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INFLUENCE OF TIME OF GLYPHOSATE APPLICATION IN THE CONTROL OF BRACHIARIA

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ABSTRACT

In the no-tillage system, the burndown of brachiaria is usually performed with the application of systemic herbicides, such as glyphosate. As a result of environmental conditions (temperature, relative humidity and winds), the timing of spraying can directly interfere in the control efficiency. Therefore, the objective was to study different times of application of glyphosate in the control efficiency of *Urochloa brizantha* cv. Marandu. The glyphosate was applied in the morning, afternoon and evening, at doses of 0; 360; 720; 1080; 1440 and 2160 g a.e. ha^{-1}. Water-sensitive papers were placed randomly on the plants at each time of application, in order to check the quality of spraying. To analyse the efficiency of *U. brizantha* burndown, the control was evaluated at 21 days after application. At 42 after application a mowing was done and 90 days after mowing, the dry matter accumulation and the Leaf Area Index of regrowth were determined. The best control results of *Urochloa brizantha* cv. Marandu were obtained in the applications of glyphosate during the morning and afternoon. Evening applications of glyphosate should be avoided.

Palavras-chave:
Tecnologia de aplicação
dessecação
condições ambientais
Urochloa brizantha

INFLUÊNCIA DO HORÁRIO DE APLICAÇÃO DE GLYPHOSATE NO CONTROLE DA BRAQUIÁRIA

RESUMO

No sistema de plantio direto, a dessecação da braquiária geralmente é realizada com a aplicação de herbicidas sistêmicos, como o glyphosate. Como resultado das condições ambientais (temperatura, umidade relativa e ventos), o horário da aplicação pode interferir diretamente na eficácia de controle. Portanto, o objetivo foi estudar diferentes horários de aplicação do glyphosate na eficácia do controle de *Urochloa brizantha* cv. Marandu. O glyphosate foi aplicado pela manhã, tarde e noite, nas doses de 0; 360; 720; 1080; 1440 e 2160 g e.a. ha^{-1}. Papéis hidrossensíveis foram colocados aleatoriamente nas plantas a cada horário de aplicação, a fim de verificar a qualidade da pulverização. Para analisar a eficácia da dessecação da *U. brizantha*, a fitotoxicidade foi avaliada 21 dias após a aplicação. Aos 42 dias após a aplicação, foi realizada uma roçada e aos 90 dias após a roçada, foram determinados o acúmulo de matéria seca e o Índice de Área Foliar da rebrota. Os melhores resultados de controle de *Urochloa brizantha* cv. Marandu foram obtidos nas aplicações de glyphosate durante a manhã e a tarde. As aplicações noturnas de glyphosate devem ser evitadas.

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INTRODUCTION

The no-tillage system is considered an important tool for sustainable production. In this system, the species of the genus *Urochloa* are the most used for straw formation (TIMOSSI *et al*., 2006) and the cultivar Marandu has become the most relevant of this genus in Brazil (RIBEIRO JÚNIOR *et al*., 2017). Generally, no-tillage burndown is done with systemic herbicides, such as glyphosate (COSTA *et al*., 2014).

Glyphosate is a herbicide with a broad spectrum of control, non-selective and recommended for application in postemergence (GALLI, 2009). It is mainly absorbed by the leaves and has a systemic effect. Its translocation occurs mostly via the phloem in a biphasic process, through aqueous pores present in the cuticle, followed by a slow symplastic absorption (WANG; LIU, 2007). For many years, it has been the most widely used herbicide in the world.

When used for burndown, their dosages may vary according to the species, stage of plant development and the plant mass (TIMOSSI *et al*., 2016). However, increasing the dose of glyphosate can cause several side effects, such as impacting on non-target organisms (CASABE *et al*., 2007) and, mainly, favouring the selection of weeds resistant to the product (VIDAL *et al*., 2014), causing an increase in the production cost.

According to Matuo *et al*. (2001), in the application of pesticides, the biologically active product should be applied on the target, with a minimum dose needed to cause an effect, as well as causing the least contamination in other areas as possible. However, in several situations these requirements are not met, due to the need to spray in large areas that can occur throughout the day (morning, afternoon and evening) even in unfavourable conditions (ALVARENGA *et al*., 2014). These conditions are considered favourable when the temperature is below 30 °C, the relative humidity is above 55% and the wind speeds is up to 12 km h^{-1} (CUNHA *et al*., 2016).

