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Management of *Urochloa ruziziensis* with glyphosate in integrated system with glyphosate-resistant corn

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ABSTRACT

This study aimed to evaluate the efficiency of the glyphosate doses in the suppression of *Urochloa ruziziensis*, to avoid the excessive competition of forage, intercropped with corn in an integrated crop-livestock system. The experiment was conducted in the experimental area of the Escola de Agronomia, of the Universidade Federal de Goiás with glyphosate-resistant corn (*Zea mays* L.) and *Urochloa ruziziensis*. The experimental design was randomized blocks with five treatments and four replications in a factorial scheme, with five herbicide doses x three evaluation periods. Treatments were control - non-sprayed, glyphosate herbicide at doses of 72, 144 and 288 g a.e. ha^{-1}, and standard treatment of 8 g a.i. ha^{-1} of the nicosulfuron herbicide. The sowing was carried out in alternate rows of corn and forage with a spacing of 0.45 m between rows. The treatments were applied with corn at V6 vegetative stage and forage with 4-6 tillers, with evaluations at 7, 14, and 21 days after application. The dose of 72 g a.e. ha^{-1} of glyphosate, had no efficiency in forage suppression. The dose of 144 g a.e. ha^{-1} of glyphosate equaled the dose of 8 g a.i. ha^{-1} of nicosulfuron, which is the standard treatment in this intercropping system. Glyphosate at the dose of 288 g a.e. ha^{-1} caused the forage's death.

Keywords: Intercrop, Forage, Integrated crop-livestock, Suppression.

Manejo de *Urochloa ruziziensis* com glifosato em sistema de integração com milho resistente ao herbicida

RESUMO

O objetivo do trabalho foi avaliar a eficiência de doses do herbicida glifosato na supressão de *Urochloa ruziziensis*, para evitar-se competição excessiva da forrageira, consorciada com milho em sistema de integração lavoura-pecuária. O experimento foi conduzido na área experimental da Escola de Agronomia da Universidade Federal de Goiás com milho (*Zea mays* L.) resistente a glifosato e forrageira *Urochloa ruziziensis*. O delineamento experimental foi em blocos casualizados com cinco tratamentos e quatro repetições em esquema fatorial com cinco doses de herbicida x três períodos de avaliação. Os tratamentos foram testemunha não pulverizada, herbicida glifosato nas doses de 72 g e.a.ha^{-1}, 144 g e.a.ha^{-1} e 288 g e.a.ha^{-1} e tratamento padrão de 8 g i.a.ha^{-1} do herbicida nicosulfuron. O plantio foi realizado em linhas alternadas de milho e forrageira com espaçamento de 0,45m entre linhas. Os tratamentos foram aplicados com milho em estádio vegetativo V6 e forrageira com 4-6 perfilhos com avaliações aos 7, 14 e 21 dias após aplicação. A dose de 72 g e.a.ha^{-1} de glifosato não mostrou eficiência na supressão da forrageira. A dose de 144 g e.a.ha^{-1} de glifosato igualou-se à dose de 8 g i.a.ha^{-1} de nicosulfuron que é o tratamento padrão neste sistema de consórcio. Glifosato a 288 g e.a.ha^{-1} causou a morte da forrageira.

Palavras-chave: Consórcio, Forrageira, Integração lavoura-pecuária, Supressão.

1. Introduction

The integrated crop-livestock systems (ICLS) consists of intercropped grain production, especially corn, sorghum, millet and soybean, with tropical forages, mainly of the *Urochloa* genus (Sin. *Brachiaria*), in both no-tillage and conventional tillage systems, with soil properly corrected, with grain production and concomitant pasture formation (Dias et al., 2018).

The adoption of this intercropping system is a management alternative that provides greater rationality in resource utilization, including time, and reduces weed infestation (Santos et al., 2008; Borges et al., 2014; Timossi et al., 2018). Competition between crop and forage and the resulting scarcity of development factors will occur, and it is necessary to balance the competitive capabilities of the species with the suppression of the forage through the herbicide application (Silva et al., 2016).

