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INFLUENCE OF INDAZIFLAM AND GLYPHOSATE HERBICIDES ON THE INITIAL DEVELOPMENT OF SUGARCANE (*Saccharum officinarum*) IN THE PRESENCE OF MICROGEO® BIOFERTILIZER

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Abstract: Weeds cause damage to sugarcane, especially in the initial 90 days, so practices for their control and strengthening of the crop are crucial to ensure high productivity. In this context, the objective of this study was to evaluate the influence of the use of indaziflam and glyphosate herbicides on the initial development of the crop in the absence and presence of Microgeo® biofertilizer. The experiment was carried out in a greenhouse, consisting of 6 treatments, with 4 completely randomized repetitions, namely, indaziflam (0.15 mg.L-1 with Microgeo®); indaziflam (0.15 $mg.L^{-1}$ without Microgeo®); glyphosate (3 $mg.L^{-1}$ with Microgeo®); glyphosate (3 $mg.L^{-1}$ without Microgeo®); control 1 (no herbicide without Microgeo®); control 2 (without herbicide with Microgeo®). Visual assessments of phytotoxicity by the ALAM scale were performed on the crop at 07, 21, 35, 45 and 60 days after treatment (DAT), at 60 DAT the shoot and root biomass and development of the root system were evaluated by image processing by the SAFIRA software from EMBRAPA, the data analyzed by the AGROSTAT Software, submitted normality test, analysis of variance (ANOVA) and Tukey test ($p < 0.05$). The results demonstrated thatthe herbicides indaziflam and glyphosate had a negative impact on sugarcane development, with a reduction in biomass accumulation and changes in root development parameters. In addition, the Microgeo biofertilizer*was able to minimize the negative effects caused by herbicides when applied in the same period.
Keywords: Glyphosate; indaziflam; soil microbiology; Sapphire EMBRAPA; root system.

INTRODUCTION

Brazil is the world's largest producer of sugarcane, with an annual production of around 642 million tons (CONAB, 2019). Among the limiting factors for production are

weeds, which interfere with the development of the crop through competition and allelopathy (LORENZI, 2014). The longer the weeds coexist with the crop, the greater the impact caused, for the crop, the initial 90 days are considered the most critical, with a drop in production that can reach 85% on ratoons and up to 100% on sugarcane. plant (IAC, 2018).

The most used method of weed control in sugarcane crops is chemical, in AGROFIT (System of Phytosanitary Pesticides) there are 476 products registered as herbicides for this crop. Among the options are non-selective herbicides, which are products that affect a wide spectrum of plants including the crop and, therefore, must be applied directed at weeds in order to avoid contact with the crop (FILHO & CHRISTOFFOLETTI, 2004).

The herbicide indaziflam is registered for the control of a broad spectrum of weeds in sugarcane, with more effective action for species of the Poaceae family (SILVA et al, 2018). In addition, it has a long residual period in the soil, greater than 150 days, persisting in the soil longer than other pre-emergent products (KAAPRO & HALL, 2012).

The glyphosate herbicide is used in post-emergence to control a broad spectrum of weeds in the crop, mainly in pre-planting and as a ripener, acting on emerged weeds. It does not show pre-emergence action due to the rapid action of soil microorganisms (ANDRIGHETTI et al., 2014). In the soil, it is degraded to different fractions, the main one being aminomethylphosphonic acid (AMPA), which despite not having a herbicidal effect, can affect other non-target organisms and has a long persistence in the soil, whose mineralization half-life is about 270 days (TEJADA et al., 2009).

Both herbicides are applied in such a way as to minimize contact with the crop, to avoid phytotoxicity symptoms, which range from mild damage to plant death. secondary (RIZZARDI et al., 2003). The two herbicides are related to rhizosphere damage (GUERRA et a., 2014). Furthermore, according to SANTOS et al. (2005) and REIS et al. (2008), this class of agrochemicals can interfere with the dynamics of the soil microbiota, since it can have an activating or inhibiting action on the metabolism of microorganisms present there (SHAFFER, 1993; SANINO & GIANFREDA, 2001; SOFO et al., 2012).

