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Susceptibility of *Merremia cissoides*, *Neonotonia wightii* and *Stizolobium aterrimum* to the amicarbazone, imazapic and sulfentrazone herbicides[1]

Suscetibilidade de ***Merremia cissoides****,* ***Neotonia wightii*** *e* ***Stizolobium aterrimum*** *aos herbicidas amicarbazine, imazapic e sulfentrazone*

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Abstract - Three experiments were developed with the goal to evaluate the susceptibility of *Merremia cissoides*, *Neonotonia wightii* and *Stizolobium aterrimum* to the amicarbazone, imazapic and sulfentrazone herbicides, by means of rate-response curves. The experiments were installed in clay soil, where eight doses of each herbicide were applied, in pre-emergency. The used doses were: 8D, 4D, 2D, D, 1/2D, 1/4D, 1/8D, and check plots without application; whereas D is the recommended dose of amicarbazone (1200 g ha^{-1}), imazapic (147 g ha^{-1}) or sulfentrazone (800 g ha^{-1}). For *M. cissoides* and *N. wightii* species, the three tested herbicides demonstrated effective control up to the 60 days, in the recommended doses. For the *S. aterrimum* species, only amicarbazone herbicide was effective, in the recommended dose. Control levels ensure these three herbicides as control options in pre-emergence for the *M. cissoides* and *N. wightii* species and only the amicarbazone herbicide, as control option for *S. aterrimum*.
Keywords: management; *Saccharum* spp.; weed; pre-emergence

Resumo - Três experimentos foram desenvolvidos com o objetivo de avaliar a suscetibilidade das plantas daninhas *Merremia cissoides*, *Neonotonia wightii* e *Stizolobium aterrimum* aos herbicidas amicarbazone, imazapic e sulfentrazone, por meio de curvas de dose-resposta. Os experimentos foram instalados em solo argiloso, onde foram aplicadas oito doses de cada herbicida, em pré-emergência. As doses utilizadas foram: 8D, 4D, 2D, D, 1/2D, 1/4D, 1/8D e testemunha sem aplicação; sendo D a dose recomendada de amicarbazone (1200 g ha^{-1}), imazapic (147 g ha^{-1}), ou sulfentrazone (800 g ha^{-1}). Para as espécies *M. cissoides* e *N. wightii*, os três herbicidas testados demonstraram controle eficaz até os 60 dias, nas doses recomendadas. Para a espécie *S. aterrimum*, somente o herbicida amicarbazone foi eficaz, na dose recomendada. Os níveis de controle garantem estes três herbicidas como opções de controle em pré-emergência para as espécies *M. cissoides* e *N. wightii* e apenas o herbicida amicarbazone, como opção de controle da *S. aterrimum*.
Palavras-chaves: manejo; *Saccharum* spp.; planta daninha; pré-emergência

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Introduction

Sugarcane (*Saccharum* spp.) is one of the main crop of the world, cultivated in more than 100 countries, representing an important form of rural production in those countries. Brazil is the biggest producer of sugarcane in the world, with significant growth in the last decades, from a little bit more than 100 million tons in 1975 to a crop forecast of 620 million tons in 2016/2017 (Brazilian Institute of Geography and Statistics – IBGE, 2016).

The improvements in relation to the production occurred to the extent that the sugarcane was advancing and new sugarcane mills were being installed (Inácio and Santos, 2011). With the expansion of the sugarcane crops, new forms of production were adopted in order to meet the operational demands, such as the intense mechanization of the crops and agricultural processes. This expansion has occurred in grazing areas as well as in small production areas of other crops, such as grains, since it is more lucrative in moments of decreasing in the price of soybean, cotton and milk (Inácio and Santos, 2011).

Due to the introduction of new crop management practices, some areas previously used as grazing areas, in which there was the employment of *Stizolobium aterrimum* (black mucuna) and *Neonotonia wightii* (perennial soybean) as fodder intercropped with grasses, have turned into infesting in sugarcane crops implanted in those places (Pereira, 2001). In addition, *S. aterrimum* was previously extensively employed in rotation during the renewal of the reed, and when managed in the wrong manner, it became the problematic weed in these areas (Azania, 2006). It is well known that plants with difficult control, such as those before mentioned plants, may derail the agricultural production or prevent the crop operation (Brighenti and Oliveira, 2011).

