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Desiccation of forage plants from *Urochloa* genus using glyphosate herbicide

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ABSTRACT

Forage species, mainly those from the *Urochloa* genus, have been an essential alternative for utilization in no-tillage systems (NTS) due to their high biomass production and C/N ratio. However, for adequate development of the subsequent crops, the desiccation of forage plants must be efficient using herbicides. This study aimed to investigate the death kinetics of forage species from the *Urochloa* genus submitted to different levels of glyphosate. The treatments consisted of four forage species (*Urochloa brizantha* cv. BRS Paiaguás, *U. ruziziensis*, *U. brizantha* cv. Piatã, and *U. spp*. cv. Ipyporã) submitted to four doses of glyphosate (250; 500; 1,000 and 2,000 g a.e. ha^{-1}). Visual assessments about the phytotoxic effect were made on 7, 14, 21, and 28 days after application (DAA). The evaluated species have different sensitivities to glyphosate and *U. brizantha* cv. BRS Paiaguás and *U. ruziziensis* are the most susceptible to this herbicide. The doses of herbicide affect the death kinetics of these forage species. Higher doses of glyphosate reduce the desiccation time of these forage plants.

Keywords: Ipyporã, No-tillage cropping system, Paiaguás, Piatã, Straw.

Dessecação de plantas forrageiras do gênero *Urochloa* com uso do herbicida glifosato

RESUMO

As espécies de forrageiras, em especial as do genêro *Urochloa* tem sido uma importante alternativa para utilização no Sistema de Plantio Direto (SPD) devido a boa produção de biomassa e alta relação C/N. Contudo, para o bom desenvolvimento da cultura subsequente, deve-se realizar a dessecação dessas forrageiras de maneira eficiente, com a utilização de herbicidas. Deste modo, objetivou-se nesse trabalho a investigação da cinética de morte das espécies forrageiras do gênero *Urochloa* submetidas a diferentes doses do herbicida glifosato. Os tratamentos consistiram na combinação de quatro espécies forrageiras (*Urochloa brizantha* cv. BRS Paiaguás, *U. ruziziensis*, *U. brizantha* cv. Piatã e *U. spp*. cv. Ipyporã) submetidas à aplicação de quatro doses do herbicida glifosato (250; 500; 1000 e 2000 g de equivalente ácido de glifosato ha^{-1}). Foram realizadas avaliações visuais do efeito fitotóxico aos 7, 14, 21 e 28 dias após a aplicação (DAA) do herbicida. As espécies possuem sensibilidade diferente ao herbicida glifosato, sendo que *U. brizantha* cv. BRS Paiaguás e *U. ruziziensis* são as espécies mais susceptíveis ao herbicida. A cinética de morte das forrageiras é afetada pela dose aplicada do herbicida. A aplicação de doses maiores do herbicida, reduz o tempo para dessecação das forrageiras.

Palavras-chave: Paiaguás, Piatã, Ipyporã, Palhada, Plantio Direto.

1. Introduction

The expansion of cropped lands under no-tillage systems (NTS) is expressive. Currently, almost all countries have cropped lands under this system. According to the FAO (2015), about 157 million hectares around the world are carried out like this way. Only in Brazil, around 35 million hectares are cropped using NTS (Febrapdp, 2018). Nevertheless, both the formation and maintenance of straw on soil are challenges for the implantation of NTS in Brazil, mainly in the Cerrado biome, because of favorable climate conditions for litter decomposition (Timossi et al., 2016; Silva et al., 2021). Therefore, the cropping of species with great biomass production is necessary for the successful no-tillage in the Brazilian Cerrado (Freitas et al., 2013).

Tropical forage species, mainly those from the *Urochloa* genus have been shown relative success to supply biomass for NTS in agricultural lands (Freitas et al., 2013; Santos et al., 2015; Da Silva et al., 2018). In this cropping system, the introduction of forage species can be made under intercropping with crops like maize (Kichel et al., 2018; Da Silva et al., 2018), sorghum (Buffara et al., 2018), sunflower (Kimecz et al., 2018) and soybean (Erasmo et al., 2017), either in a rotation cropping system or under monocropping aiming the straw production.

