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Droplets size categories and application volumes in burndown of plant covers[1]

Classes de gotas e volumes de aplicação na dessecação de coberturas vegetais

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Abstract - This study has aimed to verify the influence of the droplets size categories and application volumes on burn down *Urochloa ruziziensis* and *Conyza* sp. Therefore, two trials were conducted in a randomized block design with four replications in a 2x4 split plot arrangement. The plots consisted in droplets size categories (very fine droplets and ultra coarse droplets) and the subplots consisted in four application volumes (50, 100, 150 and 200 L ha^{-1}). For desiccation, glyphosate herbicide was used at 0.975 and 1.3 kg of a.e. ha^{-1} for controlling plant covers *Urochloa ruziziensis and Conyza* sp., respectively. Saflufenacil herbicide was used at a dose of 49 g of a.i. ha^{-1} in association with glyphosate to control *Conyza* sp. In the application was used a pressurized sprayer by CO_2 with spray nozzles model ATR 1.0 and AI 110015. At 5, 10, 15 and 20 days after application (DAA) of the herbicides, visual assessments were done of the control percentage of *Urochloa ruziziensis* and defoliation in *Conyza* sp. At 25 DAA, one regrowth percentage assessment of *Conyza* sp. plant was done. It is concluded that the category of ultra coarse droplets is efficient for desiccation of *Urochloa ruziziensis* with volumes of up to 50 L ha^{-1}, while the category of very fine droplets reduces the efficacy with reduced volume application. It was also found that reducing the application volumes increases the possibility of regrowth on burn down *Conyza* sp.
Keywords: *Urochloa* sp.; *Conyza* sp.; spectrum of droplets; application technology

Resumo - Objetivou-se verificar a influência das classes de gotas e volumes de aplicação na dessecação de *Urochloa ruziziensis* e *Conyza* sp. Para tal foi conduzido dois ensaios sob o delineamento de blocos casualizados, com quatro repetições, em esquema de parcelas subdivididas 2x4. As parcelas foram constituídas de classes de gotas (gotas muito finas e gotas ultra grossas) e as subparcelas por quatro volumes de aplicação (50, 100, 150 e 200 L ha^{-1}). Para a dessecação foi utilizado o herbicida glyphosate nas doses de 0,975 e 1,3 kg de e.a. ha^{-1} para o controle das coberturas vegetais *Urochloa ruziziensis e Conyza* sp., respectivamente. O herbicida saflufenacil foi utilizado na dose de 49 g de i.a. ha^{-1} em associação ao glyphosate para o controle de *Conyza* sp. Na aplicação foi utilizado pulverizador pressurizado por CO_2 com pontas de pulverização do

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modelo ATR 1,0 e AI 110015. Aos 5, 10, 15 e 20 dias após a aplicação (DAA) dos herbicidas foram realizadas avaliações visuais da porcentagem de controle da *Urochloa ruziziensis* e da desfolha no caso de *Conyza* sp. Aos 25 DAA foi realizada uma avaliação de porcentagem de rebrote de plantas de *Conyza* sp.. Conclui-se que a classe de gotas ultra grossa é eficiente na dessecação de *Urochloa ruziziensis* com volumes de até 50 L ha^{-1} enquanto que a classe de gotas muito fina diminui a eficácia com a redução do volume de aplicação. Constatou-se também que a redução do volume de aplicação aumenta a possibilidade de rebrotes na dessecação de *Conyza* sp.
Palavras-chaves: *Urochloa* sp.; *Conyza* sp.; espectro de gotas; tecnologia de aplicação

Introduction

The adoption of direct seeding of annual crops is increasing every year. According to FEBRAPD (2104), in 2012 the grain producing regions in Brazil already had 31.8 million hectares cultivated under Direct Seeding (DS). This system recommends the minimum soil cultivation associated with the formation of stubble by plant covers. Before the implementation and establishment of the subsequent crop, herbicide applications are required to cultivated plant cover or spontaneous vegetation desiccation in areas that remain in fallow in the off-season period.

Because of the need to use herbicides for managing plant covers and aiming at the adoption of a sustainable agriculture, one should deploy a plant cover species to hold a good ground cover, and keep a uniform canopy that will contribute to better implementation of efficiency and be more susceptible to herbicide molecules. In this sense, the sensitivity of *Urochloa ruziziensis* to glyphosate is highlighted, in which the herbicide has a rapid evolution of intoxication symptoms, which favors the operations of drying and mechanical planting (Fuchs et al., 2012; Silva, 2013). However, in areas where there is no deployment of plant covers, there is the formation of plant covers by weed species, many of which are considered difficult to control chemically, such as *Conyza* sp. (horseweed) and *Commelina benghalensis* (commonly known as Benghal dayflower, tropical spiderwort, or wandering Jew).