The *S. aterrimum* species has large sized seeds and integument toughness, which grants to said species dormancy and capacity to emerge, even when localized in the deepest layers of the soil, where most weeds would not, provoking drastic damages to the development of the reeds (Azania et al., 2011).

M. cissoides is a plant from the Tropical America (Vital et al., 2008). This species is important as ornamental, due to its showy flowers, however, it may cause serious problems to the mechanized harvest system due to its growing habit (Kissmann and Groth, 1999). The negative effects of this plant over harvests of crops were document by Davis (2008). In addition, *M. cissoides* is described as one of the main weeds in sugarcane (Kuva et al., 2007).

Currently, in the areas cultivated with sugarcane, the chemical control of weeds is predominant, with herbicide application for pre-emergence control of the infesting and of the crop (Monquero et al., 2011). In addition, in areas in which seedbank must be controlled for longer periods, such as sugarcane, it is necessary to use herbicides with prolonged residual action (Constantin, 2011). Sulfentrazone, amicarbazone, and imazapic herbicides are among the options of registered herbicides for this crop (Rodrigues and Almeida, 2011). Hence, information related to the applied dose and herbicide efficacy is important to facilitate the decision making in a production system.

This paper was developed with the goal of assessing the differential susceptibility of *M. cissoides*, *N. wightii* and *S. aterrimum* species to the amicarbazone, imazapic, and sulfentrazone herbicides, when applied in pre-emergency.

Material and Methods

Three independent experiments were developed between March and June, 2009. Each herbicide was considered as an independent experiment, using amicarbazone (Dinamic 700 GD, Arysta LifeScience), imazapic (Plateau 700 CS, BASF), and sulfentrazone (Boral 500 SC, FMC). Three experiments were implanted in an area with soil previously prepared with up to 10 cm deep harrowing, maintained without crop during the entire time. The soil of the area was classified as Dystrophic Red Latosol (Embrapa, 2006), of clay texture (66% of clay, 19% of sand and 15% of silt), whose physical and chemical analysis is presented in Table 1.

Table 1. Physical and chemical properties of the experimental area soil (Dystrophic Red Latosol). Iracemápolis (SP), 2009.

Layer (cm)	Particle size Composition [(1)] (%)					M.O. (g/kg)	pH		
	Sand			Silt	Clay				
	Thin	Gross	Total				KCl	H_2O	ΔpH
0 – 20	14	5	19	15	66	23,3	4,1	4,9	-0,8
20 – 50	12	6	18	14	68	19,7	4,2	4,4	-0,2

Chemical Analysis [(2)]

Layer (cm)	Exchangeable Cations ($mmol_c$ dm^{-3})						P ($mg\ dm^{-3}$)	Saturation (%)	
	K^+	Ca^{2+}	Mg^{2+}	SB	H+Al	CEC		V	m
0 – 20	7,6	2,9	1,6	12,1	109,1	121,2	7	10	45
20 – 50	2,5	11,5	4,2	18,2	88,4	106,6	7	17	11

[(1)] Clayey texture; [(2)]SB – sum of bases; CEC – cation-exchange capacity; V – saturation by basis; m – saturation by aluminum.

In the experiments, the adopted experimental design was of randomized blocks, with four repetitions. The *M. cissoides*, *N. wightii* and *S. aterrimum* species were seeded in the area, being distributed in lines within the portions, obtaining three linear meters for each species per plot. It was distributed 20 seeds per linear meter for *M. cissoides*, 35 seeds for *N. wightii* and 4 seeds for *S. aterrimum*.

Rate-response curve method was used for each experiment, with the following doses as recommended doses: amicarbazone (1200 g ha^{-1}), imazapic (147 g ha^{-1}) and sulfentrazone (800 g ha^{-1}). Each experiment had eight treatments, as follows: 8D, 4D, 2D, D, 1/2D, 1/4D, 1/8D, and witness without application; whereas D is the recommended dose of each product.

The applications were performed after the seeding, in March 09, 2009, with the support of a backpack sprayer pressurized by CO_2, embedded to a bar with four spray nozzles, of the flat fan type, model XR 110.02, spaced in 0.5 meter, calibrated for spray volume corresponding to 200 L ha^{-1}. In the moment of the application, the soil was humid, the air temperature was registered at 28.7 ^oC and air relative humidity at 92%. The meteorological data related to the site and period in which the experiment was on field are presented in Figure 1.