Thus, herbicides can influence the development of microorganisms added to agricultural systems. Glyphosate was considered compatible with the entomopathogenic fungi Beauveria bassiana and Metarhizium anisopliae (BOTELHO E MONTEIRO, 2011). However, other bioinputs are currently used in crop management, such as biofertilizers.

Biofertilizers act in the cycling and availability of macro and micronutrients and may have other advantages such as promoting rooting, synthesis of phytohormones, control and induction of resistance to pathogens (BHATTACHARJEE AND DEY, 2014). Often, the action of these products is associated with microorganisms that act in the physical, chemical and biological processes of the soil (NGO et al., 2019; DUBEY et al., 2016).

Among them is Microgeo®, consisting of a "pool" of microorganisms that carry out the cycling of nutrients from organic waste and has been associated with biological activities such as the reduction of the phytotoxic effect of the herbicide ametrine on the lettuce crop (REGO et al, 2014).

In this context, the objective of this study was to evaluate the influence of the herbicides indaziflam and glyphosate on the development of the sugarcane crop in association with Microgeo® biofertilizer. For this, the influence of each herbicide and Microgeo® was evaluated, in isolation, on parameters of initial development of the crop, including

aerial part and root system; if the biological product is compatible with the herbicides, that is, if the benefits associated with the use of the biofertilizer are maintained if applied concomitantly with the herbicides; and whether Microgeo® modifies the interaction between herbicides and the crop, with the aim of evaluating whether the damage associated with herbicides is mitigated by the use of biofertilizer.

MATERIAL AND METHODS

The work was carried out in a greenhouse in an area whose climate classification, Köppen and Geiger, is (aw) ie considered a tropical climate with dry winter, with an average temperature of 22.8 °C and average annual rainfall of 1268 mm.

The experimental design used was completely randomized with 6 treatments, namely: TREATMENT 1: indaziflam herbicide dose 0.15 mg.L-1 without Microgeo®; TREATMENT 2: herbicide indaziflam dose 0.15 mg.L-1 with Microgeo®; TREATMENT 3: glyphosate herbicide dose 3 mg.L-^{1} without Microgeo®; TREATMENT 4: glyphosate herbicide dose 3 mg.L-^{1} with Microgeo®; CONTROL 1: without herbicide and without Microgeo®; CONTROL 2: without herbicide and with Microgeo®. For each treatment, 4 replications were carried out, totaling 24 experimental plots.

The development of sugarcane seedlings took place in plastic bags for seedlings measuring 15 cm wide and 30 cm high. pH indices 6.4; Al3+ 0 ; K+ 2.9; Mg2+ 9 and Ca2+ 32 mmolcdm-3, sieved through a 04 wire 22 mesh coffee sieve. Mineral fertilization of planting was performed with 05-30-20 fertilizer at a dose equivalent to 500 kg ha-1. A piece of sugar cane was planted in each bag, with a healthy bud. Each plot consisted of 10 bags. Thus, there were 6 treatments, 4 replications and 10 bags per plot, totaling 240 bags.

The application of indaziflam herbicides (Alion® 500 SC) with a concentration of 500 g L-1 of ai, supplier Bayer and glyphosate (Roundup® Original SL), supplier Syngenta with concentration of 370 g L^{-1}of acid equivalent occurred soon after planting the stalk (stem), it was carried out with a volume of 200 L.ha-1. For the application of herbicides, a costal sprayer pressurized with CO2 was used, with 6 nozzles model XR Teejetf 110/03, with a pressure of 300 kPa, spaced at 50 cm, totaling 3 m in length of application range, the spray bar was kept 30 cm away from the soil surface. Before application, the equipment was checked with water to verify the flow rate and adequacy of the applicator pass at a speed of 1m.s-1. The pH of the water used was 6.9. The preparation of the syrup was carried out about 30 min before application in the plots. Irrigation was performedevery 48 hours with 6.4 mm of volume, in the interval of 10 min.

