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INFLUENCE OF THE DENSITY AND DISTANCE OF *Digitaria horizontalis* Willd IN THE BIOMETRIC AND NUTRITIONAL PARAMETERS OF PRE-SPROUTED SEEDLINGS OF SUGARCANE[1]

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ABSTRACT – Sugarcane is one of the main agricultural crops in Brazil and the presence of weeds in production areas can affect growth, development and accumulation of nutrients of the crop, which may relate to the density and area of influence of the weeds in the field. Therefore, this study aimed to evaluate the effects of the density and distance of crabgrass (*Digitaria horizontalis* Willd) on the development of pre-sprouted seedlings (PSS) of sugarcane of the variety IAC SP 95-5000. We conducted the experiment in a greenhouse in a randomized design with four repetitions. We evaluated height, leaf area, aerial dry biomass, and nutritional analysis of leaf tissue of the PSS after the weeds flowered at 84 days. The crabgrass did not interfere in the biometric and nutritional parameters when they were 18 and 24 cm away from the crop. Regardless of the planting density and the density of 80 plants m^{-2} of crabgrass for all distances, we considered the distance of six cm between the crop and the weeds critical for the crop, since they significantly reduced height, leaf area, and aerial dry biomass of the PSS. The crabgrass was a potential competitor for N, P, K, Mn, Fe, and Zn with the PSS in the conditions of 2, 6, and 12 cm when they were in 40 and 80 plants m^{-2}.

Keywords: Area of influence. Competition. Interference. Weed.

INFLUÊNCIA DA DENSIDADE E DISTÂNCIA DE *Digitaria horizontalis* Willd NOS PARÂMETROS BIOMÉTRICOS E NUTRICIONAIS DE MUDAS PRÉ-BROTADAS DE CANA-DE-AÇÚCAR

RESUMO – A cana-de-açúcar é uma das culturas agrícolas mais importantes no Brasil e a presença de plantas daninhas nas áreas de produção podem interferir no crescimento, desenvolvimento e acúmulo de nutrientes da cultura, podendo estar relacionado à densidade e área de influência que a comunidade infestante se encontra na lavoura. Neste sentido, o objetivo do trabalho foi avaliar os efeitos da densidade e da distância de capim-colchão (*Digitaria horizontalis* Willd) no desenvolvimento de mudas pré-brotadas (MPB) de cana-de-açúcar da variedade IAC SP 95-5000. O experimento foi realizado em casa-de-vegetação, no delineamento inteiramente casualizado com quatro repetições. Após o florescimento das plantas daninhas, aos 84 dias, foram avaliadas a altura, área foliar, biomassa seca da parte aérea e análise nutricional do tecido foliar das MPBs. As plantas de capim-colchão não exerceram interferência nos parâmetros biométricos e nutricionais quando se encontravam aos 18 e 24 cm de distância em relação à cultura. A distância de 6 cm entre cultura e plantas daninhas, independente da densidade de plantio e a densidade de 80 plantas m^{-2} de capim-colchão para todas as distâncias, foram consideradas críticas para a cultura, uma vez que promoveram reduções significativas na altura, área foliar e biomassa seca da parte aérea das MPBs. O capim-colchão apresentou-se como potencial competidor por N, P, K, Mn, Fe e Zn com as MPBs nas condições de 2, 6 e 12 cm quando se encontravam em 40 e 80 plantas m^{-2}.

Palavras-chave: Área de influência. Competição. Interferência. Planta daninha.

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INTRODUCTION

The use of pre-sprouted seedlings (PSS) of sugarcane has been recommended because it offers the best plant vigor and health control, saving about 20 t ha^{-1} of sugarcane culms that can be processed in sugar-energy units (LANDELL et al., 2013). However, many doubts emerge in the current scenario about the competitive potential of the crop when implanted in this system, with weeds difficult-to-control in sugarcane fields.

Different factors change the balance of interference between the crop and the weeds, which may relate to the weeds (specific composition, plant density, and distribution in the area), the crop (species or variety, plant population, and planting spacing), the management in the production area, and the time and extension of the coexistence period between them both (MOSSIN et al., 2019). Weeds can compete with the crop for nutrients, water, light and space when coexisting (BRIGHENTI; OLIVEIRA, 2011).