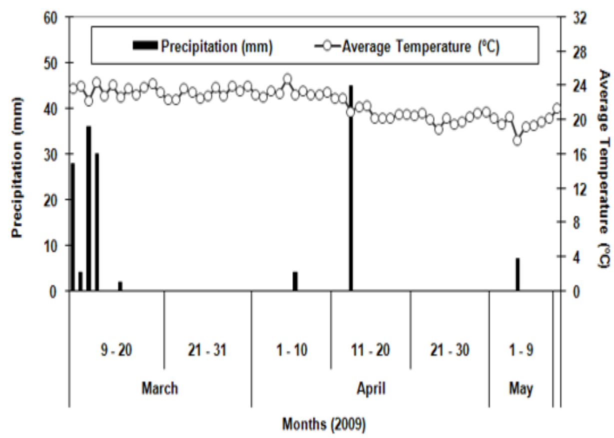

Figure 1. Daily estimated average temperature (ºC) and precipitations (mm) registered for the local and period of the development of the experiments on the field. Iracemápolis (SP), 2009.

Visual assessments of percentage control were performed within 15, 30, 45 and 60 days after the application (DAA), as well as the total dry matter of the plants within 60 DAA. The control evaluations were based in scale with variable values, ranging from zero (absence of control) to 100% (absolute control). Data was submitted to the application of F test on the variance analysis. When applicable, Tukey's test was adopted for comparing the species, with 5% of significance.

Herbicide factor levels (doses) were analyzed by means of the employment of nonlinear regressions of the log-logistic type, as per the model proposed by Streibig (1988):

$$y = \frac{a}{\left[1 + \left(\frac{x}{b}\right)^{c}\right]}$$

In which: y is the control percentage, x is the herbicide dose (g i.a. ha^{-1}) and a, b and c are the equation estimated parameters, so that a is the existing amplitude between the variable's maximum and minimum points; b corresponds to the necessary dose for the occurrence of 50% of the variable response and c is the slope of the curve on point b.

Although the logistic model parameter (b) estimates the value C_{50}, the C_{80} value was also calculated, since it is the minimum level of control considered satisfactory by the legislation in effect.

Results and Discussion

With the application of the 'F' test on the variance analysis, significance of the weed species factor was found for all the assessment dates, for all experiments. For the dose factor, it was also observed the significance; however, for some variables, the dose-species interaction was not significant (Table 2).

Table 2. Control and residual dry matter of *Merremia cissoides*, *Neonotonia wightii* and *Stizolobium aterrimum* when submitted to the application of sulfentrazone or amicarbazone herbicides. Iracemápolis (SP), 2009.

Species	Sulfentrazone		Amicarbazone
	15 DAA[2]	Dry matter	Dry matter
Merremia cissoides	50,0 A	42,6 A	37,2 A
Neonotonia wightii	47,2 A	40,5 A	35,5 A
Stizolobium aterrimum	35,3 B	55,4 B	75,7 B
LSD	9,42	7,29	19,82

[1] Data related to the average of all doses, including the witness without application; averages followed by equal capital letters in the column do not differ among themselves, according to Tukey test with 5% of significance; [2] Days after application.

In the experiment with amicarbazone, in the residual dry matter, it was observed the interaction effect, in which the susceptibility order was: *M. cissoides* = *N. wightii* > *S. aterrimum*. The controls presented in Table 2 are related to the average of all doses, including check plots without herbicide application. It was found the absence of interaction in the experiment developed with the sulfentrazone herbicide in the control assessment performed within 15 DAA and for dry matter, thus justifying the application of Tukey's test, characterizing the following susceptibility order: *M. cissoides* = *N. wightii* > *S. aterrimum* (Table 2).

In the first experiment, the amicarbazone herbicide properly controlled *M. cissoides* and *N. wightii* species, from 15 to 60 DAA, when the maximum controls surpassed 90% for the both species (Figure 2). It is assumed that the minor control observed within 30 DAA for the *S. aterrimum* species is related to the mechanism action of the amicarbazone herbicide, which is of the photosystem II inhibitor type. In said case, there is a need for emergence and establishment of the seedling until the beginning of the photosynthetic activity, when the herbicide efficiency is manifested. This corroborates with Bressanin et al. (2015), who observed controls of 60% within 15 DAA.

