Revista Brasileira de Herbicidas, v.15, n.4, p.323-331, out./dez. 2016 (ISSN 2236-1065)
DOI: http://dx.doi.org/10.7824/rbh.v15i4.493 www.rbherbicidas.com.br

Control of three *Euphorbia* species through herbicides applied during pre-emergence on sugarcane straw[1]

Controle de três espécies de Euphorbia por herbicidas aplicados em pré-emergência sobre a palhada de cana-de-açúcar

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Abstract - The permanence of straw on the ground changes the phytosociology of weeds and affects control by the difficulty of transposing from straw to soil; thus, it is extremely important to transport it as quickly as possible**.** This research had the goal to know the effectiveness of two herbicides, applied on straw in different periods without rain, in controlling three weed species from the *Euphorbia* genus. The experiments were conducted in a greenhouse using a completely randomized design, arranged in split-plot in time (rainless periods: 0, 15, 30 and 45 days), with three replications. Seeds were distributed over the soil and covered by a 10 t ha^{-1} straw layer. The application of diuron + hexazinone + sulfometuron-methyl and tebuthiuron herbicides was performed during pre-emergence on the straw. Then, respecting the rainless period, planters received an irrigation of 20 mm water. At 43 days, the visual control and dry mass of the aerial parts were evaluated. Data were submitted to analysis of variance and adjusted to the linear or quadratic equation model. *E. hirta* was 100% controlled by the two herbicides in all periods without rain. Tebuthiuron was not effective in controlling *E. heterophylla* and *E. hyssopifolia* after 45 days without rain. Diuron + hexazinone + sulfometuron-methyl herbicide is effective in controlling the three *Euphorbia* species, even when applied on the straw and after the 45-day period to be leached. Diuron + hexazinone + sulfometuron applied over sugarcane straw was effective in controlling all *Euphorbia* species studied.
Keywords: chemical control; *Euphorbia heterophylla*; *Euphorbia hirta*; *Euphorbia hyssopifolia*; raw sugarcane

Resumo - A permanência da palhada sobre o solo altera a fitossociologia das plantas daninhas e afeta o controle pela dificuldade de transposição dos herbicidas da palhada para o solo, sendo de

[1] Received for publication on 21/09/2016 and approved on 30/10/2016.
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fundamental importância o seu transporte o mais rápido possível. Este trabalho teve por objetivo conhecer a eficiência de dois herbicidas, aplicados sobre palhada, em diferentes períodos sem chuva, no controle de *E. heterophylla*, *E. hyssopifolia* e *E. hirta*. Os experimentos foram conduzidos em casa-de-vegetação sob delineamento inteiramente casualizado, disposto em parcelas subdivididas no tempo (períodos sem chuva: 0, 15, 30 e 45 dias), com três repetições. As sementes foram distribuídas sobre o solo e cobertas por uma camada de palhada de 10 t ha^{-1}. A aplicação dos herbicidas, diuron + hexazinone + sulfometurom-metílico e tebuthiuron, foi realizada em pré-emergência sobre a palhada. Em seguida, respeitando o período sem chuva, os vasos receberam uma lâmina de irrigação de 20 mm de água. Aos 43 dias, foram avaliados o controle visual e a massa seca da parte aérea. Os dados foram submetidos à análise de variância e ajustados ao modelo de equação linear ou quadrática. *E. hirta* foi 100% controlada pelos dois herbicidas em todos os períodos sem chuva. O tebuthiuron não foi eficiente no controle de *E. heterophylla* e *E. hyssopifolia* após 45 dias sem chuva. O diuron + hexazinone + sulfometurom é eficiente no controle das três espécies de *Euphorbia* mesmo sendo aplicado sobre a palhada e passando o período de 45 dias para ser lixiviado. Diuron + hexazinone + sulfometurom aplicado sobre a palhada da cana-de-açúcar foi eficiente no controle de todas as espécies de *Euphorbia* estudadas.
Palavras-chaves: controle químico; *Euphorbia heterophylla*; *Euphorbia hirta*; *Euphorbia hyssopifolia*; cana crua

