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Weed management in corn intercropped with *Urochloa ruziziensis*

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ABSTRACT

Weed populations in monocrop or succession planting systems increase under inadequate management conditions. However, intercropping *Urochloa ruziziensis* with corn and precise adjustments in herbicide doses can facilitate management. This study sought options for chemical weed control in corn intercropped with *U. ruziziensis*. Two experiments were conducted in the 2022 winter harvest, in the municipalities of Cafezal do Sul and Brasilândia do Sul, State of Paraná. The experimental design was randomized blocks with 10 treatments and 4 replications. The treatments were: Control, atrazine (2.0 L c.p. ha^{-1}), atrazine+nicosulfuron (2.0 L + 0.4 L c.p. ha^{-1}), atrazine+mesotrione in three dose combinations (1.0 L + 0.5 L; 1.5 L+ 0.75L and 2.0 L + 0.5 L, b.w. ha^{-1}, respectively), terbuthylazine in three doses (1.5 L, 2.0 L and 2.5 L c.p. ha^{-1}), and terbuthulazine+mesotrione (1.5 L+ 0.2 L c.p. ha^{-1}). The application occurred at the six-leaf stage of corn (V6). The variables evaluated were the percentage of control at 7, 14, 21, 28, 35, and 42 days after application, based on a visual scale of injury and dry biomass of weeds and *U. ruziziensis*. The treatments with terbuthylazine+mesotrione (750+96 c.p. ha^{-1}) and atrazine+mesotrione (1,000+50 g c.p. ha^{-1}) were the most efficient in controlling weeds in all evaluation periods, with a control above 80%. Treatments atrazine+mesotrione, terbuthylazine (3 doses), and terbuthylazine+mesotrione resulted in lower weed dry mass. Values of dry mass of *U. ruziziensis* subjected to atrazine (1,000 c.p. ha^{-1}) and terbuthylazine+mesotrione (750+96 c.p. ha^{-1}) applications were higher even compared to the non-application of herbicides.

Keywords: *Zea mays*; Crop-pasture integration; Herbicides in intercropping.

Manejo de plantas daninhas no consórcio de milho com *Urochloa ruziziensis*

RESUMO

Populações de plantas daninhas em sistema de monocultivo ou sucessão de culturas aumentam em condições de manejo inadequado. Entretanto, o consórcio de *Urochloa ruziziensis* com milho pode reduzir a população de plantas daninhas, favorecendo o manejo. O objetivo do trabalho foi buscar opções de controle químico de plantas daninhas na cultura do milho consorciado com *U. ruziziensis*. Foram conduzidos dois experimentos na safra de inverno 2022, nos municípios de Cafezal do Sul-PR e Brasilândia do Sul-PR. O delineamento experimental foi de blocos casualizados com 10 tratamentos e 4 repetições, sendo os tratamentos: Testemunha, atrazine (2,0 L p.c. ha^{-1}), atrazine+nicosulfuron (2,0 L + 0,4 L p.c. ha^{-1}), atrazine+mesotrione em três combinações de doses (1,0 L + 0,5 L; 1,5 L+ 0,75 L e 2,0 L + 0,5 L, p.c. ha^{-1}, respectivamente), terbuthylazine em três doses (1,5 L, 2,0 L e 2,5 L p.c. ha^{-1}) e terbuthulazine+mesotrione (1,5 L+ 0,2 L p.c. ha^{-1}). A aplicação ocorreu no estádio de seis folhas desenvolvidas (V6) do milho. As variáveis avaliadas foram porcentagem de controle aos 7, 14, 21, 28, 35 e 42 dias após a aplicação, com base em escala visual de notas de injúrias e biomassa seca de plantas daninhas e de *U. ruziziensis*. Os tratamentos com terbuthylazine+mesotrione (750+96 p.c. ha^{-1}) e atrazine+mesotrione (1000+50 p.c. ha^{-1}), foram os mais eficientes no controle de plantas daninhas em todas as épocas de avalição com porcentagem de controle acima de 80%. Combinações entre os herbicidas atrazine+mesotrione, terbuthylazine (3 doses) e a mistura de terbuthylazine+mesotrione, resultaram em menor massa seca de plantas daninhas. A massa seca de *U. ruziziensis* quando aplicado atrazine (1.000 p.c. ha^{-1}) e terbuthylazine+mesotrione (750+96 p.c. ha^{-1}) foram maiores inclusive em comparação à não aplicação dos herbicidas.

Palavras-chave: *Zea mays*; Integração lavoura-pastagens; Herbicidas em consórcio de plantas.

