Australian Journal of Crop Science
AJCS
AJCS 8(6):965-972 (2014) ISSN:1835-2707

Sugarcane cultivars present differential susceptibility to herbicides ametryn and trifloxysulfuron-sodium

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Abstract

Weed management in Brazilian sugarcane fields is accomplished mainly with herbicides. These chemical products may negatively impact sugarcane growth and development. Therefore, we aimed this study to evaluate the influence of the selective herbicides ametryn, trifloxysulfurom-sodium and its commercially available mixture on the growth of sugarcane cultivars. The experiment was conducted under greenhouse condition in a completely randomized design, using a 3 × 3 × 4 factorial scheme with four replications. Factor A comprised sugarcane cultivars (SP80-1816, RB855113 and RB867515); factor B herbicides ametryn (Metrimex®), trifloxysulfuron-sodium (Envoke®) and its mixture (Krismat®), and factor C the doses (0.0, 0.5x, 1.0x and 3.0x the label dose), where 1.0x dose = 2,000 g ha^{-1} for ametryn; 22.5 g ha^{-1} for trifloxysulfuron-sodium and 1,463 + 37.0 g ha^{-1} for the mixture. Crop toxicity was assessed 28 days after herbicide application and traits such as plant height, number of leaves per plant, stalk diameter, leaf area index, specific leaf area and crop growth rate were assessed 80 days after crop emergence. The results showed that trifloxysulfuron-sodium causes lower impact on all variables; therefore, being more selective to all cultivars. The label dose (1.0x), equivalent to 2,000 g ha^{-1} of ametryn and 22.5 g ha^{-1} of trifloxysulfuron-sodium is considered as a threshold between deficient weed control (in lower doses) and excessive crop toxicity (in higher doses). RB867515 and RB855113, respectively, were the most and least tolerant cultivars to both herbicides. In highly infested planting fields, farmers usually prefer to grow the most tolerant sugarcane cultivar when applying ametryn or trifloxysulfurom-sodium.

Keywords: ametryn, intoxication, *Saccharum* spp., trifloxysulfuron-sodium, tolerance.
Abbreviation: DAP_days after planting, DAA_days after herbicide application, LA_leaf area, LM_leaf dry mass, SM_stalk dry mass, SDM_shoot dry mass, LAI_leaf area index, SLA_specific leaf area, GR_growth rate.

Introduction

Among the biotic factors affecting sugarcane growth, development and yield, weed interference can be highlighted as a major one (Negrisoli et al., 2004; Galon et al., 2012a). Competition for water, light, nutrients and physical space cause lower industrial quality of stalks as well as reduction in ratoon longevity. Weed presence can also hinder harvest and transportation operations or even host pests (Galon et al., 2012b).

Weed control in sugarcane crop is mandatory since this crop has, in most situations, slow budding and initial growth rate (Smith et al., 2011). Among the most commonly used weed control methods, herbicide application is vastly adopted due to the large extensions of planted areas, to its effectiveness and low cost compared to other control methods. Furthermore, there are several efficient herbicides on market registered for weed control in sugarcane (Souza et al., 2009). However, these compounds present direct and indirect effects on growth and development of crops as they are developed to kill plants (Tironi et al., 2012). In sugarcane fields, post-emergence herbicides are usually applied which may cause higher phytotoxicity, compared to applied pre-emergence products, being this a relevant factor for herbicide choice and dose (Monquero et al., 2011).

Selectivity to crop cannot be securely determined only by visual symptoms, as there are known examples of herbicides which reduce crop productivity with no visually detectable signs of crop damage. On the other hand, there are herbicides which cause severe injuries to crop but allow to fully expressing its productive potential (Negrisoli et al., 2004).

Table 1. Sugarcane intoxication as a function of herbicides, multiples of the commercial doses (g ha^{-1}) and different cultivars, evaluated 28 days after herbicide application (DAA).