Introduction

The management of sugarcane harvest is undergoing a transition process all over Brazil. In Alagoas, the approval of Law n. 7,454, dated March 14th 2013, published on the Official State Government Gazette on March 19th of the same year, prohibits wildfires in agricultural, pastoral and forest areas of the state. This law regulates the progressive change of the sugarcane harvest system, without, however, defining a deadline. The manual harvest of sugarcane (*Saccharum officinarum*) is being replaced by the mechanized harvest, where there is no need for straw burning, known as raw sugarcane system (Silva and Monquero, 2013). Without burning, leaves, tops and pieces of stalks are grounded and thrown over the soil to create a layer of dead covering, called straw (Monquero et al., 2009).

The straw layer, accumulated on the soil, creates a physical barrier that causes positive changes in the physical, chemical and biological characteristics, resulting in less degradation and better soil quality (Oliveira et al., 2014). Another change caused by this layer lies in the phytosociology of weeds, where higher density, dry mass, richness and diversity are found (Mata et al., 2016).In the agro-ecosystem of raw cane there is a reduction in the infestation and diversity of weeds in the area. However, some species get to break the barrier and establish themselves, as it occurs with some species from the Euphorbiaceae family, among which there are *E. heterophylla* and *E. hyssopifolia*. They are related and considered a problem in the mechanized harvest and control is necessary to avoid reduction in the cane field productivity (Monquero et al., 2009; Mata et al., 2016).

The main weed control in Brazilian cane fields occurs with herbicides. However, straw becomes a problem, due to the barrier that hinders the contact of the product with the target-plant, leaving it vulnerable to volatilization and/or photolysis, until it leaches to the soil (Locke and Bryson, 1997). Rain is the main responsible for the transport of herbicide from the straw surface to soil; the first 20 mm are the ones representing the maximum transportation capacity of the herbicide (Toledo et al., 2009; Rossi et al., 2013; Prado et al., 2013). The transport of herbicide from the straw to the soil depends on the straw ability to cover soil and retain the herbicide, on the physical-chemical characteristics of the herbicide, on environmental conditions and on the period

during which the area remains with no rain after the application (Silva and Monquero, 2013).

Cavenaghi et al. (2007) while studying the dynamics of amicarbazone herbicide, Tofoli et al. (2009) while studying tebuthiuron and Rossi et al. (2013) while studying metribuzin, concluded that the quantity of 5 t ha^{-1} straw is already able to intercept practically all the applied product; the occurrence of rainfalls is necessary and the first 20 mm are essential to transport herbicide from the straw to the soil. This should preferably occur right after the application, so that the product transport is more effective.

The diuron + hexazinone + sulfometuron-methyl formulated mixture, according to Garcia et al. (2012) and Inoue et al. (2015) has good vertical mobility when applied on soils; it is influenced by the soil texture and by rainfalls. Both works concluded that sandy soils present higher mobility; on the other hand, the mixture mobility in clay soils is directly related to rainfalls. While studying the control of *Rottboellia exaltata*, Correia and Gomes (2014) applied herbicides on sugarcane straw in dry and humid soils, and concluded that with the increase of infestation (19.4 plants m^{-2}), clomazone + imazapyr, clomazone + isoxaflutole and diuron + hexazinone + sulfometuron-methyl treatments were superior, with better weed control. These works confirmed that this mixture presents high leaching potential.

In this system, the used herbicides must present specific characteristics, such as solubility, low octanol-water partition coefficient (Kow), low steam pressure (P) and low photolysis (Christoffoleti et al., 2009); however, little is studied about the behavior of these herbicides applied on straw and their effectiveness in controlling weeds from the *Euphorbia* genus, which can be found in the raw cane system. This work had the goal to know the dynamics of Front® (diuron + hexazinone + sulfometuron-methyl) and Combine® (tebuthiuron) herbicides in controlling three weed species from the Euphorbia genus, applied on straw and exposed to the environment for different periods without rain.