The interference of the weeds in sugarcane PSS can reduce the crop yield by up to 93.9% (GIRALDELI, 2019). Zera, Schiavetto, and Azania et al. (2016) reported that eight *Panicum maximum* specimens placed at 10 cm from PSS- cv IACSP-95-5000 negatively interfered in the height, number of tillers and dry mass accumulation of the crop. The density of 8.9 plants m^{-2} of *Rottboelia exaltata* negatively affected the productivity of the RB855156 variety of sugarcane grown in the PSS system. Despite the increase in total dry biomass of weeds due to the increase of population density, the dry mass per weed decreased because of a probable intraspecific competition (HIJANO, 2016).

According to Silva et al. (2018a), in places where PSS were planted for multiplication for commercial areas, the absence of straw may favor some weeds, such as those from the Poaceae family, with smaller seeds and positively photoblastic. However, the management of weeds from the Poaceae family may be more difficult because the seedlings arrive ready in the field, which hinders the use of herbicides with a broad spectrum of action.

The species from the genus *Digitaria sp.* are some of the main monocotyledons that can be found in Brazilian sugarcane fields (TOLEDO et al., 2017; TROPALDI et al., 2018). *D. horizontalis* is currently considered one of the most aggressive weeds because it shows high competitive potential and dispersal power (SILVA et al., 2018b). This is a species commonly found in sugarcane fields and can cause great damage to the crop when they are at high densities (PAULA, 2015).

Many methodologies can better understand the competitive process between species, such as the additive method, which is one of the most used for this type of study (RADOSEVICH; HOLT, GHERSA, 2007). In this case, the crop density remains constant and different proportions of weeds are added to act as competitors in the development of the crop until the desirable period (OLIVER; BUCHANAN; CAMPER, 1986). Besides density, the competition for space is difficult to quantify and to understand. Therefore, the use of the influence of distance methodology is an essential tool because it determines the extent of one weed interference at varying distances toward the crop even at low densities (SANTOS et al., 2004).

Studies on weed interference in PSS may help to explain unresolved management issues. Thus, this study aimed to evaluate the densities and distances of *D. horizontalis* (crabgrass) that influence biometric parameters and nutrient accumulation of sugarcane of the variety IAC SP 95-5000 grown in the pre-sprouted seedling (PSS) system.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse at the Federal University of São Carlos, Center of Agrarian Sciences, located in the municipality of Araras-SP, from October 24, 2017 to January 10, 2018. The experimental units consisted of polyethylene vases with 30 L capacity (0.1 m^2 area and 0.30 m height) filled with samples collected from the plowing layer (0–20 cm) of a dystrophic Red Latosol (LVd). Chemical and physical analyses were performed according to the methods by Raij, Quaggio, and Cantarella (1987) and Embrapa (2017) in the laboratory of chemistry and soil fertility of UFSCar (Table 1). The current base saturation of the soil (V% = 80) was above the requirement for the sugarcane crop (V% = 60), without the need for soil correction.

The pre-sprouted seedlings (PSS) of the variety IAC SP 95-5000, grown according to Landell et al. (2013), were transplanted into the center of the vases. The weed selected was *Digitaria horizontalis* (crabgrass), whose seeds were acquired with Agrocosmos, a company specialized in selling weed seeds for research. Weed sowing occurred on the same day as crop transplant. The vases were kept in a greenhouse with controlled irrigation to provide enough humidity for the seedlings and weeds to fully develop.

The experimental design was randomized in a factorial scheme of 4 × 5 + 1 with four densities of weeds coexisting with PSS (10, 20, 40, and 80 plants m^{-2}), five distances from the PSS (2, 6, 12, 18, and 24 cm) and one control plot without weed, with four repetitions. Seedlings of other species of weeds were removed by thinning to keep the initially stipulated amount of plants.

Table 1. Chemical parameters for fertility and sample granulometry (0–20 cm) of dystrophic Red Latosol.

P_{res}	O.M.	pH	K	Ca	Mg	H+Al	Al	BS	ECEC	V	Clay	Sand	Silt
mg dm^{-3}	g dm^{-3}	$CaCl_2$	------------------------- mmol$_c$ dm^{-3} ----------------------------							%	---------- g kg^{-1} ---------		
17	45	5.7	2.2	46	12	15	0.4	60.2	75.2	80	660	150	190
M	S		B			Cu		Fe	Mn			Zn	
%	---mg dm^{-3}---												
1.1	5		0.59			0.5		227	2.2			1.2	

*O.M.: Organic Matter; BS: Sum-of-bases; ECEC: Effective Cation Exchange Capacity; V: Basic saturation; m: Aluminum saturation.