While growing forage plants in direct seeding, applications of phytosanitary products are required from pre-sowing of the crop. Among the investments in the agricultural sector production chain segments, the application technology is one of the areas that should be prioritized due to various environmental factors that directly or indirectly influence the crops productivity (Bonadiman 2008), besides the costly investment made in the acquisition of phytosanitary products.

In agricultural sprays, water has been the most used vehicle to carry and distribute phytosanitary products on plants or to reach the biological target. The droplet size combined with the application volume and products diluted in the spray mix may influence the distribution and deposition quality of products. Researchers in the phytosanitary area have been working to verify the possibility of reducing the application volume in agricultural sprays with different classes of phytosanitary products as herbicides (Ferreira et al., 1998; Bracamonte et al., 1999; Garcia et al., 2004; Rodrigues et al., 2011; Bueno et al., 2013; Almeida et al., 2014), insecticides (Bonadiman, 2008; Maziero et al., 2009; Pereira et al., 2012) and fungicides (Meneghetti 2006; Oliveira, et al., 2007; Cunha and Silva Júnior, 2010).

The technical and scientific information on the application volume and droplets size category targeting efficiency in the application are essential, as it is possible to obtain efficacy on burn down of plant covers so that these do not affect the subsequent crops. However, information in the literature to assess the efficiency of reduced application volume associated with different droplets size categories in the desiccation of plant covers is not yet available, justifying the investigation. In order to obtain information regarding the reduction of volumes for herbicide application, the influence of droplets size categories and application volumes on the efficiency of herbicides application for the desiccation of *Urochloa ruziziensis* and *Conyza* sp. was investigated.

Material and Methods

This research was conducted in 2013, at the following coordinates: 17°55'31,78” S and 51°42'36,17" W. The region has an average altitude of 680 meters, and annual rainfall between 1650-1800 mm, distributed between the months of September to April, with temperatures averaging around 25 ºC (Mariano; Scopel, 2001). At 30 days before the beginning of the experiment (September 22, 2014) until its end (November 22, 2014), meteorological data were recorded (Figure 1), obtained in the INMET (National Meteorology Institute) weather station, located in Campus Jatobá of UFG (Federal University of Goiás) – Jataí Regional, GO, located at 900 meters from the experimental area.

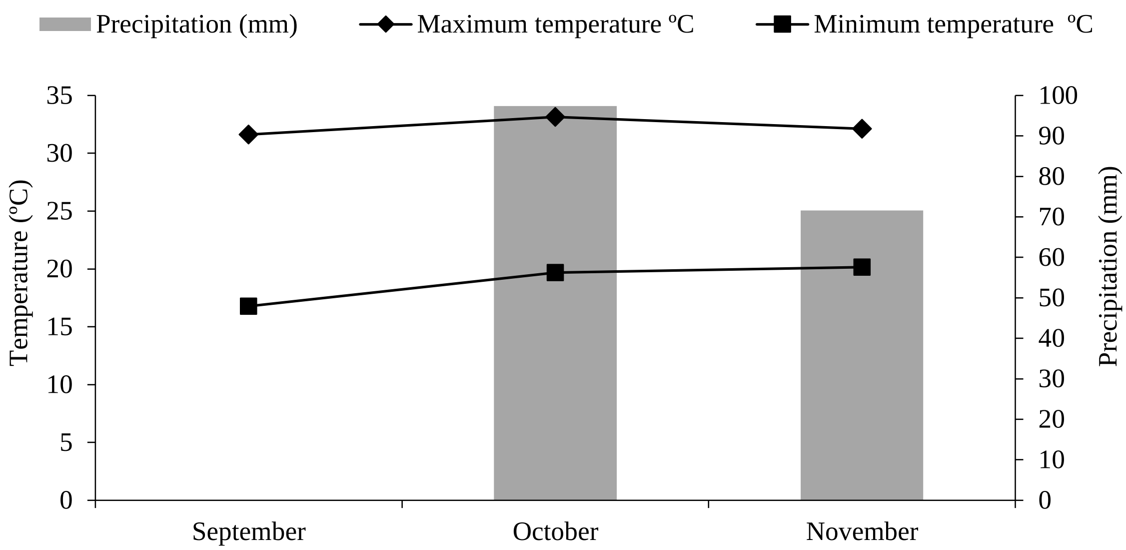

Figure 1. Maximum and minimum average air temperature and total precipitation between September 22, 2014 and November 22, 2014. Jataí, GO, 2013.