Material and Methods

Experiments were conducted in a greenhouse belonging to Center for Agricultural Sciences/Federal University of Alagoas. Each experimental unit was composed of a one liter capacity plastic planter filled with medium texture soil samples (Table 1). The used experimental design was completely randomized, arranged in split-plots in time (four periods without rain, 0, 15, 30 and 45 days), with three weed species and three replications. The three weed species used were *E. heterophylla*, *E. hyssopifolia* and *E. hirta*, which were planted separately. Two herbicides were used, Front® (diuron + hexazinone + sulfometuron-methyl, 603 g kg^{-1} + 170 g kg^{-1} + 14,5 g kg^{-1}, WG, Du Pont) and Combine® (tebuthiuron, 500 g L^{-1}, SC, Dow), in a commercial dose; each herbicide composed an experiment.

Table 1. Physical-chemical analysis of soil used in the growth and development experiment of three weed species from the *Euphorbia* genus. Rio Largo (AL), 2013.

Particle Composition [1] (%)			pH ($CaCl_2$)	M.O. (dag kg^{-1})	P (mg dm^{-3})	V (%)
Sand	Silt	Clay				
65	2	33	5.2	2.63	15.4	28
Exchangeable Cations ($cmol_c$ dm^{-3})						
K^+	Ca^{2+}	Mg^{2+}	BS	H + Al	CEC	
82	1.4	0.6	2.21	5.61	7.82	

(1) Loamy Clay Sandy; (2) BS - base sum; CEC - cation exchange capacity; V - saturation by bases.

Seeds were collected in producing areas, then benefited and submitted to preliminary germination tests. In the planters, seeds from each species were distributed on the substrate, in the required quantity for the germination of 25 plants, and then covered with a uniform layer of straw, referring to 10 t ha^{-1}. The used straw was collected in a commercial sugarcane cultivation area, right after the cutting of RB92579 variety, and air-dried.

Herbicide application was performed during the pre-emergence of weeds, on the straw, using a CO_2 pressurized back sprayer, equipped with bars, containing two XR 11002 flat-spray nozzles at 200 kPa, in order to provide a 200 L ha^{-1} mixture volume. During the application, climatic data were measured, having 27.21°C average temperature, 63.84% air relative humidity and 3.08 m s^2 wind speed. The first irrigation was given respecting the no rain treatment period. Pots received a 20 mm irrigation line through manual sprayers, 294 ml of water distributed during 10 minutes, the necessary volume to transport the herbicide from the straw to the soil. After the first irrigation, pots were irrigated only when needed, through visual evaluations that aimed at keeping soil moisture and avoid herbicide percolation.

The experiment collection occurred 43 days after the first irrigation, corresponding to each no rain period treatment, where alive plants were counted (in order to determine control effectiveness) and cut close to the soil in order to determine the dry mass of the aerial part. In order to determine dry mass, plants were cut close to the soil and placed in paper bags, and placed in an oven with forced air circulation at 65°C for 72 hours. After this period, samples were weighed on a precision analytic scale. For all evaluated variables, results were transformed into percentages, using the obtained values for the control sample (without herbicide) as 100%, and the other calculated treatments as a proportion of this last one.

Data were submitted to analysis of variance and adjusted for the linear equation model ($y= bx + c$) for *E. hirta* and *E. hyssopifolia* species, and quadratic equation model ($y= ax^2 + bx + c$) for *E. heterophylla*.

Results and Discussion

Species factors and species x no rain period interaction presented significant effect ($p<0.001$) on the relative control and dry mass for the two studied herbicides, diuron + hexazinone + sulfometuron-methyl and tebuthiuron (Table 2). In order to better understand the behavior of the species, the split of the interaction of the period with the species was presented, exhibiting graphs with linear (*E. hirta* and *E. hyssopifolia*) and non-linear (*E. heterophylla*) regression.

