

Susceptibility of *Urochloa* species subjected to pre-emergence application of [imazapyr + imazapic] herbicide

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Abstract

Intercropping imidazolinone resistance crops, resistant to herbicides imazapyr + imazapic, with forage species may be a viable alternative to recover degraded pasture areas. This practice requires herbicides to slow down development of the forage and avoid reduced rice yield. However, as it is a relatively new technology, the proper management of this herbicide to control forage is not known. The objective of this study was to determine the susceptibility of forages *Urochloa ruziziensis*, *U. brizantha* cv. *Paiaguás*, and *U. brizantha* cv. *Marandu*, submitted to the pre-emergence application of the herbicides [imazapyr + imazapic]. The experimental design was completely randomized in a 3x5+3 factorial scheme with five replications. Treatments consisted of the combination of the three species (*Urochloa ruziziensis*, *U. brizantha* cv. *Paiaguás*, and *U. brizantha* cv. *Marandu*) and five intervals between herbicide application in the soil and forage sowing (0; 5; 10; 15; and 20 days after its application), in addition to three control treatments, without herbicide application. This study found that application of herbicide on the day of forage sowing for intercropping with imidazolinone resistance crops is not feasible. Increasing the time interval between herbicide application and forage sowing provides increased development of *U. brizantha* cvs. *Marandu* and *Paiaguás*. The species *U. ruziziensis* is more susceptible to pre-emergence application imazapyr + imazapic. According to the results, *U. brizantha* cvs. *Marandu* and *Paiaguás* are more suitable to be managed by imidazolinone herbicides to recover degraded pasture areas.

Keywords: Clearfield; degraded pasture; imidazolinones; Kifix; livestock crop integration.

Introduction

Brazil has an area of approximately 100 million hectares of highly degraded pastures (Dias-Filho, 2016), with lower capacity of meat or milk production per unit of land occupied. In this context, integrated crop-livestock, a mixed system of crop and livestock farming, is a viable alternative to recover these areas (Costa et al., 2016; Santos et al., 2020).

With an integrated crop-livestock, grain production can be used to recover these degraded pastures, reducing the planting cost and increasing food production in a sustainable way without opening new areas, since recovered pastures provide higher zootechnical indexes (Borghi et al., 2013). In Brazil, the use of intercropping between crops such as corn (Mateus et al., 2019), sorghum (Santos et al., 2020; Da Silva et al., 2020), soybeans (Erasmo et al., 2017; Rodrigues et al., 2018) and sunflower (Cruvinel et al., 2017; Dos Santos et al., 2019) are increasing, mainly with forages of the genus *Urochloa* (Da Silva et al., 2018). In many cases, the grain crops cover the costs of pasture renewal.

The advent of the Clearfield[®] (CL) system including cultivars with a broad-spectrum herbicide resistance gene, such as in corn, rice and sunflower crops (Nakka et al., 2019), has increased the possibilities of forage control that can avoid competition with crops, but can affect the development of fodder in integrated production systems. Thus, using herbicide can reduce grass development and allow full development of crop cultivation to recover pastures in

degraded soils, as already demonstrated in conventional corn cultivation (Ceccon et al., 2010; Adegas et al., 2011). After harvest, the forage, already established, can fully develop and form the pasture.

In the CL system, the herbicide of the chemical group imidazolinone called Kifix[®] (imazapyr + imazapic), which is systemic and selective for CL cultivars, can be applied before or after emergence of crops without harming it (Rangel et al., 2010; Marchesan et al., 2011). The high persistence in the soil of herbicides belonging to the imidazolinone group is a noted feature of these products (Loux and Reese, 1993), in which case the residual effect of the herbicide in the soil may increase weed control. However, in an intercropping situation, it may compromise the development of the other species, as in the case of foliage, which is susceptible to the molecules.

As it is a relatively new technology, few studies have examined the pre-emergence application of herbicide [imazapyr + imazapic] for intercropping with CL crops for pasture renewal. Thus, for imidazolinone resistance crops (IMI) in polyculture, the appropriate time to apply the herbicide in pre-emergence to delay the growth of the forage without eliminating it is still unknown. Information on specific behavior of *Urochloa* species with potential for intercropping with CL crops, when submitted to the herbicide [imazapyr + imazapic] applied in pre-emergence is scarce.