1. Introduction

In Brazil, corn (*Zea mays*) production is divided between the first and second crop harvests and is the second largest crop produced in the country, behind only soybeans (Artuzo, 2019). Corn is a strategic cereal with high added value in several agribusiness sectors, supporting the economy, food security, animal feed, and even the high-tech industry (Sordi et al., 2020).

Due to the high economic and social value of this cereal, many technical issues directly influence the increase in productivity, among which are the use of no-till, biotechnology, optimization of agricultural inputs, precision agriculture, and investments related to pest, disease, and weed control. This latter is considered one of the major setbacks in agricultural production because weeds compete with crops for light, space, water, and nutrients (Artuzo, 2019).

The main problems with weeds arise from the lack of crop rotation, poor soil management, failure to manage uncultivated areas, insufficient control measures during fallow periods, and, most importantly, herbicide resistance caused by frequent applications of the same active ingredient or mechanism of action (Mendes and Silva, 2023).

Weed management should be considered as part of an integrated approach that utilizes cultural, mechanical, physical, biological, and chemical control methods. It must also consider factors such as the type of agricultural practice, terrain, crop selection, weed species, as well as the availability of equipment and labor. Despite this comprehensive framework, chemical management is still extensively adopted (Martins et al., 2016).

As a result, in recent decades, horseweed (*Conyza* spp.), sourgrass (*Digitaria insularis*), goosegrass (*Eleusine indica*), and several other weeds have shown herbicide resistance due to selection pressure from chemical control, where certain herbicides were used several times in the same site without proper rotation with other mechanisms of action or integration of other control methods (Barros and Calado, 2020). Therefore, the main resistances recorded in Brazil are related to herbicides glyphosate, 2,4-D, dicamba, and other mechanisms of action such as ALS inhibitors (Salomão et al., 2020).

Another factor contributing to the increase in the weed seed bank is the single cultivation of corn (Mechi et al., 2018). However, forage species such as brachiaria *U. ruziziensis* can grow in the spaces between the crop rows. These forage species help suppress weed communities by maintaining soil cover, which interferes with the germination and survival of weeds. Additionally, they offer other benefits, such as reducing soil moisture loss, providing nutrients through the mineralization of organic matter, minimizing soil compaction, and decreasing water erosion (Seibert and Borsoi, 2020).

In this context, chemical control is an option to assist in integrated weed management (IWM) to increase the useful life of intercropping corn with *U. ruziziensis* (Silva et al., 2022). However, for an efficient and long-lasting IWM, in addition to extensive knowledge about the crops used, it is necessary to know the weed population, its biology, and survival mechanisms (Ferreira et al., 2019).

For a successful intercropping of off-season corn and *U. ruziziensis*, it is also essential to understand the use of herbicides in this system, with an analysis of the implications for the crop and weeds (Adegas et al., 2011). In this scenario, atrazine and terbuthylazine are the main herbicides used to suppress the development of *U. ruziziensis*. However, a label dose may lead to the death of the forage, while a very low dose may not produce the expected effect, making it necessary to adjust balanced doses in the system (Oliveira et al., 2021).

Mesotrione, whose mechanism of action is the inhibition of carotenoid biosynthesis, is an alternative to suppress the growth of *U. ruziziensis* when applied in low doses. The mixture of atrazine + mesotrione also aims at both weed control and delaying the growth of corn forage. Photosystem II inhibitors are the most widely used in corn crops, but further studies are needed when intercropped with *U. ruziziensis* (Correia and Lenza, 2024).

Given the above, the present study hypothesized that the application of photosystem II inhibitor herbicides, alone or in combination, in corn intercropped with *U. ruziziensis* helps control weed infestation. Thus, this study aimed to seek options for chemical control of weeds present in the post-emergence of corn intercropped with *U. ruziziensis*.

2. Material and Methods

Two experiments were conducted during the 2022 winter harvest, in the agroclimatic zoning for off-season corn intercropped with *U. ruziziensis* in two municipalities in the western region of the State of Paraná, Cafezal do Sul and Brasilândia do Sul, located at the respective geographic coordinates 23°59'44.1"S 53°32'03.9"W and 24°03'45.1"S 53°31'21.1"W. The climate is described as subtropical humid mesothermal (Cfa). The soil of the experimental areas is classified as Dystrophic Red-Yellow Latosol, with a sandy texture (Santos et al., 2018). The meteorological data are illustrated in Figure 1.