Studies have shown that the time of application of the day and environmental conditions are directly linked to the deposition of pesticides on the target and can also affect the effectiveness of glyphosate. (MACIEL *et al*., 2016; BALAN *et al*., 2008; MOHR *et al*., 2007). However, the use of higher doses of herbicides can hinder the observation of the performance of biological phenomena associated with environmental conditions (TIMOSSI *et al*., 2016).

Therefore, the objective was to study different times of application and their influences on the glyphosate doses recommended for the control of *Urochloa brizantha* cv. Marandu.

MATERIAL AND METHODS

The experiment was conducted from November 2017 to September 2018, in the experimental field (20°46’ S, 42°52’ W, 650 m above sea level). The climate of the region is characterized by humid subtropical, with a dry winter and a hot summer, according to the Köppen-Geiger classification.

The preparation of the area for planting the brachiaria consisted of a burndown using a mixture of glyphosate (2,160 kg of a.e. ha^{-1}) and 2,4-D (670 g a.e. ha^{-1}). This led to a formation of straw before the introduction of *U. brizantha* in the no-tillage system. No-tillage seeder (Semeato SHM 11/13) was used to sow 16 Kg ha^{-1} of seeds of the species *Urochloa brizantha* cv. Marandu with 36% of pure seed and 50 cm of spacing between lines.

When the plants reached an approximate height of 90 cm, the experimental plots were demarcated, and the treatments were then applied. Each plot measured 4 m in length and 3 m in width. Six doses of glyphosate were evaluated: 0; 360; 720; 1080; 1440 and 2160 g acid equivalent (a.e.) ha^{-1}, using the commercial product Roundup® (0; 1; 2; 3; 4; 6 L ha^{-1}, respectively) and three times of application (morning, afternoon and evening). The treatments were arranged in a factorial scheme 6 x 3 (6 doses and 3 application time of day), in a randomized block design with three replications.

The application of a volume of 50 L ha^{-1} was performed using a backpack sprayer of constant pressure (CO_2) equipped with three TT11001 nozzles, spacing of 1.0 m between them, at a pressure of 3 kPa, a flow rate of 0.4 L min^{-1} and a speed of 4.8 km h^{-1}. At the time of application, two acrylic plates 2.0 m in length and 1.6 m in height were loaded on the borders between plots, to reduce potential spray drift and therefore preventing the contamination between plots.

At the beginning and at the end of each application, the values of temperature, relative humidity and wind speed were measured using a Kestrel pocket weather meter, model K3000 (Table 1). No rain was observed in a period of at least 48 h after installation of the treatments.

Twenty water-sensitive papers (WSP) were placed randomly on the plants at each time of application, in order to quantify the droplet density (number of droplets cm^{-2}), percentage of covered area (%), relative amplitude, numerical median diameter (NMD) and volume median diameter (VMD) and all these can be considered good parameters to quantify the deposition of droplets and to verify the spraying quality (MOTA, 2011). The WSP were then stored in envelopes and transferred to a glass desiccator containing silica, to avoid exposition to humidity. The reading of the cards and the posterior evaluation of the data were carried out using a scanner and the DropScope® program. The values of the 20 WSP were averaged at each time of application, just to confirm the deposition of the application.

The efficiency of burndown was determined through the visual evaluation of the control effects of *Urochloa brizantha* cv. Marandu, using a percentage scale of scores, in which 0 (zero) corresponded to no injury of the plants and 100 (one hundred) to the plant death, as suggested by the Brazilian Society of Weed Science - SBCPD (1995). The parameters used to establish the scores were: quantity and uniformity of injuries, growth inhibition and plant mortality.

The evaluations of the control effects were carried out at 21 days after the installation of the treatments. A mowing was done at 42 days after application (DAA) of the herbicide, to determine the regrowth capacity. At 90 days after mowing, the dry matter accumulation and the leaf area index (LAI) of the brachiaria were determined using a hollow metal square size of 0.50 m x 0.50 m, which was launched twice in each plot. The brachiaria was cut at ground level and placed in identified plastic bags. The leaf area of the cut plants was determined using a bench meter (Licor Equipamentos® 3100). These values were used to calculate the LAI, which is defined by the ratio of the area of leaves within a given soil area (m^2 leaves m^2 soil^{-1}), according to Rodrigues (1985).