The integration of corn and forage of the *Urochloa* genus is one of the best intercropping options due to the high metabolic efficiency of the species involved and the excellent adaptation of the forages to the Midwest region soils and climate, using basically the forages *Urochloa brizantha* and *Urochloa decumbens*, and the nicosulfuron herbicide is widely used as a standard tool for forage suppression (Ferreira et al., 2007; Cavalieri et al., 2008; Silva et al., 2014; Freitas et al., 2015).

More recently, there has been significant interest in the integration of corn with RR transgenic event associated with the species *Urochloa ruziziensis*, using the glyphosate herbicide in forage suppression as an alternative to the nicosulfuron herbicide (Silveira et al., 2017; São Miguel et al., 2018). This would combine a species with excellent characteristics such as forage and cover crops with a resistant crop to the herbicide that would allow active principle diversification, as well as good suppression of the forage for pasture or soil cover (Lima et al., 2014; Ceccon and Concenço, 2014; Jasper et al., 2015; Machado et al., 2018).

The objective of this work was to determine the best dose of glyphosate herbicide for the suppression of *Urochloa ruziziensis* in integrated crop-livestock systems with glyphosate-resistant corn.

2. Material and Methods

The experiment was carried out in the experimental area of the Escola de Agronomia (EA), of the Universidade Federal de Goiás (UFG), in Goiânia-GO (16º 44’ S and 49º 44’ W, 749 m a.s.l.).

The climate is tropical semi-humid, classified as Aw, according to Köppen and Geiger, with an annual average temperature of 23.1 °C and an annual average rainfall of 1,414 mm. During the experiment, the average temperature was 32.9º C and 0.0 mm of precipitation.

The soil, a Latossolo Vermelho, typical of tropical climate regions, was collected in the 0-20 cm layer and analyzed at the Soil Fertility Laboratory of the EA-UFG. The main soil characteristics are shown in Table 1, and the sowing of the crops was carried out on August 02, 2017.

The experimental design was randomized blocks with five treatments and four replications in a factorial scheme with five herbicide doses x three evaluation periods. The treatments were control - non-sprayed - (T1), herbicide glyphosate at 72 g a.e. ha^{-1} (T2), at 144 g a.e. ha^{-1} (T3) and 288 g a.e. ha^{-1} (T4), and standard treatment of 8 g. a.i. ha^{-1} of the nicosulfuron herbicide (T5), according to Ferreira et al. (2007) and Freitas et al. (2015).

The treatments were applied at 32 days after sowing. The forage was at the 4-6 tillers stage, intermediate between those proposed by Silveira et al. (2017) and Brighenti et al. (2011), and the corn was at the six-leaf stage (V6). Applications were made with a CO_2 pressurized sprayer equipped with a bar with a TeeJet 80.02 VS flat nozzle spray, at a constant pressure of 200 kPa, providing an application volume of 200 L ha^{-1} (Carvalho et al., 2015).

The herbicides used were glyphosate with 360 g a.e. L^{-1} of N-(phosphonomethyl) glycine, and nicosulfuron with 40 g a.i. L^{-1}, expressing the concentration of each product as usual in the literature (Cavalieri et al., 2008; Freitas et al., 2015; Silva et al., 2016; Silveira et al., 2017; Machado et al., 2018). Fertilization was carried out to meet the corn crop requirements with the application of 320 kg ha^{-1} of formulated fertilizer 5-25-15, which provided 16 kg of N_2, 60 kg of P_2O_5, and 48 kg of K_2O, according to Vilela et al. (2002). One week before the sowing of the crops, the area was sprayed using a mixture of 1,197 g a.e. ha^{-1} glyphosate, and 60 g a.i. ha^{-1} ethyl carfentrazone to the weed control.

Simultaneous sowing of the glyphosate-resistant corn and *Urochloa ruziziensis* was done in alternate rows spaced 0.45 m, with the corn seeds placed at 5 cm and the forage seeds at 3 cm deep. The sowing rate of *Urochloa ruziziensis* was 6,1 kg ha^{-1} of seeds. The stands were 3.8 corn plants and 40 *Urochloa ruziziensis* plants per meter, which arrangement was intended for forage production as Ceccon et al. (2010). The area was conducted under the no-tillage system for about six years.

Irrigation, with a 40% percentimeter, was performed by applying a 3 mm water depth three times a week for the first 14 days, with corn at the two-leaf stage (V2). Then, water management was changed by applying a 3 mm water depth five times a week, up to 25 days after sowing.

