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Herbicide and nematicide interaction in sugarcane crops[1]

Interação entre herbicidas e nematicidas na cultura da cana-de-açúcar

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Abstract - Sugarcane has great economic importance in Brazil. In order to maintain its yield, several biotic and abiotic factors can have a positive or negative influence. Among them, it is possible to mention weeds, nematodes and the synergistic action among pesticides in order to control both. Thus, the present work had the objective to study the interaction between herbicides and nematicides used in sugarcane crop. The experimental design was completely randomized, in a 5 x 3 factor scheme, with four replications. The first factor corresponds to sulfentrazone (800 g ha^{-1} a.i.), saflufenacil (98 g ha^{-1} a.i.), diuron + hexazinone (1170 g ha^{-1} a.i. + 330 g ha^{-1} a.i.), amicarbazone (1050 g ha^{-1} a.i.) plus the control sample; the second factor corresponds to the nematicides benfuracarb (2000 g ha^{-1} a.i.) and carbofuran (1750 g ha^{-1} a.i.) plus the control sample. Nematicides were applied in contact with billets and herbicides applied during the pre-emergence of the crop; this was perfomed on the RB867515, RB975201 and RB975952 sugarcane varieties. Evaluations of phytotoxicity were performed at 7, 15, 30, 45 and 60 after emergence (DAE) of the crop. During the last evaluation, the biometric parameters of height, leaf area and dry biomass of the aerial part were determined. All plants recovered after 60 DAE, and in treatments with the use of sulfentrazone higher intoxication symptoms were observed. As for the biometric parameters evaluated at 60 DAE, there was no significant interaction for herbicide and nematicide factors, but there was a difference between treatments in each variety.
Keywords: phytotoxicity; synergistic interaction; *Saccharum officinarum*

Resumo - A cana-de-açúcar tem grande importância econômica no Brasil. Para manter sua produtividade diversos fatores bióticos e abióticos podem influenciar positiva ou negativamente. Dentre eles, podem ser citados as plantas daninhas, os nematoides e a interação entre produtos fitossanitários para o controle de ambos. Em função disto, o presente trabalho teve como objetivo estudar a interação entre herbicidas e nematicidas usados na cultura da cana-de-açúcar. O delineamento experimental foi inteiramente casualizado em esquema fatorial 5 x 3, com 4 repetições. O primeiro fator corresponde aos herbicidas sulfentrazone (800 g ha^{-1} a.i.), saflufenacil (98 g ha^{-1} a.i.), diuron + hexazinone (1170 g ha^{-1} a.i. + 330 g ha^{-1} a.i.), amicarbazone (1050 g ha^{-1}

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a.i.), mais a testemunha; o segundo fator aos nematicidas benfuracarbe (2000 g ha^{-1} a.i.), carbofuran (1750 g ha^{-1} a.i.), mais a testemunha. Os nematicidas foram aplicados em contato com os toletes e os herbicidas aplicados em pré-emergência da cultura, sendo realizado nas variedades de cana-de-açúcar RB867515, RB975201 e RB975952. As avaliações de fitotoxicidade foram realizadas aos 7, 15, 30, 45 e 60 dias após a emergência (DAE) da cultura. Na última avaliação foram determinados os parâmetros biométricos altura, área foliar e biomassa seca da parte aérea. Todas as plantas se recuperaram aos 60 DAE, sendo que nos tratamentos com o uso do herbicida sulfentrazone foram observados sintomas mais elevados de intoxicação. Quanto aos parâmetros biométricos avaliados aos 60 DAE, não houve interação significativa para os fatores herbicida e nematicida, mas houve diferença entre os tratamentos em cada variedade.
Palavras-chaves: fitotoxicidade; interação sinérgica; *Saccharum officinarum*

Introduction

Weed and nematode control in sugarcane is normally performed through chemical methods. Among all control methods that may be used to manage weeds, the chemical one is still the most used; herbicides may be applied during incorporated pre-planting, pre-emergence and post-emergence. As for nematodes, in addition to the recommendation of varietal and cultural management, the chemical one is much used; its use in experiments demonstrated yield loss of the crop up to 50% when compared to the use of nematicides, which may provide yield ma7 up to 45 t ha^{-1}(Azania et al., 2009a).