Table 2. Analysis of variance summary for the relative control and dry mass in three weed species from the *Euphorbia* genus, submitted to the use of Front® (diuron + hexazinone + sulfometuron-methyl) and Combine® (tebuthiuron) herbicides in the simulation of different periods without rain. Rio Largo (AL), 2013.

Variation Source	GL	QM			
		Relative Control (%)		Relative dry mass (%)	
		Front	Combine	Front	Combine
Period (P)	3	0.256	0.934	48.275	1023.89
Error a	8	0.018	0.045	0.847	38.102
Species (E)	2	0.700**	0.688**	123.292**	1127.829**
Period (P) X Species (E*P)	6	0.202**	0.250**	17.180**	296.168**
Error b	16	0.015	0.046	1.272	42.928
CV a (%)		2.40	3.85	27.75	66.75
CV b (%)		2.20	3.91	34.02	70.86

** Significant ($p<0.001$) and * Significant ($p<0.05$).

Diuron + hexazinone + sulfometuron-methyl and tebuthiuron herbicides, applied on straw and exposed to the environment for a period of 45 days, effectively controlled *E. hirta*, with 100% relative control of individuals. *E. hirta* appeared to be very sensitive to the studied herbicides. Pires et al. (2003), while studying plants with phyto-remediator potential to tebuthiuron, observed high phytotoxicity values, above 80%, in *E. hirta.*

Data obtained for *E. heterophylla* presented adjustment to the quadratic equation, with R^2 above 80%. The "a" coefficient determines the position of the curve concavity; when the value of this coefficient is positive, the curve presents up-facing concavity and increasing value after the inflexion point of the curve. For *E. heterophylla*, the "a" coefficient was negative in response to the application of diuron + hexazinone + sulfometuron-methyl herbicide in the studied variables, having decreasing value after the flexion point of the curve.

E. hyssopifolia presented values above 90% control under the effect of the diuron + hexazinone + sulfometuron-methyl herbicide, even when the product spent 45 days exposed to solar radiation in order to be leached through irrigation until reaching the soil. In the same period, *E. heterophylla* presented 44% relative control, therefore, Front® herbicide was not effective when applied under this experiment's conditions. *E. heterophylla* control was only effective in treatments where the simulated no rain period was 15 days maximum. The herbicide presented 100% and 84% control over this species, when it was submitted to treatments of 0 and 15 days without rain, respectively. (Figure 1).

The relative dry mass of the studied species was drastically reduced with the application of Front®, whose average values remained under 3.5%. *E. hyssopifolia* produced less than 1% relative dry mass, even when submitted to the treatment of 45 days without simulated rain (Figure 2).

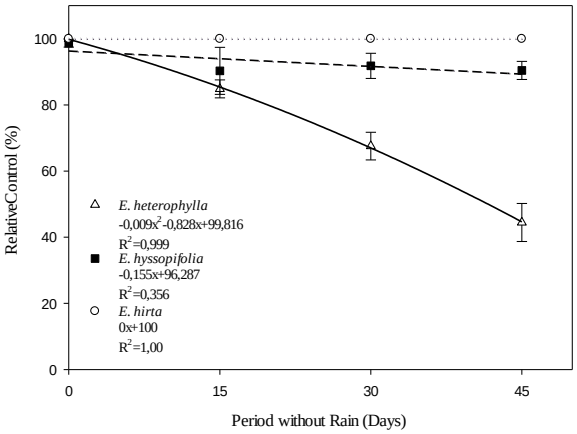

Figure 1. Relative control percentage of three weed species from the *Euphorbia* genus after the application of Front® (diuron + hexazinone + sulfometuron-methyl) herbicide on sugarcane straw and submitted to 0, 15, 30 and 45 days without rain. Rio Largo (AL), 2013.