After determining the leaf area, the samples were placed in a forced ventilation oven at 72 ºC until they achieved a constant mass. The material was then weighed (0.01 grams precision scale) to obtain the dry matter accumulation from the brachiaria regrowth of each treatment per hectare.

The experimental data were subjected to an analysis of variance and regression. Tukey's test was used for qualitative factors, at the level of 5% to compare the means. The regression was used for quantitative factors, and the models were chosen based on the significance of the regression coefficients, the determination coefficient (R^2) and on the biological behaviour.

Table 1. Environmental conditions at the time of application of the herbicide glyphosate during treatment installation

Time of Application		Relative Humidity (%)	Temperature (ºC)	Wind speed (km h^{-1})
Morning	Start: 8h	68	25	1.2
	End: 8h30min	60	27	1.6
Afternoon	Start: 13h30min	53	28	1.0
	End: 14h	52	29.2	1.2
Evening	Start: 19h	84	18.5	1.1
	End: 19h30min	87	18	0.9

RESULTS AND DISCUSSION

The application carried out in the morning provided a percentage of covered area of 5.92%, followed by 8.38% and 25.21% in the afternoon and evening, respectively. The deposition of droplets was also greater in the evening application, with 337 droplets cm^{-2} (Table 2).

The values of the relative amplitude found in the different times of application ranged from 0.83 (morning) to 1.58 (evening). According to Matthews *et al*. (2016) the lower the amplitude value (close to zero), the more uniform is the set of droplets in the sample. It is possible that the smallest droplets have evaporated in the morning and afternoon applications, thus reducing the number of droplets (Figure 1) and the relative amplitude.

The visual values of *U. Brizantha* control in the morning and afternoon applications of glyphosate were significantly higher when compared to the values in the evening (Table 3). According to SBCPD (1995), the doses of 720 and 1080 g a.e. ha^{-1} applied in the morning and afternoon, respectively, presented satisfactory levels of control (≥ 80%). On the other hand, the evening application reached only 70% of control, even in the highest doses. These results indicate that the interaction between the herbicide used and the application time of day, may have more influence on the control of brachiaria than the deposition and coverage on the target.

The dry matter of the bracharia regrowth was significantly lower in the treatments applied in the morning and evening, showing a more effective control at these times when compared to the applications in the evening (Table 4). No dry matter in the regrowth was observed, when a dose equal or greater than 1080 g ha^{-1} was applied in the morning and evening.

The evening application in the regrowth of *U. brizantha* provided significantly higher values of LAI when compared to the values achieved after the applications in the morning and afternoon, resulting in less brachiaria control (Table 5). Even at high doses, such as 2160 g a.e. ha^{-1}, a LAI value of 0.65 was found after the evening application. According to Ganie *et al*. (2017) temperature should be considered when determining the proper time of application of glyphosate, and in this study,

Table 2. Average values of the droplets deposited on the water-sensitive papers during glyphosate applications according to the analysis using DropScope® software (Average of 20 WSP)

Time of Application	Coverage (%)	Density (droplets cm^{-2})	Relative Amplitude	VMD	Dv_{10}	Dv_{90}	NMD
Morning	5.90	47	0.83	317	197	462	167
Afternon	8.40	71	0.89	309	186	462	183
Evening	25.20	337	1.58	366	159	750	124

VMD- Volumetric Median Diameter; D10 - droplet diameter below in which the total accumulated volumes are 10% of the volume; D90 - droplet diameter below in which the total accumulated volumes are 90% of the volume; NMD - Numerical Median Diameter.

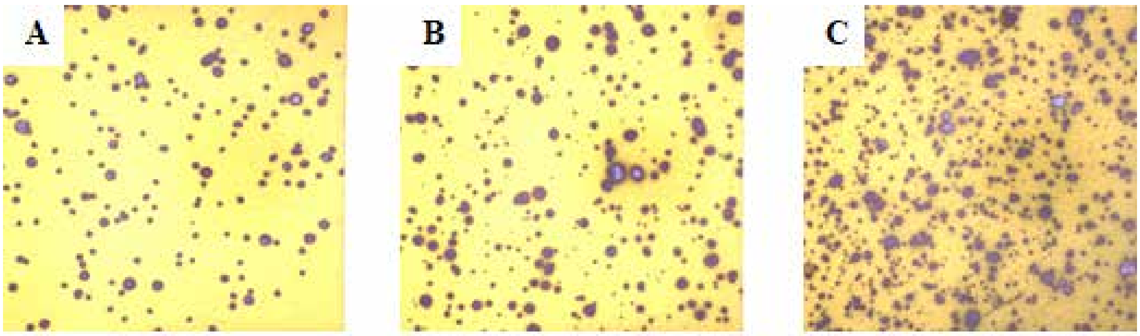

Figure 1. Examples of water-sensitive papers used to verify the deposition of droplets in the morning (A), afternoon (B) and evening (C) applications