With the lack of sugarcane varieties that are resistant to the main nematode species causing damages to the crop, control through nematicides is the mostly used method; it also reduces costs and helps maintaining yield (Silva et al., 2006).

Due to the damages caused by nematodes and weeds, in cane fields it is common to apply nematicides in plantation furrows, followed by herbicides in pre-emergence, and this product interaction may result in an increase of phytotoxicity symptoms caused by the herbicide. The synergic action was verified with terbufos nematicide, which increased the phytotoxicity symptoms of clomazone up to 88 days after application (DAA) and of clomazone + diuron + hexazinone up to 66 DAA; however, they did not reduce the number of tillers m^{-1} (Dinardo-Miranda et al., 2001).

The use of herbicides and nematicides in cane-plants has increased and according to Romão (2008), the positive response of this practice in the crop yield is because there is less competition with weeds and less incidence of nematode attacks in the root system; thus, the crop has the chance to express all its productive potential. Moreover, it is of utmost importance knowing the phytotoxic symptoms that an herbicide may cause to a crop, even more when there are associations with other products such as nematicides (Negrisoli et al., 2004).

In herbicide treated sugarcane plantations (control sample - no herbicide with manual weeding, clomazone - 1.000 g ha^{-1} a.i., tebuthiuron - 1.000 g ha^{-1} a.i. and metribuzin - 1.680 g ha^{-1} a.i.) and nematicides (control sample; aldicarb - 1.800 g ha^{-1} a.i., carbofuran - 2.275 g ha^{-1} a.i. and terbufos - 2.550 g ha^{-1} a.i.), Dinardo-Miranda et al. (2006b) verified phytotoxicity at 35 DAA; they were more accentuated in slots with metribuzin + terbufos and tebuthiuron + terbufos. There was no yield reduction due to the interactions; carbofuran even increased the yield of stalks up to 12 t ha^{-1}.

In light of the aforementioned, this work had the objective to study the interaction occurring between sulfentrazone, saflufenacil, diuron + hexazinone and amicarbazone herbicides and the benfuracarbe and carbofuran nematicides in the initial development of three sugarcane varieties.

Material and Methods

The experiment was conducted in a greenhouse from March to May 2015. The used sugarcane varieties were: RB867515, RB975201 and RB975952. The used experimental design was the completely randomized one, in 5 x 3 factor scheme, with four replications. Product doses were determined according to the recommendations presented by Rodrigues and Almeida (2011) taking into consideration the leaflet of commercial products.

The first factor corresponded to sulfentrazone (Boral 500 SC, 500 g L^{-1} a.i., SC, dose: 800 g ha-1 a.i., FMC), saflufenacil (Heat, 700 g kg^{-1} a.i., WG, dose: 98 g ha^{-1} a.i., BASF), diuron + hexazinone (Velpar K WG, 468 g kg^{-1} + 132 g kg^{-1} a.i., WG, dose: 1170 g ha^{-1} a.i. + 330 g ha^{-1} a.i., DuPont), amicarbazone (Dinamic, 700 g kg^{-1} a.i., WG, dose: 1050 g ha^{-1} a.i., Arysta LifeScience), in addition to the control sample with no herbicide application. The second factor corresponded to benfuracarbe (Pottente, 400 g L^{-1} a.i., EC, dose: 2000 g ha^{-1} a.i., IHARA), carbofuran (Furadan 350 SC, 350 g L^{-1} a.i., SC, dose: 1750 g ha^{-1} a.i., FMC) and the control sample with no nematicide application.

The experimental units were constituted by plastic planters with 5.44 L capacity, filled with soil that was collected in a Red Latosol area, clay texture, sieved and removed from the 0-20 cm arable layer. The chemical characteristics are in Table 1.

Table 1. Chemical characteristics of the soil used in the experiment. Araras (SP), 2015.

P Resin	M.O	pH	K	Ca	Mg	H+Al	SB	CTC	V	S	B	Cu	Fe	Mn	Zn
mg dm^{-3}	g dm^{-3}	$CaCl_2$			mmol$_c$ dm^{-3}				%			mg dm^{-3}			
30	30	5.5	4.6	30	10	33	44	77	57	33	0.07	4.8	15	5	1.8

On March 20th, two mini billets were planted in each pot, from each variety, with one bud each. After that, nematicides were applied in contact with the billets in the due treatments. Right after the application, billets were covered with a soil layer that was enough not to leave them exposed; then, herbicides were applied in doses referring to each treatment.