Table 1. Physicochemical characteristics of the Latossolo Vermelho of the experimental area in the determination of glyphosate doses in the suppression of *Urochloa ruziziensis* in integration with glyphosate-resistant corn. Goiânia-GO. 2017.

Physicochemical characteristics											
pH	Al^{3+}	Ca^{2+}	Mg^{2+}	K^{+}	CEC	P	O.M.	B.S.	Clay	Sand	Silt
5.7	0.0	1.8	0.7	0.38	4.1	1.0	23.3	70	29	51	20

O.M.= organic matter; B.S.= base saturation.

After 25 days of sowing, with corn plants at the four-leaf stage (V4), the water depth was adjusted again to 3 mm three times a week until the end of evaluations of the forage. No topdressing fertilization was performed on the crops.

Forage plants at 7, 14, and 21 DAA (days after application) of herbicides were evaluated for the number of tillers by direct counting and plant height (cm) from the soil surface to the end of the last fully expanded leaf. After cutting the plants close to the ground, the dry matter (g) was determined in a forced air circulation oven at 50ºC until reaching constant weight (Carvalho et al., 2015; Silva et al., 2016). The plots consisted of four rows of 4 m length, two corn, and two forage rows, totaling 7.4 m^2.

Data were analyzed using the SISVAR statistical program (Ferreira, 2011), and means were compared by the Tukey test at 5% probability.

3. Results and Discussion

Interaction between herbicide doses and evaluation periods ($p <0.05$) was observed. At 7 DAA (days after application), all doses showed a reduction of dry matter of plants when compared to the control - non-sprayed (Table 2). The glyphosate at the doses of 72 g and 144 g a.e. ha^{-1} had similar behavior, while nicosulfuron at 8 g a.i. ha^{-1} provided a reduction of around 50% in the dry matter of plants. This would be explained by the inhibition of growth within one or two hours after product absorption, typical of ALS (aceto-lactate synthase) inhibitor herbicides, according to Vidal et al. (2014).

The largest reduction of dry matter was provided by glyphosate at the dose of 288 g. a. e. ha^{-1} with a reduction higher than 50% in the values of this variable. The results confirm the high susceptibility of *Urochloa ruziziensis* to glyphosate, as reported by Brighenti et al. (2011) and Lima et al. (2014), who evaluated doses of glyphosate ranging from 180 to 2,275 g a.e. ha^{-1} in the control of *Urochloa ruziziensis*.

At 14 DAA, only glyphosate at the doses of 144 and 288 g a.e. ha^{-1} and nicosulfuron at 8 g a.i. ha^{-1} caused a reduction in dry matter of plants, indicating that the lowest glyphosate dose evaluated (72 g a.e. ha^{-1}) would be insufficient to maintain forage suppression and inhibit the increase of dry matter. The application of 144 g a.e. ha^{-1} of glyphosate, and 8 g a.i. ha^{-1} of nicosulfuron had similar performance, with a satisfactory reduction of dry matter increment compared to control (Table 2).

At 14 DAA, glyphosate at the dose of 288 g a.e. ha^{-1} caused necrosis and leaf fading, as well as drying of some forage stems, with no increase in dry matter compared to the evaluation at 7 DAA (Table 2). Symptoms of necrosis and leaf fading would already characterize the lethal effect of glyphosate mechanism of action, inhibition of EPSPs (Enol-pyruvyl shikimate phosphate synthase), according to Vidal et al. (2014).

At 21 DAA, glyphosate at the dose of 144 g a.e. ha^{-1} and nicosulfuron at 8 g a.i. ha^{-1} provided a reduction in the dry matter increment, maintaining the forage suppression. The glyphosate at the dose of 72 g e.a. ha^{-1} did not differ from the control, with recovery in dry matter increment of forage at 14 and 21 DAA. Contrary results were observed by Lima et al. (2014), who reported increased susceptibility of *Urochloa ruziziensis* to glyphosate application at 14 DAA compared to the response observed at 7 DAA. Glyphosate at the dose of 288 g a.e. ha^{-1} caused forage death after the last evaluation (Table 2).