Among the commercially available forage species from the *Urochloa* genus, the *U. ruziziensis* stands out due to its agronomic traits and forage yield (Duarte et al., 2019), besides its soil cover and capacity to maintain the soil moisture in a no-tillage cropping system (Buffara et al., 2018). However, many species like the *U. brizantha* cv. Piatã. The *U. brizantha* cv. Paiaguás (Santos et al., 2015) and the *U.* spp. BRS Ipyporã (Oliveira et al., 2020) have been demonstrated viability for implantation in production-integrated systems (PIS), producing forage in the off-season for animal feeding, and straw for the NTS after desiccation.

However, the efficient desiccation of vegetal cover is essential for the good development of the subsequent crops, and glyphosate is the most used herbicide for this purpose, either as a single source or associated with other ones (Constantin et al., 2008). This herbicide has a systemic action and non-selective one, and it is able to kill a significant number of vegetal species (Brio et al., 2018). Glyphosate is translocated by the plant through the phloem, from the aboveground part to the root system, rhizomes and meristematic tissues, inhibiting the 5-enolpyruvyl-shikimate-3-phosphate synthase (EPSP). Without this enzyme, the plants are not able to produce other essential proteins to grow and develop themselves, and end up dying because of that (Oliveira Júnior, 2011; Radwan and Fayez, 2016).

Brighenti et al. (2011) reported that there are different susceptibilities of the species *U. brizantha* cv. Marandu, *U. decumbens* and *U. ruziziensis* regarding the use of glyphosate herbicide. According to the authors, among the assessed species, the *U. ruziziensis* was more sensitive to glyphosate action, and its desiccation needed lower doses of herbicide.

Considering the constant releases of cultivars from the *Urochloa* genus in the Brazilian agribusiness, such as the *U. brizantha* cv. Piatã, the *U. brizantha* cv. BRS Paiaguás and the *U.* spp cv. Ipyporã, there is a lack of information about the susceptibility of these materials to glyphosate aiming the desiccation before implanting no-tillage systems. Thereby, the objective of this work was to investigate the death kinetics of forage species from the *Urochloa* genus submitted to different doses of glyphosate.

2. Material and Methods

The study was carried out at the experimental area from the University Center of Goiás (UNIGoiás), Goiânia-GO, 16°69'24.0" S and 49°31'02.43" W, from October to November 2019 with an average accumulated rainfall of 1924 mm year-1 and well-defined seasons. The rainy season occurs from November to March, and the dry season is from April to October (Inmet, 2019). Climate data are displayed in Figure 1.

Treatments were distributed in a randomized complete block design, arranged in a 4 × 4 factorial scheme with four repetitions. These treatments consisted of combinations between four *Urochloa* forage species (*Urochloa brizantha* cv. BRS Paiaguás, *U. ruziziensis*, *U. brizantha* cv. Piatã, and *U. spp.* cv. Ipyporã) and four doses of glyphosate [250; 500; 1,000, and 2,000 g of acid equivalent per hectare (g a.e. ha^{-1})]. Forage species were already established in the experimental area, and they were sowed in the 2018/2019 harvest. The experimental plots (repetitions) had 2.0 × 2.5 m (5.0 m^2) and 0.5 m spacing between them.

The glyphosate-based herbicide was the Zapp Qi® 620 (500 g L^{-1} of acid equivalent, SL, Syngenta), which was applied with the aid of a CO_2-pressurized backpack sprayer with 200-kPa constant pressure. This apparatus had a spray bar with two flat-jet TeeJet 80.02 VS and an application capacity of 200 L ha^{-1}. During the spraying of each plot, the herbicide was used on a plastic canvas to avoid the drift of glyphosate for near plots. The herbicide application was made at the flowering stage of forage plants. Visual assessments were done at 7, 14, 21, and 28 days after application (DAA), through grades regarding the symptoms showed by the plants, according to the methodology from the European Weed Research Council (Ewrc, 1964) and adopted by the Brazilian Society of Weed Science (Sbcpd, 1995). The grading scale is displayed in Table 1.