The application was performed with a CO_2 pressurized back sprayer, with a spray bar containing four Teejet 11002 fan type nozzles, with 2 Bar constant pressure and with an application volume of L ha^{-1}. At the time of application, the environmental conditions were: 0.4 m s^{-1} wind speed, 24.6 °C air temperature and 75% air relative humidity.

Visual evaluations of intoxication symptoms were observed at 7, 15, 30, 45 and 60 after emergence (DAE) of the crop; they were performed according to SBCPD (1995), which uses 0 to 100% scales, where 0% corresponds to injury absence and 100% plant death.

On 60 DAE, plant height was evaluated with the help of a ruler, from the plant basis to the insertion of the first leaf. Subsequently, the aerial part of plants was cut close to the soil with a pair of scissors and taken to a laboratory in order to measure the leaf area, obtained with a LICOR 3000C device. After that, plants were placed in properly identified paper bags, and placed in a forced air circulation oven at 60°C for 48 hours, in order to obtain the dry biomass of the aerial part, which was performed with an analytic scale.

Data obtained from each replication for intoxication symptoms and biometric variables were submitted to analysis of variance and when they were significant, the averages were compared by Tukey's test at 5% probability level, through the SISVAR statistical program. In order to analyze data, intoxication symptoms were transformed into $x = \sqrt{x + 1}$.

Results and Discussion

For the RB867515 variety, there was significant interaction of the herbicide and nematicide factors at 30 and 45 DAE. At 7 DAE, there was a significant difference for phytotoxicity averages within the nematicide factor, when benfuracarbe or carbofuran were applied with sulfentrazone. The use of benfuracarbe/sulfentrazone resulted in 17.5% phytotoxicity and there was no difference when compared to the use of this nematicide with diuron + hexazinone herbicides with 5.0% and saflufenacil with 10.0% phytotoxicity. As for the carbofuran/sulfentrazone treatment, the 30.0% value was statistically equal to diuron + hexazinone with 15.0%. Singularly applied nematicides do not present phytotoxicity in none of the evaluation periods (Table 2).

Table 2. Phytotoxicity evaluations for the RB867515 sugarcane variety at 7, 15, 30 and 45 DAE. Araras (SP), 2015.

	7 DAE		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	0.00 aA	0.00 aA	0.00 aA
Sulfentrazone	13.30 aA	17.50 bAB	30.00 bB
Saflufenacil	0.00 aA	10.00 abA	2.50 aA
Diuron + hexazinone	2.50 aA	5.00 abA	15.00 abA
Amicarbazone	0.00 aA	0.00 aA	0.00 aA
$F_{(herbicide)} = 11.664^*$ $F_{(nematicide)} = 2.670^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.289^{ns}$			
CV%		59.90	
	15 DAE		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	0.00 aA	0.00 aA	0.00 aA
Sulfentrazone	28.30 bA	30.00 bA	45.00 bB
Saflufenacil	0.00 aA	0.00 aA	7.50 aA
Diuron + hexazinone	0.00 aA	3.75 aA	2.50 aA
Amicarbazone	0.00 aA	0.00 aA	0.00 aA
$F_{(herbicide)} = 48.389^*$ $F_{(nematicide)} = 3.353^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.439^{ns}$			
CV%		41.03	
	30 DAE		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	0.00 aA	0.00 aA	0.00 aA
Sulfentrazone	23.30 bA	15.00 bA	45.00 bB
Saflufenacil	0.00 aA	0.00 aA	3.75 aA
Diuron + hexazinone	0.00 aA	3.75 abA	2.50 aA
Amicarbazone	6.67 aA	0.00 bA	0.00 aA
$F_{(herbicide)} = 37.059^*$ $F_{(nematicide)} = 4.793^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 4.309^*$			
CV%		47.45	
	45 DAE		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	0.00 aA	0.00 aA	0.00 aA
Sulfentrazone	15.00 bB	0.00 aA	22.50 bC
Saflufenacil	0.00 aA	0.00 aA	0.00 aA
Diuron + hexazinone	0.00 aA	0.00 aA	0.00 aA
Amicarbazone	0.00 aA	0.00 aA	0.00 aA
$F_{(herbicide)} = 61.634^*$ $F_{(nematicide)} = 17.182^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 17.182^*$			
CV%		18.56	

^{ns} Nonsignificant; * Significant at 5% probability level by F test. Averages followed by the same lowercase letter in the column and the same capital letter on the line do not different among themselves by Tukey's test at 5% significance.