Evaluated doses	Herbicides	Intoxication (%) 28 DAA		
		SP80-1816	RB855113	RB867515
0	HA[1]	0.0 aA	0.0 aA	0.0 aA
	HB	0.0 aA	0.0 aA	0.0 aA
	HC	0.0 aA	0.0 aA	0.0 aA
0.5	HA	4.7 aB	22.0 aA	7.3 aB
	HB	10.7 aA	7.0 bAB	3.3 aB
	HC	8.0 aAB	12.3 bA	3.7 aB
1.0	HA	26.3 aA	33.0 aA	15.3 aB
	HB	12.3 bA	6.3 cA	8.0 bA
	HC	7.0 bB	17.0 bA	6.7 bB
3.0	HA	68.7 aA	72.3 aA	21.3 aB
	HB	12.3 bA	6.0 cAB	5.0 bB
	HC	13.0 bB	34.0 bA	9.0 bB
C.V. (%)		32.32		

[1]HA: ametryn (2,000 g ha^{-1}); HB: trifloxysulfuron-sodium (22.5 g ha^{-1}); HC: ametryn + trifloxysulfuron-sodium (1,673 + 37.0 g ha^{-1}). [2] Means followed by the same lowercase letters in the column within each cultivar among the herbicides and followed by uppercase letters in the same row among cultivars when applying herbicides do not differ by Tukey test (p ≤ 0.05).

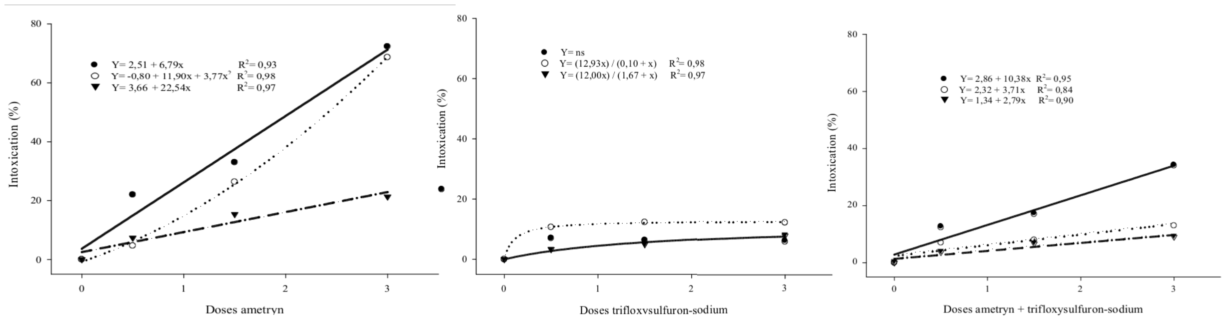

Fig 1. Intoxication (%) of sugarcane cultivars; ○ SP80-1816 - ● RB855113 and ▼ RB867515 as a function of herbicides and multiple doses of the commercial dose (g ha^{-1}) evaluated 28 days after herbicide application.

When herbicide injuries to crops are to be studied, the crop yield should not be the only target trait to be considered as it is a result of injuries suffered by the plant all along its development (Negrisoli et al., 2004; Galon et al., 2012a).

In Brazil, there are more than 130 herbicide brands available on the market for weed control in sugarcane (MAPA, 2013). Among these, ametryn and trifloxysulfuron-sodium are vastly used, either applied alone or in mixture. Ametryn is a photosystem II inhibitor, effectively controlling several mono and dicotyledonous weed species and can be applied pre- or post-emergence of weeds (Simoneaux and Gould, 2011). Trifloxysulfuron-sodium, an ALS inhibitor, is mainly recommended for early post-emergence applications (Ferreira et al., 2005) with broad weed spectrum, low doses and long residual in soil, assuring weed control during the early crop development (Smith et al., 2011). There is also a commercially available mixture of both herbicides which is widely used (Reis et al., 2008), being efficient on grasses, sedges and broadleaved weeds (Simoneaux and Gould, 2011). However, there are just a few reports regarding its effects on crop.

Herbicides are chemicals which interfere in several metabolic aspects of plants. As a consequence no herbicide is completely safe to any crop (Zimdahl, 1993), with few exceptions. Thus, there should be a dose range for each herbicide which provides optimal weed control with no significant harm to crop plants. In addition, some reports highlight the differential susceptibility of plant varieties or crop cultivars to a given herbicide. Xinfa et al. (2003) reported that Japonica-type rice cultivars are more sensitive to ALS-inhibiting herbicides than Indica-type cultivars. Guerra et al. (2010) highlighted the differential selectivity of the herbicide nicosulfuron to maize hybrids. For sugarcane, there is scarce data about varietal susceptibility to herbicides. Thus, we aimed this study to evaluate the effect of herbicides on growth and development of sugarcane cultivars.