The research consisted in two trials in which *Urochloa ruziziensis* and spontaneous vegetation (consisting mainly in *Conyza* sp.) were adopted as plant covers. The tests were conducted in a randomized block design with four replications and the treatments (Table 1) were arranged in a 2x4 split plot. The plots consisted in two droplets size categories (very fine droplets and ultra-coarse droplets) established in accordance with the volume median diameter (VMD) and the subplots by four application volumes (50, 100, 150 and 200 L ha^{-1}). Each plot consisted in a 240 m^2 (48.0 x 5.0 m) area; and the subplots by 60 m^2 (12.0 x 5.0 m) area.

The application of herbicide for plant covers desiccation occurred in the second half of October 2013. *Urochloa ruziziensis* was in full vegetative development and plant dry matter accumulation of about 4000 kg ha^{-1} was obtained. For sampling this plant cover, a 0.5 x 0.5 m hollow metal frame randomly launched three times in each plot was used. The plants contained in the frames were cut close to the ground, wrapped in paper bag and taken to drying in a forced air circulation chamber at 70 °C temperature for 72 hours to determine the dry matter. As for plant cover consisting in *Conyza* sp. (horseweed), it had a population of 7.4 plants m^{-2} at the time of application. The sampling was performed on 8.0 m^2 (4x2) in the center of each subplot, accounting for the total number of plants. Most plants of *Conyza* sp. were in full bloom.

Herbicide glyphosate was applied (Roundup Ultra, 650 g e.a. kg^{-1}, WG, Monsanto) at doses of 0.975 and 1.3 kg ha^{-1} of acid equivalent in plant covers *Urochloa ruziziensis* and *Conyza* sp., respectively. To dry the *Conyza* sp., saflufenacil (Heat, 700 g i.a. kg^{-1}, WG, Basf) herbicide was associated with the glyphosate, tank mixed, at the dose of 49 g a.i. ha^{-1} with the addition of mineral oil (Dash®) at the concentration of 0.25% v/v of spray mix. In both trials, an antifoaming adjuvant based on Silane, Gum arabic, and vehicle q.s. (quantum sufficit) (commercial mark No Spume®) was added to the spray mix solution at a concentration of 0.0025% v/v of spray mix.

Table 1. Treatments resulting from the combination of droplets size categories and spray mix volumes used for application of herbicides on *Urochloa ruziziensis* and *Conyza* sp. Jataí, GO, 2013.

Treatments	Droplets size category*	Application volume (L ha^{-1})
1	Very fine droplets	50
2	Very fine droplets	100
3	Very fine droplets	150
4	Very fine droplets	200
5	Ultra coarse droplets	50
6	Ultra coarse droplets	100
7	Ultra coarse droplets	150
8	Ultra coarse droplets	200

*Droplets size category according to the ASAE S572.1 standard classification, where: Very fine droplets (VMD 61-105 µm) and Ultra coarse droplets (VMD > 665 µm).

For herbicide application, a custom search sprayer pressurized by CO_2 with a 10-liter reservoir connected to the three-point hitch of a tractor was used. The spray boom was equipped with eight nozzles spaced 0.5 m apart. To establish the droplets size categories (very fine droplets and ultra-coarse droplets), spray nozzles of the models ATR 1.0 (empty cone) and AI 110015 (plane jet with air induction), at a working pressure of 400 and 200 kPa, respectively. The coefficients of variation of the flows of the respective spray nozzles ATR 1.0 and AI 110015 attached to the spray boom were 4.1 and 1.6 %. The working pressure on the nozzles and the flow rate in L min^{-1} were set so that when spraying the four application volumes, only the sprayer displacement rate and the herbicides concentration in the spray mixes changed. The height between the spray boom and the target was maintained at 0.75 m and 0.50 m, respectively, for nozzles ATR 1.0 and AI 110015.

The desiccation of *Urochloa ruziziensis* and *Conyza* sp. was held on October 22 and 29, 2013 between 9:00 and 11:05 a.m. and between 9:40 and 11:40 a.m., respectively. The atmospheric conditions relating to the plant covers desiccation were monitored with the aid of an Instrutherm brand digital thermo-hygrometer. Four samples of atmospheric conditions were carried out during the spraying period in order to obtain the average values. During the herbicides applications on the respective plant covers, the weather conditions were 27.6 and 30.3 °C of air temperature, 43.3 and 50.2% of relative humidity and 2.9 and 1.8 km h^{-1} of wind speed. At the time of application in both plant covers the soil surface was dry.