At 15 DAE, sulfentrazone-treated plants, singularly or in interaction with nematicides, resulted in a difference compared with the other treatments. The highest phytotoxicity average was observed in sulfentrazone/carbofuran treatments with 45.0%, differing from sulfentrazone/benfuracarbe with 30.0% average and sulfentrazone applied singularly with the lowest value of 28.3%. This result continued until day 30 DAE, but with reductions in the phytotoxicity grades. At 45 DAE there were no more injuries on benfuracarbe-treated plants, only in the treatment with carbofuran/sulfentrazone with 22.5% and sulfentrazone applied singularly with 15% (Table 2). At 60 DAE, in all treatments, no plants with phytotoxicity were observed, that is, there was a recovery of the injuries caused at the beginning of the development.

Barela and Christoffoleti (2006) studied the selectivity of herbicides when applied during pre-emergence on the RB867515 variety, previously tested with nematicide in the plantation furrow; they were three nematicides and eight herbicides, as well as the control samples. The authors also found phytotoxicity symptoms caused by sulfentrazone and diuron + hexazinone up to 90 days after blooming (DAB); however, they were not statistically different from the control sample in this last evaluation. It is the same as this work, where at 60 DAE no injuries on plants caused by these same herbicides were observed.

Carvalho et al. (2011) observed very light amicarbazone symptoms in sugarcane (RB86-5486), when it was applied during weed pre-emergence, in ratoon cane areas (first cut) at 25 after harvesting. In the three used doses, the phytotoxicity index was low, and at 45 DAA no treatment presented symptoms of intoxication by herbicide. The same was observed in this work, where at 45 DAE the RB867515 variety did not present symptoms of intoxication by amicarbazone, demonstrating high selectivity of the product.

There was no significant interaction for the biometric variables in the RB867515 variety. For the height variable there was a difference within the herbicide factor; in the amicarbazone/benfuracarbe treatment, plants with higher height averages (19.25 cm) were observed, differing from the singularly applied amicarbazone, which presented plants with 13.50 cm height. As for leaf area and dry biomass of the aerial part, there was a significant difference within the nematicide factor. In the absence of nematicides, the lowest leaf area was observed for plants that were treated with amicarbazone (178.75 cm²), differing from diuron + hexazinone (273.25 cm²) with the highest average. This result accompanied the biomass variable, where the highest average was for diuron + hexazinone (4.00 g) and saflufenacil (3.75 g) treatments, statistically differing from plants treated with amicarbazone (2.00 g) (Table 3).

Saflufenacil is an important herbicide, recommended for sugarcane and, according to Monquero et al. (2011), it effectively controls *Mucuna cissoides*, *M. aterrima* and *Ricinus communis* in the 50 g ha^{-1} a.i. dose, but it needs 100 g ha^{-1} a.i. to control *Luffa aegyptiaca*, which proved to be tolerant in the commercial dose.

The height of plants with amicarbazone application did not differ from the control sample; it was also verified by Gregorin Filho et al. (2014), when the herbicide was applied in experiments with and without straw with a sub-dose, commercial dose and super dose. These authors also observed the wide control spectrum of this herbicide; the only persisting species among the 17 found in the control samples was *Cynodon dactylon*.

For the RB975201 variety, there was significant interaction of the herbicide and nematicide factors at 15, 30 and 45 DAE. Plants from treatments with isolated sulfentrazone or in interaction with nematicides remained statistically different from the other treatments, with the exception of the evaluation at 7 DAE for saflufenacil/carbofuran, which presented a phytotoxicity average of 17.5%. At 30 and 45 DAE, in the sulfentrazone/carbofuran treatment, plants with 25.7% and 20.0% phytotoxicity respectively were observed; thus, it was higher than plants treated with sulfentrazone/benfuracarbe, which presented 8.75 and 7.50%, respectively.

Table 3. Evaluations of the biometrical variables for the RB867515 variety at 60 DAE. Araras (SP), 2015.