The period of coexistence of weeds and sugarcane PSS occurred between the emergence and flowering of the weeds, which corresponded to 84 days after transplantation (84 DAT) in the treatments with *D. horizontalis*.

At the end of the experiment (84 DAT), sugarcane plants were evaluated considering height (cm), from the base until the insertion of the first leaf, leaf area (cm^2), using a portable leaf area meter (LICOR 3000C), aerial dry biomass (g) and leaf analysis of macro and micronutrients, after cutting the plants close to the soil and drying in a forced air circulation chamber at 65 °C for 48 hours.

To determine the contents of primary macronutrients (nitrogen - N, phosphorus - P, potassium - K), secondary macronutrients (calcium - Ca, magnesium - Mg, sulfur - S), and micronutrients (boron - B, copper - Cu, iron - Fe, manganese - Mn and zinc - Zn) of leaf tissues, the +3 fully expanded leaves (third leaf from the apex of the plants) of sugarcane were collected, selecting the middle third of about 20 cm, and discarding the midrib (RAIJ et al., 1996). The samples were dried at 65 °C until they reached a constant biomass, ground in a Willey mill equipped with a 40 mesh sieve, and homogenized. The nutritional status was evaluated according to Malavolta, Vitti and Oliveira (1997). The percentage of macro and micronutrients were estimated considering the control plot (100%) according to the density and the distance of the weeds.

The results of biometric parameters and leaf nutrient contents of sugarcane plants were subjected to analysis of variance and, when significant, a regression analysis was performed to select the explanatory model of biometric parameters and leaf nutrient contents according to the density and distance of the weeds, based on the statistical significance ($p < 0.05$) and the values of the coefficients of determination (R^2).

RESULTS AND DISCUSSION

The factors of plant density and distance of *D. horizontalis* toward the crop showed significant interaction by the F test for all analyzed biometric parameters.

The highest density (80 plants m^{-2}) of *D. horizontalis* showed lower height and leaf area of sugarcane PSS in all studied distances and the aerial dry biomass reduced 62% at the distance of six cm (Figure 1A, 1B and 1C). Zera (2020) observed the influence of weed density on the height of sugarcane plants and that the distancing of *Rottboelia cochinchinensis* was critical for PSS IAC and Plene Evolve with 15 cm, which significantly reduced the size of the variety IAC SP 95-5000, regardless of the technology used. Whereas, Paula (2015) reported a 35% reduction in dry biomass accumulation of meristematic sugarcane seedlings when subjected to 90 days of competition with *D. horizontalis* in a lower proportion than the one in this discussion, being 3.8 plants m^{-2}.

With weeds positioned two cm away from the crop, we observed in all densities of *D. horizontalis* that PSS were negatively affected in height, leaf area, and aerial biomass compared to the greatest distances. However, the greatest negative effect on biometric parameters was found with 6 cm of distance between plants, in all densities, and 12 cm, with 80 individuals m^{-2} of *D. horizontalis* (Figure 1A, 1B, and 1C). In this case, we noticed that weeds had the ideal conditions to fully develop, thus, we established the area of influence and high population densities of crabgrass that can significantly affect the biometric parameters of the variety IAC SP 95-5000, based on the studied circumstances, up to 84 days after planting.

The means of all analyzed biometric parameters of PSS tended to increase as the distance between plants increased (Figure 1A, 1B, and 1C), mainly with 18 and 24 cm for all densities of *D.*

horizontalis. These results indicate that the distances of 18 and 24 cm are not the zones with the greatest influence of *D. horizontalis* on the PSS. Moreover, since our study represents a field situation in which an immediate flow of weeds after the planting of sugarcane PSS occurs, the absence of the crabgrass interference in these greater distances is due to the competitive advantage of the crop that shaded the site and reduced the weed competitive potential.