At 5, 10, 15 and 20 days after application (DAA) of the herbicide, visual assessments of the percentage of *Urochloa ruziziensis* control was done by means of a percentile rating scale, where 0% corresponded to no visible injury and 100% corresponded to death of plants (SBCPD, 2000). In the desiccation of *Conyza* sp., the same rating scale was adopted to assess the plants defoliation percent.

In the plant cover consisting in horseweed, an assessment of the plants regrowth percentage at 25 DAA was carried out. The sampling was performed on 8.0 m^2 (4x2) in the center of each subplot, where plants that had some form of regrowth and total number of plants were counted. The percentage of plants with regrowth was obtained taking into account the area of the infestation and the number of plants with regrowth.

With the data obtained from the *Urochloa ruziziensis* control percentage and defoliation percentage and regrowth of the horseweed population the analysis of variance at the 0.05 level of significance was held. When relevant, the averages were compared by Tukey's test at 0.05 probability.

Results and Discussion

At 5 days after application (DAA) of glyphosate in *Urochloa ruziziensis*, it was found that there was no interaction between factors studied (droplets size categories and application volume). There were significant differences just in the droplets size categories adopted, in which the adoption of ultra-coarse droplets grew by 4.3% in the control efficiency of *Urochloa ruziziensis*. This may be related to greater deposition, thereby increasing absorption and/or translocation of the molecule in the plant (Liu et al., 1996). In addition, when linking the application volumes with very fine droplets, losses by drift and evaporation can occur (Matthews, 2000).

Table 2. Values of F and coefficient of variation (CV %) applied to the control efficiency percentages of *Urochloa ruziziensis* evaluated at 5, 10, 15 and 20 days after application (DAA) of the glyphosate herbicide[1]. Jataí, GO, 2013.

Variables		Control %			
		5 DAA	10 DAA	15 DAA	20 DAA
F	Droplets size category (DSC)	10.573*	7.547ns	26.661*	6.874ns
	Application volume (AV)	0.884ns	2.562ns	1.688ns	0.714ns
	DSC x AV	1.271ns	8.000*	10.194*	8.084*
DSC	Very fine droplets	25.12 b[1]	–	–	–
	Ultra coarse droplets	29.38 a	–	–	–
LSD (least significant difference)		4.16	–	–	–
AV	200	–	–	–	–
	150	–	–	–	–
	100	–	–	–	–
	50	–	–	–	–
CV (%)	DSC	13.57	13.93	5.83	11.12
CV (%)	AV	12.03	6.23	5.65	5.87

[1]Glyphosate (Roundup Ultra®) at the dose of 0.975 kg ha^{-1} of acid equivalent + antifoaming (No Spume®) at the concentration of 0.0025% of v/v. ns Nonsignificant at 0.05 of significance, *Significant at 0.05 of significance.

At 10, 15 and 20 DAA, an interaction between factors droplets size categories (DSC) and application volumes is observed on the evaluations carried out. Such interactions have also been demonstrated by Costa et al. (2008; 2012), which confirmed the difference in the distribution quantity and uniformity of the spray mix sprayed on the targets evaluated due to the droplets size categories studied and hence the spray mix volume used.

At 10 DAA (Table 3), where the effects of glyphosate began to be more evident, it can be seen that the use of very fine droplets does not influence the control of *Urochloa ruziziensis*, regardless of the application volume used. However, in the use of ultra-coarse droplets, a difference in the control percentage of this kind was obtained, where the volume of 50 L ha^{-1} provided greater control over the others. Moreover, it can be seen that for this application volume the use of this droplets size category increased 14.75% in the control of *Urochloa ruziziensis* when compared to the application of the same volume with very fine droplets.

When analyzing droplets size categories in each application volume (AV) (Table 4) it can be seen that the very fine droplets did not achieve efficacy above 80% in the control of *Urochloa ruziziensis* when linked to the application volumes under study, statistically differing from the control obtained with ultra-coarse droplets, except in the AV of 200 L ha^{-1}. Moreover, when the application volume of 150, 100 and 50 L ha^{-1} was linked to ultra-coarse droplets, it can be seen that they were efficient in relation to the volume of 200 L ha^{-1}. When they were linked to the use of very fine droplets, there was no statistical difference among 200, 150 and 100 L ha^{-1}. However, by reducing the application volume to 50 L ha^{-1} there was a significant reduction in herbicidal efficacy.