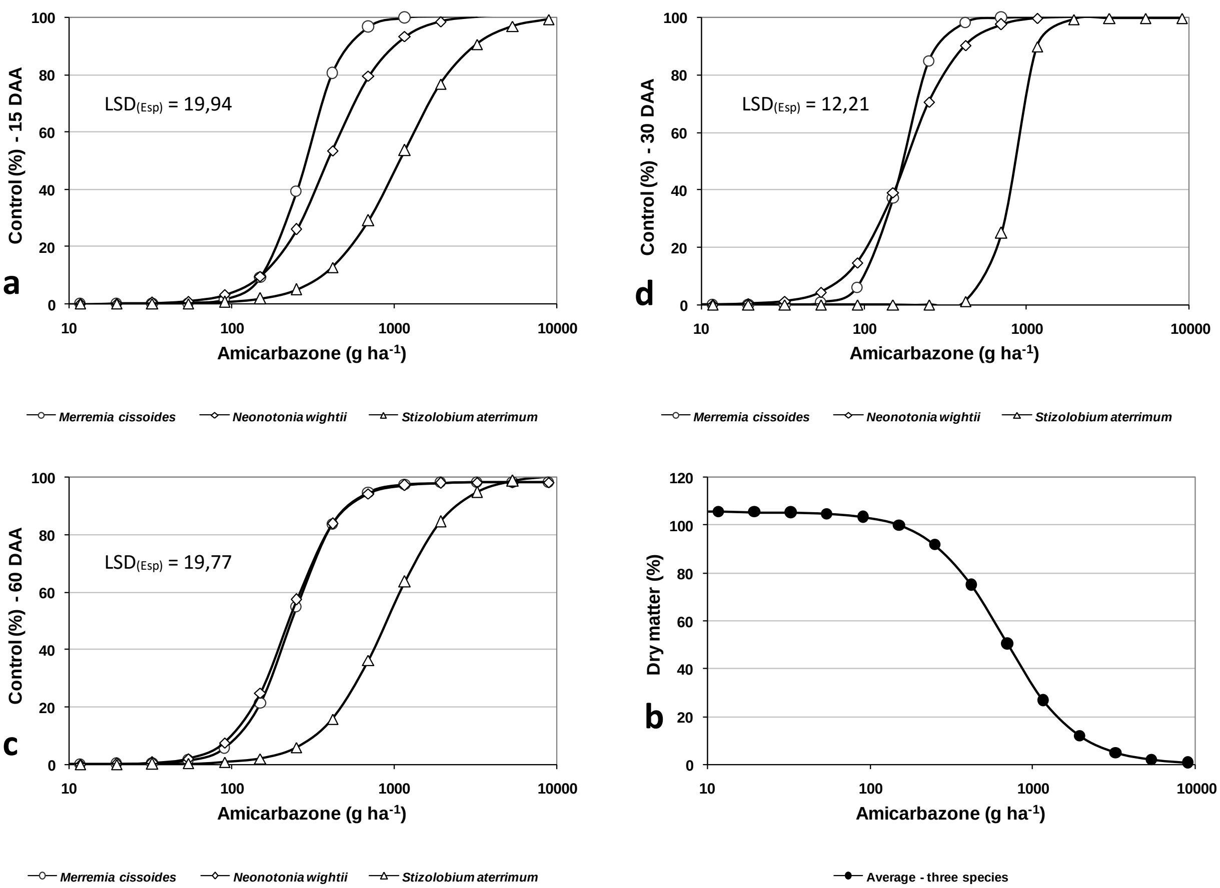

Figure 2. Control of *Merremia cissoides, Neonotonia wightii* and *Stizolobium aterrimum* with eight doses of the amicarbazone herbicide, assessed within 15 (a), 30 (b), and 60 (c) days after application (DAA) and residual dry matter (d). Iracemápolis (SP), 2009.

Bressanin et al. (2015) observed controls above 90% for amicarbazone assessed within 45 DAA. In this sense, Negrisoli et al. (2007) also observed elevated efficay of the amicarbazone to control species of the *Ipomoea* genus. However, it was noted that leaching may be a fundamental process for the proper absorption and efficay of the herbicide, especially in areas with application over the sugarcane straw. Notwithstanding, for *S. aterrimum*, minor controls within 60 DAA was observed (Figure 2), demonstrating less susceptibility for the amicarbazone herbicide, in relation to the other species in study.