Table 3. Averages values of control (%) of *U. brizantha* for the combinations of doses and time of application

Glyphosate (g a.e. ha^{-1})	Morning	Afternoon	Evening
0	0.00 a	0.00 a	0.00 a
360	69.66 a	56.11 a	3.11 b
720	92.55 a	71.22 a	17.22 b
1080	94.44 a	90.44 a	40.55 b
1440	96.44 a	94.44 a	70.00 b
2160	97.66 a	97.66 a	65.77 b

Means followed by the same letter in the same line, do not differ by the Tukey test ($p<0.05$).

Table 4. Average values of dry matter (kg ha^{-1}) in the regrowth of *U. brizantha* for the combinations of doses and time of application

Glyphosate (g a.e. ha^{-1})	Morning	Afternoon	Evening
0	2662.80 a	2580.00 a	2420.40 a
360	390.26 b	508.00 b	2173.20 a
720	178.53 b	317.20 b	1644.66 a
1080	0.0 b	0.0 b	1509.66 a
1440	0.0 b	0.0 b	804.00 a
2160	0.0 b	0.0 b	736.13 a

Means followed by the same letter in the same line, do not differ by the Tukey test ($p<0.05$).

Table 5. Average of LAI values in the regrowth of *U. brizantha* for the combinations of doses and time of application

Glyphosate (g a.e. ha^{-1})	Morning	Afternoon	Evening
0	2.43 a	2.39 a	2.29 a
360	0.41 b	0.57 b	1.80 a
720	0.18 b	0.34 b	1.73 a
1080	0.00 b	0.00 b	1.37 a
1440	0.00 b	0.00 b	0.74 a
2160	0.00 b	0.00 b	0.65 a

Means followed by the same letter in the same line, do not differ by the Tukey test ($p<0.05$).

the temperature in the morning and afternoon was higher than in the evening. As the movement of glyphosate through phloem follows the same route as the products of photosynthesis, conditions that favor photosynthesis also help the translocation of the herbicide (MONQUERO *et al*., 2004).

The control levels tended to stabilize from the dose 414 g a.e. ha^{-1} when the application was carried out in the morning, and from the dose 691.2 g a.e. ha^{-1} when the application occurred in the afternoon period. The applications in the evening presented lower control levels, with a tendency to stabilize only from the dose 1,357.2 g a.e. ha^{-1} (Figure 2).

These results are relevant when working with a more economically and environmentally friendly agriculture, in which the correct time of application of herbicide allows the reduction of the use of pesticides. Vidal *et al*. (2014) stated that simply increasing the dose of herbicides does not guarantee the effectiveness of the control, so that other factors, including the time of application and environmental conditions must be analysed together.

The regression equation of dry matter accumulation in regrowth indicates a tendency for stability from the dose 414 g a.e. ha^{-1} of glyphosate in the morning applications, 434 g a.e. ha^{-1} in the afternoon and 1827 g a.e. ha^{-1} in the evening applications. This last result is 4 times higher when compared to the results obtained in the morning and afternoon and even so it showed higher dry matter of regrowth (Figure 3).