Results

There was triple interaction among cultivar, herbicide and dose for phytotoxicity, plant height, leaf number and stalk diameter. In general, crop toxicity was higher for RB855113, intermediate for SP80-1816 and lower for RB867515, 28 days after herbicide application (DAA) (Table 2). For herbicides within cultivar, symptoms differed only for ametryn, which caused greater toxicity at dose of 0.5x to RB855113. Higher doses of ametryn also affected SP80-1816 (Fig. 1).

Trifloxysulfuron-sodium caused lower toxicity to all cultivars, and RB855113 was also more susceptible to the mixture of ametryn + trifloxysulfuron-sodium. The other cultivars were similar in tolerance to the mixture (Table 2).

Table 2. Effect of herbicides and doses on plant height, number of leaves per plant and stalk diameter in different sugarcane cultivars at 80 days after budburst.

Evaluated doses	Herbicides	Height (cm)						Number of leaves plant^{-1}						Stalk diameter (cm plant^{-1})					
		SP80-1816		RB 855113		RB 867515		SP80-1816		RB 855113		RB 867515		SP80-1816		RB 855113		RB 867515	
0	HA[1]	20.67	aA[2]	16.33	aB	19.00	aA	6.25	aA	6.25	aA	6.00	aA	1.83	aA	1.80	aA	1.83	aA
	HB	20.67	aA	16.33	aB	19.00	aA	6.25	aA	6.25	aA	6.00	aA	1.83	aA	1.80	aA	1.83	aA
	HC	20.67	aA	16.33	aB	19.00	aA	6.25	aA	6.25	aA	6.00	aA	1.83	aA	1.80	aA	1.83	aA
0.5	HA	20.67	aA	13.50	aB	18.33	bA	6.75	aA	6.00	aA	6.75	abA	1.53	aA	1.53	aA	1.83	bA
	HB	18.00	aA	15.00	aB	20.67	bA	6.50	aA	6.75	aA	6.50	bA	1.48	aA	1.33	aA	1.68	bA
	HC	19.33	aB	14.67	aC	25.00	aA	5.75	aB	6.25	aB	8.00	aA	1.70	aB	1.68	aB	2.48	aA
1.0	HA	16.67	bA	14.83	abA	16.50	cA	6.50	aA	6.00	aA	6.50	aA	1.35	aA	1.55	aA	1.75	aA
	HB	20.00	aA	17.33	aB	18.33	aA	4.75	bA	6.00	aA	5.25	abA	1.58	aB	1.43	aB	2.05	aA
	HC	19.67	aA	12.50	bB	20.00	aA	5.75	abAB	6.50	aA	5.00	bB	1.60	aA	1.68	aA	1.78	aA
3.0	HA	17.00	aA	11.83	bB	15.00	bA	5.25	aA	5.50	aA	6.50	aA	1.13	bB	0.58	bC	1.73	bA
	HB	19.67	aA	15.00	aB	16.17	bB	5.75	aA	6.00	aA	6.25	aA	1.60	aA	1.43	aA	1.58	bA
	HC	18.67	aB	15.00	aC	23.67	aA	5.25	aA	5.50	aA	6.25	aA	1.58	aB	1.43	aB	2.23	aA
C.V. (%)		9.14						14.33						15.23					

[1] HA: ametryn (2,000 g ha^{-1}); HB: trifloxysulfuron-sodium (22.5 g ha^{-1}); HC: ametryn + trifloxysulfuron-sodium (1,673 + 37.0 g ha^{-1}). [2] Means followed by the same lowercase letters in the column within each cultivar among the herbicides and followed by uppercase letters in the same row among cultivars when applying herbicides do not differ by Tukey's test ($p \leq 0.05$).

Table 3. The effect of herbicides on the variables leaf area index (LAI), specific leaf area (SLA) and growth rate (GR) evaluated 80 days after budburst.

HERBICIDE	LAI (m^2 m^{-2})	SLA (g m^{-2})	GR (g day^{-1})
HA	3.97 B[1]	0.008 ^{ns}	0.29 AB
HB	4.47 A	0.009	0.32 A
HC	4.25 AB	0.007	0.28 A B
CV (%)	13.8	30.5	20.9

HA: ametryn ; HB: trifloxysulfuron-sodium; HC: ametryn + trifloxysulfuron-sodium. [1] Means followed by the same capital letter in the column do not differ by Tukey's test ($p \leq 0.05$).