In the assessments performed within 30 and 60 DAA, the C_{80} values calculated for the application of amicarbazone in pre-emergence of the *M. cissoides* and *N. wightii* species were always inferior to the recommended dose of amicarbazone (980 g ha^{-1}), which indicates it is effective to control of these weeds even with lower doses, in addition to being considered a long residual herbicide (Negrisoli et al., 2007).

Dose-species interaction was observed within 30 and 60 DAA, whose susceptibility order was: *N. wightii* ≥ *M. cissoides* > *S. aterrimum* (Figure 2). In this sense, amicarbazone may also be characterized as an effective herbicide for the management of these weeds, especially for *S. aterrimum* when compared to the other herbicides in study.

For the second experiment, it was applied the imazapic herbicide, registered for the sugarcane culture and belonging to the imidazolinone chemical group, which has action in pre and initial post-emergence, being recommended for the control of grasses, broad leaves and perennials of difficult control (Kraemer et al. 2009).

It was observed in this experiment that, for the calculated dose for C_{80}, in the *M. cissoides* and *N. wightii* species, the values were close to the recommended dose. Differential susceptibility among species was observed, in which *N. wightii* was the most sensible species, when compared to *M. cissoides*, within 60 DAA (Figure 3). In this case, the susceptibility order to the imazapic herbicide was: *N. wightii* ≥ *M. cissoides* > *S. aterrimum* (Figure 3).