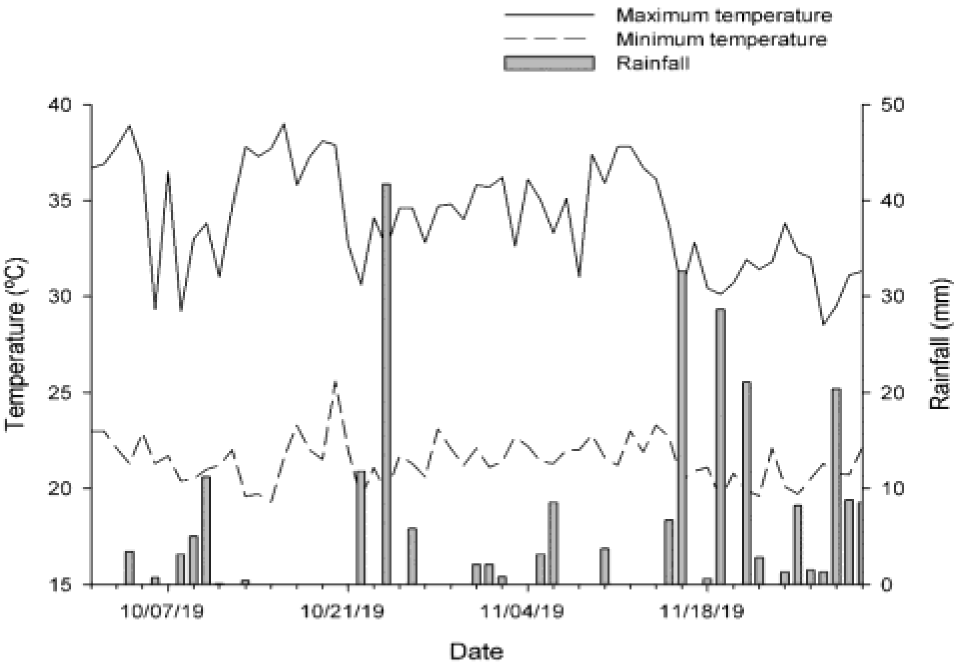

Figure 1. Climate data of maximum and minimum temperatures during the experimental period (Inmet, 2019).

Table 1. Assessment index and description of the plants' phytotoxicity according to the EWRC method (EWRC, 1964).

Assessment index	Description of the phytotoxicity
1	No damage.
2	Few visible alterations in some plants (discoloration and deformation).
3	Few visible alterations in many plants (chlorosis and wrinkling).
4	Heavy discoloration or moderate deformation without necrosis.
5	Necrosis of some leaves, with deformations of shoots and leaves.
6	Reduction of plant size, wrinkling and leaves' necrosis.
7	Over 80% of leaves were destroyed.
8	Extremely several damages in the plants, with only few green parts remaining.
9	Plants' death.

Source: Cavalieri et al. (2008).

Data were submitted to analysis of variance, and when pertinent, the factor 'species' was submitted to Scott-Knott's test ($p \leq 0.05$) while the factor 'glyphosate dose' was submitted to regression analysis with the aid of the R free software.

3. Results and Discussion

The forage species showed different responses regarding the mortality at 7 and 14 days after application (DAA) of the glyphosate-based herbicide (Table 2). At 7 DAA, the *Urochloa ruziziensis* showed high mortality (76.88%). There was an interaction effect between glyphosate dose and forage specie on the mortality at 14 DAA. From the 21 DAA, there was no difference in the mortality of plants. At 14 DAA, the *U. ruziziensis* and *U. brizantha* cv. BRS Paiaguás had the highest mortality of plants, with 93.38 and 88.38%, respectively (Table 2). These results corroborate those found by Brighenti et al. (2011) and Silveira et al. (2017). According to these authors, species from the *Urochloa* genus have different susceptibilities to glyphosate-based herbicides, mainly the *Urochloa ruziziensis*, which exhibits a particular sensitivity.