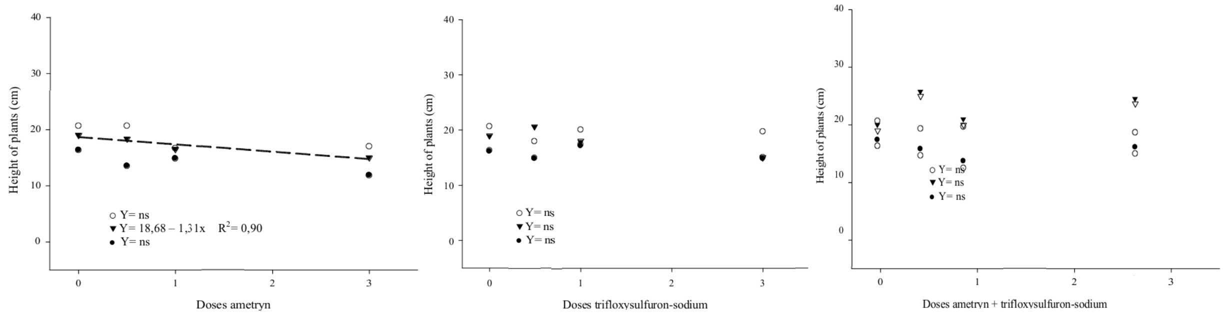

Fig 2. Height (cm) of sugarcane cultivars; ○ SP80 -1816 - ● RB855113 and ▼ RB867515 as a function of herbicides and commercial doses evaluated 80 days after budburst.

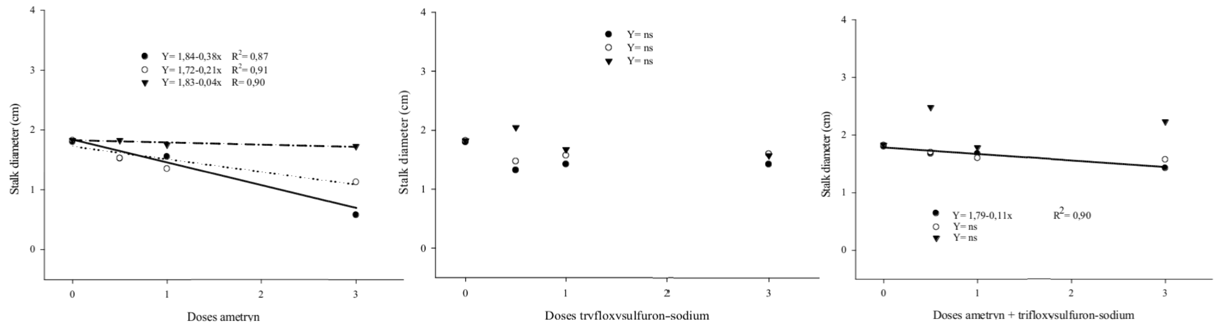

Fig 3. Diameter (cm) of sugarcane cultivars; ○ SP80-1816 - ● RB855113 and ▼ RB867515 as a function of herbicides and commercial doses evaluated 80 days after budburst.

The plant height differed among cultivars at the control plot with no herbicide (Table 3). The SP80-1816 and RB867515 cultivars were naturally taller than RB855113 also at dose of 0.5x for all herbicides, except for the mixture, where the latter was less affected than the former. At the label dose (1.0x), ametryn caused no differences in plant height (Table 3); trifloxysulfuron-sodium and the mixture affected RB855113. When comparing herbicides within cultivar, trifloxysulfuron-sodium was considered safer than ametryn, and the commercial mixture presented intermediary effect on plant height.

At 3.0x the label dose, there were differences both among cultivars and among herbicides for plant height. In general, RB855113 was the mostly affected cultivar by all herbicides. The RB867515 was taller than the control plot when under application of 3.0x the label dose of ametryn + trifloxysulfuron-sodium. The SP80-1816 and RB867515 cultivars presented similar tolerance to ametryn. The SP80-1816 was affected similarly by all herbicides, while RB855113 was more susceptible to ametryn and growth in height of RB867515 was stimulated by the herbicide mixture (Table 3).

The plant height was little affected by herbicide doses (Fig. 2). Cultivar behavior was similar for ametryn, being observed a declining trend on growth only for RB867515. The plant height was about 20% lower under dose of 3.0x of ametryn, compared to the untreated control.