Assays in controlled conditions (greenhouse) reveal the effect of herbicide application without the influence of weeds. In field conditions, weeds could lead to development of crops and weeds only, without forage, which are the targets of the present study. Thus, the objective of this work was to determine the susceptibility of forages *Urochloa ruziziensis*, *U. brizantha* cv. *Paiaguás*, and *U. brizantha* cv. *Marandu*, submitted to the application of the herbicide imazapyr + imazapic in pre-emergence.

Results and Discussion

Urochloa emergence

The results found significant interaction between the evaluated species and the interval between herbicide application and forage sowing for all variables analyzed. Similarly, herbicide application interfered with all variables compared to the control treatment.

At 5 days after sowing (DAS), only the treatments where forages were sown 20 days after herbicide application did not have reduced emergence plant, compared to control (Table 1). However, at the 10 and 30 DAS evaluations, all treatments were affected by herbicide application, with a reduced number of emerged plants compared to control. Therefore, the application of the herbicide imazapyr + imazapic significantly reduced the number of forage plants 10 days after sowing. This is due to the residual effect of the herbicide and its systemic way of acting on the plant which can germinate but may die with prolonged exposure to the herbicide.

At all evaluation periods, interval between herbicide application and forage sowing increased the number of emerged plants of all the *U. brizantha* cultivars (Figure 1). This behavior is probably because the longer time interval between herbicide application and sowing reduced the availability of herbicide molecules in the surface layer, as the constant herbicides in the mixture have high solubility (Tu et al., 2016). Studies conducted with cover crops submitted to the herbicide imazapyr also found the highest plant survival with longer intervals between herbicide application and sowing species (Zaccaro et al., 2017).

Among the evaluated species, *Urochloa ruziziensis* was most susceptible to the herbicide used. In this species, all plants died in the period between the second (10 DAS) and the third evaluations (30 DAS) (Table 1). The plants were susceptible to molecules with this mechanism of action. Thus, after herbicide application, their growth was ceased between 7 and 10 days (Oliveira Jr. et al., 2011), justifying the reduction in the amount of plants observed between the second (Figure 1B) and the third evaluation (Figure 1C). This behavior is possibly due to the mechanism of action of the herbicide, which inhibits the synthesis of Acetolactate Synthase (ALS), an essential enzyme for the synthesis of valine, lysine, and isoleucine branched chain amino acids (Rangel et al., 2010).

Studies on *Urochloa brizantha*, *U. decumbens*, and *U. ruziziensis* species found different susceptibility of *Urochloa* species to glyphosate herbicide. The authors report that *Urochloa ruziziensis* was the most susceptible to the herbicide (Brigenthi et al., 2011). This may indicate that this species is more susceptible to herbicide action, regardless of the mechanism of action, because the herbicides glyphosate and imazapyr + imazapic, *U. ruziziensis* presented possible differential susceptibility in relation to other species.

In the present experiment, the plants that received herbicide application had interveinal chlorosis and apical shoots. The same symptoms were reported in other grasses such as pearl millet (Dan et al., 2011) and sugarcane (Obara et al., 2015).

Between the second and third evaluation (30 DAS), the species *U. brizantha* cv. *Paiaguás* and *U. brizantha* cv. *Marandu* reduced their plant stand (Figures 1B and 1C). However, survival tended to proportionally increase with increasing interval between herbicide application and forage sowing (Figure 1C), indicating that *U. brizantha* cultivars have greater tolerance to the evaluated herbicides than *U. ruziziensis*. Herbicide selectivity is more related to the genetic characteristics of the evaluated species than to the chemical characteristics or dose of the applied product (Souza et al., 2009).

Regardless of the species used, when the sowing was performed on the same day of the herbicide application, the seeds germinated but all emerged plants died before the last evaluation at 30 DAS (Table 1). Therefore, we concluded that, this practice does not work for this polyculture. However, in subsequent plantings, the herbicide did not totally inhibit the development of *U. brizantha* cultivars, as long as a minimum grace period of 5 and 10 days was permitted for sowing *U. brizantha* cv. *Paiaguás* and *U. brizantha* cv. *Marandu*, respectively. The longer the period was between herbicide application and forage sowing, the greater the number of emerged plants at 30 DAE (Figure 1C).