At 20 DAA (Table 5), it turns out that the factors studied exerted similar influence on the percentage of control when compared to those obtained at 15 DAA. However, when the spray mix volumes were linked to the use of very fine droplets, there was no statistical difference among 200, 150 and 100 L h^{-1} and, when reducing the application volume to 50 L h^{-1}, there was a significant reduction in control efficacy. Almeida et al. (2013), in a similar study, have also found that droplets size categories influence the control of *Urochloa ruziziensis* in which very coarse droplets showed similar control efficacy on application volumes of 50, 100, 150 and 200 L h^{-1}, while with very fine droplets the same was true only for the volume of 200 L ha^{-1}.

Table 3. Deployment of the significant interaction for effective control of *Urochloa ruziziensis* at 10 DAA of glyphosate herbicide[1], according to the droplets size categories and application volumes. Jataí, GO, 2013.

Application volumes L ha^{-1} (AV)	Control %	
	Very fine droplets	Ultra coarse droplets
200	50.50 a* A	51.25 b A
150	47.50 a A	50.50 b A
100	44.50 a B	53.25 b A
50	45.25 a B	60.00 a A
LSD (least significant difference)		
AV within DSC	6.3	
DSC within AV	7.4	

[1]Glyphosate at the dose of 0.975 kg ha^{-1} of acid equivalent + antifoaming at the concentration of 0.0025% of v/v. *Means followed by uppercase letters in the same row and lowercase letters in the same column do not differ by Tukey's test at 0.05 probability.

Table 4. Deployment of the significant interaction for effective control of *Urochloa ruziziensis* at 15 DAA of glyphosate herbicide[1], according to the droplets size categories and application volumes. Jataí, GO, 2013.

Application volumes L ha^{-1} (AV)	Control %	
	Very fine droplets	Ultra coarse droplets
200	78.3 a* A	73.8 b A
150	74.0 ab B	81.3 ab A
100	73.8 ab B	80.8 ab A
50	65.6 b B	84.5 a A
LSD (least significant difference)		
AV within DSC	9.6	
DSC within AV	7.3	

[1]Glyphosate at the dose of 0.975 kg ha^{-1} of acid equivalent + antifoaming at the concentration of 0.0025% of v/v. *Means followed by uppercase letters in the same row and lowercase letters in the same column do not differ by Tukey's test at 0.05 probability.

In compiling results obtained by Knoche (1994), the investigations on the effects of droplet size on the herbicides performance generally show an increased biological efficacy with decreased droplet size. However, the data of the experiments presented here do not support the conclusion reached by the author. One hypothesis is that much of the collected works were carried out under controlled conditions in a protected environment, which may have directly influenced the results.

Whereas *Urochloa ruziziensis* is a forage species that makes a good plant cover on the ground, the results obtained in the research support the possibility of reducing spray mix volume in the application of glyphosate with the use of ultra-coarse droplets, between the spray mix volumes of 200 and 50 L ha^{-1} for its desiccation. The adoption of ultra-coarse droplets size category can minimize the risks of drift by horizontal and vertical convective current (Drift Physics) or by evaporation of the droplets.

It can be seen in Table 6 that after applying the herbicide (glyphosate + saflufenacil) to dry *Conyza* sp., an interaction between the investigated factors (droplets size categories and application volumes) was not found and there was no difference either between the application volumes or droplets size categories at 5, 10, 15 and 20 DAA. This demonstrates the possibility of reducing the application volume with the use of nozzles which provide an ultra-coarse droplets size category with induction of air due to having lower losses by drift compared to fine and very fine droplets (Chechetto et al., 2013).

Table 5. Deployment of the significant interaction for effective control of *Urochloa ruziziensis* at 20 DAA of glyphosate herbicide[1], according to the droplets size categories and application volumes. Jataí, GO, 2013.

Application volumes L ha^{-1} (AV)	Control %	
	Very fine droplets	Ultra coarse droplets
200	75.5 a* A	72.3 b A
150	71.5 ab B	79.5 ab A
100	71.0 ab B	79.0 ab A
50	64.0 b B	82.3 a A
LSD (least significant difference)		
AV within DSC	8.6	
DSC within AV	8.3	

[1]Glyphosate at the dose of 0.975 kg ha^{-1} of acid equivalent + antifoaming at the concentration of 0.0025% of v/v. *Means followed by uppercase letters in the same row and lowercase letters in the same column do not differ by Tukey's test at 0.05 probability.