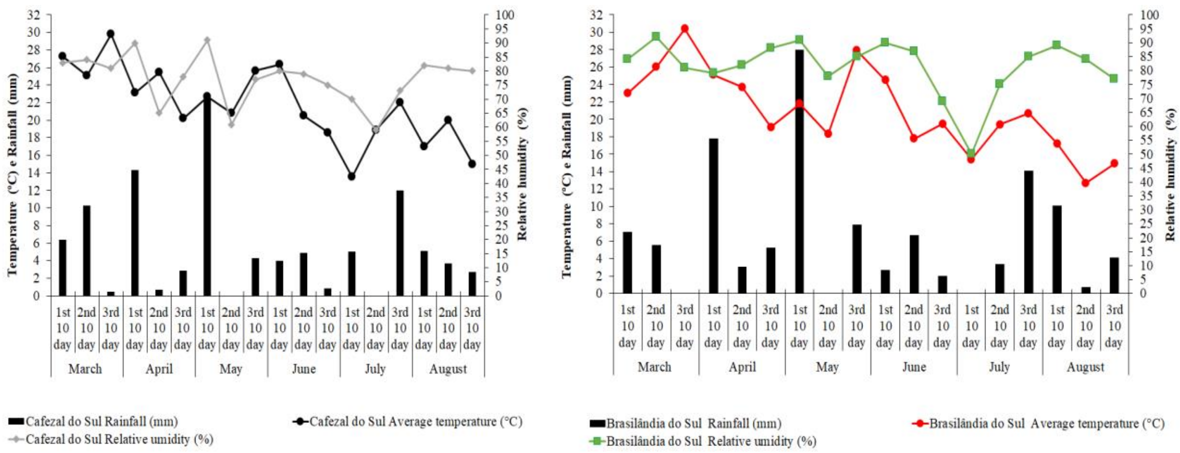

Figure 1. Rainfall, average temperature, and relative humidity for 10-day periods during the experimental period in Cafezal do Sul and Brasilândia do Sul, State of Paraná, 2022.

This was a randomized block design with 10 treatments and four replications (Table 1). The experimental units consisted of 15 m^2 (5.0 m x 3.0 m), with a population density of six plants m^2 for corn and eight plants m^2 for *U. ruziziensis*. The spacing between rows was 0.45 meters with 2.5 seeds per linear meter, targeting a final population of 61,000 seeds per hectare, at a depth of 0.05 m. *U. ruziziensis* seeds were broadcast sown with an Ikeda seeder coupled to the front of a tractor upon corn planting, with 8 kg of seeds per hectare.

The experiment in Cafezal do Sul was implemented on March 14, 2022, using the FS633PWU hybrid, which has an average plant height of 2.15 m and ear height of 1.15 m. For the Brasilândia do Sul experiment, the AS1800PRO3 hybrid was used, sown on March 19, 2022. This material has an average plant height of 2.26 m and ear height of 1.12 m. Both corn hybrids are intended for grain production. Before herbicide application, weeds, and *U. ruziziensis* were quantified using a 0.5 x 0.5 m square as a tool in four random samples. The existing populations were composed mainly of *U. ruziziensis* 8 plants m^{-2}, *Glycine max* 4.5 pl.m^{-2}, *Amaranthus viridis* 8.1 pl.m^{-2}, *Cyperus* spp. 14.9 pl.m^{-2}, *Commelina benghalensis* 4.2 pl.m^{-2}, *Sida* spp. 1.4 pl.m^{-2}, and *Bidens subalternans* 2 pl.m^{-2}. Dicotyledons had four to six leaves, and grasses had three to six tillers.

Upon application, the control form was filled out (Table 2); this information was collected to monitor the treatments. The treatments were applied at the V6 stage (6-leaf stage) of corn, using a CO_2-based pressurized backpack sprayer with six XR 110.02 flat fan spray nozzles operating at a pressure of 2.0 kgf cm^{-2} and providing a flow rate of 200 L ha^{-1} of spray. The herbicides used in the treatments were atrazine (Atrazine nortox 500sc®), nicosulfuron (Nicosulfuron nortox 40sc®), atrazine + mesotrione (Calaris®), terbuthylazine (Sonda®), and mesotrione (Callisto®).

Table 1. Treatments and their respective doses per hectare in the management carried out in Cafezal do Sul and Brasilândia do Sul, State of Paraná, 2022.

Order	Treatment	c.p. ha^{-1} (g a.i. ha^{-1})1
1	control	-
2	atrazine	2.0 L (1,000)
3	atrazine + nicosulfuron	2.0 L (1,000) + 0.4 L (16)
4	atrazine + mesotrione	1.0 L (500) + (50)
5	atrazine + mesotrione	1.5 L (750) + (75)
6	atrazine + mesotrione	2.0 L (1,000) + (50)
7	terbuthylazine	1.5 L (750)
8	terbuthylazine	2.0 L (1,000)
9	terbuthylazine	2.5 L (1,250)
10	terbuthylazine + mesotrione	1.5 L (750) + 0.2 L (96)

[1] c.p. ha^{-1} = commercial product per hectare. g a.i. ha^{-1}= grams of active ingredient per hectare.