Table 2. Dry matter of *Urochloa ruziziensis* plants in the determination of glyphosate doses in the suppression of *Urochloa ruziziensis* in integration with glyphosate-resistant corn. Goiânia-GO. 2017.

Dry matter of plants (g)			
Treatments	Days after application (DAA)		
	7	14	21
T1 (control)	10.3 Ac	18.1 Ab	24.5 Aa
T2 (glyphosate 72 g a.e. ha^{-1})	9.7 Bc	15.8 Ab	23.6 Aa
T3 (glyphosate 144 g a.e. ha^{-1})	7.0 Bcb	8.9 Bb	18.0 Ba
T4 (glyphosate 288 g a.e. ha^{-1})	4.7 Da	4.0 Ca	6.6 Ca
T5 (nicosulfuron 8 g a.i. ha^{-1})	5.2 CDc	9.8 Bb	13.6 Ba

Means followed by the same uppercase letter in the column and means followed by the same lowercase letter in the row do not differ statistically from each other by the Tukey test at 5% probability.

The number of tillers of forage (Table 3), in the first evaluation, was reduced by all treatments. Glyphosate at the dose of 288 g a.e. $ha^{-1,}$ tended to produce a smaller number of tillers, which presented severe necrosis. The satisfactory efficiency in forage tillering suppression at 7 DAA evidences a faster effect than reported by Costa et al. (2013) and Machado et al. (2018), who observed satisfactory glyphosate efficiency in reducing tillers of *Urochloa ruziziensis* only at 14 DAA for plants used to soil cover.

The faster response of forage to glyphosate in tillering reduction, even at the lowest evaluated dose, 72 g a.e. ha^{-1}, could be attributed to the suitable availability of water, via irrigation, under experimental conditions, which according to Ceccon and Concenço (2014) and Machado et al. (2018) increase the susceptibility of *Urochloa ruziziensis* to glyphosate when compared to forage response exposed to eventual water deficits.

It can also be assumed that because they are plants without vegetative propagation, therefore, with fewer reserves. According to Silva et al. (2016), even low doses temporarily reduced forage development due to the mechanism of action of glyphosate that disrupts the shikimate pathway (shikimic acid pathway), responsible for the use of 20% or more of the glucose produced in plant photosynthesis, resulting lower photosynthates availability for the plant cell metabolism, according to Vidal et al. (2014).

At 14 DAA, glyphosate at the dose of 72 g a.e. ha^{-1} no longer showed a reduction in the number of tillers concerning the control. Forage recovery from the initial effect of suppression of the lowest glyphosate dose evaluated (Table 3) was observed. This coincides with that observed by Brighenti et al. (2011), who reported higher susceptibility of glyphosate to *Urochloa ruziziensis* at 7 DAA than at 14 DAA.

Glyphosate at the dose of 144 g a.e. $ha^{-1,}$ and nicosulfuron at the dose of 8 g a.i. ha^{-1} similarly reduced the number of tillers of *Urochloa ruziziensis* concerning the control (Table 3). Silva et al. (2016) observed a reduction of the tillering of *Urochloa brizantha* at the 4-tillers stage with the application of glyphosate at the dose of 144 g e.a. ha^{-1}. In the present study, at the highest glyphosate dose (288 g a.e. ha^{-1}), there was no increase in the number of tillers concerning 7 DAA, indicating inhibition of growth of the *Urochloa ruziziensis*.

At 21 DAA, glyphosate at the dose of 72 g a.e. ha^{-1}, it was not different from the control treatment; and glyphosate at 144 g a.e. ha^{-1} and nicosulfuron at 8 g a.i. ha^{-1} had similar results, causing the decrease of the number of tillers when compared to the control, while the plants submitted to the glyphosate application at the dose of 288 g a.e. ha^{-1}, there was no increase in the number of tillers concerning previous evaluations (Table 3). The results evidence higher susceptibility of the species to glyphosate than that observed by Costa et al. (2013), who reported the emission of new leaves and tillers by *Urochloa ruziziensis* plants after application of glyphosate at doses up to 480 g e.a. ha^{-1}. The inhibition in tiller emission, according to the authors, would indicate the depletion of plant reserves.

