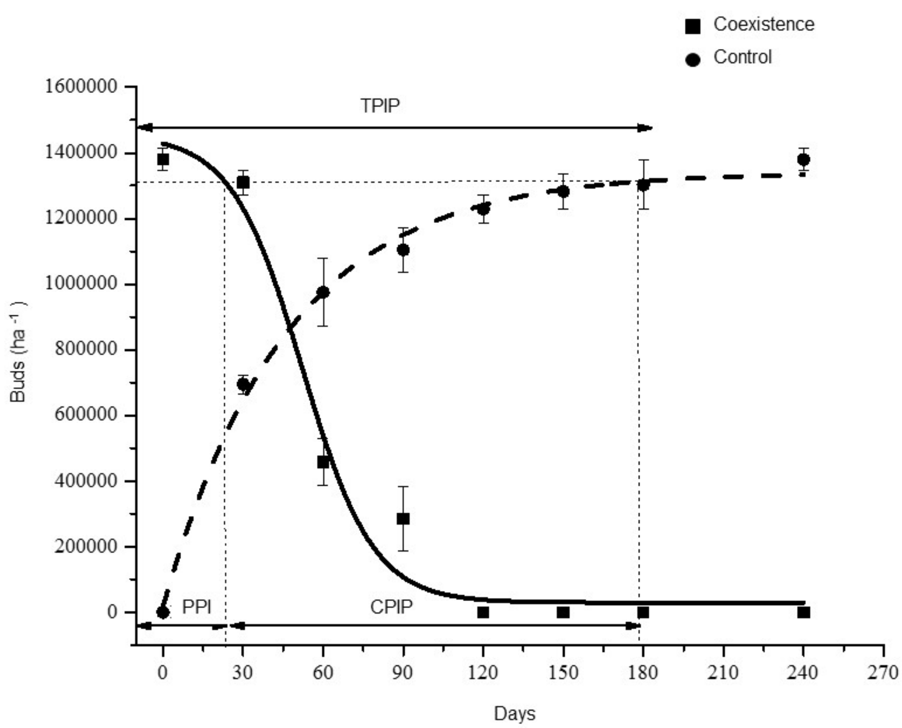
Final plant stand, that is, the number of industrializable stalks per meter of crop row at 240 DAP, is negatively influenced by coexistence of PSS with weeds (Figure 3). There were two fitted curves, coexistence and control, according to the parameters obtained by Boltzmann’s sigmoidal equation. For this variable, the period prior to interference (PPI) was 31 days and the total period of interference prevention (TPIP) was 187 days, resulting in a critical period of interference prevention of 156 days.

Figure 3 shows that, with approximately 30 days of coexistence (solid line), there is no loss of stand, since in this period of time, tillering of PSS is not so intense. After that, there was a sharp decrease in the number of tillers, reaching zero at 120 days of coexistence. Therefore, PSS need



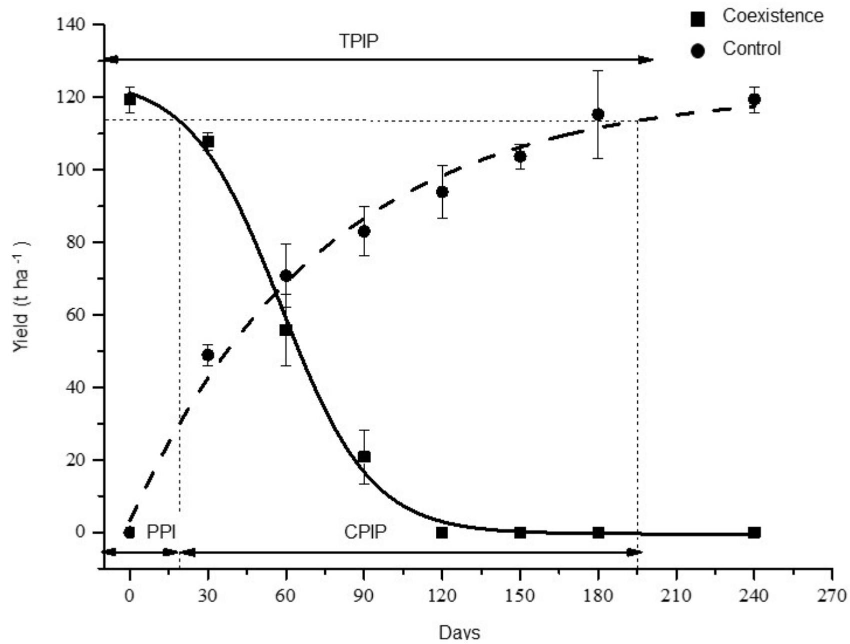
▪ Coexistence: Y = -0.34 + (14.35 + 0.34) / (1 + exp ((x-79.49) / 19.23)); R^2= 0.96
• Control: Y = 13.32 + (-24917.73 + -13.32) / (1 + exp ((x+278.52) / 36.93)); R^2= 0.98
The bars indicate the standard error of the means.

Figure 3 - Final stand of sugarcane plants at 240 DAP, according to the periods of coexistence and weed control. Holambra, SP, 2017.