According to Rizzardi et al. (2001), the reduction of leaf area may relate to the low accumulation of photoassimilate and lower accumulation of dry matter by the grown plant because of the increase of weeds in the site. The increase in the density of *D. horizontalis* in the area of influence of the crop showed a greater competition, consequently showing smaller leaf area data. These results reinforce Galon et al. (2011), who, in a study on the interference of the monocotyledon *U. brizantha* in the morphological characteristics of sugarcane, observed reductions in height, leaf area, and dry mass accumulation of the cultivars SP801816, RB72454 and RB867515 when the weed population increased.

The study by Giraldeli (2019) observed that the 84 days of coexistence between *D. horizontalis* plants and sugarcane seedlings coincide with the critical period of interference prevention (CPIP). The study recommended to manage the weeds from planting until 68 days for the variety IAC SP 95-5000 in the PSS system. The influence of crabgrass on biometric parameters shows the significance of planning activities for weed control due to the reduction of the maximum potential of the crop when competing with more aggressive plants.

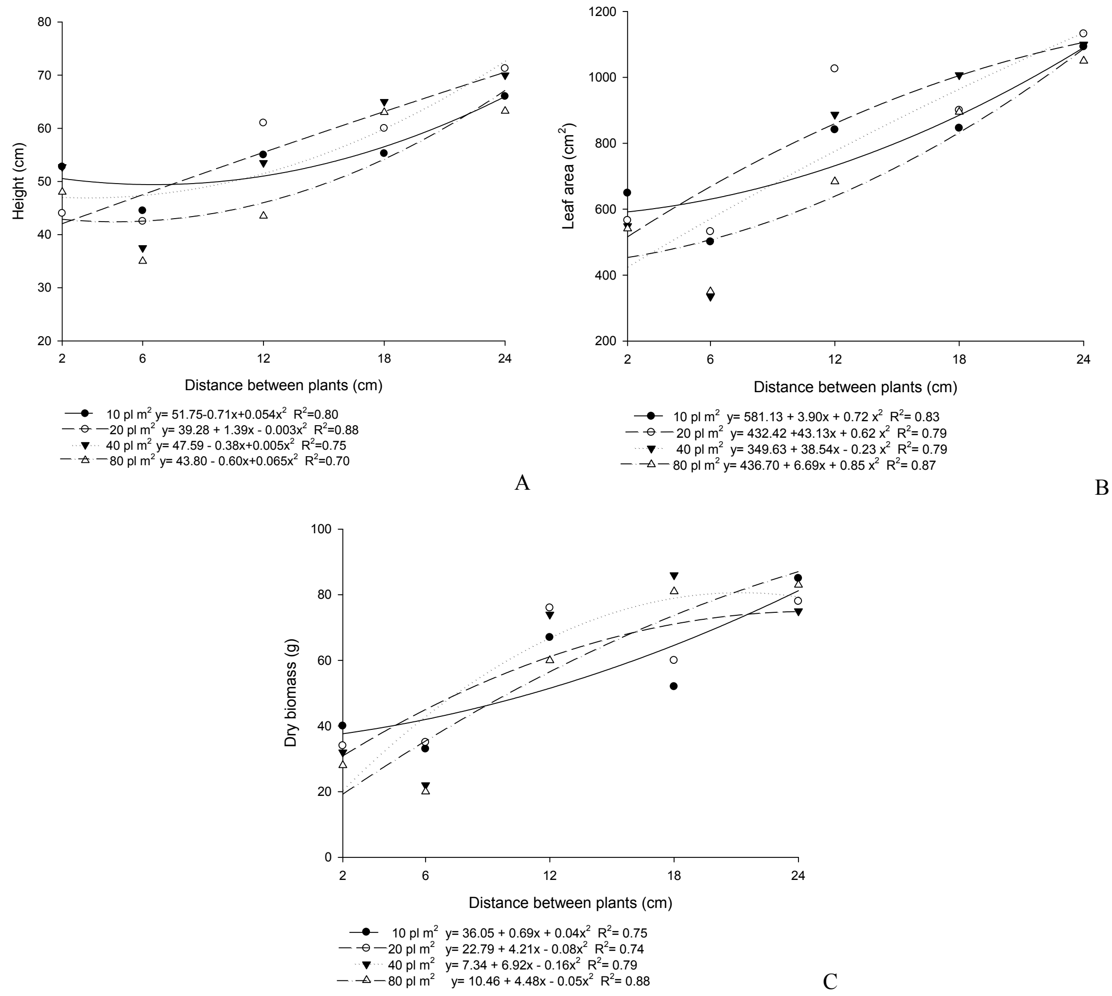

Figure 1. Height (cm) - A, leaf area (cm^2) – B, and aerial dry biomass (g) - C of sugarcane plants according to the density and distance of *D. horizontalis* plants at 84 DAT.