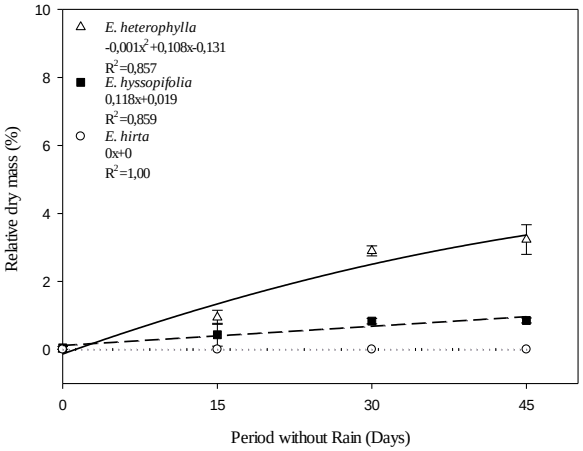

Figure 2. Relative dry mass of three weed species from the *Euphorbia* genus after the application of Front® (diuron + hexazinone + sulfometuron-methyl) herbicide on sugarcane straw and submitted to 0, 15, 30 and 45 days without rain. Rio Largo (AL), 2013.

As for *E. heterophylla*, the maximum values of relative dry mass were 2.89 and 3.23% in treatments of 30 and 45 days without simulated rain, even with a relative control of 67 and 44%, respectively.

Even with an escape in controlling *E. heterophylla*, the diuron + hexazinone + sulfometuron-methyl herbicide inhibited its development and the accumulation of dry mass in the studied species, even in the period of 45 days without rainfall simulation (Figures 1 and 2); this justifies its use in the sugarcane culture, mainly during the period of water restriction. This herbicide is commonly known as drought herbicide, because it presents individual characteristics of the three molecules; this gives the excellent result to the mixture: diuron has persistence in soils, hexazinone and sulfometuron-methyl have high solubility and biodegradation (Rodrigues and Almeida, 2011; Giancotti et al., 2012; Toledo et al., 2012).

Toledo et al. (2012) and Garcia et al. (2012) while studying the diuron + hexazinone + sulfometuron-methyl herbicide in the raw cane system confirmed the high solubility characteristic, which makes it easily leached from the straw. The presence of straw on the soil surface, even if small (2.5 t ha^{-1}), intercepts and retains this herbicide; a 10 mm water line is necessary to transport the product to the soil (Toledo et al., 2012). On the other hand, Garcia et al. (2012) demonstrated that even with no rain, only with the field capacity, the mixture of diuron + hexazinone + sulfometuron-methyl molecules, Front®, controls 80% of *Ipomoea triloba*, in the superficial soil layer from 0 to 10 cm.

In the same study, Garcia et al. (2012) confirmed the effectiveness of Front®, applied on 5 t ha^{-1} straw, presenting control over *Panicum maximum* and *Ipomoea triloba*, after a period of 180 days with water restriction. Gaincotti et al. (2014) also proved the effectiveness of this herbicide in controlling *I. hederifolia* and *I. grandifolia* after 90 days of water restriction and indicated that this satisfactory result is due to possible synergism relations among the molecules found in the product.

Tebuthiuron herbicide was effective in controlling *E. heterophylla* and *E. hyssopifolia* up to 30 days without rain after treatment application. When there was the simulation of 45 days without rain, relative controls were only 48 and 40.78% for *E. heterophylla* and *E. hyssopifolia*, respectively. In the simulations of 0, 15 and 30 days without rain after the application of Combine®, it controlled 100% of the *E. heterophylla* species and more than 75% for *E. hyssopifolia*; this indicates that the optimum residual period to control these species in the cultivation of raw cane by tebuthiuron is 30 days without rain (Figure 3).