Weed control percentages were assessed at 7, 14, 21, 28, 35, and 42 days after application (DAA) based on a visual injury scale proposed by the SBCPD (Sociedade Brasileira de Ciências de Plantas Daninhas, 1995), where 0% indicate no injury and 100% indicate plant death. The score was determined based on observation and comparison of the control treatment with the other treatments in the experiment (Gazziero, 1995). The total dry biomass of weed populations and *U. ruziziensis* was also assessed by randomly collecting plants present in 1.0 m^{-2} of each plot using a 0.5x0.5 m square.

Table 2. Data referring to the time of application of herbicides in Brasilândia do Sul and Cafezal do Sul, State of Paraná, 2022.

Application Data	Brasilândia do Sul	Cafezal do Sul
Date:	21/04/2022	21/04/2022
Initial relative humidity:	78.0%	80.0%
Final relative humidity:	78.0%	80.0%
Initial temperature:	25.4 °C	23.8 °C
Final temperature:	25.9 °C	24.4 °C
Initial wind:	4.1 km h^{-1}	4.0 km h^{-1}
Final wind:	4.7 km h^{-1}	4.2 km h^{-1}

Samples were dried in a forced air oven at 70±1 ºC to constant weight and then weighed on a precision scale. The data were subjected to analysis of variance using the F-test and, when significant, the means were contrasted using the Scott-Knott test at 5% probability. The Sisvar software (Ferreira, 2019) was used for statistical procedures.

3. Results and Discussion

There was no significant in the percentage of control between municipalities. However, an interaction between treatments was found at the respective DAA. At 7 DAA, the most effective results were achieved with atrazine+mesotrione (1,000+50 g a.i.ha^{-1}) and terbuthylazine+mesotrione (750+96 g a.i.ha^{-1}), yielding control rates of 77 and 68%, respectively (Table 3). More expressive results were noted after 14 DAA with the same combinations of herbicides, reaching control rates above 80%.

For the atrazine + mesotrione combination, the percentage of control remained above 86% even at 42 DAA. Chahal et al. (2019) reported that the combination of these modes of action offers an effective synergistic basis and that mixing with mesotrione enhances the absorption and translocation of the photosystem II inhibitor. Cabral et al. (2013) emphasized that for synergism between atrazine and mesotrione to occur, one or more bindings of atrazine to its target site must happen, underscoring the interaction between the modes of action of photosystem II and the carotene synthesis inhibitor.

Other treatments with doses below 1,000 and 50 g a.i. ha^{-1} of atrazine+mesotrione and terbuthylazine+mesotrione at doses of 750 and 96 g a.i. ha^{-1}, even after 42 DAA, presented maximum control at 75%. The other treatments showed ineffective control; atrazine alone and terbuthylazine at a dose of 750 g a.i. ha^{-1} were the least efficient, with 52 and 53%, respectively. This is a consequence of the low response of these herbicides to monocots, which alerts us to the indispensable use of carotenoid inhibitors in combinations when considering the viability of intercropping corn with *U. ruziziensis* (Almeida et al., 2019). Photosystem II inhibitor herbicides preferentially bind to plastoquinone (PQ), binding site (QB) in the D1 protein of PS II (Trebst and Draber, 1986). In resistance conditions, atrazine is unable to effectively bind to the QB binding site. Instead, it demonstrates an affinity for a second low-affinity binding site (such as QC) in the D2 protein. However, because of the low affinity of this site, only small amounts of atrazine bind, resulting in limited production of free radicals and, therefore, producing little effect in a plant that has some resistance in the QB binding site (Mendes et al., 2023).

It is important to highlight that terbuthylazine, a systemic herbicide from the triazine chemical group, acts directly on biochemical processes related to the structural activities of photosystem II, and mesotrione belongs to the triketone group and acts by inhibiting the biosynthesis of carotenoids by interfering with the activity of the HPPD enzyme (4-hydroxyphenylpyruvate dioxygenase) in chloroplasts. This raises the hypothesis that the mechanisms of synergy in both resistant and susceptible plants may be related to oxidative stress. Additionally, the combination of different mechanisms of action enhances control efficiency (Tsukamoto et al., 2021).