Biomass accumulation

For biomass production, the increase in the time interval between herbicide application and forage sowing promoted plant development, both in the shoots (Figure 2A) and roots (Figure 2B). Hence, the time interval between herbicide application and forage sowing is very important to avoid its reduced development and even death, which would make pasture formation unfeasible. The increased shoot and root biomass in *Urochloa* species are proportional due to the root anatomy of the species, which gives them a high root density per plant (Santos et al., 2015).

The minimum interval between application and sowing that allowed plant survival was 5 days for *U. brizantha* cv. *Paiaguás* and 10 days for *U. brizantha* cv. *Marandu*. In subsequent plantings, plant development was occurred proportionally to the interval between application days and sowing, both for shoot biomass production (Figure 2A) and root biomass accumulation (Figure 2B). This reinforces the information that this herbicide acts on these forages when used in pre-emergence, affecting the formation and establishment of pasture.

During period between herbicide application and forage sowing, the herbicide probably degraded, which reduced its deleterious effect on plants. This behavior was also observed in pearl millet (Dan et al., 2011) in an assay evaluating the activity of the herbicide imazethapyr (0.10 kg ha⁻¹) on the crop, where the authors report that sowing less than 40 days after application causes reduction in the plant stand due to the herbicide bioactivity in the soil.

In the present work, the dose used was higher than the dosage recommended on the package, precisely to have a safety margin and verify the effect of herbicide on forage development. Under field conditions the behavior of herbicides on these species may produce different results.

Table 1. Emerged plants of different *Urochloa* species submitted to the application of the herbicide imazapyr + imazapic in pre-sowing, Santo Antônio de Goiás, GO, 2020.

Sowing time related to herbicide application	Number of emerged plants per vase		
	<i>Urochloa ruzizensis</i>	<i>Urochloa brizantha</i> cv. <i>Paiaguás</i>	<i>Urochloa brizantha</i> cv. <i>Marandu</i>
5 DAS			
0	3.65*	1.02*	0.71*
5	4.01*	1.41*	0.71*
10	3.91*	2.74*	2.12*
15	3.82*	2.55*	2.12*
20	5.30	4.06	4.03
Control	5.77	4.16	4.01
10 DAS			
0	4.34*	3.07*	1.37*
5	4.43*	3.50*	2.07*
10	4.32*	4.32*	2.97*
15	3.96*	3.94*	3.07*
20	5.26*	3.80*	4.32*
Control	6.24	5.49	5.97
30 DAS			
0	0.71*	0.71*	0.71*
5	0.71*	1.12*	0.71*
10	0.71*	0.91*	0.94*
15	0.71*	1.02*	1.27*
20	0.71*	1.22*	1.63*
Control	5.17	4.59	5.59

DAS = Days after sowing; * = differs from control portion by Dunnett's test ($p < 0.05$).