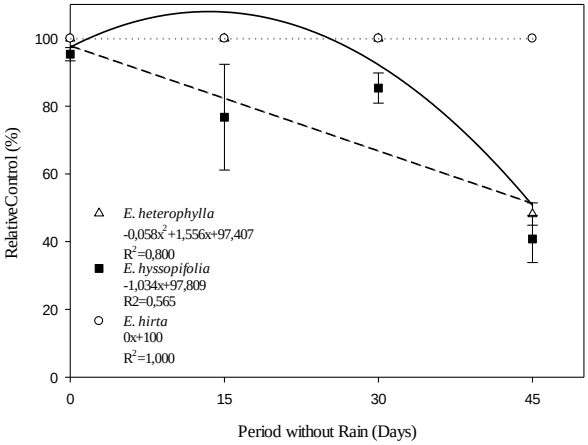

Figure 3. Relative control percentage of three weed species from the *Euphorbia* genus after the application of Combine® (tebuthiuron) herbicide on sugarcane straw and submitted to 0, 15, 30 and 45 days without rain. Rio Largo (AL), 2013.

The relative dry mass of *E. heterophylla*, when submitted to the application of Combine®, was totally inhibited in the treatments of 0, 15 and 30 days with no simulated rain; however, when there was a simulation of 45 days without rain, the relative dry mass of this species was 43.03%. *E. hyssopifolia*, when submitted to the same treatment and period, presented relative dry mass of 31.12% in relation to the control sample (Figure 4). This indicates that the herbicide was volatilized or degraded over the time exposed to the environment; it did not present effective action in controlling these species after 45 days. These species did not

present reduction in the development observed by the accumulation of weed dry mass.

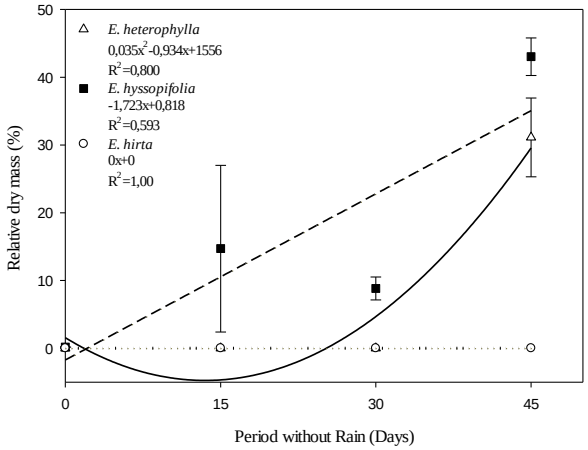

Figure 4. Relative dry mass of three weed species from the *Euphorbia* genus after the application of Combine® (tebuthiuron) herbicide on sugarcane straw and submitted to 0, 15, 30 and 45 days without rain. Rio Largo (AL), 2013.

The results obtained in the present work confirm the low effectiveness of tebuthiuron also observed by Tofoli et al. (2009). They concluded that the more contact time of the herbicide with the straw, the less its transposition to the soil, regardless of the simulated rain quantity, reducing by about 30% the total leached product when this remained exposed for 28 days after application. The active principle of this herbicide (tebuthiuron) presents long half-life, about a year in soils with high carbon content and little rain (Chang and Strizke, 1977; Helling, 2005; Gomes et al., 2006); it may have its half-life reduced up to 20 days under specific soil conditions (moisture, organic matter concentration, microbial community) and climate (temperature, radiation) (Cerdeira et al., 2007). In this study, tebuthiuron was not effective in controlling after 45 days without rain, indicating that the product may have been volatilized and/or photo-degraded during this period. Thus, it is necessary to conduct future studies about its degradation and volatilization.

Conclusions

Diuron + hexazinone + sulfometuron-methyl herbicide applied on sugarcane straw was effective in controlling *E. hyssopifolia* and *E. hirta*, even with the simulation of 45 days without the occurrence of rainfalls. Tebuthiuron herbicide applied on sugarcane straw does not present residual effect in the period of 45 days without simulated rain, for the *E. heterophylla* and *E. hyssopifolia* species.

Acknowledgements

This study received financial support from CAPES and FAPEAL, which is gratefully acknowledged.

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