Certainly, the synergistic association terbuthylazinen+mesotrione interrupts the flow of electrons and promotes the depigmentation of green tissues, respectively, therefore causing the accumulation of free radicals, similar to the effect caused by binding to QB (Bottcher et al., 2022). The consequences of this set of physical-chemical reactions at the cellular level culminate in visual symptoms and consequent death of the plant.

Regarding the dry mass of the shoot, considering all doses of terbuthylazine and its combination with mesotrione, provided the greatest reduction in the dry mass of weeds at 42 DAA (Table 4). The greatest differences were found in Brasilândia do Sul, where terbuthylazine alone or in combination, resulted in a dry mass 91% lower than the treatments with atrazine and its combinations and 96% lower compared to the control. Within the due proportions, terbuthylazine maintained a similar behavior in the municipality of Cafezal do Sul.

Table 3. Average percentage of weed control, in a joint analysis of the experiments, in six evaluations after the application of the treatments. Experiments carried out in Brasilândia do Sul and Cafezal do Sul, State of Paraná, 2022.

Treatments	g a.i.ha^{-1}*	Assessments in days after application (DAA)					
		7DAA	14DAA	21DAA	28DAA	35DAA	42DAA
Control	-	0 D	0 D	0 C	0 D	0 D	0 D
Atrazine	1,000	43.13 B	44.38 C	48.75 B	50 C	61.25 B	52.5 C
Atrazine + Nicosulfuron	1,000 + 16	60 A	64.38 B	56.25 B	56.25 C	63.75 B	53.13 C
Atrazine + Mesotrione	500 + 50	52.5 B	47.5 C	57.5 B	46.25 C	51.25 C	48.13 C
Atrazine + Mesotrione	750 + 75	68.13 A	73.75 A	78.13 A	76.25 A	77.5 A	77.5 B
Atrazine + Mesotrione	1,000 + 50	77.5 A	86.88 A	80 A	82.5A	82.5 A	86.88 A
Terbuthylazine	750	31.25 C	31.88 C	55 B	51.88 C	48.13 C	53.75 C
Terbuthylazine	1,000	43.13 B	54.38 B	66.25 B	69.38 B	65.63 B	68.13 B
Terbuthylazine	1,250	47.5 B	71.88 A	63.13 B	65.63 B	73.75 A	75 B
Terbuthylazine + Mesotrione	750 + 96	68.75 A	83.13 A	81.88 A	78.5 A	88.75 A	86.5 A
CV (%)		27.32	26.67	21.44	21.50	22.31	21.73

Mean values followed by different letters in the same column are significantly different from each other by Scott & Knott test (1974) at the 5% probability level. * g a.i. ha^{-1}= grams of active ingredient per hectare.

Terbuthylazine was developed to replace atrazine because it is more efficient in controlling weeds (Caracciolo et al., 2005). Studies carried out by Currie and Geier (2020) and Bottcher et al. (2022) demonstrated that terbuthylazine is more efficient than atrazine in controlling grasses and that it can also act as an important ally of glyphosate in controlling weeds in corn, and can be used as an alternative or in combination with atrazine.

During the experimental cycle, greater development of *U. ruziziensis* plants was also observed, suppressing weeds. Thus, it is understood that the suppressive power of brachiaria directly affects the dry matter of weeds, as well as the action of herbicides as an additive factor capable of inhibiting new flows of weeds. When poorly managed, the interference of *U. ruziziensis* in corn becomes an important factor of competition, which can cause a reduction in grain mass, potentially exceeding a 70% decline in cereal productivity (Araújo et al., 2018).

For the dry mass of *U. ruziziensis* shoots (Table 5), the data indicate interference of the environmental factor in the responses of the treatments. In Brasilândia do Sul, the dry mass of *U. ruziziensis* weeds was less influenced by the atrazine and terbuthylazine+mesotrione treatments. In the context of this study, it is clear that atrazine did not result in the death of the plants.

Our findings indicate that atrazine at a dose of 1,000 g a.i. ha^{-1} is an important tool in weed management, as well as in the lag of *U. ruziziensis* plants when intercropped with corn. Concenço et al. (2013) verified that 880 g a.i. ha^{-1} of atrazine at 14 and 24 DAE of *U. ruziziensis* suppressed between 37 and 47%, respectively. For Dan et al. (2011), atrazine is a herbicide that stands out in weed control and acts by reducing the growth rate of forage species, representing an excellent tool in intercropping management.

Table 4. Percentage of the dry mass of the shoot of weeds in experiments carried out in Brasilândia do Sul and Cafezal do Sul, State of Paraná, 2022.