▪ Coexistence: Y = 29637.70 + (1455170 + -29637.70) / (1 + exp ((x-52.22) / 13.24)); R^2= 0.96
• Control: Y = 1340910 + (-2537290000 + -1340910) / (1 + exp ((x+351.00) / 46.44)); R^2= 0.99
The bars indicate the standard error of the means.

Figure 4 - Yield of sugarcane buds per hectare according to the periods of coexistence and weed control. Holambra, SP, 2017.



▪ Coexistence: Y = -0.41 + (125.38 + 0.41) / (1 + exp ((x-58.04) / 17.26)); R^2= 0.99

• Control: Y = 122.33 + (-199989.67 + -122.33) / (1 + exp ((x+554.75) / 74.70)); R^2= 0.98

The bars indicate the standard error of the means.

Figure 5 - Yield of sugarcane stalks according to the periods of coexistence and weed control. Holambra, SP, 2017.

to be kept free from weed interference after 31 days after planting to avoid a decrease in final plant stand.

At 31 days after planting of PSS in the definitive cultivation area, therefore, when tillering of pre-sprouted sugarcane seedlings becomes more intense, the deleterious effect of weed coexistence is clearly perceived on the tillering ability of the crop. The findings of Galon et al. (2011) corroborate the data collected in the present research. Those authors found a reduction in the number of stalks per linear meter in sugarcane planted through the conventional method in an area with prevalence of palisade grass (*Urochloa brizantha).* Still according to the authors, the tillering capacity of the species of the Poaceae family is a plasticity characteristic, meant to optimize the use of environmental resources. It is one of the characteristics most susceptible to competition, since plants tend to prioritize growth and development of stalks to the detriment of tillering.

The analysis of the control periods (dashed line) (Figure 3) shows that weed control for only 30 days after planting is insufficient to ensure a satisfactory stand, since the most intense tillering occurs after that date. Therefore, it is advisable to ensure the absence of coexistence with weeds until the most advanced stages of development of pre-sprouted seedlings, at 187 days after planting, to avoid compromising this variable.

The benefits brought to sugarcane tillering by the use of PSS, especially more homogeneous tillers in terms of size and age, in contrast to the damage caused to this variable by coexistence with weeds, fully justify the need for proper management of the weed community. Proper tillering will result in enough bud yield to enable multiplication of the crop.

Bud yield per hectare should be measured, as most areas with PSS are currently being conducted as nurseries for commercial areas or as secondary and commercial nurseries, given the phytosanitary guarantees provided by the use of this crop. In addition, new clones and cultivars can be easily introduced in the production units through PSS. Figure 4 shows the two fitted curves, coexistence and control, according to the parameters obtained by the Boltzmann's sigmoidal equation.

For this variable, the period prior to interference (PPI) was 23 days, and the total period of interference prevention (TPIP) was 178 days, resulting in a critical period of interference prevention (CPIP) of 155 days (Figure 4).

Coexistence of PSS with weeds, even for a short period of time, impacts bud yield. For coexistence for only 30 days (solid line), estimated loss is 70,000 buds per hectare, decreasing from about 1,377,000 buds ha^{-1} to about 1,307,000 buds ha^{-1}. After this time, the decrease is even sharper and faster. Coexistence of PSS with weeds on the first 60 days after planting generates sugarcane plantations whose bud yield barely reaches 500,000 buds ha^{-1}, thus completely compromising the viability of this technology for formation of nurseries. After 120 days of coexistence, 100% of the plants died and, consequently, this variable was not evaluated.

As for control periods (dashed line), Figure 4 shows that the full potential of bud production from PSS plants is only achieved if they are kept free from coexistence with weeds for longer periods of time - up to 178 days after planting.

Thus, weed control is required between 23 and 178 days after planting in order for bud yield to reach its full potential and, consequently, to enhance the use of the technology as a seedling nursery.

For stalks yield, Figure 5 shows the two fitted curves according to the parameters obtained by Boltzmann's sigmoidal equation. For this variable, the period prior to interference (PPI) was 19 days, and the total period of interference prevention (TPIP) was 195 days, resulting in a critical period of interference prevention (CPIP) of 176 days.

The results found in this research for interference periods are different from those previously reported by several authors, who determined weed interference periods in conventional sugarcane plantations (30 to 70 cm long cuttings deposited in the planting furrow). Azania et al. (2010) suggested that, in general, the total period of interference prevention for sugarcane is approximately 120 days. Kuva et al. (2001) found a total period of interference prevention of 138 days in an area where the predominant weed was *Urochloa decumbens*.

In both cases, periods of interference prevention were very long, which is typical of sugarcane crops, because of the row spacing commonly used for growing them (1.50 m). Moreover, the species has its own characteristics; thus, canopy closing and the consequent complete shading between rows take a long time to occur. Even so, these periods are shorter than those determined in the present research, and it can be inferred that the use of pre-sprouted seedlings in sugarcane plantations requires longer weed management.

Considering the tolerance of 5% of losses in the evaluated parameters and the weed community with predominance of the species *Merremia aegyptia*, *Urochloa decumbens* and *Nicandra physaloides*, PPI was 31 days and TPIP was 187 days for final plant stand; for bud yield, PPI was 23 days and TPIP was 178 days; and stalks yield required a 19 days PPI and a 195 days TPIP. Weed interference was detrimental to all variables, with loss of up to 100% as of 120 days of coexistence between weeds and sugarcane PSS.

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