	Height (cm)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	14.25 aA	15.00 bA	15.50 aA
Sulfentrazone	15.25 aA	15.50 abA	15.25 aA
Saflufenacil	16.00 aA	14.50 bA	15.75 aA
Diuron + hexazinone	14.75 aA	14.25 bA	18.28 aA
Amicarbazone	13.50 aB	19.25 aA	14.50 aAB
$F_{(herbicide)} = 3.431^{*}$ $F_{(nematicide)} = 1.565^{ns}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.367^{ns}$			
CV%		13.76	
	Leaf area (cm²)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	200.00 abA	228.50 aA	218.00 aA
Sulfentrazone	213.00 abA	234.50 aA	176.50 aA
Saflufenacil	196.25 abA	247.00 aA	211.00 aA
Diuron + hexazinone	273.25 aA	207.75 aA	229.50 aA
Amicarbazone	178.75 bA	249.25 aA	245.00 aA
$F_{(herbicide)} = 0.752^{ns}$ $F_{(nematicide)} = 1.362^{*}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 2.026^{ns}$			
CV%		19.61	
	Dry biomass of the aerial part (g)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	2.50 abA	3.25 aA	3.25 aA
Sulfentrazone	3.00 abA	3.25 aA	2.50 aA
Saflufenacil	3.75 aA	3.25 aA	3.25 aA
Diuron + hexazinone	4.00 aA	2.75 aA	2.75 aA
Amicarbazone	2.00 bA	3.25 aA	3.00 aA
$F_{(herbicide)} = 1.134^{ns}$ $F_{(nematicide)} = 0.293^{*}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.939^{ns}$			
CV%		27.10	

^{ns} Nonsignificant; * Significant at 5% probability level by F test. Averages followed by the same lowercase letter in the column and the same capital letter on the line do not different among themselves by Tukey's test at 5% significance.

Plants from the treatment with isolated sulfentrazone, in this variety, demonstrated more elevated phytotoxicity symptoms at 15, 30 and 45 DAE, when statistically compared to treatments in interaction with benfuracarbe or carbofuran. In treatments involving the isolated use of nematicides, no plant injuries were observed (Table 4).

There was no significant interaction for the biometric variables in the RB975201 variety. Also Dias-Arieira et al. (2010) did not observe any significant height difference in the sugarcane, when carbofuran was applied, in comparison to the control sample in the RB867515 and RB72454 varieties. As for the leaf area variable, there was a significant difference for the herbicide factor within benfuracarbe nematicide; the highest average was observed in plants from treatments with saflufenacil alone (203.75 cm²), differing from amicarbazone treatments, with the lowest average (85.50 cm²) (Table 5). Amicarbazone is a widely used herbicide over sugarcane, due to its control effectiveness; Carvalho et al. (2012) verified the control of 99.3% weeds, at 30 DAA.

Azania et al. (2009b), while testing insecticides/nematicides and herbicides applied in the pre-emergence of the SP83-2847 variety and weeds, observed that at 30 after treatment (DAT), there were no intoxication symptoms; the highest grade was 10% at 15 DAT, when carbofuran/diuron + hexazinone were applied.

Similar values were found in this work, where the highest grade given for this treatment was at 7 DAE (15%); all the others also caused less than 10% injuries to plants, for the three varieties. According to these authors, the height variable was not statistically different from the control sample. In addition to injuries, plant height and stand were also not affected by the interaction between products (Azania et al., 2009b).

Table 4. Phytotoxicity evaluations (%) for the RB975201 variety at 7, 15, 30 and 45 DAE. Araras (SP), 2015.