At 21, 35, 45 and 60 days after treatment (DAT) visual phytotoxicity assessments were carried out using the ALAM scale (1974) and the percentage of live seedlings. At 60 DAT, aboveground and underground biomass was evaluated (KUVA 1999); and the root system was evaluated by image processing by the SAFIRA software from EMBRAPA, as illustrated in Figure 1. For this, 4 samples were collected from each plot, the roots were washed in running water and images were collected by photography on a white background, for measurement. average length, area covered by roots, volume and average root diameter. The highest value of each measurement was excluded because it belonged to the stalk used in planting.

The analysis of the results was performed using the AGROSTAT Software, and submitted to the normality test, analysis of variance (ANOVA) and Tukey's test ($p < 0.05$).

RESULTS AND DISCUSSION

Table 1 describes the percentage of seedlings on different assessment dates. At 21 DAT, the treatment without herbicide without Microgeo® presented about 37.5% of live seedlings and was considered inferior to the other treatments, which were considered similar to each other, reaching 52.5% of live seedlings for the treatment with indaziflam and with Microgeo®. At 35, 42 and 60 DAP all treatments were considered similar to each other and at different dates, reaching 77.5% of live seedlings at 60 DAT for the indaziflam treatment and with Microgeo®.

The biomass evaluation data can be seen in Table 2, and the fresh (MF) and dry (DM) matter was analyzed for aerial (PA) and underground (PS) parts. All treatments were considered similar in terms of fresh matter of PA and PS, reaching 18.92 g of FM from the shoot for the glyphosate treatment with Microgeo® and 92.64 g of FM from the underground part for the indaziflan treatment without Microgeo®.

Regarding shoot DM, treatments with indaziflam with and without Microgeo®, glyphosate with Microgeo® and controls without herbicide with and without Microgeo® were considered similar to each other, corresponding to 1.92 g DM per shoot of shoots. each plant for herbicide-free treatment with Microgeo®. There was a significant difference between the treatments with glyphosate with and without Microgeo®, with the treatment with Microgeo® considered greater than the one without, corresponding to 2.63 and 1.54 g of DM per shoot of each plant, respectively.

Regarding the DM of the underground part, the indaziflam treatments with Microgeo®, glyphosate with and without Microgeo® and the controls without herbicide with and without Microgeo® were considered similar to each other, reaching 16.41 g of DM per underground part of each plant for glyphosate and Microgeo® treatment. While, the treatment with indaziflam without Microgeo® presented about 12.66 g of DM per underground part of each plant and was considered lower than the control without herbicide with Microgeo® with 18.99 g of DM per underground part of each plant.

The results show that both herbicides affected the accumulation of crop biomass, which indicates that glyphosate and indaziflam herbicides can impact sugarcane production. And the Microgeo® biofertilizer, applied in a mixture of syrup, can minimize the impact caused by the herbicides, since the treatments with herbicides with Microgeo® were considered similar to the controls.

Kawamoto et al (2018) observed a phytotoxic effect of the herbicide indaziflam on pre-sprouted sugarcane seedlings up to 21 DAA, with a significant reduction in plant height, stem diameter and number of leaves, in addition to an increase in necrotic lesions in leaf tissues, thus demonstrating negative interference in the initial stages of sugarcane development. In work of selection of bioindicator species in monocotyledons in the order: signal grass, rice, corn, wheat, oats and in eudicotyledons: tomato, cucumber, sunflower, bean, soybean for indaziflam, a reduction in dry matter of aerial and underground parts of the plants was observed. analyzed plants, this occurred because

Plants exposed to glyphosate show reduced growth of the aerial part and root system, in addition to loss of resistance against diseases, even at doses as low as 3 mL.ha-1 of the commercial product (YAMADA and CASTRO, 2007). This may explain the lower result of 1.54 g.plant-1 of dry matter obtained for the aerial part in the treatment with glyphosate without Microgeo®.