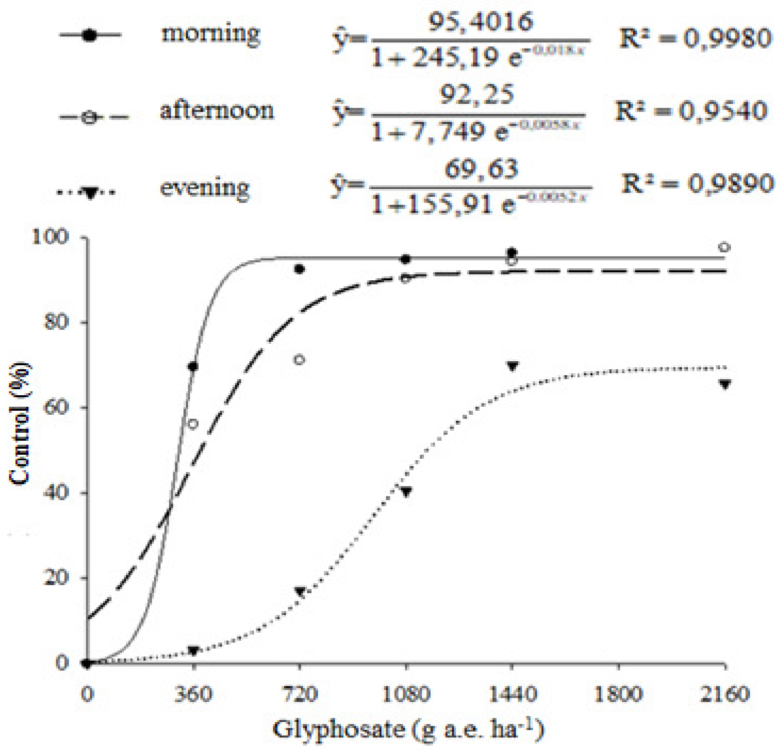

Figure 2. Control at 21 DAA, from *U. brizantha*, for different doses and time of application

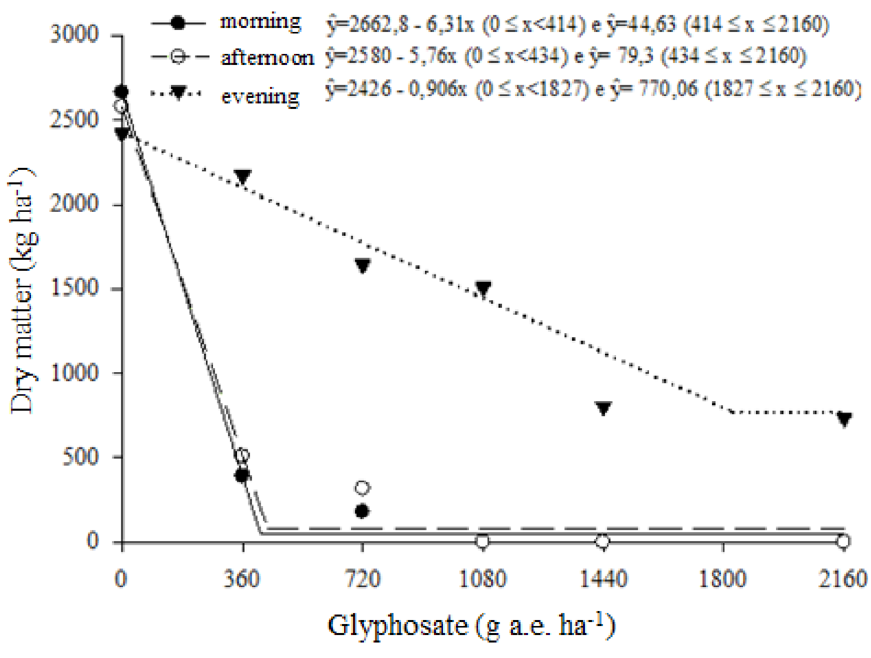

Figure 3. Dry matter of *U. brizantha* at the end of the experiment for different doses and time of application

The leaf area index of brachiaria regrowth adjusted to a regression model called Linear Response Plateau (LRP), with a decline in the LAI up to the 426 g a.e. ha^{-1} in the morning application and up to the dose of 456 g dose ha^{-1} in the afternoon application. In the evening application, for each 360 g a.e. of the glyphosate used, a reduction in the LAI of 0.360 was observed, with a tendency of stabilization at 1949 g a.e. ha^{-1} (Figure 4). Even at the highest doses tested (1440 and 2160 g a.e. ha^{-1}), a great LAI value in regrowth was achieved, leading to less control in the evening applications.

According to Matthews *et al.* (2016), the effectiveness of the pesticide is associated with the deposition of droplets on the target. Thus, it was expected that the greater spray deposition and higher percentage of covered area in the evening application, would provide a more efficient control using a lower dose of the herbicide. This did not happen, which leads to the fact that the joint action of other factors such as the environmental conditions at the time of the application has a big influence on the process. Similar results were found in literature (STEWART *et al.*, 2009; MOHR *et al.*, 2007; MARTINSON *et al.*, 2009).