Table 6. Values of F and coefficient of variation (CV %) applied to the defoliation percentage averages at 5, 10, 15 and 20 days after application (DAA) of herbicides[1] on horseweed (*Conyza* sp.). Jataí, GO, 2013.

	Variables	Control %			
		5 DAA	10 DAA	15 DAA	20 DAA
F	Droplets size category (DSC)	0.208^{ns}	0.358^{ns}	1.246^{ns}	0.128^{ns}
	Application volume (AV)	0.477^{ns}	2.100^{ns}	1.912^{ns}	1.009^{ns}
	DSC x AV	2.682^{ns}	0.201^{ns}	0.237^{ns}	0.137^{ns}
DSC	Very fine droplets	93.44	95.31	96.63	96.56
	Ultra coarse droplets	91.88	95.83	96.07	96.38
AV	200	92.50	96.25	95.50	95.75
	150	91.50	95.00	96.13	96.13
	100	93.75	96.75	97.25	97.50
	50	92.88	94.25	96.50	96.50
CV (%)	DSC	2.91	2.47	1.48	1.54
CV (%)	AV	4.12	2.34	1.55	2.20

[1]Glyphosate (Roundup Ultra®) at the dose of 1.3 kg ha^{-1} of a.e. + saflufenacil (Heat®) at the dose of 49 g ha^{-1} of a.i. + mineral oil (Dash®) at the concentration of 0.25% v/v of spray mix + antifoaming (No Spume®) at the concentration of 0.0025% of v/v. ^{ns} Nonsignificant at 0.05 significance

In addition, in Table 6 it can be seen that at 5 DAA the defoliation percentage reached levels above 90% in all application volumes bound to both droplets size categories adopted. Accordingly, it would be possible to have forage crops sowing such as soybeans, since during this period (5 DAA) defoliation of *Conyza* sp. plants had occurred and that these were dominating the weeds.

When analyzing the results (Table 7), it is noted that there is no influence of the two droplets size categories in the percentage of *Conyza* sp plants. regrown at 25 DAA. However, it is found that the application volumes interfere with the percentage of *Conyza* sp. plants with regrowth. The reduction in spray mix volume has an inverse relationship with the regrowth percentage of *Conyza* sp., since there was an increase of 7.7% of plants with regrowth by reducing the volume from 200 to 50 L ha^{-1}. Since the average population of the area at application was 73.6 thousand plants of this species per hectare, this value (7.7%) amounts to 5.6 thousand plants regrowth, i.e., that were not fully desiccated (dead) during the period evaluated.

Table 7. Values of F, LSD, coefficients of variation (CV %), applied to the regrowth percentage averages of *Conyza* sp. plants at 25 days after application (DAA) of herbicides[1]. Jataí, GO, 2013.

	Variables	Regrowth % 25 DAA
F	Droplets size category (DSC)	1.14^{ns}
	Application volume (AV)	3.89^{*}
	DSC x AV	1.62^{ns}
Droplets size category (DSC)	Very fine droplets	19.54
	Ultra coarse droplets	17.57
Application volumes L ha^{-1} (AV)	200	15.66 b[2]
	150	18.15 a b
	100	17.92 a b
	50	23.31 a
LSD (least significant difference)		6.56
CV (%)	DSC	22.24
CV (%)	AV	24.73

[1]Glyphosate at the dose of 1.3 kg ha^{-1} of a.e. + saflufenacil at the dose of 49 g ha^{-1} of a.i. + mineral oil at the concentration of 0.25% v/v of spray mix + antifoaming at the concentration of 0.0025% of v/v. ^{ns} Nonsignificant at 0.05 of significance; *Significant at 0.05 of significance. Means followed by the same letter, in the same column, do not differ by Tukey's test at 95% probability.

It is noteworthy that in all application volumes adopted the defoliation percentage of the *Conyza* sp. plants was above 95% up to 20 DAA (Table 6), in which crops such as soybeans and maize would already show sufficient development to contribute to the suppression of plant reinfestation.

Conclusions

The ultra-coarse droplets size category is efficient for desiccation of *Urochloa ruziziensis* with volumes up to 50 L h^{-1}, whereas the very fine droplets size category reduces the control efficacy with reduced application volume. In the desiccation of *Conyza* sp., reducing the application volume increases the possibility of regrowth by using both droplets size categories.

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