Dry mass of weed shoots (t ha^{-1})			
Treatments	g a.i. ha^{-1}*	Brasilândia do Sul	Cafezal do Sul
Control	-	0.26 A	8.90 A
Atrazine	1,000	0.09 B	5.55 B
Atrazine + Nicosulfuron	1,000 + 16	0.11 B	5.72 B
Atrazine + Mesotrione	500 + 50	0.10 B	5.50 B
Atrazine + Mesotrione	750 + 75	0.04 C	5.60 B
Atrazine + Mesotrione	1,000 + 50	0.00 C	1.75 C
Terbuthylazine	750	0.02 C	2.67 C
Terbuthylazine	1,000	0.02 C	1.72 C
Terbuthylazine	1,250	0.02 C	2.22 C
Terbuthylazine + Mesotrione	750 + 96	0.01 C	0.47 C
	CV(%)	20.56	24.59

Mean values followed by different letters in the same column are significantly different by the Scott & Knott test (1974) at the 5% probability level. * g a.i. ha^{-1}= grams of active ingredient per hectare.

In the experiment in Cafezal do Sul, the treatments atrazine+nicosulfuron, atrazine+mesotrione, and terbuthylazine+mesotrione had the least influence. The atrazine+nicosulfuron treatment had little influence, because of the *U. ruziziensis* tillering induced by the herbicides. The application stage may have affected the efficiency of the treatments containing mesotrione in the suppression of *U. ruziziensis* since the ideal time for application is when they have one to two tillers, and in our experimental context, the plants had three to six tillers. This herbicide is used in post-emergence in corn, providing good control of weeds, including monocots, and plays a key importance in the intercropping with *Urochloa* (Lovakovic et al., 2017).

Table 5. Percentage of the dry mass of *U. ruziziensis* shoots harvested in experiments carried out in Brasilândia do Sul and Cafezal do Sul, State of Paraná, 2022.

Dry mass of *U. ruziziensis* shoots (t ha^{-1})			
Treatments	g a.i. ha^{-1}*	Brasilândia do Sul	Cafezal do Sul
T1- control	-	7.91 C	5.91 C
T2- atrazine	1,000	15.01 A	6.47 C
T3- atrazine + nicosulfuron	1,000 + 16	5.45 D	8.76 A
T4- atrazine + mesotrione	500 + 50	8.97 C	2.40 D
T5- atrazine + mesotrione	750 + 75	10.57 C	8.89 A
T6- atrazine + mesotrione	1,000 + 50	11.84 B	8.50 B
T7- terbuthylazine	750	9.56 C	7.02 B
T8- terbuthylazine	1,000	9.82 B	7.21 B
T9- terbuthylazine	1,250	9.91 C	5.67 C
T10- terbuthylazine + mesotrione	750 + 96	13.63 A	9.70 A
	CV (%)	13.38	12.54

Mean values followed by different letters in the same column are significantly different by the Scott & Knott test (1974) at the 5% probability level. * g a.i. ha^{-1}= grams of active ingredient per hectare.

Terbuthylazine is a chlorotriazine herbicide known for its high efficiency in managing post-emergence weeds in corn. Due to its elevated adsorption coefficient, it has emerged as a suitable alternative to atrazine, posing a reduced risk of environmental contamination (Bottcher et al., 2022).

This herbicide is particularly effective against dicot weeds, although it has limited efficacy in controlling monocots (Takim and Suleiman, 2018). Furthermore, terbuthylazine's broad-spectrum activity is complemented by remarkable residual effectiveness, rapid action, and strong compatibility with other active ingredients (Mendes et al., 2017).

As noted by Bottcher (2022), the combined application of terbuthylazine, particularly in larger quantities, has proven to be one of the most effective approaches for weed control, thereby enhancing overall management strategies. However, its application in intercropping systems requires careful consideration, as high doses can significantly decrease the biomass yield of *U. ruziziensis.*

4. Conclusions

The treatments containing terbuthylazine+mesotrione (750+96 g a.i. ha^{-1}) and atrazine+mesotrione (1,000 + 50 g a.i. ha^{-1}) demonstrated superior efficacy in controlling weeds. Atrazine alone (1,000 g a.i. ha^{-1}) and terbuthylazine+mesotrione (750+96 g a.i. ha^{-1}) proved to be valuable tools for effective weed management in corn intercropped with *U. ruziziensis*. Furthermore, these same combinations contributed to an increased mass of brachiaria shoots after the corn harvest.

Authors' Contribution

Bruno Yamada Danilussi: Installation, conduction and evaluation of the experiment. Leandro Paiola Albrecht: Project supervision, experiment evaluations, statistical analysis of data and corrections to the writing. Alfredo Júnior Paiola Albrecht: Project supervision, experiment evaluations and writing contributions. Willian Bosquette Rosa: Data organization, writing adjustments, submission and corrections. Maikon Tiago Yamada Danilussi: Help with statistical analysis of data and writing contributions.