For the trait leaf number per plant, there were no differences among cultivars for all treatments (Table 4). For herbicide and doses, there was difference only for ametryn + trifloxysulfuron-sodium on SP80-1816 and RB855113. For effect of herbicides within cultivar, trifloxysulfuron-sodium reduced leaf number for RB867515 at 0.5x the label dose, and SP80-1816 at the label dose. The mixture at 0.5x promoted leaf emission for RB867515. At 3.0x label dose, there was no difference among cultivars or herbicides (Table 4). The stalk diameter was reduced as dose of ametryn was increased, being this effect most pronounced for RB855113 (Fig. 3). Different doses of trifloxysulfuron-sodium did not affect stalk diameter. There were no differences in stalk diameter among cultivars (Table 5). However, when doses of 0.5x, 1.0x and 3.0x of ametryn + trifloxysulfuron-sodium, trifloxysulfuron-sodium and ametryn, applied on SP80-1816 and RB855113 respectively, there was a reduction in stalk diameter compared to RB857515. Comparing herbicides within cultivar, stalk diameter of RB867515 was more affected than the other cultivars under 0.5x label dose of ametryn and trifloxysulfuron-sodium. At dose of 1.0x, there were no differences among herbicides. At 3.0x ametryn dose, the stalk diameter was reduced for all cultivars, while ametryn + trifloxysulfuron-sodium was more selective for RB867515, compared to the other cultivars.

No interaction occurred between cultivar, herbicide and dose for leaf area index (LAI), specific leaf area (SLA) and growth rate (GR). The LAI of RB855113 and RB867515 was little affected by the increasing dose of trifloxysulfuron-sodium (Fig. 4). The SP80-1816 cultivar did not suffer any injury from this herbicide. For ametryn and the commercial mixture, it was noticed that the increasing dose reduced LAI for all cultivars. Increasing the dose of trifloxysulfuron-sodium caused a small reduction in the SLA of SP80-1816, with no effect on the other cultivars (Fig. 5). Increasing doses of ametryn and ametryn + trifloxysulfuron-sodium increased SLA for all cultivars. The RB867515 cultivar was the one with lowest SLA among the cultivars.

Trifloxysulfuron-sodium affected the growth rate (GR) of RB855113 cultivar (Fig. 6) regardless of dosing. Increasing the dose of ametryn and the herbicide mixture reduced GR for all cultivars, being RB867515 the least affected. Different herbicides affected LAI, SLA and GR differently (Table 6). LAI was most affected by ametryn and GR by ametryn + trifloxysulfuron-sodium, both at doses beyond 1.0x (Table 7), while SLA was not influenced. Tryfloxysulfuron-sodium was

Table 4. The effect of doses of herbicides (ametryn, trifloxysulfuron-sodium and ametryn + trifloxysulfuron-sodium) on leaf area index (LAI), specific leaf area (SLA) and growth rate (GR) evaluated 80 days after budburst.

DOSE	LAI (m^2 m^{-2})	SLA (g m^{-2})	GR (g day^{-1})
D1	4.65 A[1]	0.007 ^{ns}	0.34 A
D2	4.45 AB	0.008	0.32 A
D3	4.08 BC	0.008	0.29 AB
D4	3.74 C	0.01	0.25 B
CV (%)	13.8	30.5	20.9

D1: 0.0; D2: 0.5; D3: 1.0 e D4: 3.0 times the commercial dose of ametryn (2,000 g ha^{-1}). trifloxysulfuron-sodium (22.5 g ha^{-1}) and ametryn + trifloxysulfuron-sodium (1,463 + 37.0 g ha^{-1}). Means followed by the same capital letter in the column do not differ by Tukey's test ($p \leq 0.05$).