The parameter data of sugarcane roots generated by the SAFIRA software are

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	A	B	C	D
1	Fibra #	Volume(mm³)	Área superficial(mm²)	Diâmetro ponderado(mm)
2	1	341,02	370,93	2,34
3	2	0,33	2,02	0,60
4	3	4,20	20,53	0,62
5	4	0,44	2,93	0,54
6	5	389,37	866,75	1,10
7	6	0,21	2,39	0,36
8	7	2,16	13,97	0,52
9	8	0,40	3,13	0,46
10	9	0,18	1,95	0,36
11	10	0,32	2,15	0,53
12	11	0,23	2,04	0,42
13	12	0,37	2,15	0,66
14	13	2,43	13,04	0,59
15	14	1,30	7,52	0,56

D

Figure 1. Evaluation of sugarcane root development (A – plots allocated in a greenhouse; B – example of image of the root system after washing; C – example of image processing by SAFIRA – EMBRAPA; D – example of exported root data)

Source: Personal collection.

Treatment	Days after application (%)				
	07	21	35	42	60
IndazMam without Microgeos	0.0	50.0 Aa	52.5 As	60.0 Aa	55.0 Aa
Indazifiam with Microgeoe	0.0	52.5 Aa	65.0 Aa	75.0 Aa	80.0 Aa
Glitosate without PAlcrogeos	0.0	37.5 Aa	45.0 As	52.5 Aa	55.0 As
Glitosate with Microgeoll	0.0	47.5M	55.0 Aa	65.0 Aa	75.0 Aa
Without herbicide without	0.0	42.5 As	60.0*To the*	62.5 Aa	70.0 Aa
Herbicide free with Microge.	0.0	37.5 Ba	62.5 AB	75.0 Aa	77.5M
MSD (6%)		10.17	16.23	6.09	3.44

Table 1- Comparison of the percentage of live sugarcane seedlings treated with herbicides and Microgeo®

***Different capital letters indicate difference in column and different lower case letters indicate difference in line.

Source: Personal collection.

Treatment	MF/PA (9/Plant)	MFIPS (glplant)	MS/PA (9[1]Plants)	MS/PS (9/Plant)
Indaziflam without Microgeoe	18.71 to	92.64 to	2.47 ab	12.66b
Indaziflem with Macro*	15.03 to	77.09 to	2.88 to	13.76 ab
Glitosabo without Microgeos	14.12 to	73.42 to	1.54 b	16.41 ab
Glitosate with Microgeo.	18.92 to	66.76 to	2.63 to	15.10 ab
Without herbicide without ...	13.7 to	74.45 to	1.88 abs	15.41 ab
Herbicide free with Microgeos	15.91 to	78.43 to	1.92 ab	18.99 to
MSD (5%)	2.37	4.68	0.85	0.3

Table 2- Biomass of sugarcane seedlings treated with herbicides and Microgeo®

*Different letters indicate differences by Tukey's test at 1% probability in each column.; FM: fresh mass; PA: aerial part; PS: underground part; MS: dry mass

Source: Personal collection.