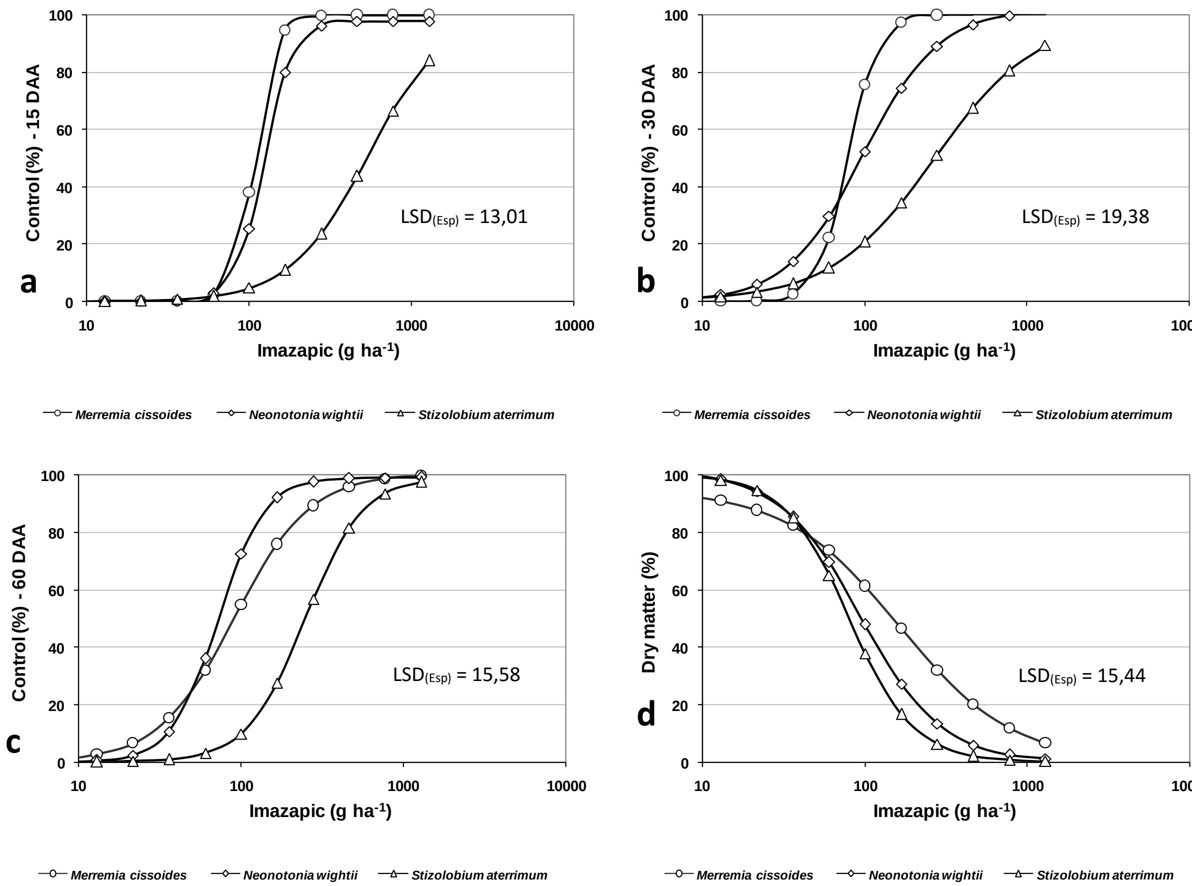

Figure 3. Control of *Merremia cissoides, Neonotonia wightii* and *Stizolobium aterrimum* with eight doses of the imazapic herbicide, assessed within 15 (a), 30 (b), and 60 (c) days after application (DAA) and residual dry matter (d). Iracemápolis (SP), 2009.

The adsorption of the imidazolinone by the soil colloids is low or very low, being highly influenced by the organic matter and clay contents, in which the soils with higher of said contents demand higher doses of the products (Miller and Westra, 1998). In addition, the dissipation of this herbicide groups is faster in soils with temperature and humidity contents that favor the microorganism activities (Loux and Reese, 1992).

It is possible to believe that in the conditions in which the experiment was developed, microbial activity had its action favored, and in the area assigned for the experiment, especially in the month of March, there was elevated temperature and high precipitation on a daily basis, mainly in the beginning of the experiment (Figure 1), maintaining the humidity contents adequate to the microbiota, reducing the herbicide effect over the development of the plants.

Hence, it was concluded that the imazapic herbicide only inhibited the development of the *N. wightii* and *M. cissoides* species, reaching results close to 80% of control within 60 DAA, with the recommended dose. However, imazapicdid not have an adequate control, and therefore, it was not a management option for the *S. aterrimum* specie, when compared to the other two herbicides, which corroborates the results of Silva et al. (2012).

For the third experiment, performed with the sulfentrazone herbicide, the recommended dose of the herbicide evidenced controls superior to 80% in the *M. cissoides* species, within 30 DAA (Figure 4), after the high pluviometric index during the two initial weeks of the experiment (Figure 1). This result was also obtained by Rossi et al. (2005), who observed better results of the sulfentrazone herbicide after high precipitations.