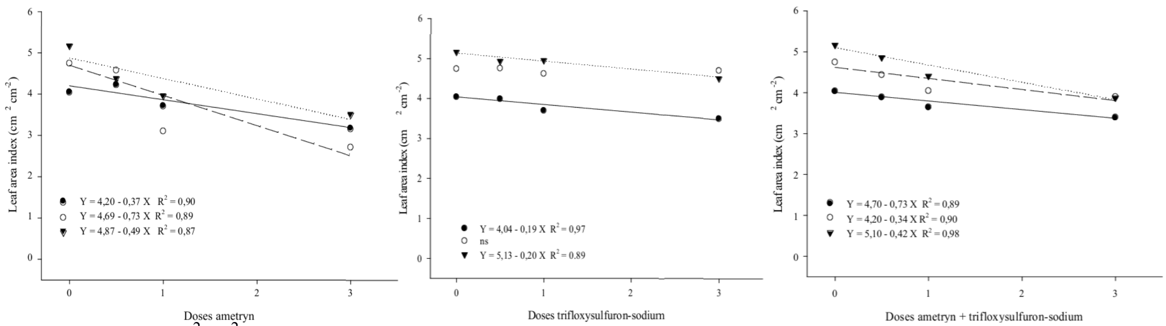

Fig 4. Leaf area index (m^2 m^{-2}) of sugarcane cultivars; ○ SP80-1816 - ● RB855113 and ▼ RB867515 as a function of herbicides and commercial doses evaluated 80 days after budburst.

Table 5. The effect of cultivars on leaf area index (LAI), specific leaf area (SLA) and growth rate (GR) evaluated 80 days after budburst.

GENÓTIPO	LAI (m^2 m^{-2})	SLA (g m^{-2})	GR (g day^{-1})
RB 855113	3.79 C	0.008 ^{ns}	0.29 AB
SP 801816	4.26 B	0.009	0.28 B
RB 867515	4.63 A	0.007	0.32 A
CV (%)	13.8	30.5	20.9

Means followed by the same capital letter in the column do not differ by Tukey's test ($p \leq 0.05$).

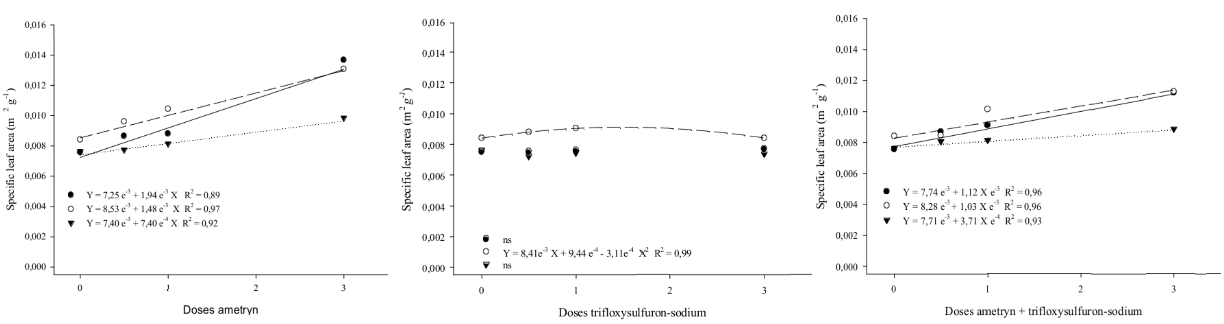

Fig 5. Specific leaf area (g m^{-2}) of sugarcane cultivars; ○ SP 80 18 16 - ● RB 855113 and ▼ RB 867515 as a function of herbicides and commercial doses evaluated 80 days after budburst.

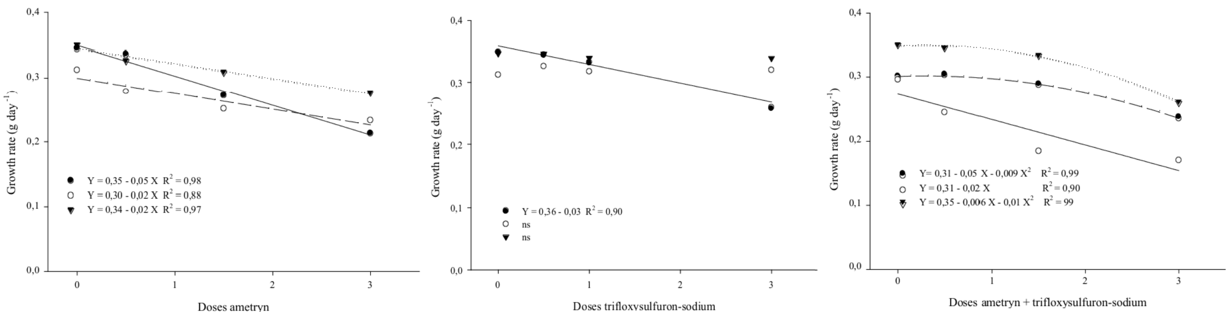

Fig 6. Growth rate (g day^{-1}) of sugarcane cultivars; ○ SP80-1816 - ● RB855113 and ▼ RB867515 as a function of herbicides and commercial doses evaluated 80 days after budburst.

the less affecting herbicide on these parameters, being in this case, the most selective one.