The obtained results demonstrated that forage species like *U. brizantha* cv. BRS Paiaguás and *U. ruziziensis* showed greater susceptibility to glyphosate, presenting high mortality rates until 14 DAA (Table 2). Therefore, these two species are more indicated to provide straw for the no-tillage system since they allow quicker sowing of the subsequent crop than the *U. brizantha* cv. Piatã and *U.* spp. Ipyporã. The sowing delay during the crop season can reduce the yield of successor crops such as soybean and maize (Carmo et al., 2018; Silva et al., 2018; Toller et al., 2018; Almeida et al., 2020). This delay submits the plants to unfavorable conditions of growth and development, that is, greater average temperatures and less rainfall (Toller et al., 2018).

Table 2. Death kinetics of *Urochloa* species submitted to different doses of glyphosate for desiccation, Goiânia-GO, 2019.

Source of variation	Squares means of the analysis of variation			
Species (E)	6282.27**	1086.23*	232.93	437.77
Dose (D)	4673.27**	5278.27**	1845.47*	3026.73**
S*D	290.81	835.36*	226.32	653.33
Block	406.82	2451.56	1174.55	1483.31
Residue	11477.19	17735.44	21347.70	16332.19
	Plants' mortality (%)			
Species	7 DAA	14 DAA	21 DAA	28 DAA
Paiaguás	58.94 b	88.38 a	94.06	95.94
Ruziziensis	76.88 a	93.38 a	94.13	95.63
Ipyporã	35.31 c	74.75 b	87.19	86.06
Piatã	36.75 c	80.63 b	87.81	87.50
CV (%)	30.73	23.56	23.99	20.87

*Means followed by the same lowercase letter in the column do not differ from each other, by the Scott-Knott's test ($p \leq 0.05$); ** ($p \leq 0.001$); DAA: days after application.

Regarding the herbicide doses, at 7 DAA, the highest mortality of plants occurred with the application of 1,440 g a.e. ha^{-1}. Under this dose, 70% of the plants died (Figure 2). These results corroborate those verified by Silveira et al. (2017), which investigated photosynthetic aspects of *U. ruziziensis* and *U. decumbens* and reported a drastic reduction in the fluorescence ratio of the desiccated species right after one week of herbicide application.

At 14 DAA, there was an interaction effect between glyphosate dose and forage species on mortality (Table 2). The species *U. ruziziensis* and *U. brizantha* cv. BRS Paiaguás showed mortality rates of around 90% with doses over 500 g a.e. ha^{-1} (Figure 3). These results represent significant importance in the decision-making of producers since they increase the options of susceptible species to glyphosate. To completely desiccate both the *U.* spp. cv. Ipyporã and *U. brizantha* cv. Piatã at 14 DAA, the applied dose must be higher, which increases the production costs. Efficient desiccation avoids problems for the subsequent crops, mainly preventing the regrowth of the straw crop that can harm the development of successor crops (Machado and Assis, 2010).

These results represent significant importance in the decision-making of producers since they increase the number of species with mortality rates of over 80%. However, to reach this rate, the needed herbicide dose was 1,429 g a.e. ha^{-1}. Such behavior can be explained, in part, by the applied dose. Therefore, the greater the dose, the greater the rate of mortality of plants (Figure 3). Glyphosate is rapidly translocated from the leaves to the meristematic and reserve tissues (Brito et al., 2018). Therefore, doses lower than 90 g a.e. ha^{-1} are not enough to cause the plant death.