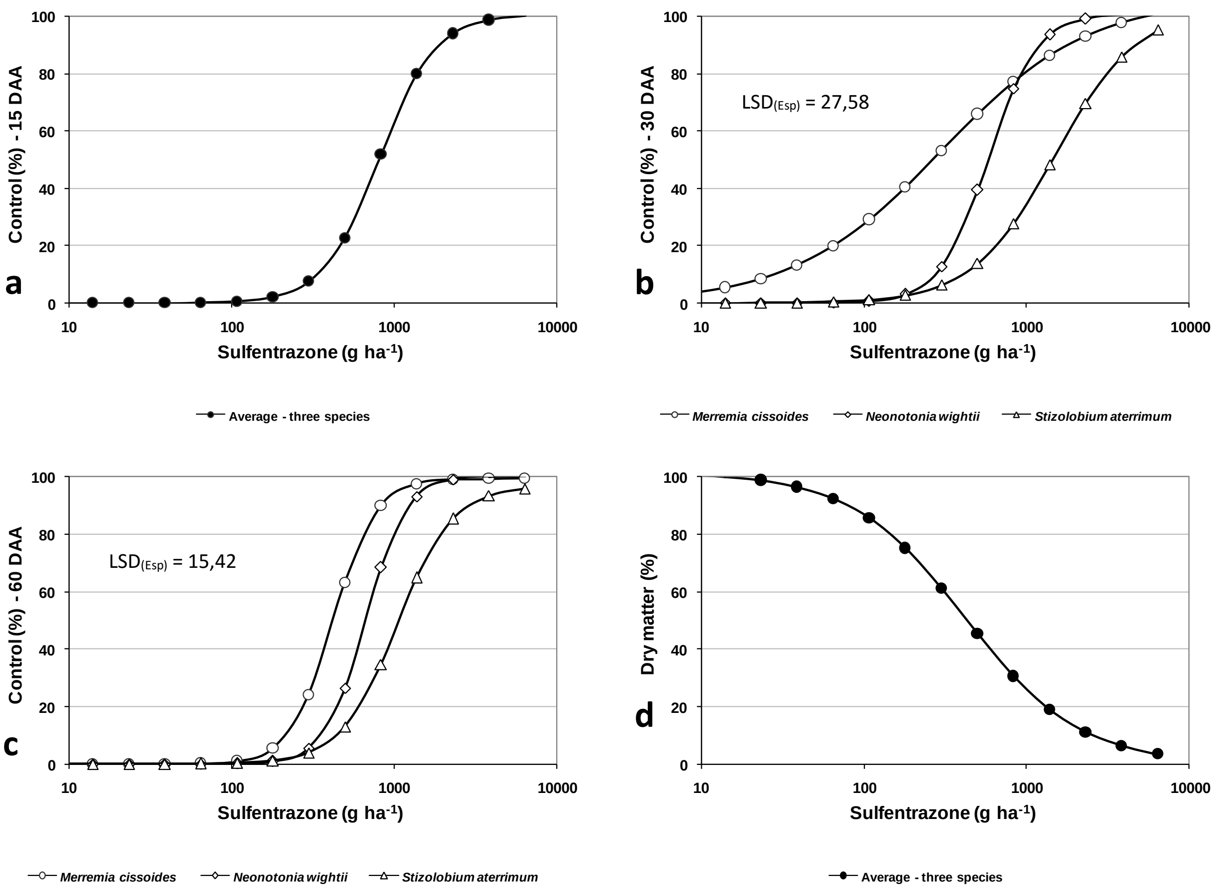

Figure 4. Control of *Merremia cissoides*, *Neonotonia wightii* and *Stizolobium aterrimum* with eight doses of the sulfentrazone herbicide, assessed within 15 (a), 30 (b), e 60 (c) days after application (DAA) and residual dry matter (d). Iracemápolis (SP), 2009.

For the *M. cissoides* species, the C_{80} calculation resulted in inferior doses than the recommended dose of the product (750 g i.a. ha^{-1}) for this soil classification, which highlights the elevated efficacy of the molecule to control species of the *Merremia* genus. In plants, the sulfentrazone acts in the route of the chlorophyll and cytochrome synthesis, inhibiting the protoporphyrinogen oxidase (PROTOX), which results in accumulation of protoporphyrinogen in the chloroplast. In high concentrations, there is the diffusion of the protoporphyrinogen to the cytoplasm, where it is rapidly converted to protoporphyrin IX. Protoporphyrin IX is a photodynamic pigment and, when in the presence of light and molecular oxygen, originates 'singlet' oxygen (O^-). Thus this free radical, highly reactive, provokes the peroxidation of the membranes' lipids, causing the death of the cell (Carvalho and López-Ovejero, 2008). These action mechanism characteristics aid in the explanation of the fast death of plants, which justifies the elevated values of control already observed in the assessment performed within 30 DAA, for the *M. cissoides* species (Figure 4).

However, for *N. wightii*, it was observed that the calculated dose for C_{80}, was superior to the recommended dose, showing its tolerance to the sulfentrazone. For *S. aterrimum* species, the calculated dose for C_{80}, in the order of 1930 g ha^{-1}, was highly superior to the maximum recommended dose for this type of soil, of the order of 800 g ha^{-1}, demonstrating its tolerance to this herbicide. Silva et al. (2012) observed satisfactory control levels around 60%, using 800 g ha^{-1}.It is also possible to correlate this inefficient control of the *N. wightii* and *S. aterrimum* species to the fact that the soil in which the essay was developed presents pH below 4.9 (Table 1). Sulfentrazone herbicide is a weak acid and may have its efficiency reduced when its pKa is higher than the soil pH, letting the herbicide in a molecular form (Bachega et al., 2009).

In this sense, the differential susceptibility of the species is characterized, in which *S. aterrimum* was the most tolerant to the sulfentrazone herbicide. The susceptibility order of these weeds was: *M. cissoides* ≥ *N. wightii* > *S. aterrimum*.

The difference of susceptibility of the species of weeds to herbicides may be related to the enzymatic affinity of the molecules; with the absorption, translocation or differential exclusion of the herbicides; or even with metabolic detoxification routes (Carvalho et al., 2006). However, more studies must be developed to clarify which factors have participation in the differential response of the control of weed species, especially for *N. wightii* and *S. aterrimum*.

Conclusions

Imazapic herbicide did not provide satisfactory control of *S. aterrimum* species, being a good control option for *M. cissoides* and *N. wightii* species.

Sulfentrazone herbicide did not provide adequate control for the *N. wightii* and *S. aterrimum* species, but was efficient to the *M. cissoides* species.

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