We did not adjust by mathematical models according to spacing the relative contents of N, K, Ca, and Mg in the leaf tissues of sugarcane grown with the lowest densities of *D. horizontalis*. On the other hand, we adjusted the relative content of P only in the treatments with 10 and 80 plants m^{-2} of *D. horizontalis*. Among the macronutrients, the relative contents of S were the only ones we described by polynomial adjustments according to spacing in all researched densities of *D. horizontalis* (Figure 1). Polynomial models with high coefficients of determination (R2 > 0.81) explained the variation of leaf contents of N, P, K, Ca, Mg, and S of sugarcane plants grown with 40 (except for P) and 80 weeds m^{-2}, according to spacing. In these cases, the greater distance between sugarcane plants and weeds increased nutrient accumulation by the crop.

Regardless of the sowing distance, the coexistence between 10 and 20 plants m^{-2} of *D. horizontalis* did not interfere in the relative contents of N in the leaf tissue of sugarcane plants (Figure 2A). Galon et al. (2012) observed that sugarcane plants of varieties RB72454 and SP801816 showed a reduction in leaf concentration of N with increases in the *B. brizantha* population. The increase in the density of *D. horizontalis* decreased the absorption of N, but only in the smallest spacings (2, 6, and 12 cm) and for the highest studied weed densities (40 and 80 plants m^{-2}).

The high concentration of N in the leaves is because the sugarcane plants associate with diazotrophic bacteria that allow for the biological fixation of N, which include *Gluconacetobacter diazotrophicus, Herbaspirilum seropedicae*, *H. rubrisubalbicans*, and *Bulkholderia tropica*, as well as strains of *Azospirilum* (SCHULTZ et al., 2014). In this case, favorable absorption of N under high weed density may occur if there is enough distance to avoid competition and so that the weed rhizosphere can act as a source of beneficial microbiota, including diazotrophic bacteria. Oliveira et al. (2011) emphasize that the maximum accumulation of the element occurs in the initial phenological phases of the crop despite the wide variation in the requirement of N by the sugarcane, occasions of greater influence of weed competition.

The content of P increased as the distance of *D. horizontalis* in the smallest (10 plants m^{-2}) and in the highest (80 plants m^{-2}) weed density also increased, which is described by polynomial adjustments with $R^2 = 0.85$ and $R^2 = 0.86$, respectively (Figure 2B). The relative contents of P in the leaf tissue of sugarcane plants that coexisted at 2 or 6 cm from the weeds showed reductions of up to 22% in the sugarcane leaf contents of P. The contents of P in sugarcane plants grown with 20 or 40 individuals of *D. horizontalis* m^{-2} were equivalent to 92% of the P observed in the control plants and did not significantly differ along the variable distance (Figure 2B).

Galon et al. (2012) used *B. brizantha* in competition with plants of varieties RB72454, RB867517, and SP801816 of sugarcane planted in a conventional system and observed that increasing weed populations reduced the leaf concentration of P in all genotypes, measured at 290 days after emergence. The low mobility of P due to its strong interaction with the soil colloids causes depletion zones with very small diameter (VIEIRA, 2017). Since absorption of P mainly occurs by diffusion, the increase in the efficiency of use of the element mainly depends on the root volume. In this sense, the PSS system can benefit sugarcane plants due to the action of the root system of seedlings before the emergence of weeds.

The absorption of K, Ca, Mg, and S for treatments involving the presence of 10 and 20 weeds m^{-2} did not show any difference, according to the distance. However, when sugarcane plants coexisted with 40 and 80 plants m^{-2} of *D. horizontalis*, we noticed a lower nutrient accumulation up to 12 cm compared to treatments with lower weed density (Figure 2C, 2D, and 2E). The presence of crabgrass did not have a negative influence when the plants were at 18 and 24 cm, since the leaf contents of Ca, Mg, K, and S were higher than those of the control plot (100%).