From the second assessment after the glyphosate application, the highest results of mortality of plants were observed under doses of 1,541 g a.e. ha^{-1} at 21 DAA and 1,437 g a.e. ha^{-1} at 28 DAA, regardless of the studied species (Figure 4). Using these doses allowed reaching a mortality rate of 100%. Silva et al. (2018) reported desiccation over 95% when they applied 1,440 g a.e. ha^{-1} of glyphosate on swards formed by *U. ruziziensis*.

Using glyphosate as an herbicide affects the biosynthesis of indoleacetic acid (IAA) (Bertoncelli et al., 2018) due to the interruption in the production of both the tryptophan and chorismate amino acids (Taiz et al., 2017). Therefore, under-doses of glyphosate do not completely stop the EPSPS activity (Pincelli-Souza et al., 2020), which justifies the lower mortalities under lower glyphosate doses. Moraes et al. (2019) verified the total mortality of *U. decumbens* plants at 21 DAA under doses over 360 g a.e. ha^{-1}. However, the authors reported that the sensitivity to the herbicide depends on the development stage of plants. In this sense, greater doses are necessary to desiccate plants in the flowering stage, as occurred in this experiment.

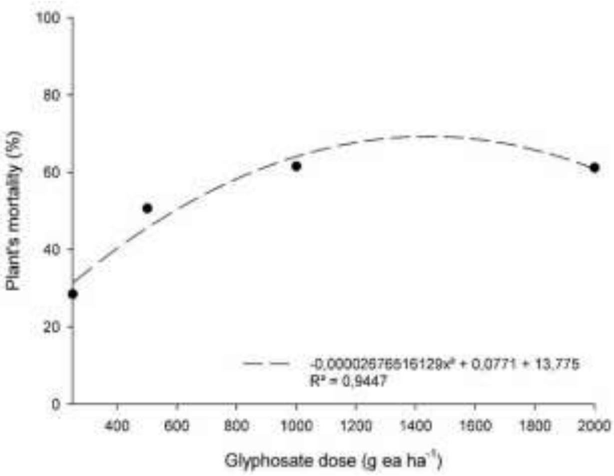

Figure 2. Mortality of plants from Urochloa genus at 7 days after application (DAA) of glyphosate for desiccation.

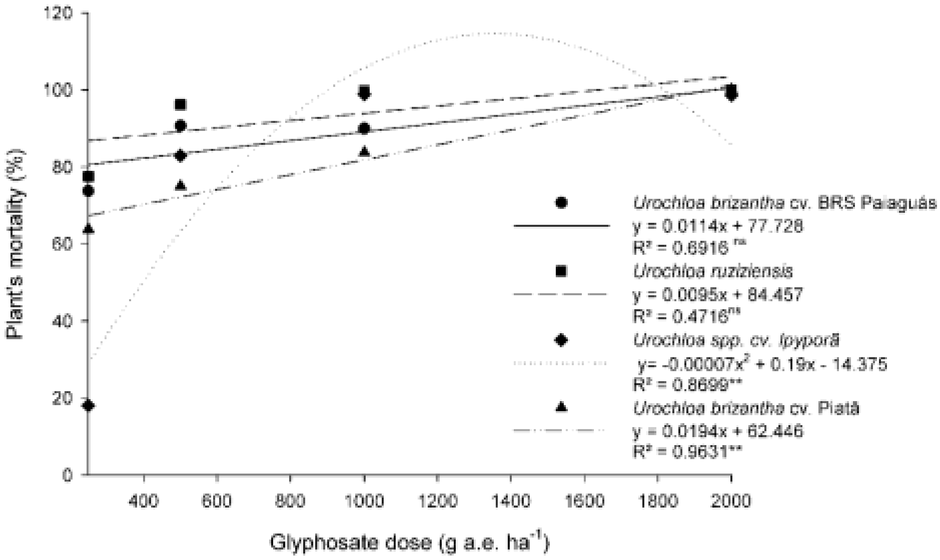

Figure 3. Mortality of plants from *Urochloa* genus at 14 days after application (DAA) of glyphosate for desiccation.