The relationship between the dose of the herbicide and the plant's response is very important in understanding its effectiveness (SOUZA *et al.*, 2000). It is worth noting that plants from the same species, that would be developed in regions with different environmental conditions, may be more or less sensitive to the same dose of herbicide (PEREIRA *et al.*, 2010). During the experiment, *Urochloa* was able to develop without major environmental stresses, since there was no shortage of rain and the conditions of temperature and relative humidity remained high, favouring the metabolism of the C4 plant.

For plant species that are adapted to the summer, the increase in temperature to optimum plant metabolism values favours the performance of the herbicide glyphosate (VIDAL *et al.*, 2014). This leads to greater absorption and translocation of the herbicide by the plant, as well as greater metabolic activities (FREY *et al.*, 2007). Thus, since *U. brizantha* is a C4 plant, the absorption and translocation of glyphosate may have been favoured in the morning and afternoon applications, as these were carried out in periods of higher temperature, when compared to the evening applications. This may have helped with the control of this plant.

According to Zanatta *et al.* (2007) the relative humidity affects the water status of the plant, changing the stomatal opening and the cuticular permeability. Likewise, the hydration of the cuticle favours the diffusion of water-soluble herbicides, such as glyphosate (VIDAL *et al.*, 2014). Although the relative humidity was higher during the evening, it was always above 50% during the three application periods. These results corroborated with Sharkhuu *et al.* (2014) and Stopps *et al.* (2013) who stated that the application of glyphosate during the daytime favours its activity, when compared to applications at night. In addition, the light intensity can cause microclimatic changes, leading to alterations in the temperature and in the relative humidity (CIESLIK *et al.*, 2014). Higher glyphosate activity, in plants in the presence of light was also

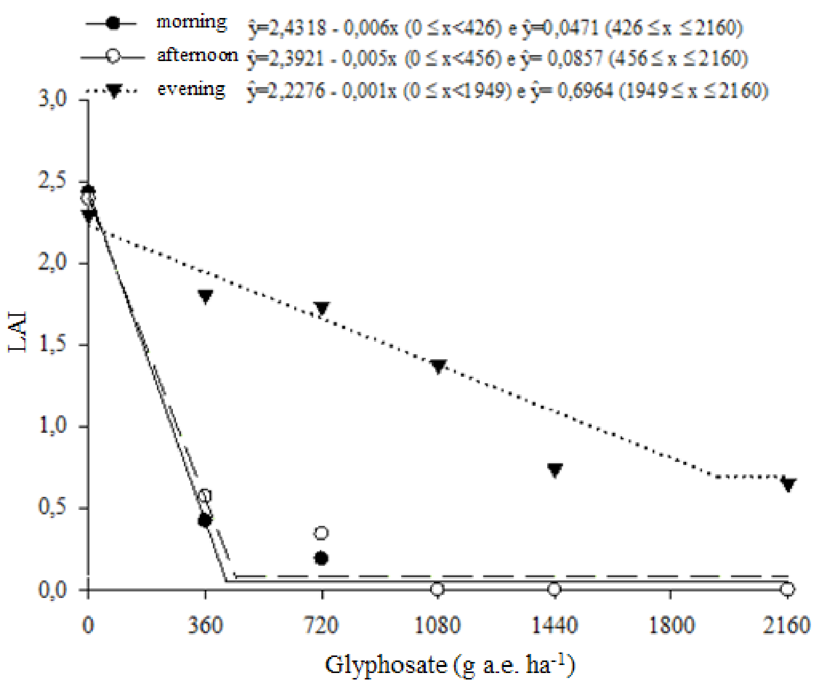

Figure 4. LAI of *U. brizantha* at the end of the experiment for different doses and time of application

found by Santos Jr *et al*. (2013). However, different results were reported by Almeida *et al*. (2014) who found no significant losses in the control efficiency of *Urochloa ruziziensis* in evening glyphosate applications. These results could be related to the doses used, where in higher doses, the time of application was not observed.

Several doses of glyphosate have been tested to the control of cover crops. Its correct dose in the burndown of these plants can vary according to the species and stage of development (RODRIGUES *et al*., 2018; TIMOSSI *et al*., 2007). In addition, the results showed that the correct time for the application of glyphosate is extremely relevant to achieve satisfactory control levels. It can also be observed that a greater quantity of deposited droplets and a greater covered area does not always result in better control of *U. brizantha*.

CONCLUSION

- The best control results of *Urochloa brizantha* cv. Marandu were obtained with glyphosate applications carried out in the morning and afternoon. The evening applications of glyphosate should be avoided.

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