Treatment	No. of reizes/plent	Volume medium(mm	Volume (mml3))/plent a	Average area (mm2)/reiz	average area (mm[tw])/ptenta	Diameter mediumlroot
Indaziflam without	43.75 to	18.45 to	503.24 to	1282.20 to	34.05 to	0.50c
Indadflam with Microgeoo	32.91 ab	23.80 to	536.14 to	1171.31 to	40.63 to	0.73 ab
Glyphosate without	21.58 b	20.70 to	414.39 to	1147.01 to	46.73 to	0.82 to
Glyphosate with	27.33 ab	23.18 to	430.42 to	1130.92 to	45.42 to	0.80 to
Without herbicide without Microgeoo	32.25 ab	9.66 to	279.41 to	726.25 to	24.29 to	0.64 bc
Herbicide free with Microgeo®	47.50 to	12.21 to	429.03 to	1170.9 to	26.76 to	0.54c
MSD (6%)	0.84	1.25	19.09	1.53	3.05	0.16

Table3- Initial development parameters of sugarcane roots treated with herbicides and Microgeo®

*Different letters indicate differences by Tukey's test at 1% probability in each column.

Source: Personal collection.

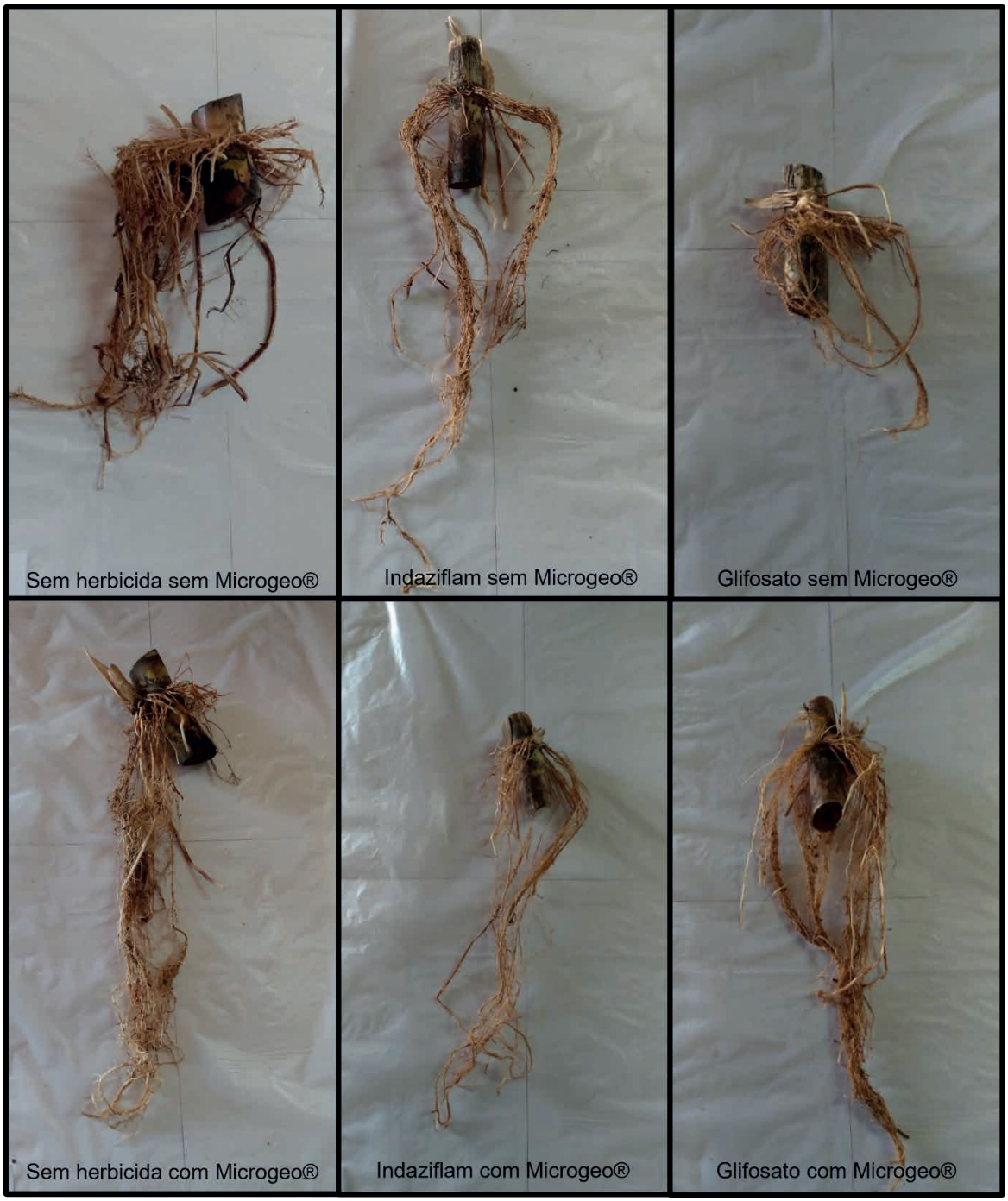

Figure 2. Examples of samples of sugarcane root system treated with indaziflam, glyphosate and Microgeo®

Source: Personal collection.

described in Table 3 and illustrated in Figure 2.

The results regarding the number of roots per plant for treatments with indaziflam with and without Microgeo®, glyphosate with Microgeo® and controls without herbicide with and without Microgeo® were considered similar, reaching 47.50 roots per plant for the control without herbicide and with Microgeo®. The treatment with glyphosate and without Microgeo® was considered lower than the treatment without herbicide with Microgeo®.

All treatments were considered similar in terms of average volume per root, reaching 23.18 mm3 per root for the treatment with indaziflam with Microgeo®. Likewise, all were considered similar in terms of volume per plant, reaching 536.14 mm3 of root volume per plant for treatment with indaziflam with Microgeo®.

The average area per root results for all treatments were considered similar, reaching 1282.20 mm2 per root for the treatment with indaziflam without Microgeo®. Likewise, all were considered similar in terms of area per plant, reaching 46.73 mm2 of root area per plant for glyphosate treatment without Microgeo®.

Regarding data on mean root diameter, treatments with glyphosate with and without Microgeo® were considered similar to each other and superior to the others, corresponding to 0.80 and 0.82 mm of mean diameter per root, respectively. The treatment with indaziflam with Microgeo® was 0.73 mm in average diameter per root, which is considered greater than the indaziflam without Microgeo® and control without herbicide with Microgeo® which was 0.54 mm in average diameter per root.