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Bibliographic References

Adegas, F.S., Voll, E.; Gazziero, D.L.P. 2011. Manejo de plantas daninhas em milho safrinha em cultivo solteiro ou consorciado à *Braquiária ruziziensis*. Pesquisa Agropecuária Brasileira, 46(10), 1226-1233.

Almeida, D.P., Furtini Neto, A.E., Lima, D.T., Fernandes, R.H., Bilego, U.O., Silva, H.F., Oliveira, G.S., Sousa, G.D., 2019. Consórcio de milho com *Urochloa ruziziensis* (Sin. *Brachiaria ruziziensis*): Controle químico de plantas-daninhas de folha estreita e seletividade dos herbicidas. Anuário de Pesquisas de Agricultura, 2 (1) 140-148. DOI: http://doi.org /10.7824/wcj.2023.22.00826.

Araújo, L.S., Branquinho, J.A.S., Silveira, P.M., Silva, L.G.B., 2018. Produtividade de milho solteiro e consorciado com *Urochloa brizantha* em dois espaçamentos de plantio no sudeste de Agrarian, 11 (2) 307-318. DOI: https://doi.org/ 10.30612/agrarian.v11i42.4335.

Artuzo, F.D., Machado, J.A.D., Oliveira, L., Souza, A.R.L., 2019. O potencial produtivo brasileiro: uma análise histórica da produção de milho. Revista Agronegócio e Meio Ambiente, 12 (2) 517-540.

Barros, J., Calado, J., 2020. Rotation of herbicides in wheat to prevent weed resistance under Mediterranean conditions. Revista de Ciências Agrárias, 23 (1), 3-13. DOI: https://doi.org/10.19084/rca.19169.

Bottcher, A.A., Albrecht, A.J.P., Albrecht, L.P., Silva, A.F.M., De Freitas, J., Souza, T. 2022. Herbicida terbutilazina: uma alternativa à atrazina para o controle de plantas daninhas em milho tolerante ao glifosato. Revista de Ciência Ambiental e Saúde, Parte B, 57(8), 609-616.

Cabral, R.S., Machado, F.G., Dourado R., Pereira, L.S, Braz, G.B.P., Pereira, B.C.S., Souza, M.F. 2023. Selectivity of herbicide associations applied in post-emergence of maize grown in second season. Weed Control Journal, 22 e202300826.

Caracciolo, A.B., Giuliano, G., Grenni, P., Cremisini, C.; Ciccoli, R., Ubaldi, C. 2005. Efeito da ureia na degradação da terbutilazina no solo. Toxicologia e Química Ambiental, 24 (5), 30-35.

Ceccon, G., Matoso, A.O., Neto, A.L., Palombo, L. 2010. Uso de herbicidas no consórcio de milho safrinha com *Brachiaria ruziziensis*. Planta Daninha, 28(2), 359-364. DOI: https://doi.org/10.1590/S0100-83582010000200015.

Chahal, P.S., Jugulam, M., Jhala, A.J. 2019. Basis of Atrazine and Mesotrione Synergism for Controlling Atrazine- and HPPD Inhibitor-Resistant Palmer Amaranth. Agronomy Journal, 111 (6), 3265-3273. DOI: https://doi.org/10.2134/agronj2019.01.0037.

Concenço, G., Ceccon, G., Correia, I.V.T., Leite, L.F., Alves, V.B. 2013. Ocorrência de espécies daninhas em função de sucessões de cultivo. Planta Daninha, 31(2), 359-368. DOI: https://doi.org/10.1590/S0100-83582013000200013.

Correia, N.M., Lenza, R.A.B., 2024. Intercropping systems of corn and forage grasses with application of low mesotrione herbicide rates. Caatinga, 37, e12520. DOI: http://dx.doi.org/10.1590/1983-21252024v3712520rc.

Currie, R.S., Geier, P.W. 2020. Comparison of Terbuthylazine and Atrazine Preemergence in Grain Sorghum. Kansas Agricultural Experiment Station Research Reports, 6(8), 16-26. DOI: https://doi.org/10.4148/2378-5977.7966.

Dan, H.A., Barroso, A.L.L., Dan, L.G.M., Procópio, S. O., Oliveira Jr, R. S., Constantin, J., E Feldkircher, C. 2011. Supressão imposta pelo mesotrione a *Brachiaria brizantha* em sistema de integração lavoura-pecuária. Planta Daninha, 29(1), 861-867. DOI: https://doi.org/10.1590/S0100-83582011000400016.