Regarding the importance of K for the sugarcane crop, Vale et al. (2011) verified that lack of potassium did not limit the growth of sugarcane of variety RB 86-7515, which reduced only 3% aerial dry mass production, 20% root dry mass, and 7% of the whole plant compared to the control plot. Our study indicates that this may occur because the stem cutting (“billet” or “sett”) works as a reservoir of K and the absorption of this nutrient is slower in the early stages of sugarcane growth. Besides, the amount of potassium in the nutrient solution of the soil must have supplied the initial needs of the plant as well.

Galon et al. (2012) verified that the leaf concentration of calcium (Ca) in sugarcane cultivars did not change with the increase in *B. Brizantha* density. The authors also emphasize that calcium is not a very limiting nutrient when it is enough concentrated in the soil and that it is more difficult for crops and weeds to compete for this element. We considered that the initial levels of Ca and Mg in the soil were high and in accordance with the high saturation by soil bases (Table 1 and Figure 2D and 2E).

The total extraction of macronutrients (kg ha^{-1}) by sugarcane may differ according to genetic potential, edaphoclimatic conditions, and the adequacy of the variety to the local environment. The absorption of these nutrients may show the following variation (OLIVEIRA et al. 2010): N - 94–260; P - 19–30; K - 212–400; Ca - 186–305; Mg - 55 –99. In this case, the amount of macronutrients in the variety IAC SP 95-5000 may be broad. However, the leaves produced more dry matter than the culms up to 120 days after sugarcane planting, which coincides with maximum tillering. Therefore, the accumulation of moving elements in the plant (N, P, and K) tends to be higher in leaves, while Ca and Mg concentrate in the culms (OLIVEIRA et al., 2011).