When cultivars were compared, RB867515 presented the highest LAI and GR (Table 8). In summary, sugarcane cultivars are distinct being also differently affected by herbicides and doses. In general, trifloxysulfuron-sodium was considered as the most selective herbicide for all cultivars, and RB867515 was the most tolerant to herbicides.

Discussion

Recent researches in Brazil reported the influence of herbicides on sugarcane's plant height with consistent damages to crop (Ferreira et al., 2005; Ferreira et al., 2012). Reis et al. (2008) found that the use of ametryn caused an increase in height of cultivar RB867515. According to these authors, the triazine herbicide promotes sugarcane plant growth but no scientific basis for this behavior was found yet. On the other hand, the synthetic auxin 2,4-D caused stagnation of sugarcane growth (Reis et al., 2008). According to Ferreira et al. (2005), the RB855113 cultivar growth was paralyzed under application of high doses of ametryn + trifloxysulfuron-sodium. Its leaf area, number of leaves and leaf and stem dry mass were also reduced.

Although not widely accepted, varieties of several crops have distinct behavior under application of a given herbicide, as reported by Xinfa et al. (2003) for Japonica- and Indica-type rice susceptibility to ALS-inhibiting herbicides and Guerra et al. (2010) for differential maize susceptibility to nicosulfuron. Although plant height and crop yield are considered not directly correlated sometimes, Law et al. (1978) and Sarwar et al. (1984) have reported strong correlation between these two traits for wheat and cotton.

Under application of the herbicides ametryn and trifloxysulfuron-sodium, alone or mixed, the increased SLA was directly correlated to LAI reduction, indicating increased leaf thickness at the expense of leaf area (Vile et al., 2005). This leads to morphological and anatomical changes in components of the mesophyll cells, causing shifts in the capture, reflection and transmission of radiation (Povh & Ono, 2008; Ferreira et al., 2005), with consequences to the photosynthetic efficiency.

We hypothesized that the both reduction in the photosynthetically active surface and the anatomical changes from differential leaf thickness reduce the amount of incident radiation converted to carbohydrates; thus, compromising growth, development and yield (Tejera et al., 2007). In our study, increase in sugarcane plant height under application of ametryn was small, contradicting with previous reports (Reis et al., 2008). Monquero et al. (2011) and Silva et al. (2013) reported correlation between plant toxicity by herbicides and plant height. However, no increased height was attributed to herbicide toxicity. This trait deserves further investigation.

Both herbicides differ in the nature of the impact on crop plants. Ametryn causes interference in the photosynthetic process, so damages to plants may be both highly and readily visible. Thus, visual evaluations of phytotoxicity under application of this herbicide may be more related to the real overall damage to crop. Trifloxysulfuron-sodium; however, inhibits the ALS enzyme, which is active in the production of aminoacids; thus, symptoms may take longer to be only barely visible.

Sugarcane is usually planted in large fields, which makes biometric evaluations an unsuitable tool to infer herbicide impact on crop in real production fields. For these conditions, we propose the use of an Infra-Red Gas Analyzer (IRGA) equipment to evaluate damages caused to sugarcane plants by ametryn. On the other side, if the weed flora present can be controlled by applying only trifloxysulfuron-sodium, smaller negative impact on sugarcane may be anticipated.

In fields, where weed infestation and composition demand for adoption of ametryn as herbicide, less susceptible sugarcane cultivars should be chosen. Among the assessed cultivars, RB867515 was the most tolerant to this herbicide. The adoption of more tolerant cultivars may avoid reductions in stalk yield, mainly in seasons where climatic conditions are unfavorable to the crop and sugarcane would find barriers to recover from herbicide damage.

Materials and Methods

Experimental design and treatments

The experiment was conducted under greenhouse conditions in Oratórios City, State of Minas Gerais, Brazil, at coordinates 20º 25' S, 42º 48' W with 600 m altitude, in completely randomized design and factorial scheme $3 \times 3 \times 4$ with four replications. Each experimental unit consisted of a plastic pot filled with 15 L of previously fertilized Red-Yellow Ultisol, according to recommendations by Novais et al. (2008), with the following chemical properties: pH (H_2O) = 5.1; OrganicMatter = 0.9 dag kg^{-1}; P = 4.5 mg dm^{-3}; and K^+, Ca^{2+}, Mg^{2+} and H+Al = 33.0; 1.5; 0.7 and 2.15 $cmol_c$ dm^{-3}, respectively. Two gems of each sugarcane cultivar were planted per pot, according to the treatment, and pots were sprinkler irrigated whenever necessary.