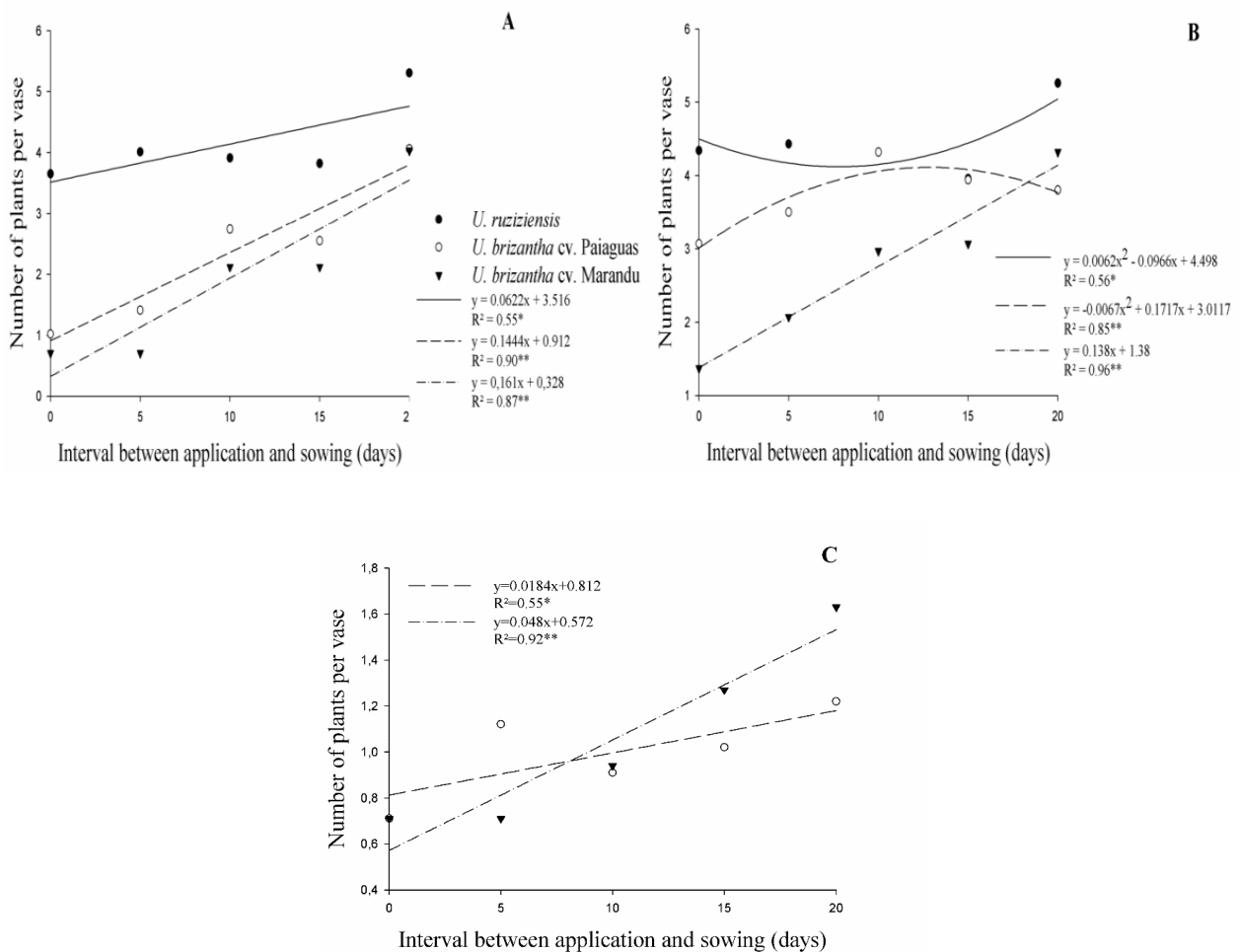


Figure 1. Emergence of *Urochloa* species subjected to application of the herbicide imazapyr + imazapic at 5 (A), 10 (B), and 30 (C) days after sowing as a function of interval between application and sowing time. Santo Antônio de Goiás, GO, 2020.

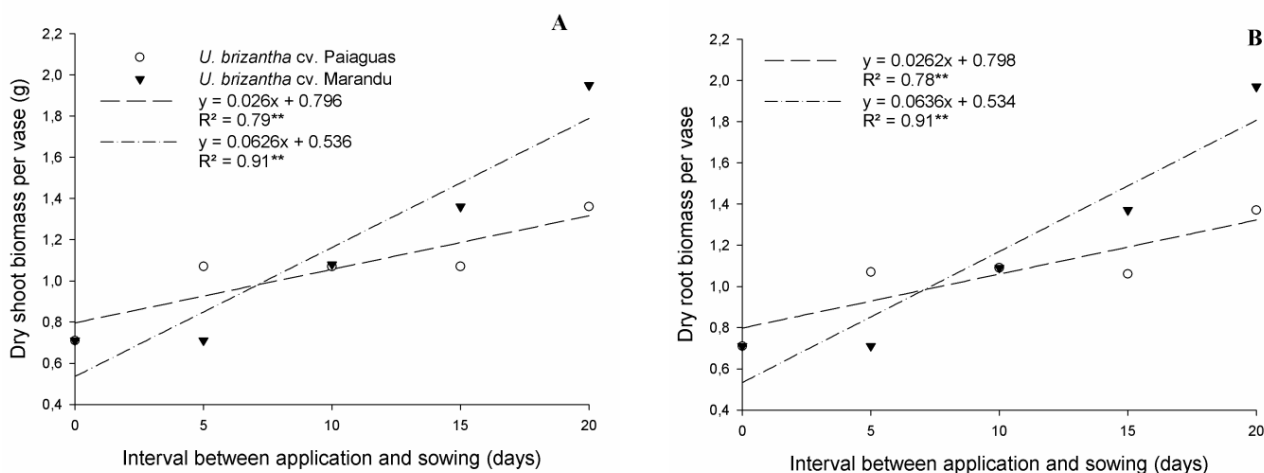


Figure 2. Biomass of dry shoot (A) and root (B) in *Urochloa* species at 30 days after emergence as a function of interval between application and sowing time submitted to the pre-emergent application of the herbicide imazapyr + imazapic. Santo Antônio de Goiás, GO, 2020.