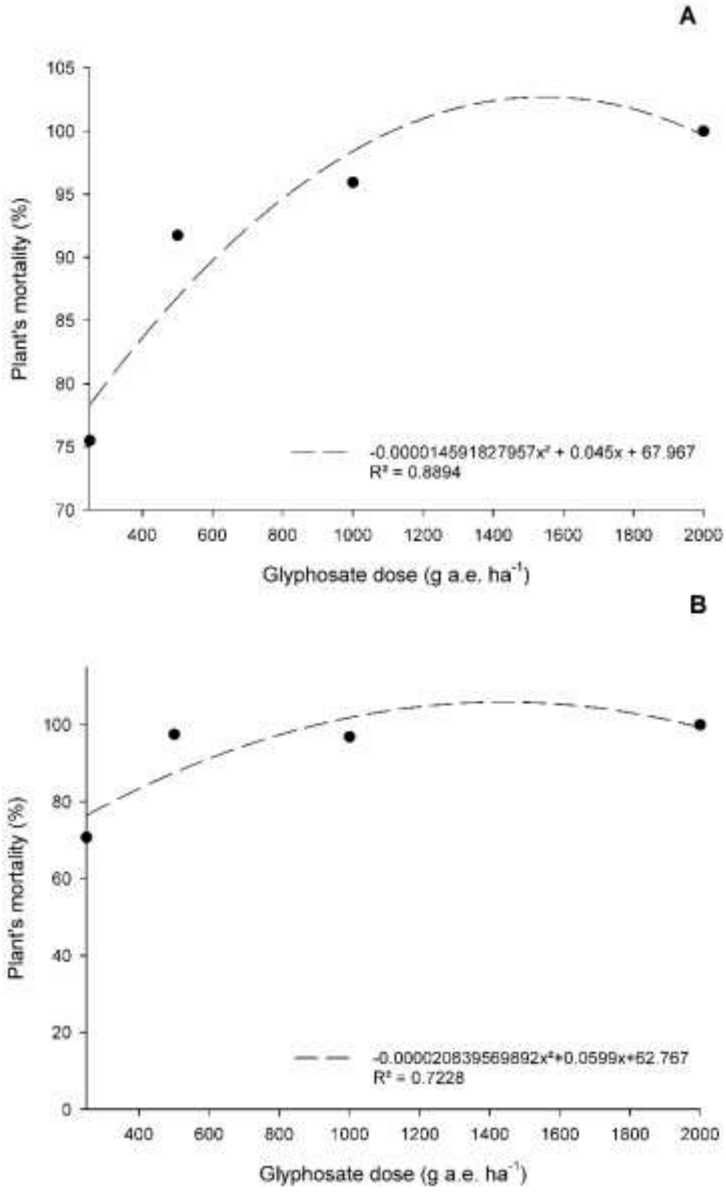

Figure 4. Mortality of plants from *Urochloa* genus at 21 (A) and 28 (B) days after application (DAA) of glyphosate for desiccation.

4. Conclusions

Urochloa species display different susceptibilities to glyphosate-based herbicides. The *U. ruziziensis* and the *U. brizantha* cv. BRS Paiaguás have greater sensitivity to glyphosate, which allows lower doses and faster desiccation. Glyphosate doses change the death kinetics of *Urochloa* forage plants, and greater doses reduce the time expended with desiccation.

Authors' Contribution

Fenelon Lourenço de Sousa Santos contributed to the execution of the experiment, data collection, analysis and interpretation of results, writing of the manuscript and final correction of the manuscript. Walisson Tavares da Silva contributed to the data collection, writing and statistical analysis and graphics creation. Francine Neves Calil contributed to the writing and data analysis. Patrícia Ribeiro da Cunha, Rommel Bernardes da Costa e Paulo Alcanfor Ximenes contributed to the design of the experimental arrangement, analysis and review of references

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