The factor A comprised of sugarcane cultivars (SP80-1816, RB855113 and RB867515); factor B herbicides ametryn (Metrimex®), trifloxysulfuron-sodium (Envoke®) and its commercially available mixture (Krismat®), and factor C the doses [0.0, 0.5x, 1.0x and 3.0x the commercially applied (label) dose], where for weed control in sugarcane, 1.0x dose = 2,000 g ha^{-1} of ametryn; 22.5 g ha^{-1} of trifloxysulfuron-sodium and 1,463 + 37.0 g ha^{-1} of the commercially available mixture (Rodrigues and Almeida, 2011).

Treatments application

The post-emergence herbicide application was accomplished 30 days after planting (DAP) on sugarcane, using a CO_2 pressurized backpack sprayer connected to a 1.0 m-wide bar equipped with two TT110.02 series nozzles spaced in 0.5 m, delivering 150 L ha^{-1} of herbicide solution. By the time of application, temperature, relative humidity and wind speed were about 25°C, 86% and 3 km h^{-1}, respectively.

Measured traits

Phytotoxicity was assessed 28 days after herbicide application (DAA), by visual scale, in which a score of zero (0%) corresponded to no injury and one hundred (100%) to plant death (Burrill et al. 1976). Plant height (cm), per-plant leaf number, stalk diameter (cm), leaf area index ($m^2\,m^{-2}$), specific leaf area ($m^2\,g^{-1}$) and growth rate (g day^{-1}) of sugarcane were assessed 80 days after bud burst. Plant height was assessed with a tape measure, from ground level to insertion of the last fully expanded leaf. The leaf number was determined by counting all the present leaves for all plants from each cultivar. The stalk diameter was determined with a caliper 5 cm above ground. Shoots were collected and packed in plastic bags, and then put into a styrofoam box with ice to avoid dehydration. Plants were taken to the laboratory immediately after collection, where leaves were separated from stalks for leaf area (LA) determination with electronic equipment. Leaves and stems were wrapped separately in paper bags and placed into a forced air circulation oven (60±5 °C) to a constant weight to measure the leaves (LM) and stalks (SM) dry mass, whose sum is the shoot dry mass (SDM). Leaf area index (LAI), specific leaf area (SLA) and growth rate (GR) were determined as follows:

$$LAI = \frac{LA}{P} \qquad SLA = \frac{LA}{SM} \qquad GR = \frac{SDM}{t}$$

Where, LA = leaf area; P = soil area; SM = stalk dry mass; SDM = shoot dry mass and t = days from crop emergence to harvest.

Statistical analysis

Data errors were tested for normality by Shapiro-Wilk test and variance homogeneity by Bartlett test. The data were transformed by Box-Cox when needed and submitted to analysis of variance by the F-test. When significant, regression analysis was applied to evaluate the effect of herbicide doses on sugarcane cultivars, and Tukey's test was used for differences among cultivars. All tests were run at 5% significance ($p \leq 0.05$) using the statistical environment R (R Core Team, 2014) with commands made available by the package "ExpDes".

Conclusions

The label dose (1.0x), equivalent to 2000 g ha^{-1} of ametryn and 22.5 g ha^{-1} of trifloxysulfuron-sodium, was considered as a threshold between deficient weed control (in lower doses) and excessive crop toxicity (in higher doses). In total, cultivars SP80-1816 and RB855113 were less tolerant to the ametryn, trifloxysulfuron-sodium herbicides and the formulated mixture ametryn + trifloxysulfuron-sodium than RB867515. Trifloxysulfuron-sodium was more tolerated by all cultivars compared to ametryn or its mixture. The trifloxysulfuron-sodium increased doses enhanced phytotoxicity to crop, with reductions in leaf area index and growth rate for all cultivars.

Acknowledgements

The authors would like to thank FAPEMIG (Minas Gerais State Foundation for Research Development), CAPES (Coordination for Improvement of Higher Level Personnel) and CNPq (National Counsel of Technological and Scientific Development) for grants and financial support

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