	7 DAE		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	0.00 aA	0.00 aA	0.00 aA
Sulfentrazone	20.00 bA	12.50 bA	5.00 aA
Saflufenacil	5.00 abA	10.00 abAB	17.50 bB
Diuron + hexazinone	2.50 aA	0.00 aA	0.00 aA
Amicarbazone	0.00 aA	0.00 aA	0.00 aA
$F_{(herbicide)} = 10.5^*$ $F_{(nematicide)} = 0.00^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.793^{ns}$			
CV%		58.98	
	15 DAE		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	0.00 aA	0.00 aA	2.50 aA
Sulfentrazone	46.67 bB	17.50 bA	22.50 bA
Saflufenacil	1.25 aA	0.00 aA	7.50 aA
Diuron + hexazinone	0.00 aA	0.00 aA	1.67 aA
Amicarbazone	0.00 aA	0.00 aA	1.25 aA
$F_{(herbicide)} = 32.737^*$ $F_{(nematicide)} = 3.076^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 3.515^*$			
CV%		51.14	
	30 DAE		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	0.00 aA	0.00 aA	2.50 aA
Sulfentrazone	53.33 bC	8.75 aA	27.50 bB
Saflufenacil	2.50 aA	0.00 aA	0.00 aA
Diuron + hexazinone	0.00 aA	0.00 aA	1.67 aA
Amicarbazone	0.00 aA	0.00 aA	0.00 aA
$F_{(herbicide)} = 61.205^*$ $F_{(nematicide)} = 13.157^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 11.56^*$			
CV%		42.20	
	45 DAE		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	0.00 aA	0.00 aA	0.00 aA
Sulfentrazone	40.00 bC	7.50 aA	20.00 bB
Saflufenacil	0.00 aA	2.50 aA	0.00 aA
Diuron + hexazinone	0.00 aA	0.00 aA	0.00 aA
Amicarbazone	0.00 aA	0.00 aA	0.00 aA
$F_{(herbicide)} = 76.768^*$ $F_{(nematicide)} = 12.00^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 14.411^*$			
CV%		31.48	

^{ns} Nonsignificant; * Significant at 5% probability level by F test. Averages followed by the same lowercase letter in the column and the same capital letter on the line do not different among themselves by Tukey's test at 5% significance.

For the RB975952 variety, there was significant interaction of the herbicide and nematicide factors at 7, 15 and 30 DAE. At 7 DAE, plants from the saflufenacil/benfuracarbe treatment presented 17.5% phytotoxicity, which was statistically different from isolated benfuracarbe and amicarbazone/benfuracarbe; both did not cause injuries to the plants. When carbofuran was applied, it was observed that plants from the treatment containing sulfentrazone, with 20% phytotoxicity, were statistically different from the other treatments. For sulfentrazone, the application of benfuracarbe and carbofuran resulted in statistical differences. For the interaction with carbofuran, plant phytotoxicity was 20%; for the treatment with benfuracarbe, the interaction with saflufenacil obtained higher injuries on plants, with 17.5% (Table 6).

Table 5. Evaluations of the biometrical variables for the RB975201 variety at 60 DAE. Araras (SP), 2015.

	Height (cm)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	14.50 aA	13.50 aA	12.75 aA
Sulfentrazone	10.25 aA	13.00 aA	14.00 aA
Saflufenacil	13.00 aA	12.75 aA	12.75 aA
Diuron + hexazinone	12.75 aA	14.50 aA	14.25 aA
Amicarbazone	14.50 aA	12.00 aA	14.75 aA
$F_{(herbicide)} = 0.821^{ns}$ $F_{(nematicide)} = 0.317^{*}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 0.692^{ns}$			
CV%		22.03	
	Leaf area (cm²)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	205.25 aA	141.75 abA	144.25 aA
Sulfentrazone	176.00 aA	167.00 abA	128.25 aA
Saflufenacil	205.50 aA	203.75 aA	154.75 aA
Diuron + hexazinone	224.50 aA	200.75 abA	188.75 aA
Amicarbazone	111.50 aA	85.50 bA	135.50 aA
$F_{(herbicide)} = 4.617^{*}$ $F_{(nematicide)} = 1.888^{ns}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 0.651^{ns}$			
CV%		34.92	
	Dry biomass of the aerial part (g)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	3.00 aA	2.25 aA	2.25 aA
Sulfentrazone	2.25 aA	2.50 aA	2.00 aA
Saflufenacil	3.00 aA	3.00 aA	2.00 aA
Diuron + hexazinone	3.25 aA	2.75 aA	2.25 aA
Amicarbazone	1.50 aA	1.50 aA	1.75 aA
$F_{(herbicide)} = 2.464^{ns}$ $F_{(nematicide)} = 1.446^{ns}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 0.435^{ns}$			
CV%		44.06	

^{ns} Nonsignificant; * Significant at 5% probability level by F test. Averages followed by the same lowercase letter in the column and the same capital letter on the line do not different among themselves by Tukey's test at 5% significance.