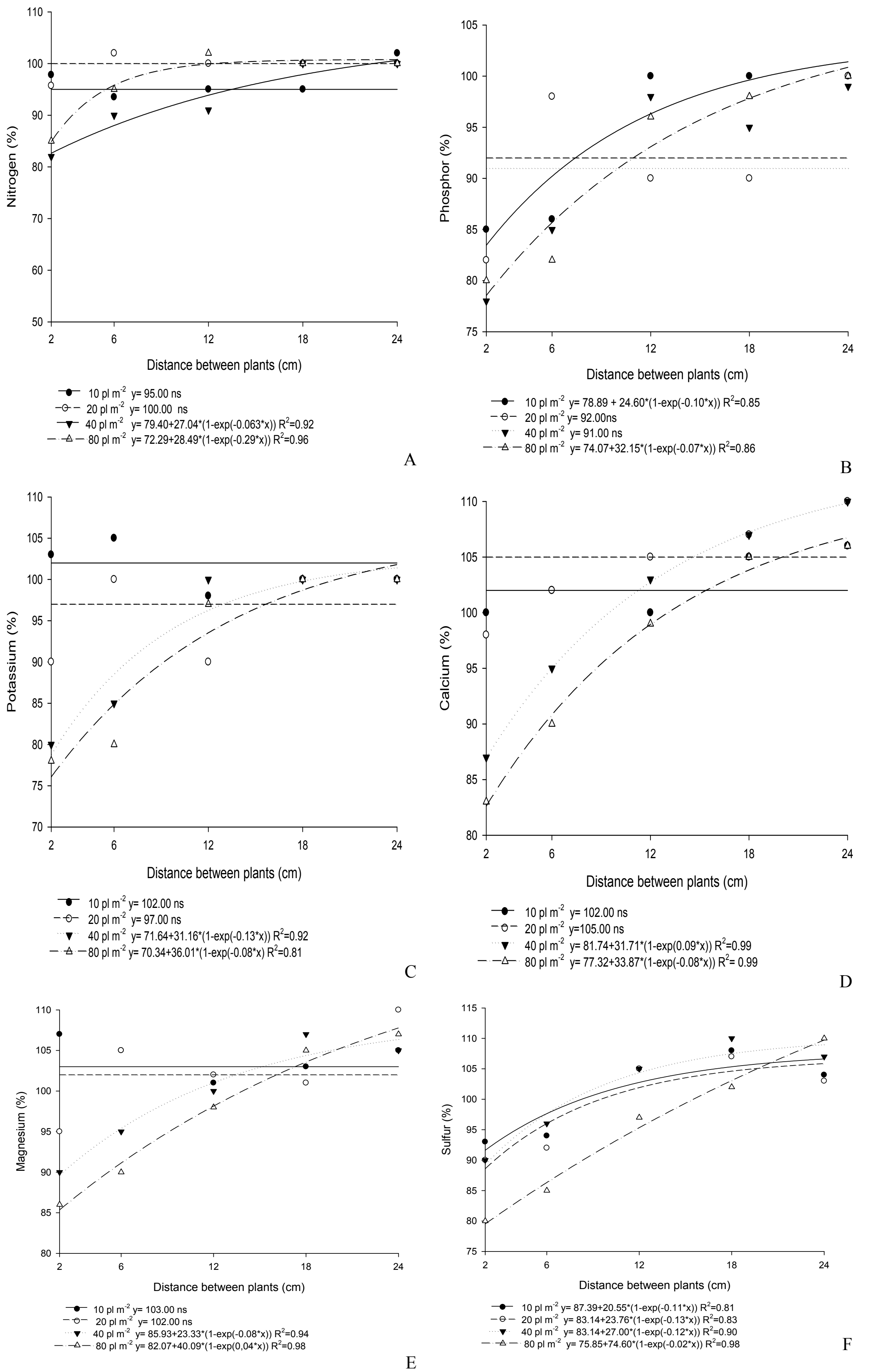

Figure 2. Percentage reduction of primary (Nitrogen - A, Phosphorus - B and Potassium - C) and secondary (Calcium - D, Magnesium - E and Sulfur - F) macronutrients toward control plot (100%) in sugarcanes, according to the density and distance to *Digitaria horizontalis*.

The leaf content of micronutrients (B, Cu, Mn, Fe, and Zn) in sugarcanes decreased in some treatments (Figure 3). However, the interference of the density and distances of the weeds differed for each micronutrient.