Ferreira, E.A., Paiva, M.C.G., Pereira, G.A.M., Oliveira, M.C., De Barros, E. 2019. Fitossociologia de plantas daninhas na cultura do milho submetida à aplicação de doses de nitrogênio. Revista de Agricultura Neotropical, 6(2), 109-116. DOI: https://doi.org/10.32404/rean.v6i2.2710.

Ferreira, D.F., 2019. SISVAR: A computer analysis system to fixed effects split plot type designs. Revista brasileira de biometria, 37(4) 529-535, dec. ISSN 1983-0823.

Lovakovic, B.T., Pizent, A., Kasuba, V., Kopjar, N., Micek, V., Mendas, G., Zeljezic, D., 2017. Effects of sub-chronic exposure to terbuthylazine on DNA damage, oxidative stress and parente compound/metabolite levels in adult male rats. Food and Chemical Toxicology, 108 (2) 93-103. DOI: https://doi.org/10.1016/j.fct.2017.07.046.

Martins, D., Gonçalves, C.G., Silva Júnior, A.C., 2019. Coberturas mortas de inverno e controle químico sobre plantas daninhas na cultura do milho. Revista Ciência Agronômica, 47 (4), 649-657. DOI: http://doi.org/10.5935/1806-6690.20160078.

Mechi, I.A., Dos Santos, A.L.F., Ribeiro, L.M. Ceccon, G., 2018. Infestação de plantas daninhas de difícil controle em função de anos de consórcio milho-braquiária. Revista de Agricultura Neotropical, 5 (3), 49-54.

Mendes, K.F., Collegari, S.A., Pimpinato, R.F., Tornisielo, V.L. 2017. Glucose mineralization in soils of contrasting textures under application of S-metolachlor, terbuthylazine, and mesotrione, alone and in a mixture. Bragancia, 77(1), 152-159. DOI: https://doi.org/10.1590/1678-4499.2016420.

Mendes, K.F., Silva, A.A. 2023, Plantas daninhas: herbicidas. Oficina de Textos, 2023, ISBN: 6586235871, 9786586235876, 200p.

Oliveira, M.K., Costa, C., Pariz, C.M., Meirelles, P.R.L., Andreotti, M., Castilhos, A.M., Souza, D.M., Ulian, N.A. 2021. Yield and nutritive value of mechanically processed corn silage from an integrated crop-livestock system. Semina, 42 (2) e845860. DOI: http://.doi.org/10.5433/1679-0359.2021v42n2p845.

Salomão, P.E.A., Ferro, A.M.S., Ruas, W.F., 2020. Herbicides in Brazil: a brief review. Research, Society and Development, 9, (2), e32921990. DOI: http://dx.doi.org/10.33448/rsd-v9i2.1990.

Santos H.G., Jacomine P.K.T., Anjos L.H.C., Oliveira, V.A., Lumbreras J.F., Coelho M.R., Almeida J.A., Araujo Filho, J.C., Oliveira, J.B., Cunha, T.J.F. 2018. Sistema Brasileiro de Classificação de Solos. Brasília, Embrapa. 356p.

Seibert, C.M., Borsoi, A., 2020. Milho segunda safra consorciado com diferentes densidades de semeadura de *Brachiaria ruziziensis*. Revista Cultivando o Saber, 13 (3), 94-177.

Silva, L.M., Reis, E.M.B., Santos, B.R.C., Pinedo, L.A., Montagner, A.E.A.D., Arévalo, B.R.S., Pessoa, A.M.N., Maia, G.F.N. 2022. Chemical weed control wichdiferent dosages of fluroxypyr + picloram based herbicide. Research, Society and Development, 11 (12), e358111234598. DOI: http://dx.doi.org/10.33448/rsd-v11i12.34598.

Sordi, A., Bernardi, G., Marodin, L.G., Dai, P.M. 2020. Crescimento do milho submetido a aplicações de nitrogênio. Anuário pesquisa e extensão unoesc, 5 e25128. https://periodicos.unoesc.edu.br/apeusmo/article/view/25128.

Gazziero, D.L.O. 1995. Procedimentos para instalação, avaliação e análise de experimentos com herbicidas. Sociedade Brasileira da Ciência Das Plantas Daninhas-SBCPD. Londrina. 42 p.

Tsukamoto, M., Kikugawa, H., Nagayama, S., Suganuma, T., Okita, T., Miamoto, H., 2021. Discovery and structure optimization of a novel corn herbicide, tolpyralate. Journal of Pesticide Science, 46 (2) 152-159. DOI: http://doi.org/10.1584 /jpestics.D20-031.