For plant height, all treatments had a reduction in the values observed at 7 DAA concerning the control (Table 4). This suppression effect persisted at 14 DAA, glyphosate at doses of 72 and 144 g a.e. ha^{-1}, and nicosulfuron at the dose of 8 g a.i. ha^{-1} had similar performance in reducing plant height. Moreover, the lowest glyphosate dose evaluated (72 g a.e. ha^{-1}) maintained its suppressive effect on forage at 14 DAA, which was not observed for the other evaluated variables.

The action of glyphosate could explain this suppression of plant height in reducing auxin levels of plants by inhibiting the synthesis of its precursor, the amino acid tryptophan; and by reducing internode length and stem thickening caused by reduced sugar supply and inhibition of mitosis in apical meristems caused by nicosulfuron (Vidal et al., 2014).

The application of glyphosate at the dose of 288 g a.e. ha^{-1} provided the largest reduction in plant height concerning the control, preventing the increase of height concerning the first evaluation. This behavior was maintained in the evaluations at 14 DAA and 21 DAA, demonstrating an overdose effect for *Urochloa ruziziensis* plants under the conditions of the experiment (Table 4).

There was no suppressive effect of Glyphosate at the dose of 72 g a.e. ha^{-1} on plant height at 21 DAA. Glyphosate at the dose of 144 g a.e. ha^{-1} and nicosulfuron at the dose of 8 g a.i. ha^{-1} maintained the reduction in height growth of *Urochloa ruziziensis* plants (Table 4). According to Silveira et al. (2017), the effect of glyphosate at a dose of 360 g a.e. ha^{-1} on this forage's photosynthetic system, would intensify from 15 DAA, due to the cumulative effect of reduced energy transfer from the light capture system to photosystem II reaction centers.

Glyphosate at a dose of 288 g a.e. ha^{-1} caused forage death at the 4-6 tillers stage, which evidences the high susceptibility of the species to the herbicide. Silva et al. (2016) reported the death of *Urochloa brizantha* plants at the 4-tillers stage, but with a higher dose (480 g a.e. ha^{-1} glyphosate).

Table 3. Number of tillers per plant of *Urochloa ruziziensis* in the determination of glyphosate doses in the suppression of *Urochloa ruziziensis* in integration with glyphosate-resistant corn. Goiânia-GO. 2017.

Number of tillers per plant			
Treatments	Days after application (DAA)		
	7	14	21
T1 (control)	15.7 Ac	21.0 Ab	25.0 Aa
T2 (glyphosate 72 g a.e. ha^{-1})	11.9 Bc	18.0 Ab	24.8 Aa
T3 (glyphosate 144 g a.e. ha^{-1})	10.5 Bc	13.3 Cb	21.6 Ba
T4 (glyphosate 288 g a.e. ha^{-1})	6.9 Ca	8.0 Da	10.7 Ca
T5 (nicosulfuron 8 g a.i. ha^{-1})	8.5 BCc	15.5 BCb	18.5 Ba

Means followed by the same uppercase letter in the column and means followed by the same lowercase letter in the row do not differ statistically from each other by the Tukey test at 5% probability.

Table 4. Plant height of *Urochloa ruziziensis* in the determination of glyphosate doses in the suppression of *Urochloa ruziziensis* in integration with glyphosate-resistant corn. Goiânia-GO. 2017.

Plant height (cm)			
Treatments	Days after application (DAA)		
	7	14	21
T1 (control)	28.7 Ac	36.8 Ab	46.3 Aa
T2 (glyphosate 72 g a.e. ha^{-1})	24.9 Bc	31.0 Bb	44.7 Aa
T3 (glyphosate 144 g a.e. ha^{-1})	21.5 Bc	26.0 Bb	36.9 Ba
T4 (glyphosate 288 g a.e. ha^{-1})	19.4 Ba	18.8 Ca	19.4 Ca
T5 (nicosulfuron 8 g a.i. ha^{-1})	20.3 Bc	28.3 Bb	31.1 Ba

Means followed by the same uppercase letter in the column and means followed by the same lowercase letter in the row do not differ statistically from each other by the Tukey test at 5% probability.

4. Conclusions

The use of glyphosate, at a dose of 144 g a.e. ha^{-1}, was efficient in the suppression of *Urochloa ruziziensis*, being an alternative for forage management, intercropped with glyphosate-resistant corn, in the integrated crop-livestock system.

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