At 15 DAE, the significant interaction was only maintained for isolated sulfentrazone or in association with nematicides, with higher phytotoxicity grade for plants from the treatments with sulfentrazone/carbofuran with 40%, which is different from sulfentrazone/benfuracarbe and sulfentrazone, with 17.5% and 20.0%, respectively. This same pattern was observed up to day 45 DAE (Table 6). As well as for the other varieties, at 60 DAE no plant injuries were verified.

There was no significant interaction for the biometric variables in the RB975952 variety. For the height variable, there was a difference for sulfentrazone according to the nematicide factor; in the treatment sulfentrazone/carbofuran, there were plants with higher height averages (17.15 cm), differing from sulfentrazone/benfuracarbe (12.5 cm) and sulfentrazone alone (12.25 cm), which may suggest stimulation to the plant growth. As for the leaf area variable, there was a significant difference for the herbicide factor within the nematicide factor. The control sample (absence of herbicide and nematicide) (155.0 cm²) was different from plants from the treatment diuron

+ hexazinone (237.0 cm²); within carbofuran, plants with diuron + hexazinone obtained the highest averages (255.25 cm²), in statistical comparison with amicarbazone (166.0 cm²) (Table 7).

Table 6. Phytotoxicity evaluations (%) for the RB975952 variety at 7, 15, 30 and 45 DAE. Araras (SP), 2015.

	Without nematicide	benfuracarbe	carbofuran
7 DAE			
Without herbicide	0.00 aA	0.00 aA	0.00 aA
Sulfentrazone	10.00 aA	5.00 abA	20.00 bB
Saflufenacil	10.00 abA	17.50 bB	5.00 aA
Diuron + hexazinone	5.00 aA	5.00 abA	6.67 aA
Amicarbazone	0.00 aA	0.00 aA	0.00 aA
$F_{(herbicide)} = 8.711^*$ $F_{(nematicide)} = 0.381^{ns}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 2.495^*$			
CV%		55.99	
15 DAE			
Without herbicide	0.00 aA	0.00 aA	10.00 aA
Sulfentrazone	20.00 bA	17.50 bA	40.00 bB
Saflufenacil	6.25 aA	0.00 aA	0.00 aA
Diuron + hexazinone	0.00 aA	0.00 aA	1.67 aA
Amicarbazone	1.25 aA	0.00 aA	0.00 aA
$F_{(herbicide)} = 38.038^*$ $F_{(nematicide)} = 4.998^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 2.571^*$			
CV%		39.17	
30 DAE			
Without herbicide	0.00 aA	0.00 aA	13.70 bB
Sulfentrazone	16.60 bA	22.50 bA	42.50 cB
Saflufenacil	0.00 aA	0.00 aA	2.50 abA
Diuron + hexazinone	0.00 aA	0.00 aA	1.67 aA
amicarbazone	0.00 aA	2.50 aA	0.00 aA
$F_{(herbicide)} = 45.657^*$ $F_{(nematicide)} = 11.998^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 3.901^*$			
CV%		39.30	
45 DAE			
Without herbicide	0.00 bB	0.00 bB	10.00 bA
Sulfentrazone	16.60 aA	25.00 aB	16.20 aB
Saflufenacil	0.00 bA	0.00 bA	2.50 bA
Diuron + hexazinone	0.00 bA	5.00 bA	0.00 bA
Amicarbazone	0.00 bA	0.00 bA	0.00 bA
$F_{(herbicide)} = 16.738^*$ $F_{(nematicide)} = 0.787^*$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.176^{ns}$			
CV%		18.46	

^{ns} Nonsignificant; * Significant at 5% probability level by F test. Averages followed by the same lowercase letter in the column and the same capital letter on the line do not different among themselves by Tukey's test at 5% significance.

The sulfentrazone herbicide, even if it caused greater phytotoxicity symptoms at the beginning of the sugarcane variety development, had its use justified, since plants at 60 DAE recovered from these injuries (Table 7). Its use becomes relevant to control weeds such as the ones from the Convolvulaceae family. Silva et al. (2015), observed over 80% control for the *Merremia aegyptia*, *Ipomoea purpurea*, *Luffa aegyptiaca*, *Mucuna aterrima* and *Ricinus communis* species, when sulfentrazone was applied in post-emergence in the commercial dose (600 g ha^{-1}). Silva et al. (2012), verified sensitivity of *M. aterrima*, *M.*

cinerea and *M. deeringiana* to sulfentrazone and amicarbazone at 45 DAA, when applied in pre-emergence.