The presented results demonstrated that the herbicides glyphosate and indaziflam altered the development of sugarcane, as there was alteration in the parameters of root development. It is interesting to note that the volume and area, which are the parameters normally evaluated in studies on roots, were not altered, which could suggest that the treatments did not have an impact. However, there was a change in the number of roots per plant, average diameter of each root and root dry matter, which emphasizes the importance of further studies on the impact of herbicides on root development in sugarcane.

Herbicides altered crop development in a different way. Indaziflam, pre-emergent herbicide with high soil stability(KAAPRO & HALL, 2012)and, therefore, mostly absorbed by the underground part of the plant, making the root system more branched, however, there was less accumulation of biomass, which may indicate that the plant emitted a greater number of branches in response to contact with the herbicide present in the soil. While glyphosate, of action only post-emergent. (ANDRIGHETTI et al., 2014), without herbicidal action in the soil, showed less accumulation of biomass only in shoots, however, it had less branched roots.

In addition, Microgeo® was able to minimize the impacts caused by herbicides. Since the treatment with glyphosate and with Microgeo® showed superior shoot DM results than the same herbicide without the biofertilizer and similar to the control without herbicide and with Microgeo®. And the control without herbicide with Microgeo® showed DM results in the underground part superior to indaziflam without Microgeo® and similar to the herbicide with the biofertilizer. This indicates that Microgeo® is compatible with the herbicides glyphosate and indaziflam in the spray mixture.

CONCLUSIONS

It was concluded that the herbicides indaziflam and glyphosate had a negative impact on the development of sugarcane, with

a reduction in biomass accumulation and changes in root development parameters. In addition, the Microgeo biofertilizer® was able to minimize the negative effects caused by herbicides when applied in the same period.

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