Nevertheless, based on the work developed here, caution should be taken in the management of forages when aiming to intercrop CL crops with these grasses, since the inadequate application of herbicide may make this technology unfeasible.

Materials and Methods

Experimental site

The experiment was conducted in a greenhouse, between August and October 2017, in Santo Antônio de Goiás, GO, Brazil. Soil was used from the arable layer (0.00–0.20 m) of a Latossolo Vermelho acriférrico típico (eq. Oxisol) (Santos et al., 2018), with clay texture with the following physicochemical characteristics: pH in H₂O: 5.2; Ca: 9.0 mmol_c dm⁻³; Mg: 2.6 mmol_c dm⁻³; Al: 1.0 mmol_c dm⁻³; H + Al: 24 mmol_c dm⁻³; P: 0.9 mg dm⁻³; K: 64.0 mg dm⁻³; Cu: 4.6 mg dm⁻³; Zn: 2.0 mg dm⁻³; Fe: 48.0 mg dm⁻³; Mn: 37.6 mg dm⁻³; OM: 19.93 g kg⁻¹; Clay: 417 g kg⁻¹; Silt: 155 g kg⁻¹; Sand: 428 g kg⁻¹.

Experimental design and treatments

The experimental design was completely randomized in a 3×5+3 factorial scheme with five replications. The treatments consisted of the combination of three forage species (*Urochloa ruziziensis*, *U. brizantha* cv. *Paiaguás*, and *U. brizantha* cv. *Marandu*) and five different intervals between the application of the herbicide Kifix[®] (525 g kg⁻¹ imazapyr + 175 g kg⁻¹ imazapic) and forage sowing (0, 5, 10, 15, and 20 days after herbicide application). Additionally, the controls treatments were the three forages sown without herbicide application.

Plant material

One week before sowing forage, 2 kg pots were completely filled with soil and fertilized with the formulated N-P₂O₅-K₂O (05-30-15), at a dosage equivalent to 200 kg ha⁻¹. The herbicide was applied at a dosage equivalent to 150 g p.c. ha⁻¹, at pre-emergence stage, using a 30 psi CO₂ pressurized costal spray with 8002 nozzles and 200 L ha⁻¹ spray volume.

For forage sowing, 40 viable pure seeds per vase were incorporated at a depth of two centimeters. The pots were irrigated daily to keep moisture close to field capacity.

Traits measured

After herbicide application, the number of plants that emerged in each vase was evaluated at 5, 10, and 30 days after forage sowing (DAS). At the last evaluation (30 DAS), the plants were cut close to the ground from each vase, and the roots were washed. The plant material was taken to drying in an oven at 65 °C for 72 h to determine the dry biomass of the shoot and root.

Statistical analysis

The data obtained were submitted to analysis of variance by the F test ($p \leq 0.05$). Dunnett's test ($p \leq 0.05$) was performed to compare treatment without application (control) with those that received herbicide application. The analysis of the plant emergence and biomass accumulation variables was performed with the data transformed into $\sqrt{(x + 0.5)}$. To determine the effect of the interval between herbicide application and forage sowing development of the forage, regression analysis was performed. All statistical analyzes were done using the R statistical software.

Conclusions

This study found that using the formulated mixture of the herbicides imazapyr + imazapic on the day sowing is unfeasible for CL crops intercropping with forages *U. ruziziensis* and *U. brizantha* cvs. *Marandu* and *Paiaguás*. The increase in the interval between the application of the commercial mixture of the herbicides imazapyr + imazapic and the forage sowing allowed increased development of *U. brizantha* cv. *Marandu* and *Paiaguás*. *U. ruziziensis* species is more susceptible to pre-emergence herbicides imazapyr + imazapic and possibly not suitable for use in CL intercropping.

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The authors declare that have no conflicts of interest.

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