As well as the control effectiveness, sulfentrazone becomes a good option when a prolonged residual for weed control is desired; Lourenço and Carvalho (2015) verified that at 182 DAA, this herbicide still had phytotoxic activity over the plant that was used as a bioindicator, *Guizotia abyssinica* Cass.

Table 7. Evaluations of the biometrical variables for the RB975952 variety at 60 DAE. Araras (SP), 2015.

	Height (cm)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	13.50 aA	14.25 aA	14.50 aA
Sulfentrazone	12.25 aB	12.50 aB	17.75 aA
Saflufenacil	14.00 aA	16.00 aA	14.50 aA
Diuron + hexazinone	16.75 aA	14.25 aA	17.50 aA
Amicarbazone	17.25 aA	15.25 aA	15.75 aA
$F_{(herbicide)} = 1.467^{ns}$ $F_{(nematicide)} = 1.622^{*}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.392^{ns}$			
CV%		19.16	
	Leaf area (cm²)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	155.00 bA	189.50 aA	215.50 abA
Sulfentrazone	190.25 abA	164.00 aA	211.50 abA
Saflufenacil	185.75 abA	214.25 aA	193.75 abA
Diuron + hexazinone	237.00 aA	196.75 aA	255.25 aA
Amicarbazone	184.00 abA	195.25 aA	166.00 bA
$F_{(herbicide)} = 3.390^{*}$ $F_{(nematicide)} = 1.522^{ns}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.773^{ns}$			
CV%		18.37	
	Dry biomass of the aerial part (g)		
	Without nematicide	benfuracarbe	carbofuran
Without herbicide	2.25 aA	3.00 aA	3.25 aA
Sulfentrazone	3.00 aA	2.00 aA	3.00 aA
Saflufenacil	3.00 aA	3.25 aA	3.00 aA
Diuron + hexazinone	3.25 aA	2.50 aA	3.25 aA
Amicarbazone	2.50 aA	2.50 aA	2.00 aA
$F_{(herbicide)} = 2.313^{ns}$ $F_{(nematicide)} = 0.687^{ns}$ $F_{(interaction\ herbicide\ x\ nematicide)} = 1.771^{ns}$			
CV%		24.40	

^{ns} Nonsignificant; * Significant at 5% probability level by F test. Averages followed by the same lowercase letter in the column and the same capital letter on the line do not different among themselves by Tukey's test at 5% significance.

Barros et al. (2006) verified the compatibility of nematicides (terbufos and aldicarbe) applied in the plantation furrow and herbicides (diuron, oxyfluorfen, ametryn and pendimethalin) applied in pre-emergence on the SP79-1011 sugarcane variety; it was possible to state that the combined use of these inputs is safe and it does not damage the control of weeds or nematodes, as well as not causing damages to the crop, since all interactions were statistically equal to the control sample in the yield parameter. It is the same as this work, where interactions did not demonstrate intoxication symptoms at 60 DAE.

Rolim et al. (2001) studies the tolerance of the SP 81-3250 variety when treated with terbufos and carbofuran nematicides in the plantation furrow, and with oxyfluorfen + ametryn, oxyfluorfen + diuron and thiazopyr - ametryn during crop and weed pre-emergence; they concluded that there was no significant interaction between the products, and that carbofuran obtained a higher yield than the control sample, at 16.4%.

Marques et al. (2013) did not find any significant statistical difference in the height of sugarcane plants when only carbofuran was used; this supports the result obtained in this work, where singularly applied nematicides were not statistically different from the control sample in the three varieties. As for the aerial part dry mass biometric variable, the result also follows what was found in this work, where there was no difference from carbofuran and the control sample.

Conclusions

There was significant interaction for the sulfentrazone herbicide with benfuracarbe and carbofuran nematicides, in the RB867515, RB975201 and RB975952 sugarcane varieties. Saflufenacil, diuron + hexazinone and amicarbazone in interaction with nematicides caused lighter phytotoxicity symptoms. At 60 DAE, the three varieties had already recovered from the symptoms; this demonstrates that plants recovered from the initial injuries during their development.

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