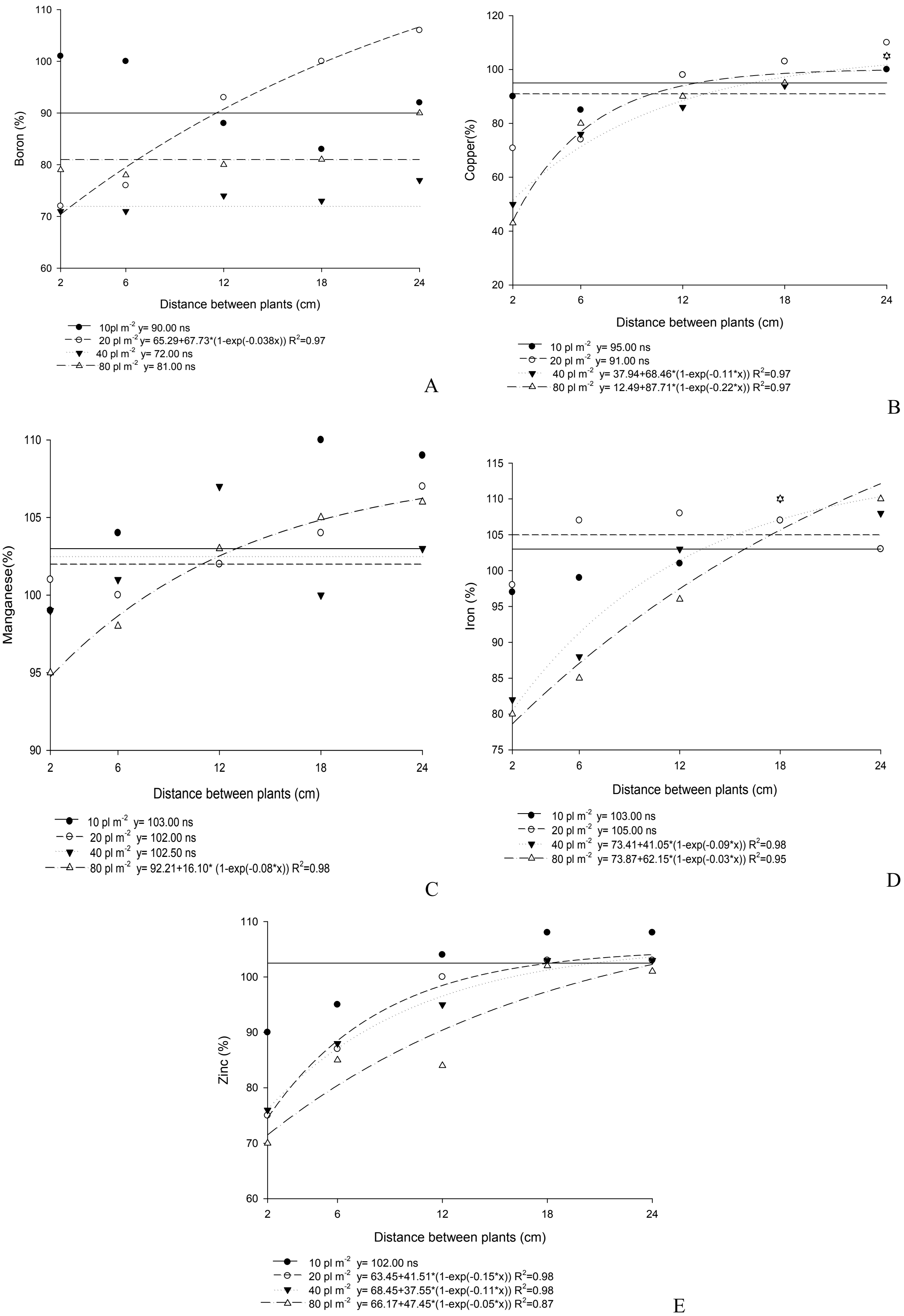

Figure 3. Micronutrients percentage reduction (Boron - A, Copper - B, Manganese - C, Iron - D and Zinc - E) toward control plot (100%) in sugarcanes, according to the density and distance to *Digitaria horizontalis* weed.

Regardless of the sowing distance of the weeds, the coexistence of the crop with 10, 40, and 80 weeds m^{-2} did not change the leaf contents of B (Figure 3A). Only the treatment with 20 weeds m^{-2} reduced contents of B, especially at the nearest distances (6–12 cm). We observed statistical differences for Cu in the treatments related to the coexistence of the crop with 40 and 80 weeds m^{-2}, and the greater the distance, the greater the accumulation of this nutrient in sugarcane leaves. R^2 was 0.97 in both cases (Figure 3B).

In the case of Mn, treatments involving the presence of 10, 20, and 40 weeds m^{-2} did not affect nutrient concentrations in the leaves of the crop (Figure 3C). The coexistence with 80 weeds m^{-2} caused less absorption of Mn up to 12 cm away. We observed that the highest weed densities (40 and 80 plants m^{-2}) affected the accumulation by Fe, since sugarcane plants showed lower leaf contents of Fe up to 12 cm away.

Sugarcane plants showed greater sensitivity when competing with weeds for Zn. Except for the lower density, the coexistence with 20 to 80 weeds m^{-2}, up to 12 cm away, decreased the leaf contents of Zn (Figure 3E). The intrinsic biological characteristics of weeds partially explain its elevate competitive ability, especially morphological and biological adaptations of the root system that increase the absorption of water and nutrients (MASSENSSINI et al., 2014). Agricultural crops have lower competitive ability due to genetic improvement processes, which are not normally aimed at improving the efficiency of nutrient use by plants, and because they are based on weed control cropping systems and with a high rate of fertilizer application (ALTIERI, 1999).

In general, we observed that weeds were potential competitors for macro and micronutrients with PSSs as the density increased, however, the interference depended on distancing. Despite more individuals, the greater distance of *D. horizontalis* allowed the sugarcane to maintain leaf contents of macro and micronutrients similar to the control plants.

The planting and cropping of sugarcane with PSS may favor the crop because it has a vigorous root system before the emergence and development of competitive weeds. Besides, we emphasize that the variety IAC SP 95-5000 was developed for cropping under the conditions of the *Cerrado*, that is, adapted to restrictive soil and water fertility.

CONCLUSION

We concluded that the shortest distances between the crop and the weeds combined with the highest crabgrass densities reduced the absorption of N, P, K, Mn, Fe, and Zn nutrients, decreasing the initial growth of sugarcane. The density of 80 plants m^{-2} of crabgrass negatively affected the growth of the plants, regardless of the distance between them.

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